Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin

PROCEEDINGS OF A BINATIONAL SYMPOSIUM

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Environmental Adaptation Research Group (EARG)

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Preface

Climate change and climate variability have profound implications for both natural processes, and the human socioeconomic systems intrinsically tied to them. Events associated with the 1997-98 El Niño have emphasized the vulnerability of many areas of North America to climate variability. Canada and the United States have a century-long history of cooperative research and shared management of resources in the Great Lakes Region. Extending this successful association to examine the potential impacts of climate change and variability in the Basin and to assess potential adaptive responses of interests was a natural outcome.

The Great Lakes-St. Lawrence Basin (GLSLB) Project was launched in 1992 as a joint American-Canadian effort to improve our understanding of the complex interactions between climate and society, so that informed regional adaptation strategies could be developed in response to potential climate change and variability. The Project is coordinated by Environment Canada, Atmospheric Environment Service, Environmental Adaptation Research Group (EARG) and the National Oceanic and Atmospheric Administration (NOAA), Great Lakes Environmental Research Laboratory (GLERL). To date, approximately thirty component research projects form part of the broader regional Project.

As part of the Project, a Symposium *Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin* was held May 13-15, 1997, in Toronto, Ontario, Canada. One-hundred-and-fifty representatives of industry, research and government departments and non-governmental organizations participated in the presentation of the research findings from the Project. The stakeholders responded by sharing their perspectives on the impacts of the climate change and variability scenarios for their sector, potential adaptation responses and future research needs. Panelists of the Impacts and Risks Panel were asked to discuss the range of impacts they saw affecting their interest, as well as how these compared and contrasted with the perceptions of their colleagues, and to identify the uncertainties needed to be clarified before further action could be taken on these impacts.

Panelists of the Adaptation Panel were asked to identify the impacts of climate change and variability of most concern, to identify sustainable, adaptive strategies being used to respond to climate change, and to comment on the cultural, institutional, economic and scientific barriers to adaptation, as well as priorities for action. Panelists of the Synthesis and Future Needs Panel were asked to highlight the most significant areas of consensus and disagreement about perceived risks and impacts, about the implementation of adaptation options, and to identify the most important adaptive action or role which should be undertaken by the interested parties represented at the Symposium.

This document, *Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin: Proceedings of a Binational Symposium*, presents an overview of the posters, keynote presentations, panel discussions, and working group reports. The Symposium attempted to balance the perspectives of different sectors and interests, including contrasting views from government, industry, academia and non-governmental organizations on climate change. The first section of the *Proceedings* provides a detailed summary of the Symposium by L. Craig and P. Kertland. J. Bruce offers his thoughtful direction in "Synthesis and Future Needs: Overview of the Symposium" in Section Two: Keynote Papers. The non-governmental, academic, governmental and industry perspectives on the Symposium are reflected in the Synthesis and Future Needs Panel in Section Three.

The second section of the *Proceedings* contains the keynote presentations. The papers range from an historical overview of research in the Great Lakes Basin, to an overview of key issues defining the broader climate change issue, and to a recommendation that research move beyond assessments of climate change and variability to atmospheric change and integrated air issues. The past research and management of the GLSLB was reviewed, as well as the historical and ongoing role of NOAA in climate research. Other papers were more contemplative, reflecting on the lessons learned from the GLSLB Project, and urging that adaptation to climate change must progress in a more active, considered fashion than it has to date.

Sections three to five present the discussions arising from three panel sessions of the Symposium. The sixth section summarizes the working groups on water use and management, land use and management, ecosystem health and human health which were charged with identifying key climate change issues that require attention, developing some initiatives and suggesting methods of implementation.

The Symposium could not have been held without the efforts of a number of people. We would like to thank the Symposium Organizing Committee for their direction in program development; Brian Mills for coordination of the poster presentations and preparation of the Symposium Program; Indra Fung Fook and Nicola Mayer for local arrangements; Jacques Lavigne and Laurie Legallais for media arrangements; the Symposium sponsors; GLIN and GLIMR web support, and David Grimes, Roger Street, and Ian Burton for their commitment to support climate impacts and adaptation research.

Ultimately, the success of the Symposium was due to the active participation of the attendees who freely shared of their ideas, opinions, concerns and needs.

Particular thanks are extended to Soonya Quon, for her editorial skills and design flair in preparing the Symposium *Proceedings* manuscript. Lorraine Craig, Brian Mills, Barbara Wrenn and Terry Allsopp provided additional editorial suggestions. We would also like to acknowledge the presenters and rapporteurs who made the effort to prepare, review and rework their presentations and summaries for inclusion in these Proceedings.

The Symposium completed the initial phase of the GLSLB Project. However, the number of suggestions for future research which arose from the component studies of the Project and the Symposium suggest that this will not be the last investigation of climate change impacts and adaptation in the Basin. In fact, this is merely the beginning of a long-term process that will enable the GLSLB community to adapt to climate change and variability in the 21st Century.

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Ontario Ministry of Natural Resources

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LIST OF ACRONYMS

$2xCO_2$	doubling of carbon dioxide concentrations by volume in the atmosphere from a preindustrial baseline
AOC	Area of Concern
CCC	Canadian Climate Centre
CFCs	chlorofluorocarbons
EARG	Environmental Adaptation Research Group
ENSO	El Niño Southern Oscillation
GCM	General circulation model
GFDL	Geophysical Fluid Dynamics Laboratory
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GLERL	Great Lakes Environmental Research Laboratory
GLSLB	Great Lakes-St. Lawrence Basin
GRCA	Grand River Conservation Authority
IJC	International Joint Commission
IPCC	International Panel on Climate Change
LaMP	Lake-wide Management Plan
MPI	Max Planck Institute
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
RAP	Remedial Action Plan
TNR	Toronto-Niagara Region
UKMO	United Kingdom Meteorological Office
US EPA	US Environmental Protection Agency
UV-B	ultraviolet B radiation

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SUMMARY

Summary

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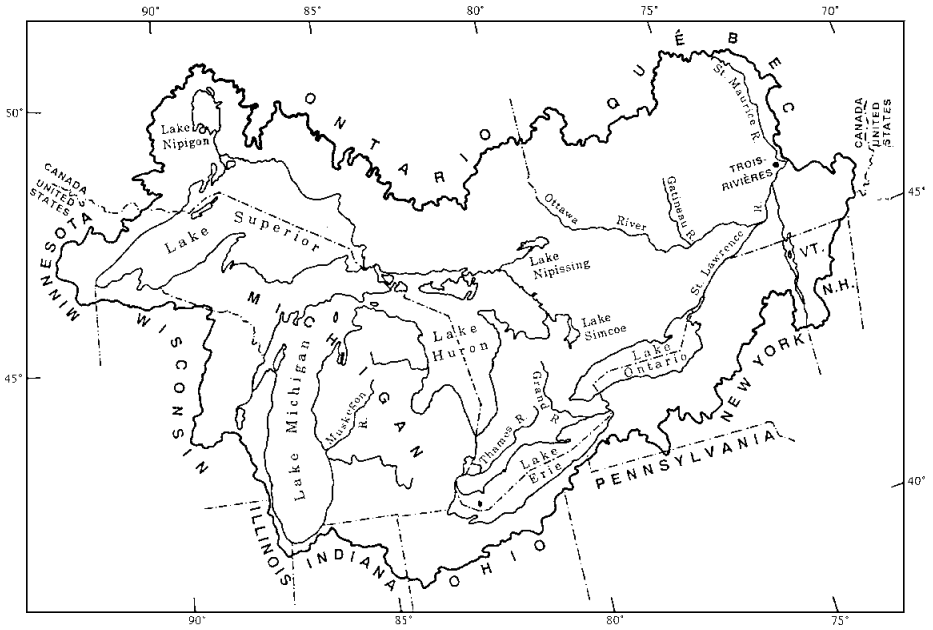
About the Great Lakes-St. Lawrence Basin Project

The Great Lakes-St. Lawrence Basin (GLSLB) contains 20% of the world's fresh water, is home to 42.5 million people and plays a vital role in the economies of both the US and Canada (Figure 1.1). If the concentration of greenhouse gases doubles in the near future, there could be severe consquences for the social, environmental and economic fabric of the region.

The Great Lakes-St. Lawrence Basin Project was launched in 1992 to improve our understanding of the complex interactions between climate and society, so that informed regional adaptation strategies might be developed in response to potential climate change and variability. The principal goal of the Project was to conduct research and deliver information to assist society in making

Figure 1.1
The Great Lakes-St. Lawrence Basin Project Study Area



Source: The National Atlas of Canada 5th Edition (1985)

better decisions about climate-sensitive activities in light of climate variability and potential climate change.

The primary objectives of the GLSLB Project were to:

- Identify and assess the physical, biological, social and economic impacts of climate change and variability,
- Identify and evaluate strategies for adapting to possible impacts, and
- Develop, test and apply methods, which would integrate and link multiple disciplines as well as incorporate adaptation responses into climate impact assessments.

The project is a joint Canada-US research initiative lead by Environment Canada's Environmental Adaptation Research Group (EARG) and the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory (GLERL). Under the GLSLB Project, approximately thirty Canadian, American and joint research studies were carried out, covering four major themes (Water Use and Management, Ecosystem Health, Human Health and Land Use and Management).

Symposium Purpose

A binational Symposium, *Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin,* was held May 13-15, 1997, to assess the risks of climate change and variability in the GLSLB and identify sustainable adaptation responses through the integration of various stakeholder perspectives. The Symposium served as the final meeting for the five-year GLSLB Project. One-hundred-and-fifty scientists, members of industry, government, academia and non-governmental organizations (NGOs) reflected on the results of the GLSLB Project, through keynote presentations, poster papers, public forums, panel discussions, and working group sessions. They aimed to achieve consensus on the following key questions:

- What interests may be significantly affected by climate change and variability; what are the range of impacts and their associated risks?
- How do industry, governments and the various public stakeholders "view" these impacts and risks, and what information is needed?
- What sustainable, adaptive strategies are climate-sensitive interests using or can be developed to respond to climate change and variability?
- What are the priorities for action; what are the cultural, institutional, economic, and scientific obstacles to action?

Key Project Findings

Scientific results from the component studies of the GLSLB Project were presented in a poster session. The studies addressed four major themes of water use and management, ecosystem health, human health and land use and management. Abstracts briefly describing the studies are found in Appendix B.

Some project findings include:

Ecosystem Health

- Remedial action plans (RAPs) in the Great Lakes have not considered climate variability and change; the study of the Bay of Quinte watershed indicates that some sub-watersheds may not be able to achieve their phosphorus loading targets.

- Wetlands will be vulnerable to hydrologic changes due to climate change with inland and enclosed shoreline wetlands at most risk.

Land Use and Management

- Focus groups with farmers suggest that farmers believe that they can adapt to slow, gradual change over a long time but abrupt changes are more difficult to respond to and lead to increased vulnerability.

- Changes to yields of different crops were dependent upon climate change scenarios used.

- Natural area management policies and plans in the Halton/Hamilton sub-watershed region do not explicitly consider climate change. The promotion of buffers, control of adjacent land uses, development or maintenance of corridors and linkages and management for biodiversity would reduce vulnerability to climate change.

Human Health

- Using temperature conditions only, the Toronto region may be more favourable to the malaria parasite and host.

- The elderly (65 years and over) in Toronto indicate a lower threshold of heat-related morbidity rates at 28°C than the young (under 65 years) at 31°C.

Water Use and Management

- Flow in the connecting channels and St. Lawrence River decreased and lake levels declined with scenarios.

- Shorelines were displaced by 200m to 6km on Lake St. Clair due to a 1.6m decrease in water level under one climate scenario.
- Uncertain flow and poor water quality in the Grand River, Ontario under climate change scenarios will make this inland water supply system less reliable for regional drinking water supply and assimilation of waste.

- There may be more conflict and competition between regions over water and rural water users are particularly vulnerable especially where ground water is the primary source.

Stakeholder Panel Sessions

Three panel discussions comprised an integral part of the Symposium, providing a forum for stakeholders from government, NGOs, research and industry to present their views.

Impacts and Risks of Climate Change and Variability

This panel presented views of stakeholders on the range of potential climate change and variability impacts: how others

in their industry or sector perceive these climate change impacts and risks, and what uncertainties must be resolved before action can be taken. Included on the panel were representatives of Great Lakes United, Grand River Conservation Authority, State of Illinois Office of Water Resources, Public Safety Branch of the Québec Ministry of Public Security, and Ontario Hydro.

A variety of potential impacts of climate change and related management challenges were identified by the resource managers including:

- the threat of loss of regional participation in policy-making on Great Lakes Basin management issues as a result of the trend towards globalization;
- failure to instill a conservation ethic and live within our own watershed budgets in the Great Lakes Basin may lead to future conflicts due to water shortages;
- higher air temperatures place additional pressure on public water supplies. For large urban areas in the Grand River Basin which rely on a heavily management inland river and ground water system for water supply and waste water disposal this has further implications for water quality (dissolved oxygen, water temperature phosphorus, sediments); water quantity and sustainability of recreation and fisheries;
- increased demand during a drought year, in addition to future population growth create additional domestic water needs;
- reductions in amounts of snowmelt and rain affect reservoir management and ability to augment low flow in summer;
- long-term lowering of water levels has implications for shoreline management and protection due to uncertainty in changes to erosion processes and erosion potential and design criteria requirements for shoreline works;
- the economic viability of harbours may be at risk due to costs of dredging to maintain operations;
- the potential for climate change to increase the likelihood of climate hazards and extreme events with resulting negative effects on human health and well-being.

Managers and decision-makers supported the concept of making proactive planning decisions based on "What if?" scenarios and "no regrets" adaptations. They expressed the need for climate change scenarios for contingency planning that provide an "expert" assessment that a reasonable range of risk had been addressed. There was still however, some uncertainty among managers about the urgency and seriousness of climate variability and change. Questions of when, how and how much need to be clarified. Tools such as a climate indicator to help predict changes in the system and measure the effectiveness of adaptive measures and options would assist resource managers in making decisions under conditions of uncertainty.

During the discussion period, audience members cited a need for more information

on climate fluctuations, climate extremes and regional variability. To date, research has focused on average or "mean" conditions, while changes in climate extremes will most affect vulnerable societies and peoples.

Adapting to Climate Change and Variability

Panelists of this session included representatives from Pollution Probe, Stonechurch Vineyards, Ontario Ministry of Natural Resources, and the US Army Corps of Engineers. They were asked to identify the impacts of greatest concern in their sector, the sustainable adaptive strategies currently being used, the cultural, institutional, economic, and scientific obstacles, and priorities for action.

The discussion of impacts touched on issues related to the consideration of climate change within the broader context of atmospheric change; implications for the Canadian wine industry; and considerations for natural resources, transportation and the electric utility industry. The key points of discussion included:

- the need to broaden the unilateral focus for air issues and develop an integrated research agenda to better understand the linkages between climate change and other air issues such as smog, acid rain, air toxics, and UV-B;

- the influence of climate on the success of the Canadian wine industry. The quality of the wine is a reflection of the climate of the year of harvest. The ice wine industry depends on a Canadian winter cold snap. The growth of powders and mildews is also influenced by temperature;

- climate variability and climate change affects ecological functioning. Therefore, all natural resources and their value and benefits are at risk. This has impacts for the economy, our communities and the natural environment;

- the management of water is the central issue since so many other natural resources depend on water for their existence;

- increased competition among both in-stream users (the support of fish and wildlife, tourism and recreations) and withdrawers will become evident.

The panel discussed examples of current adaptive strategies related to conservation initiatives, land use planning and agricultural practices. The representative from the natural resources management agency felt that water managers are constantly adapting to climate variability and, in particular, to changing resource uses, demands, values and economy. As a general approach to adaptation, it was suggested that there is a need to focus on education of children. Specific examples of adaptation strategies included the following:

- adjustments in drainage in Ontario vineyards in response to higher rainfall in the last ten to fifteen years; development of disease and pest resistant grapes. These were cited as reactive adaptation responses, as the

industry is young and has not undertaken long-term adaptation planning;

- ecosystem-oriented approach to land and resource development planning including watershed and subwatershed planning, Remedial Action Plans (RAPs), Lakewide Area Management Plans (LaMPS), forest management plans;

- hazards regulation (e.g., flood plains and shorelines);

- Conservation Practices (e.g., municipal water use efficiency, water efficiency retrofitting and "softer" approaches to stormwater management by encouraging infiltration);

- Best Management Practices (e.g., Agriculture Canada initiative on conservation-oriented irrigation);

J. Kinkead of the Ontario Ministry of Natural Resources specified the financial benefits associated with several conservation adaptation strategies and concluded with the following observation: "Those first off the mark in terms of adapting will also be first to benefit from the opportunities."

The **obstacles to action** identified by the panel members included **complacency, a lack of information about the risks and costs of inaction, a lack of appropriate valuation of natural resources, a lack of government leadership, and the need for more specific, locally relevant information** on potential impacts. The discussion of barriers to adaptation focused on the challenges of motivating individual behavioural change even among a concerned and well-educated public, particularly in light of the complexity of climate change and the need for supporting government policies to address the issue. K. Ogilvie of Pollution Probe stated that the public may perceive the issue of climate change as an issue without a solution, and are likely to "ignore" or "deny" the issue if action steps are not also provided. Shared accountability on the issue needs to be recognized. Governments must provide policy leadership and at the individual level there has to be behavioural change. It is difficult to reach the public through the media, necessary to animate individuals and communities to be part of the solution. The solutions require public policy debates around carbon taxes, green power policies on imports, transportation infrastructure issues, and energy alternatives.

Appropriate communication was considered important to encourage people to adopt adaptive measures. **Presenting climate change as an immense, unsolvable problem leads to hopelessness and inaction**, whereas presenting smaller-scale, successful solutions along with information about climate change impacts is a more helpful approach. Sustainability targets such as a 50% reduction in per capita water use by 2005, proposed by Great Lakes United are suggested as a way of providing specific goals and direction for individual behaviour change.

Working Groups Reports

Working group sessions facilitated discussion on the themes of water use and management, ecosystem health, human health and land use and management. Three tasks were assigned: 1) to identify issues that remain to be addressed in climate impact assessment for the GLSLB, 2) to develop initiatives to address those issues, and 3) to propose ways in which initiatives could be implemented.

The various working groups developed common themes on outstanding issues and proposed initiatives, which have been summarized as impacts assessment, adaptation, research approaches, communication and stakeholder participation.

Impact Assessment Research

Participants from the water use and management working groups (I and II) identified the need for more information about climate change and its impacts on water quality and water quantity. **Surface and groundwater studies need to be conducted and individual tributary watersheds need to become the scale of investigation** rather than the Great Lakes system as a whole. The impacts on ice covering the Great Lakes and secondary impacts of ice-cover on activities such as hydro-electric power and shore erosion need to be examined. The impact of water level changes and fluctuations on the Lake Ontario Regulation Plan, and especially in the St. Lawrence River Basin region, requires further study. An historical analogue of the GLSLB focusing on low water levels would be useful.

The water use and management working groups suggested the **need for a climate change detection strategy, involving the identification of specific indicators or thresholds signaling the occurrence of climate change** in parts of, or the whole of, the GLSLB.

The land use and management group discussed what indicators might be appropriate for impacts analysis (how do we detect climate-induced effects?) and to detect subsequent change (how do we detect climate-related change in human systems?). **Some indicators might help identify regions or peoples at greater or lesser risk**.

The ecosystem health working group identified the need for indicators of ecosystem health. Such indicators might be identified through increases in basic information on linkages between climate variables and ecosystem components. The group proposed a case study approach using historical data to understand how past climate conditions have affected current ecosystem health. From this research, indices of ecosystem health could be established and used as benchmarks for monitoring programs.

Data should be coordinated, standardized and shared, and collected and presented in a manner useful to water resource managers. A representative of a water management organization urged

scientists to consider the needs of front-line managers by observing that those responsible for day-to-day water management need realistic scenarios. Improved climate model outputs, particularly precipitation, and consensus building on the results of different general circulation model (GCM) scenarios outputs, was suggested by the water use and management working groups.

The land use and management working group expressed concern about the uncertain nature of climate impacts research. **Gaps in science continue to cloud the verification of issues and the identification of critical regions, making adaptation particularly challenging**. It was suggested that these **uncertainties impede both the public and politicians from embracing the climate change issue**.

The land use group suggested that sectors such as forestry, agriculture, recreation and water management require research on how routine management strategies (e.g., municipal activities such as snow removal and storm water management, soil management in agriculture in the face of extreme precipitation events, forestry practices for cutting and burning) may be affected by climate change-induced alterations in ecosystem resilience and equilibrium. This group noted that research to date has focused on the urban context, or at least in populated regions. They called for greater attention to regions of dispersed population, examination of climatic change impacts on activities such as forestry and farming, and also how environmental deterioration of rural areas may lead to urban migration.

Human health studies in the GLSLB Project have been limited in scope, and several issues need to be further expanded for future climate impact assessment. There is considerable concern that **increased climate variability will lead to a dramatic increase in intensity and frequency of extreme climatic events** (e.g., floods, severe storms, heat-waves). We need to **better understand the impacts of extreme events and trends of extreme events in regions**. The human health working group recommended that **case study analyses of recent extreme climatic events** (e.g., Chicago heat wave in July 1995; Manitoba-North Dakota floods in April 1997) be conducted to determine their psychological, health and safety impacts, and to assess the strategy and costs of adaptation options.

Air pollution has become a major concern in the highly urbanized and industrialized regions of the GLSLB. Air pollution episodes are intensified by meteorological conditions, which may increase in frequency and intensity under climate change. **Integrated examinations of air quality issues, including photochemical oxidants or smog (e.g., ground-level ozone), airborne toxic metals, acidic aerosols, and organic and inert particles, and UV-B are needed**. The Toronto-Niagara Region (TNR) Study is an example of integrative research, focusing on the science and policy of multiple atmospheric stresses, at regional and local scales.

Atmospheric and other environmental health issues are currently being addressed in a fragmented fashion by several government departments, university researchers, private sector and NGOs. **The atmospheric and medical communities need to work together to assess the availability and utility of current climate-health data in the GLSLB region**. Several data collection initiatives were proposed, including improved monitoring of insect vectors and pathogens, improved reporting of diseases caused by these pathogens, and better surveillance of morbidity and mortality caused by extreme climatic events.

The human health working group proposed that government and industry need to develop clean-emission technology to replace combustion engines and coal-generating electricity. **The group suggested that developed countries should play a greater role in exporting environmentally-sound technologies to developing countries and assisting in their implementation**.

Adaptation

Proactive rather than reactive adaptive strategies need to be used in the face of climate change, according to the water use and management working groups. Existing lake-level regulation plans for Lake Ontario should be evaluated, assessed and revised in light of information on potential impacts of climate change.

An evaluation framework is needed to determine the effectiveness of adaptation strategies. Such an evaluation would examine benefits, impacts, and public acceptability of adaptation measures.

The human health working group **proposed a study examining the determinants of behavioural change in communities over time in response to climate change**. It would identify factors promoting behaviour change as well as social barriers to adaptation. This proposed research would address questions such as: Why are some communities (e.g., Montréal) using more public transit than others (e.g., Toronto)? What motivates decision-makers to take action? What is the role of incentives or disincentives in mitigation and adaptation?

Research Approach

The water use and management working groups suggested developing a vision for the Great Lakes Basin for the year 2050 as a way of setting the research agenda. Similarly, the ecosystem health working group concluded that the first step in better management of the Great Lakes system and improved ecosystem health would be a collective decision about where we need to go and how we should get there.

It was generally agreed that **we need to shift from research on biophysical systems to research on social systems, the human components and the decision-making processes.** Further work is needed to determine the relationships between climate

and socioeconomic systems (e.g., the tourism and recreation sector). **We need integration within sectors, across sectors, sciences and jurisdictions** (especially between Canada and the US, but also between and among the provinces or states). We need to define what is meant by integration and to develop a framework for integrative studies examining the physical, social, and environmental responses to climate extremes.

A future management strategy may be to develop a framework to balance the often competitive interests of various water resources users (e.g., hydro, navigation, and recreation). **The need to integrate adaptive responses for water resources with the responses of other sectors was emphasized** throughout the Symposium.

Given the inherently complex interaction between the climate and human-based systems, and uncertain estimates about future climate change, the land use and management group agreed that **exploration of present and recent past interactions of climate and land use might provide important insights to what and might also contribute to more empirically-valid inputs to integrated models**.

Communication

All working groups identified the critical need for better communication of what is known and not known about climate change impacts and adaptive responses. To build support and credibility, scientists need to communicate clear, decisive messages to decision-makers, without overstepping the bounds of available information. **Effective communication requires clear, concise statements focusing not only on impacts, but also on adaptation strategies**, tailored to the specific information needs of various audiences. The ecosystem health working group suggested that **children are an important target group for education initiatives**.

However, the media's tendency to sensationalize research findings was identified as a threat to the credibility of the science. The ecosystem health working group recommended media workshops to provide clear messages and assist reporters with their information needs. **The public needs to become informed consumers of probabilistic data and better understand the probability of certain climate change scenarios**. Further research into ways to effectively communicate probabilistic information was urged. Communication might be best carried out by those accustomed to translating science into plain language, and scientists with a flair for communication. However, others thought that the science

community should become educated about how the public and decision-makers perceive and understand climate change issues, rather than training the public to understand the issues. The benefits of adaptation might become more relevant to stakeholders and users when linked with ongoing initiatives, such as water conservation.

The water use and management working groups suggested including key scientists and communications resource people in a communication group to plan a strategy to best convey to the public the results of the GLSLB Project. **Communication initiatives should focus on promoting the conservation ethic and linking the importance of conserving water in the GLSLB to current ecological and economic benefits**, through the telling of case studies of adaptation. Standardized benchmarks of climate change impacts should be established across the region, to facilitate communication of climate change impacts.

The land use and management working group identified **sectoral organizations** (e.g., forestry industry, Ontario Federation of Agriculture, the construction industry) as **important communicators of information** to their members and the public, and as future joint research partners. The ecosystem health working group recommended allying with those looking at solutions-oriented aspects.

The human health working group identified the **need to communicate the research findings from climate-health studies to those in a position to deliver health services or make decisions to protect community health**. Interpretation of the present state of scientific knowledge should be undertaken with care to accurately convey the level of uncertainty and the risks involved. Information needs to be disseminated to the general public on how to reduce climate-related health risks during heat-waves, air pollution episodes and flood situations. It was recommended that the weather-health watch/warning system, currently being used in Philadelphia, be tested in the GLSLB.

Stakeholder participation

All working groups expressed concern about the **limited participation of affected stakeholders in setting research agendas and in assessing the acceptability of certain impacts and adaptations**. Public participation is necessary to determine whether researchers and planners are asking questions that matter to people, and whether adaptations (or costs) are acceptable to those who may be asked to bear them. The land use and management group observed that estimating the seriousness of impacts must involve consultation and an attempt to define 1) which aspects/products of land are most highly valued socially, and 2) which regions/groups are most at risk of suffering the loss of these services (e.g., food, floodwater retention, biodiversity). **Initiatives such as**

local stakeholder forums can help bring climate change and adaptation issues to the regional and community level and facilitate the sharing of data and discussion of impacts between various sectors.

There was concern expressed that the issue of climate adaptation will continue to receive limited attention from decision-makers, planners, and the public. However, greater involvement of stakeholders in describing the role of climate in human activities, and in setting priorities for public action, may address this concern. At least, **more direct involvement of local actors might shift the perspective from expert/ elite views on climate change**, to permit the articulation of what climate change and variability means to lives of individuals.

Changed action and thought required to maintain healthy communities under variable and changing climate depends upon new values, and tremendous political will and leadership. The human health working group suggested that **an alliance of decision-makers from various municipalities in the GLSLB be established to develop a strategy to implement specific initiatives in the next three to five years**. Follow-up research to evaluate barriers and incentives to adaptation was recommended.

Panel on Synthesis and Future Needs

The Symposium concluded with a panel discussion summarizing the key points of various speakers and general discussions, from which the following observations and recommendations were drawn, under the categories of Management Issues, Integrated Air Issues, Adaptation, Communication, and Future Research Needs.

Management Issues

Decreases in lake levels and increased moisture stress in areas far removed from the GLSLB may increase demand for diversions. The International Joint Commission (IJC) regulation plans may be unable to accommodate projected impacts on lake levels. Questions may arise about whether the economic costs and environmental implications of dredging outweigh the benefits of marine transportation.

Because of these pressures, countries, states and provinces need to anticipate geopolitical issues in light of "What if?" scenarios. Some of the **projected climate change scenarios require a shift in our legal and institutional frameworks**, from managing for abundance and overabundance, to managing for scarcity and conflict.

Integrated Air Issues

Climate change is one of a number of closely linked air issues that impact the health of our ecological, social and economic systems. **We need to consider the combined effects of climate change and variability, increased UV-B, contaminants, and acid deposition on human health, and aquatic and terrestrial ecosystems and develop sustainable responses.** The TNR Study was identified as an important initiative to understand the processes, effects and responses to various atmospheric issues in an integrated fashion.

Adaptation

The **term "adaptation" must be defined** and the difference between types of adaptation should be distinguished (e.g., how does adaptation to short-term variability and climate extremes differ from adaptation to long-term climate change?). Recommending adaptations requires not only knowledge of the prospects for adaptation, but also having some basis for judging how good or bad the adaptation is.

There is **no methodological, strategic approach at any level of government to develop, assess and implement adaptation options.** Much of the work is undertaken within federal government and university research circles; consequently, developing, rather than assessing or implementing, options, is stressed. **Evaluation is needed to distinguish between appropriate and inappropriate adaptation (maladaption) strategies.**

Because of the high degree of uncertainty about the impact of climate change on the Great Lakes (e.g., lower lake levels), **various scenarios must be considered as "What if?" scenarios, and "no regrets" adaptation measures** (e.g., water conservation, sustainable river basin management and flood control) should be taken. **Many initiatives currently in place may be considered useful adaptation strategies**, even though climate change and variability were likely not the reason they were implemented. Proponents recognize that "no regrets" adaptation measures improve the overall resiliency of the systems to the stresses of climate variability and change.

Communication

Enough is known about the potential impacts of climate change and variability to persuade stakeholders to recognize climate change as a stress, among other stresses that must be addressed or coped with. **Climate change provides added purpose to attempts to sustainably manage watersheds** and other activities within the GLSLB.

Understanding concepts used by, and employing the terminology of, stakeholders can improve communication.

The GLSLB stakeholders must be recognized as an important audience for research and scientific information and should be provided with results of current research. **The tendency of print and broadcast media to sensationalize climate change issues helps to perpetuate skepticism** among the public, decision-makers and stakeholders.

Future Research Needs

A collaborative planning process to guide future research initiatives in the GLSLB was recommended by two working groups. A vision for the GLSLB for the year 2050 should be developed jointly by researchers, stakeholders and decision-makers, to establish research activities and set priorities.

The following research needs are summarized from the various Symposium discussions and presentations:

- Identify the present range of climate extremes, projected future ranges, and their impacts to spawn successful adaptation measures;
- Further assess impacts on ecosystems, including the use of new knowledge and model outputs to refine estimates of impacts of climate change on lake levels;
- Assess the combined impacts of multiple air issues on human health and ecosystems and identify adaptation strategies;
- Determine better ways of addressing "What ifs?" in our equitable sharing regimes of Great Lakes waters;
- Better understand the use of economic instruments to drive "no regrets" adaptation measures.

Conclusions

The GLSLB Project and the associated Symposium were viewed as an important turning point in climate change research and policy, bringing new insight to the potential effects of climate change and variability on ecosystems in the Region. The GLSLB Project was also vital to putting the idea of "adaptation" on the agenda of the climate debate in the Basin. However, we need to define the concept of adaptation more operationally and also assess/evaluate adaptations and maladaptations. There is no methodological, strategic approach to develop, assess and implement adaptation options. Are there adaptations that could be combined or harmonized on a bilateral basis, or in a broader strategy of integrated adaptation in the GLSLB?

The Symposium highlighted a number of strengths of the GLSLB Project, and led to a variety of recommendations. One of the main successes of the GLSLB Project was felt to be the cooperative research between climatologists and specialists in other sectors. Future collaboration, facilitated by the development of tools or detailed scenarios, is essential to make the climate change issue

more relevant to non-climatologists and better included in the planning process.

Among the recommendations arising from the Symposium was a call for integrated studies to examine changes to multiple atmospheric components (e.g., smog, climate change and UV-B). Regional scale studies, such as the proposed TNR Study, were felt to offer the best opportunity for realistic integration.

The current lack of research on changes in the frequency and intensity of extreme weather events was cited as an important gap in research. Changes in extreme events would have greater impacts on socioeconomic systems than changes to the "means," yet there is little knowledge of the current trends in extremes, let alone future changes. The rate of change was felt to be an important factor affecting the ability of systems to adapt.

More stakeholder involvement is necessary. There has been limited participation of affected stakeholders in setting research agendas and in assessing the impacts and adaptations. Public participation is necessary to determine whether researchers and planners are addressing the appropriate issues and questions, and determining whether the impacts, adaptations and costs are acceptable to those who may have to bear them.

2

KEYNOTE PAPERS

This section provides an overview of Canadian and US research activities and scientific advances made in the areas of climate change, impacts and adaptation assessment and climate prediction.

Synthesis and Future Needs: Overview of the Symposium

James Bruce
Canadian Global Change Program Board

James P. Bruce was formerly chair of the Canadian Climate Program Board and was co-chair of Working Group III (Economic and Social Aspects) of the Intergovernmental Panel on Climate Change (IPCC). A former Assistant Deputy Minister with Environment Canada, Dr. Bruce continues to provide leadership on global environmental issues through membership on the Canadian Global Change Program Board and the International Decade for Natural Disaster Reduction - Canadian National Committee.

This binational Symposium *Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin* represents an important turning point in our efforts in climate change research and policies. We are grateful to the organizers and scientists involved in the Great Lakes-St. Lawrence Basin climate impact studies. They have brought a host of new insights into the potential effects of climate change and the effects of climate variability on important systems in the Great Lakes Basin, systems important to everybody who lives in the Basin. The poster presentations provided a sense of the variety of impacts that changing climate will likely bring.

Most forcefully emphasized were those aspects of climate change not often reflected upon in the past, such as impacts on human health, the importance of extreme events, and the importance of impacts on natural ecosystems. As I. Burton described: "We've grown the island of our knowledge, but we've also grown the sea of lack of knowledge around that island." Some things have brought us up rather short, especially those facets of the future that we cannot project with confidence.

For instance, the important issue of the impact of climate change on Great Lakes levels: work with the output of the earlier generation of general circulation models (GCMs) consistently shows major drops in lake levels expected in the next century. However, some of the newer transient model runs incorporating aerosol effects, which appear to be quite significant over the Great Lakes Basin, may give considerably different results. The combination of such advances in knowledge with increasing evidence that future rains may come more in heavy bursts, with higher percentages of the rain running off, and with significant portions of the basin being gradually paved, requires a new round of analyses. This issue cannot be left as it is today. However, as L. Mortsch cast the issue,

the much lower lake level scenario must be thought of as a "What if?" scenario. Adaptation measures of a "no regrets" character need to be taken.

Many actions now underway might be characterized as "no regrets" adaptation measures. Water conservation in the Boston area, sustainable river basin management in the Grand River, addressing flood damage reduction issues, are measures designed to improve the resiliency of systems. While climate change may not have been an initial motivation for many of these measures (some may have aimed to address other stresses), the measures are now recognized by their proponents as also improving the resiliency of various systems to the stresses of climate variability and change. The climate adaptation agenda has become established in significant ways, although perhaps through the back door. However, we have to recognize that that is the way it is happening.

J. Mills' presentation emphasized that climate change is one of a number of closely linked air issues. For example, high ozone concentrations in smog pose serious health effects, and owe as much or more to weather and climate as to emissions. Mills urged us to consider the combined impacts of these air issues. The impact of combined multiple air issues on aquatic and terrestrial ecosystems needs to be considered, as well. What are the combined effects of climate change, increased UV-B, toxics, contaminants, smog and acid deposition on ecosystems? Many of these multiple air issue problems are rooted in an overdependence on fossil fuels. We have a common source as well as inter-linked effects. Of course, that will push the timing of definitive research results further along.

This Symposium raised the idea of expanding knowledge and projecting trends of climate extremes, with increased greenhouse and aerosol forcing of the climate system. J. Lacroix demonstrated how important this issue is to our safety, security, and economies, and the importance of suitable

"Many actions now underway might be characterized as 'no regrets' adaptation measures. … While climate change may not have been an initial motivation for many of these measures (some may have aimed to address other stresses), the measures are now recognized by their proponents as also improving the resiliency of various systems to the stresses of climate variability and change."

adaptation measures to climate extremes. However, this is another topic on which greater scientific consensus is needed to more fruitfully drive adaptation measures.

In the Great Lakes Basin, the apportionment of water for power production and other purposes is under international agreement, and is a regulated business under the *Boundary Waters Treaty* of 1909. Even if lake levels do not fall as much as earlier predicted, increased moisture stress in areas far removed from the Great Lakes Basin may result in greater demands for increased diversions. As M. Donahue articulated, these pressures suggest a need to get our geopolitical houses in order between the countries, between the states, and between the provinces, in light of the "What if?" scenarios, before the problems and demands for more diversions from the Great Lakes become too acute and too heated.

What messages can be taken from this workshop?

- We need more research. When I was a manager, I used to hate those projects that ended by saying, "Hey, what we really need is more research." However, it seems to me that this must be one of the main conclusions of this Symposium. While not the only conclusion, more research on the use of new knowledge and climate model outputs will allow us to refine our estimates of impacts of climate change on lake levels.

- We need to know much more about the present and projected future range of climate extremes and their impacts. This could be a good subject for a future Canada-US workshop.

- We need to know much more about the impacts, how to better adapt to them, and how to prevent the multiple air pollution problems that were drawn to our attention.

- We have to put in place a better way of addressing the "What ifs?" in our regimes for equitably sharing Great Lakes waters. As was proposed by one of the Symposium working groups, we may need to develop a vision for the Great Lakes Basin in 2050, to help us focus on where to go and how to get there.

Economic instruments have been widely recognized as a way to direct activities to become more environmentally sound; working with the Working Group III of the Intergovernmental Panel on Climate Change (IPCC) and working with economists the last couple of years has brainwashed me about the value of economic instruments in driving mitigation and adaptation measures. However, the means of using various economic instruments has not been well addressed.

Enough has been learned about the sensitivity and potential impacts to urge all stakeholders to recognize climate change and variability as a stress in addition to all other stresses that managers must cope with. Managing watersheds for sustainability must take these impacts into account, in managing issues related to deregulation of utilities, flood

damage reduction, urban design, and many other economic sectors, such as forestry. In many cases, the way to do this is already well-known. Climate change can give these adaptation-to-stress measures a new or added purpose. To achieve this recognition requires a redoubling of efforts, to engage the front-line managers in each sector more intensively in future work.

Anthropogenic climate change is a pollution-driven phenomenon. Although perhaps not at the top of politicians' hit lists this week, climate change is the most profoundly important environmental issue that humanity has faced. Inaction to reduce the emissions forcing changes in the climate system will lead to a rapidly changing climate, probably towards a $3xCO_2$ world in the next century. As J. Scheraga showed, greenhouse gas concentrations now far exceed anything experienced on earth in 200 000 years, with the likely occurrence of associated major climatic surprises as we continue on this path. On the other hand, reducing greenhouse gas emissions will mean profound shifts in our energy-driven global, national, and regional economies, with potential additional environmental benefits beyond addressing climate change. Dr. Sherwood Rowland, the atmospheric chemist who won a Nobel prize for discovering the impacts of CFCs on reducing the stratospheric ozone layer, observed that the climate issue today is about where the ozone layer issue was in the mid-1980s, before the Antarctic ozone hole was discovered. The basic science is sound, the impacts and the needed mitigation and adaptation measures are broadly recognized, but as yet, there is no smoking gun. Rowland thought that climate surprises and a growing confidence in our projections of climate extremes will provide that impetus for the climate issue in the near future.

"Enough has been learned about the sensitivity and potential impacts to urge all stakeholders to recognize climate change and variability as a stress in addition to all other stresses that managers must cope with."

On everyone's behalf, I thank Environment Canada and NOAA, and particularly L. Mortsch and F. Quinn, the researchers involved, and all of the people who helped organize this Symposium, for leading us to our present state of knowledge and understanding. Let me also thank all of you for your active participation. It was a session that pulled no punches. Disagreements were out there, and we were able to identify what we know and also where we need to know more. This Symposium will go a long way toward setting a focused and constructive research and action agenda for the future.

A Century of Progress

Stanley A. Changnon
Geography and Atmospheric Sciences Department, University of Illinois
and Illinois State Water Survey

Stanley Changnon is Professor of Geography and Atmospheric Sciences at the University of Illinois, and Principal Scientist of the atmospheric research program at the Illinois State Water Survey. He provided an overview of key research developments including those that have occurred since the first binational conference held in Oak Brook, Illinois in 1988. Major accomplishments, gaps, research and policy needs were highlighted.

Introduction

I am honored to have been asked to present the keynote address at a symposium that marks progress and sets sight on future research needs on the climate change issue and the Great Lakes. I look back on nearly fifty years of personal research that has addressed a variety of scientific aspects of the Great Lakes. Further introspection leads me to the realization that my scientific interest was rooted with a personal love affair with the lakes. This began in 1933 when, as a five-year old, I was taken to see Lake Michigan for the first time. As a country boy used to seeing endless fields of corn, I was amazed at the enormity of the massive lake in front of me. It created a lasting impression. Further, I was also taken to the Chicago World Fair, which had been built on lands reclaimed from the lake, an exciting and impressionable event. Old timers in the audience may recall that the theme of Chicago's World Fair in 1933-1935 was "A Century of Progress," celebrating the settlement and development of Chicago and the Great Lakes region.

Reflections on the scientific studies of the Great Lakes since the 1890s gave me the title for my comments. Scientists of our two nations have been on a 100-year quest to gain understanding of the physical and social dimensions of the Great Lakes Basin, truly "a century of progress." We would not be able to address the complex scientific issues of climate change without this 100-year effort.

In 1897 amazingly little was known about the Basin's hydrologic cycle and how human endeavors were affecting the Basin, and few cared - it was a different time. Here, I would like to reflect on the past 100 years and some of the key events that drove the scientific research in the Great Lakes.

How far have we come scientifically? Where are we going and why? These are appropriate questions to reflect on at the

century mark. This Symposium seeks to address these questions within the context of global climate change issue, the latest of a series of issues that have motivated much of the scientific study of the Great Lakes. I like the old adage: "The past is the prologue of the future." If you want to see what is ahead, take a look back and identify the lessons that exist.

Significant Events in the Past 100 Years of Research

The construction of facilities to divert lake waters at Chicago in the 1890s launched efforts to estimate the effects of this large diversion on lake levels (estimates later revealed to be incorrect), and to assess effects of flushing Chicago on the water quality of the Mississippi River system (then underestimated). Interestingly, the debates over these two issues led to the establishment of my agency, the Illinois State Water Survey. Further, these two early issues (that is, changing lake levels and water quality) were to forever remain as key issues helping to drive much of the scientific research of the Great Lakes.

By 1900, scientific understanding of the Basin's hydrologic cycle was in its infancy with little knowledge of the relative quantities of evaporation, runoff, and precipitation. Progress in gaining fundamental understanding of the physical system during the early decades of the 20th Century was slow. We lacked data to define many aspects of the hydrologic cycle of the lakes. Geography was the lead science as the more discipline-oriented physical and social sciences evolved. For example, the hydrologic and meteorological sciences were somewhere in their infancy, or at best teenage years, as the century dawned. It is interesting to recall that the establishment of the US Weather Service in 1870 was directly related to the huge storm damages to lake shipping and the hue and cry for forecasts of lake storms. This situation continued to drive research about the weather of the Great Lakes, but for many decades progress was slow; we simply knew too little about the behavior of the atmosphere to forecast severe storms.

As time progressed, the discipline-oriented studies of the Great Lakes took on one of two general directions. One involved the assessment of the Basin's physical system: the hydrosphere, biosphere, and the atmosphere. The other broad research focus concerned how various actions impacted the physical and socioeconomic systems of the Basin.

The huge controversies over the Chicago diversion fueled much of the scientific research into the 1920s, and resolution of these debates finally rested on the enormously important scientific analyses of the famed hydrologist, Robert Horton. He and his associates were the first to calculate reasonably correct quantitative measurements of the hydrologic cycle of the lakes.

As the science of meteorology advanced, understanding grew about how the Lakes

affected weather conditions, and in turn, how weather conditions affected the Lakes. Ivan Brunk and others had unraveled the complex statistical relationship between precipitation and lake levels by 1950. Canadian scientists including Lloyd Richards and Jim Bruce, successfully grappled with conceptual models to better define the Basin's water balance including the amount of evaporation from the lakes.

Somewhere near mid-Century, another important theme emerged: joint scientific interactions and undertakings by the scientists of both nations. Scientific studies of the Great Lakes became a common ground, acting to pull the two nations closer through sharing of unifying thinking.

A key event was the International Field Year on the Great Lakes, a joint effort of the two nations to learn more about the components of the hydrologic cycle and how the lakes affected weather and climate. As part of the International Hydrologic Decade, which began in 1965, a twelve-month field project began on Lake Ontario in April 1972. It involved radars, ships, instrumented buoys, mesonetworks, instrumented aircraft, and scientists of both nations. Considerable knowledge that we now take for granted came from this joint effort.

Other forces were at work in the 1960s that would drive the scientific studies in the succeeding decades. Four key atmospheric-hydrospheric issues emerged, each demanding scientific attention, and each relating to the ever-growing human insult on the natural resources of the Basin.

First, was a rebirth of concern over water supplies and lake levels. The drier world beyond the Basin began envying the huge fresh water resource. This led to a major policy action, *The Great Lakes Charter*, which was aimed at protecting the resource. This issue drove new investigations of the Basin's hydrologic cycle, its water resources, and ever-growing demands and uses of lake waters.

The second issue was the emergence in the 1960s of the environmental movement that focused on the immense basin-wide degradation of the quality of the waters of the Great Lakes. Human despoilment of this resource for over 100 years was a "chicken that had finally come home to roost." Something had to be done, and a water quality agreement was signed by both nations in 1972. This launched intensive research into the water pollution and abatement problem, leading to a second water quality agreement signed by all parties in 1978 and even more research.

The third human-created policy issue that emerged in the 1970s concerned air pollution and acid rain specifically. Huge concerns and differences of views over the acid rain issue launched an immense amount of research in both nations on the air pollution-acid rain issue.

The 1960s also saw the emergence of a fourth issue, one with similar components. The problem also was the result of human pollution and quickly became a policy-driven

issue. Findings indicated that large cities in the Basin, like Chicago, Detroit, and Cleveland, were not only changing their local climates but also clouds, rain, and storminess well beyond them. These findings engendered a scientific debate in the US, followed by major research projects at Chicago and elsewhere to define the urban factors causing these local and regional scale climate changes.

Thereafter, the issue of anthropogenic modification of climate expanded scales, with the suggestion of the potential for global-scale climate change emerging in the 1970s. This launched research in both nations in the 1980s, particularly focusing on the "So what?" question about climate change in the Great Lakes Basin.

Lessons about Forces Driving the Research

Reflection on the past 100 years reveals there have been four driving forces behind the scientific research focusing on the Great Lakes.

First and foremost has been straightforward scientific inquiry. The tackling of the unknowns to gain understanding. In essence, this fundamental research has been without a known user of the information but has been vital.

A second force affecting research has been the uses and users of basin resources. The ever-growing uses of lake waters for shipping, hydropower generation, water supplies, deposition of wastes, recreation, commercial fishing, and shoreline developments collectively created needs that were often in conflict. The resulting controversies led to research to answer the questions raised.

A third factor driving research of the Great Lakes Basin has been the effects of human intervention in the hydrosphere and atmosphere, their resulting impacts, and the ensuing controversies. These include the diversion of lake waters at Chicago, acid rain, and global climate change. Human settlement of the Basin, changes in existing land uses like deforestation of large areas, and despoiling the land and water environments

"Now the US global climate change research program has begun to embrace impacts and adaptation research, and to focus on 'regional issues,' finally seen as providing essential input on the seriousness of the issue and its potential importance to the voting public."

as the region became the industrial heartland of North America ultimately created an appalling situation that detrimentally affected this unique natural resource.

A fourth factor driving research has been the interest and need to understand and predict the enormous effects of these large lakes on region's weather and climate, and, in turn, assessment of the effects of these changes on activities in the Basin.

Building Momentum for the Symposium -Why Here and Now?

For those new to climate change issues and the research endeavors on the Great Lakes, I have tried to review the salient events that got us to this Symposium.

The concept for a joint research program focusing on "climate and its impacts" in the Great Lakes Basin began at a University of Toronto conference held in 1985. This meeting later led thirty scientists to gather in Ann Arbor in 1987 to assess what should be done about the potential impacts of global climate change on the Basin. They and leaders from the US National Climate Program Office and Canadian Climate Centre (CCC) agreed that the next logical step was to conduct a symposium focusing on the implications of climate change on the socioeconomic fabric of the Great Lakes Basin.

As a result, 120 scientists, engineers, and businessmen were invited to a symposium held in September 1988 at Chicago. Impacts of climate change on the Basin were seen as ill-defined but potentially very serious, and the major recommendation was that the two countries should establish a joint planning group to "develop an integrated study of the Great Lakes Basin as a regional pilot study."

This symposium was followed by a conference focused on the policy issues of the envisioned project. It was designed to inform and interest policy makers of both nations in the potential research program. This conference, held in Toronto in November 1989, made its primary recommendation as follows:

> The two nations should conceive, launch, and conduct an integrated research program to obtain in five to ten years a vigorous interdisciplinary assessment of the impacts of climate change and the means to adjust to change.

By 1990, the CCC had established a Climate Adaptation Branch, and it launched a program focusing on the Great Lakes with funded research projects beginning in 1991. On the US side, NOAA in 1992 put GLERL in charge of US endeavors with a charge to "develop the US component of a Great Lakes binational program."

The nations' two groups then formed in 1993 a Steering Committee for this "binational initiative" with the goal of "examining the impacts of climate change and climate variability on the Great Lakes basin." The committee met and convened a workshop in December 1993 (held in Ypsilanti, MI) to "develop a plan of study for

the US portion." By this time Canada already had a program plan, had established a program, and was funding research projects. But, there was no US program with funds earmarked for this program.

In 1994 the Steering Committee began developing a joint plan, and an *Implementation Plan for the Joint Great Lakes-St. Lawrence Basin* appeared in 1995. Basically research in the US has been minimal and not the "vigorous endeavor" recommended in 1989. Hence, important research remains to be tackled. The good news is that some progress has been made and we will learn about these developments at this Symposium.

What Does the Future Hold?

The dilemma that has continued to amaze and confound those of us who have been convinced in the merits of this joint program of integrated study of the Great Lakes and climate change was the frustration that we could not get, particularly in the US, strong interest and support for an international project with obvious benefits beyond just scientific knowledge. The program focused on defining the impacts of climate change, which is finally being recognized today in the US as a key issue limiting public concern and interest in the seriousness of the global climate change issue. Further, the proposed program appropriately embraced assessment of the policy issues and direct interactions with policy makers. Most importantly the Great Lakes program was based in an area where there has been more definitive scientific research than possibly anywhere in the world.

Now the US global climate change research program has begun to embrace impacts and adaptation research, and to focus on "regional issues," finally seen as providing essential input on the seriousness of the issue and its potential importance to the voting public. Thus, today there is more hope that the level of US support will increase and allow us to complete what has been well started.

In conclusion, I first wish to praise the efforts of the GLSLB Steering Committee, which has developed and persevered to bring the study of climate change forward over the past several years.

Finally, we should celebrate and honor the 100 years of scientific progress on the Great Lakes. We and our scientific predecessors have created a solid scientific foundation that allows us and future generations to tackle the complex questions posed by the global climate change issue. We are here at a critical juncture in time, essentially standing on a 100 years of scientific labor and dedication to understanding the wondrous Great Lakes. And, I hope you share my appreciation for the uniqueness of this region-one of world's amazing natural resources.

What is the Issue?

Joel D. Scheraga
Climate and Policy Assessment Division, US EPA

Joel D. Scheraga, Director of the Climate and Policy Assessment Division within the US EPA Office of Policy, Planning and Evaluation, provided a keynote presentation on Climate Change, Regional Impacts and Adaptation. The author gratefully acknowledges valuable assistance provided by Anne Grambsch. The views expressed here are the author's own and do not represent official EPA policy.

Climate Change, Regional Impacts and Adaptation

Climate change policy must be based on sound science. It is incumbent upon those of us in the research community to identify what we know about climate change, how well we know it, and what we don't know, and clearly articulate that information for policy makers and the general public.

The focus of this presentation is on two questions:

1. How well do we understand the climate system and our role in influencing it?

2. How well can we characterize the potential impacts of climate change?

The Greenhouse Effect

There is a natural greenhouse effect and its principles are very well understood. On a relative scale of one to ten, where ten represents highest confidence and one represents lowest confidence, we attach a confidence level of ten to this concept. Basic physics tells us that when an object like the Earth is bathed in visible light, it warms and emits infrared radiation. There are particular gases in the atmosphere called greenhouse gases (e.g., water vapor, carbon dioxide [CO_2], nitrous oxide and methane) that reabsorb and re-emit some of this radiation. In some sense, they "trap" heat in the Earth's atmosphere and warm the globe. Average global temperatures are approximately 60°F (15.5°C) as a result of this "greenhouse effect," which sustains human life. In the absence of the greenhouse effect, the average global temperature would be about 5°F (-15°C).

What is remarkable about the greenhouse effect is that greenhouse gases represent a very small component of the atmosphere. For example, water vapor is only about 2% of the atmosphere, and CO_2 is about .03%. Yet, these gases result in a warming effect that makes the planet habitable.

This natural greenhouse effect is good. So what's the problem? The problem is that greenhouse gases are increasing in the atmosphere because of human activities,

enhancing the greenhouse effect and increasingly trapping more heat. The rate of increase of greenhouse gas concentrations in the atmosphere since the Industrial Revolution has been dramatic. If one compares concentrations in 1994 to pre-Industrial levels, one finds that CO_2 has risen about 30%, methane over 100%, and nitrous oxides about 15%. Our confidence in these numbers is high (i.e., a confidence level of ten). They come from impeccable scientific measurements.

Some of these gases have very long atmospheric lifetimes. For example, CO_2 has a residency in the atmosphere of anywhere from 50 to 200 years. This fact, combined with the inertia in the climate system (e.g., the lag with which oceans respond), means that any warming that occurs as a result of human activities can only be reversed very slowly.

Sources of the Problem

Who is responsible for this problem? What human activities are contributing to the problem? The answer is that we are all part of the problem. First consider the US. In 1994, the total greenhouse budget for the US was 1.6 billion metric tonnes of carbon equivalent. The US is responsible for 20% of global carbon emissions, despite the fact that it represents under 5% of the total global population. The US is a big contributor to the problem.

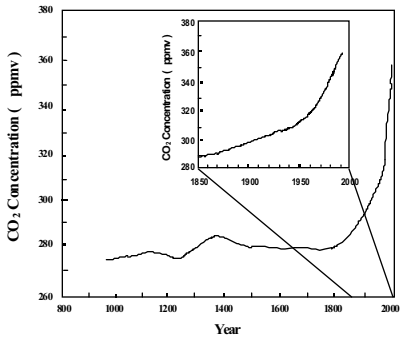
Within the US, the largest share of the total carbon budget is accounted for by emissions of CO_2, which come primarily from fossil fuel combustion. These CO_2 emissions come from millions of diverse sources throughout the economy. They come from the transportation, industrial, commercial, residential, and utility sectors of the economy. Unlike other environmental problems, no single sector of the US economy is solely responsible for CO_2 emissions.

Next consider the international picture. The US and other OECD (Organization for Economic Cooperation and Development) countries, including Canada, have been and currently still are major emitters of greenhouse gases. However, projections of global greenhouse gas emissions out to the year 2025 suggest that total emissions will continue to rise and an increasing share will come from the developing countries. In order for us to have any influence on the climate system in the long run, the developing countries also have to be part of the solution. We are all part of the problem.

Potential Consequences for the Atmosphere

What are the potential consequences of this human influence?

Figure 2.1
CO_2 Concentrations Over the Past 1000 Years



Source: Based on IPCC (1994)

As illustrated in Figure 2.1, atmospheric concentrations of CO_2 prior to the Industrial Revolution were roughly 280 parts per million (ppmv). Since the Industrial Revolution, CO2 concentrations have been rising and now stand at around 360 ppmv. If left unabated, atmospheric concentrations of CO_2 are expected to double relative to pre-Industrial levels by the year 2060 and reach 560 ppmv (the so-called "2XCO_2 world"). By the year 2100, CO_2 concentrations will double relative to current levels and reach about 720 ppmv (confidence level of seven).

Let's put these projected changes into the context of a long historical record.

Figure 2.2 illustrates the Antarctic ice core record for the last 160 000 years. Two things emerge from this record. The first is that there is a close correlation between atmospheric concentrations of carbon dioxide and global temperatures.

Second, even though there have been large fluctuations in CO_2 concentrations in the past, they have never reached the 720 ppmv level that is expected by 2100. Of particular concern is the rate at which CO_2 concentrations are expected to increase. We are talking about changes beyond human experience.

Are surprises possible? Are abrupt climate shifts possible? Yes. We are entering a new region of climate perturbation that we have never been in before. The climate system, which is a non-linear system, may respond in unexpected ways.

Potential Consequences for Climate

What are the consequences of human activities for the climate system? A continued future growth in greenhouse gases is predicted to lead to significant climatic changes. The Intergovernmental Panel on Climate Change (IPCC) concluded in its 1995 Second Assessment Report that average global temperature will increase 1.8 to 6.3°F (1 to 3.5°C) by the year 2100, with a "best estimate" of 3.6°F (2°C). But climate change is more than temperature change. Sea level will also rise. Average global sea level is expected to rise between 6 and 38 inches (15cm and 95cm) by 2100, with a best estimate of 20 inches (50cm). Precipitation is also going to be affected. The hydrologic cycle will intensify and it will likely become a wetter world. The intensity with which rainfall and snowfall occur may change, and floods and droughts may become more frequent. These are changes that are greater than anything we have seen in the last 10 000 years,

and all of these anticipated changes have important implications for impacts and adaptation.

Is the Climate Already Changing?

Is this all pie in the sky? Have we seen any evidence of climate change, whether or not it's human-induced? Yes. The climate has changed and it will continue to change. Average global temperature during the last hundred years has risen 0.5 to 1°F (0.3 to 0.6°C). Average global sea level has risen 4 to 10 inches (10 to 25cm), and precipitation has gone up approximately 1%. It has, on average, become a hotter and wetter world.

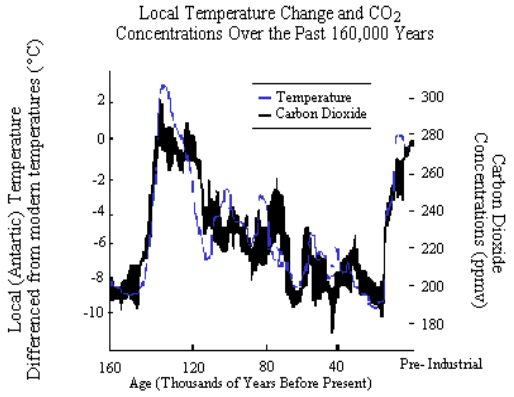
The IPCC concluded that some of this change in climate can be attributed to human activities and stated that, "The balance of evidence suggests a discernible human influence on global climate." It is not yet possible to identify what fraction of observed climate change was human induced. But a human fingerprint has been detected in the climate record (with a confidence level of five).

Regional Texture of Changes

Up until now we have been talking about global averages. This conference is about the Great Lakes, so let's talk about regional impacts.

Figure 2.3 depicts the temperature records over the last 100 years for the US.

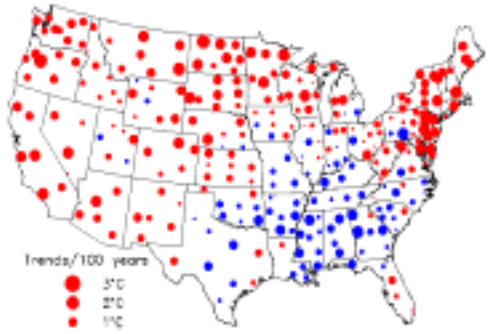
Figure 2.2



Derived from Antarctic Ice Cores
Source: Based on IPCC (1990)

Figure 2.3

Temperature Trends: 1900 to Present

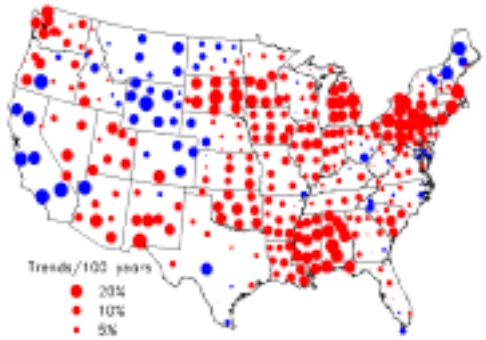


Red circles reflect warming;
Blue circles reflect cooling

Source: Karl et al. (1996)

Figure 2.4

Precipitation Trends: 1900 to Present



Red circles reflect increasing precipitation;
Blue circles reflect decreasing precipitation

Source: Karl et al. (1996)

With the exception of the Southeast, it has generally become warmer in the US. However, there is a regional texture to the changes. The warming is not uniform across the country. The increases have ranged from 1°C to 3°C, depending upon location.

We suspect that the cooling in the Southeast may be the result of increased industrialization and economic growth, which led to increased emissions of sulfur dioxide which is transformed into sulfate aerosols. These aerosols increase the Earth's albedo and have a regional cooling effect. In a sense it masks the warming that is occurring.

There is also a regional texture to the precipitation record, with increases ranging from 5% to 20%, and decreases elsewhere (Figure 2.4). What is going on in New Jersey is very different than what is going on in California. The character of rainfall has also changed. The area of the US that was affected by more extreme rainfall events (i.e., at least 2 inches [5cm] per day) has gone up. This is of concern to anyone interested in the potential impacts of climate change and climate variability, whether it is to agriculture, forestry, urban water supplies or hydropower, where one needs to worry about the rate at which precipitation events occur.

The key message is that there is a regional texture to climate change.

Potential Impacts

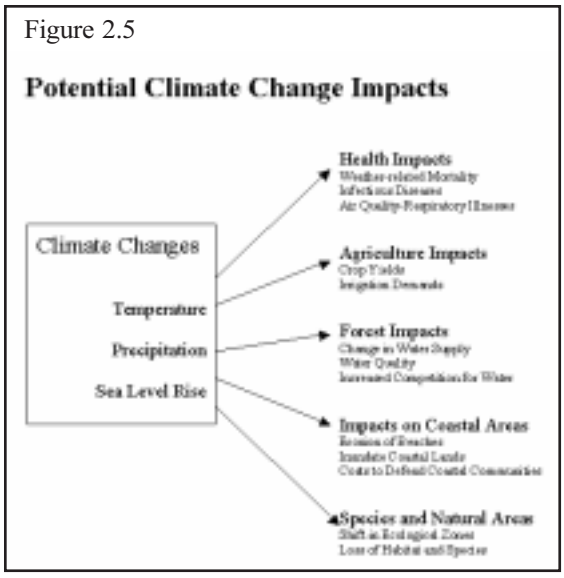
How well can we characterize the potential impacts of climate change? What does climate change mean for the average individual today and in the future?

Human health, natural ecological systems, and socioeconomic systems are all sensitive to both the magnitude and the rate of climate change. However, making predictions about impacts is difficult. Our understanding of the climate system is the best at larger geographic scales, yet impacts occur regionally and locally. Our ability to translate predictions of large scale changes in future climate into regional and local changes is limited. Despite this limitation, many valuable insights have been obtained about the risks to human health, the environment, and the economy, including:

1. Many systems that are vulnerable to climate change have already been identified. These include human health, agriculture, forests, water resources, coastal zones, and biodiversity (see Figure 2.5).

2. In the same way that there is a regional texture to climate change and climate variability, there will be a regional texture to the impacts of climate change on human health, ecosystems, and economic systems. If one is assessing the potential impacts of climate change, one must focus on a regional scale. It can be very misleading to only focus on impacts at an aggregate national level.

Figure 2.5



3. Many of the systems vulnerable to climate change and climate variability are already under stress from other factors. Climate change is an additional stressor on these systems.

4. The impacts from climate change to various systems will occur simultaneously. The systemic nature of climate change poses unique challenges to resource managers.

5. The ability of natural ecological systems to migrate appears much slower than the predicted rate of climate change. For example, the inability of forests to migrate as quickly as the predicted rate of climate change may lead to changes in the composition and distribution of forests across the US and Canada.

6. There are going to be winners and losers. If you look at any one potential impact category, some regions may benefit (at least in a $2xCO_2$ world) and others will be harmed. However, when you look across all impact categories, every region will experience some negative impacts from climate change.

7. The climate system is a dynamic system. The climate is already changing and impacts may already be occurring. Many people have the mistaken impression that there won't be any impacts until we reach a $2xCO_2$ world, and then there will suddenly be dramatic changes in the climate. That's not the way the real world works. The climate is already changing and some incremental impacts of climate change may already be occurring.

These insights can be illustrated with a few specific examples of potential impacts to human health, coastal zones (as a result of sea level rise), water resources, and agriculture.

Human Health

Climate change will affect human health through various pathways, some more direct than others. Some of the more direct effects include heat stress and health effects due to changes in extreme weather events such as floods. Some of the more indirect effects include the potential spread of infectious diseases, and impacts on health from changes in air quality and sea level rise.

Climate change is expected to increase the frequency of very hot days during the summer. Therefore, the number of deaths due to heat stress may rise.

Figures 2.6 and 2.7 depict increases in average annual weather-related mortality due to climate change for selected American and Canadian cities under one climate scenario.

Figure 2.6

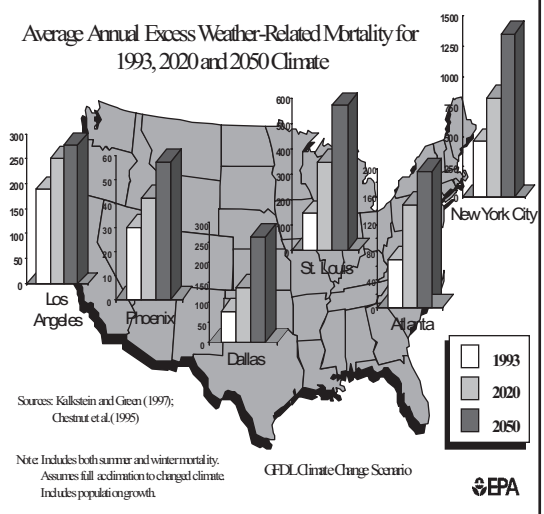
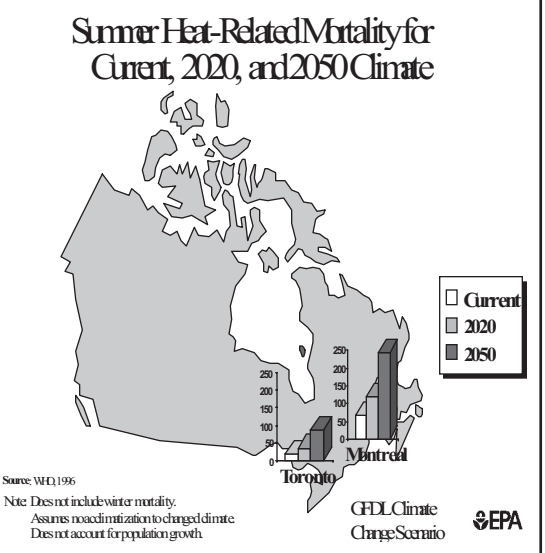


Figure 2.7



Note the regional texture to these impacts. The impacts of climate change on human mortality are city specific. This is due to a number of factors, such as differences in infrastructure, the extent to which people have physiologically adapted to extreme heat, and air conditioning use. In all cities, the most vulnerable populations are the elderly and the very young.

It has been suggested that winter mortality is likely to decline. Preliminary analyses suggest that this offsetting effect will not likely overwhelm the increase in summertime deaths. However, this effect needs to be studied further.

It is noteworthy that even under current conditions, the US public health care system is not completely effective at preventing heat-related illnesses and deaths. People die every year from heat stress in the US. This fact must be considered when assessing our ability to adapt to the additional stress of future climate change.

Climate change may also affect the risk of infectious diseases in different geographic areas. Climate change will affect both the geographic range of "vectors" (such as mosquitoes) that carry infectious diseases, and the life cycles of the vectors and the pathogens that are carried by the vectors. The IPCC has concluded that in the aggregate, climate change would increase the potential transmission of many vector-borne diseases globally. These diseases include, for example, malaria, dengue, yellow fever and some viral encephalitis.

There are those who are understandably skeptical about the potential spread of infectious diseases in the US and Canada as a result of climate change. But it is important to understand that we are not making predictions about future outbreaks of infectious diseases. Other socioeconomic factors, such as the quality of our health care systems, will affect whether or not outbreaks

actually occur. We are talking about changes in risks due to climate change.

Particular regions of the US are already at risk from some infectious diseases. Weather conditions in these regions are conducive to the transmission of particular diseases. Also, with modern international transportation, the vectors that carry diseases, and the diseases themselves can be introduced to different regions of North America.

It is noteworthy that there have, in fact, been cases of infectious diseases like St. Louis Encephalitis and hantavirus in the US, and they have been associated with specific weather patterns. Many of these are the sorts of weather patterns that one would expect to increase in frequency with climate change.

It is true that our health care systems can be a deterrent to the spread of infectious diseases. But effective health care systems come at a cost. The resources used to reduce the additional risks posed by climate change must be diverted away from other productive activities. There are also questions about the effectiveness of adaptive responses. As illustrated in Figure 2.6, people are dying of heat stress under current conditions, even though many of these deaths are preventable.

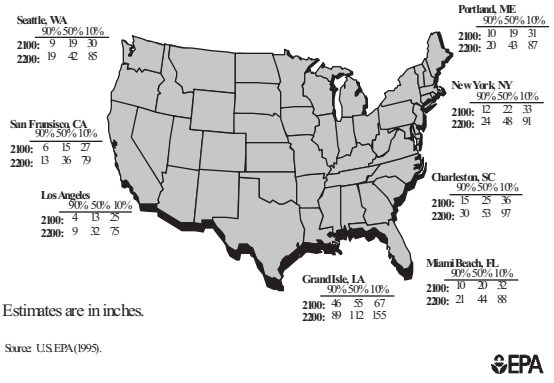
Climate change will make it more challenging for health care systems to protect public health.

Sea Level Rise

Sea level is expected to rise even more as a result of climate change. A 1997 EPA study estimated probabilities associated with future sea level rise along the continental US.

There is a regional texture to future sea level rise across the US. For example, there is a 50% probability that sea level will rise 22 inches (55cm) along New York by the year 2100, but there is a 50% probability that sea level will rise 55 inches (137.5cm) along Grand Isle, Louisiana (see Figure 2.8).

Probability of Sea Level Rise



What does this potential sea level rise put at risk? The projected average global sea also depend upon other stressors, such as level rise of 20 inches (50cm) could inundate 5 000 mi^2 (12 950 km^2) of dryland and drown 15-60% of our coastal wetlands. Whether or not these losses are incurred will land use patterns. For example, structures that are being built behind existing wetlands will

prevent migration of the wetlands as sea level rises. Once again, climate change is an additional stressor.

As noted earlier, the effects of climate change may already be occurring. The sea is already rising and wetlands are already being affected.

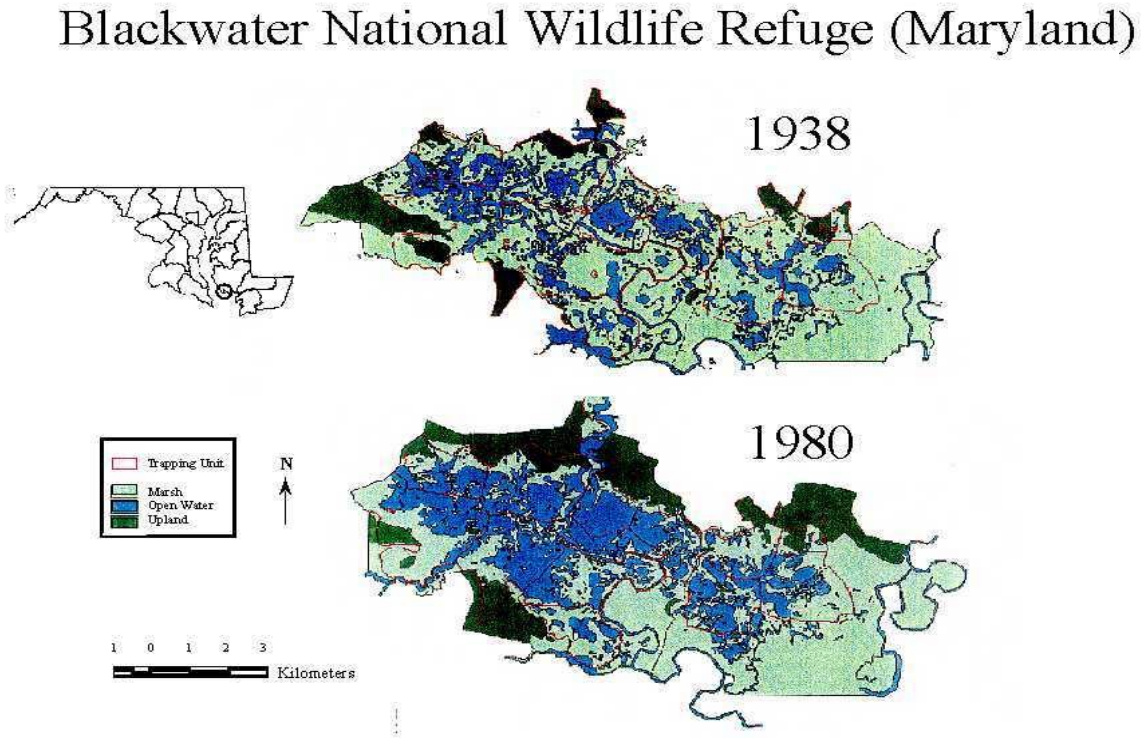
Figure 2.9 is an illustration of the Blackwater National Wildlife Refuge as it appeared in 1938 and 1980. Upland and marshlands have been lost as a result of sea level rise and other factors. These changes pose risks to fish and wildlife habitat, flood and erosion control, and water quality. The key message is that sea level rise, which is partly induced by human activities, is real. It is already occurring.

Water Resources

Water quantity and quality, a "linchpin" that integrates many regions and sectors, are particularly vulnerable to climate change. Water quantity and quality will be directly affected by precipitation changes and increased evaporation. With an intensification of the hydrologic cycle, floods will be more likely due to more intense rainfall. Droughts will be more severe due to increased evaporation and drier soils. The degree to which water quantity and quality will be affected will be region specific.

In addition, water supplies will be indirectly affected. A lot of different sectors use water. As water becomes scarcer in some areas, and as different sectors increase their

Figure 2.9



demands for that water, there will be additional stresses on available water supplies. This has important implications for the viability and effectiveness of differentadaptation strategies in different sectors. For example, an increased scarcity of water may limit the ability of "smart farmers" to adapt to climate change through increased irrigation. The water that is important to farmers is also important for hydropower, urban water supplies, fish habitat and other ecosystems, and recreational activities.

Water is also habitat for fish. A recer study by the EPA examined the potentia impact of climate change on freshwater fis in rivers and streams in the US.

The study found that cold- and cool-wate fish of varying types are vulnerable to climat change. For example, under one (Geophysica Fluid Dynamics Laboratory [GFDL]) climat change scenario, the populations of brow.. trout declined from 1% to 100% in a 2xCO_2 world in every state included in the analysis (see Figure 2.10). These losses have important implications for recreational fishing and translate into economic impacts. In the US, economic losses due to changes in recreational fishing opportunities could be on the order of tens of millions of dollars per year.

The key message is that water is a linchpin that links many different sectors together and influences the vulnerability of these sectors to climate change.

Figure 2.10

Loss of Habitat for Brown Trout from a Doubling of CO_2 - 2050

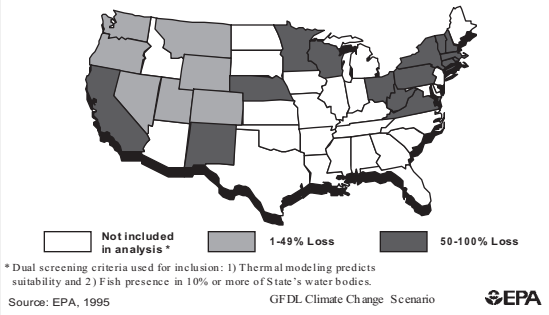
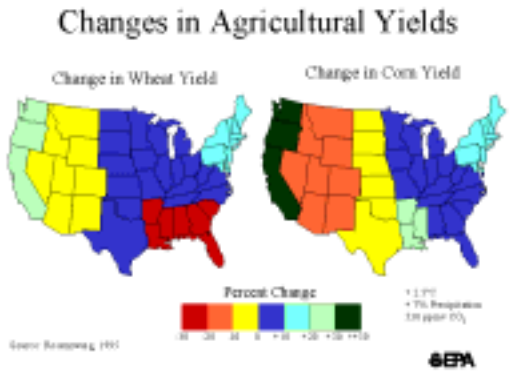


Figure 2.11



Agriculture

An examination of the agriculture sector helps to illustrate the limits of our understanding of climate impacts, as well as the difficulties that may exist to adapting to climate change.

Most studies suggest that in the aggregate, climate change will benefit US agriculture. This is particularly true if one accounts for international trade and the declines in agricultural productivity that are likely to occur in developing countries. However, by itself, this generally-accepted

conclusion is misleading because it fails to convey the regional distribution of agricultural impacts within the US. There will be a regional texture to potential agricultural impacts. Even though the US as a whole will be a winner, some regions may be net losers. There will also be distributional impacts within any particular region.

For example, under the climate scenario depicted in Figure 2.11, farmers who plant wheat in Texas may experience increases in yields (as opposed to total output) as a result of climate change. But farmers who plant corn in Texas may experience declines in yields.

Although the potential implications of climate change for US agriculture have been extensively studied, it is important to understand the limitations of existing studies. Most studies have examined the effects of changes in average climate. They have not fully accounted for changes in climate variability. Many studies also make strong assumptions about the ability of farmers to adapt, but have not fully accounted for changes in water availability (which is necessary for irrigation), and imperfect responses by farmers to changing climate (e.g., due to changes in climate variability). Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation. However, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, and other economic sectors. All of these issues deserve further study.

Conclusion

There are several key "take-away" messages from this presentation. First, the vast majority of scientists agree that climate change is a real phenomenon. Second, some human-induced climate change appears inevitable. We are affecting the Earth's atmosphere and the climate system. It is not yet possible to say how much of the historic change in climate is attributable to human activities. But a human "fingerprint" has been detected. Third, we may already be seeing the first discernible signs of climate change and the resulting impacts. Climate change has implications for the current generation, as well as future generations. Fourth, it is very hard to predict exactly where, when, and how large the impacts will be. However, we are already able to provide valuable insights to stakeholders and resource managers about the risks posed by climate change. Decisions about investments in adaptation can be made given information that is already available. Fifth, human-induced climate change would be slow to reverse.

Is this a message of "doom and gloom"? No. I suggest that in order to make intelligent policy decisions, one must understand the consequences of inaction.

As international deliberations continue about possible actions to mitigate climate change - which comes at a cost - people will ask, "What are we buying?" A better understanding of the risks posed by climate

change can help inform these deliberations. Although there is no such thing as a "free lunch," that doesn't mean that we don't want to buy lunch. It just means that we want to know what lunch we are buying.

It is also important to understand the potential impacts of climate change in order to make sensible decisions about adaptation. Some adaptation will be necessary since we are already committed to some human-induced climate change. We need to understand what the risks are and who the vulnerable populations are, in order to intelligently design adaptation options.

This isn't a doom and gloom message. This is an effort to communicate the potential impacts of climate change so that we can make intelligent and informed policy decisions.

Great Lakes-St. Lawrence Basin Project: What Have We Learned?

Linda Mortsch
Environmental Adaptation Research Group, Environment Canada

Frank Quinn
Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

Linda Mortsch, of the Environmental Adaptation Research Group, Environment Canada, serves as the Canadian Co-Chair of the GLSLB Project. Frank Quinn, of the National Oceanic and Atmospheric Administration, is the Head of Physical Sciences Division for the Great Lakes Environmental Research Laboratory, and serves as the US Co-Chair of the GLSLB Project.

Their presentation provided an overview of preliminary findings of the GLSLB Project. The Project, launched in 1992, is a joint Canada-US research initiative lead by Environment Canada's Environmental Adaptation Research Group and the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory. It aims to better understand the complex interactions between climate and society, so that informed regional adaptation strategies can be developed in response to potential climate change and variability.

When we were preparing for this talk on what we have learned in the Great Lakes-St. Lawrence Basin (GLSLB) Project, we realized that it was in May 1992 that the first Steering Committee meeting for GLSLB Project was held. Five years later, we are presenting what have we learned. The primary lesson is that the people involved in the Project have made the difference. Although we are the Project Co-Chairs, we are indebted to the Steering Committee members who have contributed their ideas, helped steer and encourage us, as well as to the researchers who have spent a great deal of time, thought, and effort in contributing to the science.

The presentation today will focus on some of the key components of the GLSLB Project, including:

- project design,
- research framework,
- scenario development,
- climate change and variability impacts,
- adaptation,
- integration, and
- communication.

Project Design

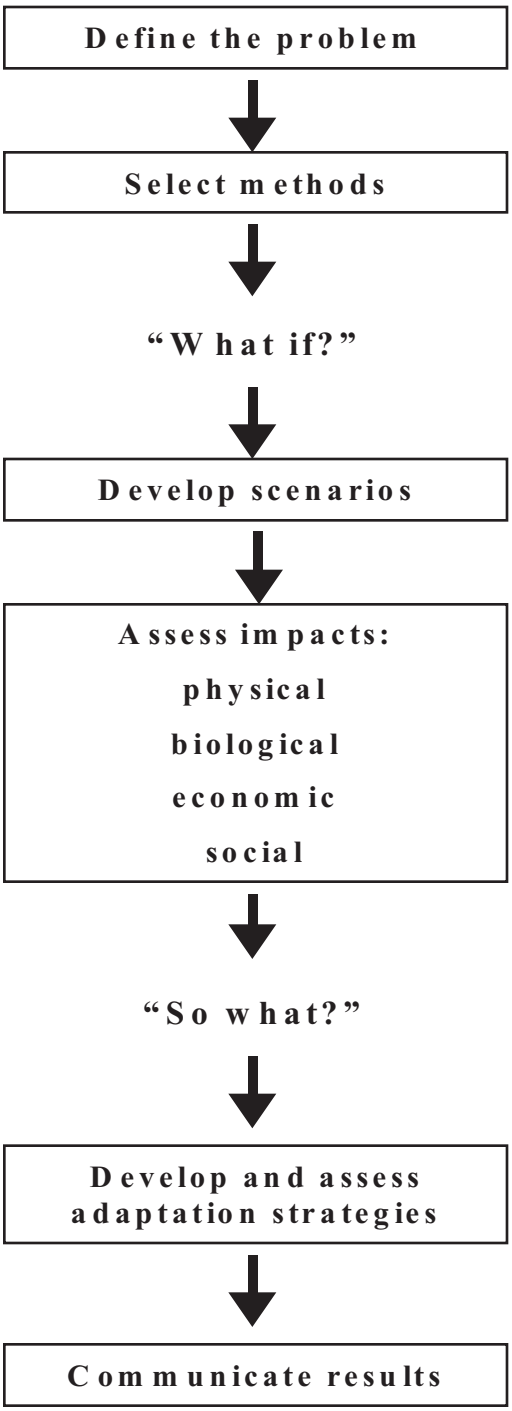
What are some of the considerations when designing a climate impact study, whether it is one with small-scale, single-sector focus or a large-scale study of a region? The process of a climate impact assessment

is outlined in Figure 2.12. Two phrases are extremely important to define the problem, select methods and undertake the assessment. First, the question, "If this were to occur, what would be the impacts?" (or "What if?"), is extremely relevant to developing scenarios and assessing impacts. Second, the question, "So what?" reminds us that simply identifying a problem is not sufficient. Solutions must also be developed; this is the adaptation component. Communication of climate change information to various publics increases their appreciation of the "What ifs?" and "So what?," and contributes to their understanding of climate change science, impacts, and adaptation strategies.

The GLSLB Project had a number of goals. The impacts of climate variability and change were assessed under four general themes: water use and management, land use and management, ecosystem health and human health.

Key principles guided the selection of component studies and the implementation of the Project. Research projects were required to emphasize the socioeconomic impacts of climate change, identify strategies for adapting to climate impacts, demonstrate integration, and build on existing research. Under the Project, researchers were encouraged to not simply identify problems, but also to demonstrate how people, sectors, and regions could develop adaptation strategies to reduce their vulnerability to climate and to be pro-active with respect to these "What if?" scenarios. Also, collaborative partnerships with researchers in other disciplines and with other agencies were formed since outreach was necessary to share

Figure 2.12
Six Steps in a Climate Impact Assessment
(modified from Carter et al. 1994)



knowledge and build capacity for understanding the climate change issue and to develop adaptations. Communication was promoted to key affected groups or people, both at the broader Project level and within the individual studies.

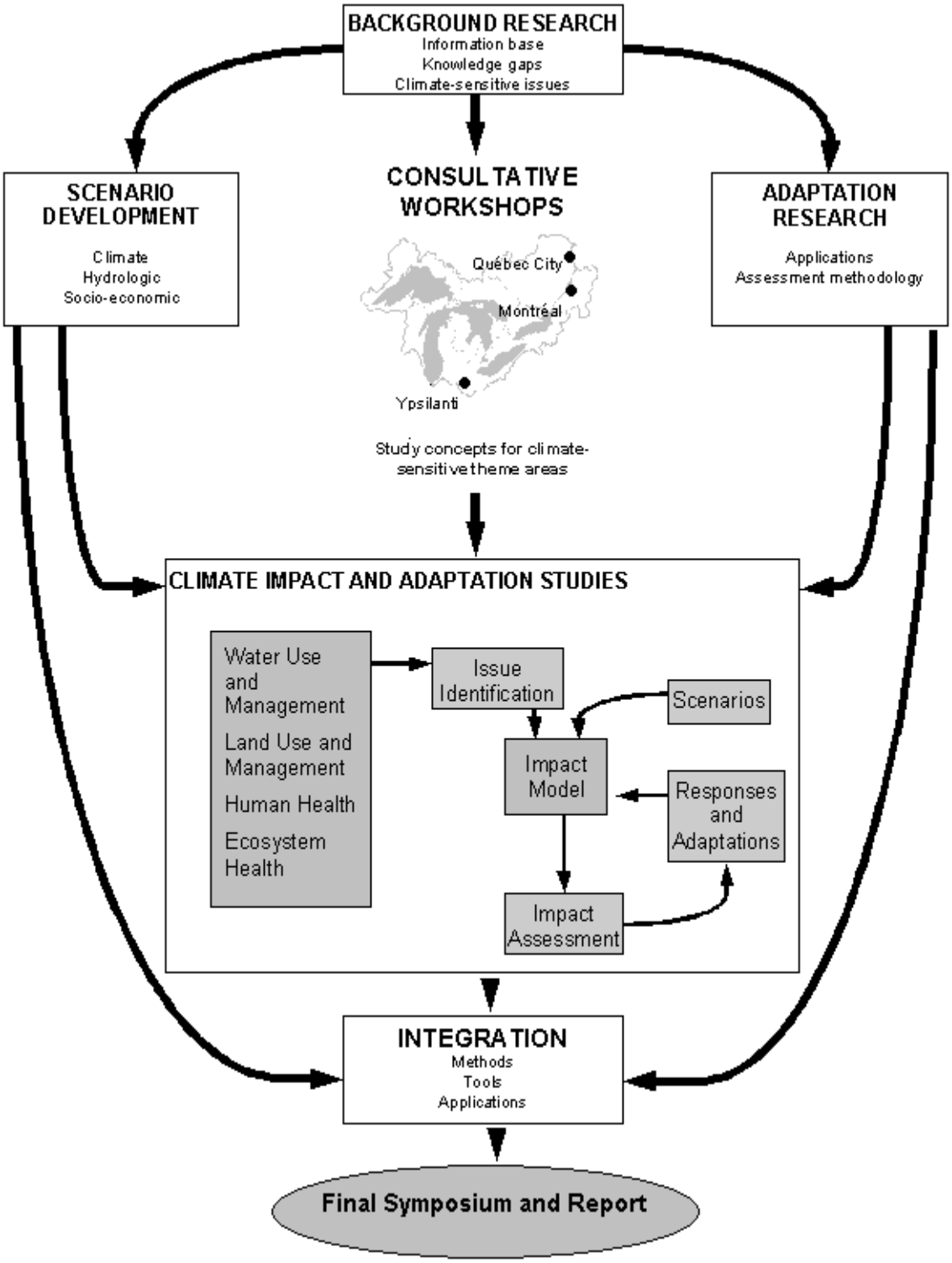
What have we learned in defining the problem? There are a number of questions that require consideration: "For whom is the project or study being undertaken?" "What are the anticipated outcomes?" Science goals are the substantive and methodological contributions; however, the Project's contribution to policy formulation and decision-making is the other important component of climate impact assessment. The climate change issue is so multifaceted, so far-reaching and complex that no single discipline can answer all the questions and provide all the needed expertise. Many people from many different disciplines must work together. Developing multidisciplinary partnerships poses a challenge, constantly requiring an immense amount of effort. Collaboration requires that researchers become fluent in, understand and appreciate other disciplines, as well as instruct others about their own discipline. Defining the problem requires defining the study area. One might pose questions such as: "Is the study area I have chosen representative?" "Is the information from this area transferable to other regions?" "Is the scale relevant to the research and stakeholders?" The large size of the GLSLB Project study area was not a comfortable scale for many of the researchers. Climate and hydrologic scenarios were developed for the entire Basin, but most of the component research studies focused on much smaller portions of the GLSLB, where data, models and expertise were available.

"The climate change issue is so multifaceted, so far-reaching and complex that no single discipline can answer all the questions and provide all the needed expertise."

Research Framework

Figure 2.13 outlines the research framework for the GLSLB Project. The first step was to review past climate impact assessment research in the Great Lake Basin and to decide where to go next. The document *Climate Sensitivity, Variability and Adaptation Issues in the Great Lakes-St. Lawrence Basin: A Reference Document* (Koshida et al. 1993) provided a basic understanding of the resource bases, institutional framework and environmental issues in the GLSLB to develop links between climate variability and change, and activities in the Basin. This review identified key climate sensitivity, variability and adaptation issues within the GLSLB. The issues

Figure 2.13
GLSLB Project Research Framework



identified in the document contributed to workshop discussions identifying climate-sensitive issues, from which the study concepts for the Project were developed. Three consultative workshops were held, two in Canada (in Québec City and Montréal), and one in Ypsilanti, MI. These workshops brought Basin interests together to discuss and begin to understand the issue of climate change, to develop study concepts, and to identify people to undertake the research. Scenario development and adaptation research formed key elements of the Project. Of the scenarios developed, climate and hydrologic scenarios have been more successful than socioeconomic scenarios. One of the most significant contributions of the GLSLB Project is that it introduced the concept of adaptation into climate impacts research in the Basin. The climate impact and adaptation studies were undertaken on four climate-sensitive themes with many studies incorporating a model of issue identification, scenario use, impact assessment and response and adaptation identification. Integration will be a challenge, but various approaches will be used including the Symposium discussions and the Final Report.

"One of the most significant contributions of the GLSLB Project is that it introduced the concept of adaptation into climate impacts research in the Basin."

Scenario Development

The GLSLB Project employed a number of climate scenarios, and some of their uses, and strengths and weaknesses will be presented. Most common were scenarios developed from general circulation model (GCM) 2xCO_2 runs. Although GCMs provide the best atmospheric science available, they still have shortcomings. The climatological information is at a large spatial scale often in monthly values. Scenarios of changes in variability and extreme events cannot be developed. Impacts researchers must use out-of-date scenarios because of the time lag in obtaining new GCM results. For example, the impacts of sulphur aerosols on reducing regional temperature increases have not yet been incorporated into an impact assessment of the GLSLB. The scenario development technique for annual temperature using the CCC GCMII and current climate information is illustrated in Figure 2.14. In the southern portion of the Great Lakes Basin, the current average annual temperature is 8-10°C. What would it mean if the average annual temperature were to rise to 12-16°C? One might pose similar for precipitation and other climate elements. Four climate transposition scenarios were developed for the Project using the annual temperature increases projected by GCM scenarios and precipitation

Figure 2.14: Climate Scenarios: Temperature

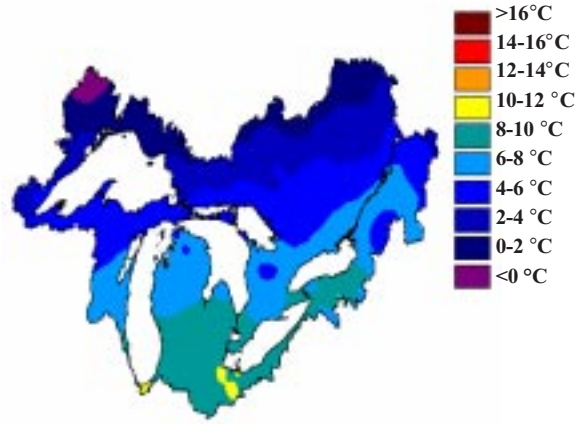


Figure 2.14a 1951-88 annul average GLSLB temperature (basecase)

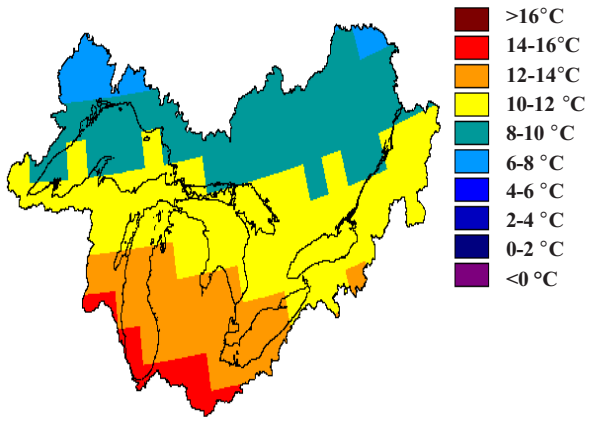


Figure 2.14c CCCGCM 2xCO_2 annual average GLSLB temperature (interpolated onto a 1x1 degree grid)

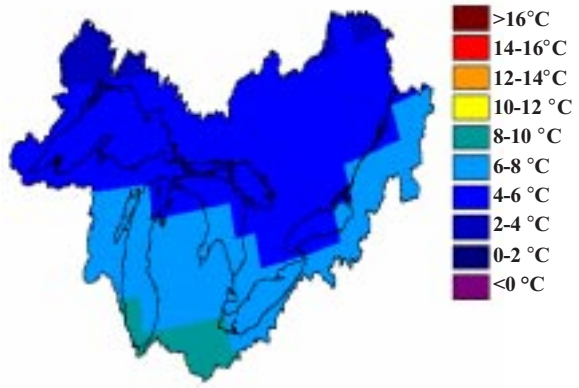


Figure 2.14b CCCGCM 1xCO_2 annual average GLSLB temperature (interpolated onto a 1x1 degree grid)

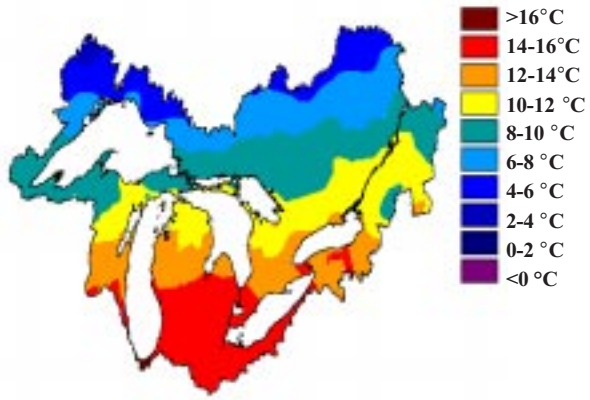


Figure 2.14d Annual average GLSLB temperature climate change scanio (2xCO_2 - 1xCO_2 + 1951-88 basecase)

characteristics (wet or dry) as a guide to select the regions. For example, the climate from a region 6°S and 10°W of the Great Lakes Basin reflecting a warm, dry region was imposed on the Great Lakes to assess effects on hydrology. These scenarios introduce changes in the mean and variability in climatic elements spatially and temporally, and to provide shorter time steps for analysis. However, transposing climates from another region to the study region lends difficulties, such as inappropriate topographic effects.

Historical analogues have been used such as "the 1988 Drought or Heat Wave" and "the 1960s Low Water Levels." G. Koshida and J. Brotton (see Appendix B.), and L. Rissling (1992), respectively, assessed the impact of the 1960s low water levels and the 1980s water level changes. These analogues demonstrate climate vulnerability, serve to document the impacts, and illustrate the adaptations that were undertaken to respond to particular events. They reveal both individual and societal responses. While

future climate change may likely be greater and more severe than the historical analogues that were examined by researchers, historical analogues provide a valuable tool to illustrate how extreme events were dealt with in the past. Historical analogues help make issues related to climate change real to policy-makers and decision-makers.

Climate change scenarios must be communicated as possible futures, not as predictions. They provide a "practice climate": "What if?" such a scenario were realized, how would, or should, we respond? What are the personal, political, environmental, social and economic ramifications of such a scenario?

At present, we are not very effective at addressing the socioeconomic scenarios. At the 1988 US-Canada Great Lakes Symposium, Impacts of Climate Change on the Great Lakes Basin, Peter Timmerman used the phrase, "Everything else remains equal" to highlight that in most impact assessments, climate change of the future is imposed on society, technology, population, and socioeconomic conditions of today. However, these will not remain static. Some researchers have sought to address this problem. In the Grand River Study, Southam et al. (1997) projected the effect of population growth to 2021 on water demand, then determined the effects on meeting basin water supply and wastewater treatment targets. Scenarios of climate change reductions in water supply were combined with the projected basin population and water demand. These scenarios illustrate that increases in population and associated water demand will exceed, at some point in the future, the reliable sources of water in the Grand River Basin; climate change scenarios shorten the period of reliable water supply.

Climate Change and Variability Impacts

In the next few paragraphs, findings under each of the four theme areas of the GLSLB Project will be reviewed.

Human Health

In the Great Lakes Basin, climate impact assessments on human health has received the least attention. Under the GLSLB Project, we completed a study examining whether the future mean daily temperature conditions, projected under a CCC GCM II scenario, may be suitable for the development and transmission of *vivax* and *falciparum* malaria in the Toronto region (Duncan 1996). This study considered the physical potential (i.e., temperature conditions) alone and not social, economic, and behavioural factors that also contribute to the incidence of malaria. An analysis of the relationship between weather and heat-related morbidity was undertaken for Toronto (Tavares 1996). At a maximum temperature threshold of 28°C, morbidity cases for the elderly increased (people greater than and equal to 65 years old), while morbidity cases for younger people (under 65 years) increased at a temperature threshold

of 31°C. A 2xCO_2 scenario projects more high-temperature days in the summer. The changing age structure in the GLSLB renders that an important planning consideration; the aging baby-boom generation is increasing the most vulnerable population.

Ecosystem Health

There are forty-three areas of concern (AOCs) in the Great Lakes-St. Lawrence Basin for which remedial action plans (RAPs) are being developed and implemented. None of these RAPs have considered climate variability and climate change. One study of the Bay of Quinte watershed indicates there may be changes in phosphorus loading to the Bay and that some sub-watersheds may not be able to achieve their RAP phosphorus loading targets. The higher water temperatures and lower water levels projected with climate change will impact the remedial efforts around the Great Lakes in many ways.

Wetlands are recognized as valued ecosystems that must be preserved. However, they are extremely vulnerable to changes in hydrology. What are the risks to inland wetlands and to shoreline wetlands from climate change? Shoreline wetlands that are open, without barrier beaches, may be able to migrate lakeward to respond to lower lake levels. New wetlands may be created, depending on slope, sediments, and seed banks available for recolonization. However, inland and enclosed wetlands are vulnerable; they may dry and become land.

B. Fooks (1996) reviewed government and private sector management policies and plans for natural areas in the Halton/Hamilton sub-watershed region of the Great Lakes Basin. None of the policies and plans explicitly considers climate change. The promotion of buffers, control of adjacent land uses, development or maintenance of corridors and linkages, monitoring and management for biodiversity would reduce vulnerability to climate change, yet Natural Area Management Plans in southern Ontario do not strongly incorporate these initiatives.

Land Use and Management

B. Singh et al.'s (1997) research indicated that climate change impact findings depend on the scenarios used. For example, if climate change alone is considered in agricultural yield models, crop yields increase and decrease, depending on the crop considered. The crop is vulnerable based on the acceleration of the maturation date and moisture stress. However, if CO_2 fertilization is included, yields increase, at least in the Québec region. One of the major conclusions from this study is that aside from impacts and yield changes, one must also consider the farmer's behaviour, his/her decision-making, management and adaptation to those particular changes, factors not often considered sufficiently in this kind of research. Focus groups with farmers provided

information on how climate change and pace of change are perceived. Farmers can adapt to slow, gradual change over a long time; abrupt changes are more difficult to respond to and lead to increased vulnerability. B. Smit et al.'s (1997) research showed that farmers respond to the climate or growing conditions of the previous year for corn hybrid selection. The year following a particularly dry, warm or wet year led to a change in behaviour. After a warm year, farmers seemed more willing to take risks such as choosing a longer maturing crop to enhance yield and after a cool year their adaptive behaviour was much more conservative.

Water Use and Management

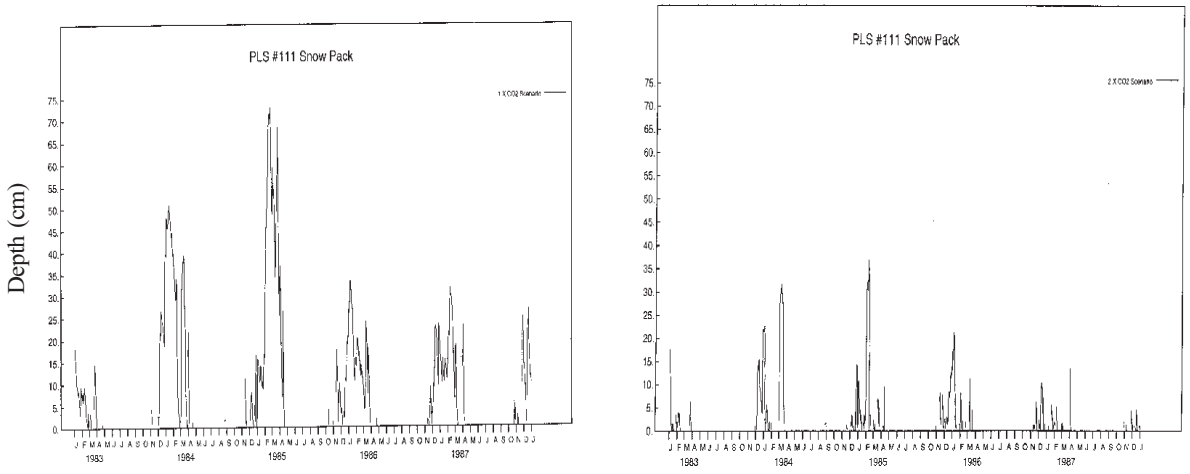
Water use and management in the GLSLB has been subject to the most research; results indicate that the GLSLB region may move from managing for an overabundance of water to managing for scarcity of water due to climate change.

Under $2xCO_2$ scenarios, lake levels decline. "What if?" water levels in Lake Michigan-Huron were to drop more than 1m? "What if?" levels dropped 0.8 to 1.9m on Lake Erie and 0.2 to 0.5m on Lake Superior? Lee et al. (1996) used an estimated 1.6m drop in the mean level of Lake St. Clair from the CCC GCMII scenario and Geographic Information System (GIS) modeling to determine the new shoreline configuration. The shore moves lakeward 200m to 6km. "What if?" wetlands, cottagers, boaters, municipal sewage outlets and water intakes will be affected?

The *Lake Ontario Regulation Plan* cannot meet minimum downstream flow requirements under climate change scenarios; consequently, the Lake Ontario Board of Control is considering re-evaluation of the regulation plan. Regulation of the lake must balance upstream interests in Lake Ontario (e.g., cottagers, boaters, hydrogeneration) with downstream interests in the St. Lawrence River (e.g., Port of Montréal, navigation). Lower water levels may require harbours and shipping channels to be dredged. Many sediments contain toxic chemicals; how will dredge spoils be disposed? The impact assessment of the Bay of Quinte demonstrates the change in the duration and amount of snow cover from current conditions to a $2xCO_2$ scenario
(Figure 2.15 a and b). In the $2xCO_2$ scenario there is a significant decrease in the snow cover depth. It becomes more intermittent and almost non-existent in some years. More precipitation falls as rain in the winter because of winter temperature increases; rain falls on snow, resulting in conditions for winter flooding, but causing less snow cover and a reduction in the spring freshet.

S. Changnon (1994) used the Lake Michigan diversion at Chicago as an analogue for climate change impacts and potential responses. His research suggested there will be enhanced controversy over existing diversions, and attempts at new intra- and inter-basin diversions under climate change

Figure 2.15a and b:
Snow Cover for the Current Climate (a) and 2xCO_2 Climate Scenario (b) for the Northwestern Portion of the Bay of Quinte Watershed (Walker, 1996)



a) b)

conditions. During the 1988 drought, barge traffic was affected on the Mississippi River. This led to a request for more diversion of water through the Chicago sanitary and ship canal to augment flow in the Mississippi River. Under *The Great Lakes Charter*, all the State governors and the two Provincial premiers have agreed not to allow diversions of water out of the Great Lakes Basin. However, climate change will challenge institutions and laws dealing with water.

R. Kreutzwiser (1996) identified vulnerable areas in southwestern Ontario for potential conflicts in rural water use, and interviewed people in the region to identify their concerns and to identify desirable, effective adaptations. His work indicated that there will be more conflict and competition between regions over water, and that rural water users are particularly vulnerable, especially where groundwater is the source of their water supply.

C. Southam et al.'s work (1997) on the Grand River Basin indicates that uncertain flows and poor water quality in the Grand River under climate change scenarios will make the inland water supply system more vulnerable and less reliable for regional drinking water supply and the assimilation of waste.

The climate impact assessment integration framework developed for the GLSLB Project is outlined in Figure 2.16. It identifies the cross-cutting research components that should be included in the climate impact assessment studies: climate and physical systems, socioeconomic impacts, adaptation, communication and education and assesses how well those components were integrated into the component studies.

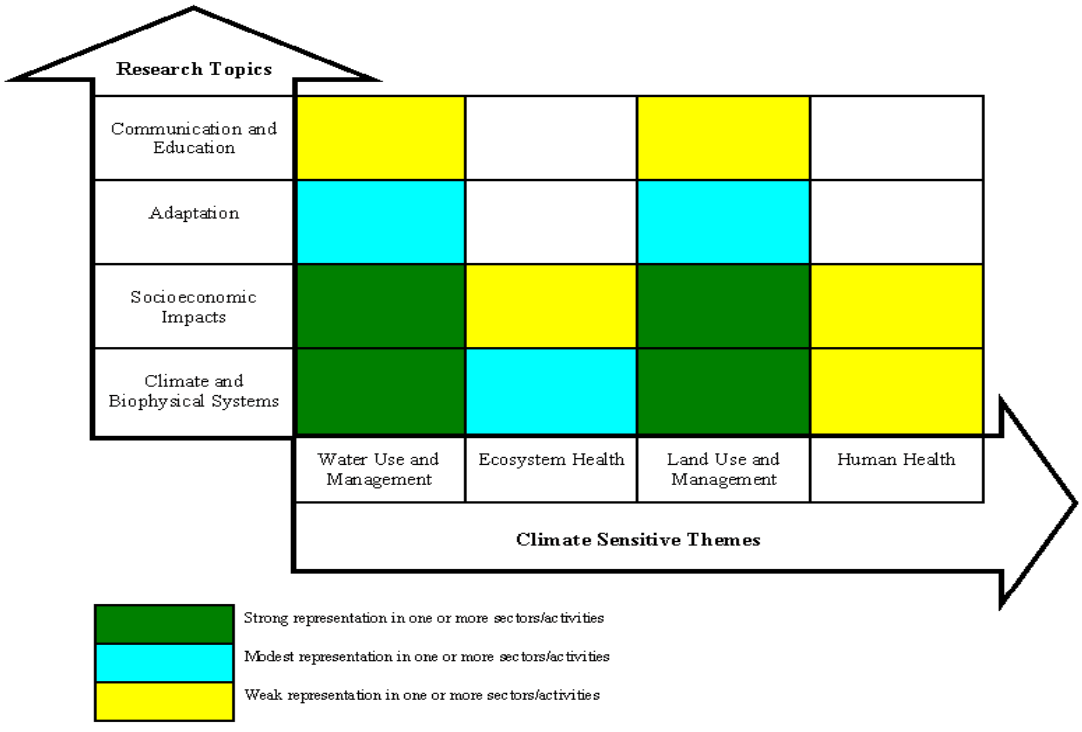
Most advanced are the themes of water use and management, and land use and management, for addressing climate and physical systems, socioeconomic impacts, adaptation, and communicating and educating others. The land use and management studies focused on agriculture and forestry, yet the GLSLB has a large urban component. Research on the effects of climate variability and change on urban areas is required. Ecosystem health has received some attention but requires more research on ecosystem processes and remediation efforts. Research on human health issues within the GLSLB is a significant missing link.

From these climate impacts, one might ask, "So what?" What are the potential adaptation responses?

Adaptation

To paraphrase Donahue (1994), the choices to respond to climate change are: a) "do nothing," b) "assume the worst case scenario," and c) "implement 'no regrets' adaptation strategies." The "do nothing" response means waiting for scientific certainty on estimates of the magnitude and direction of climate change. Then strategies can be designed with confidence and political will for implementation will be present. This may mean reacting to emergency conditions. There is delay in being adaptive. When assuming a worst-case scenario, the policy response can be immediate, aggressive, and affect socioeconomic conditions and behaviour. Aggressive measures are risky

Figure 2.16
Cross-cutting Research Topics

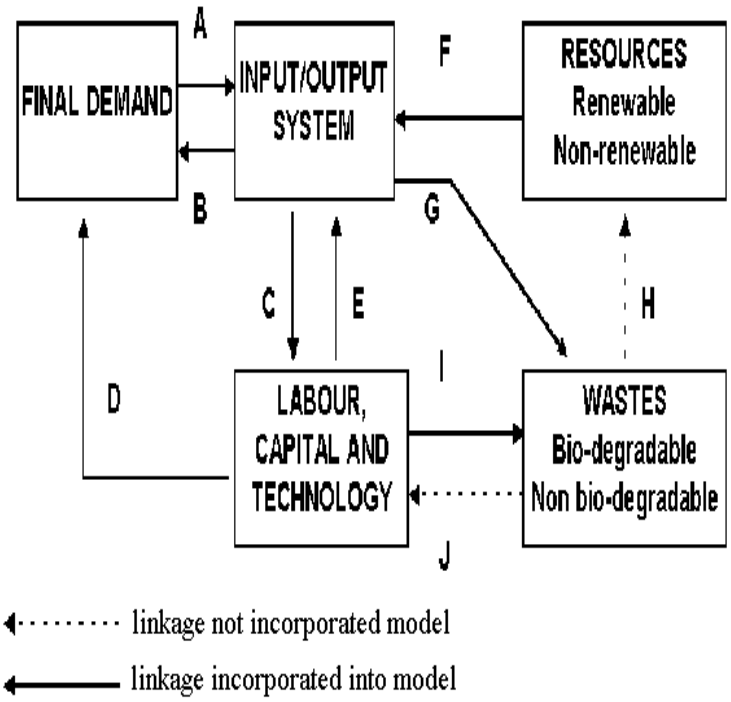


because of the uncertainty in climate change science, and in the effectiveness of actions. As well, initiatives may lack political support.

An alternative is "no regrets" adaptation strategies, actions that make sense now, irrespective of the nature of climate change, and which help to correct other known environmental problems (e.g., water conservation, no-till agriculture). These actions set the foundation for thinking proactively about climate variability and change, and for more aggressive measures if needed. This is an anticipatory, preventative mode.

I. Burton's work on adaptation has led to a typology of adaptations: sharing the loss, bearing the loss, modifying events, preventing effects, research and education, and avoiding the impacts. What adaptations resulted from the GLSLB Project? Studies examining land use and management and water use and management themes advanced and addressed adaptation. In the land use and management theme, two points of view emerged about agricultural adaptation. Farmers are adaptable and can change their crops and techniques, given the impetus to change, but also farmers are maladaptive to climate and thereby incur economic losses. The latter is often because government subsidies help absorb climate-related risks, and discourage adaptation. In water use and management, adaptation was addressed in the Grand River Basin and rural

Figure 2.17
The Environment-Economy Framework for the LINK Model



A. The demand for products determines what the economy produces. The input/output system identifies where the production will take place and what technologies will be used.
B. The economy generates income and taxes which, in turn, supports the demand for products and services.
C. As a result of economic activity, additions are made to the capital stock, such as buildings, roads, machinery and information production.
D. Requirements for new capital goods add to the demand for products from the economy.
E. Capital (including labour as 'human capital') provides services to the economy that are essential for production.
F. The economy requires resources from the environment which are obtained by the industries such as logging and mining, or through direct extraction in the case of water withdrawals.
G. Economic activity generates wastes which, in this context, includes all types of unwanted by-products coming from industry or individual consumers.
H. Wastes disposed into the environment can affect the capacity of the environment to provide some types of resources e.g. the effects of acid deposition on forestry and agriculture.
I. Changes to the economy's capital stock generates wastes (and causes environmental

water use studies (Southam et al. 1997 and Kreutzwiser 1996). Adaptations to streamflow changes in the river were assessed in the context of the Grand River *Vision*, a long-range, watershed planning document. With modest changes in river flow, the goals were projected to be achievable but complicated. Moderate changes in flow would make the watershed goals difficult to achieve and would lead to conflicts among users. When the flow declines became severe, there would likely need to be a "new operating environment" on the river and the goals of the planning document would no longer apply.

When interviewing rural residents in southwestern Ontario on adaptation to rural water supply shortages, the approach of supply management (drill new wells) was preferred over demand management (regulating water withdrawals). Residents also favoured restricting new rural non-farm development, suggesting potential conflicts between rural and urban/suburban residents. Among the methods used to gather ideas were questionnaires, focus groups, and historical analogue analyses.

Integration

Integration is a difficult task. What does integration mean? It means combining parts into a whole, or making them more unified or harmonious. J. Bruce asked those of us at the 1993 Symposium, "Is full integration possible or desirable?" We would answer no, but would suggest that "integration must be purposeful and selective." There should be a distinction made between hard and soft integration. In the GLSLB Project, we have focused more on "soft" integration, where biophysical, socioeconomic and adaptation knowledge are linked by multidisciplinary studies. These are "end-to-end" studies. Quantitative and qualitative information from the climate impact assessments provides input to sustainable development in the Basin, particularly as it affects the policy-making and decision-making process. In the GLSLB Project, we have used a number of integration tools: the binational framework, climate scenarios, an economic tool the LINK model, and GIS. The concept of adaptation has been useful to integrate research results. We have also directed research toward policy targets, such as the *Great Lakes Water Quality Agreement* (e.g., RAPs).

"Hard" integration was undertaken in the Project, but there have been some problems. Figure 2.17 illustrates the components of LINK, an input-output model, used to integrate the results from previous climate impacts on agriculture, tourism, and shipping, as well as new assessments for forestry and energy demand, to assess climate change impacts on the economy of Ontario. Impacts were reflected in the model by changes to current output levels by sector and by county. Among the limitations of this kind of a study is that it traces economic activity, but not wealth or well-being. The impact assessment was undertaken on sectors representing only

10% of the economy of Ontario, in terms of employment. Full integration would not be achievable using this particular model since we could not undertake enough climate impact assessment studies for comprehensive integration. As well, the positive and negative impacts identified in the climate impact assessment studies were obscured by a presentation of the net impact on the Ontario economy. This failed to capture the trade-offs between regions or sectors, and the policy implications.

Communication

Communication is a significant challenge for the climate change issue. How do you communicate an issue that has no real sense of urgency; where there are many uncertainties in the science; which is very complex; and for which there are no easy solutions? Why should you communicate? The goal of communication is to raise awareness, to give people an understanding of the issue and impacts, and to help motivate them to action or change. Communication also helps build support for the climate change issue. Development of adaptation strategies requires effective communication. Including stakeholders in designing and undertaking research for mutual learning should be important components of future climate impact assessments. Communication is often a significant missing link in efforts.

Lessons Learned

From the review of the GLSLB Project, a number of key lessons might be highlighted. We need to:

- address policy and decision-making issues as well as science issues;
- build a multi-disciplinary perspective with commitment to information exchange and appreciation of other disciplines;
- use a range of climate scenarios and link scenarios and impacts to historical extreme events for "grounding in reality";
- undertake careful, purposeful integration of results;
- identify "no regrets" adaptation strategies;
- communicate impact assessment results and adaptation strategies, and
- include stakeholders in the design and undertaking of research.

Questions/Comments

An unidentified questioner asked for clarification on where data for heat wave-associated mortality came from, observing that critical temperatures differ depending on location.

Another questioner asked whether there might be a challenge in communicating information about climate change to aboriginal peoples, or other unique populations, and effecting adaptation which benefits all populations. L. Mortsch concurred that a link missing in the GLSLB Project is a lack of aboriginal community studies or participants.

NOAA Advances and Activities in Climate Prediction

Alfred Beeton
National Oceanic and Atmospheric Administration

Alfred Beeton, Acting Chief Scientist at the National Oceanic and Atmospheric Administration, presented an overview of NOAA activities and recent advances in the area of climate prediction.

It is truly a pleasure to have this opportunity to come here and meet with many old friends. I started my research on the Great Lakes in 1955, so it has been a long time. I go back as far as Jim Bruce; he and I were junior people when we first met years and years ago. I have seen a lot of people here that I have not had a chance to visit with for a number of years, and it is great to see them all again.

I bring regrets to you from Jim Baker, the Administrator of the National Oceanic and Atmospheric Administration (NOAA). The Great Lakes now have greater visibility in Washington than they had in the past, consequently he looked forward to attending and discussing Great Lakes issues that are important to you and to NOAA. He was unable to attend because we are dealing with our 1998 budget, which will begin October 1st. There are innumerable hearings coming up all the time, and at the last minute, Congress scheduled a hearing for today. Therefore he could not make this trip and said "Al, you had better go." So I lucked out for a change!

The National Oceanic and Atmospheric Administration is a diverse agency, with many different facets, responsibilities, and obligations. NOAA was formed some twenty years ago, in response to the Stratton Commission Report, which recommended that ocean science, ocean operations, weather service, and related agencies be combined as one large agency. Consequently, NOAA houses the National Weather Service (NWS), National Marine Fisheries Service (NMFS), National Ocean Service (NOS), National Environmental Satellite, Data, and Information Service (NESDIS), and a unit called Ocean and Atmospheric Research (OAR). These are separate and distinct units under the umbrella of NOAA.

We are making some changes within NOAA, to refocus some of our programs. One of the challenges has been to get the research community within NOAA to work together more closely. With declining budgets

and down-sizing we must work together as partners within the agency, as well as with academia, industry, and other agencies, to preserve our research agenda and move it ahead. Likely that is a concern to any administrator dealing with research.

Because of increasing recognition of the importance of coastal issues, NOAA will focus over the next four years on NOS. NOAA intends to refocus NOS to emphasize coastal issues. This may be of interest to the participants of this Symposium, because there have been proposals to include other parts of NOAA, such as the Sea Grant Programs, the National Undersea Research Program, and the Great Lakes Environmental Research Laboratory (GLERL) within that organization. The most likely to move would be GLERL, which would broaden the horizon of and increase responsibilities for that organization.

I wish to provide an overview of things being done at NOAA related to climate forecasting. Among the significant accomplishments have been major advances in the science of climate prediction. Climate system monitoring has improved dramatically because of better observations and the development of models that can predict tropical ocean variability up to a year in advance. This level of forecasting has several implications for the Great Lakes. Being able to predict such variability up to a year in advance will lead to being able to predict global climate regimes. With the basic research that set up this capability, we have a greatly improved understanding of mechanisms for climate variability, and especially the El Niño Southern Oscillation (ENSO). Also, NOAA has begun short-term climate predictions, based largely on a good understanding of the general circulation models (GCMs).

The outlook is that we will significantly increase the skill and utility of forecasts ranging from time scales that have primarily been in weeks to several seasons in the future. Currently, we are releasing some predictions for up to a year. New products will be developed to provide forecasts and warnings of severe short-term climate events, such as droughts and floods, and heat waves, and cold spells, which all have large economic and societal impacts. For example, during the heat wave we had just a few years ago in Chicago, many people lost their lives, more lives than are lost from tornadoes each year. We need to do a much better job on predictions. Much of the information lately has been centered on floods, such as the one on the Red River, because they have such a large impact and are so costly. If we could do a better job on predictions to allow mitigation measures to be taken, as much as 25% of the costs (some billions of dollars) of some of these natural disasters could be avoided.

The spatial and temporal scales we are concerned with range from short-term local weather to long-term regional climate regimes. When dealing with floods the time

scale can be minutes to weeks. On the other hand, droughts usually span from months into decades. Looking at the atmospheric disturbances, tornadoes occur in minutes, thunderstorms and large fronts moving through have a scale of hours to days, hurricanes develop in days to weeks, and heat waves can be in the week to month scale. Events like ENSO extend from the scale of one to several years.

Developing an ability to predict climate has been aided significantly by a buoy system called TOGA, the Tropical Ocean Global Atmosphere Array, positioned across the Pacific Ocean. In addition, tide gauge stations are located around the Pacific Ocean, drifting buoys, volunteer observing ships, and expendable bathythermographs contribute to our understanding of thermal structure as well as sea surface temperatures.

When an El Niño develops, sea surface temperatures will increase, and barometric pressure will lower; these factors will affect climate conditions globally. Through 1997, temperatures have been increasing; the anomaly is up to 1.5°C in the western Pacific, about 1°C above what would be "normal" or usual. If you have a warm episode developing in the Pacific during the northern hemisphere winter periods, part of the southwestern Pacific region becomes very dry, because the storms that usually dump a lot of precipitation in this area have moved north and farther out to sea. Other parts of the world, like Indonesia and northern Australia, are dry, and the Gulf of Mexico region will have a wet and cool period. It will be warmer than usual in Alaska, and in southern Africa it will be dry and warm. It has been consistently shown that for the ENSO in the Northern Hemisphere during the summer period an expanding dry area in the southern part of the Caribbean and very warm areas in South America occur. On this

"The outlook is that we will significantly increase the skill and utility of forecasts ranging from time scales that have primarily been in weeks to several seasons in the future… New products will be developed to provide forecasts and warnings of severe short-term climate events, such as droughts and floods, and heat waves, and cold spells, which all have large economic and societal impacts."

basis, we are moving toward the ability to predict and forecast climate conditions on a global basis. Some countries are using this kind of information now for crop planning.

A cold episode essentially reverses the situations of the ENSO. As the Pacific air cools and the anomalies drop more than a degree, higher pressures occur over the Pacific, with the result that areas once quite dry are now wet. Storms are heavy over Indonesia and there is less rain over the Pacific. Summers are cool and wet, as opposed to dry during the warm period.

There are currently research projects underway on a global scale, to see to what extent we can expand our prediction ability. We can even do a better job by looking at other parts of the global ocean. Seventy percent of the globe is water, and that water is the determining factor for much of the climate that we see. Our global drifter array can accumulate limited information, about sea surface temperature, barometric pressure, and salinity. This system will lead to a possible expansion to a system similar to TOGA in other parts of the ocean.

Some climatologists feel confident enough to release long-term predictions. The National Weather Service, the National Centre for Environmental Predictions, and the Climate Prediction Centre released Volume 4, Number 4 for May 1997 to June 1998.

NOAA contributes to the global carbon cycle measurement network database in cooperation with other global agencies. Stations are positioned throughout the world. A few sampling locations have very high towers, and in some cases, aircraft are used to get CO_2 measurements. To obtain useful and valid data, we must have global partnerships and global cooperation.

Data from the NOAA Mauna Loa Observatory, American Samoa or the South Pole show similar long-term trends from in the 1970s and into 1994, although there are some slight short-term differences. These projects illustrate the benefits of global cooperation.

Questions/Comments

An unidentified questioner asked what triggers the ENSO phenomenon and where does the process initially start. A. Beeton explained in brief that the warming of the sea surface leads to additional evaporation and the development of a larger cloud cover, in turn affecting the distribution of moisture and temperature.

Interest in twelve monthly forecasts generated by the National Weather Service led to discussion about whether these might be extended into Canada. However, T. Croley (GLERL) mentioned that the Weather Service will not extend the maps into Canada because of Canadian forecasting responsibilities. During this discussion, A. Beeton mentioned the International Research Institute, which forecasts El Niño, will centralize functions associated with

producing and disseminating forecast information.

J. Lacroix (Ministry of Public Security of Québec) asked what is the accuracy of the annual predictions. A. Beeton stated that short-term forecasts are quite good, but longer-term forecasts become less and less reliable the longer they try to predict. A user of such forecasts has to realize the limitations.

Moving Beyond Climate Change and Variability to Atmospheric Change and Integrated Air Issues

John Mills
Environment Canada-Ontario Region

John Mills, Regional Director General, Environment Canada-Ontario Region, presented an overview of Environment Canada research findings and current initiatives addressing atmospheric change issues.

I want to thank the organizers of this event for inviting me to take part in the binational GLSLB Project Symposium, *Adapting to Climate Change and Variability*. Initially the Minister of the Environment was planning to be here, but something happened on the way. I think an election was called, and so he is doing other things. But I am very pleased to be here, and I certainly do look forward to participating for part of the afternoon and to hearing the final outcome.

To set the context, I will talk a little about what we at Environment Canada refer to as air issues, and then I will outline some of the areas on which we are currently working. The next challenge will be to move beyond addressing issues on an individual basis, beyond addressing only climate change and variability, towards addressing atmospheric change. It means that we need to look at the issues in an integrated fashion, linking the research and the policy development for these air issues of concern. Then I want to describe to you a type of cross-cutting impact study that needs to be done to advance the science and to contribute to the policy formulation of these issues. And finally, I will talk about one or two efforts currently underway.

The focus of this Symposium is climate change, but I would like to introduce a number of other air issues to the discussion, including smog, stratospheric ozone

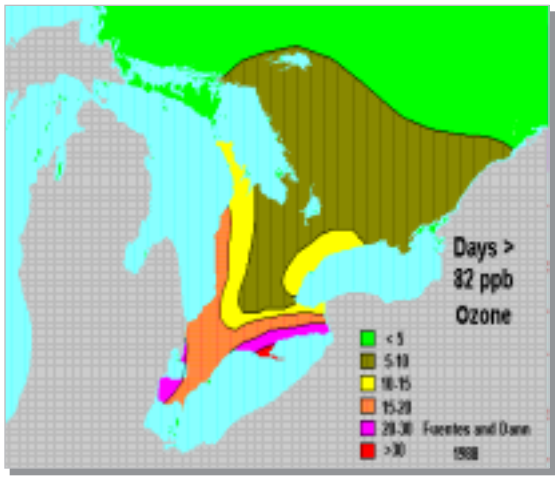
"The next challenge will be to move beyond … addressing only climate change and variability, towards addressing atmospheric change. It means that we need to look at the issues in an integrated fashion, linking the research and the policy development for these air issues of concern."

depletion, toxics, and acid deposition. These are specific air issues around which federal air programs are based. We are trying to manage air issues using an airshed concept, using physical boundaries as opposed to jurisdictional boundaries. The current challenge is to try to deal with all these issues in a more integrated fashion, recognizing how they interrelate and affect each other rather than focusing on single, separate air issues. I will focus on two air issues, smog and toxics, to illustrate my point.

Smog and Ozone

Why is smog an air issue? Pollution levels in both Canada and the US pose a health concern for humans and the environment. Certainly people in Canada, in the lower Fraser Basin, in Toronto, in the Windsor-Québec City corridor, and in parts of the Maritimes, are well aware of smog. Smog in this context refers to photochemical smog: the accumulation of emitted pollutants and those formed by chemical reactions driven by bright sunshine. The most prominent of these formed, or secondary, pollutants is ozone (ground level ozone). Increasingly, inhalable and respirable particulates are considered part of the smog issue. Smog and ozone are regional-scale problems, not just local air quality issues.

Figure 2.18
Average Days Per Year With Hourly Maximum Ozone Above 82ppb



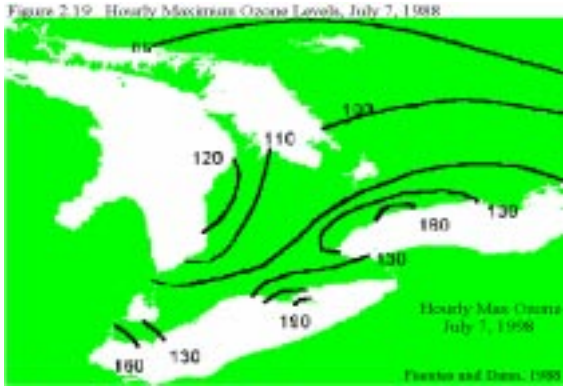
New research is showing measurable human health effects in the presence of relatively low ozone concentrations; there is no threshold below which no effects are seen. Figure 2.18 shows the average number of days per year with the hourly maximum of ozone above 82 parts per billion, which by Canadian ozone standards is considered poor. In southern Ontario particularly, about half of the problem is viewed as a result of atmospheric transport from the US, although this varies across the province. While we are the recipients of air problems, we also transport smog or smog precursors to our neighbours, both in Québec and upper New York. Ozone climatology is affected by the Great Lakes; while the ground is a major ozone sink, the lake surface does not act the same way. Ozone and its precursors can also be trapped in lake breeze circulations.

Smog is an example of a cross-cutting air issue which is affected by climate variability and climate change. Smog depends on emissions and meteorology. Meteorology can lead us to exceed our current guidelines, even with lower emissions of precursors. Three

meteorological factors affect smog levels: temperature, changing weather patterns, and changing local effects. Temperature drives up emissions due to volatility, because of increased power demands, and because at higher temperatures chemical reactions can be affected. Regional transport can be a major contributor or remover of smog, and changing storm patterns will affect the frequency of critical transport patterns. Local effects, changing lake effects can also affect smog levels.

Ozone exceedances, in Ontario defined in terms of number of hours when more than 80 parts per billion are measured at long-term stations, are illustrated in Figure 2.18. Meteorology and climate can drastically affect ozone exceedances; year-to-year variations are tremendous and are dictated by climate variability, not emissions. Further, due to continued population growth and current lifestyles, precursor emissions are still projected to increase eventually, even with current reduction efforts. Figure 2.19 illustrates the spatial pattern for a particularly warm day during the summer of 1988. Such conditions may be exacerbated by climate change with increased climate variability.

Figure 2.19 Hourly Maximum Ozone Levels, July 7, 1988



Toxics

Toxics may be considered another air issue, having an effect on human and environmental health. Those of us who live in the GLSLB are well aware of the issue of toxics on the Great Lakes ecosystem. We want healthy ecosystems, for example, to be able to eat the fish from the Lakes without worrying about fish advisories issued because of high levels of mercury.

However, antipollution efforts on the Great Lakes will not fully solve the problem, since long range transport of toxics is a significant factor. As an example, Lake Ontario receives about 1500 kg of toxics per day. Sixty-seven percent of that comes from the Niagara River, 19% is identified as coming from urban runoff and sewers, and the remaining 14% can be attributed to atmospheric deposition. In the upper Great Lakes, atmospheric deposition becomes much more dominant. For example, in Lake Superior up to 90% of some pollutants come from atmospheric deposition.

Atmospheric deposition is an issue of ongoing research, and the airshed to consider must include at minimum all of the northern hemisphere. Like smog, toxic events are episodic, because of long range transport. Therefore, climate change on both the global and local scale will affect this issue, and its human and environmental impacts.

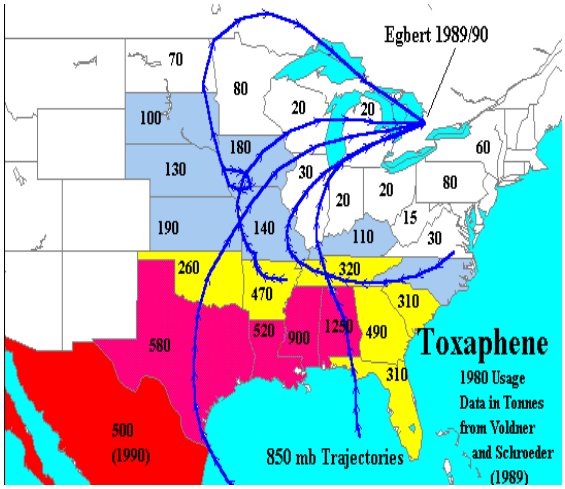
Toxaphene is a pesticide which was used extensively in the cotton fields of the southern

US, but has been banned for some twenty years. Such substances are still being emitted from the soil, and are transported far beyond the areas in which they were used. Figure 2.20 shows a selection of days with high air loadings of toxaphene as measured in southern Ontario, attributable to transport from source regions. The loadings are related to weather patterns; changing storm patterns due to climate variability and change will affect the frequency of such transport.

There are a number of atmospheric issues that have been identified, ranging in scale from urban, to continental, to global. We know that the ultimate source of the problem is human activity. While we have a fair understanding of the overall sources, we have limited understanding of the direct impacts, poor understanding of the integrated effects and impacts, and minimal development of integrated policy.

The study of integrated air issues is a good idea, and there are specific areas where further research is needed. Most impact studies to date are "first order," or issue or sector-specific. Although work of this sort is needed, we must encourage work that goes beyond the first order impacts and looks at the cross-linkages between air issues and resulting impacts (for example, we must go beyond a study of changes in crop yields, to examine the resultant impacts on the viability of the agricultural sector).

Figure 2.20
Days with High Air Loadings of Toxaphene



Great Lakes 2000 Program

Several initiatives are underway under the Great Lakes 2000 Program. Climate change impacts on sustaining Great Lakes inland and shoreline wetlands are being investigated, and the impacts of climate change on lake water quality, thermal stratification, gas transfer are being assessed. Under the program, decision support systems to evaluate adaptation and mitigation strategies are being developed. Attempts are being made to reduce the vulnerability of a Remedial Action Plan (RAP) to climate variability and change. The Toronto-Niagara Region (TNR) Study represents a first step at an integrated assessment of atmospheric change and variability.

The Toronto-Niagara Region Study

Despite extensive research on atmospheric issues, there continues to be limited understanding of the processes and effects of climate at the regional scale. We have limited understanding of the science of atmospheric stresses and the interactions between them, of the impacts of atmospheric stresses upon our human and natural systems, of the sensitivity of our human and natural systems, or of appropriate mitigative and adaptive responses.

Given the nature of the research problem as it applies to this region, it is necessary to examine the underlying drivers of atmospheric change, such as lifestyles and emissions (specifically land use and transportation), atmospheric stresses (e.g., climate change and variability, stratospheric ozone depletion, acidic deposition, long range transport of hazardous airborne pollutants, ground level ozone and suspended particulate matter), biophysical and human impacts (including, but not restricted to, the biodiversity of the ecosystem, and water resource management, economic and social systems, and on human health), and adaptation and mitigation responses (both autonomous and policy-driven).

The Study aims to synthesize our current knowledge of atmospheric stresses and their interactions in the Toronto-Niagara Region (see Table 2.1, conceptual framework for the study).

Table 2.1
TNR Study Conceptual Framework

- synthesize current knowledge
- construct an historical record
- establish a baseline inventory
- develop scenarios of atmospheric change and impacts
- assess sensitivities and vulnerabilities identify mitigative and adaptive actions

The aims of the study include developing both an historical record of the climate and atmospheric conditions and their impacts in the Toronto-Niagara Region, and a baseline inventory of the region's ecosystem health and atmospheric stresses. Scenarios of expected changes in climate and other atmospheric stresses will be developed, leading to the derivation of impacts on the health of the region's ecological and social systems. The sensitivity of the systems to current and future atmospheric stresses will be assessed, and linkages examined between societal decisions and actions, and emissions. Finally, the study intends to identify and appraise mitigative and adaptive actions that can be undertaken by governments, businesses, and individuals in response to current conditions to prepare for and accommodate a broad spectrum of future changes in atmospheric stress.

The Toronto-Niagara Region was selected for a number of reasons. The economic heartland of Canada, the "Golden Horseshoe," is the most populous region in Canada, with a growing and aging population; consequently, it is particularly vulnerable, in

terms of human health, to atmospheric change. The area hosts unique biodiversity and rural and urban ecosystems, as well as a number of special geographic features: the Niagara Escarpment, the Oak Ridges Moraine, the Scarborough Bluffs, and Niagara Falls. On the Niagara Peninsula, a wide range of agri-food products are grown/ produced which are unique in Canada, such as the tender fruit industry, and the grape and wine industry.

While it is a major contributor of emissions nationally, the Region has undergone significant emissions reductions. The Region has both the scientific and economic resources, with potential for collaborative research and multi-stakeholder involvement to deal with emissions problems. Having the participation of many stakeholders ensures broad representation of ideas, knowledge, responses and financial support from more than specific interest groups. If the problems cannot be dealt with in this region, it is unlikely they can be dealt with elsewhere in Canada.

The TNR Study will provide an integrated framework to incorporate many independent research initiatives already underway, and to support new research. By connecting pieces under an overall framework, we can see how things fit together and where the gaps still remain. Multi-stakeholder involvement in this initiative is a critical factor for success. No single agency, certainly not Environment Canada alone, can provide the kind of resources required and broad involvement in all the stages of the process necessary to ensure that the results address the needs and concerns of the broader public.

I have sought to review selected air issues in the Great Lakes Basin, and to identify research needs. There remain major gaps in our knowledge. More research on the impact of climate change and variability is needed, particularly as these changes influence or interact with other air issues. Also, we need an understanding of how we can adapt to these impacts.

We Can, Must, and Will Adapt

Ian Burton
Environmental Adaptation Research Group, Environment Canada,
and the Institute for Environmental Studies, University of Toronto

Ian Burton, Scientist Emeritus with Environment Canada's Atmospheric Environment Service and Adjunct Professor with the Institute for Environmental Studies at the University of Toronto, discussed issues related to adaptation, including the need to more carefully define and operationalize the concept.

Today I am not going to pretend I am presenting something before a parliamentary standing committee on the environment or some equivalent body of congress. I am going to let my hair down a little bit. I want to say one or two things that I hope you will find a little radical and challenging; perhaps such things are easiest to say among friends. Thanks to L. Mortsch and the Organizing Committee for giving me this opportunity. As was described in yesterday's sessions, we can adapt, and are already adapting. Climate is already changing, and somehow we will develop the necessary political and other will to cope with this change. That disposes of the title, but not the content, of my talk.

I want to take the chance to reflect on where we have been and where we are going. I am tempted to tell you the story about the Toronto businessman lost in the by-roads of Newfoundland, who stopped his car, wound down his window and said to a local, "Tell me friend, I am lost. How do I get to Corner Brook?," and the local said "Well, if I were going to Corner Brook, I wouldn't start from here." Where did we start from, did we start from the right place, and where are we going?

The other evening, S. Changnon presented a 100 year perspective of the progress of science on the Great Lakes. Let me go back just to September 1988, and Oak Brook, IL, where the first US-Canada symposium on climate change of this kind was held. Nine years have passed since that initial symposium at Oak Brook; only a handful of people in this room were there. Of many outcomes and recommendations from that symposium, there was a single, major recommendation picked out by S. Changnon in his summary report: "…[N]ow is the time to translate past experience into future programs aimed at ensuring availability of the widest possible management options for current and future planners based on application of the broadest scientific knowledge. To this end, the conferees strongly recommend two actions: 1) develop a US-Canada integrated study of the Great

Lakes Basin as a regional pilot project for an international response to global climate change; 2) establish a joint planning group to organize and develop the pilot project." He described how this should include the remedial action people and the IJC-established lake levels reference studies. The strong impetus of that meeting has led to this joint GLSLB Project. That is the initiative that brings us here today, near the end culmination of that study.

The Oak Brook recommendation presents two points for reflection. First, the study was meant to be integrated. Is it integrated? How can all those posters of this Project and all the papers and discussions of this Symposium be integrated? Some integration has been achieved; however, most of us would likely agree it still falls short of our ambitions in 1988.

Second, the Project was meant to point to an international response. However, I have heard nothing in the discussions about an international response, or about what it might be. Is there anything the US and Canada should do now as a result of the GLSLB Project? Are there specific implementation tasks or research we would like to suggest?

The Oak Brook Symposium and particularly the GLSLB Project were vital in putting the idea of "adaptation" on the map. At Oak Brook, talk of adaptation was limited. Nine years later, adaptation has moved from the periphery to closer to the centre of the climate debate. While it does not monopolize the centre, it has become an important element in the portfolio of responses to climate change.

We started off on the wrong foot, by defining the climate change issue as a pollution problem. We entrenched this concept in the *Framework Convention on Climate Change*, likely because we were flushed with the success of the *Vienna Convention* on substances that deplete the ozone layer, and with the *Montréal Protocol,* which called for a reduction and eventual phase-out of chlorofluorocarbons (CFCs). This has led to trouble, because the climate change issue is partly, not solely, a pollution problem. We, the scientific community, helped perpetuate the notion that if, like CFCs and ozone layer depletion, we turn off or slow down the tap then we would get rid of the problem entirely, or at least manage it. We failed to convey to the policy community and the public the extraordinary complexity and dynamic and pervasive nature of the climate issue, much more complex than the ozone layer depletion question.

Perhaps the scientific community tends to perceive the problem too much as a question of reducing uncertainty. Atmospheric scientists convey the message that new GCMs allow for long-term climate predictions, but a great deal of uncertainty remains. They assert that an increased understanding of atmospheric dynamics and better projections about the future state of the atmosphere would produce better advice to the policy process on when and how to begin to contain greenhouse gas emissions.

The policy process accepted the issue as defined, incorporating it into Article Two of the *Framework Convention on Climate Change*. This reads:

> The ultimate objective of this Convention and any related legal instruments that the conference and the parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Knowing what we now know, and having had the experience of the past decade, would we now advise the policy and the diplomatic community to phrase that objective that way? I suspect not. Since that objective was written, we have acted in ways that reinforce the original definition of the issue as a need to control emissions. What should be the objective? While I do not propose new language, I propose that the article needs to acknowledge the relation between humanity (and our social and economic development aspirations) to the atmosphere and in particular to the climate change component, to recognize the dynamic and interacting nature of the impacts. It is an extraordinarily complex problem, calling for a portfolio of responses. By declaring that the importance of mitigation is first and foremost, we relegate everything else to the label of "adaptation." We adapt to climate all the time: to extreme climatic events, to variability, to long-term means and climate norms. These are three quite separate kinds of adaptation, involving different experts and different stakeholder groups. Lumping all sorts of responses under the label of "adaptation" has served to destroy or diminish the value of the word. The idea of "adapting" to climate change has become inoperable, it means so many things.

For awhile, the climate issue enjoyed enormous success. We have been saying we are not getting our message across to the public and that people do not understand what climate change is all about. But if you think back to 1987-88, the climate change issue was the top environmental issue at a time when the environment itself was high on the public agenda. This is quite astonishing considering that we were talking about long range issues, about what will happen in the middle of the next century, proposing reactive measures that would require radical changes to our energy-based economy. The issue appealed to a wide range of people, who could see their own interests in the climate issue. Even the fossil fuel industry had to come to the table, in the hope of being able to say, "That's humbug, and we really shouldn't pay attention to that." However, it was such a popular, widespread and widely recognized issue that the fossil industry clearly could not stay away

from the table.

But, some people did stay away: the impacted sectors of the economy. At IPCC meetings, the agricultural community, the forestry community, and water managers have not been present. Those you might imagine are most concerned about the climate issue have not been actively involved in the debate. Even at this Symposium, where a concerted effort was made to involve impacted stakeholders, few have come. It is hard to attract them to discussions about the impacts of climate change. Why this is merits some reflection.

The definition of the issue and the way it was approached led to it being not oversold, but rather incorrectly positioned. We tended to jump from the atmospheric science of the problem and take a giant leap over to the concept of mitigation. What we viewed as the top problem in 1988 no longer seems to need to be solved. Because of the lack of success in conveying and sustaining the message to the public, even the atmospheric science community seems to be losing confidence in the importance of the issue. Continued atmospheric science is urgent and important, but there is a sense that the glory days of the climate change issue may have gone by. Everybody converged on mitigation. That was the most contentious and divisive part of the problem, dividing one region from another in a country, one sector of the economy from another, and on a global scale between different blocs of countries. This has made negotiations extraordinarily difficult. We have focused on the most difficult part of the problem, and declared that to be the entire problem. There has been little agreement on how to deal with the climate change issue. In the countdown to Kyoto, it is clear that the divisions are as deep and as sharp as ever. The agreements reached at Kyoto will likely be minimal and not far-reaching, and will likely deal entirely with the question of mitigation.

"We might think about adaptation in three ways. First, adaptation might be spontaneous and tactical (autonomous adaptation). Second, it might be guided, professional, engineered, planned, strategic, setting a broad decision-making context. I submit that there is a third level, to do with fundamental shifts in behaviour, in values, in lifestyle, with the kind of things that we have put under the banner of sustainable development."

As atmospheric research has advanced over the last decade, uncertainties have increased. Compare this process with the growth of an island of knowledge in a sea of ignorance; the larger the island becomes, the greater the boundary for the unknown. We do acknowledge that we know more than before, but we realize there is more we do not know and there is a greater degree of uncertainty. These uncertainties proliferated and tended to undermine or weaken the public perception of the message that we were trying to convey.

So the policy-makers, certainly in Canada, began to ask the impacts community for dramatic evidence of serious impacts. They wanted to know about malaria in Toronto, about the archipelago Prince Edward Island will become with sea level rise, about forest fires practically everywhere. We recognize the enormity of the climate change issue, its pervasiveness, its capacity to effect everything. We recognize unanticipated links, indirect effects, surprises, but we have been losing the battle. In some ways, we have lost the battle.

Can we redefine the climate issue, and would it help? Would it help to see it more as an integrated systemic problem in which adaptation has a central role? As I indicated earlier, adaptation is a hopelessly, broad, inoperable concept. It needs to be broken down into much more specific and operational ideas, because we are adapting to future climate. We have talked about adaptation to future climate as formulated in $2xCO_2$ GCM scenarios. We are talking about incremental progressive adaptation as the climate changes in a transient manner. We are talking about adaptation to present and future climate, characterized by variability and increasing frequency of extreme events.

It would be helpful for us to think about adaptation of different kinds. The literature recognizes a process of autonomous adaptation that is spontaneous and tactical, like choices that farmers make about particular cultivars suited to the upcoming season. Other adaptation is guided, professional, engineered, planned, strategic, whether in water management or agricultural policies, price supports, insurance, subsidies and markets, all of which sets the context for farmers making their choices and their adaptive decisions. I submit that there is a third level, which has to do with more fundamental shifts in behaviour, in values, in lifestyle, with the kind of things that we have put under the banner of sustainable development. On this level are behavioural changes, necessary for an effective mitigation approach.

We need to begin to get our adaptation story straight. We are in the state of confusion about adaptation, partly because so many things are labeled adaptation. We need to break that concept apart and define it more operationally.

Why, from the beginning, did we adopt this somewhat artificial distinction between mitigation and adaptation? In part, we were afraid that talking about adaptation gave the

wrong message, that climate change is inevitable, and that talking about adaptation would encourage us to think that there is nothing we can do about climate change, so we should learn to live with it. That was an unacceptable message to those who thought that mitigation would allow us to prevent or substantially slow down the rate of climate change. Now people are much more willing to accept that climate change is underway (and the IPCC is admitting this now), and that a certain amount of adaptation is necessary. Adaptation now has a legitimacy lent by the work of the IPCC.

Another reason why the notion of adaptation was not particularly acceptable was because it might convey the message that we can adapt. We have an enormous adaptive capacity, an advanced industrial technological society, a great deal of capacity to buffer ourselves from whatever the anticipated changes in climate may dish out. We are now in danger of pretending that we can take care of the whole problem by adaptation, but that is not the case. First, there will be the costs of mitigation, which in the long run will be substantial. The cost of adaptation will also be substantial, depending on the situation and location. Even adaptation and mitigation together will not entirely protect us from damage from climate and climate change; there will always be residual, remaining damages. We need to think much more clearly about the kind of economic framework that will permit us to say, "How much mitigation, when, and how fast, and how much adaptation, when and how fast, and how much residual risk and residual damage is tolerable and acceptable?"

"Are there adaptations in the Canadian part of the Great Lakes Basin that could be combined or harmonized with adaptations in the US? Is there not dialogue that we ought to be engaged in about adaptation measures?"

This economic calculation admittedly is extremely difficult, whether at the local level, at the level of the Great Lakes Basin, or on a broader international level. We have barely begun to do it. We have put a lot of our past effort into trying to understand the atmospheric science, but much less in trying to provide the policy process with an understanding of the costs of those three major elements.

Ten years or so ago, the National Academy of Sciences reported on the policy implications of climate change, recognizing that human activities are sensitive to climate change, but observing that most activities can be adapted at a certain cost. Farming, forestry, water resource use can be adapted, but at a cost. The natural landscape is more of a problem, and adaptation there is questionable, as it is in marine ecosystems.

Industry and energy have lower sensitivity. Tourism and recreation, settlements and coastal structures can be adapted at a cost. Even health has low sensitivity. Human migration may occur, but that can be adapted at a cost.

Part of the reason for the relative neglect of adaptation in the *Framework Convention on Climate Change* was the feeling that the industrialized countries really could take care of themselves when it came to climate change. We have been asking recently what it is that determines adaptive capacity on a broad comparative international basis. These are some of the major determinants, although not the only ones. Certainly the richer a country is the better it is able to allocate resources to adaptation. The more educated the citizenry, the more training, the more skills available, the better it can deploy resources of that kind to manage the adaptive process. As well, there is the question of ownership and access to technology, both hardware and software technology, and of the organizational and institutional effectiveness of government and other agencies, other institutions within society. When you ask yourself these questions, it is clear that highly industrialized, developed, well-organized societies have the elements of adaptive capacity and that the developing countries, particularly the poorer developing countries, lack the adaptive capacity. That is why the IPCC has concluded that although the climate will change least in low-latitude countries, that is where the damages of the impacts will be greatest, primarily because the capacities to adapt in those countries is lowest.

In the *Framework Convention on Climate Change,* we made some modest concessions to the question of adaptation, recognizing the specific needs of the developing countries. In particular, Article 4, Section 4 says, "The developed country parties and other developed parties [the European community] shall also assist the developing country parties that are particularly vulnerable to adverse effects of climate change, and meeting the costs of adaptation to those adverse effects." We are now approaching a new twist in the debate about climate change. That is, on what basis are the developed industrial nations going to provide financial assistance to the developing countries to meet the costs of adaptation? That has led us into some interesting gymnastics. First of all we are asking ourselves, "What defines a particularly vulnerable country? Do you measure vulnerability in terms of climate change, or in terms of adaptive capacity? Do you apportion the funds that are available from the Global Environmental Facility, or other sources, to developing countries, for adaptation on that kind of a basis?" Given the complexity of the concept of adaptation and its multifarious meanings, what activities in a developing country might qualify for that kind of financial assistance? The terms of the establishment of the Global Environmental Facility specify assistance for climate change, adaptation to climate change, but not adaptation to climate. Will a

developed country, threatened with hurricanes and needing to build coastal defenses, which if higher could also serve to protect against sea-level rise, have to calculate which part of the cost of those coastal defenses can be attributed to climate change, and which part can be attributed to normal climate? We know what we need to aid developing countries in coping with climate change and variability, and yet we are specifying this extraordinarily complex set of requirements.

I have tried to argue that we have actually got ourselves a little bit off on the wrong track, and maybe we should try and redefine the issue of climate change. I offer other, perhaps not well thought out, ideas. If we could add to the *Framework Convention on Climate Change* a protocol dealing with adaptation, what would that look like? If instead of an energy, CO_2 reduction, emissions and targets protocol, we had an adaptation protocol, what would that look like, and how would it fit in with the existing definition of the objectives of the *Framework Convention on Climate Change*, Article Two? If we could revisit Article Two, how would we recast it to more properly take account of the diverse portfolio of potential responses available to climate change?

Closer to home, are there adaptations in the Canadian part of the Great Lakes Basin that could be combined or harmonized with adaptations in the US? Is there not dialogue that we ought to be engaged in about adaptation measures? Of course there are. We have seen that over, the Great Lakes diversion question, but there may be others that we ought to be talking about, both on the mitigation and on the adaptation side. We have talked a lot about integration, and we want to have a better sense of the integration of impacts, but if we are beginning to think about how to integrate impacts and get a better understanding about overall impacts, should we not be thinking in similar terms about adaptation? Are adaptations going to be in separate compartments or should we not have a vision at least of a broader strategy of what we mean by integrated adaptation?

"Should we not to be trying to get a better, integrated understanding of adaptation, the way we are for impacts of climate change? And should we not have a vision of what we mean by integrated adaptation?"

In thinking about this as a science and a science policy question, would it be worthwhile to put some sort of a cross border think-tank together, to discover what we actually want to do with this concept of adaptation in relation to climate change. Can

we take it somewhat further on a bilateral basis? The notion of the Toronto-

Niagara Region Study has been cited as an example, looking at climate change not as an isolated air issue, but with links to other air issues. However, should we be thinking of this in a trans-border context, as the Toronto-Niagara-Buffalo study? This is a question that we ought to ponder.

3

SYNTHESIS AND FUTURE NEEDS: A PANEL REFLECTION ON THE SYMPOSIUM

The moderator for this session was Jim Bruce, Canadian Climate Program Board. Louise Comeau, Sierra Club of Canada, provided a synthesis from a non-government organization perspective. She identified the need for further integration of adaptation efforts, and communication of up-to-date climate change scientific findings. Michael Donahue, Executive Director of the Great Lakes Commission, provided a government perspective. He reflected on the appropriate role of governance in the climate change issue, and on the weaknesses and strengths inherent in our present Great Lakes institutional arrangements to respond to climate change. Barry Smit, University of Guelph, urged that we reflect on several key points arising from the Symposium, about the nature of climate change, adaptation and uncertainty. Dennis Heydanek, Dow Chemical Company, called for the industries of the GLSLB to act on climate change as part of long-term planning.

This panel was asked to synthesize the deliberations at the Symposium, from the governance, non-governmental, research and industry perspectives, in particular to:

- highlight the most significant areas of consensus and disagreement with respect to the perceived risks and impacts of climate variability and change,
- highlight the most significant area of consensus and disagreement with respect to the development, assessment and implementation of adaption options, and identify the most important adaptive action/role which should be undertaken by each interest (non-government, research, governance, industry) in response to climate change within the next 5 years.

Louise Comeau
Sierra Club (Non-government)

I have chosen to focus on three themes in talking about climate change: integration, communication, and "good and bad adaptation."

During the Symposium, discussion of the subject of integration failed to include the issue of sustainability. That is really what we are supposed to be working on. This is the challenge of Agenda 21 in moving forward from the Earth Summit. All the analysis of the progress we have made since 1992 has clearly identified the need for integration; that is the challenge both at a scientific level, and at a policy level. Few areas require integration more than responses to climate change. I urge, despite difficulties, a greater call for integration.

When we start to integrate and look at the broad range of impacts and the other implications of the primary contributor flow, one of which is fossil fuel consumption, we hit upon one of the fundamental pillars of sustainability: energy. Perhaps we have been somewhat sidetracked by an artificial separation between adaptation and mitigation. I would like to thank A. Maarouf for taking a courageous step to support The Sierra Club by asserting that the greatest adaptation inevitably must be to wean ourselves from our dependency on fossil fuels. We must eliminate the internal combustion engine. We must get off coal for electricity. Those of us who have the courage to say so early will have the last laugh.

There is a real frustration about the failure to communicate this information. The Sierra Club and other similar groups are an important audience for your research and scientific information. It is absolutely critical that we get information that is not only relevant, but up-to-date. How do we participate in the scientific process to make sure that we are getting information that is as up-to-date as possible? I would strongly support the recommendation that a communication team be established, to strengthen communication. It is not about educating the public about uncertainties. In fact, the public is quite bright and we need to trust their intelligence. The public understands that pollution hurts the air and is making people sick. It is really quite simple. The public perception is not related to risk in a probabilistic way, as scientists would understand it, but is related to voluntary versus involuntary risk. That is how you have to communicate the issue to the public. An individual will take on a personal risk, for example, cigarette smoking or driving too fast. When they choose to take it on, their tolerance for it is very high. But the tolerance for involuntary risks, those risks imposed on them, is very low. This is the issue with climate change and the risks that we are about

to impose on society involuntarily. That is when the public reacts.

There are some descriptions of what I call "good and bad adaptations." The scientific community would serve certain audiences quite well by clearly identifying what is an inappropriate adaptation. The next person who says that the response to lower water levels for hydro-electricity generation is to burn more fossil fuels, should get slapped; we should no longer count that as an acceptable adaptation to lower water levels. Distinctions must be made between what is and what is not an appropriate adaptation.

I have two final points that have not been adequately addressed, and about which I am not sure we came to any clear agreement on where we need to go. These are the issues of conflict and competition. The scientific community is challenged to identify where is the competition for resources in a world of changing climate, to identify what are the impacts that such competition will have on communities and societies, and what is the consequent potential for conflict. These areas really need to be explored.

"An individual will take on personal risk…When they choose to take it on, their tolerance for it is very high. But the tolerance for involuntary risks, those risks imposed on them, is very low. This is the issue with climate change and the risks that we are about to impose on society are involuntary."

Michael J. Donahue
Great Lakes Commission (Governance)

I am here to represent a government perspective, in terms of synthesis and future needs. I represent the Great Lakes Commission, an association of the eight Great Lakes states responsible for undertaking policy research and development and representing the interests of the Great Lakes states in state capitals and Washington, DC. This talk will touch on the significance of water resources in the Great Lakes Basin vis-a-vis the climate change and variability issue, on the policy implications of change, and describe the management framework in place that helps us deal with the adaptation issue.

I took my charge very seriously. For the last couple of days I have sat quietly in the back of the room and faithfully recorded all sorts of ideas and points brought up. I have managed to capture a rather methodical list of points of consensus and disagreement from the speakers.

In terms of the public policy significance of water resources, I need not go into any great detail at all. I would like to leave you with a single figure from the Great Lakes Water Use Database maintained by the Great Lakes Commission for the states and provinces, which we use to estimate annual in-stream and withdrawal water usage. This usage totals about 989 billion gallons per day. That fuels a whole host of activities in the industrial heartland of North America. So you can see how important this issue is from a water quantity standpoint.

A number of speakers have talked about different climate change and variability scenarios and impacts including lake levels, ice-cover, shipping, water quality, biological diversity, fisheries, and agriculture. There are two levels at which a state or a regional government will look at the policy implications of climate change and variability. For example, on the issue of lake level impacts, a state government would typically ask, "Can lake regulation plans currently maintained by the International Joint Commission accommodate projected climate change impacts on lake levels?" or "How should state coastal zone management plans and land use policies deal with anticipated climate change impacts?" For the navigation community, questions might include, "At what point would the economic costs and the environmental implications of dredging outweigh the benefits of maritime transportation?" D. Injerd indicated that, under the worst case scenarios, perhaps two of the three federally maintained harbors in Illinois could not meet that cost-benefit analysis. That is an indication of the kind of practical questions that state governments are likely to ask about this issue.

A second level of questions is more in the purview of those regional organizations

supported by the states, such as the Great Lakes Commission, taking a longer, broader look at issues. Questions they might ask about include the change in water availability and usage in the basin and in non-basin areas, resulting in increased diversion pressures and intra- and inter-regional conflicts. This very real issue can help states get their hands around the climate change and variability issue.

Another concern is that some of these projected climate scenarios require a shift in our legal and institutional needs, from managing for abundance and overabundance, to managing for scarcity and conflict. We have no experience in dealing with these within our legal and institutional systems; we have no legal and institutional framework, per se, for managing climate change and variability. Arguably, we do have one of the best-developed institutional and legal frameworks for water quantity management. All of these tools can be adapted to climate change and variability. The *Boundary Waters Treaty* of 1909 provides the International Joint Commission with investigative, recommendatory and judicial authorities; the *Great Lakes Basin Compact* of 1955 empowers the Great Lakes states on such issues. The US Supreme Court decrees on the Lake Michigan diversion at Chicago are an important component of the water quantity management frame-work. Also, *The Great Lakes Charter* of 1985, which is a "gentlemen's agree-ment" among the governors and premiers, provides some guidance in Basin-wide water management that is indirectly relevant to the climate change and variability issue. Finally, various pieces of state, provincial and federal legislation offer some limited guidance with these issues.

" The binational element in dealing with this issue should not be discounted; there is inherent added motivation for both governments to comply with binational agreements."

What are the strengths in our current management framework from a governance perspective? Our well-developed institutional infrastructure may have been generated primarily by crisis, but can be anticipatory when political will and motivation are present. The binational element in dealing with this issue should not be discounted; there is inherent added motivation for both governments to comply with binational agreements. *The Great Lakes Charter* serves as a guiding mechanism for gradual but steady progress in getting our house in order in terms of data gathering, consistent legislation and plan development.

What are the weaknesses in terms of the water quantity management framework? Weaknesses include our historic emphasis on

managing for abundance, not limited supplies; our legal and institutional basis is largely advisory as opposed to regulatory. As well, there are delays in implementing aspects of *The Great Lakes Charter,* including the current lack of a water resources management program. Legal uncertainties also exist in terms of how the *Boundary Waters Treaty* might be applied. Further, some basic inconsistencies between *The Great Lakes Charter* and the *Federal Water Resources Development Act* of 1986 raise questions as to how diversion and consumptive use proposals are to be addressed. Just as this issue moves forward, there is declining congressional representation in the Great Lakes Basin. As these climate impacts kick in, we are going to see a double-digit decrease in congressional representation from the Great Lakes region, and representation is going to increase proportionately in those areas most in need of additional water supplies.

Finally, in discussing areas of consensus and disagreement, I want to briefly recount some of the key points that I heard sitting in the back of the room for the last couple of days. On the topic of risks and impacts of climate change and variability, I heard three points of consensus:

1. The last ten years have seen considerable progress in how governments, particularly the federal governments, have examined the risks and prospective impacts in the Great Lakes Basin. Clearly much of this is attributable to the work of the GLSLB Project. I think both S. Changnon and L. Mortsch made that quite clear.

2. The preponderance of this work has been accomplished by federal agencies and academic institutions, and has been confined largely to discussions in professional symposia and related settings. Within the general population our speakers indicated that: a) impacts are either not fully recognized, b) are viewed with great skepticism, or c) are sensationalized so that they tend to add to that skepticism.

3. The Great Lakes states are certainly aware of climate change and variability issues. But despite a general understanding of risks and impacts, the issue is (with some notable exceptions) only on the periphery of their radar screen; other more pressing and immediate issues capture their attention at this time. I suspect that could be said for most local governments as well.

I noted some points of disagreement among the speakers. The Symposium attendees seem to mirror the general population in terms of how they approach the issue of uncertainty. At least two of the speakers placed confidence levels on their own statements. Some participants are clearly going to accept many assumptions and inferences. Others express a healthy skepticism and prefer to see more compelling and quantifiable evidence before accepting the need for adaptation strategies.

Finally, on this issue of risks, there was another point of disagreement relating to

scientific credibility and integrity of research. As I noted in my own session, it is a problem of "grey literature" sensationalizing the issue; this tends to give everyone more than a healthy dose of skepticism. One of the most important things we can do is to help to distinguish good science from opinion that comes under the guise of science; special interests promote preconceived biases and conclusions, a problem across Great Lakes opics. K. Ogilvie hit it right on the head when he talked about the need for a commitment to science by all concerned.

"These projected climate scenarios require a shift in our legal and institutional needs, from managing for abundance and overabundance, to managing for scarcity and conflict. We have no experience in dealing with these within our legal and institutional systems."

The second area of developing, assessing and implementing adaptation options contained several points of consensus. It was generall agreed there was no methodical strategic approach at any level of government to develop, assess and implement adaptation options. Much of the work is performed within federal government and university research circles, with a decided emphasis on developing these options as opposed to actually assessing and applying them. Many initiatives and behaviors now underway qualify as adaptation strategies, even though climate change and variability is not the motivating factor for them. This is the whole idea of the "no regrets" policy and it includes measures such as water conservation, mechanisms for evaluating diversions, consumptive uses, etc. However, speakers at this Symposium articulated diverse viewpoints about whether adaptation options are, or are not, being developed or implemented. Some speakers have argued that the issue of climate change and variability is too subtle, too complex or too speculative to really plot any type of methodical development and implementation of options. Others argued that adaptation options are already being implemented, although perhaps subtly or under the guise of other public policy objectives. J. Kinkead and E. Stakhiv both made that point, with E. Stakhiv stating, "Techniques may be chaotic and inefficient, but they are effective."

The final topic was on the important roles of interest groups in effecting adaptation. I

noted that, in many of the presentations, there was an assumption or a desire that government agencies should be responsible from "cradle to grave" on this whole issue. Typically, in many areas of public policy, it is public outcry that motivates political action and, in turn, motivates legislative action. However, a number of the speakers, even the speakers from NGOs, seemed to foist upon government the responsibility not only for research, but also for analyzing impacts and developing adaptation options, for communicating this information to the general public, and for motivating behavioral change. This was not countered in any of the main presentations, although in one of the breakout sessions it was noted that "Not government!" is the way implementation should proceed. There remains some uncertainty in that area.

Finally, the most important point of disagreement relates to the question of the ultimate role of government. Should the government be a researcher, strategist and communicator, or should the government be a regulator? There seems to be strong consensus that this first suite of activities is legitimate, but there is no consensus about the regulatory function. One presenter proposed a 50% reduction in basin, per capita water consumption. Others talked about new land use policies, and still others talked about water quality standards, air emission standards, and new energy policy and even ridding ourselves of the combustion engine. At the very time we are talking about government downsizing, deregulation and place-based management, adaptation strategies have a real potential to point us in a different direction for government involvement and intervention. We have not spent nearly as much time assessing options as we have in developing them. I suspect that the question about the prospective regulatory role of government in adaptation options is going to be contentious and something worthy of much more discussion.

Barry Smit
University of Guelph (Research)

I have chosen to select four points which relate to the focus of this meeting, the themes of adaptation to climate variability and change.

My first point deals with climate change and variability. During the course of the discussions, some people talked exclusively about long-term climate change, largely in mean conditions. Other people focused on climatic extremes or other attributes of shorter term variability, and several people actually made finer distinctions: daily weather, seasonal variations, variations from year to year, ENSO-related variations over decadal periods, and changes over centuries. So what is the point of this? I believe that if we are talking about adaptation we need to specify adaptation to what. Are we talking about adaptation to long-term climate change? Are we talking about adaptation to isolated extremes, adaptations to the risk of climatic deviations or to particular types of events? These are not separate; in fact they are related. Shorter term variations occur within longer term climate change, and the frequency and magnitude of extremes are influenced by both. In terms of adaptations, think about how climate change will be felt or is felt by any interest. For a bird population, or a farmer or a floodplain dweller, which characteristics and time intervals of climate are important, and prompt or warrant adaptation? Do daily events, yearly conditions, or cumulative effects over decades have the most significant effect? Climatic variation and climate change are not separate. Those with interest in adaptation to climate change must recognize the need for adaptation to shorter term variations and extremes.

"For predicting adaptations, you need to understand what the adaptation is; what are its precursor conditions, the things that either enhance it or impede it? For recommending adaptations, not only do you need to know something about the prospect for adaptation, but you need to have some basis for judging how good or bad it is."

My second point looks at the term "adaptation." As I. Burton pointed out and

others have illustrated, the term is used to capture a variety of things. L. Comeau broadened it to include mitigation, as in the reduction of greenhouse gases. We need to reach some agreement on the types of adaptations and definitions. One distinction we need to be aware of is between what have been called autonomous adaptations and recommended adaptation policy initiatives. The former are the adaptations or adjustments that happen spontaneously or occur anyway in systems. A study like the GLSLB Project takes interest in these adaptations to be able to predict impacts. For example, whether you assume that farmers adapt autonomously or not will influence an impact assessment. We want to understand behaviour so we can predict impacts. Thus, the analytical exercise with autonomous adaptation is a predictive one. We need to understand adaptation to do a better job of assessing the magnitude of the consequences of variation, of change in extremes, or of climate change. That is different from adaptation interpreted as a policy strategy. In this case, the analyst's task is to identify adaptations that should be. These are not necessarily ones likely to occur, but rather ones that are considered meritorious or optimal on some basis. We recommend them. It is an evaluative exercise. The implication for studies where we are dealing with adaptation is at least to make a distinction between these two interpretations. There are many other distinctions to make and the methodologies for addressing these or implementing them are quite different. They are not unrelated but they are different.

For predicting adaptations, you need to understand what the adaptation is; what are its precursor conditions, the things that either enhance it or impede it? For recommending adaptations, not only do you need to know something about the prospect for adaptation, but you need to have some basis for judging how good or bad it is. What are the criteria for evaluating options? E. Stakhiv has a paper where he spells out criteria for assessing adaptation policy initiatives. Is adaptation part of understanding the implications of climate variation or change, or are you looking at adaptations as potential policy recommendations?

My third point deals with the topic of uncertainty, a topic raised many times. Two quite distinct verbs have been used with the word uncertainty. Some people talk about the need to *remove* the uncertainty; others are talking about the need to *clarify* the uncertainty. This distinction is important, and a number of people have addressed it. Several presenters have talked about compounding ignorance, and the more we know, the more we realize that the nature of the phenomenon is so variable that uncertainty is a fact of life. An aim to remove uncertainty in this case may be futile, and probably misleading. It is certainly not necessary. An alternative is to assess impacts in terms of risk, recognizing the uncertainty, and think of adaptation as a type of risk management. These are terms which stakeholders use already. They are understood, so we will make some progress

in other areas as well, such as dealing with stakeholders.

A number of people have talked about the need to involve stakeholders, and have lamented the fact that we do not have many representatives from interest groups at this Symposium. Recall how the stakeholders present have characterized this issue. What terms have they used? The representatives from the Stonechurch Vineyards talked about cool, wet years, particularly in the harvest period. The urban water people are worried about dry years or several dry periods. The people interested in emergency preparedness are concerned about the extremes, and the people who live in flood prone areas worry about the magnitude and frequency of floods. The shoreline managers are interested in periods which result in too much or too little moisture. Farmers, who I deal with most, worry about the late frost or the short growing season or the dry spells. When you ask these specific interests, you find out what characteristics of climate are relevant to them, and the language they use to describe climate-related risks to which they must adapt. To do a better job relating to stakeholders, we need to do a better job of understanding the language and the concepts used by them. If we go there and say "Hey, we've got this wonderful conference about future climate change and we are using 2xCO_2 scenarios and we've got coupled ocean-atmosphere GCMs which suggest average temperatures next century may be a few degrees warmer," it is a wonder we had three stakeholders here.

If you really wish to look at adaptation, then focus directly on adaptation. Seek to understand the sensitivities of systems and interests, and the nature of adaptation. Do it with the tools and the techniques and the methodologies that are appropriate for that task. It will require using the expertise in and language of those systems and interests. But if this is not done we will not progress beyond naïve hypothetical speculation about adaptation, and will not involve stakeholders in a meaningful way.

"When you ask these specific interests, you find out what characteristics of climate are relevant to them, and the language they use to describe climate-related risks to which they must adapt. To do a better job relating to stakeholders, we need to do a better job of understanding the language and the concepts used by them."

Dennis Heydanek
The Dow Chemical Company (Industry)

(D. Heydanek was unable to attend the Synthesis Panel Presentations, but prepared the following paper as part of a pre-Symposium information package.)

A Call to Action for Industry in the Great Lakes-St. Lawrence Basin: Assessing the Impact of Climate Change

Companies today are faced with a myriad of issues and public policy debates covering economic, environmental and social concerns. Where businesses choose to invest precious time and resources depends on their unique market situation. In 1992, the Dow Chemical Company decided to dedicate resources to the issue of global climate change. Why? Dow's attention to this issue is based on four fundamental beliefs:

1. Global climate change is still an emerging and evolving issue. We believe scientific assessment should precede and guide policy-making. Now is the time to understand and contribute to the science, while international policy still is debated.

2. Industry often invests for a 20- to 30-year asset lifetime. We have an obligation to our shareholders to understand the competitive environment and to address issues that have a potential impact on our core businesses during that lifetime.

3. The climate change issue will probably catalyze consumer lifestyle and behaviour changes. To be successful in the future, companies today must analyze and anticipate changes in the marketplace to acquire a competitive or technological advantage.

4. In the long-term, public policy likely will evolve at the regional and local level. Despite the current drive to manage climate change as an international issue, we expect regional government ultimately will implement unique policies. To be competitive, companies must understand local markets and evaluate potential options.

The GLSLB Project is seeking to understand the potential local impact of the climate change issue. We believe that companies that care about doing business in the GLSLB should participate in this project where possible. Now is the time to act while policy-makers are gathering data and fostering debate.

"In the long-term, public policy likely will evolve at the regional and local level. Despite the current drive to manage climate change as an international issue, we expect regional government ultimately will implement unique policies."

4

IMPACTS AND RISKS OF CLIMATE CHANGE AND VARIABILITY: STAKEHOLDER PERSPECTIVES

The moderator for the panel was William Bolhofer, National Oceanic and Atmospheric Administration. Sarah Miller, from Great Lakes United and the Canadian Environmental Law Association, presented the non-governmental perspective, articulating concerns about water use, and the lack of opportunities for public involvement in the issues. Lorrie Minshall, of the Grand River Conservation Authority, described current planning and management initiatives, and the potential impacts of climate change, in the Grand River Basin. Dan Injerd, Illinois Department of Natural Resources, presented climate change impacts on Illinois, particularly for navigation and water supply. Difficulty communicating climate change and the urgency of other problems, often obscure the issues. Jacinthe Lacroix, of the Ministry of Public Security of Québec, and President of the Québec Association of Climatology (ACLIQ), considered potential positive and negative impacts of climate change on various sectors in Québec. Better regional climate projections are needed. Don Power, of Ontario Hydro, presented some energy industry concerns about climate change.

Panelists from climate-sensitive sectors were asked to discuss the following questions:

- What are the range of possible impacts and impacts of most concern?
- How do others associated with your activity perceive these impacts and risks?

What uncertainties must be clarified before decisions can be made with respect to impacts?

Sarah Miller
Great Lakes United and the Canadian Environmental Law Association (Non-government)

First let me say that I am not really representing legal interests in the GLSLB, because I am not myself a lawyer. The hat that I prefer to wear today is as the co-chair of the Water Sustainability Taskforce of a group called Great Lakes United. It is quite a daunting task today to be one of the few speakers trying to represent the public interest in this issue.

Our taskforce has set itself a rather major task; that is, to re-engage the public in the issue of the long-term sustainability of the Great Lakes. We have been involved in this issue since 1982. Great Lakes United, a coalition of conservation, environmental, health, sports and tourism groups, native nations, educators and labour, has had a reactive role since its beginning.

If I could describe its evolution, in 1985 Great Lakes United contributed greatly to strengthening *The Great Lakes Charter*, the only ecosystem document on the Great Lakes that tries to manage the Lakes' waters. Great Lakes United has responded to the many diversion and withdrawal proposals for the Great Lakes that continually arise. As well, every year we bring together our diverse membership from around the Great Lakes, to build policy and resolutions, hopefully with long-term legislative protection for the Great Lakes. Water is the key concern of our members. However, it has become increasingly difficult for us to address in an integrated fashion the many things impacting water.

Our task force aimed to define the problem in lay language. We decided that we needed to look at all of the stresses to the Great Lakes foreseeable in the next millennium. This involved looking at our history of dealing with issues, and at the state of sustainability in the Great Lakes. All this we attempted in our report, "The Fate of the Great Lakes-Sustaining or Draining the Sweetwater Sea?" We released this report February 10, 1997, on the twelfth anniversary of *The Great Lakes Charter*. Ironically, this is the first invitation to engage in debate with policy makers and scientists on some of the things in that report, which received quite wide coverage throughout the Great Lakes Basin.

While I will not dwell on impacts, I want to assert that the public views long-term impacts as very important. Survey after survey reinforces that the public wants politicians to take strong environmental positions. While the environment is one of the three top public concerns, increasingly, the public finds itself locked out of opportunities to participate on these issues, and that fewer and fewer politicians are taking their concerns to heart.

Talking about our preparedness and the

state of sustainability in the Great Lakes provides some opportunities for this meeting, the long-term objective of which is to better engage the public. Stakeholders and managers of the Great Lakes have prided themselves in the last few years on the success of taking an ecosystem approach to toxic issues and pollution prevention, but they have failed miserably at taking an ecosystem approach to managing the various activities that influence the water of the Great Lakes.

In the Great Lakes Region, jurisdictions continue to act in their own interests. Old problems, such as historic diversions of Great Lakes waters, continue to be the focus of dispute. In the last couple of years, a dispute between Michigan and Illinois over the amount of the Chicago diversion managed to stay out of the Supreme Court through mediation. The Water Resources Committee, the water management watchdog organization that arose from *The Great Lakes Charter*, failed to meet for three or four years. Data they have gathered have not helped predict our regional water needs. Many of our old problems in the Great Lakes persist. There has been a long-lived paranoia in the Great Lakes region that continental water shortages in the US will lead to raids on Great Lakes water, that the Great Lakes will have to share their water. Because of our neglect of the past twenty years, we are creating a moral dilemma for the future generations of the GLSLB. We have failed to instill a conservation ethic in citizens of the Great Lakes Basin, probably ensuring that future generations will have to deal with far more conflict than we face now.

And climate change is the wild card. Our actions today will accumulate with the impacts of climate change, leading to further reductions in the levels of the Great Lakes. For example, quite a few withdrawal proposals for Great Lakes water are not captured by *The Great Lakes Charter*. In Michigan, a huge irrigation proposal to withdraw volumes of water exceeding the levels in the *Charter* is not considered a diversion, and therefore not captured. When we look around the Great Lakes, we see that we are our own worst enemy. Many of the diversion withdrawal proposals today come from within the Basin.

"We have failed to live within our water budgets. We have failed anywhere to charge the true cost of providing water, and increasingly, we are seeing our government getting out of hands-on activities regarding the Great Lakes."

Great Lakes United conducted an independent survey of municipal staff of communities on the boundaries of or just outside the GLSLB. When asked where they will get their future water supply, they often expressed a belief that, "We can always turn to the Great Lakes." Areas like Akron and Cleveland propose the withdrawal of waters for growth outside of the Great Lakes region, a proposal circumventing *The Great Lakes Charter*. While these proposals allow for growth outside of the Great Lakes region, the region will experience no net loss; groundwater sources are taken from another supply to top up the waters taken from the Great Lakes. We are failing to live within our own watershed budgets within the Great Lakes today. York region, north of Toronto, certainly has been an example of that, with their recent pipeline proposals.

We have some new problems, but also some new opportunities that we need to look at. A startling statistic is that only 1% of the water of the Great Lakes Basin is now renewable. The other 99% of the waters were deposited 20 000 years ago by glacial melt. Once the various withdrawals in combination with the impacts of climate change are below that 1%, we are no longer using a resource sustainably. Most of us do not recognize that we are irretrievably eroding our precious water supplies.

Not yet mentioned but of great concern is that the Great Lakes will increasingly feel the impact of global agendas. We have been accustomed to making decisions that influence our region. Yet nowhere else are the effects of globalization more apparent than in the Great Lakes region. This may lead to the public losing its voice and ability to influence policies affecting the region. Trade agreements are predicated on moving goods over large distances; the Great Lakes region is witnessing the increasing commoditization of the water in the region, and pressures for multinational water companies to tap into the multibillion dollar water market are perceived to be here in North America in the next millennium. Some thirty of these water companies are seeking contracts for managing water and waste water plants around the Great Lakes, particularly in Ontario and in the US.

The public relies greatly on scientists to provide information about climate change. While the involved citizens of the Great Lakes accept that climate change is with us, increasingly they find fewer and fewer ways to personally address the problems. We in the Great Lakes continue to be the largest per capita wasters of water in the world. We pay less for water than almost anyone in the world: US pays the least for water, while Canada comes second. We pay a quarter of what European countries pay, and yet we are stewards over one-fifth of the world's water. This discrepancy puts us in a morally bankrupt situation. We have failed to live within our water budgets. We have failed anywhere to charge the true cost of providing water, and increasingly, we are seeing our government getting out of hands-on activities regarding

the Great Lakes. In Ontario, the Ministry of Natural Resources has been devastated, their staffing cut by at least a third. We are seeing a devolution of government programs to municipal levels, federal government devolving programs to provincial levels. There is a lot of confusion and chaos. I think the public really wants to be involved, and not only by being good consumers and saving water, but by being involved in policy issues. The challenge today is to figure out ways to do that before
it is too late, before we go for so long that no one in the GLSLB has the tools to promote a conservation ethic, or to deal with the major challenges and conflicts that we will face in future.

The World Watch Institute is predicting that the next wars in the world will be water wars. For the Great Lakes region that may be extreme, but for future generations, our neglect will mean disturbing conflicts and tensions that could have been avoided. Prevention should start now. That is why Great Lakes United is launching our campaign to have a Great Lakes sustainable water strategy in place by 2005, and we feel that it is a reasonable objective to have a 50% target for reduction of use by all sectors of Great Lakes water by that time.

Lorrie Minshall

Grand River Conservation Authority (Governance)

As the Grand River Conservation Authority (GRCA) is a watershed-based organization and I am among the group of front line water managers, I will talk about the issues of climate variability and impact from that perspective.

I am going to talk a little bit about the GRCA, a bit about the dependence of this growing population on this heavily managed river system, about its greatest sensitivities to climate variability, and the process that the stakeholders have established to deal with some of these and other issues that we have talked about today.

First of all, the GRCA is a partnership of fifty-four municipalities in the Grand River watershed for water and natural resource management on a watershed basis. This partnership was formed in 1938, in response to water quality and flooding issues. It was the first organization of its kind in Canada, and we believe it was the third in the world.

The Grand River watershed is located in southwestern Ontario, immediately west of the Greater Toronto Area and the Niagara Escarpment. The watershed has a population

of 787 000*, 90% of whom live in the watershed's cities: Kitchener, Waterloo, Guelph, Cambridge and Brantford. The watershed covers 7 000 km^2, contributing about 10% of the drainage area to Lake Erie, the largest tributary of Lake Erie on either the Canadian or the American side. Its contribution to Canada's gross domestic product is larger than that of several provinces, and it is comparable to that of Nova Scotia. The central portion of the Grand River watershed is one of the fastest growing areas in Ontario, and the population is expected to grow by 37%* over the next twenty-five* years, for an increase of about 300 000* people. The Grand River and its major tributaries has been proclaimed a Canadian Heritage River, based on its outstanding recreational opportunities in a natural setting and on the River's history in the development of Canada.

Unlike most other large centres in Ontario which depend on the Great Lakes, this is the only heavily populated area in Ontario that is dependent on an inland river and groundwater system for water supply and waste water disposal. This heavily managed system is close to the line in terms of being able to meet these demands. The City of Guelph, Waterloo Region (which serves the Cities of Waterloo, Kitchener and Cambridge), the City of Brantford and the Six Nations Reserve all withdraw water from the Grand River system for their water supply. The remainder of the watershed is supplied from groundwater. Waterloo Region projects that its water supplies and allocations are sufficient for the next fifteen to twenty* years including growth projections. About 600 000 people in cities, towns and villages discharge treated sewage to this river system. Consequently, water quality is a major issue.

"The system can handle such dry years as the 1962-1966 period and 1988, but years drier than these may be disastrous to that fine balance between the water quality and the water withdrawal for water supply."

The biggest water quality problems now are low dissolved oxygen levels; excessive phosphorus, which affects the dissolved oxygen, bacteria and *Cryptosporidium*, which affects the surface water supplies and the recreational use of the river; and suspended solids, which also affect recreational use and increase the cost of water treatment. Withdrawal for water supply is directly linked to water quality, in particular to the dissolved oxygen condition.

* Author's note: this number has been updated since the presentation was originally made.

Many of the smaller towns along the river system are looking to the Grand River as a focus for developing a viable tourism industry. Fishing in the Grand River system has attracted national and international attention over the last two years, prompting increased commercial activities to accommodate this new demand. Many people come from all over the world to fish brown trout, pickerel, salmon, and other game fish throughout the Grand River system. Over the last forty years, a great deal of cleanup has occurred. Boating, rafting and canoeing have increased, placing additional responsibility on the watershed partners to improve water quality.

Water quality and water supply are improved by the operation of multi-purpose reservoirs. The GRCA operates four multi-purpose reservoirs as a system for low flow augmentation and flood control. The Shand Dam, built in 1942, was the first reservoir in Canada built for water conservation purposes. The reservoirs are filled with snow-melt and rain in February and March, and then are drawn down through the summer to maintain the river flows. For example, 85% of the flow through Kitchener during dry summer periods comes from reservoir storage. The reservoirs are operated very carefully on a day-to-day basis and they have a 96% reliability of being able to meet the flow requirements based on the last thirty-five years of record. The design of this entire system is based on what has happened in the last thirty-five years.

To deal with these major issues at the same time that budgets are shrinking, the GRCA has invited together the partners to set priorities for action and pool their efforts to best benefit watershed health. This process is called *The Grand Strategy* and involves the Basin's fifty-four municipalities, the First Nations, the GRCA, the three local universities, the numerous non-government organizations representing farmers, field naturalists, anglers and hunters, and the provincial ministries. *The Grand Strategy* is producing these products: a joint work plan for the partner groups, expanded forums for the partners to meet to deal with the issues and to pool their information and expertise, an annual report card to assess progress on the work plan and of the health of the watershed in general, and a maintained and accessible information base. Three hundred people are actively participating in various parts of this process, and have identified their priorities and they have sketched out a five-year action plan called *The Joint Work Plan*. As a result of B. Mills' presentation to various working groups in this partnership, the considerations for climate variability and change have been incorporated into that work plan, particularly the considerations for "What if?" and the "no regrets" adaptation strategies.

What are the major climate and variability concerns? Because of the reservoirs, the system can handle seasonal shifts in water inputs. We are prepared to make adaptive changes in our standard operating procedures

to deal with these seasonal variations as the situation arises. The system can handle such dry years as the 1962-1966 period and 1988, but years drier than these may be disastrous to that fine balance between the water quality and the water withdrawal for water supply.

Successive years of low precipitation that lower the groundwater levels, such as in the early 1960s, will affect the groundwater supplies which form part of that balance, and put more pressure on the surface water supplies. Successive years of low precipitation will also seriously affect the rural community, which is largely dependent on the groundwater system, and the natural environment, which is dependent on the groundwater discharge.

Increases in water temperature that worsen the dissolved oxygen problem, even two parts per million, will upset this water quality and water supply balance, and will affect the diversity of fisheries habitat and the outdoor recreation opportunities. A serious risk of continued, significantly lower annual precipitation would preclude the Grand River system from having the capacity to support its growing population. Consequently costly water supply and management decisions will have to be made. There will undoubtedly be discussions about a Great Lakes pipeline, or, alternatively, there will have to be major changes made in the way we use water.

In summary, we have a growing population dependent on an inland water source. We have a heavily managed river system, where the targets and allocations and long-term strategies are based on the last thirty-five years of record. We have a commitment of water managers and others in the watershed to deal jointly with their current and future water issues on a watershed basis, and we have a well-established process locally to do this. There is an uncertainty among managers about the urgency and seriousness of climate variability and change, but there is a preference to be proactive rather than reactive. There are large sums of municipal dollars that are tied to water supply and management decisions in this system.

"We need information about the urgency: when? how? how much? We need design scenarios for contingency planning. What series of scenarios would make the climate experts comfortable that a reasonable range or reasonable risk had been investigated?"

We need information about the urgency: when? how? how much? We need design scenarios for contingency planning. What series of scenarios would make the climate experts comfortable that a reasonable range or reasonable risk had been investigated? Because locally we are at the leading edge in dealing with these issues, we need assistance in developing tools that will help predict changes in the system and consider the "What if?," to test the effectiveness of adaptive measures and options. We would like to discuss a partnership with you in order to make this happen.

Questions/Comments

J. Barnett (US EPA) wanted clarification whether L. Minshall referred to surface water or groundwater or both when she talked about municipal water withdrawal. L. Minshall clarified that she referred to surface withdrawal, although the water supply in the Grand River Basin has traditionally been groundwater.

B. Baker (Tourist Park and Recreation consultant) inquired whether the hydrological data used for the Grand River, collected twenty or thirty years ago, might need to be updated, especially because of the increase in development in the basin. L. Minshall replied that the data might be considered useful since, in terms of the climate and water regimes, most of the effects of change has been removed from the data. (Author's note: the thirty-five year hydrologic data sets that have been developed for use in water management studies and systems design have been modified to remove the effects of new reservoirs and changes in reservoir operating policies over that thirty-five year period. The data sets are currently being modified to remove the effect of changing municipal supply withdrawals and wastewater discharges over that period.)

Baker further asked whether the lessened grants to Conservation Authorities from the provincial government would affect maintenance of the program. L. Minshall replied that the core business of the Conservation Authority has persisted despite recent cuts in provincial grants, especially because the municipalities have been able to maintain the municipal levy to GRCA. There is concern that, with increasing burden being placed on municipalities by the downloading of service costs from the provincial government, municipalities may not be able to support Conservation Authorities to the same degree in the future.

I. Burton (Environment Canada) inquired whether L. Minshall had information about loss of water in the municipal supply system through leakage, and what amount of the total supply might be lost, with implications for demand management, marginal cost pricing and water user efficiency. L. Minshall was unable to comment on this. (Author's note: I am able to confirm that each of the five cities has been pursuing a water efficiency program

to reduce water loss in the municipal supply system.)

G. Wall (University of Waterloo) inquired about the extent to which water conservation will be accepted as a viable solution and whether the long-term water supply strategies include new reservoirs or pipelines to the Great Lakes. L. Minshall replied that water conservation programs are quietly going on behind the scenes and will remain a major part of a water supply solution. She observed that long-term water supply strategies (such as new reservoirs and a pipeline to the Great Lakes) have been around for decades, although many in the Grand River basin would prefer future sustainable use of the water in the basin over these other strategies, and this may lead to the raising of issues again.

Daniel Injerd

Lake Michigan Management Section, Illinois Department of Natural Resources (Governance)

Good afternoon. I appreciate the opportunity to participate on this panel, and provide my perspective on three very important questions.

The first question is, "What is the range of possible impacts and what impacts of climate change are of most concern?" As the person responsible for the day-to-day management of Illinois' diversion of water from Lake Michigan, I must say that this has not been a subject of concern. We have experienced cool springs, high lake levels and flooding for many years, and if you ask anyone on the streets of Chicago about global climate change and warming, he or she is apt not to take you seriously.

One of the primary issues to consider in a warmer climate scenario is the additional pressure that will be placed on the public water supplies. Figure 4.1 is a graph of historic Lake Michigan domestic pumpage by communities in Illinois that have a permit to divert Lake Michigan water. There is a definite spike in the drought year of 1988 (about a 100 cubic feet per second increase, or 65 million gallons per day (mgd)).

"The pressing problems of today take precedence [over climate change]…We can generate some impetus and political support for funding [for the pressing problems in a way that we cannot for climate change]."

However, compared to total pumpage, it is not all that significant. In 1994, another spike resulted from the addition of about 500 000 people to our Lake Michigan water service area.

It is important to know the future population. Our regional planning commission has forecasted an increase of about 1.5 million people from the year 2000 to 2020 (see Figure 4.2). About 700 000 to 800 000 of them will use Lake Michigan water. Looking at the increased demand during a drought year, plus the addition of 700 000 to 800 000 people, enables us an estimate of the future demand under a future warmer climate: about 225 cfs (145 mgd) in additional domestic water in addition to what we currently use. Careful management of Illinois's Lake Michigan diversion will enable us to service this additional demand brought about in part by a warmer climate.

Another issue affected by climate change is shoreline management. All of the global climate change information points to long-term lowering of water levels. A 5 foot (1.5m) average reduction in water level on Lake Michigan has been mentioned, a phenomenal drop. What does it do for erosion potential? The IJC Lake Levels Reference Study concluded that erosion is a continual process that occurs at all lake elevations. However, there has not been much examination of how the erosion process will change as a result of a substantial drop in water levels. That is an area for future research. But unfortunately for us today, we have a $270 million project that is just getting underway in Chicago to protect 8 miles (12.8km) of deteriorated shoreline. Since we still have to design for record high water levels, we achieve no savings from looking at the impacts of a potential warming and lowering of Lake Michigan water levels.

Figure 4.1

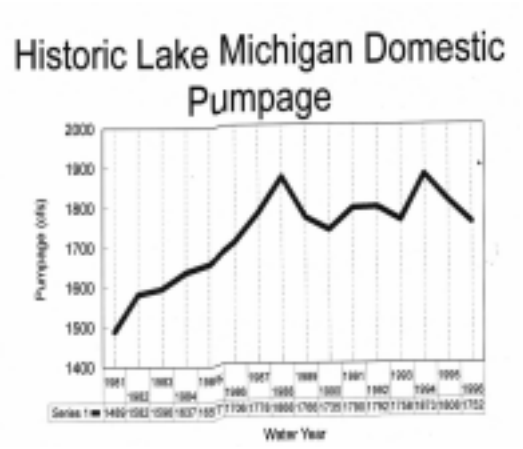


Figure 4.2

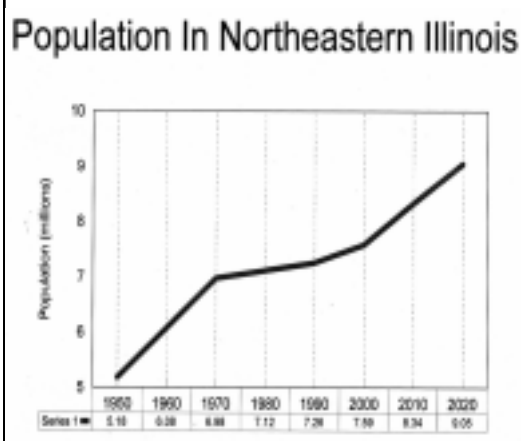
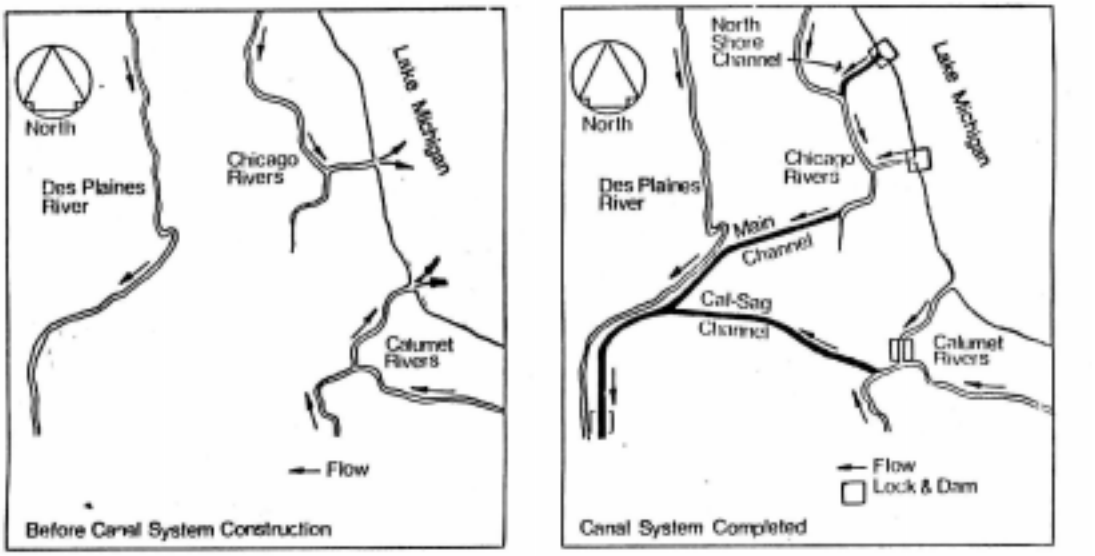


Figure 4.3
Before and After Building the Chicago Sanitary and Ship Canal System



Dredging is identified as another problem resulting from global climate change. In Illinois, most of our recreational harbors are quite deep, since Chicago's lakefront has been extensively filled. A 5 foot (1.5m) drop in lake level will necessitate dredging, but because it will occur over fifty to eighty years, these harbors can be maintained. However, the costs of continual dredging required at our three federally-maintained commercial harbors would be substantial, and two of the three may no longer be maintained for deep draft navigation since the cost to dredge would likely exceed the benefits.

Impacts to water supply intake is another frequently mentioned concern. Illinois has twenty-seven water supply intakes in Lake Michigan, generally located 3 000 to 5 000 feet (900 to 1500m) offshore for water quality purposes and protection from ice. Because of this distance, there should be no major problems in adjusting to a lower lake level regime. The energy costs to bring water to the plants will increase, but this does not present a significant percentage of the total cost of water production.

By far the most significant impact we would have to face in Illinois is the operation of the diversion management system. Figure 4.3 illustrates what the area was like before the Chicago Sanitary and Ship Canal system was completed, resulting in the diversion of the Chicago and Calumet Rivers from Lake Michigan into the Illinois waterway and Mississippi River system. When completed at the turn of the century, the diversion kept sewage from contaminating the water supply intakes for the City of Chicago.

Figure 4.4 compares water levels on Lake Michigan to the normal canal elevation.

Since the early 1940s, the canal elevation has been maintained several feet below the level of the lake, providing a positive difference between the lake and the river, and allowing lake water to be diverted into the canal system. Operating the canal system under a climate change/lowered lake level scenario (using the natural lake level variation of the past twenty-one years, and the full effect of Lake Michigan water level lowered 5 feet [1.5 m]) (see Figure 4.5) will require us to choose one of two options. In one case, the canal must be kept at its current level. Navigation could continue without the need for expensive dredging of the waterways. However, the Chicago diversion would no longer be operative since the water level in the canal system would be higher than the level of the lake. A lockage through one of the lakefront facilities would thus divert water from the river into the lake, just the opposite of today. No longer would we be able to withdraw Lake Michigan water to maintain water quality conditions in the canal system during the summer.

Figure 4.4

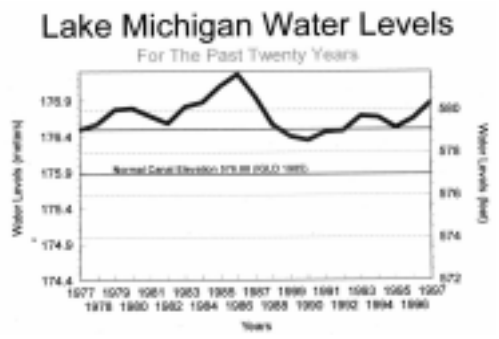
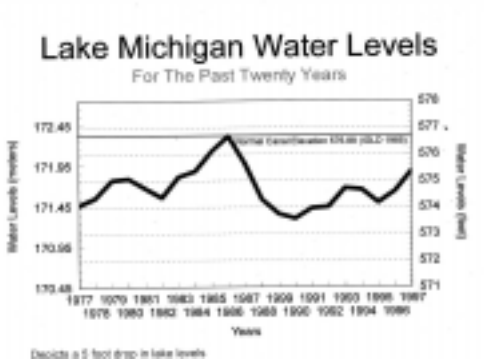


Figure 4.5



In the other option, the canal elevation would be maintained a minimum of 1 foot (33cm) below the level of Lake Michigan. Canal levels would have to be lowered a full four feet (1.2m). At least 30 miles (48km) of the canal system would have to be dredged; 15 to 17 miles (24 to 27km) would be rock excavation, with incredible costs. No one has attempted to estimate this cost. Without federal or state funds for this dredging, we would likely cease to operate the Chicago diversion, and allow water to flow back into Lake Michigan, at least for purposes of maintaining navigation.

That is a quick overview of what I think would happen in Illinois in response to global climate change. The second question I was asked to address is, "How do others associated with your activity perceive these impacts and risks?" The following are strictly my own opinions. First, global climate change in the Chicago area is not considered a serious issue; we have been conditioned to be skeptical. The last twenty-five years of high

lake levels, cool weather and numerous hundred-year (and five-hundred-year) floods have reinforced that skepticism.

Second, communication about this subject has fallen prey to the tendency of the media to sensationalize and then forget. The only articles about global climate change and warming in Chicago area papers are in response to an unusual weather period.

Third, the pressing problems of today take precedence. There is a passage of Scripture that says, "Do not be anxious for tomorrow; we have enough problems for today. Let's take care of those." That is a paraphrase, but typically that is what governments do. We worry about the pressing problems, about which we can generate some impetus and political support for funding. For example, flood control structures are not designed for future hundred-year events, but to contain the volumes of past flood events. I know of no one looking at the future hundred-year flood event in Chicago considering global climate change. That might be a problem, but that is the way the system operates today.

Fourth, the changes and impacts are so big they invite inaction. When you begin to contemplate the issues involved and the costs, we simply ask, "How can we ever deal with this?"

Finally, the inability to accurately predict current hydrometeorological events (e.g., the missed flood height predictions on the Red River flood) causes people to seriously question long-term forecasts: "If you can't predict what a current flood crest is going to be, how can you predict what the future climate is going to be in fifty to one hundred years?"

The last question posed was, "What uncertainties must be clarified before decisions can be made?" There seems to be a difficulty in clearly detecting human-induced climate change. This issue needs additional work. The new emphasis on global climate change and variability, rather than global warming, needs clearer explanation. As one not involved in this field, this shift away from global warming caught me by surprise. Another issue is data quality. A review of historical data inevitably uncovers major problems and inaccuracies in data collection, whether for flow or rainfall, and perhaps even temperature. Is this historic data valid enough for predictive capabilities?

"The changes and impacts are so big they invite inaction. When you begin to contemplate the issues involved and the costs, we simply ask, "How can we ever deal with this?"

And finally, we need to be very careful to keep the science of global warming or global climate change clean. The foundation studies need to be clearly identified, their limitations plainly stated, and their conclusions carefully worded and quoted. The tendency, especially for the media, to go beyond a study's limitations, can hinder advanced understanding of this complicated issue

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Questions/Comments

An unidentified questioner likened perceptions of climate change for the public to the public perception of smoking cigarettes and lung cancer. Early research on the latter met denial and confusion because of the lack of a strong link. However, that link has been established now. Similarly the climate change issue will build over the next few years, where overwhelming evidence will attract strong public attention.

Jacinthe Lacroix
Public Safety Branch, Ministry of Public Security of Québec
and the Québec Association of Climatology (Governance)

At the Public Safety Branch, we are involved in emergency measures, getting to people after disasters such as floods, tornadoes, forest fires, landslides, snow avalanches. Working with people in distress makes it evident that we get busier every year, especially in the last few years, with 1996 standing out as a particularly bad year. During quieter times, we work with the municipalities in developing emergency plans and assessing the risks and the vulnerabilities within their jurisdiction.

In Québec, prior to the Saguenay flood, talk about climate change would provoke people to look at you with glazed eyes and say, "Oh yes, climate change, that is a fuzzy thing!" It meant nothing to them. However, the Saguenay flood and four other episodes of heavy rain in 1996, followed by flash-flooding and hundreds of landslides, rang a bell. Last November, my Assistant Deputy Minister asked me if climate change meant from now on having other years like 1996. His strong interest stemmed from the high social and economic costs of climate hazards. We cannot live with those kinds of disasters

year after year. While I would have liked to ask him, "What if it just meant that?," I had to reply that I did not know.

No one knows for certain what will be the impacts of climate change on climatic extremes and risks. Those of us working in emergency measures have to come to realize forcefully that climate change can have a strong social and economic impact on people.

Even with a great deal of emphasis and energy, we will likely not significantly reduce greenhouse gases. Developing nations will continue to use more and more fuel, at a rate surpassing the reduction rate in the developed countries. This inability to reduce greenhouse gases means that climate change will happen, and that we must adapt to it.

However, adaptation requires being able to anticipate the impacts of climate change. It is widely agreed that impacts will include a rise in temperatures. In the St. Lawrence River Basin, a $2xCO_2$ scenario implies a temperature increase of about 2°C. Precipitation is expected to be about the same or a little less. Among the anticipated impacts on the various sectors, one with the most important implications is of decreased water levels in the St. Lawrence River system. While we know this means reduced stream flows and less flooding, we know little about potential changes to the other rivers flowing in from the south and north shores.

Less flooding along the St. Lawrence River also means there will be more land available for agricultural needs. Such positive impacts should be factored into consideration; while we tend to focus on the negative impacts of climate change, in almost every sector there may be positive impacts as well.

Impacts may be expected on population well-being and human health, although at present we know little about what these impacts might be. While a reduction in the frequency and severity of cold waves would be a positive impact, an increase in episodes of hot spells may be bad, especially for elderly people and people with respiratory or cardiovascular problems. Researchers working on climate and health are concerned about emerging infectious diseases.

The recreation and tourism sector may be affected by climate change as well. A rise in temperature could mean a shorter ski season, or no ski season at all, but could alternately mean more green time for golfers. We know little about those possible impacts.

The potential increase in climate hazards and climate extremes due to climate change is an issue with major impacts on the general population, and is of great interest to people. At present, we are not able to evaluate what climate change will do to climate fluctuations and variability, such as the frequency, duration, intensity of events, annual variability and daily variability.

There is a perception that climate change and a rise in temperature may be a good thing for people in Québec, considering the long cold winters there. However, implications such as a large reduction in water availability and water quality present the negative implications of climate change. We live too

close to the water and water is central to many activities.

In summary, there remains a great deal of uncertainty about the potential impacts of climate change on the St. Lawrence River Basin. While there are potential positive impacts, potential negative impacts are evident. The implications of changes in climate variability and climate extremes are large unknowns and scare people the most because this is where there are major impacts. Even with general agreement that climate is changing, uncertainty about climate fluctuations, climate extremes, and regional variability prevents us from properly assessing climate change impacts. Without being able to assess the impacts, we cannot clearly assess what kinds of adaptation are required.

As a response to such uncertainties, I suggest the development of a climate indicator for monitoring, not simply for "normals." As well, we need to increase our understanding of the links between the ocean and atmosphere. Despite GCM warming scenarios for Québec under climate change, we presently observe a cooling trend, especially in the northeast part of Québec, which experts relate to the North Atlantic Oceanic oscillation. To reduce uncertainties, these are the areas where we have to concentrate our efforts.

"Those of us working in emergency measures have to come to realize that climate change can have a strong social and economic impact on people."

Don Power

Ontario Hydro (Industry)

The utility industry is going through a restructuring process. Ontario Hydro is typical of other utilities around the Great Lakes, even though "hydro" is in the name. I will try to place our business in the context of the other utilities, as well as talk about how Ontario Hydro operations might adapt to climate change. I will outline which of the climate change impacts are of most interest to the industry, and how efforts to reduce greenhouse emissions will impact prices and decision-making in our business.

Despite being called Ontario Hydro, we rely on hydro-electric and nuclear facilities for only 25 to 30% of our power generation, or on a good day, about 58%. We are comparable to Commonwealth Edison in Illinois. Our swing resource is fossil fuel; we are basically a thermal utility, with over 60% of our resources coming from a thermal base,

whether nuclear or fossil. We are a large user of water even though we are a thermal-based system, and many of the utilities in the region are similar. For example, our nuclear facilities use about fifty times the daily use of water in the Metro Toronto area, and our fossil facilities use five times the daily use of water in the Metro Toronto area. Water is used mainly for cooling, so changes in ambient temperature will impact our business. At other utility companies, such as in New York, 22% of facilities are hydro-electric, with the rest comprised of thermal facilities. Operations of such facilities are impacted by changes in temperature (heating and cooling), droughts and flooding.

Changeable seasonal load patterns may require us to reschedule our hydraulic facilities to meet the peak demand, resulting in a different water use pattern. We face thermal operation, reduced efficiencies, the difference between the inlet and outlet temperatures, being able to achieve higher efficiencies out of our thermal plant; efficiency is reduced because of lower cooling. Severe storms affect heating and cooling load, and consequently the system operation. Ontario has had a recent history of increased lightning storm frequency through the 1980s. Such storms require a reduction to safe operation loads, entailing locally-based power generation that is higher in cost, instead of using facilities farther away that are cheaper. For example, during storms in the New York City area, they go to higher inner-city generation. The system's operational economics can be affected by the nature, severity and frequency of storms. Many people are converting to gas power for winter heating. Our system is changing to a summer peaking system, like most utilities south of the Great Lakes. In the past, we were a winter peaking utility. However, over the last few years we have been a duel peaking system, and are now becoming a summer peaking system. Higher summer temperatures and higher cooling demand means a summer peaking system because the residential and commercial air-conditioning load is sensitive to weather.

How do we cope with this predicament? We must learn to adapt to lower water levels by extending water pipes for cooling farther and deeper into the lake and reduce hydraulic production by adding more facilities or utilizing other facilities, in this case, fossil or coal which is our swing facility. We will have to reschedule our maintenance because of increased summer loads.

Adaptation will be more possible if climate changes occur gradually. However, severe and sudden change might pose a problem for the electric utilities. Having to locate generation sources closer to the load, needing more transmission lines because tornadoes down lines and having alternative paths could lead to less reliable, but more costly, power systems. Such operational effects during the industry's restructuring are a big concern. There is a reluctance to accept anything that will increase the price of power.

Will capital dollars be invested in

achieving lower energy costs? Another phenomenon is the acceleration towards electro-technologies, which focus electricity use where we live rather than requiring us to come downtown or live closer downtown, with associated commuting costs. Electric vehicles are a prime focus of application of electro-technologies. Certainly the idea is to use electricity made from various inputs, whether fossil, nuclear or hydro-electric, as a currency to counter increased capital and operating costs, leaning towards higher capital costs at the front end. How can these choices be brought forward? What decisions are going to be made, and how are those decisions going to be influenced in the marketplace?

Fuel prices will likely affect energy costs. Carbon taxes favour lower carbon fuels with high hydrogen content, such as gas. However, high hydrogen-low carbon fuels are presently rather scarce. North America has about ninety to one hundred years of known, technically recoverable gas, based on present consumption rates. By the year 2015, based on natural growth to the system and replacement of existing capacity, a one-third increase in present consumption is expected, mostly attributable to electricity produced from gas-driven engines, air-derivation turbines or other gas technologies. Then there is coal. Coal is dirty and high in carbon, but cheap and there are about five hundred years worth of known coal resources, of various levels of quality. Rising fuel costs should accelerate the development of efficient supply-side technologies, fuel cells, high temperature combustion turbines, integrated gasification combine cycle plants, which involve conversion of coal to gas, and non-fossil resources such as solar and wind, and perhaps nuclear fusion or fission.

Now where does this lead us? What are the decisions we must make in the future? Investments in existing coal plants may be harder to justify because of the air quality requirement for NO_x and SO_x, higher fuel costs, and CO_2 restrictions. This could lead to a re-powering of existing plants on gas, with a move towards a gas economy. Is that sustainable? How would prices be affected? Today, gas is plentiful and cheap, but not very well utilized within the utility industry. We might see expansions of nuclear plants; Baltimore Gas and Electric is seeking to extend the life of their Calvert Cliffs plant, which soon faces its forty-year operating license renewal. There could be a

"Adaptation will be more possible if climate changes occur gradually. However, severe and sudden change might pose a problem for the electric utilities."

development of fusion technology, and development of renewable energy resources.

Any restructuring of the utility industry is influenced by cost. Costs of the system today stem from previous decisions, possibly encouraged by government regulatory environments; but we are also changing the frame of reference upon which future decisions are going to be made. How can you ask somebody to make decisions today based on a frame of reference that may or may not be binding upon the parties? Therefore, we need strong direction from the government, not only local or national government but an international governing body, setting out the rules of the game. These must be enforceable with associated penalties for non-compliance, to create a level playing field.

What type of responses are we looking at? We talked about stabilizing and reducing greenhouse gases, switching to efficient fuel technologies, but the responses might be mitigation, CO_2 trading, reforestation, or adaptation. We have to adapt operationally, to storms, to changing loads. These are the types of issues that people are trying to bring forward to make decisions about the future of our industry given the impact on the price of our product in the marketplace.

Questions/Comments

J. Bruce (Canadian Climate Program Board) took issue with the assumption that a carbon tax would lower economic growth. Some studies suggest that wise use of the revenue from a tax can increase economic growth. Studies in the US have shown that many people are willing to pay more for electricity derived from non-polluting sources and the same would likely be true for Ontario. J. Bruce asked how that public view gets translated into the decision-making of an organization like Ontario Hydro? D. Power agreed with the questioner that it is one perspective that carbon taxes would reduce economic activity, and that more efficient use of electricity might spur the economy; the markets for green technology and green products are being examined by Ontario Hydro. He countered the sentiment of willingness-to-pay with an example where Québec Hydro in association with a Vermont utility offered green energy called Green Mountain Power. Price and reliability were more important to decision-makers than the source being environmentally friendly. L. Corbett (Toronto Atmospheric Fund) reasserted that Ontario Hydro's own focus groups suggest that residents are willing to pay anywhere from ten to twenty dollars a month more for green power. She was concerned that the company had recently cut its renewable energy technology section. T. Yonker (Lake Erie Alliance) observed that

D. Power did not identify as an option the wheeling of power between existing peaking and base-load facilities in the Great Lakes, to take advantage of efficiencies, although this option had been suggested as a way to reduce greenhouse gases and CO_2 emissions in a study of various utilities in the Great Lakes. D. Power replied that Ontario Hydro engages in interconnected sales of energy at times of low loads, especially from nuclear generation.

B. Hobbs (Johns Hopkins University) observed that the prospect of restructuring has chilled demand side management and renewable energy efforts in the US, with likely similar effect in Canada. He asked what Ontario Hydro plans to do with their demand side management budget specifically, and how will it be financed, with less ability to recover costs from rate payers. He also asked whether there is any policy initiative under discussion in Canada as there is in the US Congress, which might lead to imposing a national renewables energy portfolio standard for all utilities, to make sure that some of these resources continue to be supported in a restructured environment. D. Power replied that Ontario Hydro does not have an incentive-driven demand management program, although energy improvement initiatives with various clients are ongoing. Ontario Hydro is voicing a willingness to participate with governments and other entities looking to restructure the industry and understand what are the proper rules and regulations that have to be put in place, but only if other players in the market are equally affected by the rules. Such initiatives have come from both the Canadian and US governments, often jointly addressing the issue so that the playing field is level internationally.

General Discussion

The moderator W. Bolhofer reiterated that the panel was meant to address impacts of most concern, sustainable adaptive strategies and climate sensitive interests with respect to climate change and variability, and cultural, institutional, economic, and scientific obstacles to action. He urged the discussion to focus on climate variability and extremes.

R. Street (Environment Canada) observed that increased climate variability will make us unable to forecast weather to the degree that we now require for day-to-day operation. This will have consequences on water supply and hydropower capability, where an inability to predict climate impacts will make the availability of water resources less reliable and the pricing of water resources more difficult and sporadic. How will climate change be raised in the re-negotiation of treaties, such as the binational Treaty on the Niagara River, which require predictions of our energy uses in the next millennium.

J. Bruce (Canadian Global Change Program Board) asked L. Minshall for ideas on how to spread the idea of living within the constraints of the water resources of one's local basin, with the ability to control such things as water quality. L. Minshall mentioned the need for municipal partnerships relying on inland water systems, especially in the smaller, growing communities. She observed that the question of increased population is historically a local land use control issue, not dealt with at the state (or provincial) level. Increased population is not as much a problem as increased development (which are not necessarily correlated), and the desire to live in the suburbs. This needs to be addressed through the economics of providing infrastructure services to developing areas, to encourage growth in existing areas.

M. Clamen (International Joint Commission) asked J. Lacroix to specify suggested indicators of health in the Great Lakes system, and asked generally if anyone had suggestions for appropriate indicators of climate change, and at what scale are the indicators most appropriate? G. Vigeant (Environment Canada) observed a need to be close to reality, using regional climatic indicators. He provided an example of an indicator proposed by Tom Karl which takes into account the number of consecutive days in a month without precipitation, allowing you to discern between months with the same reported precipitation, and to determine in a five year period where climate has put important stress on a sector.

The moderator redirected the discussion to deal with how to address perceptions of decision-makers, and specifically communication difficulties. One of the panelists observed that there needs to be better understanding of the relationship

between groundwater and surface water, especially because decisions about piping surface Great Lakes water would be premature without this knowledge.

S. Miller observed that the most significant impacts will be sociological impacts within the region, within the systems, among the sectors; without addressing these impacts, reduced lake levels in the Great Lakes will be the consequence.

L. Minshall observed that conflicts will increase and new ones appear between urban and rural communities over ground and surface water supplies, and between water users, if climate change leads to generally lower precipitation in the watershed. She distinguished between taking doable "no regrets" measures, from planning for the future with high costs and drastic measures.

D. Injerd anticipated major clashes between water use sectors and power, including shipping, and a renewed discussion of what is of priority use in the Great Lakes.

5

ADAPTING TO CLIMATE CHANGE AND VARIABILITY: STAKEHOLDER PERSPECTIVES

The moderator for this panel was Michel Slivitzky, of the Institut nationale de la récherche scientific-eau. Ken Ogilvie described how Pollution Probe is engaged in leading public debate on climate change issues. Key challenges to the public changing their behaviour in the face of climate change may be summarized as a lack of research, leadership, and solutions. Lisa Lepp, of Stonechurch Vineyards, presented an industry perspective, describing anticipated impacts of climate change on the wine industry of Ontario. John Kinkead, with the Ontario Ministry of Natural Resources, identified the ecosystem approach, conservation and best management practices as necessary adaptations, and described the challenges he sees to their implementation (complacency and lack of integration). Eugene Stakhiv, with the US Army Corps of Engineers described the climate change research from the Institute for Water Resources. He believes that adaptation is something that is occurring already in the water management sector.

Representatives from climate sensitive sectors provide their perspectives on the following three questions:

- What are the impacts of most concern?
- What are sustainable, adaptive strategies that climate-sensitive interests are using and can develop to respond to climate change and variability?

What are the cultural, institutional, economic, and scientific obstacles to and priorities for action?

Ken Ogilvie
Pollution Probe (Non-government)

I represent Pollution Probe, one environmental organization among many that are interested in climate change and adaptation. Pollution Probe is currently developing a broader program in the area of climate change, drawing upon the results of a conference we ran in November 1996.

Pollution Probe has a mission that revolves around research, education and advocacy for practical solutions. We try to stimulate and lead public debate on issues that we choose to focus our energies on, and we also try to influence public and corporate policies. We work hard to build "horizontal partnerships" among industry, governments and a range of interest groups to come up with solutions that can be moved into new policies and programs. A case in point right now is four years of effort by Pollution Probe to get the Ontario Government to implement a vehicle inspection and maintenance program. We are optimistic that a decision will be taken on the program this year. Once we have framed a policy decision that we would like to see, and we have built partnerships, we hang with an issue until we get a decision. [Note: The vehicle inspection and maintenance program was subsequently announced on August 22, 1997.]

Smog is a key issue on which we are working. It is linked to climate change, especially in relation to transportation energy demand. Mercury elimination and reduction is another big program for us. Pollution Probe ran a two-day conference earlier this week to get the science and the solutions out on that issue. We addressed climate change at a conference last November, especially in the context of atmospheric change and the inter-linkages among issues, including acidifying emissions, air toxics, smog and so on. At the November conference, Pollution Probe supported EARG's lead on the need for a TNR Study, which is an integrated air issues

"Smog is the top public issue in the Toronto area, and Pollution Probe is constantly challenged to look at issues very simply. The concept 'smog kills,' is more simple and effective than linking five or six related atmospheric issues, the solutions for which are sometimes common."

study that we would like to see proceed.

Our focus group work on the Great Lakes told us two years ago that the public was starting to fall into two groups: "no need" and "no hope." "No need" means, if you throw a big issue at the public without solutions, the public is just as likely, if not more likely, to ignore, avoid or deny the issue as to animate around it. Do not simply give the public issues without solutions. The "no hope" group in essence has the same concern as the "no need" group, that if solutions are not on the table, nothing will be done. Using the focus group work and our interest in sound science and partnerships, Pollution Probe presents both the science and the solutions, showing what has been done and what is currently under debate.

The public expects leadership. If the government is not showing leadership, it is hard to get the public to take an issue seriously and support doing something about it. Even when the public does take an issue seriously and has been well-educated, and cases in point include smog advisories and the UV index, it is still a challenge to get the public to change their behaviour. I would like to address that challenge briefly in terms of both solutions and adaptation.

Multitudes of environmental impacts of concern are associated with climate change, such as flooding, heat stress, water quantity-quality linkages, and so on. Smog is an issue that we have dealt with for years at Pollution Probe. While they are associated issues, we have had a hard time convincing ourselves to drop the simple word "smog" and link it too tightly to climate change. Smog is the top public issue in the Toronto area, and Pollution Probe is constantly challenged to look at issues very simply. The concept "smog kills" is more simple and effective than linking five or six related atmospheric issues, the solutions for which are sometimes common. Having been through the experience of the Ontario Round Table and its Transportation and Climate Change Collaborative, where we found that if you address energy as an issue, you eliminate a lot of other pollution issues along with it. Pollution Probe still finds it difficult to communicate climate change as an issue. The public does not animate around climate change the way it does around issues like smog. At a certain point, Pollution Probe will have to broaden the debate, but we are moving cautiously.

Canada needs more climate change research, but we need to reduce the scientific uncertainties that were mentioned earlier in the conference. We need the integrated research that the TNR Study will generate, because we cannot effectively communicate integrated issues to the public if we do not have integrated research. We may be stuck with dealing with unilateral issues in public until we have a better understanding of atmospheric issue linkages. The TNR Study would be the first of its kind in a densely populated urban setting. Pollution Probe could work to animate public debate around this study.

Education in itself is great, but it has to

have an objective to be effective and it cannot just be education about the problems. Solutions also have to be on the table, and the public has to see somebody willing to act on those solutions. When we get to solutions, we are going to have to work on focussed things, not on generalities. In Kyoto later this year, commitments may be made to targets that are more binding than the current stabilization target, which has been treated as little more than an input to public policy making. A binding target would impose constraints on decision-making, with severe implications in terms of public policy instruments that will be applied and other decisions that will be taken.

"The message I would leave the conference with is: do not expect too much adaptation by the public and industry if the supporting government policy decisions are not made. The public has to see both the problems and the solutions if we are ever going to get real change to happen."

Canada will have to address difficult issues, such as transportation, which is a growing source of greenhouse gas emissions. Policies will have to address the problems related to urban automobiles, freight movement and air transport, which are hard to control. For example, when we get to the urban automobile we have to deal not only with infrastructure needs for roads and transit, but also pricing issues related to use of automobiles, in addition to all the technology development work that is going on. This means road pricing, or fuel taxes, or CAFE (Corporate Average Fuel Economy) standards. Those types of instruments are going to have to be debated, and the public is going to have to participate in that debate, no matter how complex it is. We also have to address power generation, and the shift from coal fire utilities to conservation and renewable energies, with many transitions along the way. These are big issues and they are all going to involve controversial public policy debates about carbon taxes and green power policies on energy imports. New policy tools, such as emissions trading, will be explored and debated. All of that is going to go on while we are asking the public to think about lifestyle changes and accept pricing changes to influence behaviour and rationalize and finance our infrastructure. We will also have to target a great deal more educational efforts at children, who will have to live differently than us if the changes we have in mind come

about.

The message I would leave the conference with is: do not expect too much adaptation by the public and industry if the supporting government policy decisions are not made. We are going to debate greenhouse gas targets and related policy directions, but the public has to see both the problems and the solutions if we are ever going to get real change to happen. It is time that this debate got opened up in a structured way involving specific solutions and policy instruments. I hope that coming out of Kyoto, Canada will be committed to discussing in public the decisions that need to be taken. The science community is a fundamental part of ensuring a rational public debate on climate change and adaptation, and I compliment the organizers of this Symposium for bringing together some of Canada's finest researchers in this area.

Lisa Lepp

Stonechurch Vineyards (Industry)

When I was asked to speak to you today on behalf of the industry, I decided it was in my best interest to seek some counsel on the subject of climate change. When I did that I was astonished by the results.

As I went around asking different vintners, wine makers and vineyard managers, "What did you do to adapt or change?," no one really had an answer. It seems we tend to simply react. The winemaking industry is a very young industry, so when something occurs we react without necessarily realizing it. For instance, right now we are planting a vineyard site and putting in drainage every 5 feet (1.5m) as opposed to every 10 to 15 feet (3 to 4.5m), which was the norm, just based on the fact that there have been higher than normal rainfalls in the last ten to fifteen years. So we are adapting that way. However, given the discussion on climate change impacts during this Symposium, we have not really come to terms with the question, "Okay, what can we do?" It is definitely something we should look into, since what we produce, wine, definitely reflects the climate of that year.

I have been tasting the '96 vintages this past week, and I can tell you that if you are into purchasing wines, you should buy some '95 reds right now. This is an issue where climate adaptation comes into play. If we could have foreseen this, or if we had planted clones that required fewer heat units per year but still develop the quality, we could have adapted our '96 vintage and would have had a superior quality. The '96 vintage coming out is good, but it is different from the '95; you almost taste the heavy rains of September

and October.

But the change in the industry is gradual and I think it is coming about. Impact studies are a wave of the future, something we will have to look at. When I asked people, "What would you say to me if I told you that global warming is going to affect temperature by approximately 2°C?," every wine maker, every vintner said, "Great, we can grow awesome reds, that's wonderful for quality." Then I asked, "But how is that going to affect something that is our hottest commodity right now, ice wine?" I looked back at the '96 harvest that took place on two occasions, in December '96 and in January '97. I am not sure how up-to-date everybody is on ice wine, but it is definitely affected by climate. We harvest it at approximately -10°C, and Canada is the only known place in the world where we can do that consistently year after year after year. Ice wine has become a flagship for our industry, not to mention it has been deemed the best ambassador Canada has right now. In '96 we had a quick cold snap in December, which is exactly what we wanted. Unfortunately harvesting ice wine is very labour intensive and we could not get everything off in time. The following day the temperatures rose up to zero and a little bit above freezing. This thaw results in a loss of juice available to harvest, although not necessarily a loss of quality. When I looked at the tonnage per acre that was harvested, in December compared to January when temperatures permitted completion of the harvest, there was a 50% decrease. I was astounded by the drop in yield. I could not believe that there was that much of a change. The winemaking industry should be saying, "There are climate changes that are occurring and this isn't something that is common. We should look at preventative measures." Of course when I brought that up and asked what we can do, no one seemed to have answers.

"The winemaking industry should be saying, 'There are climate changes that are occurring and this isn't something that's common. We should look at preventative measures.' Of course when I brought that up and asked what we can do, no one seemed to have answers."

The other issue that arose in my discussions with vintners and vineyard managers was vine resistance to various types of powders and mildews. While clones are being developed right now, I do not think they

are being developed quickly or aggressively enough. Every year something different and new develops out in the vineyards: a new species of berry moth, a different kind of infection in the vines, etc. The *phylloxera* scare recently occurred in California and that was something that we responded to very quickly, by developing and planting clones resistant to that disease. To this day we continue to plant accordingly.

In conclusion, climate plays an important role in wine production. The quality of the wine produced and the harvest of ice wine grapes are particularly sensitive to changes in climate. Meanwhile, consumers are demanding quality wines; the percentage sales increase of Liquor Control Board of Ontario alone in the past year have gone up 20%. Consumer awareness is certainly there. Therefore, if we want to continue to produce the quality wines that the consumer is demanding, climate change and adaptation is something that we definitely need to address.

Questions/Comments

S. Mazur (Kensington Worm Composting Project) inquired about the time span common between identifying a problem and developing a clone plant with resistance to a pest/disease; L. Lepp replied that such solutions take years to develop.

An unidentified questioner asked whether wine producers can participate in provincial crop insurance programs. L. Lepp explained that if grapes are grown on site (i.e., an estate winery), participation is offered to the winery; poor year impacts may or may not be cushioned by insurance.

John Kinkead
Ontario Ministry of Natural Resources (Governance)

I want to focus on the question of what kind of adaptation do we see happening, what are some of the obstacles, how do we get around those obstacles through change, as well as how do we identify the priorities.

From the perspective of belonging to a natural resources management agency, the view is that all natural resources, and their associated value and benefits, are at risk, and that those risks will impact the economy, our communities and the natural environment. The main mechanism is that climate change and variability affects ecological functions. The first speaker today, J. Scheraga, talked about impacts on water. Other speakers have talked about human intervention, dredging channels to ensure that navigation can continue, or building pipelines to bring water to communities which have used more than their locally available resources. The management of water has become a linchpin issue; so many other natural resources cannot exist without that important connection to water. Climate change will bring on

"Two key obstacles to implementing climate change adaptation tools such as best management practices and conservation are complacency on the one hand, and the inability or the need to integrate on the other."

dramatically altered hydrologic regimes beyond the natural alterations. We will see increased competition among water users. Because we are a natural resources management agency, we want to make sure that the debate surrounding water use is not just a debate among water withdrawal users, but among all stream users, ensuring an equal valuing of support for fish and wildlife, as support for tourism and recreation. All uses need to be accommodated, and all needs considered equally.

The other challenge arising because of climate variability is planning and managing for climate extremes when managing water. The municipalities are a good example; on one hand they manage their growth and development relative to floodplains or shorelines, while at the same time searching for a secure long-term water supply.

Taking ecosystem-oriented approaches to land and resource development planning is an example of adaptation. This is not simply limited to land and resource development planning. The Bay of Quinte RAP area is an example of an ecosystem-oriented approach being taken. Ontario has experienced a fair rate of growth; the pursuit of watershed management has led to some 100 watershed or subwatershed level management planning exercises initiated since 1990. Other examples of ecosystem-oriented approaches include forest management planning and lake-wide management plans (LaMPs). While I have been detached from that area for some time, my sense is that LaMPs are still very much water quality focused. Some plans, like the Lake Ontario plan, is even more narrowly focused around toxics. A truly ecosystem-oriented approach at the lake-wide area level requires us to include quantity issues as well as quality issues.

Ontario has had a fairly long and successful history dealing with hazards regulation (e.g., floodplains and shorelines). However, people seem to have selective hearing when confronted with the evidence of climate change. For example, they hear only that water levels may be going down, and conclude that they may be able to build in floodplains. It becomes a challenge within our organization and when dealing with municipalities not to lose sight of the continued importance of the floodplain and regulating the use of floodplains now and in the future.

Conservation and Best Management Practices (BMPs) are becoming commonly used tools (which might be considered adaptation tools). The Canadian Council of Ministers of Environment developed a national action plan to encourage municipal water use efficiency. We are seeing participation in this program, and from it some real success stories. K. Schaefer mentioned that a water efficiency retrofit program at the nearby Sheraton Hotel has reduced their municipal water bill by $250 thousand per year, while reducing their energy bill by $1.2 million per year over a very short payback period. After a year, or the time it takes to pay off the initial investment, the accumulated savings are quite significant. We are seeing growing interest in the promotion of softer approaches to stormwater management, such as the encouragement of infiltration, and less of the traditional "get the water off the land as quickly as possible" attitude. Within the last year, Agriculture Canada put out a best management practices document discussing conservation-oriented irrigation practices, although we have yet to see much adoption of it in rural areas. Most jurisdictions have groups within agencies looking at pollution prevention and taking a multi-media approach, combining conservation-oriented thinking about water and air emissions, with thinking about treatment of waste. Research is being undertaken on fish, wildlife and forest adaptation, on both the habitat and the population composition and dynamics perspective.

Two key obstacles are complacency and the inability or the need to integrate. Complacency stems from policy makers or the public asking, "Where's the evidence?" We see contradictory evidence. What is the sense of urgency? To address those issues, communication is key. It is important to get information out to people, such as findings from the GLSLB Project and other research that many Symposium participants are involved in, and tracking those observations against the hypotheses that have developed about what is expected to happen as a result of certain climate change scenarios. Communication is necessary to assure policy-makers that observations are fitting expectations, and explain not just the observations and the impacts, but also their implications. What will it mean for specific sectors and interests, such as farmers? What are the impacts on municipal water supply costs, or on transportation, or on fishing opportunities? This Symposium has not dealt much with the valuing of natural resources. There is a real need to include resource and environmental economists in this work, and to help get the message out.

Our actions are compounding a future debt for our children. However, on the positive side there must be opportunities. And I think these have to be highlighted; those first off the mark in terms of adapting will also be first to benefit from the opportunities. If an opportunity is just being able to sustain a business or to accommodate growth, those

communities which have already learned to adapt will get that opportunity first.

On the integration side, I think there is still a lot of confusion as to whose problem this is to solve: is it the government's, the public's, the researchers'? How do we effect integration among jurisdictions, among disciplines?

On the solution side, the only approach is one of shared accountability. There must be leadership at the government level, but it also gets down to behavioural change at the level of individuals. We need to set sustainability or adaptation targets; what are we shooting for? S. Miller observed that a Great Lakes United document proposes a target of 50% reduction in per capita use in any water sector by the year 2005. We need such targets to shoot for. We need to be comprehensive. The solutions do not just lie in legislation or in policy. A comprehensive suite of actions is needed to adapt. Many people have gone before us, or are proceeding at the same time, from whom we can learn.

We need to place priority on these issues. With governments in an expenditure-reduction mode, and government agencies still reeling from the last round of cuts and looking forward to more cuts, the ability to stem that tide and gain leadership will only come from a strong voice from outside. Bringing stakeholders into our discussions as partners, increasing stakeholder awareness and involvement will help change public attitude. This will allow, or force, the politicians to place priority on these issues. Many adaptation successes are happening throughout the GLSLB, within communities, within sectors like the business or water use sectors. Let us get that information out and build on it. Let us invest for the future, in public policy or programs, by investing in capital infrastructure where the most efficient technologies in retrofit programs or the design of new facilities are encouraged.

"Communication is necessary to assure policy-makers that observations are fitting expectations [of climate change] and explain not just the observations and impacts, but also their implications."

Eugene Stakhiv
Institute for Water Resources, US Army Corps of Engineers (Research)

I will address the questions posed to the speakers, but first I want to go through some of the climate change impact analysis work the US Army Corps of Engineers has done in US river basins. Many lessons we have learned are based on a comparison of these various river basin studies.

The Institute for Water Resources has been involved in the analysis phase of several multimillion-dollar case studies, such as of the Rio Grande and the Great Lakes Basins. We have the databases, the socioeconomic projections and forecasts of future population, which are all part and parcel of integrated socioeconomic impact analysis. We are undertaking analysis of water resources systems to determine their responsiveness to various climate scenarios. We want to look at the robustness, the resiliency and the performance of systems based on specific indicators of reliability, of in-stream-flows, of flood damage reduction. We have factored a lot of economic information into the models, and ultimately want to establish how climate change impact analysis fits into planning studies. Should we do them, and exactly what do we study? How will this impact operating reservoirs? Do we change design criteria for levees and the probable maximum flood for dam safety?

I will briefly review the Great Lakes model. In each of our studies, we have used existing information. We did not create GCM information. We did not create the GLERL net basin supply model. We have simply adapted and used it. We use all credible sources of information. We created the climate change impact model, a simulation model examining the trade-offs between the impacts of hydropower, shore erosion, flood damage reduction, hypolimnion reduction, and wetlands. Managing these levels leads to winners and losers, pluses and minuses; it is hard to know what is the optimal response. We are using the latest three IPCC certified transient models, comparing these with the steady state models. Each GCM (the Geophysical Fluid Dynamics Laboratory [GFDL] model, the Max Planck Institute [MPI], the German model, and the United Kingdom Meteorological Office [UKMO] model) is driven by standard scenarios, the equivalent CO_2 levels based on assumptions of the IS92a [Editor's note: the IPCC describes IS92 scenarios a-f as scenarios of climate change that assume no climate policies, but which include plausible changes in emissions of greenhouse gases and aerosols]. Fundamentally, CO_2 increases by a certain percentage each year, which is why it

is called transient rather than equilibrating at some point in the future. Using the same models, the same data and the same assumptions allows comparison of results. Results of the CCC model cannot be compared with the other GCM scenarios because they do not use the same assumptions for future emissions, growth, population, and other influencing factors. While many models provide interesting results, the outcomes cannot be compared with one another.

These are some of the basic assumptions that go into the IS92a emissions scenarios. Adaptation is already manifest; there is an assumed change in international controls on sulphur dioxide, nitric oxides, etc. Now comparing new models, you can see some of the results. Under UKMO and MPI, the net basin supply for Lake Superior increases. The most adverse model is the MPI model and it is similar in outcome to the CCC model. The net basin supply for the new generation of models is greater than the old generation of steady state models. Translated into long-term water levels, the two models are basically stable over the future, considering average annual. We could generate monthly data, tracing monthly variability; the MPI generates daily pressure patterns and temperature precipitation. The scenario is now shifting and it all boils down to which model you believe. Two of the accepted international standards say that there will not be much change. The MPI says that you are going to have a serious problem. So which model do you believe?

Before discussing adaptation, I am going to present a modification of the J. Scheraga index of confidence: an index of ignorance. From impact analyses, from the GCMs, interpolating and translating that into basic physical processes and effects, to primary water management impacts, socioeconomic impacts, adaptation and management strategies available, uncertainty propagates through the models and through your assumptions exponentially. I want to assure you that I am not naïve in thinking that because we have models and can manipulate these things that we actually know what we are doing. We have data, we have answers, but that does not mean much.

What do our impact models do? We include hydropower impacts, navigation impacts, erosion, flooding, and cold water fish habitat. We are working on wetlands, a factor difficult to incorporate, because ecologists do not know what fluctuating lake levels do to wetlands. We have reams of input data, but only for the stage damage curves (where a certain damage function is translated into dollars lost for each reach, which can be combined by season or by lake) for flooding and erosion.

What are the results? For hydropower, not unexpectedly, the MPI model has the biggest impact. The Niagara Hydropower average annual value is about $940 million dollars which will reduce according to the model used, and decreases significantly under MPI. For shipping, anticipating lower lake

levels, the need for dredging will increase, more ore will be used, smaller draft vessels will be used and a greater number of them required for the same commodity, repair of erosion and flood damage will incur costs, if translated into an average cost per ton ship.

Based on thermal effects in each of the lakes, we have measures of what is the volume of the cold water part of the habitat, important in maintaining the top of the food chain, the cold water fish species. We have used as a minimum limit Lake Erie in 1970; the average cold water hypolimnion volume in September, the worst month, was about 15km^3, while the minimum in 1970 was about 3km^3. Unfortunately, there are no cold water species in Lake Erie. To reestablish them, a hypolimnion must be reestablished.

On the topic of adaptation, I depart from my colleagues in this way. I do not understand what people mean when they say we are not adaptive. We are constantly adapting in the water management field. We are constantly adapting to climate variability, and in particular we are adapting to changing resource uses, demands, values, and the economy. There is not a year in the US when the Corps, the Bureau, the Soil Conservation Service, EPA do not look at studies. There are about 2300 watersheds in the US covering 10 000 km^2. In any given year, about 500 of them are under study for one reason or another. Despite huge public involvement from 2500 watershed groups in the US, hardly anyone raises the issue of climate change.

Different types of analyses and studies are constantly undertaken. We need to take into account what effect technology will have on our ability to adapt in future. In particular, what role will bioengineering have? In the Asian bank alone are a hundred thousand different cultivars (genetic strains) of rice that can adapt to virtually any potential climate combination. In future, we will likely have fusion energy, and hydropower will be forgotten by the year 2050, according to the MPI scenario. What would be the implications for ecosystem management, for all of the other water uses in the Great Lakes, if you did not need to regulate the Great Lakes for hydropower? Right now in the Great

"I do not understand what people mean when they say we are not adaptive. We are constantly adapting in the water management field. We are constantly adapting to climate variability, and in particular we are adapting to changing resource uses, demands, values, and the economy."

Lakes, we have all of these initiatives. I was involved in the IJC Great Lakes Water Levels Reference Studies I and II. We spent seven years, and $20 million studying this stuff, we generated 128 management alternatives, rated and ranked them, and they are sitting there. These are adaptation options! If you adapt to climate variability, if you adapt to population growth, if you adapt to all of the uses, what else are you looking for when you talk about adaptation to climate change? I challenge anyone on the IJC lake levels board to tell me what else they would do if they knew with certainty that the MPI scenario was going to happen differently than what we already came up with in those studies.

In 1975, there were various prestigious water commissions and committees in the US, such as the Resources for the Future, the National Water Commission, projecting water demands of the future. I was on the Water Resources Council study group at that time, and was put in charge of creating a forecast for the low water use scenario, including very modest conservation measures and pricing. We knew the *Clean Water Act* was in place that would require recycling of wastewater. However, the actual water use as measured by the US geological survey is going down. Early data from 1995 appears to be following the same projection. While water management in the US, with all of the adaptive techniques available may be chaotic, and not particularly efficient, they are effective.

Our national draw management study included forecasts of water use and demand management. As one example, in Boston, water use dropped 30% in a matter of five years. They raised their water rates from about an average of $200-700 a year to pay for waste water treatment. This will happen with revision of the *Safe Drinking Water Act.* With the new version of the *Clean Water Act*, everyone will be paying a lot more money for water. One does not even have to formally price water supply; it is happening indirectly, and this is the effect in virtually every city that we have studied. We did our own forecast, for Boston rather than the Greater Boston Metropolitan Area. With current fixtures required by code and rebate programs plus price increases, even in the future with increased population, water demand in Boston will continue to drop. The same is true for every city, Los Angeles, San Francisco, everywhere we have done the analysis. Do not tell me that adaptation is not working. We are spending a lot of money, $125 billion per year, to restore the environment, adapt it, and make it a livable place. We are not simply sitting waiting for things to happen.

Adaptation is slow. I have been involved in two of these IJC Great Lakes Water Level Reference Studies, on many different watershed studies and river basin studies and it is agonizingly slow. The more people involved, the greater the level of collaboration, the more difficult it is to come

"We are following a 'no regrets' adaptation policy in the water management field. This does not mean that we should not be doing anything; that is a false option. We are doing lots of things. We need to organize better, become more efficient. We need to continue promoting systems risk and multi-objective analysis at the watershed river basin level, focus on unmanaged systems."

to decisions. But decisions are being made, changes are being implemented, and it is entering legislation, and changing behaviour. The changes are becoming part of the culture of the people we deal with. One problem that we have is that we need to standardize climate change impact analyses. I have read many reports from various agencies, and hardly any one of them uses the IPCC guidelines for climate change impact analysis. This is a pretty good guide, but it is disturbing how many basic impact procedures are violated.

In conclusion, when I say no need for a radical shift in strategy, it is because I maintain that we are following a "no regrets" adaptation policy in the water management field. This does not mean that we should not be doing anything; that is a false option. We are doing lots of things. We need to organize better, become more efficient. We need to continue promoting systems risk and multi-objective analysis at the watershed river basin level, focus on unmanaged systems, because all of the systems mentioned by me are managed with reservoirs and levees. We have a presence. We know what the hydrology is, we know what the rules and principles for management are. What about unmanaged systems? We need to focus on water quality and ecosystem-related impacts. That will be a fairly large problem, and we need to continue to do a better job on climate change impact analysis.

Question/Comments

An unidentified questioner asked whether the transient models spoken of included sulphate aerosols. E. Stakhiv replied yes.

The same unidentified questioner commented that because of evidence that the areas in which the frequency of heavy, short-duration rainfalls are occurring is or has been

increasing in the US, would not residents of small watersheds be equally, if not more, concerned about climate change than residents of big watersheds? E. Stakhiv stated that as a technical consultant he has not been confronted with the distinction. While he agrees that the frequency of such events appears to be increasing, real hydrologists claim there is no statistical evidence to suggest this increase in frequency.

General Discussion

The moderator M. Slivitzky revisited the three questions asked of the panel members, and raised the question whether we will need to enforce mandatory limits on greenhouse gases, and what will the economic impacts be of such mandatory enforcement? Unidentified speakers focused the discussion more on adaptation. One speaker observed that not only are we adapting to climate change, but we are also adapting to the measures put in place to deal with climate change.

Discussion arose from E. Stakhiv's apparent optimism about our ability to adapt to changing climate system, and whether this was a point agreed to or a mistaken assumption. At what price will adaptation occur in a certain direction? Adaptation must consider all interests.

B. Smit (University of Guelph) highlighted points from E. Stakhiv's presentation. One, impact studies are designed in such a way to compound the errors, starting from the climate scenario, to the physical impacts, tracing through the economic system and arriving at adaptation. Two, adaptation is going on, and options are available. However, adaptation still requires choices to be made; it is not a panacea. B. Smit suggested a need to start with the systems and not a scenario as a fundamentally different approach. E. Stakhiv replied that impact assessment often occurs within the project analysis, and that sensitivity analysis is more in the academic realm (not cost effective or possible?). We are not yet in a position to translate findings of sensitivity analysis into policies and actions.

I. Burton (Environment Canada) asked E. Stakhiv whether he felt he failed to account for the impacts of climate change on other systems that have direct and indirect effect on water resource systems. E. Stakhiv acknowledged the limitations of such examinations, especially due to a limited budget.

G. Vigeant (Environment Canada) wondered how we can choose adaptation

routes without having a final objective, a vision of an optimal solution. The series of pathways available to us as a starting point usually means that we end up taking the cheapest socially, economically, ecosystemically and technologically, the lowest and cheapest curve for adaptation.

6

FUTURE DIRECTIONS: REPORTS OF THE WORKING GROUPS

Working groups on human health, ecosystem health, land use and management, and water use and management report on three tasks which were used to identify the next steps for the GLSLB Project:

- Identify issues that remain to be addressed in climate impact assessment for the GLSLB
- Develop 2-4 initiatives for the next 3-5 years to address those issues
- Propose ways in which initiatives could be implemented

The groups approached these tasks in various ways. The summaries of their discussions and recommendations are presented.

Water Use and Management I

Chair: Murray Clamen, International Joint Commission
Rapporteur: Rob de Loë, University of Guelph

The session was attended by approximately twenty people, including Canadian and US representatives, representing the social and natural sciences, and public and private agencies (utilities, universities, government regulators, and local water management organizations).

Issue Identification

Nineteen distinct issues were identified. These are organized for clarity in Table 6.1 Participants were concerned about the level of scientific uncertainty regarding climate change and its impacts on water resources, unsurprising given the many questions yet to be resolved. Interestingly, six of the issues related to the need for a change in the approach to scientific research. Reflecting the diversity of backgrounds, one social scientist called for more emphasis on understanding human behaviour, while natural scientists wanted to improve the pursuit of existing lines of research by focusing on smaller lake systems, rather than only the Great Lakes. A representative of a local-level water management organization urged that scientific researchers keep in mind the needs of front-line managers. Realistic scenarios are required by people who perform day-to-day water management. Reflecting the theme of the Symposium - adaptation to climate change - several people suggested that the approach to resource management needs to change.

Some issues raised related to the need for a better balance of those interests affected by changes in water levels, the need for consideration of a wider range of responses, and the need to integrate responses among water and other sectors. Improved communication was identified as a key issue only twice, but this area was considered to be the one with potentially the greatest impact. Finally, several issues were identified that did not fit easily into other categories, including a lack of political will to adapt to climate change, and issues relating to the importance of climate change relative to other concerns that face society.

Initiatives

Fourteen initiatives under four general categories were identified by the group (Table 6.2). Within each category, the initiatives are listed in the order they were supported by the votes of working group members. The most highly favoured research initiative

Table 6.1
Outcdome of the Water Use and Management Group 1: Issues

Category	Issues
Scientific Uncertainty	• Lack of knowledge of current conditions, e.g., ground water • Need to reconcile near-term and long-term impacts, e.g., on lake levels • Uncertainty regarding causes of changing lake levels
Research Thrust or Approach	• Too much emphasis on understanding biophysical systems and not enough on human behaviour • Need realistic scenarios for front-line managers (focus on their needs) • Need co-ordination and standardization of use of existing data • Need to focus on Great Lakes overshadows smaller lake systems • Day/night asymmetry of warming being ignored even though it is strongly observed in climate modelling • Focus on larger systems and what community will ask for because knowledge of physical climate systems is too weak for specifics
Management Approach	• Need to consider a wider range of responses regarding lake levels • Need to consider together physical, social, and environmental response interactions to specific extreme events • Need to balance impacts and interests of water usesr • Need integration of adaptation responses for water and other sectors
Communication	• Need improved communication of what we and do not know, and how can we get scientists to communicate issues well • Need to improve scientists' communication skills • Need clearer statement of impacts, synthesized in one phrase
Miscellaneous	• Deregulation of electricity will produce more carbon dioxide • Assessing the importance of climate change relative to other issues • Lack of consensus in science confuses public and affected parties • Lack of political will

related to the development of approaches that can be used to educate the public regarding probabilistic data. This initiative also appears under communication (see below). Two integration initiatives were equally favoured, reflecting the various components of integration: within the water sector (i.e., integration of surface and ground water, quality and quantity, rural and urban, etc.), and across sectors, sciences, and jurisdictions (especially Canada-US, but also between and among provinces). Seven communication initiatives were proposed, with the public education initiative appearing again. The next most highly-rated communication initiatives related to adaptation and likely impacts. Several other basic communication strategies were suggested, including preparation of materials for the press and for schools, and the creation of local stakeholder forums.

Table 6.2
Outcome of the Water Use and Management Group 1: Initiatives

Category	**Initiative**
Research	• Develop methods, and educate the public to be informed consumers of probabilistic data/information • Identify and focus on proactive rather than reactive adaptive strategies • Focus research on tributary basins (rather than just the Great Lakes) • Investigate impacts arising from greater warming at night than during the day
Integration	• Improve integration of issues across sectors, science and jurisdictions • Better integrate all aspects of water (de-compartmentalize)
Communication	• Begin to develop and educate the public to be informed consumers of probabilistic data/informatio • Improve communication about adaptations, rather than impacts (tailored to specific groups) • Develop a clear statement of impacts • Initiate local stakeholder forums • Prepare background press briefings • Develop and share resources (e.g., guides for schools)
Other	• Get tools to front line people so that they can investigate impacts and develop solutions • Continue to emphasize "no regrets" actions which benefit water management· Internalize resource use

During discussions, group members emphasized that better communication of scientific findings was important, but difficult because this requires scientists who are effective communicators, or willing to receive communication training. Finally, various other initiatives were identified, two of which received the next highest number of votes. One related to the issue of getting tools and information to front-line water managers. The person representing a local water management agency argued strongly that basic tools and models developed for "front-line" needs were crucial. Additionally, reflecting a theme that appeared during the Symposium, group members strongly supported initiatives that would continue to emphasize actions that made good water management sense anyway.

Implementation

The group had time to consider fully only the most highly regarded initiative (development of public education tools). Focusing on this initiative allows:

- Incorporation of some of the uncertainty inherent in estimates;
- Distinguishing "legitimate" research from "grey literature;"
- Front line people to access tools despite uncertainty.

Obstacles to achieving this initiative included that probability is difficult to understand. The people who should be key players are those whose duties involve translating science into plain language, and scientists with a flair for (or the proper training for) communication. This could be achieved by creating positions for the "translators," and by providing training for the "volunteer" scientist communicators.

Water Use and Management II

Chair: Deborah Lee, Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration
Rapporteur: Grace Koshida, Environmental Adaptation Research Group, Environment Canada

Fifteen people attended this working group session, representing NGOs, government and industry.

Issue Identification

A number of issues were identified by the group, and broadly categorized as either impact or adaptation issues. Issues associated with climate variability impacts included the need to further assess the relationships between present climate and socioeconomic systems and to determine the impacts of historical water level changes and fluctuations, especially in the St. Lawrence River Basin. Climate change impacts requiring further research include impacts of climate change and groundwater resources, and climate change and ice cover on the Great Lakes. Subsequent consequences for hydroelectric power and shore erosion should also be assessed. Several issues relating to adaptation to climate change were identified. The existing lake level regulation plan for Lake Ontario needs to be evaluated, assessed and revised, potential changes in energy sources used under climate change needs to be assessed, and, more generally, scientific adaptation findings need to be applied to stakeholder needs by linking to on-going initiatives. Obstacles and benefits to implementing adaptation strategies need to be identified. There is also a need to create a

vision for the year 2050 of the Great Lakes Basin, and for a climate change detection strategy to identify signals that climate change is occurring. Communicating climate change impacts and adaptations was regarded as important. This could be facilitated by promoting a regional resource conservation ethic (e.g., water conservation) and by using standardized benchmarks to illustrate climate change impacts. Regional integrated assessments and historic analogues were also viewed as important methods to both understand and communicate climate change issues. Each level of government (i.e., federal, provincial/state, municipal) has a role to play in the development of policies related to climate change. Finally, there is a need to improve the modeling of regional climate change impacts, especially for certain climate variables (e.g., precipitation), and to arrive at a better consensus between climate model outputs.

Initiatives/ Implementation

Among the initiatives suggested to address these issues is the promotion of a resource conservation ethic, through means such as demonstrating success stories, explicit linking of altered actions to environmental and economic benefits, and initiating local involvement via such projects as RAPs. What might be accomplished over the next three to five years is the undertaking of an historical analogue analysis of the GLSLB, focusing on low water levels, using methods similar to the MINK study in the US Midwest.

However, a number of potential obstacles to such initiatives were recognized. The public, when faced with present high water levels, may not believe that future low water levels are a pressing matter; the public receives mixed signals from the government about current water levels (e.g., location and development on

Table 6.3
Outcome of the Water Use and Mangement Working Group II

Issues Identified	Initiatives/Implementation
· Need to assess environmental and socioeconomic impacts of present climate and climate variability · Need to determine climate change impacts on groundwater resources and how Great Lakes ice cover changes would affect water levels and flows · Need to develop, assess and prioritize adaptation options· Need to create a vision for year 2050 in the Great Lakes Basin · Need better means to detect climate change· Communication issues · Historic analogues and regional integrated assessments · Policy development for climate change· Water conservation · Improve forecasting techniques	· Promote conservation ethic · Increase participation of stakeholders

floodplain zones). Good baseline data on water consumption and withdrawal rates in the Great Lakes Region is also lacking.

Another initiative identified was the increased participation of affected stakeholders in adaptation research. Both stakeholders directly affected (e.g., agriculture, forestry and other resource industry sectors) and indirectly affected (e.g., insurance, emergency response groups), as well as managers of risk (e.g., bankers, insurance professionals) should be invited. A potential obstacle to this initiative may be the difficulty in convincing those stakeholders of the need to participate.

Implementation of these initiatives was viewed as being better led by non-governmental organizations, with credibility in the region, rather than by government departments. Such groups would benefit from collaboration with municipalities, RAPs, and watershed management groups. Organizers would ideally involve people with knowledge of climate change and adaptation issues, such as the GLSLB Project Steering Committee.

Human Health

Chair: Pierre Gosselin, Comité de santé environnemental du Québec
Rapporteur: Abdel Maarouf, Environmental Adaptation Research Group, Environment Canada

Nine participants representing stakeholders from the health-care sector, university and government research, policymakers and NGO attended this workshop. Initial discussion established agreement among participants that human health indicates not only the absence of disease and infirmity, but also a state of complete physical, mental and social well-being. Participants accept the notion that climate is related, both directly and indirectly, to human health and safety. Climate plays a major role in controlling human comfort and can promote disease or disease vectors. It can also support healing and favour recreation. Climate variables such as temperature, precipitation, wind, humidity, barometric pressure, solar radiation and electrical phenomena can act singly or together to bring about these effects. Atmospheric hazards such as hurricanes, tornadoes, floods, hail, lightning, winter storms, heat-waves and pollution episodes cause serious injuries, loss of life, and damage to habitats, farmlands, crops and freshwater supplies.

The workshop recognized that climate (meaning also climate change, climate variability and climate extremes) is closely related to other atmospheric environmental issues such as air quality (e.g., smog and inhalable particles), increased UV-B radiation

Table 6.4
Outcome of the Human Health Working Group

Issues Identified	Initiatives/Implementation
· Extreme events · Smog, air quality and other air issues · Water · Infectious diseases · Transportation · Demographic changes · Urban focus · Social behaviour and attitude · Public perception and education · Policy research · Integration	· Zero-emission technology · Case studies · Data sets · Regional studies and urban focus · Study of social determinants · Education and communication · Weather-health watch/warning systems · Policy analysis · Preparedness plans · Environment-public health cooperative

(resulting from stratospheric ozone depletion), and acidic deposition. All these atmospheric stresses are commonly found in the densely populated region of the GLSLB, and their combined effects on human health are likely to be significant.

It was evident from several presentations at this Symposium that human health studies in the GLSLB project have been limited in scope, and several issues still remain to be addressed or need to be expanded in the framework of climate impact assessment.

Issue Identification

Extreme Events

Each year, natural disasters kill, injure and displace many people, and cause millions of dollars worth of economic losses. There is considerable concern that with increased climate variability, the intensity and frequency of extreme climatic events (e.g., floods, severe storms, heat-waves) could increase dramatically. The psychological, health and safety impacts of these events need to be addressed. High-resolution climatology and trends of extreme events in the region are not currently available.

Smog, Air Quality and Other Air Issues

Air pollution has become a major element of the local climate in the highly urbanized and industrialized region of the GLSLB. There is strong circumstantial evidence that contemporary air pollution is adversely affecting human health. In particular, photochemical oxidants or smog (e.g., ground-level ozone) are very reactive and cause damage to human health and agricultural crops. Airborne toxic metals, acidic aerosols, and organic and inert particles are also a major health concern. Acidic

deposition (acid rain) cause damage to vegetation, freshwater, soils and ecosystems. Stratospheric ozone depletion has led to an increase in the amount of UV-B radiation reaching the surface. Human health impacts of UV-B include increased incidence of cataracts and other ocular effects, skin cancer and suppression of the immune system.

Air pollution episodes are intensified by meteorological conditions. These usually involve temperature inversions and light winds. Concern is growing that climate change (global warming) may result in increased frequency and intensity of air pollution episodes.

Several diseases have high seasonal morbidity rates(e.g., asthma and hay fever). They are triggered by aero-allergens which are weather and climate related. Heat and cold may affect the sensitivity of stressed individuals.

Water

Impacts of climate change on the global hydrological cycle, extreme weather and climatic events, warming of GLSLB, drop in lake levels and decline in water quality are major concerns. The consequent impacts on fresh water supply for drinking and irrigation, potential conflicts over water shortages, and other health problems are still largely unknown.

Infectious Diseases

Micro-organisms and parasites require certain climatic conditions, in particular specific temperature and humidity ranges. Indirect effects of climate change include increases in the potential transmission of vector-borne infectious diseases (e.g., malaria, dengue and some viral encephalitis). Climate plays an important role, affecting the life cycle and survival of micro-organisms, the cycle of the vector, and the route of transmission. Several disease vectors are currently found south of the GLSLB and could extend their range northward. Predator/prey relations could be disrupted, weakening natural controls on pests and pathogens. Alteration of biodiversity regimes may affect the availability of medicinal plants and limit the chances for discovering new drugs and vaccines.

Transportation

Each year, a large number of vehicle occupants, pedestrians, cyclists and motorcyclists are killed or injured in traffic accidents. Time spent in traffic jams contributes to stress and pollutants emitted from the transportation sector cause health problems. The role of climate change and other atmospheric stresses (e.g., increased precipitation events, freeze/thaw cycle) on road safety needs to be assessed. Studies of viable transportation options (e.g., automobile versus railway) and the potential

impacts on human health need to be undertaken.

Demographic Changes

Underlying all aspects of climate change and atmospheric stress are the population dynamics in the GLSLB. Population growth, aging population, continental migration, increased domestic and international travel, and potential for influx of political, economic and environmental refugees are just a few aspects of demographic changes which could influence the transmission and spread of disease, and put an increased stress on natural resources.

Urban Focus

Over 40 million people inhabit the GLSLB, mostly in large urban centres. More attention needs to be focused on the health implications of climate change and atmospheric stresses in the urban environment.

Social Behaviour and Attitude

The negative impacts of climate change (e.g., heat stress, shortage of fresh water, regional migration, refugees) may contribute to violence and conflict. In addition, exposure to heat, air pollution, UV-B radiation, and disease-causing agents, could increase population vulnerability and influence the incidence of disease, depending on the behaviours and attitudes adopted towards current and anticipated atmospheric stresses.

Public Perception and Education

Public perception of climate change, its impacts and associated risks are important factors in examining mitigation and adaptation options. Public opinion often drives the policy-making process, and public education about the health risks of climate change needs to be expanded.

Policy Research

All atmospheric issues, including climate change, are strongly inter-related, and policies designed to address single issues may not be optimal in the broader picture. For example, improved home and building insulation in recent years as a result of energy conservation policies may have also contributed to less ventilation and lower indoor air quality. Indoor air pollution aggravates respiratory and other diseases, such as asthma.

Integration

Participants reported that atmospheric and other environmental health issues are currently being addressed in a fragmented fashion by several government departments, university researchers, private sector and NGOs. Institutional integration and

coordination of human health studies, at least in the GLSLB region, would allow for priorities to be set about various issues, leadership, jurisdictional responsibility and communication strategies.

Initiatives/ Implementation

Towards Zero-Emission Technology

Workshop participants believed that clean air, water and soil must be an environmental vision shared by all citizens. In achieving this vision, government and industry must genuinely try to replace combustion engines and coal-generating electricity by clean-emission technology. Because climate change is a global issue and the atmosphere knows no boundaries, developed countries should export environmentally sound technologies to developing countries and facilitate their implementation.

Case Studies

Recent extreme climatic events and air pollution episodes in various parts of North America may have caused serious health problems (e.g., Chicago heat-wave in July 1995; Manitoba-North Dakota floods in April 1997). Participants recommended that research be extensively conducted on these and similar events to determine their health and psychological impacts, and to assess the strategy and costs of adaptation options.

Data Sets

The atmospheric and medical communities should work together to assess the availability and usefulness of current climate-health data in the GLSLB region. There is a need to list and expand data sets for the purpose of health studies in relation to climate change and atmospheric stress. The following are a few examples of proposed improvements to data collection activities:

- Monitoring the distribution and abundance of insect vectors and the pathogens that they carry;
- Comprehensive reporting of diseases caused by these pathogens;
- Surveillance of heat-related illnesses, injuries and fatalities;
- Gathering of baseline data for the evaluation of time trends and disease outbreaks;
- Surveillance of casualties in the wake of extreme climatic events (e.g., heat waves, storms, lightning, floods, pollution episodes, etc.);
- Surveillance of water quality and water-borne diseases;
- Surveillance of soil, pest and crop environments which could be affected by climate and atmospheric stress, and their effects on nutrition and related diseases;
- Monitoring the breeding and spread of bacteria, viruses, fungi, pollen and other forms of biotic agents and aero-allergens.

Regional Studies with Urban Focus

The Great Lakes 2000 initiative provides a good example of an integrative study that looks into the impacts of and adaptation to smog, air toxics and other air and water issues. Another regional study that is currently being promoted is the Toronto-Niagara Region Study. Its focus will be on the integration of science and policy across all atmospheric stresses, on regional and local scales. The ultimate goal is to build healthy communities, adapt to atmospheric change, and achieve sustainable development. Government, industry, various citizen groups, and NGOs should support these initiatives.

Study of Social Determinants

A study is needed to examine the changing behaviour of various communities over time in response to climate change messages, and determine the social barriers to adaptation. Also, why are some communities (e.g., Montréal) using more public transit than others (e.g., Toronto)? What are the factors that increase the region's vulnerability to climate change (e.g., building in flood plains)? Of special interest also is finding out what motivates decision-makers to take action. How do incentives or disincentives help to mitigate atmospheric stress or adapt to climate change?

Education and Communication

Education can have a considerable effect on the health status of human populations and their vulnerability to disease incidence. Educating diverse groups of people (e.g., general public, health-care officials, decision-makers and other stakeholders) about the potential health impacts of atmospheric stress is an essential tool. Interpretation of the present state of scientific knowledge should be undertaken with care so as to accurately convey the level of uncertainty and the risks involved. Reliable and credible information and research findings from climate-health studies should be communicated to those in a position to deliver services or to act to protect community health. Information should also be disseminated to the general public on how to reduce climate-related health risks (e.g., during heat-waves, air pollution episodes and flood situations).

Weather-Health Watch/Warning Systems

A weather-health watch/warning system designed to broadcast information and advice ahead of health-related adverse conditions, such as oppressive air masses, is currently used in Philadelphia and could be tested in the GLSLB. Oppressive air masses can be predicted two to three days in advance and a series of intervention activities could be initiated to reduce morbidity and mortality rates, such as media announcements,

increased emergency medical service, special care to the elderly and homeless.

Policy Analysis

Policymakers should examine viable alternatives to reduced or discontinued services and practices. For example, in the transportation sector, reduction in railway subsidy could increase travel by cars leading to more greenhouse gas emission, more hazardous pollution and road accidents.

Preparedness Plans

Programs and activities should be developed to ensure that specific future health needs are met, and that appropriate medical supplies and health assistance are readily available. Preparedness plans to assist communities in dealing with atmospheric natural hazards should be established.

Environment-Public Health Cooperative

The changes and actions needed to sustain healthy communities in a variable and changing climate will require new ways of thinking, new values, tremendous political will and leadership. Workshop participants suggested that an alliance of decision-makers from various municipalities in the GLSLB be established to develop a strategy to implement several sound actions in a given period of time. An investigation should follow of who does and who does not implement the actions, and of the opportunities and obstacles to adaptation as well as possible incentives that could be used to achieve desired goals.

Land Use and Management

Chair: Ray Rivers, Environment Canada
Rapporteur: John Smithers, University of Guelph

The Land Use and Management Working Group brought together a variety of professional experiences and perspectives representing government, universities, and the private sector. This diversity was reflected in both a wide ranging set of views and interests concerning land management, as well as some apparent differences relating to gaps and issues in the area of adaptation research. Three main issues were identified; however, points raised for one issue often applied to one or both of the other theme areas.

Issue Identification

The group sought to clarify the meaning of "land use/land management." The topic was broadened to encompass issues of land allocation, land management (the manner in which given uses are undertaken), and governance (the manner in which policy

related to land use is implemented).

Three families of issues are summarized here which bear on the four perspectives identified in the charge to the group: the nature of research, the role of actors, and priority sectors and regions.

Future Adaptation Research

Several issues reflected the recognition of needs for future adaptation research. The uncertain nature of climate impacts (and subsequently of adaptation) research raises some issues. Gaps in science cloud the verification of issues (and critical regions), and undermine the credibility of the adaptation problem societally. Such uncertainties impede both the public and elected decision-makers from adopting the issue. Related to this was the recognition that uncertainty might be reduced by better models, but that the problem of climate impact and adaptation is inherently messy and that the complexity of human-environment systems should be accommodated in integrated analyses rather than segregated as single discipline studies. Finally, greater attention should be given to research on climate change impacts application. Current interactions between climate and human activities (various sectors) need to be scrutinized to ascertain the nature of sensitivity and the types of impact thresholds.

Role of Stakeholders

Other issues concerned the role of stakeholders in setting research agendas and in assessing the acceptability of certain impacts and adaptations. Historically, the public has limited involvement in governmental and academic adaptation

Table 6.5
Outcome of the Land Use and Management Working Group

Issues Identified	Initiatives/Implemented
· Need to acknowledge the uncertainties of climate impacts, scientific gaps and lack of credibility · Need to clarify the role of stakeholders in setting research agendas; need for increased consultation; voluntary vs. legislated land use and management · Need for attention to climate change implications for rural Canada · Need to consider influence of change on established management regimes	· Improve science of climate prediction, while accepting uncertainties · Balance regulation and management · Develop indicators of change · Investigate historic and present analogues of climate change and adaptation · Need increased recognition of the issue by decision-makers, and greater involvement of stakeholders in setting priorities for public action · Make use of established sectoral organizations to disseminate information

research. As researchers and planners, are we asking the questions that matter to people? Are the adaptations (or costs) that experts envision acceptable to those people who will be asked to bear them? This raises issues about legislated versus voluntary change in land use and management governance. Consultation is needed to estimate the seriousness of impacts, and to attempt to define those aspects/products from land most highly valued socially, and those regions/ groups most at risk of suffering the loss of these services.

Various issues arose regarding the regional and sectoral nature of adaptation research. To date, emphasis has been on the urban context, or at least on more densely populated regions. Greater attention should be paid to regions of more dispersed population, specifically for forestry and farming, the industries prevalent in rural Canada, and also for domestic/residential sustainability. Research and planning for land use and management must account for the continued rapid population growth in the GLSLB (especially urban sprawl), and also recognize that a deterioration in land suitability for traditional land based production in rural areas will further stimulate urban migration.

As well, issues were raised about management for various land-based sectors, such as forestry, agriculture, recreation, and water management. For these sectors, effort is needed to identify how the routine management strategies might be affected (e.g., municipal activities such as snow removal and storm water management, soil management in agriculture in the face of extreme precipitation events, forestry practices for cutting and burning given the likely alterations in ecosystem resilience and equilibrium). A more general point concerned the possibility that climate change may alter the assimilative capacity of ecosystems for "shocks" of all types.

Initiatives

From the issues identified above, three initiatives seemed to emerge most prominently:

1. Balance is needed between land use regulation and management to help manage specific uses and the consequent altered environment under an altered climate. At the same time, there needs to be recognition of opportunity to seek advancements in the adaptive capacity of specific land uses. Efforts must be made to improve the science of climate prediction, understand the nature of locally/ sectorally specific tolerance limits and coping/assimilative capacity, and ascertain the status of existing and emerging technology that may alter sensitivity.

2. Develop indicators of impacts and change for both impacts analysis (how do we detect climate-induced effects?) and for the nature of subsequent change (how do we detect climate-related change in human systems?). There was

a brief discussion of the notion of risk and the possibility that certain indicators might be of value in identifying regions (or peoples) that are at greater or lesser risk.

3. Explore the interaction between climate and land use both historically and in the present. Recognizing that future climate change prediction remains somewhat uncertain, and that the interaction of climatic and human-based systems is inherently complex, there was agreement that explorations of present (or recent past) interactions of climate and land use may provide important insights in their own right, and might also contribute more empirically validated inputs to integrated modelling frameworks

Implementation

The working group was unable, in the time available, to fully explore the topic of implementation. However, the following points, gleaned from the broader discussion, are relevant to implementation:

1. Continued funding for integrated research (bearing in mind the research issues cited above) is vital to improved understanding of the regionally distinctive nature of climate impacts and adaptation prospects.

2. The nature of the climate question, and its attendant planning issues, extend well beyond the planning horizons of political bodies, granting councils, and perhaps even the lifespan of individuals. Climate adaptation may struggle to attain recognition given the relative short-term perspectives of decision-makers, planners, and the public.

3. Greater involvement of stakeholders in describing the role of climatic conditions in human activities and in setting priorities for public action may counter the short-term view. More direct involvement of local actors is seen as a means of including the lay perspective in the meaning of climate change and variability in the lives of individuals.

4. While individuals may not yet be actively seeking information concerning possible changes in climate, and its implications for them, the same is generally not true of the sector groups that represent them (e.g., the forestry industry vs. forest workers; the Ontario Federation of Agriculture vs. private producers). Such sectorally-based organizations may represent important and appropriate conduits to members of the public. These contacts may be confined to the transfer of knowledge (both ways), but may also represent possibilities for joint research targeted to specific (applied) societal needs and priorities (with a caveat, that there will of course be societal needs/issues not represented by economically defined organizations, such as seniors.)

Ecosystem Health

Chair: Russ Moll, Michigan Sea Grant
Rapporteur: Christiane Hudon, Environment Canada

Thirty participants contributed to the Ecosystem Health Working Group.

Issue Identification

The recommendations of the members of the group were divided among four major issues. Below, the issues are described and justified, potential obstacles identified, and initiatives to address them and concrete examples currently under way in specific areas are presented.

Linkages between Climate Variables and Ecosystem Components

Understanding linkages helps establish the relationship between the output of climate models (temperature and precipitation), the physical processes (e.g., lake stratification, water level, rate of evapotranspiration, ice conditions) and the biological components of ecosystems (species composition, diversity, production, respiration, recruitment, mortality). This basic information should allow the identification of aspects of climate variability that are most ecologically relevant

Table 6.6
Outcome of the Ecosystem Health Working Group

Issues	Initiatives/Implementation
· Need for linkages between climate variables and ecosystem components · Need to identify and monitor indicators of ecosystem health · Need to provide information to the public · Need for an integrated management for Great Lakes System including prioritization of issues	· Use historic data bases, and present day analogues used as referents for climate change future · Develop regional models and analysis techniques · Establish monitoring to ascertain the changes in the ecosystem · Undertake an effective and targeted public communication campaign · Attempt coordinated management of the Great Lakes as a system

and of the segments of ecosystems most sensitive to climate change. The type and magnitude of impacts are expected to differ markedly between lake and river ecosystems.

The Problem of Scale

Information from global climate models should be interpreted using regional models and/or statistical and analysis techniques to provide information at temporal and spatial scales compatible with those of the physical and biological processes under investigation. Current climate model results are often presented as yearly average conditions over large continental regions, whereas ecosystem components form a complex mosaic at local/regional scales and may be strongly influenced by short-lived, extreme or seasonal conditions. Although climate models predict progressive, linear changes through time, ecosystem response is most likely non-linear, with an apparent resistance to change up to a certain threshold, beyond which time a rapid (catastrophic) transition will occur. Such a threshold response should be well-understood by managers, so that they can assess the amount of stress an ecosystem can sustain before it is irretrievably damaged.

Confounding effects

Assessment of ecosystem health with respect to climate change is complicated by a lack of understanding of the effects of other, previous human interventions. Ecosystems have already been considerably altered by the cumulative effects of management, water level regulation, pollution, introduction of exotic species and resource exploitation, which may decrease our ability to detect or predict a change.

Linkage of water quantity and quality

Water quantity and quality are of concern to inhabitants of the GLSLB, and together constitute an integral part of the ecosystem health of the basin. Water quality (e.g., affected by nutrients, or toxics) and water levels are currently monitored by both US and Canadian agencies. Research indicates that climate change and other scenarios may severely impact water supply to the basin, resulting in significant changes in water level and discharge rate. Changes in the hydrological balances of the GLSLB potentially affect water quality through changes in loading, lessened dilution of point source contaminants, or modification of the relative importance of contaminants originating from other sources (released from lake sediments, atmospheric sources, groundwater or surface flow). Further, sensitive environments of the land-water interface such as wetlands, are particularly at risk from large scale changes in the

hydrologic regime. Uncertainties are great about both water quantity and water quality changes in the GLSLB as a result of climate change. From an ecosystem health perspective, continued monitoring and research to reduce uncertainties is recommended as essential for the basin.

Initiatives/Implementation

How might these issues be addressed?

1. Investigate the current response of ecosystems to present and past conditions
2. Build up and document case studies for critical components/areas
3. Carry out field experiments
4. Make use of historical data bases
5. Utilize regional models and analysis techniques to bridge the gap between global scale climate change and regional responses of ecosystem(s) to climate forcing

Examples

Numerous studies can be found in the published literature linking individual ecosystem components and relevant climate variables. These studies need to be synthesized and critically reviewed to identify information gaps and future research needs. The Canada Country study is an initiative currently under way to accomplish this goal.

Identify and Monitor Indicators of Ecosystem Health

Meaningful indicators of ecosystem health can be derived from the understanding of basic links between climate, physical environment and biological response (see initiative 1). These indicators will in turn allow identification of variables that should be monitored to obtain the relevant information at the appropriate temporal and spatial scales. Acquisition of basic information regarding the current status of ecosystem health is crucial for future comparisons. Involvement of the public for such monitoring is advisable, in order to increase their awareness and provide a wealth of information at low cost, although this type of participation may restrict the choice of variables to be monitored.

Initiatives/Implementation

1. Make available existing data banks on Internet Web Sites.
2. Critically assess current monitoring programs and adjust them to future needs.
3. Increase public involvement through school programs.
4. Evaluate existing indicators of ecosystem health for their possible use with climate change issues.

Examples

1. Biosphere (Environment Canada, Québec region) monitoring program involves schoolchildren in observations of the incidence of external parasites of fish in various areas of the St. Lawrence River.

2. Numerous organizations (Environment Canada, US EPA, Hydro-Québec) have devoted efforts to the identification of biological indicators of ecosystem health, some of which specifically address the GLSLB.

3. Major data banks are already available through Internet.

4. Historical trends in Great Lakes variables should be evaluated to assist in developing indicators.

5. Environment Canada runs a volunteer climate observation network (volunteers are trained to take temperature readings, measure precipitation and use Environment Canada equipment). This allows data to be obtained at a higher density within any specific region and at more stations than the current weather observation network, thus filling in the gaps.

Public Communication and Education

Scientists should be made more aware that their findings need to be presented in more useful forms to be helpful to managers, decision-makers, policy-makers and ultimately to the general public. Scientists should also try to bring more clarity to the degrees of confidence that can be placed in their conclusions and to use a more global, integrated (ecosystemic) approach, rather than a narrow and specialized approach. Ultimately, the goals of such a program should be to encourage human behaviour to change toward ecologically-sound practices. A major problem today is a basic misunderstanding of the nature of science by the public. The current emphasis in science curricula has trained the public to expect definite answers from science. Thus when results of science investigations give contradictory results or probabilities instead of certainties, a distrust of science and scientists evolves. Results stemming from global change research are particularly prone to this kind of misunderstanding.

Initiatives/ Implementation

1. Provide information for the public, to assist decision-making about personal life-styles and behaviour. Since people rely on different media for different types of information, diversify the message and send it through many media.

This implies a need for:

a. Media workshops, to provide clear messages and assist reporters with their information needs. Focus on solution-oriented approaches when faced with decisions.

b. Development of a documentary about global change in the GLSLB and/or a

set of public service announcements about benefits of changing the current behaviour patterns contributing to environmental problems. Most people claim that they get most of their information about the Great Lakes from the television.

c. Contribute to ongoing efforts of respected groups who are planning or already doing things to get public attention to environmental changes. Ally primarily with those looking at solution-oriented aspects. The public does not respond well to "downers" from the media where a course of action is not suggested.

2. Focus publicity on children, since they bring the message home (literally) and represent the consumers of tomorrow. Assist and/or support school system efforts to modernize science curricula including the addition of substantial treatment of system science to the type of science currently being taught. This can be fostered by developing integrated science curricula and teaching material to replace the traditional biology, chemistry, earth science and physics; promoting the effective use of internet and CD-ROM technology in school science programs; and providing Great Lakes and global change science educational opportunities for teachers and school science leaders.

Examples

1. Great Lakes educational materials (Climate and water intersections, 1996 ; GL instructional materials for the changing earth system, 1996 ; Environmental issues for the GL, 1997) from Ohio Sea Grant Publications, Columbus

2. Earth systems education (Mayer and Fortner, 1995 [eds.]. Science is a study of earth. The Ohio State University Research Foundation, Columbus, Ohio) and Mayer, V.J., 1997. (Global science literacy: an earth systems view (Guest editorial). J. of Res. In Sci. Teaching 34: 101-105). Prairie grass - the public is encouraged to plant a mixture of wild species of prairie grass on their lawn instead of commercially available grass

3. Mighty Acorn Program

4. Numerous educational programs currently under way in the US and Canada

Integrated Management of the Great Lakes System

It is important to know where we want to go in the future before setting management priorities for the basin as a whole. Great Lakes management can be better coordinated among users and stakeholders, through the allocation of weights and priorities to the different uses of water from the Basin. Potential conflicts among users must be identified and solutions must be developed prior to the occurrence of a crisis generated by resource shortages.

Initiatives/Implementation

1. Allocate a two-year time frame to the IJC for production of a water management plan for the GLSLB, which would address multiple needs both in terms of water quantity and quality.

2. Seek consensus through public consultations and exchange of information among stakeholders.

3. Encourage the IJC and other agencies to deal with stakeholders as well as local, state, provincial and federal authorities to establish mutually suitable priorities for future water allocation and resolution rules for potential conflict over periods of short supply

Examples

1. A new program is being started to prepare report cards for ecosystems of the US. GLSLB could be included in this program, with participation by a Canada-US joint expert team

2. The IJC has already put forward the Scope of Work Plan to obtain the basic information required to include additional (environmental, small craft navigation) criteria in the management of Great Lakes and St. Lawrence River water levels.

3. At a smaller scale, the Nipigon River Water Management Plan exemplifies the collaboration of a number of interest groups concerned with : conservation of brook trout and other fish species, production of hydroelectricity, preservation of shoreline property, recreational boating and domestic water supply [Atria engineering Hydraulics Inc. 1994. Nipigon River: Development of a water management plan. Final report. North Shore of Lake Superior Remedial Action Plan. Technical Report no. 20: 36 pp + app].

APPENDICES

Appendix A: Symposium Agenda

Adapting to Climate Change and Variability in the Great Lakes-St. Lawrence Basin

A BINATIONAL SYMPOSIUM

May 13-15, 1997 - SkyDome Hotel - Toronto

TUESDAY, MAY 13, 1997

18:00	***Symposium Registration*** *(entrance to Northern Lights Ballroom)*	
19:00-22:00	***"Highlighting the Science" An Opening Reception and Poster Session***	**Doug Cuthbert (moderator)** *Environment Canada*
	A Century of Progress	**Stan Changnon** *Illinois State Water Survey*
	Introduction of Posters	**Roger Street** *Environment Canada*
	Poster Session *(Northern Lights Foyer)*	

WEDNESDAY, MAY 14, 1997

8:30	***Symposium Registration*** *(entrance to Northern Lights Ballroom)*	
9:00	***Welcome and Purpose of Workshop***	**Frank Quinn** *National Oceanic and Atmospheric Administration*
9:15	***Climate Change, Regional Impacts and Adaptation***	**Joel Scheraga** *US Environmental Protection Agency*
10:15	*Coffee*	
10:30	***Great Lakes-St. Lawrence Basin Project: What Have We Learned?***	**Linda Mortsch** *Environment Canada* **Frank Quinn** *National Oceanic and Atmospheric Administration*
11:45 13:00	*Lunch (Sightlines Restaurant)* ***Post-Luncheon Address***	**John Mills** *Environment Canada*
14:00	***Impacts and Risks of Climate Change and Variability: A Panel Discussion*** • What are the range of possible impacts and impacts of most concern? • How do others associated with your activity perceive these impacts and risks? • What uncertainties must be clarified before decisions can be made with respect to impacts?	**William Bolhofer (moderator)** *National Oceanic and Atmospheric Administration* **Sarah Miller** *Canadian Environmental Law Association* **Lorrie Minshall** *Grand River Conservation Authority* **Daniel Injerd** *State of Illinois* **Jacinthe Lacroix** *Ministry of Public Security, Québec* **Don Power** *Ontario Hydro*

	Coffee (available during entire panel session)	
15:30-17:30	***Adapting to Climate Change and Variability: A Panel Discussion***	**Michel Slivitzky (moderator)**
	• What are the impacts of most concern?	*Institut nationale de la recherche scientifique-eau*
	• What are sustainable, adaptive strategies that climate-sensitive interests are using and can develop to respond to climate change and variability?	**Ken Ogilvie** *Pollution Probe*
	• What are the cultural, institutional, economic, and scientific obstacles to and priorities for action?	**Lisa Lepp** *Stonechurch Vineyards*
		John Kinkead *Ontario Ministry of Natural Resources*
		Eugene Stakhiv *US Army Corps of Engineers*
	Dinner (enjoy the hospitality of Toronto)	
19:00-22:00	***Adapting to Climate Change and Variability in Toronto***	
	A public forum hosted by the *Canadian Global Change Program of the Royal Society of Canada*	**Jeffrey Watson (moderator)** *Canadian Global Change Program*
		Henry Hengeveld *Environment Canada*
		Jack Layton *Metropolitan Toronto*
THURSDAY, MAY 15, 1997		
8:30	***We Can, Must, and Will Adapt***	**Ian Burton** *University of Toronto and Environment Canada*
9:30	***Charge to Working Groups***	
	Coffee (available in breakout rooms)	
9:40	***Working Group Session*** *(breakout rooms will be posted in registration area)*	
	Working groups on *human health, ecosystem health, land use and management, and water use and management* will address the questions discussed during the panel sessions.	
12:00	*Lunch (Sightlines Restaurant)*	**Alfred Beeton** *National Oceanic and Atmospheric Administration*
13:15	***Post-Luncheon Address***	
14:00	***Closing Plenary*** Working Group Reports and Discussion	
	Coffee (available during entire panel session)	
15:00	***Synthesis and Future Needs Panel***	
	Representatives from non-government organizations, the research community, government, and industry will be asked to provide their perspective on the Symposium discussions and to identify future needs.	**Jim Bruce *(moderator)*** *Canadian Climate Program Board*
	NON-GOVERNMENT	**Louise Comeau** *Sierra Club of Canada*
	RESEARCH	**Barry Smit** *University of Guelph*
	GOVERNANCE	**Mike Donahue** *Great Lakes Commission*
	INDUSTRY	**Dennis Heydanek** *The Dow Chemical Company*
16:45-17:00	**Concluding Remarks**	

Appendix B: Abstracts

This section provides abstracts of various Canadian and US studies forming a solid scientific foundation for assessing the risks of climate change and variability in the Great Lakes-St. Lawrence Basin and identifying sustainable adaptation responses.

PUBLIC RESPONSE TO CLIMATE CHANGE: PLANNING FOR IMPROVED COMMUNICATION

Jean Andrey and Brenda Hachey

Department of Geography
University of Waterloo
Waterloo, Ontario

Over the past decade, global climate change has emerged as one of the most intensely researched environmental issues, with millions of dollars being spent in efforts to understand natural and anthropogenic causes, future climate scenarios, and potential impacts. Despite the abundance of expert knowledge on these topics, and the many public communications about global warming, there has been little associated change in human behaviour. This raises questions about the effectiveness of current efforts to communicate global climate change information to the public.

The communication study had three principal objectives. The first was to develop a set of guidelines for evaluating public communication strategies/programs that deal with the causes and implications of global climate change. The second was to compile an inventory of global climate change communication activities that are directed toward the citizens, educators, businesses and policy makers of the Great Lakes Basin. The final objective was to select and interview staff from three specific organizations identified during the inventory phase about their specific communication activities.

The methodology involved three steps. First, the dominant characteristics of global climate change are identified. Second, the communication challenges that are associated with these characteristics were defined. Finally, a set of communication guidelines was developed to address these challenges at least partially.

LAURENTIAN GREAT LAKES ICE COVER

Raymond A. Assel

National Oceanic and Atmospheric Administration
Great Lakes Environmental Research Laboratory
Ann Arbor, Michigan

Great Lakes ice cover affects mass and energy exchange between the atmosphere and lake waters and thus also affects the regional economy, winter ecosystem, and climate of the Great Lakes. It is also a sensitive indicator of regional climate change and climate variability. Thus, improved understanding of ice cover and its climatic variability is needed for development of climate adaptation strategies. Under the current climate ice forms in shallows of the Great Lakes in late fall-early winter, in the deeper areas of the Great Lakes in mid-winter, reaches its greatest extend in February or early March (90% Lake Erie, 75% Lake Superior, 68 % Lake Huron, 45% Lake Michigan, and 24% Lake Ontario), and dissipates during March and April most years. Maximum ice cover varies from less than 30% to over 90% under the current climate. Retrospective analysis indicates significant changes in Great Lakes ice cover extent and duration has occurred over the past 100 to 150 years. These changes may have affected the lake fishery and the under-ice ecology of the Great Lakes. If winters become warmer it

is likely that average ice cover duration and extent will be reduced significantly and perhaps the new ice cover norm will be similar to what we now consider much below average ice cover under the present climate. Less extensive and shorter duration ice cover will affect lake levels, navigation, hydropower generation, shore erosion, lake-effect snowfall zones, and the biota of the Great Lakes, possibly in ways we have not anticipated.

THE LAKE MICHIGAN DIVERSION AT CHICAGO: AN ANALOG FOR IMPACTS AND RESPONSES TO GLOBAL CLIMATE CHANGE

Stanley A. Changnon

Changnon Climatologist
Mahomet, Illinois

Since 1900, when the diversion of water from the Great Lakes at Chicago began, there have been a series of major national and international controversies over the diversion and its effect on the Great Lakes. These controversies have occurred primarily during dry periods and relate to concerns over economic and environmental effects of less water in the lake system. Importantly, defining the impacts and how the private sector and governments responded offer an excellent opportunity to assess what may happen under a drier climate that may develop as a result of global warming. This paper explores the seven major controversies, the ever-changing social and economic forces involved in the controversies, and identifies a series of issues related to a change in climate. Finally, the impacts and responses identified in this study that relate to global climate change are listed. The results suggest a shift in climate as projected will lead to enhanced controversies over the existing diversion, efforts to enhance the amount of water diverted, attempts to divert water elsewhere in the basin, and major controversies and cases that will require settlement in the highest courts.

THE TORONTO-NIAGARA REGION STUDY

Quentin Chiotti

Environmental Adaptation Research Group
Environment Canada
Toronto, Ontario

It is widely recognized that global atmospheric change, such as climate change and variability and other air stresses, poses a significant challenge to the health of our ecosystems, social and economic systems. Although there is extensive research on various atmospheric issues, there remains a relatively inadequate understanding in the processes, effects and responses at the regional scale: in the science of atmospheric stresses and the interactions between them (climate change and variability, stratospheric ozone depletion, acidic deposition, long range transport of hazardous airborne pollutants, smog and suspended particulate matter), their impacts upon our human and natural systems; the vulnerability of these systems; and the development of sustainable responses.

This poster highlights the Toronto-Niagara Region Study, a proposed integrated regional study of atmospheric change, and situates it within the context of other climate change research initiatives within Canada. The paper focuses on the study's unique attributes, with emphasis on its reseach methodology, conceptual framework and operational structure. In framing the problem, it extends the climate change research agenda to include other atmospheric stresses, and focuses upon the largest urban centred region in the country. It integrates the six atmospheric issues within the context of impacts, adaptation, mitigation and emissions. Involving the participation of the Climate Change Study Group at the University of Toronto, Environment Canada and other research partners, it also represents a unique collaborative and multi-stakeholder initiative, where public participation at various stages of the study is encouraged.

CLIMATE TRANSPOSITION EFFECTS ON GREAT LAKES LEVELS

Thomas E. Croley II and Frank H. Quinn

Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
Ann Arbor, Michigan

Past climate impact studies applied corrections, generated from general circulation models (GCMs), to historical meteorology to estimate future $2\times CO_2$ climates for hydrological models. That approach considers changes in mean hydrological values, but variability changes are not addressed. However, variability is the singular key problem for shipping, power production, and resource managers in the Great Lakes. The Great Lakes Environmental Research Laboratory (GLERL) investigated variability changes with data for climates existing to the south and west of the Great Lakes that resemble some $2\times CO_2$ GCM scenarios. GLERL assembled data, transposed it to the Great Lakes, and estimated lake effects to apply to it. This preserves reasonable spatial and temporal variations in meteorology and the interdependencies that exist between the various meteorological variables. GLERL estimated Great Lakes hydrology for each transposed climate by applying their hydrological models to these data sets directly and to a base case derived from historical meteorological data.

ANTHROPOGENIC GREENHOUSE GAS-INDUCED WARMING: SUITABILITY OF TEMPERATURES FOR THE DEVELOPMENT OF VIVAX AND FALCIPARUM MALARIA IN THE TORONTO REGION OF ONTARIO

Kirsty Duncan* and Brian Mills

*Department of Geography
University of Windsor
Windsor, Ontario

A literature review provided background on the nature and transmission of malaria. Key elements of the disease which must be understood include: the causative agent (Plasmodium), the vector (mosquito), the relationship between the causative agent and humans, the clinical features of the disease, the environment in which transmission occurs, and the history of the disease in North America. This study applies the temperature thresholds for anophelines and *Plasmodium* to a scenario of mean daily temperatures associated with a doubling of carbon dioxide in order to determine if anthropogenic greenhouse gas-induced temperatures are suitable for the development of *vivax* and *falciparum* malaria in the Toronto region of Ontario.

The following conclusions about the potential suitability of temperature conditions for two forms of malaria, *Plasmodium vivax* and *Plasmodium falciparum*, under current climate and climate change scenarios were made. Current mean daily temperatures, averaged over the recent past (1951-88), prevent the development of malaria because they are too low to allow *Plasmodium* to develop in the mosquito *A. quadrimaculatus*, even if it were present in the Toronto region. However, mean daily temperatures associated with the CCC GCM II $2xCO_2$ scenario may allow for the development of malaria in the Toronto region, specifically:

- the development of both *P. vivax* and *P. falciparum* in the mosquito; and
- the transmission of both *vivax* and *falciparum* malaria.

Nevertheless, it is not suggested that climate change alone will permit the spread of malaria with warmer temperatures; climate is merely one factor, among many, which is relevant to the aetiology of malaria.

NATURAL AREA MANAGEMENT AND CLIMATE CHANGE IN THE HAMILTON/ HALTON SUB-BASIN OF LAKE ONTARIO

Brenda J. Fooks

c/o Environmental Adaptation Research Group
Environment Canada
Burlington, Ontario

The objectives of this study were to review existing government and private sector natural area management policies and the relative ability of management plans to adapt to, or ameliorate, anticipated negative impacts of climate change. Literature relating to climate change, ecosystems and adaptation was examined. Changes in environmental conditions, due to expected increases in temperature and precipitation, will impact upon ecosystems within natural areas by affecting the growth of plants and their ability to reproduce, changing competitive relationships between species and by accelerating invasions of certain exotic species.

The ability of natural areas to recover from such changes depends largely upon the resiliency and diversity of species both within the affected ecosystem and in proximate ecosystems. Ecosystems in natural areas, degraded and fragmented by settlement and agriculture, may be unable to recover from the impacts of extreme weather events and climate change. Therefore, it is imperative that the remnants of natural habitat be preserved and enhanced, to create a viable, integrated and resilient ecosystem that will adapt to human-induced global climate change.

Provincial and municipal natural area management policies affecting the Halton/Hamilton sub-basin of Lake Ontario were examined qualitatively together with the policies of a small selection of private organizations. The relative ability of management plans to adapt to, or ameliorate, anticipated negative impacts of climate change was evaluated through the presence or absence of the following criteria established from the literature review: 1) species inventories; 2) classification of natural areas; 3) monitoring capacity; 4) buffer and adjacent land-use; 5) corridors and linkages; 6) future acquisitions and restoration; and 7) management for biodiversity as opposed to individual species. None of the eleven management policy documents reviewed contained specific references to climate change, however, many of the policies supported maintaining or enhancing the presence of one or more of the criteria listed.

SO WHAT? ANALYZING THE RELEVANCE OF CLIMATE CHANGE TO SHORE PROTECTION, LAKE LEVELS MANAGEMENT, AND WETLANDS RESTORATION

Benjamin F. Hobbs*, Boddu Venkatesh, Philip T. Chao, Jeffrey A. Bloczynski, Joseph F. Koonce and W. Thomas Bogart

*The John Hopkins University
Baltimore, Maryland

Is the prospect of possible climate change relevant to Great Lakes management decisions being made today? And, if so, how ought that prospect be considered? These questions can be addressed by decision analysis, which we apply to investments in the Great Lakes region: restoration of Metzger Marsh in western Lake Erie; a regulatory structure for Lake Erie; and breakwaters to protect Presque Isle State Park, PA. These decisions have the elements that potentially make climate change relevant: long-lived, "one shot" investments; benefits or costs that are affected by climate-influenced variables; and irreversibilities. The decision analyses include the option of waiting to obtain better information, using Bayesian analysis to detect whether climate change has altered water supplies.

The analyses find that expectations about climate change can indeed affect optimal decisions. Furthermore, ignoring the possibility of climate change can lead to significant opportunity losses, in the cases here, as much as 10% or more of the construction cost. Therefore, climate uncertainty should be considered in water project design. Yet the consequences of climate uncertainty for Great

Lakes management do not appear to be qualitatively different from those of other risks, and thus do not deserve different treatment. The methods of sensitivity analysis, scenario planning, and decision analysis, all of which are encouraged under US federal guidelines for water planning, are applicable. We recommend increased use of decision trees and Bayesian analysis to consider not only climate change risks, but also other important social and environmental uncertainties.

NOAA OFFICE OF GLOBAL PROGRAMS: CLIMATE RESEARCH ACTIVITIES

John Kermond

Office of Global Programs
National Oceanic and Atmospheric Administration
Silver Spring, Maryland

The National Oceanic and Atmospheric Administration's Office of Global Programs exhibit will show some of the Seasonal to Interannual Climate Variability research conducted as part of the agency's contribution to the US Global Change Research Program. Specifically, the El Niño-Southern Oscillation (ENSO) phenomena will be displayed. ENSO is considered the second strongest climate signal on this planet, second only to the seasons.

CAUSES AND IMPACTS OF 1960s LOW WATER LEVELS ON CANADIAN GREAT LAKES INTERESTS

Grace Koshida* and
Janet M. K. Brotton

*Environmental Adaptation Research Group
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Burlington, Ontario

The low water levels experienced in the Great Lakes basin during the mid-1960s was the focus of a climate analogue study. Climatic and hydrological records (1951-1970) of the Great Lakes basin were analyzed to determine the cause of the historically low water levels. Study results found that below-average precipitation in the Lake Superior Basin from the 1950s and a severe drought within the Great Lakes basin during the early 1960s (1962-1964) were the main factors responsible for the rapid drop in water levels. The socioeconomic effects of the low water levels for Canadian interests dependent on Great Lakes levels and flows were ascertained. The interests chosen for the study included hydro-electric power generation, commercial navigation, tourism and recreation, wildlife and environment, and municipal water supply.

Study results found that the effects of low water levels in the Great Lakes basin were often significant, both in qualitative and quantitative terms. Impacts included significant losses in hydro-electric power output, reductions in cargo carrying capacity for the Great Lakes commercial shipping fleet, economic hardship for marina operators and other lakeside recreational facilities, loss of wetland area, and degradation in municipal water quality. Economic costs were updated to current levels (1994 dollars) where possible. The numerous solutions proposed to alleviate the low water level crisis (e.g., inter-basin water diversions, lake level regulations) were also reviewed, and it was found that few were actually implemented. The analysis of this historical extreme event provides insight into how Great Lakes interests may react in the future to warmer and drier conditions expected in the basin under various climate change scenarios.

CLIMATE VARIABILITY, CLIMATE CHANGE AND RURAL WATER SUPPLIES

Reid Kreutzwiser

Department of Geography, University of Guelph
Guelph, Ontario

Drought is a recurring problem in southern Ontario, with some water uses in some parts of the Province being impacted almost every year. During dry spells, competition and conflict among rural users of surface and especially ground water supplies intensifies. This research identified rural areas in southern Ontario susceptible to climate-induced water supply problems, described rural water user problems and responses, and assessed a range of adaptations to climate variability and change. In selected townships, with high rural water demand, 35% of surveyed water users reported experiencing a water quantity problem in 1988 or subsequently. Common responses included reducing outdoor water use, drilling a new well or deepening an existing one, installing a domestic water-saving device, and irrigating. Despite problems experienced, fewer than 30% of water users are expecting an increased frequency of dry spells. Users were asked to assess the effectiveness of, and preference for, a range of adaptations to climate variability. Respondents generally rated supply management actions, such as drilling new wells, more effective than demand management actions, such as regulating water withdrawals. One demand management action, restricting new rural non-farm development to settlements that could be serviced with communal water systems, was widely preferred. This support for integrating water supply with land use planning is notable, given opportunities presented under Ontario's *Planning Act* reforms. Adaptation to climate variability could also be enhanced through modifications to the Province's *Permit to Take Water* program.

TEMPORAL VARIABILITY IN EXTREME CLIMATE CONDITIONS IN THE GREAT LAKES REGION

Kenneth E. Kunkel, James R. Angel, and K. Andsager

Midwestern Climate Center, Illinois State Water Survey
Champaign, Illinois

We investigated temporal changes in two climate variables that represent severe conditions. Intense middle latitude cyclones are responsible for much of the damage caused by wave action along shorelines. A homogeneous data set of intense cyclones was constructed, covering the period 1900-1990. A time series of annual intense cyclone occurrence shows an upward trend during the 20th century, from about 8/year at the turn of the century to 10-15/year during the period 1980-1990. Much of the upward trend occurred during the first half of the century, with cyclone frequency remaining about constant since 1950. We also examined trends in the frequency of heavy rain events, particularly 7-day events. The frequency of such events has increased dramatically in the last 15 years, being about 20% higher than the mean for the rest of the century. The period 1991-1995 experienced the highest number of these events of the entire century. These increases are most apparent in the southern portion of the Great Lakes.

CLIMATE CHANGE IMPACTS ON WESTERN LAKE ERIE, DETROIT RIVER, AND LAKE ST. CLAIR WATER LEVELS

Deborah H. Lee*, Ralph Moulton and Brad A. Hibner

*Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
Ann Arbor, Michigan

The means and frequencies of Lake St. Clair, Detroit River, and western Lake Erie water levels are computed for a changed climate resulting from a doubling of atmospheric carbon dioxide, and compared to those of the present climate. Lake level frequencies for specific sites in the study areas, and potential movement of the shorelines due to decreases in mean lake levels, are illustrated by a series of maps. General surveys of impacts on wetlands, recreational boating, commercial navigation, and public water supply intakes are given. The intent of this work is to provide basic data to other researchers performing broader and more detailed impact studies as part of the Great Lakes-St. Lawrence Basin Project. With the changed climate scenario, the surface area and volume of Lake St. Clair decreases by 15% and 37%, respectively, relative to that of the present climate. Likewise, the surface area and volume of the western Lake Erie basin decreases by 4% and 20%. The surface area of the lower Detroit River decreases by 19%. The shoreline moves from less than 1km to 6km offshore from that of the present climate, with significant loss of freshwater estuaries and embayments.

THE GREAT LAKES INFORMATION MANAGEMENT RESOURCE (GLIMR) AND GREEN LANE

Wendy Leger, Scott Monds, and Rosie Mazzone

Environmental Services Branch-Ontario Region
Environment Canada
Burlington, Ontario

The Great Lakes Information Management Resource (GLIMR) is part of Environment Canada's departmental web-site, known as The Green Lane on the information highway. Through the Green Lane you can learn about the environment and what you can do to build a green and prosperous society. GLIMR is a user-friendly source of information about the Great Lakes. You can study educational materials and explore programs, publications and databases on Great Lakes issues simply by pointing and clicking text and images that appear on the screen. GLIMR and The Green Lane are also windows to other Canadian and US Great Lakes environmental networks. They are available to anyone with a computer connected to the Internet. You can visit them on the World Wide Web at the following addresses: GLIMR *http://www.cciw.ca/glimr/* and The Green Lane *http://www.ec.gc.ca*

CLIMATIC IMPACTS OF IDEALIZED GREAT LAKES IN A GENERAL CIRCULATION MODEL

Brent M. Lofgren

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Ann Arbor, Michigan

Comparison is made between general circulation model (GCM) cases with and without the inclusion of idealized Great Lakes, in the form of four rectangular bodies of water, each occupying a single grid cell of the GCM at R30 resolution. The presence of idealized Great Lakes, as opposed to land, results in a phase shift in the annual cycle of latent and sensible heat flux. Very high upward sensible heat flux occurs over these idealized Great Lakes during the early

winter. On the average over a region encompassing these idealized Great Lakes, evaporation and precipitation increase during the autumn and winter and decrease during the late spring and summer due to the lakes. Annual average water vapor flux convergence increases.

The Great Lakes also alter the meridional air temperature gradient. During the autumn and winter, the meridional temperature gradient is intensified to the north of the Great Lakes and diminished to the south. This intensifies the mean jet stream core and displaces it toward the north. This effect is reduced during the winter compared to the autumn because air temperature changes due to the lakes are unable to penetrate as deeply into the strongly stable stratified winter atmosphere. The increase in jet stream speed seems to increase synoptic wave activity to the northeast of the Great Lakes.

EVALUATION OF THE VULNERABILITY OF QUÉBEC BREEDING BIRDS TO CLIMATIC CHANGE

**F. Morneau, D. Lambert,
Mario St-Georges*,
J.-L. DesGranges and J. Milton**

*G.R.E.B.E.
Montréal, Québec

THE BINATIONAL GREAT LAKES-ST. LAWRENCE BASIN PROJECT

**Linda Mortsch*, Frank H. Quinn,
Grace Koshida, Barb Wrenn and Brian Mills**

Environmental Adaptation Research Group
Environment Canada
Burlington, Ontario

There still is much uncertainty about the timing, the rate and the magnitude of climate change in the Great Lakes-St. Lawrence Basin (GLSLB); yet concern for potential impacts remains. The GLSLB contains 20% of the world's fresh water and is home to over 42.5 million people. It is a region rich in human and natural resources, with diverse economic activities and complex infrastructures. Significant economic restructuring and environmental changes are underway. Governments, industries and other Basin interests will have the added complication of managing the multiple activities within the Basin under the exacerbating conditions of potential climate change. This challenge must be addressed; first through research, and then by applying the research to all levels of management within the Basin.

The GLSLB Project was initiated in 1992 to improve our understanding of the complex interactions between climate, environment and society so that regional adaptation strategies could be developed in response to potential climate change and variability. The primary objectives of the GLSLB Project are to:

1. identify and assess the physical, biological, social and economic impacts of climate change and variability;
2. identify and evaluate strategies for adapting to possible impacts; and
3. develop, test and apply methods which will integrate and link multiple disciplines as well as incorporate adaptation responses into climate impact assessments.

The activities of the Project are divided into five streams: background research, scenario development, adaptation research, integration research and theme-based climate impact and adaptation studies. In meeting the objectives, research focuses on four climate-sensitive theme areas: land use and management, ecosystem health, water use and management, and human health.

THE IMPACT OF CLIMATE CHANGE ON DOWNHILL SKIING IN THE GEORGIAN BAY REGION OF SOUTHERN ONTARIO

Matthew Ordower

c/o Environmental Adaptation Research Group
Environment Canada
Burlington, Ontario

HYDRO-PHYSIOGRAPHIC CHARACTERIZATION AND MODELLING OF THE GRAND RIVER WATERSHED FOR THE ESTIMATION OF CLIMATE CHANGE IMPACTS ON GROUND AND SURFACE WATER RESOURCES

Andrew Piggott*, Ghosh Bobba, Syed Moin and Doug Brown

*National Water Research Institute, Environment Canada
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There is an emerging consensus that accurate management of water resources requires knowledge of the relation between ground and surface water and of the performance of groundwater as an independent water supply. This is particularly appropriate when estimating the impacts of climate change where groundwater forms an important link between climatic variables such as precipitation, hydrologic impacts such as reduced base flow, and societal concerns such as degraded water supplies.

The Grand River watershed has been selected by the Great Lakes 2000 program as a prototype for estimating the impacts of climate change and variability on the sustainability of ground and surface water resources. From a hydro-physiographic perspective, the watershed is characterized by complex physiography, geology, and surface and subsurface hydrology and therefore is a useful venue for the development of analytical methods. From a socioeconomic perspective, the watershed is subject to expanding urban, industrial and agricultural development and a pronounced reliance on groundwater relative to similar settings in eastern Canada. Water use models developed for the watershed are based on simplified representations of the groundwater resource and hydrologic models are lacking in description of regional scale groundwater conditions.

The objective of this study is to resolve these issues through the development of an integrated ground and surface water model for the watershed. To date, a database of 85 000 water well construction records has been assembled and multivariate and GIS analyses have been applied to hydro-physiographic data derived from the database and from topographic maps. These analyses have been used to reduce the hydro-physiographic data to two composite characterization parameters which represent the depth and productivity of the groundwater flow system and to delineate areas of contrasting groundwater conditions. Conceptual models and numerical analogues are presently being developed to represent the interdependence of the hydro-physiographic data. These component models will from a defensible basis for numerical modelling of groundwater flow and ground and surface water interaction.

SENSITIVITY OF THE PRODUCTION STRUCTURE OF THE GREAT LAKES-ST. LAWRENCE BASIN SAWMILLING INDUSTRY TO CLIMATE CHANGE-2xCO_2

G. David Puttock and A. Sen

Silv-Econ Ltd.
Newmarket, Ontario

With more than four hundred firms of varying sizes, the lumber manufacturing industry within the Great Lakes-St. Lawrence Basin (GLSLB) of Ontario, Québec, and New Brunswick makes an important contribution to provincial and local economies. Consequently, the sensitivity of this industry to climate change is of considerable interest. Attributes of an industry's structure are embodied in its production technology and can be studied empirically using a translog cost function approach. Total cost was specified as a function of industry output, the input prices for wood, labour, capital, and energy, a trend variable, and provincial fixed effects. The price of wood and capital inputs is significant. As expected, both have positive coefficients. The coefficient on the price of wood is of greater magnitude. The effect of forest productivity on the price of wood input was also estimated, using average volume per hectare as a proxy for forest productivity. The price of wood is expected to decrease with increasing volume per hectare. The next phase in the research is to assess the sensitivity of the production structure of the industry to climate change. This requires information on the possible effects of a 2xCO_2 scenario on the growth and yield of forests within the GLSLB. Possible scenarios will be identified through a review of relevant literature and focus-group discussions.

THE CAUSES AND IMPACTS OF 1980s HIGH AND LOW WATER LEVELS ON THE TOURISM AND RECREATION SECTOR OF LAKES HURON AND ERIE

Lori Rissling

c/o Environmental Adaptation Research Group
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Burlington, Ontario

During the 1980s, water levels on the Great Lakes reached extreme high levels and then rapidly declined. Climatic and hydrological data (1980-1990) from two unregulated lakes (Lake Huron and Lake Erie) were examined to determine the cause for this unprecedented, rapid change in Great Lakes water levels. Several Great Lakes interests are affected by fluctuating water levels, either directly or indirectly. The impacts to the tourism and recreation sector, specifically Ontario Provincial Parks, recreational boaters in Ontario, and shoreline property owners in Ontario, were examined. Ontario Provincial Parks suffered damage to facilities during both the high and low water level periods. Trails, campgrounds, and buildings were washed out with high levels. Docking facilities and wetlands were stranded with the low water levels and some beaches temporarily expanded in size. Recreational boaters in Ontario favoured the high water levels to the low in the 1980-1990 period, although normal lake levels were preferred over either. During the high levels, boating was safer and more areas were accessible by boat, but conversely, some marinas were flooded. The low water levels left insufficient water in bays and channels, caused congestion in the deeper areas, and forced an increase in channel and harbour dredging. Shoreline property owners in Ontario, unlike the boaters, felt the low water levels were less of a threat to their investments since shoreline and bluff erosion were reduced and they incurred less damage.

ADAPTATION STRATEGIES FOR CLIMATE RELATED CHANGES IN LAKE ERIE WATER QUALITY

William M. Schertzer and David L. C. Lam

National Water Research Institute, Environment Canada
Burlington, Ontario

Lake Erie is the shallowest of the Laurentian Great Lakes and is susceptible to water quality degradation. Maintaining a high level of water quality is important as it impacts on potable water supplies, ecosystem health, and such socioeconomic factors as a viable fisheries and recreation. Research has been conducted to understand the water quality conditions and lake/basin dynamics which affect water quality conditions. The NWRI 9-box Water Quality Model integrated meteorological, hydrological limnological and biochemical processes into a mathematical framework to simulate long-term water quality on Lake Erie. Preliminary research indicated that under current climate conditions, persistent levels of hypolimnetic anoxia in the central basin were related to nutrient (total phosphorus) levels and the controlling effects of daily weather. Overlake meteorology affects lake heat budgets, vertical mixing, the thermal stratification cycle, hypolimnion depth and volume and vertical diffusion across the thermal interfaces which strongly influences the development of anoxia under prevailing conditions of sediment, water and biological oxygen demand. Monitoring of lake water quality conditions has shown that even with significantly reduced nutrient loadings, central basin hypolimnetic anoxia still occurs and emphasizes the influence of weather on the lake physical and water quality conditions.

GCM model outputs and limited regional assessments have indicated that climate warming may be a factor in the Great Lakes region. Climate warming is expected to affect such physical characteristics as basin hydrology (i.e., inflows, outflows and water levels), over-lake meteorological fields (i.e., air temperature, humidity, wind speed, surface heat fluxes) and lake thermal stratification (i.e., lake temperatures and heat storage, duration of thermal stratification, depth of thermal interfaces). Biochemical processes that may be affected by warming include sediment and water oxygen demand rates as well as process rates (i.e., resuspension, reaeration). This study is concerned with potential responses of Lake Erie to climate warming, which may impact on water quality conditions and ultimately on the development of "adaptation" strategies in response to potential changes. A poster presentation details objectives, model framework and current status of simulations with respect to lake thermal responses and nutrient loading under a base case and derived CCC climate scenario. These responses are to be incorporated into the biochemical submodel to assess water quality responses to climate changed conditions. Hypothetical adaptation strategies are suggested for selected water quality conditions that may occur under climate changes.

CLIMATE CHANGE AND VARIABILITY AND ADAPTATION IN AGRICULTURE, QUÉBEC

Bhawan Singh, Christopher Bryant, Mustapha El Maayar, Pierre André and Jean-Pierre Thouez

Department of Geography, University of Montréal
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A climate change deriving from the enhancement of the greenhouse effect is highly likely to occur in the coming decades. Such a change in climate would certainly affect the climate sensitive resource sectors of the Canadian economy, especially agriculture.

This poster presents the effects of a greenhouse gas (GHG) induced climate change on several key agroclimatic factors, namely temperature, precipitation, evapotranspiration, soil moisture and corn heat units (CHUs) and subsequently on crop

yields for a variety of agricultural crops (16) and regions (12) in southern Québec. Subsequently, the adaptation to climate change amongst the farming community in selected areas (Montréal and Québec City) is explored.

Climate change impacts and crop yields are derived through coupling down-scaled GCM (CCC) data with a crop model (FAO). Adaptation studies data are gathered through focus group meetings with targeted farming communities.

Our results show that in general a GHG climate change may cause the yields of C_4 cereal (corn and sorghum), oleaginous (canola and sunflower) and specialized (potato, tobacco, sugarbeet) crops to increase and the yields of C_3 cereal (barley, oats, wheat), leguminous (soybean, phaseolous beans and green peas) and vegetable (onions, tomatoes, cabbage) crops to decrease. The decrease in yields is largely attributable to the acceleration in maturation under the warmer $2xCO_2$ climate, although moisture stress and optimal temperature conditions may also be involved. However, yield decreases are diminished and even reversed when CO_2 fertilization is considered in the crop yield model.

Regarding agricultural adaptation to climate change, two points of view that confront each other emerge. The first one suggests that agriculture would be naturally capable of adapting because the conditions faced by farmers already vary considerably both geographically and temporally. Farmers are therefore prepared to change crops or techniques to obtain better yields under the changed conditions, whether we are talking about a one year drought, a decade that has greater precipitation than average or a longer term climatic change. The second perspective, in contrast, holds that agricultural practices in Québec are not adapted to climatic variability and that the economic losses of this maladaptation are already considerable. However, farmers believe they are capable of adapting to climatic change, and the historical analyses of changing agriculture do indeed show an industry that has undergone tremendous change over the last half century.

ADAPTING TO CLIMATIC VARIABILITY IN AGRICULTURE

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Conventional climate impact and adaptation research is scenario-based, focuses on climatic averages, assumes human responses and adaptations, and ignores or assumes away non-climate forces. This project evaluates some of these assumptions. Its goals are to identify past and current farming adaptations to climate in light of other forces such as economics, technology, and policy conditions, and to evaluate opportunities for future adaptation. This is achieved via a number of empirical investigations in southern Ontario which identify attributes of climate to which farming is sensitive, determine characteristics of farms and agricultural systems which influence adaptive responses, document the nature of adaptations undertaken in the past, and indicate adaptive strategies likely or possible in the future given specified conditions.

THE IMPACT OF CLIMATE VARIABILITY AND CHANGE ON THE GRAND RIVER BASIN: WATER SUPPLY AND DEMAND ISSUES

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The surface water component of the Grand River Basin (GRB) Study is one of several theme-based studies initiated as part of the Great Lakes-St. Lawrence Basin (GLSLB) Project. Building from past research, the work examined the potential impacts of climate change and variability on streamflows and watershed management objectives and identified possible adaptation strategies. A formal model was set up to simulate system streamflows under various combinations of surface water supply; system operation (reservoir configuration and operation); and, water use. In total, twenty-four application scenarios were developed for model evaluation and impact assessment purposes. The scenarios modelled produce a wide range of impacts on streamflows. All scenarios suggest increased difficulties meeting current minimum streamflow targets specified for water quality purposes. These changes would have an impact on water management in the Grand River system and affect the realization of the shared vision for the watershed. For the scenarios modelled, three distinct conditions (modest, moderate and severe changes in streamflow) and response options (eliminate, reduce or accept the impacts) emerged. Recommendations are made for adaptation strategies.

THE CANADA COUNTRY STUDY

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How will climate change affect the lives of Canadians? Environment Canada is tackling this very complex question by initiating the first-ever national integrated assessment of the social, biological and economic impacts of climate variability and change, the Canada Country Study. In the past decade, researchers have conducted over 100 studies on the possible impacts of climate change on Canada. These studies have for the most part focused on a specific sector or small region (for example, the effects on corn crops in Ontario or of sea level rise on PEI). Exceptions include a recently-completed comprehensive assessment of climate change impacts on the Mackenzie Basin and a similar investigation of impacts on the Great Lakes-St. Lawrence Basin that will wrap up in 1997.

While these studies offer glimpses of what we can expect from a warming climate, they do not give the big picture of what climate change will mean for Canada. In an effort to fill this knowledge gap, the Canada Country Study is bringing together climate experts from all levels of government, industry, academia and non-government organizations. During Phase I of the study, these experts will review existing knowledge on climate change impacts and adaptation, identify gaps in research and suggest priority areas where new knowledge is urgently needed. The information gathered will form the basis of a national synthesis document, to be published in the fall of 1997. This document will include:

- Six regional reports on BC/Yukon, the Prairies, Ontario, Québec, the Atlantic and the Arctic.
- Twelve sectoral reports on agriculture; built environment (e.g., roads); energy; fisheries; forestry; health; insurance; recreation and tourism; transportation; unmanaged ecosystems, biodiversity and wildlife; water resources; and wetlands.
- One volume on cross-cutting issues, including changing landscapes; climate change and other air issues such as acid rain and smog; domestic trade and commerce; extra-territorial influences

(e.g., droughts or famines leading to an influx of refugees); extreme events; sustainability and the two economies.
- One national summary for policy makers.
- One national and six regional plain language summaries.

Phase II of the study, set to begin in late 1997 or early 1998, will involve the development of research projects to address the gaps and priority areas identified in Phase I. By providing a clearer sense of the risks associated with climate change in Canada, and how we can respond or adapt to them, the Canada Country Study will be a valuable source of information for policy makers in both the public and private sectors, the scientific community and the Canadian public. It will also form an integral part of Canada's contribution to the UN-led Intergovernmental Panel on Climate Change's (IPCC) next report on the global impacts of climate change, to be released in 2001.

WEATHER AND HEAT-RELATED MORBIDITY RELATIONSHIPS IN TORONTO (1979-1989)

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Weather substantially affects human health and in recent years, the emphasis of bio-meteorological studies has moved towards understanding the relationship between climate change/climatic extremes and human health effects. This study primarily examined the relationship between weather and heat-related morbidity in Metropolitan Toronto. Weather and morbidity data were examined (June-September, 1979-1989). Morbidity data were organized into two groups: the heat-related morbidity data sample included approximately 8 000 emergency hospital admissions, and the total morbidity data sample consisted of approximately 450 000 hospital admissions. Each group was further subdivided into two age categories: <65 years and 65 years or greater. Two multiple regression statistical approaches were used: a threshold temperature sampling technique and a case-control sampling procedure. In the threshold temperature sampling technique, the younger age group (<65 years) had a temperature threshold of 31°C, whereas the older group (>=65 years) was sensitive to a lower temperature threshold (28°C). This suggested that age was a factor in weather and heat-related morbidity relationships and that the strongest relationship between weather and morbidity would be found in the elderly heat-related group. However, the model only produced a coefficient of determination (R^2) of 0.04. Similar R^2 were obtained for the elderly total morbidity group, as well as the <65 heat-related morbidity group. The strongest correlation occurred for the <65 total morbidity group in which approximately 14% of the variability in all hospital admissions was explained by weather. The case-control sampling method involved selecting the highest and lowest total morbidity rate for each day of the week in each of the 11 years studied. These observation days were then compared to weather elements (e.g., maximum temperature and maximum humidity) and derived elements (e.g., "time of season" and "days in sequence"). Maximum temperature was the most significant weather element, producing the highest R^2 value of 0.11.

QUEBEC REGIONAL CONTRIBUTION TO THE CANADA COUNTRY STUDY

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CLIMATE CHANGE IMPACTS: AN ONTARIO PERSPECTIVE

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What evidence is there to support the notion of climate change? What is the risk of climate change to Ontario's environment and economy? This study, completed in 1995, summarized the most up-to-date research on climate-sensitive issues such as water resources, human health, global and regional trade, environment and international security. Evidence concerning the risk of climate change, based on analyses of climatic trends and the results of atmospheric and oceanic modeling exercises, was documented. The potential implications of climate change were determined by synthesizing the findings of climate impact studies that were based on climate model simulations that provide a 'snapshot' of the world's future climate. The literature review revealed significant direct impacts to Ontario's water resources, agriculture and tourism and recreation sectors, among others. The study suggests that those with less resources are likely to be most affected by climate change, and the impacts on other regions of the world will be more significant to Ontario in the global economy than the direct impacts on Ontario itself. National and global actions to deal with the issue of climate change continue to develop in the areas of reductions of greenhouse gas emissions, climate adaptation and improved scientific understanding. The 'precautionary principle' and 'no regrets' measures are being considered as guides to action. The report can be accessed via the World Wide Web at the following address: *http://www.on.doe.ca/earg/ortee*

LINK, AN ENVIRONMENT-ECONOMY FRAMEWORK FOR ASSESSING THE ECONOMIC IMPACTS OF CLIMATE CHANGE ON THE ONTARIO ECONOMY

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Economics offers several techniques that can be used to integrate the impacts of climate change and variability including cost-benefit analysis, input-output analysis, and econometrics. The purpose of the study was to investigate the LINK model as an integration tool. LINK is an economy-environment framework and linkages model for Ontario. The input-output model has twenty-five industrial sectors and choices can be made with respect to final demand, technological processes and regional location. The LINK model extends the input-output model of the Ontario economy to consider natural resource use in terms of stocks and flows in mining, forestry, agriculture, and water use. The environmental impacts of economic activity or residuals generated as air emissions, waste, water pollution and energy use are also computed.

To test its applicability as an 'integration framework', LINK was used in this study to assess the net economic and associated environmental implications of sectoral impacts determined in separate assessments using two climate change scenarios (GFDL and GISS). The economic impacts computed

for some sectors and subsectors such as agriculture and skiing were negative, while those for other sectors such as forestry and camping were positive. As a result, the net economic impacts were small (less than 1% of economic activity in each of six regions in Ontario, and for the Province as a whole). The GFDL scenario produced a small total economic loss while the GISS scenario produced a small gain. Although the overall economic impacts were identified as relatively small, greater variations were observed within individual sectors, and between geographic areas.

The study provided guidance to the impact assessment community on the model's strengths and limitations and identified implications for the design of future impact studies. The final assessment of the potential economic impacts of climate change in Ontario proved to be the least important outcome of the modeling exercise; the value of the study was in describing the difficulties associated with integrating information from a large number of disparate climate impact studies into the LINK framework.

HYDROLOGIC IMPACTS OF CLIMATE VARIABILITY AND CHANGE IN THE BAY OF QUINTE WATERSHED

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A climate change impact assessment for the Bay of Quinte Watershed is developed from the output of the CCC GCM. Under climate change, air temperatures are expected to increase by 1.6°C to 9.6°C, more precipitation occurs, and higher wind energy is experienced during the first half of the calendar year at the expense of the second half. The effect of these climate changes is to reduce overall runoff to the Bay of Quinte by about 12% over the long-term with the largest reductions originating in the southern and eastern portions of the watershed. Major shifts in runoff within the hydrologic year are also predicted and result in a shift from a typical pattern of a cold-frozen low flow winter followed by a rapid snowmelt and spring freshet to a $2xCO_2$ pattern of low winter snowfall replaced by more rain, frequent winter runoff events and a minor spring freshet. These shifts in overall runoff over the year are accompanied by major shifts in the watershed soil moisture balance.

Drought flows will increase in frequency in the Bay of Quinte Watershed streams while the frequency of high flow rates will remain similar. This fact has negative implications in terms of the health of aquatic ecosystems and available water supplies.

As a result of shifts in water balance components over the hydrologic year, the leaching and transport of watershed soil phosphorus is also affected. During drier years there is a tendency for phosphorus concentrations in runoff to decrease since surface runoff and erosion events are expected to occur less frequently. During wetter years, there is a tendency to higher phosphorus concentrations in runoff especially during winter as the protective effect of the snowpack is lost and soil erosion events are more common. This is particularly true for agricultural areas. This fact has negative implications in terms of farmland management and soil conservation.

Over the long-term, it is estimated that phosphorus concentrations in runoff would increase about 8% as a result of larger reductions in flows than in phosphorus loadings to the Bay. This would have negative implications in terms of the trophic status of streams and lakes within the Watershed and in the Bay of Quinte as higher phosphorus concentrations and lower rates of flushing would stimulate nuisance plant growth and upset oxygen dynamics.

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