Atmospheric Change in the Toronto-Niagara Region

Towards an Integrated Understanding of Science, Impacts and Responses

Toronto-Niagara Region Study on atmospheric change

Proceedings of a workshop held
May 27-28, 1998
University of Toronto

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February 1999

Support provided by:

Environment Canada / Environnement Canada

- Atmospheric Environment Service
- Ontario Region
- Ecological Monitoring Coordinating Office
- National Water Research Institute

Ontario Ministry of the Environment

- Environmental Monitoring and Reporting Branch
- Standards Development Branch

University of Toronto Institute for Environmental Studies

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Acknowledgements

This workshop would not have been possible without the support and direction of the organizing committee (*Terry Allsopp, Ian Burton, Walter Chan, Quentin Chiotti, Lorraine Craig, Adam Fenech, Pamela Kertland, John Lawrence, Eric Loi, Abdel Maarouf, Roger Street, Hague Vaughan, and Dave Yap*). Financial and in-kind contributions were made by the Ontario Ministry of the Environment (Environmental Monitoring and Reporting Branch, Standards Development Branch), Environment Canada (Ontario Region, Ecological Monitoring Coordinating Office, National Water Research Institute and Environmental Adaptation Research Group) and the Institute for Environmental Studies at the University of Toronto.

The organizing committee is indebted to the speakers, panelists, facilitators, and rapporteurs whose efforts have laid a solid foundation for the Toronto-Niagara Region Study and a challenging benchmark for future meetings. Thanks are also extended to Indra Fung Fook, Sarah Kalhok and Mona El Hadaad for their assistance with workshop registration and local arrangements.

I would personally like to acknowledge the co-editor of this document, Lorraine Craig. Her professional editing, formatting and workshop coordination skills were much appreciated and only overshadowed by the infectious energy and passion that she holds for the study.

Finally, the Toronto-Niagara Region Study, and therefore this workshop, would not have been a reality without the drive and determination of Quentin Chiotti. His dedication to this research project in the face of significant adversity continues to amaze me and is a source of inspiration for everyone associated with the study.

Brian Mills
TNR Study Coordinator

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on atmospheric change

This publication is dedicated to the memory of Dan Leckie (1949-1998)

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Atmospheric Change in the Toronto-Niagara Region: Workshop Summary

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INTRODUCTION

Atmospheric change is a growing concern of Canadians. Climate change and variability, ground-level ozone, particulate matter, acidic deposition, hazardous air pollutants and stratospheric ozone depletion are threats to our health, natural environment, infrastructure and economy. This suite of air issues, their underlying causes and effects, manifest themselves at a variety of scales due to differences in pollutant sources; residency, transformation, and transportation of pollutants in the atmosphere; and the spatial and temporal variability in the vulnerability of human activities and interests. The natural and human processes at work are immensely complex and while the science of atmospheric change and the management of air issues have made great strides over the past two decades, surprises are and will continue to be the norm. Our ability to predict and resolve future atmospheric conditions is especially limited at the regional level, the critical scale where many human decisions that affect vulnerability and pollutant emissions are made.

In May 1998, a group of 70 research scientists and decision-makers from government, academia, non-government groups and the private sector convened to discuss the subject of atmospheric change in the Toronto-Niagara Region (TNR) of southern Ontario and the scope of an emerging study to address research and information gaps - The Toronto-Niagara Region Study on Atmospheric Change. Participants of previous conferences established the need for conducting atmospheric change research in the TNR (Ogilvie *et al.*, 1997) and have produced an inventory of possible methods for conducting integrated assessments of multiple air issues (Munn, 1995). With a 1996 population greater than 5.5 million, the TNR is Canada's largest urban area and its economy is greater than that of several provinces. All of the air issues noted above affect this region, and most contain a significant transboundary element. This implies that atmospheric change impacts cannot be solely attributed to the pollutants emitted in the TNR. Nevertheless, industry, government and non-government groups have been actively managing and making progress on individual air issues for over two decades through activities such as the Flood Damage Reduction Program/municipal land use controls (climate variability/extreme events); Eastern Canada Acid Rain Program (acid deposition); Toronto Atmospheric Fund (climate change); and the Ontario Smog Plan, Pollution Probe's Clean Air Commute, and Hamilton-Wentworth Air Quality Initiative (smog). However, few attempts have been made to integrate the multiple atmospheric concerns in the TNR from both scientific and policy perspectives. The region's size, economic importance and exposure to multiple atmospheric stresses make the TNR an ideal focus for research on the effects of, and responses to, atmospheric change. Meanwhile, the regional leadership demonstrated in dealing with air issues like climate change and smog make it likely that the results stemming from such research will actually be considered if not implemented in future policies.

The objectives of the workshop were to review the current state of knowledge on atmospheric change issues in the Toronto-Niagara Region and to identify opportunities to improve our understanding of these issues through the design and implementation of the Toronto-Niagara Region Study on Atmospheric Change. A series of presentations, panel discussions and breakout group sessions were held during the workshop and organized around five overlapping themes:

1. Atmospheric science and modelling,
2. Natural environment impacts and adaptation,
3. Infrastructure and economic impacts and adaptation,
4. Human health impacts, and
5. Emissions and mitigation.

Speakers were given the demanding and upon reflection perhaps impossible task of summarizing the current state of understanding for each theme, identifying knowledge gaps, and highlighting on-going work that could contribute to a study on atmospheric change in the Toronto-Niagara Region. Working group participants were equally challenged to establish priorities for research and to develop specific initiatives that would address information gaps. Selected findings and observations from the workshop, arranged by theme, are discussed throughout the remainder of this summary. The final section identifies general recommendations for implementing the TNR Study.

ATMOSPHERIC SCIENCE AND MODELLING

Bohdan Hrebenyk and Jim Young presented selected findings from a background report they prepared for Environment Canada-Ontario Region and the Toronto-Niagara Region Study (Hrebenyk *et al.*, 1998). In the report, they examined the interaction of air issues from both scientific and policy perspectives. Their presentation was followed by remarks from two panelists, Dave Yap and Don McKay, representing the Ontario Ministry of the Environment and Environment Canada, respectively.

Observations

The presentation and panel session revealed the incredible challenge associated with integrating the science of air issues and air management policies at the scale of the Toronto-Niagara Region. While sparse knowledge exists to understand future regional climatic variability and change, the formation of secondary pollutants, and the role of clouds, some of the factors connecting air issues have been identified. The strongest links among the air issues are weather and climatic variables and common sources of key pollutant emissions, such as the transportation sector. The role of weather and climate variables becomes apparent when one considers that approximately 43-60% of the variability in daily ozone concentrations in the Windsor-Quebec City corridor appears to be related to maximum daily temperature, air mass trajectory, 850-1000mb level thickness and relative humidity. Although the influence of climate is great, programs and policies tend to treat each issue independently and without fully acknowledging natural climatic variability let alone the prospects of climatic change. Canada and the U.S. are, however, moving towards developing an integrated strategy to deal with multiple air issues.

Research Priorities and Recommended Initiatives

Research priorities and recommended initiatives pertaining to atmospheric and other modelling activities were drawn from all breakout group discussions and workshop deliberations. While atmospheric modelling can be considered a distinct enterprise, the majority of workshop participants viewed it as a tool whose output can be used to better understand future impacts and risks. A general call was made to include greater focus on the Toronto-Niagara Region within current or planned atmospheric modelling exercises. Specific recommendations were made to:

- improve the capability to model climate variability and climate change at the regional level for the Great Lakes Basin as a whole;
- determine the relationship between climate variability and air pollutant concentrations;

- expand the domain of the oxidant model in the CRCM for studying high ozone episodes to include the Toronto-Niagara portion of the Windsor-Quebec Corridor;
- augment the air quality modelling capability of the above-noted model to include long range transport of particulate matter into the region;
- better understand the relationship between weather variability and fluctuations in sea surface temperatures in the tropical Pacific (i.e., ENSO phenomenon), as well as the North Atlantic (i.e., NAO phenomenon); and
- better understand the role of clouds in chemical reactions for air pollutants, as well as their role in affecting the dynamics of cyclones and anticyclones.

These are expensive ventures and the long-term investment required to deliver results cannot be overstated. While efforts to build a Toronto-Niagara Region component into these large modelling efforts are worthy pursuits, it was recommended that empirically-based downscaling techniques be developed that relate climate variability at the regional scale of the Great Lakes Basin to synoptic and large scale circulation features from standard meteorological observations or those modelled by Atmosphere-Ocean General Circulation Models (AOGCMs). This option would be less costly and more timely.

The purpose of these modelling and downscaling activities would be to develop a range of possible atmospheric futures that could then be used by other researchers to assess effects and evaluate various responses. In lieu of the traditional modelling approaches mentioned above, a number of alternative methods could be used to feed atmospheric scenario information into other research activities that examine impacts or responses, including:

- developing consensus on probable regional climate scenarios for the next 50 years;
- developing probable future scenarios based on existing model results for the regional scale (TNR), with some degree of consensus and the level of consensus identified;
- establishing a "worst case" scenario for the TNR (e.g., displacement of nuclear energy with import of "dirtier" energy from outside Ontario) and determine the impacts of air quality in the TNR airshed; and
- examining historic (analogue) periods, including periods of extreme climatic anomaly, for parallels and trends that can inform the future.

Regardless of what approaches are adopted, a desire was expressed to ensure that the resulting information would be useful to those assessing impacts and to those making policy and other decisions. Modelling and down-scaling exercises should develop a variety of predictors in addition to simple averages, the most useful including maximum and minimum temperatures; persistence, duration, and frequency of weather conditions; and air pollutant concentrations.

Data are vital inputs to all forms of modelling and improvements to monitoring networks, especially for particulate matter and hazardous air pollutants, are needed. Recognizing that many disparate atmospheric and pollutant monitoring programs and data archives exist, it was recommended that data from all programs and activities be assembled into one comprehensive database that will assist in identifying relationships among various pollutants. Participants also supported greater integration of existing climate data, rather than the collection of more baseline information, in a form and combination of use to impacts researchers.

NATURAL ENVIRONMENT IMPACTS AND ADAPTATIONS

Tom Hutchinson (Trent University) uncovered many disturbing trends and possible feedbacks in the natural environment of the TNR, drawing on data collected from research plots stretching along a transect from downtown Toronto to Eganville, northeast of Peterborough. Panel comments were provided by Deborah Ramsay (Niagara Escarpment Commission) and Adam Fenech (Environment Canada).

Observations

Although primarily considered an urban area, the Toronto-Niagara Region contains many remnant features of the ecosystems prevalent before European settlement. Terrestrial features are concentrated along the Niagara Escarpment, Oak Ridges Moraine, river valleys, and scattered among broken woodlots that generally increase in density with greater distance from the heavily urbanized Lake Ontario shoreline. Aquatic components include the near- and off-shore waters of Lake Ontario and Lake Simcoe and the numerous small lakes, streams and wetlands draining into these water bodies. The natural environmental features of this region serve both functional and aesthetic needs of society, filtering pollution of all types from the air and water, and providing an alternative habitat for the urban resident and tourist alike.

Many factors other than those emanating from the atmosphere have shaped the current natural environment including urban encroachment and expansion of road networks, agriculture, the introduction of invasive exotic species, development of recreation resources, natural area protection policies, demands for surface and ground water, reforestation programs, and quarrying. The object of research quickly distills to one of understanding how these factors interact with atmospheric stresses.

The work of Hutchinson and his colleagues, although preliminary, tells a compelling story about the impact of urban influence on forest biodiversity and functioning. It shows that soils are depositories for airborne metal accumulation and that this may be a long-lasting reservoir. It also demonstrates that the diversity of the spring flora is sensitive, adversely affected by urban and highway stresses. The presence of mosses and lichens, for instance, is greatly reduced in urban areas. The ability of micro-organisms to decompose fresh litter (needles) and, therefore, release and recycle nutrients, is also impaired in the more heavily urbanized sites examined.

Evidence of the effects of atmospheric stressors like acidification is beginning to emerge from Hutchinson's field research. In a series of plots, plant biodiversity was generally observed to increase as one proceeded northeast from the built up areas of Toronto towards Peterborough. Acid-tolerant species have become more dominant over the past twenty years as soil conditions reflect increased loadings of acid precipitation.

Other concerns point to the potential for cumulative effects on ecosystems. For example, one might expect an earlier start to the growing season under a scenario of climate warming, as occurred during 1998 under the influence of a strong El Nino event. Many plant species are most susceptible to UV damage as new growth emerges from the soil during early spring, especially in the absence of a forest canopy. The lowest levels of stratospheric ozone and thus greatest increases in UV radiation occur in late winter and early spring. The earlier the growing season, the sooner plants will bud and the more vulnerable they may become to UV damage. This form of impact, or that induced by severe ground-level ozone episodes, drought or other climate extremes (e.g., 1998 ice storm), tends to be acute and relatively simple to identify. The chronic effects of atmospheric stress are much less certain but potentially even more important for the long-term health of ecosystems.

Research Priorities and Recommendations

Most of the research recommendations offered during the workshop and working group session related to defining basic relationships and impacts, reinforcing the underlying lack of existing information about the cumulative or even individual effects of air issues on receptors in the natural environment. Priorities for research included:

- identifying the current state of the TNR with regard to land ownership, planning and legislation, economic patterns, and the values and expectations of the stakeholders in the region;
- assessing air quality issues and ecosystem effects acknowledging that many effects are not quantifiable, or have not yet been able to be quantified (an example of a specific research project might be to map the vegetation types, communities, and density gradients outward from the TNR urban centre as a quantifiable illustration of the effects of urbanization and related air issues on biodiversity and natural ecosystems); and
- mining of existing data sets for patterns and trends of action/adaptation, and for responses by natural and socio-economic systems under extreme climate events.

A second set of priorities focused on informing and securing the involvement of stakeholders to define the value and importance of the natural environment. It was recommended that a means of public consultation be established for the study, possibly in the form of a *public forum* seeking to identify values about the natural environment, and what form or degree of naturalness stakeholders wish to see. Public outreach might take the form of a report, available within two years, that could include:

- key findings of adaptation and mitigation from historical reviews, and
- the presentation of a regional probable future scenario, associated likely impacts to the natural environment, and a specification of the kinds of decisions that stakeholders need to make (e.g., decisions about what is valued in the natural environment).

HUMAN HEALTH IMPACTS

Much of the public concern and media attention towards atmospheric change has been related to its implications for human health and the organizers were fortunate to have two presentations on the subject. Jeffrey Brook (Environment Canada) discussed the issue of human health and air quality while Karen Smoyer (University of Alberta) commented on the relationship between heat stress impacts and mortality drawing from U.S. and Canadian research. The presentations were complemented by panel remarks from Franca Ursitti (City of Toronto) and Kirsty Duncan (University of Windsor).

Observations

The Toronto-Niagara Region has been the subject of research on the relationships between air pollutants and human health effects for over 15 years. This ecological epidemiological research has clearly demonstrated that a number of different air pollutants, including ground-level ozone, particulate matter and carbon monoxide, at concentrations observed in the Toronto-Niagara Region, are associated with respiratory and cardiac health effects. For ozone, there appears to be no threshold below which health impacts are drastically reduced. Recent research has shown that it is necessary to consider the cumulative impacts of the entire mixture of pollutants in urban smog to more fully account for the acute effects arising from inhalation exposure to air pollutants. Failing to account for multiple pollutants leads to an underestimation of the impact on human health.

Many past human health effects studies have sought to control for the effects of weather and then focus only on air pollutant relationships or *vice versa*. Weather and climate variables are known to exhibit strong associations with indicators of human health. With respect to mortality from single events, the impacts of climate on human health are the most severe of any air issue considered during the workshop. For example, the heat wave of 1988 resulted in an estimated 5,000-10,000 deaths in the United States (National Climatic Data Center, no date). In a study of weather-related mortality in 10 large Canadian cities, summer weather/mortality relationships were identified for Toronto and Montreal (Kalkstein and Smoyer, 1993). U.S. research on the New York City-Wilmington area, a region that experiences similar climatic conditions, demonstrated that significant variation in heat-related mortality is associated with differences in socio-economic factors including housing stock, air conditioning rates, and poverty and unemployment rates.

Without diminishing the importance of understanding these direct effects of climate, Kirsty Duncan noted significant secondary effects associated with infectious, vector-borne diseases whose ranges may be expand into southern Canada as the climate warms. Incidences of ailments such as malaria and Lyme Disease may become more common in northern latitudes and the health community must become aware of this potential.

Two connections between air quality and climate change were emphasized during the presentations and could be pursued as a means to integrate future research. First, synoptic climatological analyses show that there are certain weather patterns or flow patterns that lead to higher air pollutant concentrations. Should these patterns become more frequent due to a change in climate, then air quality in the TNR could deteriorate. This deterioration, coupled with more extreme heat episodes, would have a detrimental impact on public health in the TNR. Secondly, many of the human activities contributing to greenhouse gas emissions and climate change are also sources of regional air pollutants associated with health effects. Thus there are likely co-benefits associated with reducing emissions that have not been thoroughly researched.

Research Priorities and Recommendations

Several research priorities were highlighted during the plenary presentations and in the human health working group discussion. Both Smoyer and Brook advocated assessing the combined effects of weather and air pollutant variability in future health impacts research, some of which could be started immediately with existing data. The long-term objectives of a Toronto-Windsor Corridor study proposed by Smoyer included building air quality parameters into the weather-related mortality research.

There is also a need to bring greater attention in health effects research to socio-economic variables such as demographics, housing stock characteristics and household income. These factors are thought to explain spatial and temporal variation in the vulnerability to health effects from weather and air quality conditions. Since these variables change over time, predictive analyses, such as those designed to assess the effects of climate change, must account for future socio-economic conditions. The assumption of "everything else remains equal", where only changes in atmospheric conditions are assessed against health indicators, must be challenged in health effects research.

Many of the priorities noted relate to improved ecological epidemiological research. Gaps also exist in our comprehension of the specific physiological mechanisms that are responsible for health effects experienced by a given individual as well as in our understanding of the chronic effects of exposure to air pollutants.

The final priority identified was raising awareness of the implications of atmospheric change among health officials and professionals. This group is responsible for individual and community health and is the primary mechanism for communicating with the public and responding to health risks and impacts.

Research priorities and recommended initiatives for the human health theme were synthesized through the working group process into three projects that could be achieved using existing resources and built from on-going research.

An *Historical Analogue Study* was proposed to examine daily and seasonal analyses of atmospheric variables (including climate and air pollution) for years known to have been hot/dry and smoggy (e.g., 1988 or 1987-1989) versus years with relatively mild and low-pollution summers (e.g., 1986 or 1984-1986). The objective would be to compare morbidity and mortality statistics for the TNR during these two distinct analogue periods as a measure of impact. Adaptive measures taken to reduce vulnerability during the periods of heat and/or smog would be documented and evaluated. Results and recommendations would be provided to urban planners and policy makers.

The *Toronto-Windsor Corridor Study* being developed by Karen Smoyer was also identified as a candidate project. The proposed work involves using an air mass-based approach to analyze 17 years (1980-1996) of heat stress events and mortality statistics. The importance and implications of climate change, demographic change, and other socio-economic indicators would be considered, and the analysis eventually expanded to include air quality data, downscaling (of climate change impacts), morbidity statistics, the urban heat island effect and energy demand.

The final recommended initiative was a *Plain Language* document summarizing what is known about climate change, the atmospheric environment (in general), and associated human health impacts in Canada and the TNR. Among other sources, material could be drawn from the Canada Country Study (Duncan *et al.*, 1998) and Health Canada/Environment Canada joint health effects research (see reference list for Brook, this volume) identifying relationships between poor air quality and human health or quality of life.

INFRASTRUCTURE AND ECONOMIC IMPACTS AND ADAPTATIONS

Heather Auld (Environment Canada) reviewed the impacts of atmospheric change and variability on infrastructure in the TNR. Panel comments were provided by Donald Haley (Toronto and Region Conservation Authority) and Kevin Loughborough (City of Toronto).

Observations

The built environment and urban infrastructure support many of society's economic and social activities. Infrastructure includes houses, offices, plants, hospitals, schools, shopping facilities; structures for the supply, generation and distribution of water, electricity, gas and oil; facilities for collection and treatment of waste; road networks; waterways, bridges, canals, wharves; airport runways and control towers; and communications towers and lines. No other region of similar size in Canada can claim to have as much valuable infrastructure as found in the TNR.

The built environment affects, and is affected by, atmospheric change. Recent billion dollar weather-related disasters, including the Ice Storm of 1998 in eastern Canada, have drawn attention to society's vulnerability to climate variability and the potential implications of climate change. The disasters have people wondering whether the frequency and severity of extreme weather is increasing or if society is becoming more vulnerable by placing more people and property in risky areas.

Most elements of the built environment, including transportation, energy, and water infrastructure, as well as the construction industry itself, are very sensitive to weather and climate. Infrastructure is designed to operate within and withstand a certain range of conditions and when these exceed design criteria, failure may occur. For instance, energy and water demands may not be met or, in extreme cases, the physical infrastructure may be damaged or destroyed as occurred with hydro transmission towers and poles during the January 1998 Ice Storm. In contrast to extreme events, where the damage is done in seconds or minutes or days, premature failure caused by weathering deterioration usually takes months or years to become evident. Structures are also subject to erosion by the slower day-to-day processes of wind and water, freeze-thaw cycles, abrasion, the action of broad spectrum solar and ultraviolet (UV) radiation, and by chemical breakdown in the presence of water, oxygen and assorted pollutants. Concerns over the premature deterioration of clay bricks and reinforced concrete materials have already been raised in the North American construction industry.

While directly affected by the atmosphere, the built environment also contributes to many of the region's atmospheric change and environmental issues. This occurs primarily through the inefficient use of energy for heating, cooling and electricity in buildings and through our transportation systems. The construction of infrastructure also consumes a tremendous amount of energy. By using energy these activities generate emissions, often some distance from where the energy was produced, exacerbating both air pollution and greenhouse gas-induced climate change. The built environment also directly affects local climate. Compared to the surrounding countryside, cities have warmer temperatures (urban heat island effect), lighter winds (except for gusts around tall buildings) and lower humidity and visibility.

In spite of the importance of the built environment to the economy of Ontario and Canada, little research is available to assess the implications of climate and other atmospheric change on the built environment. A sample of tentative impacts identified by several researchers (Smith *et al.*, 1998; Dalgliesh, 1998; Davenport, 1994) is provided below.

- Warmer winters may bring more frequent freeze-thaw cycles and greater weathering of infrastructure materials.
- Increased acidification along with a greater frequency of precipitation episodes may exacerbate the deterioration of materials.
- Snow loads may decrease as more winter precipitation falls as rain, depending on how warm winters become, but risk of roof failure in flat-roofed buildings might increase since many of these roofs currently have to support rain loads that are greater than snow loads.
- Warmer climate will bring a reduced need for winter heating while summer air-conditioning needs should increase, as hot spells become more common and average temperatures increase in summer.
- Warmer winters will lengthen the construction season, although many impacts of climate change on other weather-construction relations are unknown.
- Decreased snowfall could result in fewer transportation disruptions.

Because little research is available on the impacts of atmospheric change on the built environment beyond that of water resources, minimal adaptation research also exists. The potential is high for developing successful adaptation options to atmospheric change in the built environment. This is particularly true since the construction industry has a long history of designing and adapting to the extremes of weather and has experience in dealing with uncertainties. Hazards can be managed through proper land use, good engineering design and practice, and good weather warnings (Auld, 1996).

Research Priorities and Recommendations

A number of broad research priorities were recommended during the working group session to address knowledge gaps, including:

- determining how atmospheric change may affect energy demand, supply and distribution systems;
- assessing the costs over time of atmospheric change for all sectors/activities in the TNR and integrate costs, if possible;
- assessing the different costs between chronic long-term effects of atmospheric change vs. impacts of acute episodes;
- determining how vulnerable "essential" services in the TNR such as water supply and sewage systems, electricity distribution systems and communication systems are to atmospheric change and extreme weather events;
- determining the use, and barriers to, behavioural adaptive strategies such as water conservation in the TNR;
- assessing how water infrastructure (e.g., water intake pipes) can be affected by atmospheric change (impacts on water quality, frequency of lake turnover, subsequent impacts on water use such as deep water cooling);
- assessing how water transport systems may be affected (estimate costs of replacing existing infrastructure to deal with future hydrological conditions, impacts of more extreme precipitation events);
- determining how flood regulation may be affected by changes in hydrological conditions in the future;
- assessing how atmospheric change can affect the dominant modes of transport in the TNR (e.g., automobile travel, trucking, rail, and coastal marine);
- determining how existing National Building Codes might have to be modified in the future under atmospheric change;
- identifying the barriers to changes in various infrastructure systems and standards; and
- assessing how atmospheric change can affect social infrastructure in the TNR (e.g., recreational beaches, and marinas).

Two initiatives were recommended to begin addressing a few of the these priority research gaps. The first, *Development of a Long-term Strategy for Sustainable Energy Use and Management in the TNR*, would be conducted in consultation with stakeholders such as the Federation of Canadian Municipalities, Municipal Electrical Association, municipal utilities, Ontario Hydro, and Better Building Associations. The primary product would be a report that summarized the state of knowledge on current energy use/mix and potential impacts of atmospheric change; identified next steps, research needs and scenarios of possible futures; and identified potential mitigation and adaptation options.

The second initiative proposed would *Determine the Sensitivity of Water Supply Systems to Atmospheric Change.* This activity would address the following components:

- Effects of atmospheric change on water infrastructure.
- Resiliency of existing water supply to atmospheric change and population change.
- Effects of surface temperature changes on drinking water quality.
- Effects of atmospheric change and urban change on basin ecosystems.
- Changes in base flows and effects on recreation, wetlands and fisheries.
- Impacts of future demands for inter-basin water transfers and competing water demands.

EMISSIONS AND MITIGATION

A significant challenge of this workshop was the merging of both the impacts research community and those involved in analyzing and assessing ways to reduce emissions contributing to atmospheric change. Presentations by Ken Ogilvie (Pollution Probe) and Peter Timmerman (University of Toronto) were interspersed with panel remarks from Richard Gilbert (Centre for Sustainable Transportation), Jay Barclay (Environment Canada), Joe Berta (Toronto Hydro), and Lois Corbett (Toronto Atmospheric Fund).

Observations

Notwithstanding information gaps and uncertainties, the impacts sessions revealed many of the negative implications for human health, ecosystems and the built environment that could accompany a "do nothing" approach to air issues. Communicating the seriousness of air issues and potential impacts to the public, politicians and other stakeholders was identified throughout the emissions and mitigation session as a major obstacle to changing behaviour and attitudes toward emissions reductions. As Lois Corbett commented, "*it is really important to take the issue out of the research arena, the laboratory and the computer models, right down to the floor of the council chambers.*" New information produced through research projects such as the TNR Study sustains interest in air issues, especially when non-government organizations such as Pollution Probe help to deliver and translate the findings to the public through open forums and other communication channels.

Ken Ogilvie postulated that if society was as collectively concerned with climate change and other atmospheric issues as with winning World War II, then many measures could and would be quickly implemented to solve the problem. While this sense of urgency does not exist at present, many opportunities to reduce emissions were identified during the session, especially within the electricity generation and transportation sectors. For example, Ogilvie noted that retrofitting all 312 operating coal-fired electricity generating plants in the Ohio Valley through to the east coast of Canada with the best available emission control technology would achieve an 80% reduction in emissions of SO_2 and NO_x, a 50% reduction in particulate matter, and a significant reduction in mercury emissions. Retiring all plants older than 40 years by 2010 would result in a 60% reduction in CO_2 emissions. While these extensive emission reductions are only rough calculations on paper, innovative programs such as the Toronto Atmospheric Fund are already taking action through landfill methane recovery, lighting retrofit and other projects, making substantive progress at reducing CO_2 emissions while simultaneously generating revenue.

During the 1997/98 academic year, students of a University of Toronto Institute for Environmental Studies (IES) graduate course led by Peter Timmerman and colleagues investigated a range of emissions reduction measures for transportation and other sectors. The class went through the exercise of developing and apportioning baseline and future greenhouse gas emission estimates to the TNR. They also evaluated response measures that would enable the region to achieve the 6% reduction target that Canada agreed to as signatory to the Kyoto Protocol. Timmerman made the observation that the class may have played out the global argument in miniature, with the TNR as a "developed region" within Canada. What ought the required emissions reduction share for the TNR really be, given its importance in the country? The course also uncovered a number of concerns that may jeopardize reaching the Kyoto target, including the continuing uncertainty about the general energy production mix in Ontario (with 7 nuclear reactors going off-line in 1997) and deregulation of the electricity market.

Transportation measures examined by students in the IES course included switching to more efficient vehicle fuels, traffic calming and land use controls, economic instruments and raising average vehicle occupancies. One student (Khan, 1998) estimated that a combination of variable road pricing, inspection and maintenance programs, physically restraining traffic, and developing additional priority lanes for carpooling could reduce greenhouse gas emissions from automobiles by 35% in the TNR. Other speakers and panelists were less optimistic that such reductions would be achieved and suggested that future per capita emissions reductions will be offset by the greater use of vehicles for the movement of freight and passengers. The dramatic growth of non-work or discretionary travel was identified as a particularly important issue that has received much less attention in research and policy circles than concerns over commuting patterns.

The danger of focusing entirely on one air issue was brought out using the example of energy efficiency in buildings. Although relatively cheap technology exists to retrofit old or construct new buildings and achieve much greater energy efficiency, through recycling of conditioned air in office towers for example, doing so could compromise indoor air quality. Similarly in the transportation sector, while substantive effort has been devoted to understanding and developing measures to control vehicle emissions to the atmosphere, much less attention has been paid to air quality within automobiles which one panelist claimed may exceed ambient concentrations by a factor of 18 for certain pollutants.

An analytical framework that might provide integrated insight into these and other conflicts is under development by Environment Canada, Health Canada and other partners as a contribution to Canada's National Implementation Strategy for climate change. The framework would be used to trace how a specific measure changing pollutant levels at a certain source (whether it be an area or point source) will, through atmospheric transportation and related processes, alter things like air quality, water quality, and ecosystem health. These changes will in turn affect human health, land productivity and the durability of built infrastructure. The rationale for the approach is that certain energy forms are preferable from an environmental perspective because they produce fewer CO_2 emissions and also offer ancillary benefits to other air issues. It may be better to reduce CO_2 to a greater extent in large urban areas like the TNR than in remote locations since the measures are also likely to assist in the management of ground-level ozone precursors and other pollutants.

Research Priorities and Recommendations

The emissions and mitigation working group developed a number of general recommendations, priority research topics and projects. General recommendations included increasing domestic investment in pollution reduction and improving our science and modelling capacity. Coordinated monitoring programs and harmonized regional-level emissions inventories should be developed to support both of these actions.

Several priority research topics were identified, including:

- review of success stories in emissions reduction to identify what works, why and where;
- review of existing data sources to identify the true levels of emissions and air quality in the TNR;
- review of case studies to determine how deregulation affects emissions;
- review of fuel consumption data in the region (home fuel, automobile use, etc.); and
- research to develop technology to move water (and thus energy) through pipes more efficiently in support of district cooling/heating systems.

The working group recommended three priority projects for the study. A *Review of Emission Reduction Case Studies* would draw from international emission reduction experiences, such as the introduction of natural gas vehicles in New Zealand, to identify factors associated with the success of these various initiatives and expected emission reductions if similar actions were taken in the TNR. Information would be obtained through literature reviews and interviews with representatives of the various initiatives. Case studies could be selected from a priority list of sectors that present opportunities for mitigation in the TNR (e.g., public transportation and electricity generation).

The second project identified would examine *Existing and Projected Emissions and Air Quality in the TNR*. Current and projected regional emissions would be determined for each sector and fuel type through a review of best available data sources of emissions (criteria and toxic pollutants, mobile emissions) by sector and fuel type. Current modelling approaches using existing emission and monitoring data would be reviewed to characterize regional air quality at present and in 25 years.

The final project proposed by the working group for implementation in the TNR Study was an *Urban vs. Suburban Study of Individual and Industry Contributions to Emissions*. The exercise would build a community focal point by identifying the extent to which individuals and local industries in specific geographic areas of the Toronto Niagara Region contribute to atmospheric change. An "ecological footprint" approach would be used to determine the relative contributions (point and non-point source emissions) of urban and suburban lifestyles. Based on the analysis, mitigation strategies could be recommended for individuals, communities and industries in each specific location.

GENERAL RECOMMENDATIONS FOR IMPLEMENTING THE TORONTO-NIAGARA REGION STUDY

The plenary and working group sessions conducted on the final day of the workshop provided useful feedback and direction on the structure, goals and products of the proposed Toronto-Niagara Region Study. Workshop participants felt strongly that a clear set of goals and objectives was needed to identify priority research initiatives and entice additional participation in the study. The following TNR Study goal statement was suggested and generally agreed upon by workshop participants.

"The development and/or promotion of adaptive and/or mitigative response strategies to reduce vulnerability to atmospheric change in the Toronto-Niagara Region."

To achieve this general goal, participants recommended that proponents of the TNR Study develop the following list of products over the proposed 4-year lifespan of the project.

1) Workshop report or proceedings.
2) Monograph series-type publications.
3) Background reports.
4) Follow-up meetings to complete the tasks started during the May 1998 workshop.
5) Assessment of mechanisms for effective public participation.
6) Assessment of stakeholder needs and development of strategies for involving a broader range of stakeholders at the project/theme (e.g., human health) level.
7) Inventory of mitigation and adaptation actions for the benefit of the public, urban planners, industry, policy makers, and others.

While these products are important, there was general agreement among participants that immediate efforts focus on developing and contributing to a *State of the Regional Atmosphere* type of report over the next 2 years. This report, developed in consultation with stakeholders, would discuss the likely impacts of atmospheric change over the next 25 years by:

- synthesizing existing literature and stakeholder viewpoints;
- documenting uncertainties in the estimates of impacts and the range of possible impacts of atmospheric change;
- recommending actions to minimize or adapt to critical impacts;
- examining the role of public consultation; and
- identifying research and mechanisms required to develop better and more integrated solutions.

In closing, workshop participants felt that the need for the project is clear, so that next steps must focus on moving the level of debate forward and identifying specific actions to address atmospheric issues. The proponents of the TNR Study will do their best to thoroughly review, consider and implement workshop recommendations and take advantage of the tremendous enthusiasm shown during the meeting towards improving our understanding and ability to resolve atmospheric issues in the Toronto-Niagara Region.

REFERENCES

Auld, H. 1996. Dealing With Weather Extremes and Climate Variability. In *Ecosystem Effects of Atmospheric Change*. Proceedings of a meeting convened under the Memorandum of Understanding on Science and Technology for Sustainable Development in the Natural Resources Sector, March 5-6, 1996, Pointe Claire, Quebec.

Dalgliesh, A. W. 1998. "Built Environment Sector", chapter 9 in G. Koshida and W. Avis (eds.) *Canada Country Study: Climate Impacts and Adaptation, National Sectoral Volume*. Environment Canada, Downsview, Ontario.

Davenport, A. 1994. Atmospheric Extremes, Insurance and Construction. In J. McCulloch, and D. Etkin (eds.), *Proceedings of a Workshop on Improving Responses to Atmospheric Extremes: The Role of Insurance and Compensation*, October 3–4, Toronto, Ontario.

Duncan, K., T. Guidotti, W. Cheng, K. Naidoo, G. Gibson, L. Kalkstein, S. Sheridan, D. Waltner-Toews, S. MacEachern, and J. Last, 1998. "Health Sector", chapter 11 in G. Koshida and W. Avis (eds.) *Canada Country Study: Climate Impacts and Adaptation, National Sectoral Volume*. Environment Canada, Downsview, Ontario.

Hrebenyk, B., J. Young, and P. Coutts, 1998. *Effects of Weather, Climate Variability and Climate Change on Air Issues in the Toronto-Niagara Region/Great Lakes Basin*. Report prepared by SENES Consultants Limited for Environment Canada-Ontario Region.

Kalkstein, L.S. and K.E. Smoyer, 1993. *The Impact of Climate on Canadian Mortality: Present Relationships and Future Scenarios*. Environment Canada/Canadian Climate Center. Report No. 93-7, 50 pp.

Khan, E. 1998. *Strategies for Achieving the Kyoto Commitment in the Toronto-Niagara Region*. Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Munn, R.E. (ed) 1995. *Atmospheric Change in Canada: Assessing the Whole as Well as the Parts, Summary Report of a Workshop,* March 27-29, 1995. Institute for Environmental Studies, Toronto, Ontario.

National Climatic Data Center (*no date*). Billion Dollar U.S. Weather Disasters 1980-1996. Website summary statistics (http://ncdc.noaa.gov/ol/reports/billionz.html).

Ogilvie, K., D. Bell, R. White, and Q. Chiotti (eds) 1997. *Climate Variability, Atmospheric Change and Human Health Conference Proceedings,* November 4-5, 1996, Pollution Probe, Toronto, Ontario.

Smith, J., B. Lavender, H. Auld, D. Broadhurst and T. Bullock, 1998. *Adapting to Climate Variability and Change in Ontario.* Environment Canada, Ontario Region, Toronto, Ontario.

SECTION 1: CONTEXT FOR THE TORONTO-NIAGARA REGION STUDY

Toronto-Niagara Region Study

on atmospheric change

The Toronto-Niagara Region Study: Setting and Research Framework

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INTRODUCTION

The Toronto-Niagara Region (TNR) Study on Atmospheric Change is an integrated scientific and policy assessment of atmospheric issues, examining emissions, impacts, and effective mitigative and adaptive responses. The purpose of this paper is to describe the historical context of the TNR study, provide an overview of the setting and research framework for the study, and to review the objectives of this workshop.

BACKGROUND AND HISTORICAL SETTING

The idea for a study of atmospheric change in the Toronto-Niagara Region was first raised in November 1995, during the second meeting of the Climate Change Study Group (CCSG), at the University of Toronto. Organized in autumn 1995 by the Environmental Adaptation Research Group (EARG), Environment Canada, and the Institute for Environmental Studies at the University of Toronto, the CCSG was created in response to a perceived research need in the area of climate change. In recent years, numerous faculty and students from across the three campuses of the University of Toronto were engaged in climate change research, however there was no forum in place to facilitate the exchange of information and ideas, or to foster collaborative research activities. The CCSG was thus created, consisting of over 50 faculty members, researchers and scientists from the University of Toronto and the Atmospheric Environment Service of Environment Canada.

The conceptual antecedents of the TNR study can be linked to two distinct research thrusts: climate variability and change in the Great Lakes-St. Lawrence Basin, and the integration of atmospheric issues. The original idea for an assessment of climate change impacts upon the Great Lakes Basin can be traced back to a workshop held in King City, Ontario, in 1985 (Timmerman and Grima, 1985). By the early 1990′s, the concept of a regional climate change impact assessment was further developed into the Great Lakes-St.Lawrence Basin (GLSLB) Project (Mortsch *et al.*, 1998; Mortsch and Mills, 1996). The initial stages of this project involved conducting an in-house review of the literature (Koshida *et al.*, 1993), and holding a series of stakeholder consultative workshops. Combined, these activities helped to establish the framework for the GLSLB Project, formulate the research questions to be addressed, and identify the specific research activities to be supported. This bi-national study focused on climate variability and change, with specific reference to the role of adaptation in reducing the possible social, economic and ecological impacts in four specific climate-sensitive issues: water management, ecosystem health, human health, and land use and management (Mortsch *et al.*, 1998). While notable for its integrative approach, no impact assessment can be all-inclusive; hence, many knowledge gaps remain in our understanding of climate change impacts in the Great Lakes Basin, particularly in urban centres and in the interface between urban and rural areas.

In recent years there has also been a growing recognition that the problem of climate change needs to be expanded to include other atmospheric issues, specifically the integration of climate variability (including extreme events), stratospheric ozone depletion (leading to UV-B increases), acidic deposition, smog (tropospheric SO_x, NO_x, VOCs and tropospheric ozone episodes), hazardous air pollutants (heavy metals, POPs, etc.), and particulate matter. By the late 1980's, a few studies had emerged which addressed important interactions amongst various combinations of air issues (e.g., White, 1989; Krupa and Kickert, 1989). Building upon these publications, a workshop on atmospheric change in Canada was held in Toronto, Ontario on March 27-29, 1995 (Munn, 1995). The first workshop in Canada to assess atmospheric change issues from the perspective of "the whole as well as the parts", its primary goal was to examine methods that might be used to undertake integrated assessments of a selected number of atmospheric issues. This was followed in February 1996 with a more focused workshop that aimed to formulate a Canadian science agenda on the effects of atmospheric change on biodiversity (Munn, 1996).

In recent years there has also been a growing recognition that the problem of climate change needs to be expanded to include other atmospheric issues, specifically the integration of climate variability (including extreme events), stratospheric ozone depletion (leading to UV-B increases), acidic deposition, smog (tropospheric SO_x, NO_x, VOCs and tropospheric ozone episodes), hazardous air pollutants (heavy metals, POPs, etc.), and particulate matter.

Intending to build upon these two distinct but related research thrusts, the CCSG, in conjunction with EARG and the Institute for Environmental Studies at the University of Toronto, proposed to examine the impacts from, and adaptations to, atmospheric change in the Toronto-Niagara Region. A straw proposal drafted by a small research team in April 1996 (Chiotti *et al.*, 1997), led to the November 1996 conference/workshop *Climate Variability, Atmospheric Change and Human Health* (Ogilvie *et al.*, 1997), organized in association with Pollution Probe, a prominent Environmental Non-Governmental Organization based in Toronto. Intended to provide an initial scoping of the research problem, and to help raise awareness amongst the science, policy and public stakeholder community, the workshop attracted over 160 participants and received considerable media coverage. The need to examine both impacts and emissions associated with atmospheric change was strongly communicated at this workshop, thereby implying a need to look at both adaptive and mitigative responses.

In an effort to capitalize upon the interest and enthusiasm generated at this workshop, the first meeting of the TNR Study advisory board was held in May 1997. Scheduled immediately following the final symposium of the Great Lakes-St.Lawrence Basin Project, the meeting attracted 20 stakeholders from across the TNR, with those in attendance expressing considerable interest in the proposed study. Although encouraged by this show of support, the TNR study still faced formidable challenges involving its organization, financial resources, and research partnerships. Unlike two previous climate change impact assessment projects led by EARG which were supported by the Green Plan (e.g., Cohen, 1997; Mortsch *et al.*, 1998), the fiscal climate of the late 1990's is quite different, requiring the TNR Study to function with limited financial resources, and consequently with restricted ability to contract out research to universities or the private sector. This challenge is further intensified as budget cuts, downsizing, and downloading seem to be occurring at all levels of government, and even in many areas of the private sector.

By the conclusion of the May 1997 advisory board meeting, it was widely accepted that for the TNR Study to succeed, it would have to rely upon a core group of contributors, and in-kind support from the major government supporters. This core would initially consist of scientific and advisory boards drawn from the researchers, policy-makers and stakeholders in attendance, and which could then be expanded as research and funding partners joined the study. This prompted EARG to establish a study office in July 1997, at the University of Waterloo, with Brian Mills as project lead, and Dr. Quentin Chiotti as scientific authority. Since then, the Ontario Region of Environment Canada has made the TNR Study a high priority amongst their research activities, and memorandas of agreement or understanding (MOAs/MOUs) have been signed with the Environmental Conservation Service of Environment Canada, and with the Ontario Ministry of the Environment. A small number of research activities have already contributed to the study over the past two years, or are presently in progress, addressing various issues pertaining to atmospheric change in the TNR. Furthermore, a number of work plans are also currently being developed or linked directly into the TNR Study. These activities range from university undergraduate papers and graduate student reports, to scientific assessments such as the report prepared by

Senes Consultants Limited (Hrebenyk *et al.*, 1998). In the latter case, I would like to acknowledge the generous financial and in-kind support from the Ontario Region of Environment Canada and the Great Lakes 2000 program.

In November 1997, a national workshop was held in Toronto to report on Phase I of the Canada Country Study, a multistakeholder initiative led by EARG on climate impacts and adaptation (Maxwell *et al.*, 1997). Three directions for future research can be identified from the national workshop as strongly applicable to the TNR Study: (i) extend the climate change problem to include all atmospheric issues; (ii) incorporate mitigation with impacts research; and (iii) improve our understanding of impacts and adaptation at the regional scale. Subsequently in January 1998, there was a consensus amongst the members of the advisory board that the research agenda for the TNR study needed to be moved forward even further, and the idea for this workshop was germinated.

Three directions for future research can be identified from the national workshop as strongly applicable to the TNR Study: (i) extend the climate change problem to include all atmospheric issues; (ii) incorporate mitigation with impacts research; and (iii) improve our understanding of impacts and adaptation at the regional scale.

This workshop was the first meeting of a growing network of TNR research partners that includes government and academic researchers, public and private policy-makers, and representatives of non-government organizations. The objectives of this two-day workshop were to:

- review the current state of knowledge on atmospheric change issues in the Toronto-Niagara region; and
- identify opportunities to build on the current state of knowledge within the Toronto-Niagara Region Study.

The focus of the first day was on assessing the science of the interaction of air issues, potential impacts and response options, whereas second day activities focused on identifying research priorities, objectives and workplans for the Toronto-Niagara Region Study. The organizers hoped that the research activities eventually emerging from this workshop would make a significant contribution to Phase II of the Canada Country Study, as well as to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC).

The participants in this workshop all shared an awareness, if not a concern, about the problem of atmospheric change in the Toronto-Niagara Region. In particular, there was concern about the interaction of the six atmospheric issues and how they affect the health, social and economic well being of Toronto-Niagara Region citizens and the environment within which they live. The following section provides the science and policy context for the study, and states why the TNR is an appropriate region in the country to examine the interaction of atmospheric issues.

SCIENCE AND POLICY CONTEXT

The integration of all atmospheric issues is a complex problem and represents an enormous scientific research and policy challenge. While extensive research has been conducted on specific atmospheric issues, or even combinations of issues, significant knowledge gaps remain in our understanding of the science of all atmospheric issues, the interactions between them, and their ecological, social and economic impacts on a regional scale. While each individual atmospheric issue poses a significant environmental problem, in the TNR Study we are especially concerned with their interactions and multiple or synergistic effects. Maarouf and Smith (1997) have shown that atmospheric stresses are highly interactive (Table 1), and that climate variability and change may have a profound impact upon other air issues. In particular, climate variability and change could have a strong effect upon acidic deposition and smog, with somewhat less of an effect upon stratospheric ozone depletion and suspended particulate matter.

The interaction of atmospheric issues is also very important from a policy perspective. In recent years there has been growing recognition that policies designed to address individual atmospheric issues create the possibility of conflicting and inefficient policies and regulatory actions. Furthermore, it is also recognized that actions addressing a single atmospheric issue can have ancillary benefits for other atmospheric issues.

In terms of impacts and adaptation, the literature has similarly focused on specific atmospheric issues, generally ignoring the additive or synergistic effects from multiple stresses. A recent workshop on atmospheric ozone (smog and UV-B) suggests an emerging interest in additive effects (OCAC, 1997), but the preponderance of impacts and adaptation research to date has been on specific stresses, particularly in the area of climate change and variability (Maxwell *et al.*, 1997), and to a lesser degree acidic deposition (TAETG, 1997). Even in the case of climate change and variability, however, significant knowledge gaps continue to exist regarding our understanding of impacts and adaptation, especially at the regional scale of analysis. This is perhaps most apparent in our limited understanding of urban centred regions, the rural-urban interface, and the effects of extreme weather events.

Table 1. Interactions between atmospheric issues

Air Issue	Climate Change	Stratospheric Ozone Depletion	Acidic Deposition	Smog	Suspended Particulates
Climate Change		-1 but several counteracting effects	-1 but several counteracting effects	+1	-1 (globally) -2 (regionally)
Stratospheric Ozone Depletion	+ 1		0	-1	+1
Acidic Deposition	+2	+1		U	+1
Smog	+2	+1	+1		highly correlated
Suspended Particulates	+1	+1	0	Highly correlated	

A qualitative summary of the linkages among the air issues. Effects of the atmospheric change issues listed **horizontally** on the air issues listed **vertically** are shown as 0 (no effect); 1 (some effect); 2 (strong effect); U (unknown). Positive and negative signs indicate increasing (worsening) and decreasing effects.

Source: Maarouf and Smith, 1997

The interaction of atmospheric issues is also very important from a policy perspective. In recent years there has been growing recognition that policies designed to address individual atmospheric issues create the possibility of conflicting and inefficient policies and regulatory actions. Furthermore, it is also recognized that actions addressing a single atmospheric issue can have ancillary benefits for other atmospheric issues. For instance, greenhouse gas (GHG) emission reductions for climate change will have co-benefits for acidic deposition and smog. It is therefore advisable that future air issue policies adopted on a regional scale be more firmly based on integrated scientific and socio-economic research. This is particularly important considering the different levels of policy and decision-making that may influence atmospheric issues at the regional scale (e.g., federal, provincial and municipal policies).

In response to the implications of atmospheric change and the relative lack of knowledge at the regional scale, the TNR study is shaped by a vision, which we all probably share:

> *"A Toronto-Niagara Region in which the quality of life (economic, environmental and social well being) is sustained or enhanced in the face of inevitable challenges imposed by atmospheric stresses."*

As an extension to this vision, the primary goal of the TNR Study is to:

> *"Provide an improved scientific foundation for responding to atmospheric change in the Toronto-Niagara Region, by strengthening our understanding of the synergistic effects of atmospheric change, its causes and implications, for the most populated, economically important and ecologically diverse region in Canada, and to examine effective mitigative and adaptive responses."*

When the problem of atmospheric change is examined on a regional scale, one is confronted with many uncertainties, unknowns, and sources of conflicting information. Recognizing this fact, proponents of the TNR Study are seeking clarity for the residents, policy makers and stakeholders who live, work and play in this region to provide a better understanding of the science, impacts and responses to integrated air issues at the regional scale. To achieve this goal, the TNR Study has the following objectives:

1. To develop a framework for identifying and assessing current and future:
   - sources and trends of various emissions;
   - causal mechanisms for pollutants;
   - impacts and cumulative effects;
   - feedbacks, linkages and interactions;
   - risks and vulnerabilities; and
   - both mitigative and adaptive response options.
2. To solicit study partners and collaborators throughout the research process to:
   - ensure that scientific contributions are credible, adequately reviewed and documented;
   - engage policy and decision makers wherever possible or appropriate; and
   - facilitate the exchange of information and views, and disseminate or communicate the information as widely as possible.

THE TORONTO-NIAGARA REGION AND ATMOSPHERIC CHANGE

...regional air quality continues to be a major concern for policy makers, especially in terms of the impacts upon human health, and this problem is likely to get worse under climate change. Moreover, air quality in the TNR is greatly affected by southern air masses, which transport upwards of 50 percent of atmospheric pollutants, primarily from the Ohio Valley.

One of the underlying questions that the TNR Study is attempting to address is "how do we manage atmospheric issues at the regional scale?" In justifying the pursuit of this question, there are some general arguments that can be used to support the need to examine atmospheric change at the regional scale of analysis. First, air sheds tend to function on a regional basis and air pollutant sources, transport mechanisms, and underlying meteorological conditions are best examined at this scale. Second, from a policy perspective, those regulating emissions or developing effective adaptive strategies need to recognize the hierarchical structure of our governmental system, and the different layers of jurisdiction and authority between or within national, provincial and local government agencies. This is perhaps most obvious when it comes to addressing transboundary pollution and the interconnectedness of the airsheds across North America. Third, effective adaptive responses to climate change and other atmospheric issues can result in strong benefits through damage reduction or avoidance. These benefits are concentrated in the region where the responses were undertaken. Lastly, although Canada contributes barely over 2 percent of global emissions of greenhouse gases, reductions of these emissions can have ancillary benefits at the regional scale, especially in terms of improving regional air quality and reducing the negative impacts from other air pollutants upon our natural, social and economic systems.

While the need to examine atmospheric change at the regional scale is quite clear, so should the selection of the TNR as an appropriate region in Canada to address the integration of all atmospheric issues (Figure 1). The ecological, social and economic suitability of the TNR for such an assessment has been well documented (Chiotti, 1997). First, there is considerable evidence of climate change and variability in Ontario, as well as significant changes in climate conditions projected by the General Circulation Models (GCMs) for the Great Lakes-St. Lawrence Basin (Table 2). Recent extreme events in other parts of Canada (e.g., 1996 Saguenay-Chicoutimi flood, the 1997 Red River flood, the 1998 ice storm), and the latest El Nino episode have also raised concerns regarding the TNR's vulnerability to similar types of climatic extremes, if not those of greater severity or frequency.

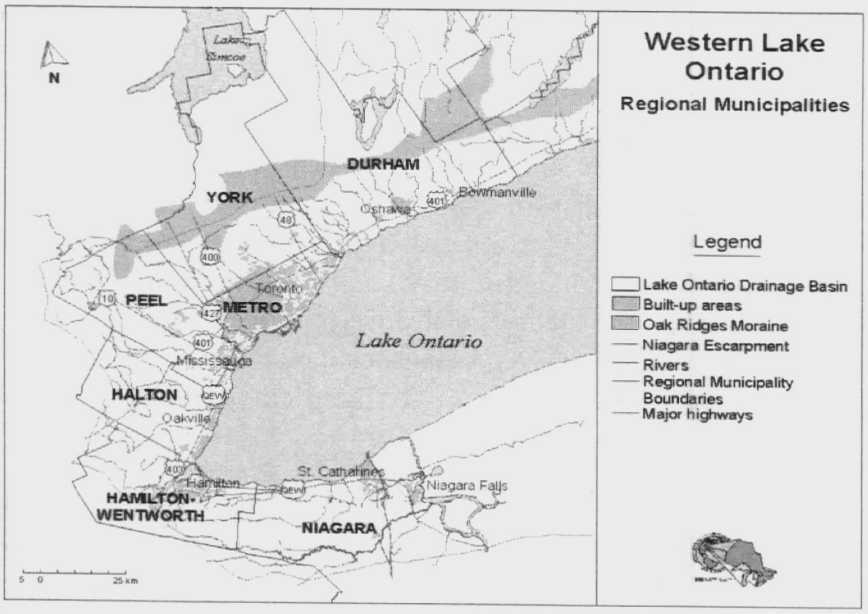

Figure 1: Municipal boundaries and major geographical features of the Toronto-Niagara Region

Table 2: Recent evidence of atmospheric change in Ontario

1.	In the period 1895-1992, the average annual temperature of the Great Lakes-St.Lawrence Lowland increased by 0.6C. Temperature increases varied considerably by season, registering a 1.0C increase in winter temperatures, 0.8C in spring, 0.1C in summer, and 0.3C in autumn (Environment Canada, 1995);
2.	Since approximately 1950, there has been a trend towards increasing precipitation and cloud cover for the Great Lakes-St.Lawrence Lowlands (Mortsch, 1995);
3.	Results from General Circulation Models (GCMs) predict an average annual warming of some 3-8C in Ontario under a 2xCO_2 scenario, with winter increases exceeding those of summer (Mortsch, 1995);
4.	Total [stratospheric] ozone over Toronto declined by approximately 6-8% between 1966-1991 (Government of Canada, 1991);
5.	In southern Ontario, the average number of days per year with an hourly maximum ozone level above 80 ppb (referred to as poor), has been closely related with high temperatures and stationary air masses, notably during the summer of 1988. Presently, half of the ozone is a result of transboundary air pollution from the U.S., especially the Ohio Valley (Ministry of Environment and Energy, 1996).

Sources: Government of Canada, 1991; Hengeveld, 1995; Mortsch., 1995; Ministry of Environment and Energy, 1996.

Second, regional air quality continues to be a major concern for policy makers, especially in terms of the impacts upon human health, and this problem is likely to get worse under climate change. Moreover, air quality in the TNR is greatly affected by southern air masses, which transport upwards of 50 percent of atmospheric pollutants, primarily from the Ohio Valley (Ontario Ministry of the Environment and Energy, 1996). Deregulation of the energy sector across North America, and particularly Ontario (Gibbons and Bjorkquist, 1998) and the Ohio Valley (Love *et al.*, 1998), could further exacerbate the adverse effects from transboundary air pollutants. Local sources of NO_x emissions, however, which contribute to acidic deposition and smog, are also prevalent throughout the TNR, illustrating that sources of air pollutants are both a transboundary and local problem.

> *[The TNR] has the largest concentration of population, industry, and other economic activity in Canada, as well as environmentally sensitive ecosystems, including the most productive farmland in the country. It experiences unique, often localized, atmospheric conditions due to the effects of the Great Lakes, and given the present magnitude and foreseeable growth of population and economic activity, any impacts from and responses to atmospheric change will be magnified here in the nation's economic heartland.*

Third, the TNR has unique (for Canada) natural and socio-economic features. It has the largest concentration of population, industry, and other economic activity in Canada, as well as environmentally sensitive ecosystems, including the most productive farmland in the country. It experiences unique, often localized, atmospheric conditions due to the effects of the Great Lakes. Given the present magnitude and foreseeable growth of population and economic activity, any impacts from and responses to atmospheric change will be magnified here in the nation's economic heartland. From an impacts perspective, the breadth of issues are expansive, ranging from preparing for an anticipated increase in segments of society (e.g., the poor, the elderly) that are acutely vulnerable to atmospheric stresses, to the empowerment of individuals, firms or agencies who may be able to capitalize upon new opportunities arising from atmospheric change. From a mitigation perspective, and considering the recently negotiated Kyoto Protocol, the national commitment to reduce greenhouse gas emissions has been further intensified, and the TNR will be expected to reduce emissions accordingly. However, the recent unexpected announcement by Ontario Hydro to prematurely retire 7 nuclear power plants and replace this energy with coal- or oil-fired electric generation plants directly challenges the regional, if not national, ability to meet the reduction targets of 6 percent below 1990 levels by the year 2010.

Lastly, the TNR has an extensive scientific and policy community engaged in atmospheric issues research. This includes scientists and policy experts based in Environment Canada and other federal departments, Ontario Ministry of the Environment and other provincial ministries, and within municipalities, commissions and conservation authorities located throughout the TNR. Within a two-hour drive from downtown Toronto, faculty and students from a variety of academic disciplines at 9 universities (University of Toronto, Ryerson Polytechnic University, York

University, McMaster University, University of Guelph, Wilfrid Laurier University, University of Waterloo, Trent University and Brock University) are actively engaged in atmospheric change research. In recent years, community response to atmospheric issues has also been significant within the region, notably through the Toronto Atmospheric Fund, and the Hamilton-Wentworth Air Quality Initiative. Furthermore, many non-governmental organizations in the TNR are active in the process to find solutions to atmospheric issues, such as Pollution Probe, the International Council for Local Environmental Initiatives (ICLEI), and the Ontario Clean Air Alliance (OCAA). In addition, countless potential stakeholders exist in the private sector, representing the concerns of various industries with a vested interest in developing effective mitigative and adaptive responses to atmospheric issues (e.g., Ontario Natural Gas Association, Waterfront Regeneration Trust). Collectively, these groups represent an enormous opportunity for the development of collaborative research partnerships and activities.

The intention of the TNR study is not to provide answers to all of the knowledge gaps pertaining to air issues within the region, but rather to begin the challenging task of addressing some of the important science and policy questions that are key pieces to the atmospheric change puzzle.

RESEARCH FRAMEWORK: AN INTEGRATED ASSESSMENT OF ATMOSPHERIC CHANGE IN THE TNR

A number of important knowledge gaps exist at the regional scale of analysis, regarding atmospheric issues. For the TNR Study, important knowledge gaps to be addressed exist in the:

- science of atmospheric stresses and the interactions between them;
- impacts of atmospheric stresses upon the region's ecological, social and economic systems;
- sensitivity and vulnerability of the region's ecological, social and economic systems; and
- effectiveness of appropriate mitigative and adaptive responses.

The challenge facing researchers is how to address these knowledge gaps in an integrative manner? Before outlining a conceptual framework to address this question, it is important to consider what is meant by an "integrated assessment". Separating the term into two parts, "integrated" implies the linking of diverse elements into a unified common model, whereas "assessment" implies a scientific evaluation that extends beyond a synthesis of existing knowledge. Ideally then, the issue of atmospheric change within the TNR should be examined from the most comprehensive and integrative perspective possible, but a more pragmatic approach is undoubtedly needed due to time, financial and human resource constraints. The intention of the TNR study is not to provide answers to all of the knowledge gaps pertaining to air issues within the region, but rather to begin the challenging task of addressing some of the important science and policy questions that are key pieces to the atmospheric change puzzle.

The following research framework can be referred to as an "integrated, full-cycle" model of atmospheric change (Figure 2). The framework is multidimensional in scope, incorporating the core attributes of atmospheric change (the inner interconnected boxes) within the context of four integrative themes (the outer boxes). First, there are the core attributes of the model: emissions, atmospheric change, impacts, and responses. Based on the conventional perturbation/dose-response relationship typically adopted in climate change impacts assessment research (see Smit, 1993), the framework is "full-cycle" because it is extended to include the mitigation side of the atmospheric change equation. With emissions (Box 1), we are interested in air pollutants generated from natural (e.g., volcanoes) and anthropogenic activities (e.g., fossil fuel combustion and production, industrial processes, land use changes, and waste disposal) which contribute to atmospheric change (Box 2). Atmospheric change refers to six atmospheric issues (climate change and variability, stratospheric ozone depletion, acidic deposition, smog, hazardous air pollutants, and particulate matter (Munn, 1995). These issues are driven by several air pollutants, including greenhouse gases, NO_x, SO_x, O_3, PM, volatile organic compounds, pesticides, radionuclides, and heavy metals, whose emissions, concentrations and interactions lead to perturbations in the atmosphere.

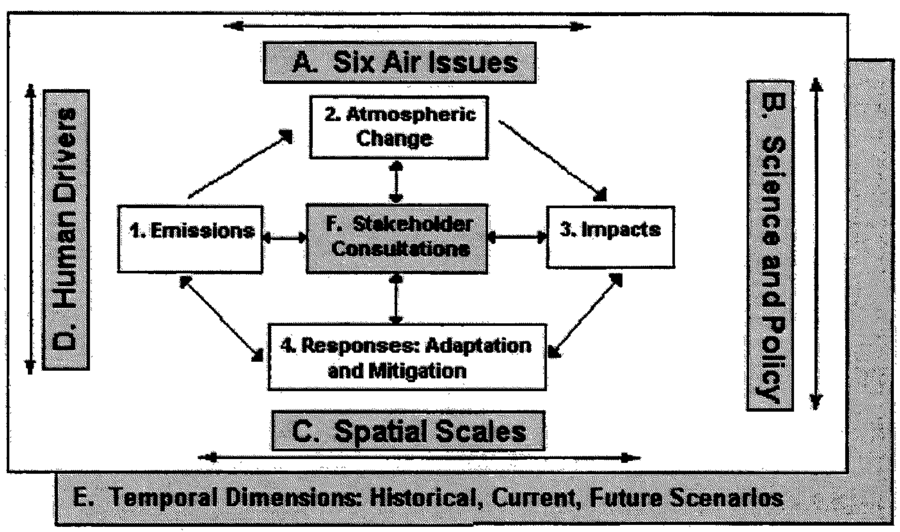

Figure 2: Toronto-Niagara Region Study research framework

Impacts (Box 3) refer to the direct and indirect effects of atmospheric stresses upon our ecological, social and economic systems. According to Smit (1993), impacts assessment involves examining both the nature of the stress (e.g., magnitude, frequency, duration, suddenness and areal extent), and the characteristics of the system being impacted (e.g., degree of stability, resilience, flexibility and vulnerability). A survey of climate change impacts and adaptation literature provides a useful but incomplete list of sectors and systems in the TNR that may be vulnerable to atmospheric change, or capable of capitalizing upon new opportunities (e.g., Watson *et al.*, 1996; Maxwell *et al.*, 1997). Not all sectors and systems listed in the literature apply to the regional scale, or to a region with the specific ecological, social, and economic characteristics of the TNR. Furthermore, extending Cohen's observation that the relationship between climate change and impacts involves people and places (Cohen, 1997), scientists would be well-advised to engage local stakeholders in the process to define the research problem. Stakeholders include individuals, firms, agencies, or departments living/working/operating in the TNR who are, or will be, impacted by atmospheric change. With these qualifiers, a tentative list of sectors and systems that could be assessed in the TNR Study can be identified (Table 3). In addition, TNR study proponents might also adopt the approach taken by the Canada Country Study (Maxwell *et al.*, 1997) and address cross-cutting topics as well, such as costs, extra-territorial issues, extreme events, the urban-rural interface, and sustainability.

Responses (Box 4) describe actions that can be either mitigative (actions to reduce emissions) or adaptive (actions to minimize the risk or costs associated with atmospheric issues or to capitalize upon new opportunities) in nature. A wide range of mitigative and adaptive responses exist, and have been addressed elsewhere in the literature (Smit, 1993; Watson *et al.*, 1996; Maxwell *et al.*, 1997). As with impacts, not all of these responses are applicable to the TNR, and the specific actions examined are also best identified in consultation with stakeholders. Nonetheless, some general characteristics of mitigation and adaptation responses can be identified. Responses are likely to be autonomous in nature, involving individuals, firms, agencies/organizations, neighbourhoods or communities, or could be driven by policy decisions at the municipal, regional, provincial, national, binational, and multinational levels of government.

The various components of the research framework depicted in Figure 2 are interconnected in several ways. The linking of emissions, atmospheric change, impacts and responses is inherently integrative. The assessment of impacts, for example, can be integrated from either a horizontal or vertical perspective. The former approach is the more traditional of the two, for example assessing the linkages between the impacts of climate change on water resources and the effects on agriculture. The latter approach is less common, but enables the researcher to adopt the core attributes of the atmospheric change framework, such as linking mitigative actions with impacts. For instance, a vertical linkage might include an assessment of the co-benefits of GHG emission reductions upon other atmospheric issues (smog or acidic deposition), and the resulting impacts upon human health.

A further five integrative themes operate in the model. The most obvious of these concerns the interaction of the six atmospheric issues (Box A), examining some combination of the stresses, and their additive or synergistic effects. The second integrating theme concerns the linking of science and policy (Box B). Whether there is a need for policy to be science-driven, or vice versa, an important aspect of this study is to link scientists directly with policy-makers and other stakeholders. Examining atmospheric issues also requires one to consider various spatial scales (Box C). Depending upon the atmospheric issue, air pollutants can originate from regional or global sources, and are often transboundary in nature. Responding to emissions from coal-fired power plants, for example, may require adaptations at the local scale, whereas policy responses directed at mitigation would be required at the municipal, provincial, national and binational levels of government. "Human Drivers" is the fourth integration theme in the framework (Box D), and is largely directed at the processes underlying emissions of atmospheric pollutants. Transportation and land use decisions are perhaps the most obvious of these, as well as additional factors contributing to increased consumption of fossil fuels, such as population and economic growth.

Table 3: Elements of ecological, social and economic systems that could be impacted by atmospheric change in the Toronto-Niagara Region

1.	Biodiversity and natural ecosystems
2.	Water resources (quality, quantity, waterfront)
3.	Agriculture (tender fruit, grape and wine, livestock)
4.	Recreation and tourism (ski industry, sport fishing, boating)
5.	Energy (hydro, nuclear, natural gas, renewables)
6.	Transportation
7.	Construction
8.	Urban infrastructure
9.	Human health (heat stress, infectious diseases, respiratory illnesses)

Sources: adapted from Watson *et al.*, 1996; Maxwell *et al.*, 1997.

The final integrative aspect of the framework involves the temporal dimension that is adopted in specific research projects (Box E). Many options are available, each having particular strengths and limitations. Given the breadth of the research problem, which incorporates both mitigative and adaptive responses, no single approach or time scale is being advocated at this time. In fact, it may be more appropriate to adopt a variety of temporal dimensions as they apply to specific research projects. This could involve a reconstruction of the TNR's paleoclimatological record, or an assessment of some future projection, based upon an historical or spatial analogue, or various scenarios generated by General Circulation Models (GCMs) (e.g., 2 or 3xCO_2 levels). Current conditions could be the focus of analysis, as well as recent trends. Munn (1991) also suggested the development of historical futures where, instead of generating future scenarios of atmospheric change based upon current trends, one begins by identifying a future vision of where we want to be, then backtrack and implement policies which will empower society to achieve this goal.

Throughout this description of the TNR Study research framework, the role of stakeholders has been emphasized and researchers are encouraged, if not expected, to engage stakeholders in the process to define and shape the research problem, to help support research and communication activities, and to help disseminate the research findings.

The last component of the research framework concerns the extensive role of stakeholders (Box F). Their role is not limited to the communication stage, where the research findings are delivered to policy-makers with the expectation that the recommendations will be universally embraced and implemented into policy. Such an approach is rarely successful in influencing policy, and merely tends to reinforce the very gulf that separates the science and policy communities. Throughout this description of the TNR Study research framework, the role of stakeholders has been emphasized and researchers are encouraged, if not expected, to engage stakeholders in the process to define and shape the research problem, to help support research and communication activities, and to help disseminate the research findings. These principles were successfully incorporated to some degree within the Great Lakes-St.Lawrence Basin Project (Mortsch *et al.*, 1998; Mortsch and Mills, 1996) and the Mackenzie Basin Impacts Study (Cohen, 1997). However, it would be beneficial to further embody these principles in the TNR Study, possibly by following the Integrated Environmental Assessment (IEA) approach adopted by the ULYSSES Project (Urban LifestYles, SuStainability and Integrated Environmental ASsessment) (Kasemir, 1996). Emphasis within ULYSSES is placed on incorporating scientific inquiry into political decision-making through the use of "IEA-juries" (the combining of focus groups and citizen juries) to generate response strategies that better reflect the cultural and political realities of the region than those developed under the more traditional top-down science-to-policy approach.

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CONCLUSIONS

The challenge of embarking on a study of this kind is enormous, but the need has never been greater, and the task never more important. Given the breadth and depth of the research problem, obviously it is impossible to cover all aspects of atmospheric change. However, specific aspects of this complex problem can be addressed and by doing so help to provide an improved foundation for responding to multiple air issues in the TNR. The TNR Study approach is unique in considering the following aspects in the research design to better understand scientific issues and policy responses to atmospheric change:

- interaction of atmospheric issues;
- linking of emissions, impacts and the assessment of both mitigative and adaptive responses;
- focus on an urban-centred region
- integration of science, social science, and policy;
- interdisciplinary character; and
- extensive stakeholder involvement

As well, there are many benefits to be achieved by examining atmospheric change in terms of its temporal and spatial dimensions. Two of the biggest obstacles to communicating climate change and stimulating policy responses have been the temporal and spatial dimensions of the problem. By broadening climate change research and discussion to include other atmospheric issues, the problem is brought into the current time frame, where understanding the emissions and impacts and developing effective mitigative and adaptive actions are more immediate and regional-scale concerns. In short, the TNR Study addresses an environmental challenge that has significant meaning for our own back yard, today, tomorrow and throughout the next millennium. It is time that the research and policy communities move forward and construct a solid foundation from which to make sound decisions.

Two of the biggest obstacles to communicating climate change and stimulating policy responses have been the temporal and spatial dimensions of the problem. By broadening climate change research and discussion to include other atmospheric issues. the problem is brought into the current time frame, where understanding the emissions and impacts and developing effective mitigative and adaptive actions are more immediate and regional-scale concerns.

REFERENCES

Chiotti, Q. 1997. Atmospheric Change and the Toronto-Niagara Region. In Ogilvie, K.B., Bell, D.V.J., White, R. and Chiotti, Q. (eds) *Climate Variability, Atmospheric Change and Human Health Conference Proceedings.* November 4-5, 1996, Pollution Probe, Toronto, Ontario, pp. 89-111.

Chiotti, Q., R. White, R. Gilbert, K. Ogilvie, and P. Blais 1997. Preparing for Current and Future Atmospheric Change in the Toronto-Niagara Region. In K. Ogilvie, D. Bell, R. White, and Q. Chiotti (eds) *Climate Variability, Atmospheric Change and Human Health Conference Proceedings.* November 4-5, 1996, Pollution Probe, Toronto, Ontario, Appendix III.

Cohen, S.J. (ed) 1997. *Mackenzie Basin Impact Study (MBIS): Final Report.* Environment Canada, Downsview, Ontario.

Gibbons, J. and S. Bjorkquist 1998. *Electricity Competition and Clean Air.* Ontario Clean Air Alliance, Toronto, Ontario.

Hengeveld, H. 1995. *Understanding Atmospheric Change: A Survey of the Background Science and Implications of Climate Change and Ozone Depletion*, second edition. Minister of Supply and Services Canada, Ottawa, Ottawa.

Hrebenyk, B., J. Young, and P. Coutts, 1998. *Effects of Weather, Climate Variability and Climate Change on Air Issues in the Toronto-Niagara Region/Great Lakes Basin.* Report prepared by SENES Consultants Limited for Environment Canada-Ontario Region.

Kasemir, B. 1996. *ULYSSES: Summary of the Envisaged Project*, unpublished manuscript, EAWAG, Swiss Federal Institute for Environmental Science and Technology, Switzerland.

Koshida, G., B. Mills, L. Mortsch, and D. McGillivray 1993. *Climate Sensitivity, Variability and Adaptation Issues in the* Great Lakes-St.Lawrence *Basin: A Reference Document.* Climate Adaptation Branch Bulletin 93-06. Environment Canada, Atmospheric Environment Service, Downsview, Ontario.

Krupa, S.V. and R.N. Kickert 1989. The greenhouse effect: impacts of UV-B, CO2 and O3 on vegetation. *Environmental Pollution* 61: 263-393.

Love, P., D. Pengelly, S. Labatt, K. Ogilvie, B. Lourie, and B. Kelly 1998. *Emissions from Coal-Fired Electric Stations: Environmental Health Effects and Reduction Options.* Institute for Environmental Studies, University of Toronto and Pollution Probe, Toronto, Ontario.

Maarouf, A. and J. Smith 1997. Interactions Amongst Policies Designed to Resolve Individual Air Issues. *Environmental Monitoring and Assessment* 46: 5-21.

Maxwell, B., N. Mayer, and R. Street (eds) 1997. *The Canada Country Study: Climate Impacts and Adaptation – National Summary for Policy Makers.* Environment Canada, Ottawa.

Mortsch, L. D. (ed.) (1995) *Climate Change Impacts: An Ontario Perspective.* Report prepared by Environment Canada, Smith and Lavender Consultants and Sustainable Futures for the Ontario Round Table on Environment and Economy Transportation Collaborative. Toronto: Air Issues Branch and EARG, Environment Canada; Ontario Hydro; Ontario Ministry of the Environment and Energy; Royal Society of Canada: Canadian Global Change Program.

Mortsch, L., S. Quon, L. Craig, B. Mills, and B. Wrenn (eds) 1998. *Adapting to Climate Change and Variability in the Great Lakes - St. Lawrence Basin, Proceedings of a Binational Symposium*, May 13-15, 1997. Environment Canada, Downsview, Ontario.

Mortsch, L. and B. Mills (eds) 1996. *Great Lakes-St.Lawrence Basin Project Progress Report #1: Adapting to the Impacts of Climate Change and Variability.* Environment Canada, Downsview, Ontario.

Munn, R.E. (ed) 1996. *Atmospheric Change and Biodiversity: Formulating a Canadian Science Agenda, Summary Report of a Workshop*, February 26-29, 1996. Institute for Environmental Studies, Toronto, Ontario.

Munn, R.E. (ed) 1995. *Atmospheric Change in Canada: Assessing the Whole as Well as the Parts, Summary Report of a Workshop*, March 27-29, 1995. Institute for Environmental Studies, Toronto, Ontario.

Munn, R.E. 1991. A New Approach to Environmental Policy Making: the European Futures Study. *The Science of the Total Environment*, 108, 163-172.

Ogilvie, K., D. Bell, R. White, and Q. Chiotti (eds) 1997. *Climate Variability, Atmospheric Change and Human Health Conference Proceedings*, November 4-5, 1996, Pollution Probe, Toronto, Ontario.

Ontario Climate Advisory Committee (OCAC) 1997. *Workshop on Atmospheric Ozone: Proceedings of the Ontario Climate Advisory Committee*, September 30 - October 1, 1996. Environment Canada - Ontario Region, Downsview, Ontario.

Ontario Ministry of the Environment and Energy 1996. *Supporting Document for Towards a SMOG Plan for Ontario: A Discussion Paper.* Ontario Ministry of the Environment and Energy, Toronto, Ontario.

Smit, B. (ed) 1993. *Adaptation to Climatic Variability and Change: Report of the Task Force on Climate Adaptation*, Occasional Paper No. 19. Department of Geography, University of Guelph, Guelph, Ontario.

The Acidifying Emissions Task Group (TAETG) 1997. *Towards a National Acid Rain Strategy.* Environment Canada, Ottawa, Ontario.

Timmerman, P. and L. Grima (eds) 1985. *Climate Impact Assessment in the Great Lakes Basin: Overview and Research Recommendations*, Proceedings from a Canadian Climate Program Workshop, 8-9 February, 1985, Environmental Monograph No. 7. Institute for Environmental Studies, University of Toronto, Toronto, Ontario.

Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds) 1996. *Climate Change 1995 - Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

White, J.C. (ed) 1989. *Global Climate Change Linkages: Acid Rain, Air Quality and Stratospheric Ozone, Proceedings of a Conference*: Elsevier, New York.

SECTION 2: ATMOSPHERIC SCIENCE AND POLICY LINKAGES

Toronto-Niagara Region Study

on atmospheric change

Effects of Weather, Climate Variability and Climate Change on Air Issues in the Toronto-Niagara Region/Great Lakes Basin

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INTRODUCTION

The purpose of this paper is to present the main findings of a report commissioned by Environment Canada-Ontario Region to review and assess the scientific understanding of integrated atmospheric issues and approaches to policy development (Hrebenyk *et al.*, 1998). The paper presents what is known about the effects of weather, climate variability and climate change on regional air issues and discusses the degree to which policy responses consider the integrated nature of air issues. The paper identifies scientific and policy research needs to better understand and respond to integrated air issues in the Toronto-Niagara Region.

METEOROLOGY AND AIR POLLUTION

Ambient concentrations of air pollutants are linked to meteorological conditions through a complex set of non-linear, physical and chemical interactions which determine their dispersal, transformation and removal from the atmosphere. In the case of biogenic emissions, meteorological conditions influence the rate of emission for a multitude of volatile organic compounds, sulphur-bearing gases such as DMS and H_2S, ammonia, oxides of nitrogen, and some volatile and semi-volatile organic compounds such as pesticides that are retained in soils after application. During periods of drought, wind erosion of surface soils can inject large quantities of particulate matter into the atmosphere. Certain constituents of soil-derived matter can subsequently act to buffer the acidity of sulphates and nitrates in rainfall. Drought conditions also contribute to the number and extent of forest fires that can increase the regional to global levels of particulate matter. Meteorological conditions can also influence the rate of emission from anthropogenic sources such as motor vehicles, power generation, as well as commercial and residential heating and cooling.

The change in a specific meteorological parameter can lead to primary changes in air quality parameters which in turn lead to other air quality changes or impacts on the environment. The potential impacts of various climate changes on air quality are presented in Table 1. Once emitted, the variability of parameters such as temperature, humidity, clouds and solar radiation can either increase or retard the formation rate of secondary air pollutants such as sulphates, nitrates and organic aerosols, as well as the transformation of toxic air pollutants into other toxic or non-toxic species. Much of this activity is inherently tied to the formation, movement and persistence of synoptic scale weather systems (i.e., cyclones and anticyclones). The climatology of high air pollution episodes for regional scale smog is related to the frequency and persistence of stagnant anticyclonic weather patterns. The build-up of high concentrations of air pollutants under these anticyclonic systems is also linked to their subsequent long range transport and wet deposition in cyclonic systems.

Despite the relative importance of meteorological variability in determining air pollution levels, the development of air quality management policies in North America over the last two decades has not explicitly incorporated the assessment of climate variability on interdecadal time scales with the development of emission control strategies for air quality issues such as smog, acidic deposition and hazardous air pollutants.

In the Great Lakes Basin, evidence for the influence of meteorological conditions on air pollutant levels is available in the analyses of the variability in ground-level ozone, fine particulate matter and acid deposition. Up to 90% of the ozone in southern Ontario can be related to long range transport of ozone and its precursors from source regions in the United States. At least one study has reported that the levels of fine particulate matter in the Windsor area are affected by medium and long range transport from across the U.S. border. Approximately 43-60% of the variability in daily ozone concentrations in the Windsor-Quebec City corridor appears to be related to maximum daily temperature, air mass trajectory, the thickness of the 850-1000 mb level and relative humidity. Similarly, about 46-81% of the year-to-year sulphate deposition in eastern Canada is related to meteorological variability, including large deposition events or episodes that lead to the build-up of acidic pollutants in air and their deposition in moderate to heavy precipitation events. Some studies have noted that the year-to-year variability of PCBs and other persistent organic pollutants in the atmosphere over the Great Lakes region is highly dependent on interannual temperature variability. Episodic high concentrations of pesticides were reported for 1987 and 1988, two years that also happened to have significantly more episodes of high ground-level ozone. Thus, all of the major air quality issues are intrinsically related to short-term (i.e., interannual) meteorological variability.

Table 1. Potential impacts of climate change on air quality

Initial Condition and Primary Impacts	Secondary Impacts on Atmospheric Conditions	Additional Effects on Environment and Health
(A) AS TEMPERATURE INCREASES		
Power demand in summer increases	⇒ VOC increases ⇒ NO_x increases ⇒ SO_2 increases	⇒ O_3 increases ⇒ Acidic deposition increases ⇒ Acidic deposition increases
Cloud cover increases	⇒ O_3 decreases	
Precipitation decreases*	⇒ Dust levels increase	
Greater frequency of stagnating anticyclones	⇒ Regional O_3 increases	⇒ Smog levels and health impacts increase
Transport trajectories change	⇒ Reduced wind speed ⇒ Distribution of acid precipitation changes	⇒ Dust levels decrease
H_2O_2 increases	⇒ Chemical reaction rates change	
OH increases	⇒ Chemical reaction rates change	
Water vapour levels increase	⇒ Aerosol concentrations	⇒ Health and vegetation impacts increase
Greater atmospheric instability	⇒ Local pollutant levels increase	
Isoprene emissions increase	⇒ O_3 increases	
Temperature extremes become more frequent	⇒ Increased frequency of high air pollution episodes	
Periods of drought are more severe	⇒ Increased frequency of high air pollution episodes	
Transpiration from vegetation is reduced	⇒ Changes in regional air chemistry ⇒ Changes in concentration of O_3 ⇒ Changes in concentration of fine particles	⇒ Changes in impact on human health
Boundary layer depth is increased	⇒ O_3 decreases	
Lake evaporation increases	⇒ Increased volatilization of HAPS from lakes	
(B) AS TEMPERATURE DECREASES		
Precipitation increases*	⇒ Dust levels decrease	
(C) AS CFC's IN THE STRATOSPHERE INCREASES		
Temperature + UV Radiation increases	GO TO (A)	
VOC from vegetation increases	⇒ O_3 increases	⇒ Health impacts increase
NO_x from soils increases	⇒ O_3 increases	⇒ Health impacts increase
Cloud cover increases	⇒ O_3 decreases	
Aerosols (SO_4 & NO_3) increase	⇒ Acidic deposition increases	⇒ Impacts in lakes increase, more Hg mobilized ⇒ Impact on fish increases ⇒ Impact on humans increases
(D) WITH PRECIPITATION, O_3, WIND SPEED, HUMIDITY, TEMPERATURE LOW AND PRESSURE HIGH		
NO_3 increases	⇒ Acidic deposition increases	
(E) WITH STRATOSPHERIC OZONE DEPLETION		
Urban O_3 could decrease or increase		

* Due to the interaction of other variables (e.g., cloud cover, winds, ocean circulation), precipitation may increase or decrease in response to global temperature increases. The selection above is based on trends in the last 50 years.

Source: Modified from Hrebenyk *et al.*, 1998.

AIR QUALITY MANAGEMENT

Despite the relative importance of meteorological variability in determining air pollution levels, the development of air quality management policies in North America over the last two decades has not explicitly incorporated the assessment of climate variability on interdecadal time scales with the development of emission control strategies for air quality issues such as smog, acidic deposition and hazardous air pollutants. For example, the traditional approach adopted in the U.S. for formulating regional air quality management plans for ozone attainment has been to select a multi-day episode in a base year and then determine, through photochemical modelling, the degree of reduction in VOC and NO_x precursor emissions from anthropogenic sources that would be required to reduce the 1-hour ambient ozone concentration below 120 ppb for the meteorological conditions of that episode (Kuklin and Seinfeld, 1995). Projected growth in emissions to some future year is also accounted for in this approach. Because the heat wave in 1988 was responsible for a sharp increase in the total number of ozone non-attainment areas in the U.S. (Chock, 1995), the meteorological conditions prevailing in the summer of 1988 are often used as the base year for photochemical episode modelling studies. This approach has also been adopted in Canada for the NO_x/VOC Management Plan and in Ontario for the Ontario Smog Plan (OSP). In the Windsor-Quebec City Corridor (WQC), the period of record considered by the NO_x/VOC Management Plan for the development of emission reduction strategies was 1983-89, with 1988 as the base year of highest recorded maximum ozone levels (Environment Canada, 1990). Similarly, a high ozone episode from August 1988 was used to evaluate the performance of photochemical models considered in the development of the OSP (MOEE, 1996).

However, as the National Research Council (NRC, 1991) noted, the unusually high ambient ozone concentrations that occurred in 1983 and 1988 in the United States and Canada cannot be assumed to be true anomalies because the period of record considered (1980-1989) was too short to capture the full range of potential meteorological conditions. Since it is believed likely that meteorological fluctuations were largely responsible for the high concentrations in 1983 and 1988, as well as the low concentrations in 1989, it is necessary to first determine whether the range of meteorological fluctuations experienced during this period adequately represents the complete range of fluctuations that might be experienced over longer (i.e., interdecadal) time scales. In defining air quality management plans based on projections of anthropogenic emissions to the year 2010 or 2020, is it not also necessary to consider projections of possible changes in the range of meteorological fluctuations which might arise from changes in natural climate variability on interdecadal time scales? In the United States, the question of interannual meteorological variability has been addressed by the adoption in 1997 of new ambient air quality standards for ozone and fine particulate matter which are based on the 98th percentile value averaged over a three year period. This approach effectively eliminates concerns over short-term, interannual climatic variability from policy issues because occasional high pollutant concentrations which exceed the standards due to unusual meteorological conditions are removed since they are not relevant in determining whether or not a region is in attainment of the air quality standards. However, this U.S. policy change does not address lower frequency, interdecadal climate variability.

The question that needs to be asked in defining air quality management plans based on projections of anthropogenic emissions to the year 2010 or 2020, is whether it is not also necessary to consider projections of possible changes in the range of meteorological fluctuations which might arise from changes in natural climate variability on interdecadal time scales.

Short-term meteorological variability is also not considered in defining allowable emissions for industrial air emission permits issued by provincial or state regulatory agencies in Canada and the United States. In principle, a regulatory agency in either country may require up to five years of meteorological data to be used in an air dispersion modelling assessment in support of an emission permit application. It is assumed that the use of five years of meteorological data should account for a significant degree of interannual climate variability. However, in practice, it is often difficult to obtain five years of representative meteorological data for a particular site, and many air quality impact assessments are based on as little as one year of meteorological data. In special cases in the United States, a state agency has the authority to limit the requirement for on-site meteorological data collection to as little as four months prior to issuing an air emission permit if, in the opinion of the regulatory official, this length of data record is considered sufficient to conduct a "complete and adequate analysis" of emission impacts on air quality. However, what constitutes a complete and adequate analysis is undefined, and left to the discretion of the regulatory official (USEPA, 1990). Thus, in the United States, permitting of emission sources often does not consider interannual variability in determining appropriate emission limits for individual sources and, in some cases, interannual variability may be ignored entirely.

In the past, the use of a point-of-impingement (POI) approach for air pollutant emissions from point sources in Ontario implicitly incorporated climatic variability. The air quality impact assessment of the release was based on the use of a theoretical set of meteorological conditions that would be expected to result in the maximum ground-level concentration. However, Ontario has recently announced a decision to discontinue the use of POI and adopt those methods currently used by the USEPA for dispersion modelling assessments. Moreover, POI is not suitable for assessing impacts from large area sources or those impacts related to persistent pollutants, global warming, ozone depleting substances, or secondary aerosol formation. For the latter air quality issues, climatic variability on interdecadal time scales is not considered either implicitly or explicitly. For example, recently proposed national and international policies targeting greenhouse gas emissions are designed to deal with the long-term trends in climate change rather than with climate variability on interdecadal time scales. In fact, climatic variability on these time scales is often referred to as "white noise" that needs to be filtered out of meteorological time series data sets in order to detect the trends in climate change, the primary topic of interest.

INFLUENCES ON NATURAL CLIMATE VARIABILITY

It is now well recognized that the natural variability of the earth's climate system incorporates substantial periods of warming and cooling over decadal-to-centennial time scales (Hunt, 1998). Within the past millennium, historical examples of such long-term climate anomalies include the Medieval Warm Period (1000-1250) and the Little Ice Age (1300-1820). According to Hunt, naturally-occurring, non-linear interactions between the atmosphere and oceans, at least as simulated within a coupled ocean-atmosphere general circulation model, are capable of explaining the existence of both high frequency interannual variability in weather phenomena, as well as lower frequency, persistent climate anomalies on multi-decadal time scales, without resorting to any external forcing mechanisms such as solar fluctuations, volcanic eruptions or greenhouse warming. Over a 500-year simulation using a climate model which satisfactorily replicates many aspects of the present climate, Hunt noted that ocean-atmosphere interactions alone were capable of inducing distinct climatic anomalies of warm and cold episodes lasting several decades. This is analogous to the warming period of the past century from 1900 to 1940, followed by the cooling period from 1940 to the late 1970's. Within the climate modelling output presented by Hunt, neither warming nor cooling trends were associated with monotonic global temperature anomalies, and exhibited considerable yearly variability, precisely as observed with present day climatic variability. The maximum range in global mean temperature generated by the model over the 500-year simulation was 0.7^0C, which is of the same order of magnitude as the observed increase in global mean temperature over the past decade of about 0.5^0C ($\pm 0.2^0$C). Local temperature anomalies of several degrees were associated with warming and cooling trends. Thus, local temperature anomalies were simulated to be greater than the anomalies in global mean temperature.

The implication of the analysis presented by Hunt (1998) is that coherent processes in the ocean-atmosphere system alone are capable of producing persistent, multi-decadal climate trends without external forcing mechanisms. However, while ocean-atmosphere dynamics can account for much of the observed climatic variability, the full spectrum of potential quasi-periodic, interannual, interdecadal and intercentennial influences on natural climate variability are described in Table 2 (Huggett, 1997).

The dominant influence on interannual climate variability appears to be related to ocean-atmosphere interactions associated with sea surface temperatures anomalies of the ENSO cycle in the tropical Pacific, while the North Atlantic Oscillation (NAO) in sea surface temperatures may introduce lower frequency variability on 20 year cycles. Occasional volcanic eruptions may superimpose additional short-term climate anomalies. The longer term variations over multiple decades arising from dynamic instabilities between oceans and atmosphere discussed by Hunt, as well as the 80, 200 and 2000 year cycles listed in Table 2, have not been studied in as much detail to date. They are only mentioned here as significant sources of climatic variability that should not be overlooked.

The existence of such major modes of natural climate variability should not be interpreted as implying that global warming due to greenhouse gases has not occurred during the past century. Rather, as indicated by the modelling analysis presented by Hunt (1998), it implies that natural climate variability is capable of producing changes in climate variables that are at least as large as the reported magnitude of global warming currently being attributed to increased concentrations of greenhouse gases. However, the existence of natural climate variability of the magnitude indicated by Hunt's analysis increases the difficulty in separating the trends associated with anthropogenically-induced climate warming from those arising from purely natural processes because the natural variability can serve to obscure or distort greenhouse warming trends. For example, Hunt suggested that, in an equilibrium $2xCO_2$ climate, natural variability may be capable of occasionally overwhelming the CO_2-induced warming on a seasonal basis over extensive regions of the earth.

Table 2: Potential influences on natural climate variability (Huggett, 1997)

TIME FRAME	DESCRIPTION
26 months	Quasi-biennial oscillations (east phase to west phase) in the direction of wind flow in the tropical stratosphere referred to as the QBO
2-7 years	Rapid switch in atmospheric pressure distribution across the southern Pacific Ocean which is linked to changes in atmospheric and sea surface temperatures and together is termed the El Nino-Southern Oscillation (ENSO)
~11 years	Quasi-periodic variation in upper air flows corresponding to the solar sunspot cycle
~18.6 years	Quasi-periodic variation corresponding to the lunar nodal cycle; quasi-20 year oscillations in the sea surface temperatures of the North Atlantic
~80 years	Quasi-periodic variation corresponding to the Gleissberg cycle of solar activity that was first detected in records of auroral activity in the polar regions over the last 130 years
~200 years	Quasi-periodic variations, possibly corresponding to the solar orbital cycle
~2,000 years	Quasi-periodic variation of uncertain correspondence detected in radiocarbon dating of tree rings over the last 9,000 years

...natural climate variability is capable of producing changes in climate variables that are at least as large as the reported magnitude of global warming currently being attributed to increased concentrations of greenhouse gases.

From a regulatory perspective, natural climate variability on multi-decadal time scales has two possible implications:

1) Policies adopted to manage such air quality issues as regional smog and acid deposition during a cooling period may underestimate the degree of emission control that could be required if the cooling period abruptly ends and is followed by a warming period.

2) Policies adopted at the end of a warming period may appear to be more effective as the local climate changes from a period of warming to a cooling trend.

Given the relatively short period of available air pollution monitoring data (i.e., about 20-25 years), there has been little opportunity to explore issues related to the effect of climate anomalies on air quality issues to date. Moreover, despite the fact that climatic variability has been all but ignored in air quality policy development to date, significant progress has been achieved in reducing some air pollutant levels. For example, there appears to have been a significant reduction in sulphate deposition over the period from 1980 to 1993, and levels of particulate matter have declined over the same period. Ground-level ozone has also been declining in most regions of northeastern North America, but not within the Windsor-Quebec City corridor. Nitrate deposition has not been reduced either, and it is not clear to what extent the lack of progress may be related to the variability in meteorological processes. However, it may be relevant to ask whether the air quality management policies that were adopted during the 1980's and 1990's will still serve us well after the year 2000 if we were to suddenly return to the climate that existed in the Great Lakes Basin during the cooler, drier 1950's and 1960's, or during the drought years of the 1930's.

Therefore, in developing future policies, it may be worthwhile to consider the significance of meteorological variability over the next few decades. The observational record of meteorology during the past century indicates the occurrence of significant variations in a number of climate parameters. The frequency and intensity of cyclones and anticyclones has differed during at least two, and possibly three, distinct periods lasting several decades each. Surface temperatures have shown periods of warming in the early part of this century, followed by a cooling trend after 1940 and then another warming trend beginning in the 1970's. Precipitation has increased overall during this century, but there have been distinct periods of drought in the 1930's and 1950's, with a wet period in the Great Lakes Basin beginning in the 1960's. Total snowfall has decreased in the late winter and spring, particularly since the end of the 1970's, coinciding with the period of more intense ENSO activity in the tropical Pacific. Cloud cover has also increased in the past century over Canada and the Northern Hemisphere as a whole, although less is known about the variability of cloud cover over the Great Lakes Basin in relation to cyclonic and anticyclonic activity. It has been suggested that clouds play an important role in maintaining the pressure field over the Great Lakes region and may be an important factor in determining the association between cyclonic/anticyclonic activity and temperature in the region.

It may be relevant to ask whether the air quality management policies that were adopted during the 1980's and 1990's will still serve us well after the year 2000 if we were to suddenly return to the climate that existed in the Great Lakes Basin during the cooler, drier 1950's and 1960's, or during the drought years of the 1930's.

With respect to long-term climate change, it is still uncertain what effect greenhouse gas-induced global warming will have on future climate variability (Turekian, 1996). According to Turekian, changes in climate variability will occur, but there is no clear indication of how the character of interannual variability may change due to greenhouse warming. The potential exists for multi-faceted and complicated, even counter-intuitive, changes in variability. Therefore, in planning for the future of air quality management policies, it may be crucial to first understand the implications of climate change due to anthropogenic emissions on natural climate variability.

Due to the complexity of the interactions between meteorology and air quality, it is difficult to predict the potential impact of a changing climate on future air quality. Consider, for example, the ongoing debate about the efficacy of controlling NO_x emissions versus VOC emissions for reducing ground-level ozone. Despite the fact that we have near-perfect knowledge of the existing meteorology and reasonably accurate estimates of actual emission inventories, there is still considerable difficulty in determining whether it would be better to control NO_x emissions alone, or adopt some combination of both NO_x and VOC control strategies. The current level of knowledge for the formation of secondary organic aerosols is imperfect at best. Yet, the resolution of these issues is relatively straightforward compared with the requirements for making quantitative estimates of future air quality impacts due to climate change. Given the remaining large degree of uncertainty concerning the effects of global climate change on regional physical, chemical and biological processes and feedback mechanisms, quantitative projections which go beyond the level of qualitative assumptions as presented in Table 1 will require the development of more comprehensive analytical tools that incorporate the effects of both natural climate variability and anthropogenically-induced climate change.

According to Turekian (1996), changes in climate variability will occur, but there is no clear indication of how the character of interannual variability may change due to greenhouse warming. There is a potential for multi-faceted and complicated, even counter-intuitive, changes in variability.

APPROACHES TO POLICY DEVELOPMENT

The following list summarizes important issues and statements to consider in the formation of potential policy approaches to integrated analyses of atmospheric issues as they are impacted by climate variability:

- the atmosphere is no longer external to the decision making process, it is now affected by human activities;
- human health and environmental impacts could be significantly reduced by focussing collaboratively on a few key sources;
- terrestrial and aquatic ecosystems play important roles in the transport of many pollutants, acting as both sources and sinks;
- once deposited, many pollutants can bioaccumulate through food webs reaching humans in highly concentrated and harmful levels;
- domestic investment in pollution reduction;
- improved science and modelling capacities;
- harmonized emission inventories;
- generation and use of quality information;

- coordinated monitoring programs; and
- the need exists to catalyze international, inter-agency and interdisciplinary cooperation in 1) measuring, monitoring and assessing pollutant atmospheric releases; 2) studying transport and transportation, wet and dry deposition; and 3) understanding pollutant pathways in terrestrial and aquatic ecosystems.

According to The Acidifying Emissions Task Group (1997) an integrated, multi-pollutant approach to managing pollution should happen at the following levels:

- developing national policies;
- developing regional air quality management plans;
- managing all pollutants in a given source region to achieve multiple benefits;
- issuing new regulations on emissions;
- promoting research on environmental effects; and
- regionally orienting climate change initiatives.

The U.S. is developing an integrated strategy to manage ground-level ozone, particulate matter and regional haze in designated "areas of influence" that affect downwind "areas of violation". Canada is moving in a similar direction, with Regional Smog Management Plans and the Sulphur Oxide Management Area (SOMA). These and other regional activities could form the basis for integrated plans to deal with multiple air issues, since many pollutants have common emission sources.

RECOMMENDATIONS

Scientific Research Activities

Scientific research needs to improve our understanding and responses to the integrated nature of air issues in the Toronto-Niagara Region are summarized in Table 3.

To better understand the effect of climate variability and climate change on regional air quality, it is necessary to first comprehend the potential causes of climate variability and change over different spatial and temporal scales. While observational data can assist us to a certain extent, given the long time scales of certain periodic fluctuations reported in the literature, a stronger reliance on climate models will be needed. These will include general circulation models for characterizing large scale features of the global and hemispheric atmospheric circulation patterns, as well as finer scale, regional models that take into account the moderating influence of the Great Lakes themselves on the local climate. In short, there is a need to develop a comprehensive understanding of climate variability on large and small scales, and determine the relationship between climate variability and variability in air pollutant levels.

As reported by Kittel *et al.* (1998), coupled ocean-atmosphere-land models are proving to be unusually sensitive to errors in component systems. This leads to problems in correctly simulating (1) the climatology and the spectrum of climatic variations for current climate conditions, and (2) potential climate variability in the future under various climate change scenarios. Essentially all existing coupled atmosphere-ocean general circulation models (AOGCMs) being used by various international climate modelling groups are subject to large regional biases for both temperature and precipitation, particularly in regions of strong gradients such as those that exist in central North America, including the Great Lakes Basin. Therefore, there is a need to improve the capability to model climate variability and climate change at the regional level for the Basin as a whole.

...there is a need to develop a comprehensive understanding of climate variability on large and small scales, and determine the relationship between climate variability and variability in air pollutant levels.

Table 3. Summary of integrated air issue scientific research needs

- Improve the capability to model climate variability and climate change at the regional level for the Basin as a whole.
- Determine the relationship between climate variability and air pollutant concentrations
- Expand the domain of the oxidant model used in the CRCM for studying high ozone episodes to include the Toronto-Niagara portion of the Windsor-Quebec Corridor
- Augment the air quality modeling capability of the model to include long range transport of particulate matter into the region
- Develop downscaling techniques that relate climate variability at the regional scale to synoptic and large scale circulation features from standard meteorological observations and/or as modeled by AOGCMs
- Better understand the relationship between weather variability and fluctuations in sea surface temperatures in the tropical Pacific (i.e., ENSO phenomenon), as well as the North Atlantic (i.e., NAO phenomenon)
- Better understand the role of clouds in chemical reactions for air pollutants, as well as their role in affecting the dynamics of cyclones and anticyclones
- Improve the network for monitoring particulate matter and hazardous air pollutants
- Better co-ordination among the various monitoring programs to bring all of the data together into one comprehensive database

Ideally, from the perspective of supporting research on the effects of climate variability and climate change on air quality in the Great Lakes Basin, it would be desirable to have a regional, dynamic climate model on a fine grid that is driven by the synoptic scale information provided by an AOGCM on a coarser grid. Such a regional model is currently available in the form of the Canadian Regional Climate Model (CRCM). Furthermore, an oxidant model for studying high ozone episodes has been linked to the CRCM and is being tested for use within the Windsor-Quebec City corridor (WQC). At present, the modelling domain covers a limited area centred on Montreal, and is not yet available for use in the Toronto-Niagara portion of the WQC. Expansion of the modelling domain should be considered a priority to support future air quality studies in the TNR. There is also a need to augment the air quality modelling capability of the model to include the long range transport of particulate matter into the region from source regions in the United States, as well as the in-situ formation of secondary particulate matter from gaseous organic emissions from the Basin. A modelling component to estimate the cycling of pollutants between air and water in the Lakes should also be considered a priority.

...an oxidant model for studying high ozone episodes has been linked to the CRCM and is being tested for use within the Windsor-Quebec City corridor (WQC). At present, the modelling domain covers a limited area centred on Montreal, and is not yet available for use in the Toronto-Niagara portion of the WQC. Expansion of the modelling domain should be considered a priority to support future air quality studies in the TNR.

Since it will take some time to implement and validate the regional dynamic climate model (perhaps as much as 5 years, depending on the availability of research funds), it would be useful and less expensive in the intervening period to develop empirically-based downscaling techniques that relate climate variability at the regional scale of the Great Lakes Basin to synoptic and large scale circulation features from standard meteorological observations and/or as modelled by AOGCMs. Such empirical downscaling, to account for lake-effect modifications to local climate, has already been used to some extent in adjusting climate parameters such as precipitation, temperature, cloud cover, wind speed and vapour pressure by Kunkel *et al.* (1995) for studying hydrological impacts resulting from regional climate change scenarios.

There is a need to better understand the relationship between weather variability within the Basin in connection with periodic fluctuations in sea surface temperatures in the tropical Pacific (i.e., ENSO phenomenon), as well as in the North Atlantic (i.e., the NAO phenomenon). The ENSO cycle has already been shown to be an important factor in explaining interannual variability in temperature and precipitation in North America as a whole. The NAO appears to operate on a slower temporal cycle but may explain some of the variability in quasi-20 year drought cycles in central North America. With respect to air quality, years with a higher frequency of ozone episodes appear to follow in the wake of a strong El Nino event, and may be related to the effect that the particular phase of the

ENSO phenomenon has on upper level flows in the atmosphere. Since ozone episodes are linked to the frequency of occurrence and intensity of stagnant high pressure systems, it would be worthwhile to consider what effect the ENSO cycle has on the variability of cyclonic and anticyclonic systems in North America as a whole, and in the Great Lakes region in particular. However, according to the U.S. National Research Council (NRC, 1994), the understanding and successful simulation of the extratropical response to the tropical sea surface temperature anomalies of the ENSO cycle has proven to be more difficult than originally anticipated. Furthermore, much less is known about the effect of the NAO cycle on low level jet stream formation and persistence over the Great Plains region of North America. This is an area of climate research that warrants further attention.

It would also be valuable to develop empirical relationships between climate variability and air pollutant concentrations. The climatologies for both high ozone episodes and acid deposition are relatively well understood and are related. Some regional episodes of periodic increases of particulate matter are also related to these episodes of high ozone and SO_2/SO_4 concentrations. In addition, the long range transport of persistent organic pollutants (POPs) is largely dependent on environmental conditions, particularly air temperatures, concentrations of particulate matter, and transport trajectory for regional wind flow patterns (Finizio *et al.* 1998). Therefore, there is a need to develop an integrated climatology of episodic air pollutant concentrations in relation to cyclical variations in interannual and interdecadal climate variations.

Angel and Isard (1998) have suggested that, within the Great Lakes Basin, the inverse relationship between cyclonic/anticyclonic activity and temperature may be related to cloud cover. Since in-cloud oxidation of sulphur dioxide can be increased by up to an order of magnitude compared with gas phase oxidation in the atmosphere, cloud cover is an important factor in determining the rate of transformation, and therefore the location of deposition, for acidifying air pollutants. Clouds also play an important role in the oxidation of oxides of nitrogen. Both primary and secondary organic and inorganic particulate matter can act as cloud condensation nuclei for the formation of clouds. Therefore, from an air quality perspective alone, it is necessary to understand the role of clouds in chemical reactions for air pollutants, as well as their role in affecting the dynamics of cyclones and anticyclones. Clouds also play an important role in affecting the hydrologic cycle of precipitation and evapotranspiration, and can therefore affect the deposition of hazardous air pollutants to the Great Lakes waters as well as the volatilization of the same pollutants from the water to the atmosphere. Mackay and Bentzen (1997) have noted that the role of snowfall in wet deposition of contaminants to the Great Lakes is not well understood. Snowfall has been decreasing in certain seasons over the past few decades and may continue to do so in the future. Since snowfall is intrinsically related to cloud cover, understanding the relationship between changing snowfall and changing cloud cover may be an important factor in understanding the deposition of hazardous air pollutants such as PCBs and HCH to Great Lakes waters. With respect to oxidation of air pollutants and their deposition, knowing the variability in the extent of cloud cover is not enough because oxidation rates differ for various cloud types. Thus, there is a need to better understand both the variability in cloud cover and variability in cloud type with respect to changing frequencies in synoptic scale systems and their effect on ambient concentrations of air pollutants. It may be possible to complete this type of research with existing meteorological records.

Whereas the observational network for recording variability in climate parameters is largely in place, there is a lack of adequate monitoring data for certain air pollutants. Although regional air pollutant monitoring networks are in place for some common pollutants such as ozone, SO_2 and acidic pollutants, much of the monitoring for particulate matter is restricted to urban areas and may have limited relevance for characterizing regional episodes of high particulate concentrations. Similarly, much of the monitoring data for hazardous air pollutants such as mercury and various POPs has been limited to short-term monitoring programs. The data record is either too short or too incomplete for characterizing pollutant variability with respect to climatic variability. Furthermore, because there has been limited coordination among various monitoring programs, it is difficult to relate episodes of high levels of mercury or HCHs identified in one monitoring program with episodes of regional smog. The data may exist in the records of the individual monitoring programs, but some effort is required to bring all of the data together into one comprehensive database that will assist in identifying relationships among various pollutants. In this manner, data gaps can be identified which will suggest where additional monitoring efforts should be directed in future studies.

Whereas the observational network for recording variability in climate parameters is largely in place, there is a lack of adequate monitoring data for certain air pollutants. Although regional air pollutant monitoring networks are in place for some common pollutants such as ozone, SO_2 and acidic pollutants, much of the monitoring for particulate matter is restricted to urban areas and may have limited relevance for characterizing regional episodes of high particulate concentrations.

Policy Development

Based on the work presented in this report, SENES recommends or supports the following approaches to policy development.

Environment Protection and Human Health

All jurisdictions must work together as partners to protect the environment and health of all Canadians. History has proven that many severe environmental problems have been prevented, controlled or contained as a result of coordinated federal-provincial-territorial efforts. Acid rain, control of the pulp and paper sector, and stratospheric ozone depletion are prime examples of coordinated efforts. Continued intergovernmental cooperation on the environment is essential for the following reasons (Environment Canada, 1996b):

1. Environmental problems like air and water pollution, climate change and accidental spills of toxic substances can transcend geographic and jurisdictional boundaries.
2. Ecosystems frequently encompass more than one jurisdictional territory.
3. Pooling our resources and expertise with the powers and tools of all levels of government to address environmental problems gives Canadians the best possible solutions.
4. Diminishing government resources, in all parts of Canada, make working together essential.

The *CEC Continental Pollutant Pathways Study (CEC, 1997)* presented five key messages:

1. there is a need for urgent action to reduce pollutant for common sources without delay;
2. there is a need for Canada, the United States and Mexico to co-operate to deal with continental pollutant pathways;
3. continental pollutant pathways are very complex and synergistic;
4. integrated holistic monitoring is required; and
5. sustainability and equity are very important.

Division of Powers

The issues discussed in this report are experienced at local, regional and global scales. Therefore, solutions to these issues require active participation of technical and policy staff from municipalities, provincial and federal departments, representatives of potentially affected industrial sectors, and representatives of the environmental community in many countries.

Land Use and Transportation

Actions taken in the transportation sector will have a positive effect on several air issues, such as climate change (reducing CO_2), acid rain (reducing NO_x and SO_x), ground-level ozone (NO_x and VOC) and toxics. Examples of measures that will have positive impacts on one or more air issues include low emissions vehicles, reformulated gasoline, vehicle emission inspection and maintenance controls, car pooling, and anti-idling by-laws.

Energy

Energy management initiatives are among the most cost-effective local actions that can be taken to reduce air pollution. Some of the multiple benefits from energy conservation and efficiency improvements are summarized in the points below:

- *Job creation.* Energy management activities, and especially energy efficiency improvements, are among the most efficient investments when it comes to job creation. When energy management activities reduce expenditures on fuel and electricity, the savings are then "re-spent", usually within the community, and very often in the service sector where the ratio of employment generated to money spent is particularly high.
- *Local economic development.* The energy management industry itself is a growth industry and its promotion can be an effective component of community economic development strategies.
- *Partnership potential.* Utilities, private enterprises, financial institutions, and other levels of government are pursuing energy management for various reasons and they have recognized that urban governments are well suited to the type of integrated programme delivery often required to achieve energy efficiency objectives. Local governments can lever their own resources by participating in government and utility programmes for energy management.
- *Global warming.* Concern over the "greenhouse effect" and the realization that climate change represents a problem that must be tackled by all levels of government has led many local governments to declare targets for the reduction of CO_2 emissions in their community.

As these cities proceed to translate their commitments into action plans, energy management initiatives are invariably among the highest priorities.

- *Greening of cities.* Any consideration of how to achieve sustainable cities will necessarily require consideration of how to achieve sustainable urban energy use patterns. It is becoming increasingly clear that many of the long-term solutions to the environmental problems faced by cities lie in a gradual but profound redesign of urban form and spatial structure, a redesign that can only come about as the result of active leadership from the urban planners in local governments.

In terms of energy-related policies and activities, SENES recommends:

- increasing energy efficiency in industrial, commercial, and residential sectors;
- reducing the need for transportation in cities through land use planning tools such as residential intensification, energy efficient land use policies, ecological development incentives and rezoning;
- promoting public transport, telecommuting and high occupancy vehicles;
- implementing a carbon tax;
- reducing the consumption of fossil fuels through the reduction of energy consumption;
- reducing Environment Canada's corporate energy requirements through specific requirements on vehicles, buildings, equipment and programmes to reduce costs and demand on resources;
- increasing the awareness of the unique needs of Canadian cities among the manufacturing, engineering, contracting and financing sectors with the ultimate goal of creating new technology, service and financing products that are aimed at the urban energy management market;
- examining the potential of using zero discharge as the long-term goal (100-year) for all current environmental decisions;
- creating an international coordinating agency for interdisciplinary integrated cooperation; and
- harmonizing emission inventories and monitoring activities within North America.

International Trading

Canada, Mexico and the U.S. have begun implementing environmental and climate change policies and national joint implementation programs, and there is some experience with economic instruments (e.g., emissions trading) to reduce atmospheric pollution relevant to climate change issues.

A report to the North American Commission on Environmental Cooperation (1997) suggests that there is significant variability among the three countries in terms of the legal frameworks and responsibilities for the management of natural resources, energy and environmental matters.

International trading programs should aim for international compatibility by minimizing potential conflicts with existing and future international regimes such as the Framework Convention on Climate Change, the Kyoto Protocol, NAFTA, the Montreal Protocol and other environmental agreements.

Related Policy Issues

Monitoring funds should continue to be allocated to the collection of data to facilitate the integrated study of climate change and variability with air issues.

Public communication should be aimed at the scientific and related professional and public interest communities, legislators and their staff, and the general public. A public outreach program should include, but not be limited to, the following components:

- progress made towards addressing air issues and the difficulties that have been experienced in attempts to comply with standards;
- industrial control measures and other strategies (e.g., pollution prevention) that have been developed and implemented or are under consideration;
- the public's role in generating emissions (i.e., as "part of the problem") and steps that the public could take (e.g., episodic controls) to limit those emissions;
- success stories of measurable progress toward the goals in reducing the impacts of air issues; and
- information to educate the public about long range transport of pollutants as a regional (i.e., not simply urban) issue.

Mechanisms

All mechanisms have advantages and disadvantages. The key point is to use a mixture of mechanisms that suit individual needs and sectors with a full analysis of the requirements integrated over all issues.

CONCLUSIONS

All of the major air quality issues are linked to meteorological conditions. In the Great Lakes Basin, the dispersal, transformation and removal of air pollutants are influenced by temperature, precipitation, wind speed, humidity, and synoptic scale weather systems (i.e., cyclones and anticylones). Despite the existence of scientific evidence of the linkages between meteorological conditions and ambient air pollution concentrations, air quality management policies have yet to adopt an integrated approach and have failed to consider the full range of potential meteorological fluctuations that might be experienced over longer time scales. Canada and the U.S. are however moving towards developing an integrated strategy to deal with multiple air issues. There is a need to improve the capability to model climate variability and change at the regional level and understand the relationships between climate variability and air pollutant concentrations. Solutions to regional air issues will require a partnership between municipalities, provincial and federal departments, industry and the environmental community. Actions taken in the land use, transportation and energy sectors will achieve positive impacts on several air issues including climate change, acid rain, ground-level ozone and air toxics.

REFERENCES

Angel, J.R. and S.A. Isard 1998. The Frequency and Intensity of Great Lakes Cyclones. *Journal of Climate*, 11:61-71.

Chock, D.P. 1995. Issues Regarding the Ozone Air Quality Standard and the Design Value. *Journal of the Air & Waste Management Association*, 45:893-898.

Commission for Environmental Cooperation (CEC) 1997. *Meeting the Challenges of Continental Pollutant Pathways: Towards a Framework for Trinational Cooperation and Action. Draft.* Prepared by The North American Expert Advisory Panel on Continental Pollutant Pathways.

Environment Canada 1996b. *Strengthening Environmental Protection in Canada: A Guide to the New Legislation.*

Finizio, A., A. Di Guardo, and L. Cartmale 1998. Hazardous Air Pollutants (HAPs) and their Effects on Biodiversity: An Overview of the Atmospheric Pathways of Persistent Organic Pollutants (POPs) and Suggestions for Future Studies. *Environmental Monitoring and Assessment*, 49:327-336.

Hrebenyk, B., J. Young, and P. Coutts 1998. *Effects of Weather, Climate Variability and Climate Change on Air Issues in the Toronto-Niagara Region/Great Lakes Basin.* Report prepared by SENES Consultants Limited for Environment Canada-Ontario Region.

Huggett, R.J. 1997. *Environmental Change*. Routledge, New York, NY.

Hunt, B.G. 1998. Natural Climatic Variability as an Explanation for Historical Climatic Fluctuations. *Climatic Change*, 38:133-157.

Kittel, T.G.F., F. Giorgi, and G.A. Meehl 1998. Intercomparison of Regional Biases and Doubled CO_2-sensitivity of Coupled Atmosphere-Ocean General Circulation Model Experiments. *Climate Dynamics*, 14:1-15.

Kuklin, A. and J.H. Seinfeld 1995. Emission Reductions Needed to Meet the Standard for Ozone in Southern California: Effect of Boundary Conditions. *Journal of the Air & Waste Management Association*, 45:899-901.

Kunkel, K.E., S.A. Changnon, T.E. Croley II, and F.H. Quinn 1995. *Scenarios for Climate Change Impacts Assessments in the Great Lakes Region*. Great lakes Environmental Research Laboratory, Ann Arbor, MI.

Mackay, D. and E. Bentzen 1997. The Role of the Atmosphere in Great Lakes Contamination. *Atmospheric Environment*, 31(23):4045-4047.

National Research Council (NRC) 1994. *Global Ocean-Atmosphere-Land System (GOALS) for Predicting Seasonal-to-Interannual Climate*. National Academy Press, Washington, DC.

National Research Council (NRC) 1991. *Rethinking the Ozone Problem in Urban and Regional Air Pollution*. National Academy Press, Washington, DC.

North American Commission on Environmental Cooperation 1997. *Analysis of the Potential for a Greenhouse Gas Trading System for North America. Phase I.* Prepared by J. Swisher, E. Hoyt, E. Haites, C. Zamudio and S. Embree. May.

Ontario Ministry of Environment and Energy (MOEE) 1996. *Towards a Smog Plan for Ontario*. A draft discussion paper prepared by Science and Technology Branch, Ontario Ministry of Environment and Energy, Toronto, Ontario.

Turekian, K.K. 1996. *Global Environmental Change*. Prentice Hall, Upper Saddle River, NJ.

United States Environmental Protection Agency (USEPA) 1990. *New Source Review WorkshopManual*. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

Perspectives from the Ontario Ministry of the Environment

***Remarks by David Yap,* Ph.D.**
Ontario Ministry of the Environment

The overview presentations of Dan Hrebenyk and Jim Young on the science and policy of the interaction of air issues were most informative. Their summary findings are noteworthy and the recommendations for actions are all desirable in an ideal world. To complement their presentations, several points are offered in the following text.

Recently, there has been a shift in emphasis to consider not only episodic levels but also the air quality that occurs year-round as increasing scientific evidence suggests that certain pollutants (e.g.. ozone and fine particles) can have health impacts at extremely low concentrations. In future, data analysis and impact assessment studies will have to focus more on the entire frequency distribution of such pollutants that the population is exposed to.

Linkages between air quality, climate, and ecosystems

There are strong scientific linkages between air quality, climate, and ecosystems. Air quality can affect both climate and the ecosystem and the converse is also true. For example, the composition of the atmosphere (indirectly air quality) affects the climate through temperature change due to absorption of sunlight by soot or by infrared radiation by carbon dioxide. Climate, on the other hand, affects the composition of the atmosphere as evapotranspiration rates respond to changes in surface temperature. The composition of the atmosphere can also affect the ecosystem by, for example, toxicity damage to vegetation. The converse is also true as ecosystems can alter the composition of the atmosphere when changes in carbon dioxide flux occur due to altered rates of decomposition.

Role of climatic factors in poor air quality episodes

It is also important to recognize that there are unique features in the regional/synoptic climatology that lead to elevated or episodic conditions of poor air quality over southern Ontario and indeed the Toronto-Niagara Region (TNR) or the Golden Horseshoe. The principal track of anticyclones in summer is northwest to southeast across the upper and lower Great Lakes and then eastward to the Atlantic. South to southwest flows on the back of high pressures (anticyclones) favour transboundary flow of polluted air into southern Ontario and often result in elevated levels of ozone and particulate pollution in the summer over the TNR. Under future climate scenarios, changes in the track could potentially result in different climatic conditions over the TNR. Regional climate models derived from or nested in larger general circulation models will have to provide critical resolution of such issues.

Why focus only on episodes?

With reference to air quality issues, studies in the past have focused primarily on elevated levels or episodic conditions. Recently, there has been a shift in emphasis to consider not only episodic levels but also the air quality that occurs year-round as increasing scientific evidence suggests that certain pollutants (e.g., ozone and fine particles) can have health impacts at extremely low concentrations. In future, data analysis and impact assessment studies will have to focus more on the entire frequency distribution of such pollutants that the population is exposed to.

...it is important to recognize that the control of emission sources to address one air issue could result in negative impacts to another air issue. For example, automobile catalytic converters reduce smog precursors but, at the same time, result in the increase of nitrous oxide, a strong greenhouse gas.

Linkages among air pollutants, air issues and management programs

Linkages exist between the air pollutants that are typically monitored by provincial agencies (e.g., ozone, sulphur dioxide, oxides of nitrogen, volatile organic compounds, toxic organics, particulate matter and total reduced sulphur compounds) and air issues (e.g., smog, global warming, urban air quality, acidic deposition, health and aesthetics). As air issues arise from the life cycle and residence time of these contaminants in the atmosphere, they are closely linked to the weather and climate.

Linkages between air issues, emissions and government programs have been in place over the past decade. For example, in Ontario regulations have been introduced to reduce the emissions of chlorofluorocarbons, acid rain precursors, mobile and stationary sources. Some of these regulations have served to address multiple air issues. A key sector identified repeatedly is transportation. This sector is a prime source of carbon dioxide, smog precursors and urban toxics and hence, impacts on a number of air issues.

In terms of policies, reducing greenhouse gas emissions or smog precursors is generally linked to the same kind of requirements: more efficient cars, more use of public transit in urban areas, less use of coal in the electricity system, and more efficient use of energy in industries, businesses and homes. Possible actions advocated to address the climate change issue have been used or can be used to address other air issues, including emissions trading, taxation policy, transportation (support for public transit and alternative transportation fuels and regulating more efficient cars and trucks) and shifts in electricity generation.

However, it is important to recognize that the control of emission sources to address one air issue could result in negative impacts to another air issue. For example, automobile catalytic converters reduce smog precursors but, at the same time, result in the increase of nitrous oxide, a strong greenhouse gas.

Perspectives from the Federal Atmospheric Research Community

Remarks by Don McKay, Ph.D.
Air Quality Research Branch, Environment Canada

Jim Young and Dan Hrebenyk provided an excellent overview of the work that SENES has done in trying to understand the integrated aspects of air issues (Hrebenyk *et al.*, this volume). David Yap (this volume) covered a number of important points as well.

The subject of integrating air issues is certainly something that scientists in Environment Canada's Air Quality Research Branch (AQRB) have been thinking about and trying to do for a number of years. There is just one atmosphere and it happens to be a "big soup". As atmospheric scientists, we have the difficult job of trying to understand the complex processes at work in the atmosphere, how various emissions entering the air interact with one another, and how they are transported. When initially faced with a complex problem or issue, people (including scientists and policy-makers) tend to adopt a stovepipe or linear approach. Scientifically, it has been easier in the past to examine one pollutant, determine its effects, and assess the level of action required to reduce or eliminate the effects. Politically, it has been easier in the past to take this scientific information, design and implement appropriate policies, and declare the problem solved. Unfortunately, as we know with the acid rain issue, the problem is not simple and past actions often help but do not solve the problem. Policy-makers and the public think that acid rain is no longer an issue but in fact it has not been solved.

Thus there is a need for workshops like this one, and hopefully others, that try to link the scientific and policy aspects of several atmospheric issues. In conjunction with its university, government and private sector partners, ARQB is working on several projects to move towards an integrated understanding of air issues. One such activity that ARQB will be pushing over the next few years is the development of an integrated model that incorporates multiple atmospheric stressors and pollutants. Ultimately this model will be used to run and test future emission scenarios and emission reduction strategies. The difficulty is scale, as current models that are being examined for incorporation into the integrated model must be adjusted to obtain a higher resolution in order that more localized types of problems can be addressed. With respect to monitoring, ARQB is looking at integrated approaches such as developing 5-6 core sites on a regional basis across Canada. Researchers would use a variety of instrumentation, located within this series of regional core sites, to examine and integrate quite different sets of measurements in order to develop the bigger picture. Environment Canada's CARE (Centre for Atmospheric Research Experiments) facility located near Cookstown just north of Toronto, as an example of one of these core sites, could be used as a staging ground to develop instrumentation and perfect measurement techniques prior to expanding to other regions across the country or undertaking an extensive field study.

The time is certainly ripe to start pushing collectively on climate and air quality issues. Canada is slowly emerging from tough economic times. It is pretty hard to worry about breathing bad air when you haven't the means to feed or clothe your kids. As economic conditions improve, the environment is gaining more prevalence among the general public eye and this can only assist us in dealing with air issues, developing some common understanding and implementing solutions.

In terms of policy, one of the most important things is to work together and integrate responses from international through to municipal levels. The federal government is trying to do this with our provincial colleagues in a harmonization program. Agreements are being discussed and negotiated to harmonize monitoring programs, establish Canada-Wide Standards (CWS) and to streamline research and development activities. The biggest problem seems to be reaching consensus at the higher management levels. This runs counter to my experiences working together towards harmonization on science issues with colleagues from MOE. Hopefully we can influence senior management and move the entire process forward.

It must be remembered that harmonization and similar activities are occurring in the context of recent and on-going government downsizing and restructuring. The Standing Committee for Environment rapped Environment Canada in May 1998 for not doing a good enough job, an opinion that is somewhat understandable given recent downsizing of the department. It is important that people are hearing this as well as statements from the Commissioner for Sustainable Development, who also criticized the work of Environment Canada. Although it is difficult to accept the criticism when I see my colleagues going full-out and doing the best they can, I do understand it. I prefer to maintain the "half glass full as opposed to the half glass empty" attitude while digesting these comments. While being told that you are not doing a good job is not nice, it does open up a possible opportunity. If the general public, who politicians are accountable to, is upset and concerned about the state of Environment Canada, then maybe this provides an impetus to work together to develop the momentum and resources required to effectively deal with environmental issues.

The time is certainly ripe to start pushing collectively on climate and air quality issues. Canada is slowly emerging from tough economic times. It is pretty hard to worry about breathing bad air when you haven't the means to feed or clothe your kids. As economic conditions improve, the environment is gaining more prevalence among the general public eye and this can only assist us in dealing with air issues, developing some common understanding and implementing solutions. Working together in an integrated way is certainly the right step to go forward.

Toronto-Niagara Region Study on atmospheric change

The Hamiton-Wentworth Air Quality Initiative: An Executive Summary

Eric Loi
Ontario Ministry of the Environment

Rosemary Foulds
Regional Municipality of Hamilton-Wentworth

It is estimated that there are at least 90 premature deaths per year, and up to as many as 321 premature deaths, as a consequence of current air quality in Hamilton-Wentworth. Further, there are 300 additional hospital admissions per year due to current air quality in Hamilton-Wentworth.

The Hamilton-Wentworth Air Quality Initiative (HAQI) is a living model of how science and policy can be linked for the purpose of understanding and managing several air issues at the local scale. Air quality has always been a concern in Hamilton-Wentworth. There is evidence of improvements in Hamilton-Wentworth's air quality over the last 40 years, due to emissions reductions by industries and enforcement of regulations by government. However, more work is needed to ensure continued improvements and explore more effective strategies for managing the air quality into the next century and beyond. As one step to address the concerns of the community, the Regional Municipality of Hamilton-Wentworth, Ministry of the Environment, and Environment Canada started the Hamilton-Wentworth Air Quality Initiative. This summary paper is based upon a larger document that focuses on the synthesis of existing local ambient air data, modelling information, health research and community surveys. The report is the result of collaboration between agencies and individuals in the community who share an interest in air quality issues.

One of the challenges faced in the design of the assessment study was deciding which pollutants are the most important. In order of priority on human health effects, the pollutants selected for the HAQI study are:

1. Inhalable/Respirable Particulates ($PM_{10/2.5}$), particularly Sulphates (SO_4);
2. Ground-level Ozone (O_3);
3. Sulphur Dioxide (SO_2);
4. Nitrogen Oxides (NO_x);
5. Carbon Monoxide (CO); and
6. Air Toxics.

It is estimated that there are at least 90 premature deaths per year, and up to as many as 321 premature deaths, as a consequence of current air quality in Hamilton-Wentworth. Further, there are 300 additional hospital admissions per year due to current air quality in Hamilton-Wentworth (Figure 1). Inhalable particulates and especially its sulphate component have by far the greatest impact, accounting for 76% of the air pollution related premature mortalities and 64% of the air pollution related hospital admissions.

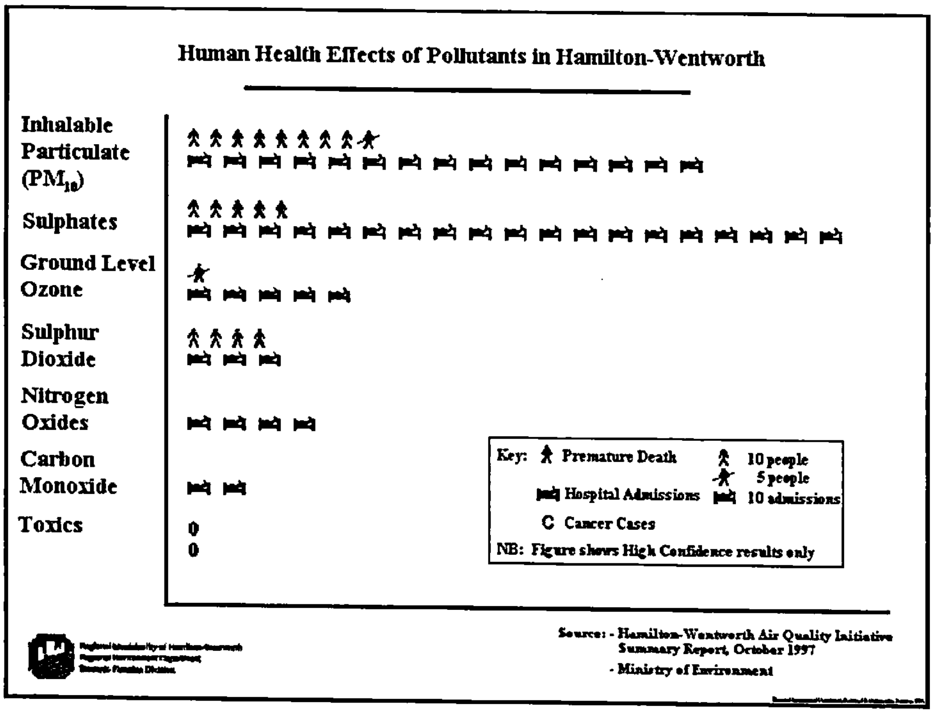

Figure 1. Human health effects of pollutants in Hamilton-Wentworth

These pollutants come from a variety of sources. Some are local, while others are well beyond municipal boundaries. In the industrial areas, industrial activities can contribute more than 50% to the inhalable particulate concentrations. In the neighbourhoods located farther from the industrial areas, approximately 55% of the inhalable particulates come from sources outside of Hamilton-Wentworth, 30% come from urban sources such as cars and 15% come from industrial sources (Figure 2). Weather also plays an important role in air quality, as the prevailing south and west winds bring pollution from outside the Region, and temperature inversions trap local emissions.

The general level of pollution from industrial sources has declined since the 1970s, when controls were first brought in. Vehicle exhaust also has an impact on air quality. In the past 20 years, the number of vehicles using the roads have increased significantly. Even though emission control standards have become more stringent, these benefits have been offset by the increases in vehicle usage and congestion on the roads.

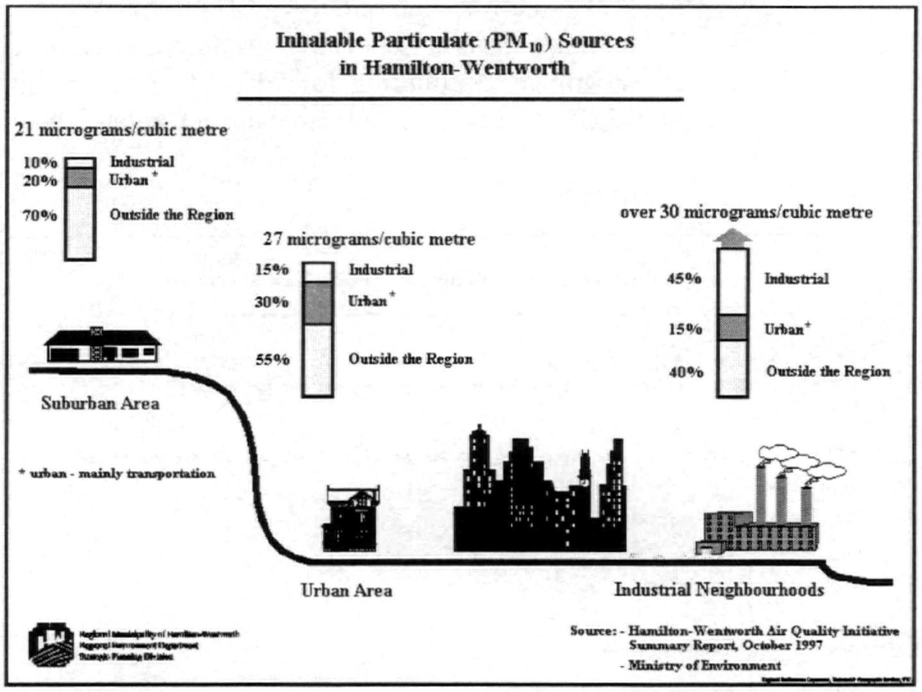

Figure 2. Sources of inhalable particulate (PM_{10}) in Hamilton-Wentworth

In the past 20 years, the number of vehicles using the roads have increased significantly. Even though emission control standards have become more stringent, these benefits have been offset by the increases in vehicle usage and congestion on the roads.

Modelling results show that in the absence of continued improvements in vehicle technologies, emissions of nitrogen oxides, carbon monoxide and hydrocarbons from transportation sources will increase by 26% to 36% by the year 2021 (during morning rush hours) based on current vehicle use, existing vehicle emission controls and enforcement, and population growth projections (Figure 3). These estimates indicate emissions from transportation sources will have the potential to be an even more significant source of air pollution in Hamilton-Wentworth in the future.

Air quality is of great concern to the citizens of the region, highlighted most recently by the Plastimet incident (Figure 4). The Ministry of the Environment logs about 500 complaints about air quality annually and the issue receives frequent media coverage. This is not surprising, since health studies have connected air quality, particularly inhalable and respirable particulates, ground-level ozone and sulphur dioxide, with premature mortality and hospital admissions. Not only are people concerned about air quality, a study undertaken during HAQI's investigations show people are prepared to pay an extra $40 per month in property tax to improve air quality and reduce the health effects. Poor air quality also adversely affects a Region's image as a place to live, to invest and to do business.

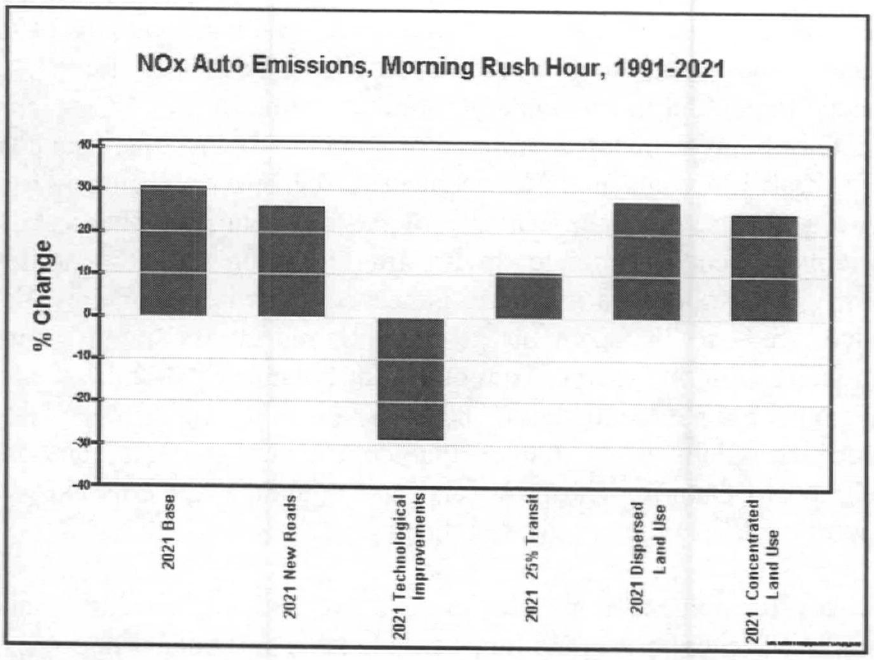

Figure 3. Change in NO_x emissions during morning rush hour from 1991-2021 under various scenarios of land use, technological, and behavioural change

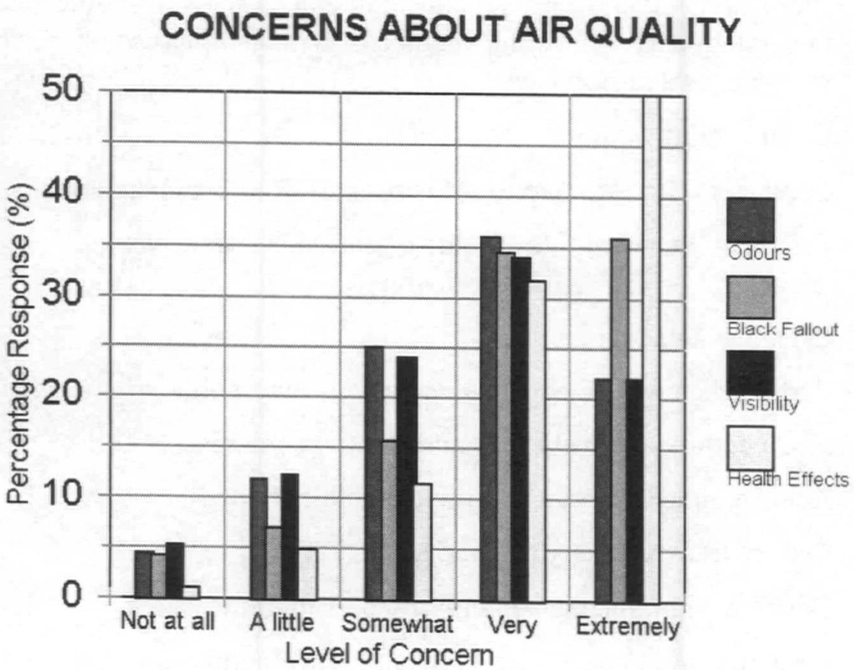

Figure 4. Concern among Hamilton-Wentworth residents about four aspects of air quality

Clearly, there is support for measures to improve air quality. The research that was compiled during the HAQI helps to focus ongoing efforts to further control emissions. Three sources have been identified: industry, transportation and transboundary pollution. Some industries in Hamilton-Wentworth have already committed to voluntary reductions. One example is the draft Environmental Management Agreement between Environment Canada, Dofasco and the Ministry of the Environment. These and other initiatives need to continue. In the transportation sector, a strategy to modify automobile and truck use is needed. This is a challenge, but one which needs to be taken up in order to reduce the rapid growth of emissions from this source. To reduce transboundary pollution, the federal government must continue its negotiations with the United States to reduce emissions from sources that contribute significant amounts of pollution to Ontario. The provincial and municipal governments should support the federal government in the negotiations.

The key recommendations for future actions to improve air quality in Hamilton-Wentworth should focus on inhalable particulates and sulphates. The following measures can help:

1. Promote public awareness to show the public how they can make a contribution.
2. Implement code of practice/guidelines/best available control technology for industrial sources, with emphasis on inhalable particulates and sulphates.
3. Control fugitive dusts.
4. Implement Strategic Options Process (SOP) recommendations.
5. Establish standards for vehicle emissions and vehicle emission testing.
6. Establish anti-idling bylaw.
7. Reduce the number of single-occupancy automobile trips.
8. Enact commercial vehicle maintenance standards.
9. Achieve more efficient commercial vehicle flow.
10. Reduce transboundary pollution.
11. Develop and implement energy conservation measures.
12. Research to identify and evaluate information about health and environmental effects, sources of pollutants and projections of future trends in emissions.

Finally, it is important that actions are taken on the findings and recommendations in this report. There are a number of measures that could be taken to improve air quality. Measures to strengthen the regulatory authorities in their dealings with persistent offenders are needed. Other measures may be accomplished through partnerships. One potential of the HAQI is an opportunity to build on the partnership to carry out the recommendations. The recent experience with the serious fire in Hamilton reinforces the importance of continued dialogue and partnership. An interim organizational structure is proposed in the full report for implementing the recommendations of the study and exploring the long-term management of air quality in Hamilton-Wentworth.

REFERENCES

Regional Municipality of Hamilton-Wentworth 1997. *Hamilton-Wentworth Air Quality Initiative Summary Report*. Regional Municipality of Hamilton-Wentworth, Hamilton, Ontario. Available on-line (http://www.cciw.ca/glimr/data/haqi/intro.html).

Toronto-Niagara Region Study on atmospheric change

SECTION 3: IMPACTS OF ATMOSPHERIC CHANGE ON THE NATURAL ENVIRONMENT

Toronto-Niagara Region Study

on atmospheric change

Impacts on the Natural Environment in the Toronto-Niagara Region

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INTRODUCTION AND CONTEXT

I have already learned quite an interesting and hard lesson this morning that possibly has some relevance to the topic of this workshop. I set off from Peterborough foolishly thinking that leaving at quarter to seven in the morning would get me in to downtown Toronto comfortably at about quarter to nine or, at most, nine-thirty but I got in just after ten o'clock. As far as I could judge, there were no accidents on the way down, the traffic was just completely jammed starting virtually as soon as I came off Hwy. 115 through Oshawa, and all the way down ultimately to the University.

It is clear that we have some major transportation problems with a very large population attempting to commute back and forth to work every day. The commuters are traveling in all possible directions, not just to downtown Toronto. A trip to Burlington from Peterborough last week took me five hours and it was done in an astonishing air pollution episode which I later read in the papers had increased in the direction from Burlington east through Toronto to Oshawa and ultimately out to Peterborough. Transportation and air pollution go hand in hand and, from episodes so far in 1998, it is obvious that we are getting into quite a mess. The very bad pollution episode of 1988 may not be a thing of history. The high temperatures and substantial air pollution experienced in 1998 look like another challenge to people and to ecosystem health.

Another fact is that we are just getting bigger. The population of Greater Toronto now tops four million people. In all parts of the world, there is an accelerating movement to urbanization. We have gone from a Canadian population in 1870 which was 20% urban and 80% rural to a situation now where we are very close to 80% urban. In a country with a huge land mass, we have actually concentrated four million inhabitants into Toronto. While urbanization is going on apace, increasing numbers of people hanker for rural living and to get away from the high land prices and high air pollution and away from the spread of concrete across the agricultural landscape. Toronto, similar to many other major urban centres, is spreading out as a concrete cover over the land with urban development replacing the photosynthetic potential of natural and agro-ecosystems to a very large extent. As you know, the former Metro Council had some interesting thoughts about balancing some of this photosynthetic loss by planting trees elsewhere, inspired by geographers at the University of Toronto. To allow an equivalent carbon fixation to that of the carbon dioxide output caused by energy consumption and industrial activity in Metro Toronto, council actually voted for tree planting in Costa Rica some time ago.

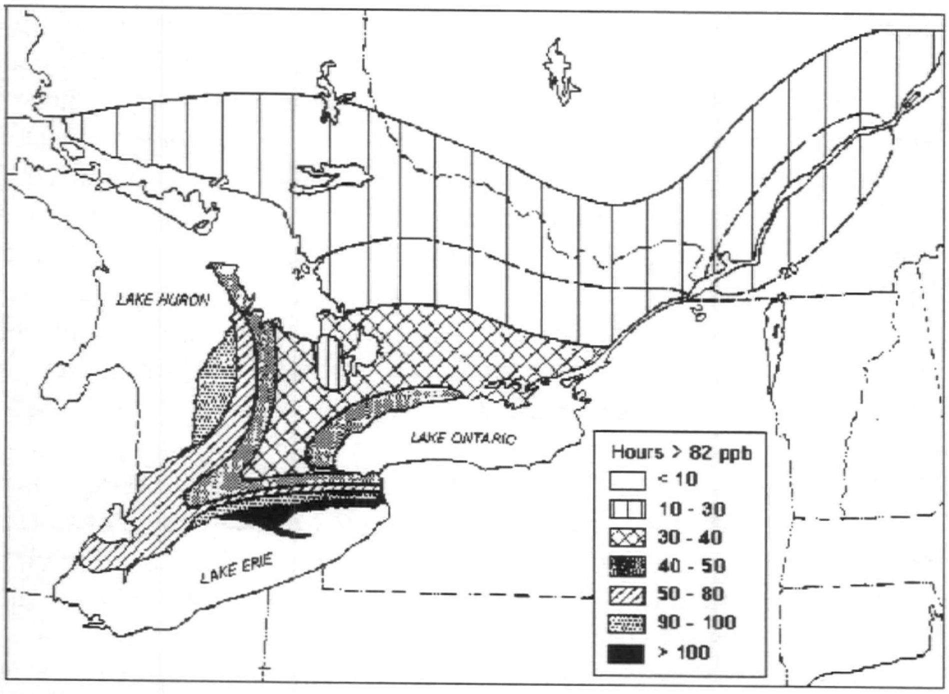
Toronto, similar to many other major urban centres, is spreading out as a concrete cover over the land with urban development replacing the photosynthetic potential of natural and agro-ecosystems to a very large extent.

Although the focus in air pollution at the moment tends to be on ozone, we have to recognize that both the human population, with a lifespan of 70 to 80 years, as well as the natural environment, has experienced a lot of changes over the last 150 years. We have moved, for example, from horse-drawn carriages generating ammonia to individual houses burning wood and coal, generating arsenic trioxide and dust. We have passed through the sulphur dioxide phase caused by fossil fuel combustion, dominant until very recently, to that of photochemical oxidant production. Think about how the lichen flora growing on the trunks and branches of trees are reacting. These plants must respire this air which has changed in chemical composition over time, and they must respond continuously to it. The ground flora, the herbaceous plants as well as large long-lived trees, are responding to atmospheric change and they are responding to it through all kinds of physiological and biochemical mechanisms of adaptation. They are also altering the sort of genetic material that will be passed into the future. If one goes back 50 years in time, no doubt there was a shuffling of the genes in the plants of the ravines of Toronto which was moving them in a direction of more and more sulphur dioxide tolerance. There has been some pressure taken off that in recent times with a reduction in sulphur dioxide levels and now we are selecting tolerance genes for exposure to photochemical oxidants. We have shuffled genes in the past for heavy metal tolerances to such elements as lead. Lead levels have dropped substantially since non-leaded gasoline was introduced, while ozone concentrations have risen. One can, therefore, look at the floras as indicators of change. A historical retrospective analysis must account for these pollutant shifts and the changes in floral composition of communities, which is a biological recognition of other changes. In addition, we must also be able to associate those meteorological, chemical, and atmospheric changes that have accompanied the floral changes. Clearly it is a complicated process.

ACUTE AND CHRONIC EFFECTS

Figure 1 shows some of Environment Canada's own data. The map depicts the spatial distribution of the average number of hours when ozone concentrations exceeded 82 parts per billion (ppb) during 1980-91 in southern Ontario. Some centres in our area have had greater than 10 hours of greater than 120 ppb. What is the significance of all this? Obviously, it is an air pollution issue. Most higher plant species will respond negatively, that is, there will be negative effects on growth. Plants respond in the long term, showing chronic effects, and they respond in the short term through immediate damage or acute injury caused by pollutant episodes. Chronic injury often occurs at somewhere between 50 and 80 ppb. This is also true of SO_2 as well as ozone. Most plants, crops and native species will show some damage above 80 ppb of ozone while sensitive ones will show damage at 50 ppb. We need to be concerned about short-term acute episodes because they are frequently very damaging and we need to be concerned about the long term ambient backgrounds. The regional patterns and directions of air movement are also important considerations.

The ground flora, the herbaceous plants as well as large, long-lasting trees are responding to this and they are responding to it through all kinds of physiological and biochemical mechanisms of adaptation as well as by altering the sort of genetic material which will be passed into the future.



Source: Fuentes and Dann, 1993

Figure 1. Average number of hours when ozone concentrations exceeded 82 parts per billion (ppb) during 1980-91 in southern Ontario

Currently, I am working on a transect of mature woodlots which runs out from Toronto through Peterborough towards Pembroke and Eganville, which happens to be the prevailing summer wind direction and, therefore, the major course for the movement of air contaminants. A good deal of evidence has been obtained suggesting that substantial ozone levels occur in the Peterborough region. In 1988, the year of high ozone levels, concentrations at Long Point were in excess of 170 ppb for three consecutive days. Virtually no crops or forests in the vicinity would have escaped some degree of damage from this episode. There was substantial damage to crops in 1988, partly due to the management practice of selecting species and varieties that will grow very fast. To achieve this, we need to provide ideal conditions of moisture, temperature and nutrient supply. These crops don't need a thick waxy cuticle restricting water loss and protecting the plant because humans ensure it receives adequate water. So what we have done in agriculture, and quite deliberately, is to reduce the thickness of the cuticle. In our selection for fast growth in crop plants, we made them very vulnerable to air pollutants. One could generalize and say that the agricultural plant breeding direction for high productivity has inevitably led to potential sensitivity to any air pollutants and in any mixture. Yet, while natural vegetation has to adapt to the climate and air quality as humans change it over time, agricultural crops can be altered genetically and grown in different locations without much difficulty. Tobacco production offers a good example. In the 1950's and 1960's, we introduced genes simply by old-fashioned selection of tolerant individuals during the growing season. During ozone episodes or in greenhouses where you're deliberately fumigating them with air pollutants, plants that show less damage are selected and grown and the seeds are collected. During the 1950's, when significant ozone damage was already occurring on tobacco farms, laborious research by various agencies in Canada lead to the development of the Delhi variety of tobacco. This variety tolerated a much higher level of ozone and was grown in southwestern Ontario where ozone continued to be a problem. The genetics of the Delhi strain have since been introduced into American varieties and modified and extensively used in the United States.

We need to be concerned about short-term acute episodes because they are frequently very damaging and we need to be concerned about the long term ambient backgrounds.

Dealing with long-term, chronic effects requires a long-term view. Long-term changes will take place even if you cannot measure the magnitude of the change from time to time. Everyone here probably accepts the virtues of long-term monitoring and ecological studies. Such studies have produced some astonishing discoveries this century. For example, meticulous studies were done by Tyler and Tamm in Sweden in which they re-analyzed soils from the forests of Sweden by collecting fresh samples in 1984 and comparing the pHs of these soils with samples collected and stored in 1949. The contemporary samples were taken from the same soil pits and by the same method used in 1949. In all cases, a substantial acidification had occurred from 1949 to 1984. Soils to a depth of 1 metre were strongly acidified. Since this work was done in the early days of acid rain research, the scientists ascribed their observations to surface acidification from acidic inputs. While there has been a surface acidification effect, which is a function of tree growth itself, there has also been acidification to 1 metre depth that represents long-term change. Other examples of long-term change are even more compelling and obvious. During the establishment of the International Geophysical Year in 1957, some wise scientists decided to set up long-term monitoring of the earth's atmosphere. One of the things they measured was CO_2, which led to the long-term data generated by the Mona Loa Observatory in Hawaii. The data produced from this observatory, indicating the interannual trends and seasonal fluctuations in CO_2 have had a very profound impact, almost like the first satellites looking down at the earth. The annual increases in CO_2 have been made apparent. At the same time, scientists established monitoring of the chemistry of rain via a network in Scandinavia. The chemical data collected over time demonstrated the occurrence of acid rain and identified sulphate as the main contributor to the acidity, specifically related to long range transport of sulphur compounds. The monitoring network also led to the realization that there was a coincidence in time and space between increasing rain acidity, lake acidification and loss of fish stocks.

CONSIDERATIONS FOR IMPACT ASSESSMENT

A number of important and relevant questions arise when considering the impacts of atmospheric change on the natural environment. How can we assess if a floral change is occurring and how it is occurring? One of our concerns is that the chemical changes in the atmosphere may be driving changes in natural ecosystems. If we demonstrate changes in plant communities or in distribution of individual species, how can we ascribe cause to it in a complex ecological world? In other words, we might be able to demonstrate change over time or change over space, but how do we achieve the situation of ascribing particular causes to it? Bearing in mind that even if the cause is air pollution, it is a complex atmosphere and chemical soup that we're dealing with. Is atmospheric-derived acidification the factor that caused the change? In the case of acid rain, does it matter whether the acidic source is sulphur-dominated or nitrogen-dominated? To answer any such questions, long-term observations using permanent plots for plant communities are the surest way of detecting change. Some places, by chance or by design, have long-term records. For example, the Rothamsted plots in the U.K. were set up in 1832. In assessing the impact of acid rain in the Netherlands, Sweden, the United States, and Germany, one difficulty has been limited knowledge of past conditions. Some of the most valuable data has come from long-term data sets from Sweden. Very few long-term records were found in Canada. We have long-term meteorological data that is turning out to be valuable and, through the EMAN (Ecological Monitoring and Assessment Network) program, more long-term monitoring data sets are being established for different ecosystems. The EMAN program is providing very useful direction despite its very low level of funding; it is acting as a catalyst.

Another way to approach the problem, using acidification as an example, is to deliberately cause accelerated acidification. Maybe we can speed things up and find out the direction of impacts. One needs always to be concerned about how much you're speeding things up and in what direction you are taking them, but some very useful information has come from historical floral reconstructions, peat cores, sediment cores, herbarium specimens, etc. Most recently, the herbarium specimens in the U.K. have been used to provide long-term data sets regarding stomatal changes. Outstanding work by I. Woodward at the University of Sheffield has shown that the plants are responding to atmospheric changes in humidity and CO_2 over time. Studies of herbarium specimens from the last century combined with present-day experiments on the same species have shown a selective mechanism for changes in CO_2 and humidity conditions.

It is also possible to identify vulnerable, sensitive organisms and then to examine regionally, whether or not such sensitive indicators have been affected. Obvious ones include lichens, the feather mosses of the boreal forest. Lichens are universally sensitive to air pollution and have a widespread occurrence from tundra to boreal and hardwood forests, tropical rain forests, deserts and grasslands. Fungal fruiting bodies, such as forest mushrooms, are also good indicators. The presence or absence of these groups of organisms and their health and reproductive vigour allow one to assess ecosystem health.

Another approach is to ask experts, people who have studied systems for a long time to ascertain what is going on. A number of studies have looked at the same plots over long periods of time. Tom Siccamma, a Yale forestry professor, and his associates looked at particular sites in the Adirondacks from 1966 to 1994. His conclusion, based on my discussions with him about three years ago, was that acid-loving species of the mature northern forests have increased over time. Particular examples that he identified included Clintonia borealis, Lycopodiums pp, Maianthemum canadensis (Mayflower), Oxalis and a Trillium species. The Trillium species he noted was an acid-tolerant one, different to the large white Trillium grandiflorum everyone is familiar with. These species have increased from the observations made in the Adirondacks. Similar changes have been noted with acid-tolerant species increasing in the forests of Central Europe and in southern Sweden. Other species have decreased in occurrence. This change is quite rapid, having been recorded since 1966.

TORONTO-PETERBOROUGH URBAN-RURAL CORRIDOR STUDY

Turning once again to the Toronto-Peterborough urban-rural corridor study, we have selected 20 sites stretching 300 km northeast from downtown Toronto to Shaw Woods at Eganville (see Figure 2 for sites referenced in this paper). Two criteria were adopted for site selection, (1) they have to have a Trillium presence and (2) they have to be on flat ground, not in valleys. The selected sites are all mature sugar maple forests and are located in a variety of settings. Some sites are situated within heavily urbanized areas (Toronto brickworks, Glendon campus, headquarters site of the Ontario Federation of Naturalists site right at Leslie St. and Hwy. 401), while others are located adjacent to major highways (along Hwy. 401 at Ajax, and Hwy. 404 at Markham), or at more rural, pristine sites through Peterborough and Eganville. A large number of parameters are measured to examine the health of these forests, not knowing in advance which variable will be most useful. The assessment includes evaluating the diversity, health and occurrence of tree species; many aspects of the ground flora; and determining seed banks. We want to know what is present, what is viable and what can germinate in the soil at each site. Lichens on the trunk of the trees are being monitored, as well as mycorrhizal fungi. Some bird studies have begun on spring migrants, focusing particularly on breeding species. Other foci are on the microbial population involved in litter decomposition and the measurement of litter inputs.

Along the Toronto-Peterborough transect, we represent in space what has happened over time. The steep urban-rural gradient of disturbance and traffic is accompanied by a pollution gradient. A temperature gradient also exists from a Toronto-centred heat island outwards to cooler rural areas. The hypothesis is that urban and rural sites should be similarly influenced for all woodlot parameters. Tables 1-4 show some of the data. The total number of species per unit area is shown in Table 1. Diversity increases in the ground flora from about 6 at the Toronto sites to a rural number of 14-15 species. Although the particular species are not identified, a gradual increase in the species composition is apparent as you go out from the city. The second thing to notice from Table 1 is that cryptogams, principally mosses but also lichens and liverworts on the ground, increase with distance from Toronto. In fact, the data suggest that the Toronto region is a lichen and moss desert. The lichens and the mosses do not have a cuticle, so they extract nutrients and water directly from the air. Anything potentially toxic in the air will be intercepted and adsorbed thus they seem to be very vulnerable.

Along the Toronto-Peterborough transect, we represent in space what has happened over time. The steep urban-rural gradient of disturbance and traffic is accompanied by a pollution gradient. A temperature gradient also exists from a Toronto-centred heat island outwards to cooler rural areas.

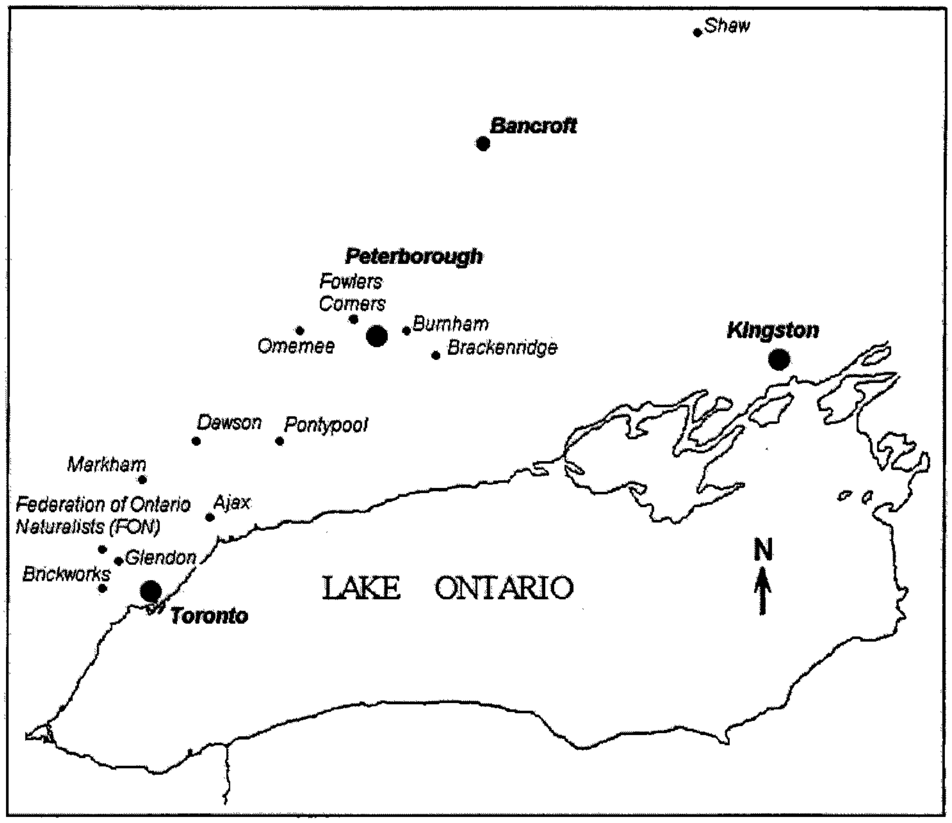


Figure 2. Toronto-Peterborough Urban-Rural Corridor Study field sites (map not to scale)

Table 2 shows the percentage of trees having lichens on their trunks up to 2.5 m from the ground. I used to think Toronto was not too polluted when I lived here but, upon assessment of 20 sugar maples at each of the three Toronto sites, no lichens were discovered. There is a gradual increase at the Ajax site adjacent to Hwy. 401 where the noise is so great that you can hardly hear yourself. Only 10% of the trees have epiphytic lichens on their trunks at this site. The number of different lichen species also gradually increases as you move from the city too. When questions are asked about how to measure forest health, the lichens and mosses are potentially sensitive species.

When examining the vascular species, one would expect them to be a bit more robust than the lichens and mosses, however the data for spring flora in Table 3 suggest otherwise. While the sampling is a little biased because, in site selection, we said that Trillium had to be present, there is a gradual increase in the spring flora out from Toronto. Spring flora appear vulnerable in many ways as we detected a diminution in the number of species, percent cover of each of the species, and in the occurrences of the species at the Toronto sites. Highway sites also act to some extent like mini urban areas such that a rural woodlot immediately against the 401 is also adversely impacted. Of course, these sites also receive extra pollutants specific to the highway location, including salt and a variety of hydrocarbons. In addition to the effect on spring flora, microbial flora and the rates of litter decomposition (Table 4) are also affected at the urban and highway sites.

Table 1. Floristic composition of sugar maple woodlots - forests along urban-rural corridor

Site	Mean Total No. Species per m^2 quadrat	Mean Cryptogams No. Per m^2
Brickworks	6.4	0.0
Glendon	6.7	0.2
FON	7.3	0.0
Markham	8.5	1.8
Ajax	5.9	0.2
Dawson	11.2	1.6
Pontypool	14.6	0.7
Omemee	9.0	0.4
Burnham Woods	14.2	1.6
Brackenridge	14.4	1.5
Shaw	4.6	1.8

Table 2. Occurrence of epiphytic lichens on sugar maple tree trunks to 2.5 m height above ground (15-20 trees).

Site	% Occurrence	# lichen spp.
Brickworks	0	0
Glendon	0	0
FON	0	0
Markham	20	3
Ajax	10	3
Dawson	66	5
Pontypool	30	4
Fowlers Corners	66	4
Burnham	66	6
Brackenridge	100	7

Interestingly, plenty of deer were discovered living immediately behind housing estates at the Ajax and the Markham woodlots. We also found some of the biggest trees in the province at some of these sites, with many from 140 to over 150 feet in height. These urban and highway sites are not depauperate in that deer are present, but the bird populations, especially in respect to the adverse effect of highway noise, are depauperate. Our observation was when we went to the Ajax and Markham sites, one got badly bitten by insects. The highway sites are a nightmare in that you virtually have to shout in each other's ears to be heard. It is a most unpleasant experience and the whole ground vibrates as one walks in these sites. If the ability of the birds to sing and set up their territory is compromised by highway noise, especially from trucks, then there may be a lack of insect-eating birds.

From our data, it is apparent that the inner sites in Toronto have not only lost the lichens, the rates of litter decomposition have already been reduced.

During the fall, litter is collected from the trees, dried and chemically analyzed. The litter is then placed back in the forest in nylon bags, each containing 2 grams of material. We place hundreds of these bags at the sites and then we retrieve them at intervals to assess how quickly the litter will decompose. In a hardwood forest, when maple leaves come down in the fall, one walks through a deep leaf carpet. By the following mid-summer, there is not much litter on the ground and, by the time you get to the next autumn, virtually all of the previous year's leaf litter should be decomposed. Complete decomposition of leaf litter within a year gives complete recycling of all the elements that have come down with the leaf fall and is indicative of a healthy system. The leaf litter and its decomposition is essential for all aspects of forest systems. Something is wrong with a hardwood forest system in which significant leaf material remains on the ground in the late summer before the next leaf fall. If nutrients can't cycle, then the system will lose vigour. From our data, it is apparent that the inner sites in Toronto have not only lost the lichens, the rates of litter decomposition have also been reduced. Our sampling indicates that there is a reduction in rate of litter decomposition for both white pines and sugar maples. Is this due to the fungal flora? Is it the lack of arthropods? Is it reduced insect populations in the soil? From studies completed in New York, we do know that the earthworm population has decreased in most of the urban sites. Based on our analysis, there is also evidence of accumulations of heavy metals and lead in the leaf litter, a possible explanation for the observed decline in decomposition rate. The litter seems to act as a kind of wick. Elemental concentration of white pine litter six months after it was placed in the sites were measured relative to what was in there in the beginning (Table 4). In the interim, about 12% of the litter has decomposed but, over this period, there has been a huge increase in the amount of lead in the litter in those nylon bags. An organic cation exchange occurs rather like the bioconcentration that we used to worry about with DDT, but for somewhat different reasons. The result is that you begin immediately after leaf fall with relatively low levels of lead and, over the course of sitting on the forest floor for six months in an urban site, the litter becomes grossly contaminated. These subtleties in the system are probably useful ways of looking at things.

Table 3. Occurrence of spring flora at sites from Toronto to Peterborough (Data are of occurrences in 10 randomly placed 1m² quadrats)

Spring Flora										
Total % Present in 10 sample plots (total number of occurrences)										
Species	**Brick.**	**Glend.**	**FON**	**Ajax**	**Mark.**	**Daw.**	**PP**	**FC**	**Burn**	**Brack.**
Trillium grandiflorum	6 (2)	0	50 (5)	1 (1)	0	6 (4)	10 (6)	22 (5)	4 (3)	15 (8)
Hepatica acutiloba	0	0	0	0	1 (1)	3 (3)	0	0	1 (1)	8 (7)
Maianthemum canadensis	0	3 (1)	0	0	1 (1)	17 (9)	9 (8)	5 (1)	4 (3)	21 (5)
Cauliophyllum thalictroides	0	2 (1)	0	0	0	12 (3)	0	0	59 (8)	24 (6)
Smilacina racemosa	3 (3)	0	14 (4)	2 (2)	0	0	0	0	103 (10)	11 (5)
Asarum candense	0	0	1 (1)	0	0	0	0	0	0	2 (1)
Podophyllum peltatum	35 (2)	0	0	68 (3)	0	0	0	24 (2)	0	10 (2)
Polygonatum sp.	0	0	2 (1)	0	0	0	4 (4)	0	2 (2)	0
Actaea pachypoda	0	0	0	0	3 (1)	1 (1)	6 (3)	0	6 (3)	3 (1)
Aralia nudicaulis	1 (1)	0	18 (3)	0	0	0	161 (10)	42 (6)	0	3 (1)
Thalictrum dioicum	4 (1)	0	0	0	0	0	0	12 (1)	0	0
Trientalis borealis	0	0	0	0	0	0	3 (3)	0	0	0
Steptopus roseus	0	0	0	0	0	0	13 (3)	2 (2)	1 (1)	3 (1)
Arisaema atrorubens	0	10 (6)	1 (1)	4 (1)	15 (7)	0	0	0	3 (3)	0
total #	9	8	15	7	10	20	37	17	34	37
total %	48	13	86	75	18	29	197	107	175	93
**total % does not include +, while total # takes presence into account										

If we move the season forward giving an early spring, there may be a possible overlap of increased UVb due to the ozone thinning with the spring flora unfolding. This year (1998) provided an example of the move forward of spring by about three weeks or four weeks in some areas of southern Ontario. However, at the same time, we did not have the excessive UVb that we have seen in some previous years.

Table 4. Elemental Content of White Pine Litter Bags after 6 months in Field Sites (ICP-MS ug) Compared with Fresh Litter.

Site	Lead	Vanadium	Calcium	Chromium
Time Zero*	1.8 (1.0)	0.3 (.07)	17.0 (1.6)	2.3 (1.3)
Brickworks	16.5 (9.4)	2.7 (0.7)	19.7 (2.5)	4.9 (0.7)
Glendon	22.7 (16.5)	3.9 (2.9)	21.7 (10.6)	6.1 (3.9)
FON	36.8 (28.5)	4.8 (2.2)	24.7 (2.0)	7.2 (1.3)
Markham	12.2 (1.8)	5.3 (3.1)	20.3 (0.9)	7.8 (3.0)
Ajax	20.0 (8.5)	4.4 (1.1)	19.4 (1.5)	9.2 (0.8)
Dawson	11.8 (2.5)	1.9 (1.6)	22.7 (2.8)	4.3 (2.1)
Pontypool	13.8 (9.2)	1.4 (0.2)	22.3 (0.5)	2.3 (0.7)
Fowlers Corners	13.7 (6.3)	1.9 (1.1)	20.0 (1.3)	4.8 (2.5)
Brackenridge	8.7 (2.6)	1.0 (0.5)	17.5 (4.4)	2.8 (1.0)
Shaw	9.8 (7.9)	0.9 (0.6)	19.6 (3.9)	2.7 (1.4)

A study by Diane Smith looking at Trillium indicated that, in our urban sites, seed set is reduced. This is an interesting ecological response, yet Trillium is still surviving in these sites. Is this reduction in seed set due to a decrease in pollinators or is it because the stigma of the flower in some way gets acidic droplets or metal contaminated droplets on it at the time of pollination, and pollen tube growth is consequently reduced? We do not know but both are real possibilities. Certainly, one might suspect that, in urban sites, where insect pollinators are essential for the spring flower, they may also be in trouble.

Another concern for the forest system relates to the combined effects of stratospheric ozone depletion and climate variability. Consider the time of the year at which we might expect excessive UVb relative to background levels due to polar ozone holes in the stratosphere. This normally occurs in the late winter months of February and March. In the boreal forest, nothing is growing at this time while in the hardwood forest, by the time we get into May, the flora is growing but the winter UVb levels are already declining. If we move the season forward giving an early spring, there may be a possible overlap of increased UVb due to the ozone thinning with the spring flora unfolding. This year (1998) provided an example of the move forward of spring by about three weeks or four weeks in some areas of southern Ontario. However, at the same time, we did not have the excessive UVb that we have seen in some previous years. We should set ourselves up experimentally to be in a position to look at this coincidence of early spring and enhanced UVb. It is very likely that the spring flora, since it is sitting on the forest floor without a tree canopy, is going to be vulnerable. The other sensitive element is the canopy itself, which normally would be expanding in May. This year, the canopy emerged in April. This early date moves the canopy emergence into a period of risk in terms of the ecology of these forest systems.

Overall, the studies emphasized the need to have a detailed knowledge of forest systems. It seems that several components of the forests are vulnerable to urban factors and, to a lesser extent, to highway proximity. Epiphytic lichens, ground flora, mosses, macrofungi fruiting bodies and rate of litter release from leaf fall all are sensitive. The spring flora is notably sensitive.

Overall, our research has emphasized the need to have a detailed knowledge of forest systems. It seems that several components of forests are vulnerable to urban factors and, to a lesser extent, to highway proximity. Epiphytic lichens, ground flora, mosses, macrofungi fruiting bodies, and the rate of litter release from leaf fall all are sensitive. The spring flora is notably sensitive.

SUMMARY

The data to date, while clearly preliminary, are part of a large study that seems to show a significant impact of the urban factor on forest biodiversity and functioning. It shows that soils are depositories for airborne metal accumulation and that this may be a long-lasting reservoir. It also shows that the diversity of the spring flora is a sensitive one, adversely affected by urban and highway stresses. The ability of micro-organisms to decompose fresh litter (needles) and, therefore, release and recycle nutrients, is also impaired in the more urban sites examined. Mosses and lichens are greatly reduced in the urban areas.

ACKNOWLEDGEMENTS

This study is supported by research grants from the Natural Sciences and Engineering Research Council of Canada and the Ivey Foundation.

REFERENCES

Fuentes, J.D. and T.F. Dann 1993. *Ground-Level Ozone in Canada During 1980 to 1991.* ARD-93-010. Atmospheric Environment Service, Downsview, Ontario.

Perspectives from the Niagara Escarpment Commission

Remarks by Deborah Ramsay
Niagara Escarpment Commission

The topic of my discussion is "what adaptive measures can be taken to reduce the vulnerability of the regional ecosystem to air issues?" Consideration of what is meant by "adaptive measures" should not be restricted to specific ecosystem responses. Rather, adaptive measures should include a broader range of adaptive concepts, including institutional adaptations, adaptations to management techniques, as well as adaptations to monitoring programs and assessment techniques. The other aspect of my discussion relates to the fundamental knowledge gaps associated with understanding the cumulative effects of atmospheric change. I am not going to prescribe what those information gaps are, but rather provide some direction in terms of what a planner and someone involved in ecosystem planning and management needs to know to get at those questions.

...at some point the Commission will need to address what ecosystem changes are associated with human or land use impacts, what changes are associated with natural ecosystem variability, and what changes are associated with broader atmospheric issues that we don't necessarily deal with.

The first point deals with institutional adaptations. It is important to recognize the integrated monitoring and assessment networks that are developing across Canada as well as the Niagara Escarpment. The Niagara Escarpment is part of the Ecological Monitoring and Assessment Network (EMAN) of Environment Canada. This Network has provided the Commission with access to monitoring protocols that have potential address many atmospheric issues identified during the workshop. The Network is important to the Niagara Escarpment Commission and for administering the Niagara Escarpment Plan for two reasons.

First, at some point the Commission will need to address what ecosystem changes are associated with human or land use impacts, what changes are associated with natural ecosystem variability, and what changes are associated with broader atmospheric issues that we don't necessarily deal with. The second reason relates to the spatial and temporal scales of assessment. The monitoring framework that we have currently for the Niagara Escarpment prescribes three scales of analysis: the "regional level", which really deals with satellite image analysis and tracking long term landscape and land use change; the "area level" at about a 1:50,000 scale of assessment, that tries to link cause and effect of change or at least deal with some of the synergistic relationships between land use change and ecosystem change over time; and, finally, the "intensive scale" that functions at the plot based monitoring level of analysis trying to understand exactly what the ecosystem or habitat effects are due to a number of variables. As you work through the scales of analysis, each level of change contributes to an effect or an impact at the intensive scale of monitoring. But in terms of identifying the cause of those effects, one cannot stop at the intensive level; you have to move up the scale of analysis and observation. Our ceiling is at the regional scale of analysis. We're not necessarily purview to the atmospheric and climatic variability information that needs to be factored into the analysis. For this reason, it is important to be part of a broader network that provides an additional scale of spatial and temporal analysis.

The next point pertains to planning adaptations, our historical tendency to deal with planning in terms of regulating land use and human effects on the landscape. As a planner, there is also a recognized need to deal with some of the other aspects of planning that hopefully can address the atmospheric issues or at least help ameliorate some of the effects. This involves things like transportation and urban planning issues, the form and density of urban systems, as well as thinking about how we plan for and start to restore natural systems to offset some of the carbon loading effects. Do we plan for the purposes of restoring historical biodiversity or do we try to provide species that perhaps are a little more tolerant to change? The work of Dr. Tom Hutchinson will help us to address some of those issues.

Implementation approaches are also worth considering. Traditionally, many organizations have followed a policy perspective or more of a top-down approach in identifying what the issues are and in establishing planning or regulatory mechanisms to deal with them. A strong basis of support exists for grassroots initiatives which are based on demonstration projects. Communities may then see how locally-based actions and responsibility can benefit climate, ecosystem and atmospheric issues. Biosphere Reserves are ideally set up to implement such an approach. The Niagara Escarpment is designated by the United Nations as a biosphere reserve so we have a responsibility to be connected with international and national programs such as with EMAN and with the Atmospheric Environment Service. We also have a responsibility to take that information and put it in the context of how communities can work towards addressing some of those broader issues in a sustainable way. I would like to make this responsibility an opportunity as well as a challenge.

Assessment tools are a vital part of our analysis. The Niagara Escarpment Commission has a monitoring program in place and we have identified some monitoring techniques and protocols based on what we consider appropriate indicator species for land use threats. We really haven't put our minds to what indicator species we should be using to look at atmospheric or climatic variability. We are interested in doing that because we are going to have to deal with the variation between human impacts and the broader scale impacts of atmospheric change.

A strong basis of support exists for grassroots initiatives which are based on demonstration projects. Communities may then see how locally-based actions and responsibility can benefit climate. ecosystem and atmospheric issues.

We need tools and techniques to assess linkages or interrelationships to identify synergistic and the cumulative effects. We don't know how to tease those effects apart into local level planning concerns and those that must be dealt with at a broader policy level. Another potential tool would be the establishment of what I would call a "clearinghouse" for monitoring data and assessment. We're happy to provide the monitoring data that we're collecting for assessment in a broader context. However, a central authority is needed to take information, from permanent monitoring plots set up along the Niagara Escarpment for example, and look at relationships between changes in habitat types or ecosystems and broader climatic factors. This represents an opportunity for us to share information.

The last points deal with partnerships and implementation. Partnerships are needed for monitoring assessment, understanding the effects, as well as the planning and management response. Partnerships enable us to use tools that are available to address not only those issues that we directly have control over, but those having a broader benefit. I mentioned the biosphere reserve concept and how it can be a model for sustainability. I noticed that there is a speaker here from the Region of Hamilton-Wentworth. Many opportunities exist to work with municipalities along the Escarpment that are already starting initiatives. Another aspect deals the notion of carbon credits. There is the opportunity to link offset of carbon loading and carbon credits to restoration projects that in turn have biodiversity benefits.

In closing, things can come together in a very cohesive and tight package. It just relies on communication and partnerships and thinking about things in creative and different ways.

Perspectives from Environment Canada's Ecological Monitoring and Coordinating Office (EMCO)

Remarks by Adam Fenech
Ecological Monitoring Coordinating Office, Environment Canada

Basic knowledge about an ecosystem is required before one can begin deciphering the impacts of atmospheric change. Towards this end, our office recently completed a species diversity assessment for the mixedwood plains ecozone, an area that encompasses the Toronto-Niagara region (Smith, 1998). Fourteen different species groups were examined to determine those at risk and what the human impacts are on particular species. The publication is just a summary of the actual 1800 page document that is contained within a CD-ROM provided in the back of the summary. The complete report is also available on-line (http://www.cciw.ca/eman-temp/reports/publications/Mixedwood/intro.html).

To complement the excellent talk provided by Dr. Hutchinson, I will raise a question based partly on some observations made in an excellent paper by Alanna Naber (Naber, 1997). Figure 1 shows the landscape of southern Ontario in pre-European colonization, drawn from land surveys completed between 1798-1850. The natural landscape represented in the figure is primary forest with the red being hardwood-dominated. Naber looked at the question of predicting the composition and extent of forests in southern Ontario as a result of future climate change. In the literature it has been suggested that, as temperature increases, the trees will march north. However, it is really difficult to predict the composition and extent of forests in the future because, primarily due to colonization limitations, trees lack the ability to respond quickly to change. The maximum migration rates have been calculated in eastern North America at 10-30 km per century. Other scientists have suggested this rate could be between 30-40 km per century but even these faster estimations are still less that the expected rates of isotherm displacement which is anticipated to be 120-630 km per century. In other words, the rate of climate change may outstrip the rate at which many of these forests can respond. In addition, Ontario has the unique problem in that, although it contains the northern limit of the Carolinian zone, the surrounding lakes create a significant barrier to migration. Thus one factor that probably controls the likelihood of forests adapting to projected atmospheric changes in the Toronto Niagara Region is the extent of the current forest habitat. Figure 2 is the contemporary version of the landscape of the early 1800's shown in Figure 1. Most of the red (hardwood-dominated forest) has disappeared and since been converted to urban or agricultural land uses, leading to a question for Dr. Hutchinson. How significant are atmospheric change impacts on the natural environment of the Toronto Niagara Region when compared with the obvious large impacts of urbanization and harvesting? Perhaps this is a question that a natural environment component of TNR Study can address over the next few years.

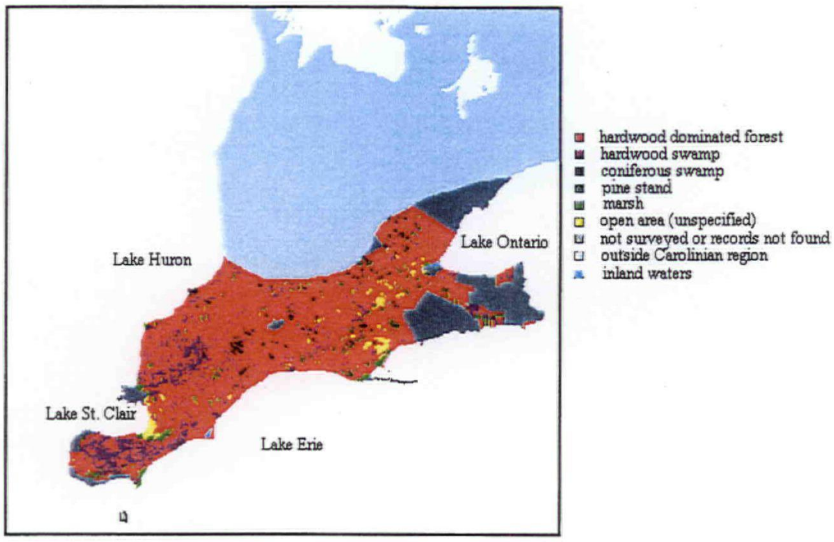


Figure 1. Landscape classification for southern Ontario prior to European colonization

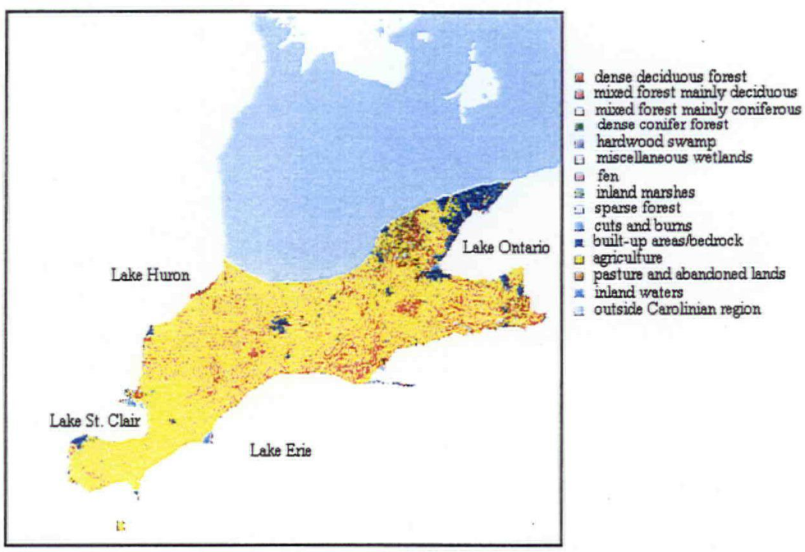


Figure 2. Contemporary landscape classification for southern Ontario

REFERENCES

Naber, A. 1997. *Forests of South-western Ontario, Past and Present...and Future?* Unpublished report prepared for Environmental Adaptation Research Group, Environment Canada, Downsview, Ontario.

Smith, I.M. (ed.) 1998. *Assessment of Species Diversity in the Mixedwood Plains Ecozone*. Printed Summary. Ecological Monitoring Coordinating Office, Environment Canada, Burlington, Ontario.

SECTION 4: IMPACTS OF ATMOSPHERIC CHANGE ON HUMAN HEALTH

Toronto-Niagara Region Study

on atmospheric change

Health Effects of Atmospheric Change in the Toronto-Niagara Region

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CONTEXT FOR THE PRESENTATION

Atmospheric change and multiple air issues is a broad topic. There are two interpretations of atmospheric change and related health effects from which to begin this discussion. First, atmospheric change could be considered any adjustment in the chemical composition of the atmosphere or atmospheric behaviour, whether resulting from human activities or natural variability. Second, atmospheric change could be a change in the atmosphere's behaviour due to changes in chemical composition. In this case chemicals, gaseous or aerosol, alter the radiative balance and the atmosphere responds. Different atmospheric behaviour (e.g., changes in weather patterns, precipitation amounts) influences the transport, transformation and deposition of air pollutants.

For this discussion, the first interpretation noted above was followed with the focus on the human health effects of air pollutants as their atmospheric concentrations change from zero or natural background levels to present levels in the Toronto-Niagara Region (TNR). The overall focus of the workshop was on several air issues. The issues related to air pollutants were smog and particulate matter (PM), which in reality are one issue falling under the category of "poor air quality". Examples of how smog and PM concerns are linked and how they are connected to the climate change issue are provided in the following sections.

Four questions related to the health effects of changing air quality were posed by the workshop organizing committee, ranging from what is known about the effects of atmospheric change on health in the TNR to what are current and future research and policy implications. Some of these issues are covered in this presentation overview.

There is a history of at least 15 years of health effects research based upon over 20 years of data in the TNR. This research has clearly demonstrated that a number of different air pollutants, at concentrations observed in the TNR, are associated with respiratory and cardiac health effects. Some of the highlights of this research are summarized in Table 1.

In some of the studies included in Table 1, temperature was also found to have an influence on the health endpoints. In particular, large values of dew point temperature were associated with higher mortality rates. Thus, there is a potential direct link between climate and health (see Smoyer, this volume, for a more detailed discussion). Recent TNR health research demonstrated that after correcting for temperature or dew point temperature effects, significant air pollutant associations remained.

The latest health studies showed that it is important to consider the full mix of pollutants in urban smog, clearly highlighting the fact that the air quality air issues are linked. Failing to account for multiple pollutants leads to underestimates of the impact and there is greater uncertainty in estimating effects due to individual pollutants.

The latest health studies showed that it is important to consider the full mix of pollutants in urban smog, clearly highlighting the fact that the air quality air issues are linked. Failing to account for multiple pollutants leads to underestimates of the impact and there is greater uncertainty in estimating effects due to individual pollutants.

Furthermore, these links extend from their combined health effects, which are difficult to disentangle, through common atmospheric processes, pollutant sources, and control policies. The key pollutants in the urban smog (CO, NO_2, SO_2, O_3 and PM) are all associated with combustion sources, many of which directly or indirectly emit these pollutants. Combustion processes also emit CO_2 and thus, in terms of sources and possible controls, the air quality and climate change issues are closely linked. Possible co-benefits of reductions in PM resulting from CO_2 controls have been estimated to be large (Lee Davis *et al.*, 1997). These co-benefits may even have been underestimated since they were based entirely on PM reductions and did not include concurrent reductions in CO, NO_2 or other pollutants that should accompany CO_2 emission reductions.

The main point of the previous discussion is that, from the standpoint of acute effects arising from inhalation exposure to air pollutants, it is necessary to consider their cumulative impacts. As well, when control options are considered, it is clear that air quality problems are linked to the problem of greenhouse gas (GHG) emissions.

There is another potential link between climate change/GHG and air quality issues, which is related to second interpretation of atmospheric change noted at the beginning of this paper. Climate change could lead to changes in the regional scale weather patterns influencing the TNR (Bass and Brook, 1997). Synoptic climatological analyses show that there are certain weather patterns or flow patterns that lead to higher air pollutant concentrations. If these patterns were to become more frequent due to a change in climate, then air quality in the TNR could deteriorate. This deterioration, coupled with more extreme heat episodes, would have a detrimental impact on public health in the TNR. For this reason, expansion of research examining how climate change due to higher GHG concentrations will affect regional weather patterns (temporally, horizontally and vertically) in the TNR continues to be important. This is currently a key knowledge gap that needs to be bridged in order for our understanding of the impacts of atmospheric change on the TNR to be advanced.

Table 1: Highlights of air pollutant health effects research in the TNR

1983	Ozone and sulphur dioxide correlated with respiratory hospital admissions in S. Ont. Pollutant effects not corrected for the strong temperature effect.	Bates and Sizto (1983)
1987	Expanded previous study and particulate sulphate included in analysis and shown to be associated with hospital admissions. "Acid summer haze effect".	Bates and Sizto (1987)
1989	S. Ontario children shown to have poorer pulmonary function compared to children in Sask. Average of a 2.1% decline in forced vital capacity (FVC) between the two groups of children, which is related to pollutant differences.	Stern *et al.* (1994)
1989	S. Ontario children shown to experience a decrease in pulmonary function during pollution episodes. Particle acidity (H^+) was included and considered to be a potentially important pollutant related to the "Acid Summer Haze".	Raizenne *et al.* (1989)
1994	Ozone and sulphate clearly associated with respiratory admissions in S. and C. Ontario. No evidence of a threshold, with effects down to low concentration. The confounding effect of temperature was accounted for.	Burnett *et al.* (1993, 1995)
1994	Ozone and H^+ found to account for 24% of mean Toronto hospital admissions.	Thurston *et al.* (1994)
1996	Gradient in pulmonary function such as FVC across 24 N.A. communities, including 3 in S. Ontario, is shown to be strongly linked to community to community differences in H^+ and PM.	Raizenne *et al.* (1996)
1997-	Full impact of urban smog, which is made up of multiple pollutants, is demonstrated. This combined effect is greater than the individual pollutant effects and primary gases such as carbon monoxide and nitrogen dioxide shown to be important pollutants.	Burnett *et al.* (1997, 1998a, 1998b)

Another gap in our knowledge involves developing approaches to integrating social, political and technical changes into our predictions of the health impacts of atmospheric change. It is obviously difficult to predict changes in society, but recognition of these parallel changes and close links in health impacts studies would round-out the research. Research on the vulnerability of the TNR to atmospheric change that simply adopts the "all things being equal" assumption in its projections of future conditions will unnecessarily and unjustifiably limit the scope of the study.

The bulk of the current evidence on health effects is from large-scale ecological epidemiological studies that do not provide a direct link back to specific individuals. Without this link and without stronger evidence on the full extent of air pollutant effects, it will continue to be difficult to convince policy makers, industry and the public of the need for action.

There are also gaps in our understanding of the air pollutant health effects, including the:

- physiological mechanisms responsible for observed associations between air quality and health;
- full range of impacts from air pollutant exposure and of the significance of premature mortality; and
- chronic effects from air pollutant exposure.

Progress in these areas is needed in order to provide better information to guide policy decisions. The bulk of the current evidence on health effects is from large-scale ecological epidemiological studies that do not provide a direct link back to specific individuals. Without this link and without stronger evidence on the full extent of air pollutant effects, it will continue to be difficult to convince policy makers, industry and the public of the need for action.

In terms of policy, Canada has or is in the process of developing policies on:

- air quality (O_3, PM, SO_2, NO_x, VOCs);
- acid deposition (SO_2, NO_x);
- stratospheric ozone (CFCs); and
- hazardous air pollutants (banned substances).

But, at the time of this workshop, Canada does not have a clear policy on climate change or GHG emissions. Given the link between these emissions and air quality discussed previously, it is prudent to target CO_2 emission reductions as an important policy because less combustion (assuming that the policy leads us in this direction) will have positive spin-offs in terms of improved air quality. Thus, we can and should use the air quality and health issue and current research results as an additional driver for greenhouse gas policy.

There are a number of current research projects underway in Canada that are expected to produce results in the upcoming year or two. Much of this work is relevant to the TNR. Although funding has been severely cut, Health Canada, Environment Canada and associates are working on a number of studies. These are focused on issues such as the role of particle acidity on respiratory and cardiac effects (Saint John, NB study); particle toxicity and combined particle-ozone effects (*in vivo* animal studies); combined air pollutant, weather and aeroallergen effects on asthmatics (Ottawa area population); human responses to controlled exposures to particles and particle-SO_2 mixtures (University of Toronto, Gage Institute); the links among the full ranges of possible effects from mortality to sub-clinical effects (Saint John study and Montreal mortality study); reanalysis of major U.S. epidemiological studies (University of Ottawa); new air pollutant monitoring on particle chemistry; and analysis of the Canada Health Survey. This is not a complete list of new or ongoing Canadian research. Work is also underway in Alberta and British Columbia of relevance to the TNR Study and, worldwide, the subject of air pollutant health effects is receiving more attention.

Recently, members of the Ontario Medical Association (i.e. doctors) joined together to release a strong statement regarding their concerns about the effects of poor air quality on the health of Ontarians. The interest in health offers an opportunity to expand the health impacts research, which has only been focused on the impacts of present and past air pollutants, to include additional air issues many of which are clearly linked and fall under the broader issue of atmospheric change.

In terms of linking the atmospheric change issues, new research is needed. Some research could be started today with available data and results. For example, the past research results on the health effects of the individual issues have not been combined to estimate the sum of their stresses on health. First attempts on this could be started today, resulting in a broader picture of the full impact on health and also a clearer idea of what areas require more immediate research in order to provide a more complete and realistic picture in the future. These results could then be integrated to obtain an estimate of the cumulative effects up to a given time in the future (e.g., year 2020). In the short term, this could be based upon the "all things being equal" assumption but, in the longer term, attempts to consider societal changes, in response to and independent of atmospheric change, would be beneficial. This work would help quantify the vulnerability of the TNR to atmospheric change. Another example of research that could be started today with available data would be to expand the ecological epidemiological studies in the TNR area to evaluate the combined effects of air pollutant and weather variables. Past studies have sought to control for the effects of weather and to then focus only on air pollutants or *vice versa*.

In summary, air quality is a major public health issue at the present time. It is a key area of interest for the federal Minister of Environment and new Canadian policies are being actively debated (e.g., sulphur content in fuels) where health is a major driver. Recently, members of the Ontario

Medical Association (i.e., doctors) joined together to release a strong statement regarding their concerns about the effects of poor air quality on the health of Ontarians. The interest in health offers an opportunity to expand the health impacts research, which has only been focused on the impacts of present and past air pollutants, to include additional air issues, many of which are clearly linked and fall under the broader issue of atmospheric change.

REFERENCES

Bass, B. and J.R. Brook 1997. The derivation of high-resolution meteorological data sets: a review of downscaling procedures for integration of multiple air issues. *Environmental Monitoring and Assessment*, 46: 151-174.

Bates, D.V. and R. Sizto 1983. Relationship between air pollutant levels and hospital admissions in southern Ontario. *Can. J of Pub. Health*, 74: 117-122.

Bates, D.V. and R. Sizto 1987. Air pollution and hospital admissions in southern Ontario: the acid summer haze effect. *Environ. Res.*, 43: 317-331.

Burnett, R.T., R.E. Dales, M.E. Raizenne, D. Krewski, P.W. Summers, G.R. Roberts, M. Raad-Young, T. Dann, and J.R. Brook 1993. Effects of low ambient levels of ozone and sulphates on the frequency of respiratory admissions to Ontario hospitals. *Environ. Res.*, 65: 172-194.

Burnett, R.T., R.E. Dales, D. Krewski, R. Vincent, T. Dann, and J.R. Brook. 1995. Associations between ambient particulate sulfate and admissions to Ontario hospitals for cardiac and respiratory diseases. *American Journal of Epidemiology*, 142: 15-22.

Burnett, R.T., S. Cakmak, J.R. Brook, and D. Krewski 1997: The role of particulate size and chemistry in the association between summertime ambient air pollution and hospitalization for cardio-respiratory diseases. *Environ. Health Persp.*, 105: 614-620.

Burnett, R.T., S. Cakmak and J.R. Brook 1998a. The effect of the urban ambient air pollution mix on daily mortality rates in Canadian Cities. *Canadian J. Public Health*, June issue.

Burnett, R.T., J.R. Brook, S. Cakmak, O. Philips, M. Raizenne, D. Stieb, R. Vincent, H. Ozkaynak, and D. Krewski 1998b. The association between ambient carbon monoxide levels and daily mortality in Toronto Canada. *J. of Air and Waste Management Assoc.* (in press).

Lee Davis *et al.*, 1997. Short-term improvements in public health from global-climate policies on fossil-fuel combustion: an interim report. *The Lancet*, 350: 1341-1349

Raizenne, M.E., R.T. Burnett, B. Stern, C.A. Franklin, and Spengler J.D. 1989. Acute lung function responses to ambient acid aerosol exposures in children. *Environ. Health Persp.*, 79: 179-185.

Raizenne, M., L.M. Neas, A.I. Damokosh, D.W. Dockery, J.D. Spengler, P. Koutrakis, J.H. Ware, and F.E. Speizer 1996. The effects of acid aerosols on North American children: pulmonary function. *Environ. Health Persp.*, 104: 506-514.

Stern, B.R., M.E. Raizenne, R.T. Burnett, L. Jones, J. Kearney, and C.A. Franklin 1994. Air pollution and childhood respiratory health: exposures to sulphate and ozone in 10 Canadian rural communities. *Environ. Res.*, 66: 125-142.

Thurston, G.D., K. Ito, C.G. Hayes, D.V. Bates, and M. Lippmann., 1994. Respiratory hospital admissions and summertime haze air pollution in Toronto, Ontario: Consideration of the role of acid aerosols. *Environ. Res.*, 5: 271-290.

Integrated Analysis of Weather-Related Mortality in Southern Ontario

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INTRODUCTION

Climate influences human health, ranging from the direct impacts of weather-related mortality and illness, to indirect impacts such as ecosystem disruptions that result in explosions of insect and rodent populations and the diseases they transmit. The Canadian Global Change Program Health Issues Panel recommended that "Canada should take a lead role in facilitating the development and conduct of a long-term international cooperative health research program related to global change" (1995:21). Steps have been taken in this direction, but much remains to be done. One example of current research activity addressing this area is an analysis of the human heath impacts of climate variability and change in the Toronto-Windsor Corridor (TWC) of southern Ontario. This project, which includes both present-day relationships and mortality estimates under climate change scenarios, is the latest initiative of the Climate and Health Research Program at the University of Alberta. The study objectives are to (1) identify the distribution of weather-related mortality in the TWC, (2) develop an integrated model of weather-related mortality for the region and (3) use this model to estimate potential mortality impacts under climate change scenarios.

In addition to climate variability, six atmospheric issues have been identified as key areas of concern in Canada: climate change, stratospheric ozone depletion, acidic deposition, smog, suspended particulate matter, and hazardous air pollutants (Munn and Maarouf, 1997). Of these issues, the impacts of climate on human health are the most severe, in terms of numbers of deaths stemming from a single event. Among climatic events, winter and summer weather (mainly temperature extremes) result in a greater number of excess deaths in North America than more violent weather events. For example, the heat wave of 1988 resulted in an estimated 5,000-10,000 deaths in the United States, while the number of deaths resulting from each of the major floods, hurricanes, and blizzards between 1980 and 1995 ranged from 0-270 (National Climatic Data Center, no date). Although more deaths occur in winter than in summer (and thus baseline mortality is higher in winter than summer) in North America, individual weather events have a more direct and immediate impact on human health in summer than in winter. In a study of weather-related mortality in 10 large Canadian cities, no significant winter weather/mortality relationships were found, while summer weather/mortality relationships were identified for Toronto and Montreal (Kalkstein and Smoyer, 1993a). The proposed study, therefore, focuses on summer weather-related health impacts (primarily heat-related mortality) although winter/mortality relationships will also be explored.

As well as causing heatstroke, hot weather exacerbates pre-existing health problems. Increases in hospital admissions and deaths from many different causes have been observed to occur within two days of exposure to heat wave conditions (Kilbourne, 1989; Tavares 1996). Weather-related events that damage property and infrastructure, such as tornadoes or hurricanes, may have lingering health impacts that are difficult to measure. These factors make the identification of historical heat wave impacts relatively straightforward, which reduces sources of uncertainty when estimating future impacts associated with general circulation model (GCM) projections of climate change scenarios.

Much of the focus of climate change research has been on modelling how the climate is likely to change. One method for estimating how human health may be affected by these changes is to use warming analogs or GCM-derived climate change estimates in models of present-day weather/mortality relationships (e.g., Kalkstein and Smoyer, 1993a, 1993b). But change is occurring in the human realm as well as in climate, and both dynamic global systems need to be considered when estimating climate change health impacts. For example, regardless of climate change, vulnerability to weather-related mortality in the TWC may increase as a result of several factors, including an aging population and increasing urbanization in the region. The elderly are disproportionately at risk of weather-related mortality, and thus vulnerability is likely to increase as the number of elderly residents in the region increases. Also adding to vulnerability is continuing urban sprawl in the TWC, which may lead to a strengthening of the urban heat island, thus increasing the risk of heat-related mortality. The major health hazard is expected to come from higher minimum (nighttime) temperatures in cities, which impede physiological cooling processes, although declining air quality would also be a contributing factor. On the other hand, increased air conditioning use or the implementation of weather watch/warning systems may help to mitigate vulnerability to summer weather. An increased understanding of how demographics, housing, land use, and socio-economic factors affect present-day weather/health relationships will enable researchers to make

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better-informed estimates about the magnitude and distribution of future health impacts.

METHODS

Although winter weather-related mortality does not appear to be a function of urbanization, heat-related mortality is most severe in urban areas. The study therefore will focus on the urban centers of the TWC. Weather/mortality relationships will be investigated using daily mortality from all causes for the elderly (>64 years) and non-elderly (<65 years) at the census subdivision (CSD) level for 1980-1996 for the following CSDs: Pickering, Ajax, Oshawa, Markham, Richmond Hill, Aurora, Newmarket, Scarborough, Toronto, East York, North York, York, Etobicoke, Mississauga, Brampton, Oakville, Burlington, Hamilton, St. Catherines, Cambridge, Kitchener, Waterloo, Windsor, and London (Figure 1). Adjacent and relatively similar CSDs with populations below 75,000 will be merged to ensure sufficiently large populations for mortality rate stability. Although the CSDs within the TWC experience similar weather, health outcomes, if analogous to responses documented in the United States (Smoyer, 1996; Smoyer, 1998), are expected to vary within the region. Within the TWC, variables that may influence vulnerability to weather-related mortality are not uniformly distributed [e.g., the proportion of elderly persons (Figure 2) and housing density (Figure 3)].

To categorize the weather, an air mass-based spatial synoptic classification will be used (Kalkstein *et al.*, 1996). High-mortality summer and winter air masses will then be identified. Multiple regression will be used to identify weather, population, housing, and socio-economic variables associated with mortality in the TWC during the study period. Then, to estimate future impacts associated with societal changes, demographic, housing, and socioeconomic projections will be substituted into the model. To investigate impacts associated with climate change, GCM-based scenarios will be used to provide new weather variables for the integrated models. Downscaling approaches are currently being explored as alternatives to using GCM-derived estimates.

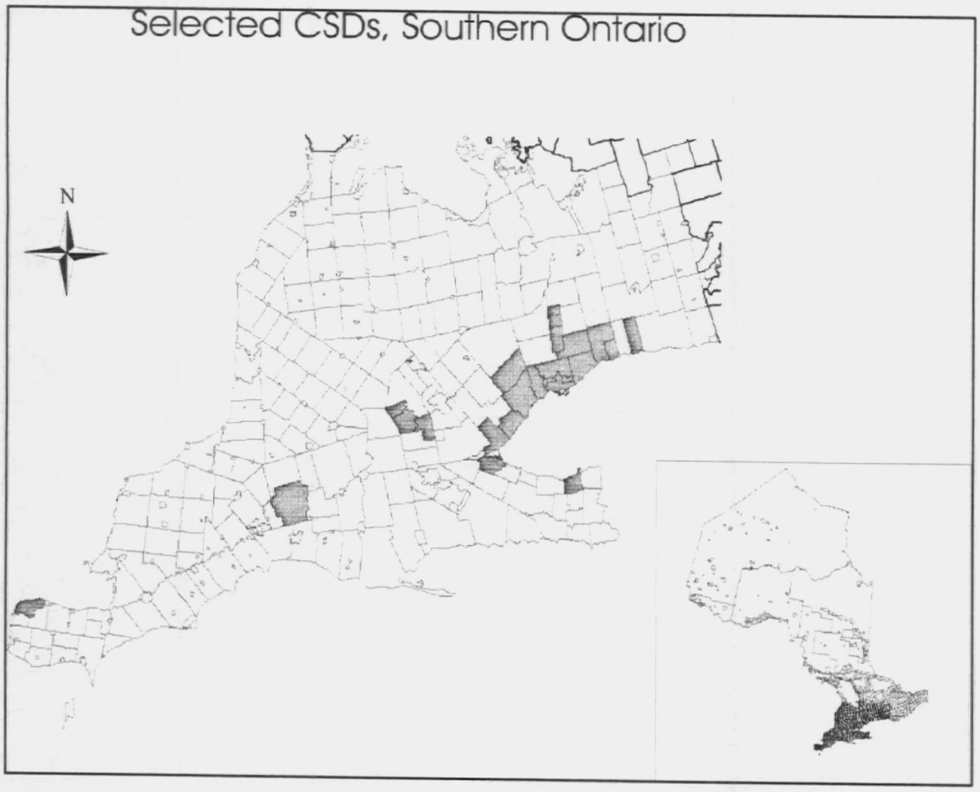

Figure 1. Census Sub-Divisions (CSDs) in southern Ontario selected for the Toronto-Windsor Corridor (TWC) study

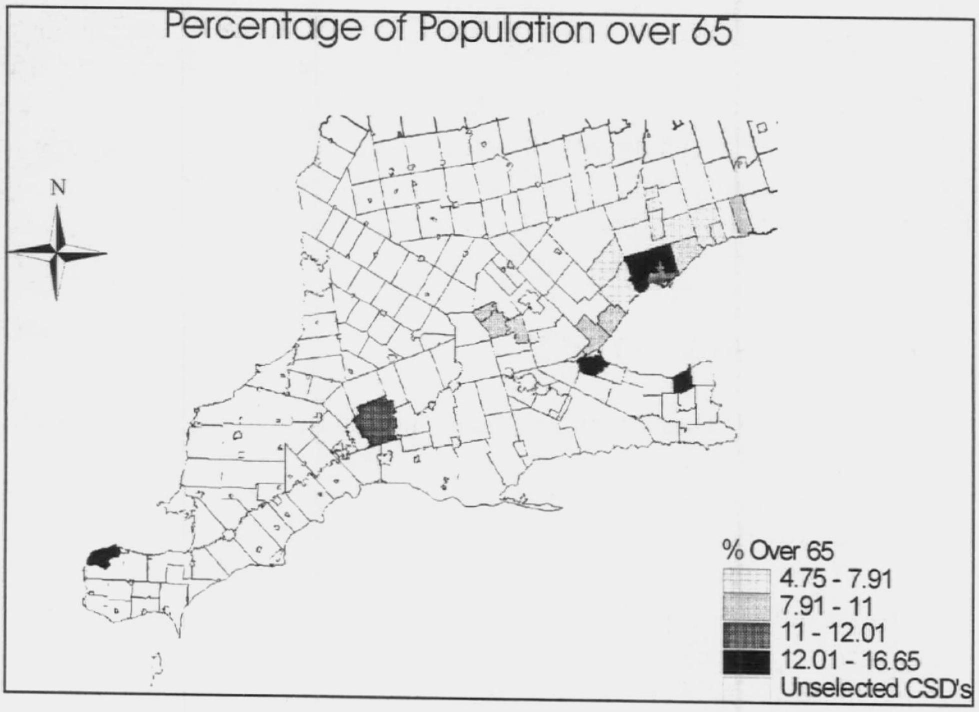

Figure 2. Percentage of population greater than 65 years old for selected southern Ontario Census Sub-Divisions (CSDs)

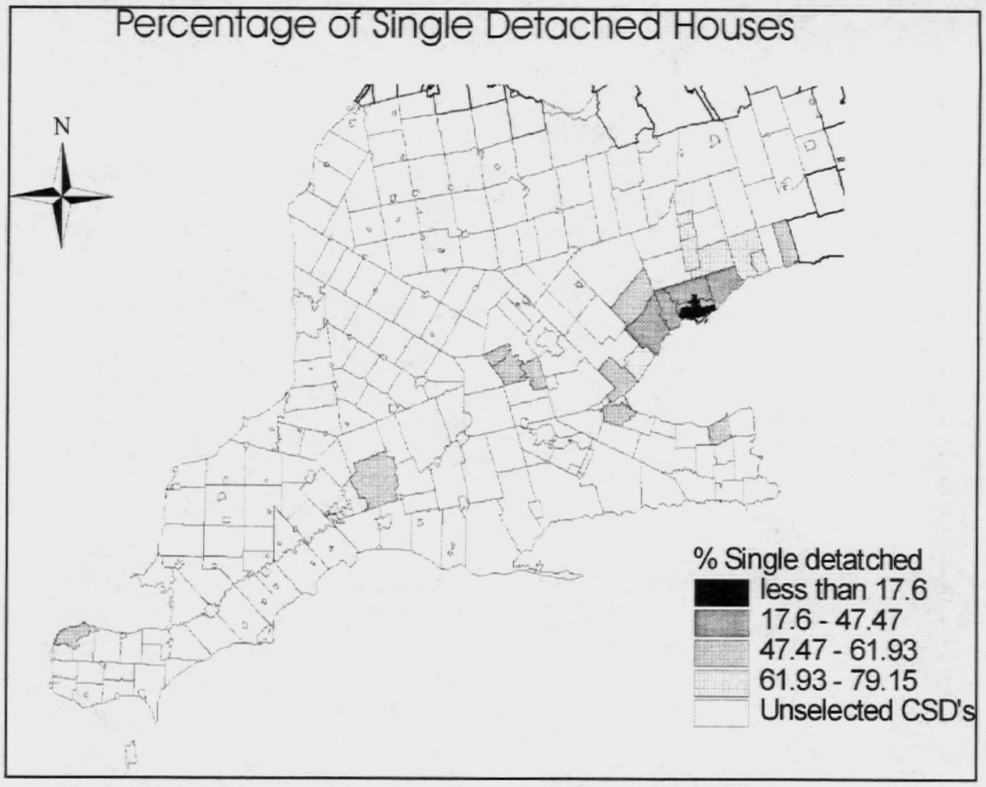

Figure 3. Percentage of dwelling stock composed of single detached houses for selected southern Ontario Census Sub-Divisions (CSDs)

Additional variables to be considered for the models, depending on availability, include the five other atmospheric issues identified previously, measures of urban heat island effects (available from LANDSAT data), and air conditioning usage. Air conditioning usage can be estimated from monthly residential energy use data if municipal utilities and/or Ontario Hydro will provide the data.

OTHER CONSIDERATIONS

The interaction between climate and air quality and the relationship of this interaction with health is an important consideration. Climate change is expected to increase the harmful effects of stratospheric ozone depletion, acidic deposition, smog, and suspended particulates (Maarouf and Smith, 1997). Despite air quality standards, increasing automobile use and length of work commute are challenges in maintaining healthy air quality and may result in increased health risks in the future. Even current ambient levels of ozone and sulfates have been shown to be statistically associated with hospital admissions for respiratory illnesses (Burnett *et al.*, 1994). The major difficulty in including all six atmospheric issues in this study is the limited availability of temporally and spatially overlapping data for all six parameters. In southern Ontario, there are ozone and sulfate monitoring sites dating back to 1983. The distribution of ozone monitoring across the study region is fairly good, but there are substantially fewer sulfate monitoring sites in the area (Burnett *et al.*, 1994). A second phase of the proposed project will include ozone emissions. Other atmospheric issues are being explored and will be considered for inclusion depending on data availability, quality, and distribution within the TWC.

RELATED PROJECTS

Past studies of U.S. metropolitan areas have revealed intra-urban and intra-regional variations in weather-related mortality despite similar weather conditions. In Canada, weather/mortality relationships have been examined *between* regions (Kalkstein and Smoyer, 1993a), but to date, there have not been any comparisons of mortality variation *within* regions or metropolitan areas. Past work on summer weather-related mortality within the city of St. Louis (at the census tract level) identified socio-economic factors, such as poverty and neighborhood decline, and environmental variables, including heat-retaining housing and lack of air conditioning, as heat-related mortality risk factors (Smoyer, 1996; Smoyer, 1998). These factors may be significant in summer weather-related mortality in the TWC as well.

In a study of heat-related mortality at the county level in the highly urbanized area between New York City and Wilmington, Delaware, differences in mortality were observed despite a similar climate in the region (Smoyer *et al.*, 1998). High-density, urban areas with older housing stock, lower air conditioning rates, and high poverty and unemployment rates typically had the highest heat-related mortality (Figure 4). Using these variables to define a heat-related mortality risk index, some exceptions were noted where heat-related mortality was higher or lower than expected (Figure 5). The anomalous counties are currently being investigated in greater detail. Intra-urban and intra-regional climate/health analyses provide information about how non-climatic factors interact with weather events to exacerbate or mitigate health impacts. Although climatic factors are the source of the hazard, vulnerability is situational and arises from a combination of demographics, the built environment, and socio-economic factors. Previous research in this area has given insufficient attention to these factors and instead has focused on climatic and atmospheric change. A fully integrated approach to estimating global change impacts must include societal as well as atmospheric change.

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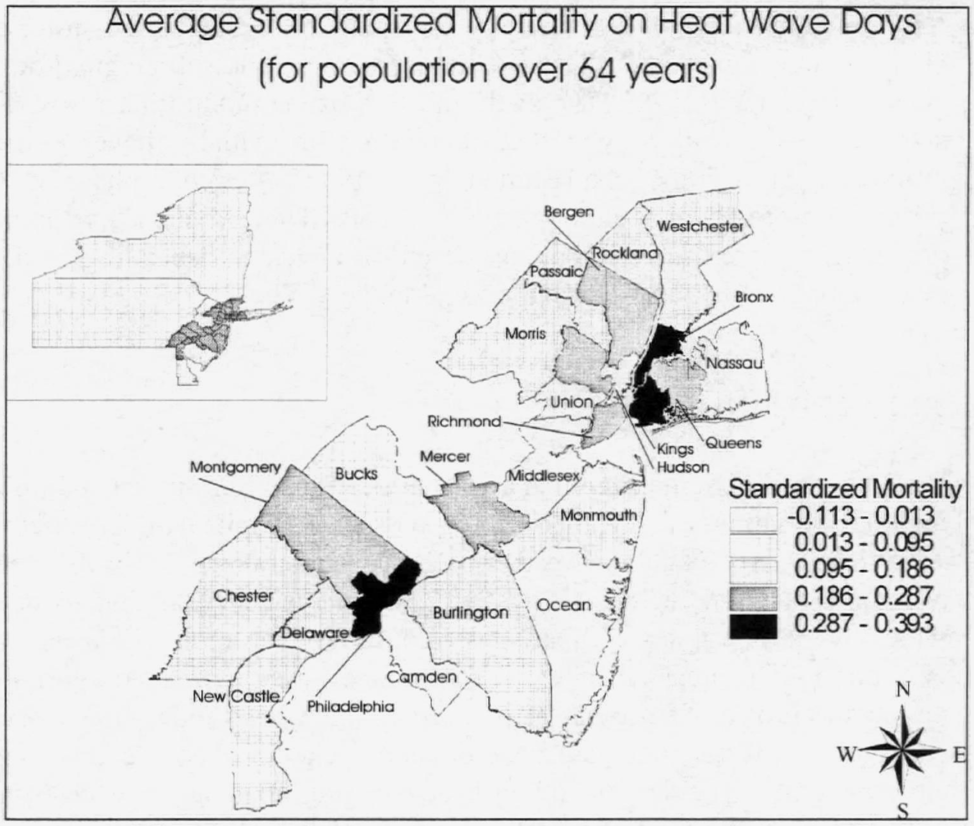

Figure 4. Average standardized mortality on heat wave days

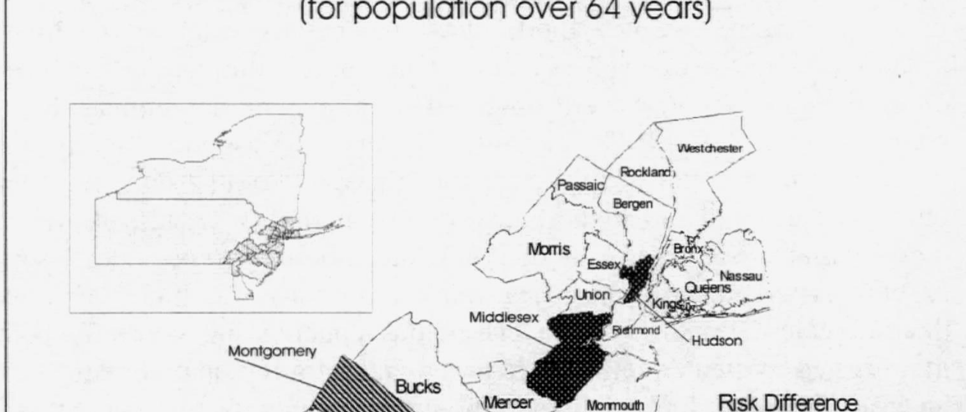

Figure 5. Difference Between Actual Heat Related Mortality and Expected Risk (for population over 64 years)

REFERENCES

Burnett, R.T., R.E. Dales, M.E. Raizenne, D. Krewski, P.W. Summers, G.R. Roberts, M. Raad-Young, T. Dann, and J. Brook. 1994. Effects of Low Ambient Levels of Ozone and Sulfates on the Frequency of Respiratory Admissions to Ontario Hospitals. *Environmental Research*, 65:172-194.

Canadian Global Change Program 1995. *Implications of Global Change for Human Health*. Incidental Report No. IR95-2. The Royal Society of Canada.

Kalkstein, L.S. and K.E. Smoyer. 1993a. *The Impact of Climate on Canadian Mortality: Present Relationships and Future Scenarios*. Environment Canada/Canadian Climate Center. Report No. 93-7, 50 pp.

Kalkstein, L.S. and K.E. Smoyer 1993b. The Impact of Climate Change on Human Health: Some International Implications. *Experientia*, 49: 969-979.

Kalkstein, L.S., M.C. Nichols, C.D. Barthel, and J.S. Greene. 1996. A New Spatial Synoptic Classification: Application to Air-Mass Analysis. *International Journal of Climatology*, 16: 983-1004.

Kilbourne, E.M. 1989. Heat Waves. In *The Public Health Consequences of Disasters*, ed. MB Gregg, pp. 51-61. U.S. Department of Health and Human Services, Centers for Disease Control, Atlanta.

Maarouf, A., and J. Smith. 1997. Interactions Amongst Policies Designed to Resolve Individual Air Issues. *Environmental Monitoring and Assessment*, 46: 5-21.

Munn, R.E. and A.R. Maarouf. 1997. Atmospheric Issues in Canada. *The Science of the Total Environment*, 203: 1-11.

National Climatic Data Center (*no date*). Billion Dollar U.S. Weather Disasters 1980-1996. Website summary statistics (http://ncdc.noaa.gov/ol/reports/billionz.html).

Smoyer, K.E. 1996. Environmental Risk Factors in Heat Wave Mortality in St. Louis: Implications for Mortality Projections under Climate Change Scenarios. *Proceedings of the 14th International Congress of Biometeorology (Part 2)* 3:150-157.

Smoyer, K.E. 1998. A Comparative Analysis of Heat Waves and Associated Mortality in St. Louis, Missouri—1980 and 1995. *International Journal of Biometeorology*, 42:44-50.

Smoyer, K.E., L.S. Kalkstein, and J. Detwiler 1998. Looking Beyond Climate: An Inter-Urban Analysis of Housing and Population Risk Factors in Heat-Related Mortality. Conference Presentation, Association of American Geographers, Boston.

Tavares, D. 1996. Weather and Heat-Related Morbidity Relationships in Toronto (1979-1989). In *Great Lakes-St. Lawrence Basin Project Progress Report 1: Adapting to the Impacts of Climate Change and Variability*. Ed. L.D. Mortsch, and B.N. Mills, pp. 110-112. Environment Canada, Downsview, Ontario.

A Public Health Perspective

Remarks by Franca Ursitti
Environmental Protection Office, Department of Public Health
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I have been asked to provide a perspective on how the City of Toronto has managed multiple air issues and their cumulative effects from a public health perspective. We have dealt with multiple air issues, but not always in an integrated manner, and have generally been driven by a single issue.

... although we may have looked at the multiple air issues, we have not yet looked at them in an integrated fashion. As a municipal government, we need to examine the range of air issues and we rely on the research that is being conducted by the workshop participants and other groups. We all need to work collaboratively in incremental steps to get things done. We have seen through the smog issue that health has been the driving force. Maybe we can learn from the smog issue and apply the lessons to the issue of climate change.

In 1988, Toronto Public Health conducted a community health survey in Toronto where we found that the main environmental concern was air quality. In 1993, Public Health examined the air quality issue more closely by conducting a monitoring study and by examining the emerging health evidence. In addition to finding levels of criteria air pollutants in the range of reported health effects, the air monitoring found 160 additional compounds in Toronto's air at various levels. Fourteen of these air toxics were identified as priority compounds for exposure reduction.

Recently, our work has been focussed on smog. Kevin Loughborough (City of Toronto Public Works) (this volume) mentioned that over the years we have seen a groundswell of political and public support on the smog issue. Non-government organizations have certainly done a lot of work to move this issue along and, most recently, the Ontario Medical Association has come on board. The issue is really progressing at the municipal level and Toronto City Council unanimously passed a Smog Reduction Initiative. Part of the strategy, the response component, went forward in June 1998 in the form of a Corporate Smog Alert Response Plan.

At the municipal government level, we don't have the regulatory authority over the Toronto emissions airshed, however there have been opportunities to pass certain by-laws that impact on air quality. For example, an idling control by-law was passed in the former City of Toronto that is aimed at preventing unnecessary vehicle idling. In October 1998, the Idling Control By-law was expanded to capture the whole New City of Toronto. We are also working on educational campaigns to minimize idling through local community efforts in schools and daycares.

I mentioned that, although we may have looked at the multiple air issues, we have not yet looked at them in an integrated fashion. As a municipal government, we need to examine the range of air issues and we rely on the research that is being conducted by the workshop participants and other groups. We all need to work collaboratively in incremental steps to get things done. We have seen through the smog issue that health has been the driving force. Maybe we can learn from the smog issue and apply the lessons to the issue of climate change.

Air Pollution, Ozone Depletion and Climate Change: Perspectives from a Health Impacts Researcher

Remarks by Kirsty Duncan, *Ph.D.*
Department of Geography, University of Windsor

In the medical research community, the focus has really been on air pollution including air toxics, acid precipitation, smog, particulates, and also the adverse effects of sunlight. This has also been the focus of Health Canada. There have been major initiatives in air pollution health effects research, many identified by Jeffrey Brook in his presentation, as well as those examining the adverse effects of stratospheric ozone depletion and resultant increases in ultraviolet radiation.

I think the Toronto-Niagara Region study provides a unique opportunity. To date we have individual researchers looking at climate change and health. It would be nice to tie in with people at the Institute of Environment and Health, people at McMaster, University of Toronto, University of Alberta, Health Canada and bring them all together. I think if we can get everyone sitting around the table, we can make a real difference.

There is a need for linking the different air issues. Jeffrey Brook mentioned the desire to assess the combined effects of different pollutants, and it would also be useful to look at different air issues, for example heat stress plus pollution as noted by Karen Smoyer. There is also a need for additional regional studies; we have this for air pollution in the TNR and other scientists have begun to conduct regional research on ozone depletion and ultraviolet radiation in western Canada. No similar studies have been done in Ontario, even though increased ultraviolet radiation may be among the most dangerous factors associated with global change. For example, for every one percent decrease in ozone we can expect a one to three percent increase in skin cancer. Over the past two decades over a thousand articles have looked at the adverse effects of sunlight. So it would be a great benefit to look at the adverse effects of sunlight here in the Toronto-Niagara Region. Such studies need to become transdisciplinary and transboundary in nature.

The sixth air issue that Quentin Chiotti discussed in his presentation was global warming or climate change, an issue that has largely been ignored. There have been just ten empirical studies that have looked at climate change and health for all of Canada, three of those in the Toronto-Niagara Region. Significantly more work has been undertaken in the United States than here in Canada, although most papers on climate change are conjecture. I've said this numerous times, but Health Canada does not recognize climate change as an important air issue. The department has fifty issues that they are interested in and climate change is not among them. This situation is unlikely to change unless new empirical research on climate change and health impacts is conducted. Karen Smoyer's proposed work is extremely exciting and will contribute towards this end, especially if it considers air pollution as well as climate factors.

There is also a need to look at vector-borne diseases. The climate change health-related research that has been completed in the U.S. has focused on both heat-related mortality and vector borne diseases. Two diseases that are of interest are malaria and Lyme disease. Lyme disease is currently endemic in Long Point, Ontario - the only place in Canada. Only about 100 cases of Lyme disease have been reported in Canada but the disease is now the most commonly reported infectious disease in the U.S. with about 30,000 cases per year. It was only recognized as a disease in 1976 however cases are now reported from every state in the U.S.

In brief, more geographical studies looking at particular regions are required, along with more surveillance and monitoring. I think the Toronto-Niagara Region study provides a unique opportunity. To date we have individual researchers looking at climate change and health. It would be nice to network with people at the Institute of Environment and Health at McMaster University, University of Toronto, University of Alberta, and Health Canada. I believe that if we can get everyone sitting around the table, we can make a real difference.

SECTION 5: IMPACTS OF ATMOSPHERIC CHANGE ON ECONOMY AND INFRASTRUCTURE

Toronto-Niagara Region Study

on atmospheric change

Adaptation to the Impacts of Atmospheric Change on the Economy and Infrastructure of the Toronto-Niagara Region

Heather Auld
Atmospheric Science Division, Environment Canada-Ontario Region

INTRODUCTION

Many of us today live in an era where people work in air-conditioned offices, return to climate-controlled homes, communicate electronically, eat fresh food trucked in from farms thousands of kilometers away, and travel large distances by air in a few hours. In these times, it's very easy to lose sight of the degree to which our lives and infrastructure depend on a narrowly prescribed range of climatic conditions. People in the Toronto-Niagara Region (TNR), for example, generally live where water is adequate if not abundant; where energy is available for running their homes and freely transporting them about; and where other needs are met by way of agricultural and industrial systems that also require particular temperature, rainfall, and humidity conditions.

The TNR is one of the most built-up and infrastructure-intensive regions in all of Canada. This infrastructure is needed to support its huge population. Although the TNR or the "Golden Horseshoe" of Canada makes up only a small percent of Canada's area, it is home to a significant percentage of Ontario's and Canada's population. The Golden Horseshoe, defined rather liberally here, accounted for some 22% of Canada's total 1997 population. By 2007, less than ten years from now, one trend prediction company has projected that the region will be home to 36% of the Canadian population (Strategic Projections Inc., 1997). All of these people are going to need more shelters and more infrastructure.

BUILT ENVIRONMENT

The shelters and other infrastructure that we humans build for our needs can be described as the "built environment". The built environment is made up of buildings and other infrastructure to serve the buildings. Humans build shelters or buildings to insulate themselves and their social

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and economic activities from weather elements and other aspects of the outside environment. Their primary function is to establish and maintain an indoor environment for our activities that is often at a nearly constant temperature and humidity. Other parts of the built environment, like roads and electrical transmission lines, provide supporting infrastructure for both buildings and activities (Dalgliesh, 1998).

This built environment underpins almost all of society's economic and social activities. It is made up of houses, offices, factories and plants; it consists of structures for supply, generation and distribution of water, electricity, gas and oil, as well as facilities for collection and treatment of waste; it includes our network of roads and waterways, bridges, canals, wharves, airport runways and control towers, our communications towers and lines; and it includes miscellaneous other facilities from hospitals, schools, shopping centres and amusement parks to penitentiaries.

Over the past few years, our built world has been shaken by what appear to be an increasing number of weather or climate-induced disasters. Since 1988, the U.S. has experienced some 25 weather disasters, each costing $1 billion or more. Twenty-one of these occurred in the 42-month period from August 1992 until May 1997 (National Climatic Data Centre, 1998). These weather disasters have included floods, blizzards, ice storms, hurricanes, heat waves and droughts. Prior to 1988, no weather disasters of this magnitude had ever been reported.

So what is going on? Are weather and climate becoming more variable and the extremes becoming more extreme and more frequent? Is society becoming more vulnerable to the existing extremes of weather and climate?

These trends could be influenced by many factors:

- Increasing numbers or intensities of extreme events (not clear since recorded weather history is relatively short);
- Increasing vulnerability (more real estate of higher value, more expensive assets, greater insurance coverage?);
- A high technology society more vulnerable to outages in infrastructure, a more urbanized population, and infrastructure sited in more risky locations (i.e. when extreme weather hits, more targets);
- Changes to the design of infrastructure (e.g. lighter roofs today; are new technologies and revised codes allowing us to design more on the edge?); and
- A highly competitive (low margin?) construction industry.

Over time, natural hazards like hurricanes, flash floods, severe winter storms, windstorms and earthquakes are inevitable. While these hazards and the phenomenon that cause them are generally beyond our control, our vulnerability to them is almost always within control. When a natural hazard becomes a natural disaster and leads to disruptions of entire communities, the result is as much a function of the way that society does business and adapts to the hazard as it is of the natural hazard itself. A natural hazard does not have to become a disaster as long as the risks associated with the hazard are managed. In the built environment, natural hazards can be managed through proper land use, good engineering design and practice, and good weather warnings (Auld, 1996). While land use issues are more difficult to tackle, the development of good engineering codes and standards are tractable and have already been and will continue to be successful in preventing much harm to the built environment.

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Our infrastructure needs to be designed and constructed to withstand the "freak events of weather", including the extremes of cold, snow, rain and wind. In Canada, building codes have been developed cooperatively by three levels of government for half a century to prescribe minimum safety requirements. Building codes, by law, require the incorporation of design information about the climate. Other major parts of our infrastructure, including communication towers, transmission lines, highways and bridges and dams, are designed in a similar fashion to meet national standards.

The starting basis for safe design is a set of climatic and seismic design values. These design values reflect an acceptable risk against the extremes of nature. Quantities like the 10, 30, or 100-year worst storm wind or rainfall are used and these values vary considerably from one location to another (Canadian Commission on Building and Fire Codes, 1995). The storm or risk that is considered acceptable depends on the structure and its use. A school, a hospital and other post-disaster structure that has to be more resilient to the elements is designed to a lower acceptable risk or a greater storm (i.e. for a 100-year wind storm) than a house (typically designed for a 30-year storm). Other forms of infrastructure are designed to other combinations of acceptable risk.

In the end, decisions on how to build structures are primarily driven by the need to build both safely and economically. The appropriate balance must be struck between strength or safety and serviceability over the life of the structure and over initial and maintenance costs. This can only be done using realistic estimates of future wind and snow loads. While structures can always be "over-designed" to protect against natural hazards, the economic costs to society can be prohibitive. Because of the significant economic value of our built infrastructure, it is important that structures be designed and constructed as economically as possible.

The value of all new and repaired construction in 1990, at the start of a recession, was over $102 billion and employed some 985,000 workers. The $102 billion accounted for nearly 15% of GNP. About 30% of that construction in Canada took place in Ontario (Dalgliesh, 1998). A systematic overdesign of 20% would cost the $102 billion industry a considerable amount of money.

Over time, natural hazards like hurricanes, flash floods, severe winter storms, windstorms and earthquakes are inevitable. While these hazards and the phenomenon that cause them are generally beyond our control, our vulnerability to them is almost always within control. When a natural hazard becomes a natural disaster and leads to disruptions of entire communities, the result is as much a function of the way that society does business and adapts to the hazard as it is of the natural hazard itself.

The design of structures also requires an appreciation of the variability and uncertainty of the engineering technology. For critical post-disaster buildings like schools and hospitals, basic engineering or starting values are increased by a set percent (e.g., 150%) to account for uncertainties in strengths of materials and other engineering technologies. But, unlike the engineering calculations, the climatic values are considered to be accurate and no uncertainty is assigned to them. Structural failures can result when climate extremes approach their design values and the engineering performance of the structure encroaches or exceeds its uncertainty limits.

The choice of safety margin or multiplication factor used depends on the intended occupancy of the building. The greater the number of people expected to use the building, the *safer* the design of the building must be. Transmission lines, on the other hand, aren't designed with large safety factors - maybe 10-30% allowed for uncertainties - since their failures are considered to bring economic losses rather than losses of lives. The Ice Storm of January 1998 illustrated that impacts from failure of the electrical distribution system brought more than economic losses.

Some of the safety factors used for design of various infrastructure were set many years ago at a time when society was perhaps less sensitive to infrastructure failures. If our society becomes any more vulnerable to climate extremes or if climatic design values become more uncertain, then these safety factors will need to account for the impacts of an increasingly uncertain climate. The Ice Storm that hit eastern Canada in January pointed out just how vulnerable our modern, high-tech and "just in time" society has become to outages in infrastructure.

ICE STORM '98

The Ice Storm demonstrated graphically that extreme weather can cripple today's high technology infrastructure. The storm illustrated our society's vulnerability to interruptions in electricity, water supply, sewage treatment, transportation and other failures of infrastructure. A similar storm 30 years ago might not have left as severe an impact. In January, many homes turned dangerously cold during the power outages because most furnaces could not operate without electricity to run electronic controls. Whole industries needed to be shut down when the power went out, some sustaining significant losses. In the case of one large metropolitan centre, power outages threatened treatment of drinkable water.

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This extreme ice storm was remarkable for its persistence, its extent, and the magnitude of its destruction. Over a period of about six days, up to 100mm of freezing rain fell intermittently over an area that at one point extended from central Ontario to northern Nova Scotia. The storm destroyed trees and downed power lines and giant transmission towers in record numbers. It directly affected more people than any previous weather event in Canada and will go down as the costliest in Canadian history-to this point. At its peak, more than 3 million people were without power, some for as long as 5 weeks. In eastern Ontario, the storm left more than 500,000 without power, damaged over 100 transmission towers and destroyed 30% of the distribution system in the area (Ontario Hydro, 1998). A total of 10,750 wood poles were snapped off by ice, many toppling their transformers and spilling insulating oil onto the ground, some containing PCBs. Because communications towers are currently designed for higher ice and wind loads than electrical distribution lines, enough towers remained operational to support mobile communications in eastern Ontario. It is fortunate that many of these mobile communications structures were designed for higher weather loads because cellular phones and mobile radio communications proved essential for communications and coordination of emergency response during and after the storm. Most telephone lines suffered the same fate as the electrical distribution lines.

In hindsight, several adaptive actions could be undertaken by householders to reduce the impact of future ice storms in more risky areas. Some actions are quite simple and most save energy. For example, insulated water pipes don't freeze and cause water problems as quickly as uninsulated ones, and save energy the rest of the time. Energy efficient refrigeration systems maintain cold temperatures for a longer time during power outages and save energy. Well-insulated houses with energy efficient windows stay warm longer in winter and cooler in summer during power outages and also save energy. In addition, energy efficient windows deteriorate more slowly from climate-induced moisture accumulation than leaky ones. Finally, renewable or even fossil-based backup power-generation systems can be downsized considerably (and run longer) if the energy loads they need to serve are highly efficient.

CLIMATE CHANGE IMPACTS ON INFRASTRUCTURE

...several adaptive actions could be undertaken by householders to reduce the impact of future ice storms in more risky areas. Some actions are quite simple and most save energy. For example, insulated water pipes don't freeze and cause water problems as quickly as uninsulated ones, and save energy the rest of the time. Energy efficient refrigeration systems maintain cold temperatures for a longer time during power outages and save energy. Well-insulated houses with energy efficient windows stay warm longer in winter and cooler in summer during power outages and also save energy.

Global warming will bring impacts beyond changes in temperature. As climate change progresses, weather extremes will likely change in intensity and shift their location, requiring changes to the criteria for design of structures. Existing structures built to old standards will remain robust if extremes decrease, while those designed for lower extremes will come under greater risk of collapse should extreme events become more severe or frequent. One of the great future issues, according to the IPCC Second Assessment (IPCC, 1996), will be to develop economical methods to retrofit substandard buildings and other structures to the latest building code and standards requirements needed as the climate changes.

In the end, it remains unknown whether the margins of safety built into building codes and other standards will be sufficient under future climates to maintain safe and economical structures, even with good workmanship and materials (Smith *et al.*, 1998). It is expected that in areas where the current code is deficient or uncertain, those deficiencies could be exacerbated by changes in climate.

It also remains unknown whether the costs of adapting to changed climatic loads will increase or decrease (Smith *et al.*, 1998). In the TNR, it is possible that snow loads will decrease as more winter precipitation falls as rain, depending on how warm winters become. For flat-roofed buildings, this change might increase risks of collapses since many of these roofs currently have to support rain loads that are greater than snow loads.

A warming of the seasons will also affect the sizing of heating, cooling and ventilation equipment. Since the size of this equipment depends on the near extremes of heat, cold and humidity, any warming will directly affect guidelines for sizing of furnaces, air-conditioners, dehumidifiers and ventilation systems (Davenport, 1994). Unfortunately, it is not possible to determine how extreme humidities and temperatures will respond to climate change.

A warmer climate will bring a reduced need for winter heating since the energy for winter heating depends strongly on temperatures or accumulated temperatures. Summer air-conditioning needs should increase as hot spells become more common and average temperatures increase in summer. Some projections using changes in cooling degree day values have indicated that the year-round net energy used may decrease per household because more energy will be saved from heating than will be consumed for additional air-conditioning (Bhartendu, 1987). This conclusion probably requires further research, especially since additional work is needed to develop relationships that describe current cooling loads as a function of climate variables. The energy needed for summer cooling is considerably more complicated than that for heating and depends on temperature, humidity, wind, solar radiation, cloud cover as well as the structure considered, its internal sources of heat, and its siting. As a result, typical cooling loads (and heating loads) are modelled by engineers for the more complex buildings.

The net energy impact for all of the TNR will depend on energy prices, the development of energy efficiency technologies, economic and population growth as well as the energy efficiency of the new and old building stock.

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WEATHERING OF INFRASTRUCTURE

In contrast to extreme events, where the damage is done in seconds or minutes or days, premature failure caused by weathering deterioration usually takes months or years to become evident. Like the structures of nature, man-made structures are also subject to erosion by the slower day-to-day processes of wind and water, freeze-thaw cycles, abrasion, the action of broad spectrum solar and ultraviolet (UV) radiation, and by chemical breakdown in the presence of water, oxygen and assorted pollutants.

The premature deterioration of clay bricks in some parts of North America has been recognized by the industry as an emerging problem needing a solution. The brick industry is attempting to further study the causes of clay brick weathering so that approaches can be developed to prevent the accelerated deterioration. It is hoped that the existing clay brick standard can be revised or a new standard developed that will apply to all of North America. A similar problem exists with accelerated deterioration of reinforced concrete materials. Existing standards do not adequately protect concrete in some parts of the country, including the TNR. It is essential that preventive actions be developed today so that infrastructure does not become more vulnerable in the near future.

Under climate change, it is expected that warmer winters may bring more frequent freeze-thaw cycles and greater weathering of infrastructure materials (Smith *et al.*, 1998). Increased acidification along with a greater frequency of precipitation episodes may exacerbate the deterioration of materials. Further research is needed to determine the impact of climate change and other trends in society on acidification and possible increases in pollution episodes.

Current projections indicate that UV levels should return to pre-1980 values by 2050, assuming that ozone-depleting substances can be replaced and eliminated well before then.

CONSTRUCTION

The construction industry is highly sensitive to weather. Both extreme events and average climatic conditions play a direct role in the construction process. Weather limits many construction tasks including excavation, earthmoving, foundation works, concrete placement, steel erection, masonry, crane operations, exterior finishing, paving and road building. Snow conditions, for example, can also affect on-site operations and transportation to and from the site. High humidity interferes with plastering and painting while low humidity can crack cement. Variations in temperatures, solar radiation and cloud cover affect thermal expansion and contraction of materials. Winter construction may require temporary enclosures and heating and thawing of foundation material while spring construction is often delayed or undone by heavy rains and flooding (Smith *et al.*, 1998).

Many of the impacts of climate change on these weather-construction relations are unknown. In general, warmer winters will lengthen the construction season. A decrease in snowfall could result in decreased transportation disruptions. Changes in wind patterns will have a significant but unknown impact since future wind patterns are not known.

IMPACT OF THE BUILT ENVIRONMENT ON THE ATMOSPHERE

While the atmosphere has a tremendous impact on the built environment, it is equally true that the built environment can significantly affect the atmosphere. As Toronto has grown, its average temperatures have increased. The 1980s were nearly 2°C warmer than temperatures 100 years ago, when Toronto's population was one-quarter of its present size. How much of this 20th century warming can be attributed to general climate change over southern Ontario versus the urbanization of Toronto is unknown. Large cities like Toronto can produce their own weather and local "greenhouse warming". Compared to the surrounding countryside, cities have warmer temperatures (urban heat island effect), lighter winds (except for gusts around tall buildings) and lower humidity and visibility. Cities experience less sunshine, more cloud, more fog and rain, and less snow. The "heat island" effect of large cities is particularly noticeable on clear, calm nights and early mornings in the winter, leaving the city as much as 5-8°C warmer than its rural neighbours. In summer, daytime temperatures can be 1-2°C higher in urban areas, depending on smog levels (Auld *et al.*, 1990). Generally, the degree of warming increases with the size of the city and its population density.

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Cities at the latitude of the TNR can reap benefits from this added urban warmth, including lower heating bills. Heating costs for the same house would be 15% higher in Richmond Hill, north of Toronto, than in the city centre. Of course, Richmond Hill's weather is colder and snowier for many reasons: the urbanization effect, elevation, and distance from Lake Ontario. The extra warmth also means 15 to 30% fewer snow days in downtown Toronto, reducing the cost of snow removal. On the other hand, cities consume additional energy dollars through a greater need for air-conditioning. The urban heat island effect can also bring about a longer growing season. The number of frost-free days in downtown Toronto averages 191 days, dropping off to 164 days in North York and to 145 days in locations further north.

Our infrastructure inflicts considerable damage or alteration to the environment. Buildings, for example, account for one-third of the energy used in Ontario for space and water heating, lighting, cooling, ventilation and operation of equipment. In reality, the built environment accounts for more energy than that, considering the energy inherent in the manufacture of structural materials (Dalgliesh, 1998). As a result of the energy needed to build and operate buildings, owners need to extend the useful life of structures by providing for durability and change of use at some later stages. Other actions that the construction industry can take to significantly reduce its energy impact on the environment include the construction of buildings that are energy efficient, as well as durable and healthy for their occupants. Research is required into ways of incorporating flexibility in design, allowing economical rearrangement and reuse of components and assemblies.

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It can been claimed that the most environmentally friendly energy is energy that is saved. With this in mind, The National Building Code Commission developed and published two National Energy Efficiency Codes, one for residential buildings and another for all other buildings. The National Energy Codes for Houses and Buildings were established to encourage energy efficient buildings (Canadian Commission on Building and Fire Codes, 1997a, 1997b). These energy codes also contain a unique feature that can provide consideration for the environmental costs of using various heating and cooling energy sources. These environmental costs can be described as the externalities of energy use. Energy externalities are costs not included in the price of energy that reflect the *real* costs that society, taxpayers and future generations will pay for the health and environmental impacts associated with its use. The net result of designing structures using the National Energy Codes and incorporating environmental externalities is new buildings that withstand the weather elements in the most economical and energy efficient manner while bringing the least harm to the environment from the use of energy. Unfortunately, representative values of these environmental externalities are not yet available for inclusion in the energy code-another significant research gap. The use of energy codes and environmental externalities in the economically significant building construction sector would send a powerful signal to other economic sectors in favour of sustainable practices.

Currently, there are many building energy savings technologies waiting to be adopted into use. Unfortunately, it can be difficult to get these technologies accepted in the marketplace, priced competitively, used by the trades, and requested by buyers. A significant research challenge is to understand some of the barriers to the adoption of energy efficient technologies and to determine which of the energy savings technologies are most appropriate for the present and future climate of the TNR.

Some of the most energy efficient buildings can still have high total building-related CO_2 emissions. A recent study of Ottawa federal office buildings showed that some 43% of total building-related emissions were due to commuting vehicles (Royal Architectural Institute of Canada, 1996). As buildings become somewhat more efficient, it is reasonable to speculate that a greater percentage of building-related emissions contributing to the global warming effect will be attributable to the use of vehicles by its occupants. The location of buildings relative to public transport is therefore a planning issue of great importance in trying to improve the environmental performance of buildings. In the context of most urban structures, this means high-density and mixed-use buildings. Further research is needed to augment that underway by the Canadian Mortgage and Housing Corporation and Natural Resources Canada to investigate prospects for broader adoption of high-density and mixed-use buildings that are adaptable to changes in use over time.

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More research is needed to assess the role of climate change on our built environment. Until the impacts of climate change on weather extremes can be assessed, it is hard to advise the construction industry and code setting agencies on whether stronger, more robust structures are needed. It is equally difficult to determine when certainty in climate change projections of extremes will be sufficient to advise the code setting agencies on when to better incorporate climate change impacts.

CLIMATE CHANGE ADAPTATION OPTIONS

There are several adaptive options available to society to reduce the vulnerability of our infrastructure to future climate change. One significant contribution would be to continuously assess and update climatic design values for building codes and standards over time. The updating of climatic design values with information on the changing climate and its variability will ensure that building designs do not become more vulnerable to climate surprises. In some other cases, current long-standing gaps and deficiencies in the determination of climatic design values prevent optimum decisions from being made today and long into the future (Dalgliesh, 1998). Structures designed using climatic design values that are based on poor climatic data or previously short records may be particularly vulnerable to climate change.

The second set of actions addresses the uncertainty surrounding the strength and robustness of structures. Varying safety factors are applied for the unknowns in the engineering of structures. Therefore, it is theoretically possible that some structures designed for 30-year return period extremes might withstand more extreme atmospheric hazards having much longer return periods while others may be standing at the limits of their load tolerances. This would be true if the engineering uncertainty factors are too conservative. Further study is needed to determine whether and when the uncertainty or safety factors should consider the increasing uncertainty in climate design values as the climate changes. Research is also needed to consider the impact of changing engineering practices and building codes on the ability of structures to withstand surprises in extreme weather loads.

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Climate adaptation could also be enhanced through the provision of additional funding to support a network investigating natural disasters (Dalgliesh, 1998). Disaster investigations pay dividends in mitigation and adaptation measures for future events. The performance of structures during extreme events should be monitored to confirm and further fine-tune engineering design practice as well as climatic design values. As an example, many lessons were learned from the detailed investigations of how structures responded to the Barrie and Grand Valley tornadoes in 1985. The results indicated that occupants of houses that were destroyed by the tornadoes survived when the walls of their homes were properly secured to the foundations of their houses using adequate washers. The 1995 National Building Code of Canada increased requirements for anchoring of walls to foundations for tornado prone areas (yet to be defined). Similarly, hurricane clips (economically priced) might prove successful in anchoring the roof of a structure to its walls. Research on the impacts of the Barrie and Grand Valley tornadoes indicated that measures to prevent walls from collapsing on the occupants, during and after the tornado, saved lives.

Several other knowledge gaps exist in the area of climate change impacts and adaptation. Adaptation and mitigation actions that can account for the variable lifespans of structures need to be investigated. The design life of a structure becomes important in determining what climate change impacts can be expected over its lifetime. On the adaptation side, structures with a design life of 30-50 years need to consider different future climate conditions than others with a longer design life of 100 years. Heating, ventilation and cooling systems have shorter lifespans than the buildings they are housed in, typically 25 years or less, and can be replaced in the future before the climate begins to change significantly.

The varied lifespans of structures and their components also has importance in designing strategies to limit emissions of greenhouse gases. Existing physical, institutional and behavioral infrastructure limit our capacity to mitigate emissions in the short term. The lifetime of an electrical generating plant is several decades; transportation infrastructures are similarly hard-wired and slow to change; our stock of buildings and houses, much of it energy inefficient, are also slow to change over. For example, 69% of all houses in Canada were built before 1978 when energy-efficiency requirements were much less stringent. It will take time to change institutions and policies to reflect climate change realities. Again, the future challenge will be to economically retrofit older infrastructures to become more energy efficient and environmentally benign.

ENERGY INFRASTRUCTURE

Energy, which is essential for sustaining economic prosperity and maintaining national security in our country, is also linked with many of our most pressing environmental and social problems. The problems include pollution and its impacts on human health and both the natural and built environments, trade deficits and economic prosperity. Historically, energy use was tied to Gross National Product; the more energy consumed per capita, the more prosperous the country. Today, it is slowly becoming known that reducing energy and other resource waste can spur economic development, often at the local and regional level, and that reductions also lead to greater security of abundant energy and a cleaner environment.

There are several adaptive options available to society to reduce the vulnerability of our infrastructure to future climate change. One significant contribution would be to continuously assess and update climatic design values for building codes and standards over time. The updating of climatic design values with information on the changing climate and its variability will ensure that building designs do not become more vulnerable to climate surprises.

Ontario energy consumption has been rising at an annual rate of 1.5% since 1985 (Mercier, 1998). This rate is considerably slower than the overall growth in the economy, indicating some increase in energy efficiency. About two-thirds of Ontario's energy is derived from imported sources including oil, gas and coal imports, which may increase. This proportion has recently increased in light of difficulties with nuclear power use in the province.

By 2020, it is projected that natural gas and refined petroleum products will remain Ontario's main sources of energy (Mercier, 1998). Overall, greenhouse gas emissions from the energy sector are projected to increase nearly 40% in the province unless rather drastic conservation and fuel switching actions are undertaken. These projections reflect many of the benefits of incentives aimed at reducing greenhouse gas reductions. The increases in the TNR could be similar or perhaps even greater, considering the projected population increases for the area. The TNR study should look at various scenarios of future energy use and energy-related greenhouse gas emissions, including the influence of population changes as well as possible energy efficiency and energy conversion options.

As noted, seasonal variations in energy demand for heating, cooling and ventilating buildings are influenced by weather. Under climate warming and assuming that current technologies remain in place, space heating requirements will decrease while summer cooling will increase, encouraging a decrease in natural gas consumption and an increase in electricity consumption (Bhartendu, 1987). It is also possible that peak power demand associated with cooling may rise as the frequency and magnitude of summer heat waves increases, requiring alteration to the structure of the electrical power supply system (Columbo, 1997). Higher summer temperatures could also raise vehicle energy consumption through increased use of vehicle air-conditioning and trucking industry refrigeration.

On the supply side, weather and climate affect the efficiency of thermal generating units and their cooling apparatus, as well as the water supply for hydroelectric plants. Since climate influences the electrical distribution lines and towers, warmer summer weather may lead to decreased transmission efficiency and sagging lines. Although freezing rain and winds can damage the electrical distribution lines, it is not known how climate change will influence these variables in the TNR. The Ice Storm of January 1998 reminded many Canadians of the vulnerability of the electrical distribution infrastructure to ice storms.

WATER SUPPLY AND DEMAND

The impacts of climate change on the water sector could be far-reaching, since much of existing industry, built environment, and transportation and distribution systems of the TNR and other areas have limited resilience to large fluctuations in water flows and levels. Changes in climate variability could have large impacts on: aquatic ecosystems, wildlife, tourism, recreation, fisheries, effluent and drinking water treatment, power generation, transportation, and the local availability of water for agriculture, industry and urban areas.

Studies of changes in surface water resources and groundwater recharge rates all suggest large decreases in water supply. It is expected that a warmer climate in the TNR will mean earlier peak stream flows (due to lower snowpacks) and more frequent winter floods (Smith *et al.*, 1998). All of these changes may mean that infrastructure such as water supply systems, and wastewater and hydroelectric plants may need modification or redesign to stand up to climate change. The changing climate may also result in greater variability of water levels and flows due to changes in the number and severity of extreme rainfall events.

Soil moisture is estimated to decrease by some 14-67% in the Great Lakes Basin due to greater rates of evapotranspiration (IJC, 1991). As a result, more irrigation will be needed in the agricultural sector unless water-saving techniques are introduced. Other indirect impacts on water supplies could result as agriculture adapts to an extended growing season and elevated temperatures by shifting practices towards crops requiring irrigation in areas where irrigation is not currently needed. Similarly, municipal water use is projected to increase under a warmer climate. The rate of increase in municipal water use may also be successfully mitigated using water management strategies.

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Water levels on the Great Lakes are projected to drop to levels near or below historical lows (Cohen, 1986, 1987, 1988; Hartmann, 1990; IJC, 1993). In some studies, lake levels are projected to drop about one metre without accounting for increased consumption. The lowering of lake levels will have serious impacts for lake transportation and will increase costs for dredging, relocating beach facilities, extending and modifying water intakes and sewage outfalls, and for changing slips and docks. On the other hand, warmer winters should decrease lake ice cover and perhaps allow for a longer lake shipping season.

A weakness with all of the studies that have assessed the impact of climate change on the Great Lakes water levels is their poor ability to consider the impact of changing consumptive use, changing climate extreme events, and changing surface wind speeds and humidities over the lakes (Smith *et al.*, 1998). The magnitude of the various climate scenarios developed to date needs to be interpreted with care since they are based on General Circulation Models that cannot properly account for the influence of the Great Lakes and other important physical processes in and around them.

It is quite possible that future disputes over water supply will make water management difficult in the Great Lakes Basin. The conflicting demands of the various stakeholders are likely to intensify, both among sectors such as agricultural, municipal/residential and recreation, and among geographical areas. Changes in Great Lakes water levels will also have regional, national and binational implications for management of water resources. There could be demands for the diversion of water to locations south of the Canada-US border. As these demands increase, water could well become one of the great continental issues in the 21st century.

Adaptation actions to reduce the stresses on future water management and water infrastructure problems include the implementation of water saving measures, the construction of new water infrastructure for improved management of water resources and perhaps even for diversions. These actions are also likely to require refinement and strengthening of institutions for the governing of water resources and their uses.

Adaptation actions to reduce future water management and water infrastructure problems include the construction of new water infrastructure, for improved management of water resources and perhaps even for diversions, and the implementation of water saving measures. These actions are also likely to require refinement and strengthening of institutions for the governing of water resources and their uses.

Water quality is also expected to suffer under climate change. Increases in the severity and frequency of summer droughts will likely lead to higher concentrations of plant nutrients and contaminants (Smith *et al.*, 1998). Any lakeward displacement of shorelines could also increase a local population's exposure to toxic sediments. Increases in the frequency or magnitude of extreme precipitation events could also cause increased loadings from sediments, nutrients, and contaminants from agricultural and urban areas.

TRANSPORTATION INFRASTRUCTURE

An efficient transportation system is essential to connect population centres and to stimulate economic development. At the same time, our transportation system in Canada accounts for some 30% of total energy use and greenhouse gas emissions. Motorized transport also contributes significantly to other air issues such as smog and particulates.

Canadian research on the impact of climate change on transportation is scarce and tends to be focused on the direct and negative impacts of climate change on (1) shipping in the Great Lakes system, (2) coastal infrastructure, and (3) northern roads (Andrey and Snow, 1997). Only the shipping research is applicable to the TNR region. As mentioned earlier, reduced Great Lakes water levels would translate into significant, negative impacts on commercial navigation in the Great Lakes system. Changes that increase the length of the shipping season could also affect demand for land-based bulk shipment by rail. Likewise, changes in production of climate-sensitive commodities such as agricultural products could affect demand for rail and marine transport.

Little work has been done to look into the implications of climate change on trucking or automotive, rail, or air travel. Current sensitivities of these modes of transportation to weather suggest that land-based transportation costs will be reduced by climate change because of shorter and less harsh winters. More study is needed on the potential impacts for aviation and to consider the disruptive capabilities of extreme weather events on transportation.

Canadian expenditures on infrastructure for roads are higher than for any other mode of transportation. Climate and weather, especially the harshness of winter, affect both the initial construction as well as the maintenance costs of these roads. Studies are needed to determine the impact of climate change on the road infrastructure of the TNR region. It is suspected that a warmer climate may have beneficial impacts on pavement lifespans. At the same time, the need for snow and ice removal on roads and aircraft deicing at airports could be reduced in the TNR if winters warm sufficiently (Smith *et al.*, 1998). Warmer winters in the TNR could also reduce the winter maintenance costs for rail operators. Transportation fuel consumption could increase in urban areas due to greater demands for air-conditioning in vehicles though.

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Of all the transport modes, aviation has the potential to be the most sensitive to climate change. Despite this, there are very few research results available on the implications of climate change for aviation in Canada, let alone the TNR. Some literature is available suggesting the possibility that aircraft pay loads may need to be reduced on warm summer days due to lower air densities.

CONCLUSIONS

The built environment is important to the economy of the TNR region. There are few other regions of Canada that can claim to have as much valuable infrastructure. At the same time, the built environment contributes to many of the region's atmospheric change and environmental issues. In spite of the importance of the built environment to the economy of Ontario and Canada and to atmospheric environmental concerns, it is surprising that so little research is available to assess the implications of climate and other atmospheric change on the built environment. The TNR study should focus some of its efforts on the region's important built environment.

Because there has been little research on the impacts of atmospheric change on the built environment beyond that of water resources, minimal adaptation research also exists. The potential is high for developing successful adaptation options to atmospheric change in the built environment. This is particularly true since the construction industry has a long history of designing and adapting to the extremes of weather and has experience in dealing with uncertainties.

REFERENCES

Andrey, J. and A. Snow, 1997. "Transportation Sector", chapter 8 in G. Koshida and W. Avis (eds.) *Canada Country Study: Climate Impacts and Adaptation, National Sectoral Volume.* Environment Canada, Downsview, Ontario. Available on-line (http://www.ec.gc.ca/climate/ccs/sectoral_e.htm).

Auld, H., M. Loiselle, B. Smith and T. Allsopp 1990. *The Climate of Metropolitan Toronto.* Climatological Studies Number 41, Canadian Climate Program. Canadian Government Publishing Centre, Ottawa, Ontario.

Auld, H. 1996. Dealing With Weather Extremes and Climate Variability. In *Ecosystem Effects of Atmospheric Change.* Proceedings of a meeting convened under the Memorandum of Understanding on Science and Technology for Sustainable Development in the Natural Resources Sector, March 5-6, 1996, Pointe Claire, Quebec.

Bhartendu, S., and S. J. Cohen 1987. Impact of CO_2-induced Climate Change on Residential Heating and Cooling Energy Requirements in Ontario, Canada. *Energy and Buildings* 10 (2): 99–108.

Canadian Commission on Building and Fire Codes 1995. *National Building Code of Canada.* Institute for Research in Construction, National Research Council of Canada, Ottawa, Ontario.

Canadian Commission on Building and Fire Codes 1997a. *Model National Energy Code for Houses.* Institute for Research in Construction, National Research Council of Canada, Ottawa, Ontario.

Canadian Commission on Building and Fire Codes 1997b. *Model National Energy Code for Buildings.* Institute for Research in Construction, National Research Council of Canada, Ottawa, Ontario.

Cohen, S.J. 1986. Impacts of CO_2-induced Climatic Change on Water Resources in the Great Lakes Basin. *Climatic Change* 8: 135–153.

Cohen, S.J. 1987. Sensitivity of Water Resources in the Great Lakes Region to Changes in Temperature, Precipitation, Humidity, and Wind Speed. In S. Soloman, M. Beran and W. Hogg (eds.), *The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources*, 489–499, August. IAHS Publication 168, Vancouver, British Columbia,.

Cohen, S. J. 1988. Great Lakes Levels and Climate Change: Impacts, Responses and Futures. In M. H. Glantz (ed.), *Societal Responses to Regional Climate Change: Forecasting by Analogy*, 143–167. Westview Press, Boulder, Colorado.

Cohen S.J. and T. Allsopp 1988. The Potential Impacts of a Scenario of CO_2-Induced Climatic Change on Ontario, Canada. *Journal of Climate* 1: 669–681.

Columbo, A. 1997. *Climate Warming and the Change in Frequency of ExtremeTemperature Events for Nine Sites in Canada.* University of Toronto Press, Toronto, Ontario

Toronto-Niagara Region Study on atmospheric change

Dalgliesh, A. W. 1998. "Built Environment Sector", chapter 9 in G. Koshida and W. Avis (eds.) *Canada Country Study: Climate Impacts and Adaptation, National Sectoral Volume.* Environment Canada, Downsview, Ontario. Available on-line (http://www.ec.gc.ca/climate/ccs/sectoral_e.htm).

Davenport, A. 1994. Atmospheric Extremes, Insurance and Construction. In J. McCulloch, and D. Etkin (eds.), *Proceedings of a Workshop on Improving Responses to Atmospheric Extremes: The Role of Insurance and Compensation,* October 3–4, Toronto, Ontario.

Hartmann, H. 1990. Climate Change Impacts on Laurentian Great Lakes Levels. *Climatic Change* 17: 49–67.

IJC (International Joint Commission) 1991. CCC GCM 2xCO_2 Hydrological Impacts on the Great Lakes. In *Phase 2–IJC Levels Reference Study.*

IJC (International Joint Commission) 1993. *Methods of Alleviating the Adverse Consequences of Fluctuating Water Levels in the Great Lakes-St. Lawrence River Basin.* A Report to the Governments of Canada and the United States, Washington, DC and Ottawa, Ontario.

Intergovernmental Panel on Climate Change (IPCC) 1996. *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, eds. R.T. Watson, M.C. Zinyowera, and R.H. Moss.

Koshida, G. I. 1989. *Causes and Impacts of 1960's Low Water Levels on Canadian Great Lakes Interests.* Unpublished work report conducted through the Department of Geography, University of Waterloo. Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

Kreutzwiser, R .D. and R. B. Feagan 1989. Municipal Utilization of Water Demand Management: The Ontario Experience. *Water Resources Bulletin,* 25(3), 667–674.

Mercier, G. 1997. Energy. In *Canada Country Study: Climate Impacts and Adaptation,* National Sectoral Volume. Environment Canada, forthcoming.

National Climatic Data Centre 1998. *Billion Dollar U.S. Weather Disasters 1980-1998.* Research Customer Service Group, National Climatic Data Centre, NOAA, Asheville, U.S.

Ontario Hydro 1998. *A Report on the Electricity Supply Impacts of the January, 1998 Ice Storm in Eastern Ontario.* Ontario Hydro Services Company, (May 1), Toronto, Ontario.

Royal Architectural Institute of Canada 1996. High Density and Mixed Uses. *Advanced Buildings Newsletter,* Volume 1, Number 13, May/June 1996.

Sanderson, M., and J. V. Smith 1990. The Present and 2xCO_2 Climate and Water Balance in the Grand River Basin. In M. Sanderson (ed.), *The Impact of Climate Change on Water in the Grand River Basin, Ontario,* Department of Geography Publication Series No. 40. Department of Geography, University of Waterloo, Waterloo, Ontario.

Smith, J., B. Lavender, H. Auld, D. Broadhurst and T. Bullock, 1998. *Adapting to Climate Variability and Change in Ontario.* Environment Canada, Ontario Region, Toronto, Ontario.

Strategic Projections Inc. 1997. *Tomorrow's Markets Today.* Strategic Projections Inc., Oakville, Ontario.

Perspectives from the Toronto and Region Conservation Authority

Remarks by Donald Haley
Toronto and Region Conservation Authority

I would first like to thank Heather Auld (this volume) for a very comprehensive review of climate change and its effects on infrastructure now and in the future. The Toronto and Region Conservation Authority is in the business of watershed management with our key partners, the local and regional municipalities. Watershed management in the TRCA includes social, terrestrial, and aquatic components, as well as my area of concern, flood and erosion hazard management. Climate change affects all of these issues since they are all directly connected to the hydrologic cycle. For example, the TRCA operates dams, channels, and dikes for flood control purposes. Operating procedures have already been adjusted at some of the dams within the Toronto area just to deal with changes in the hydrologic cycle associated with land use alterations. We expect that a similar reanalysis of those operations and procedures will be necessary as climate change occurs. Stormwater management is another activity where policies are continuing to evolve.

Heather Auld (this volume) talked about the 100-year design storm for rainfalls and how climate change could lead to more extreme events. If the current 100-year event is going to be a 50-year design storm in 2030, this will become a major issue that the TRCA must deal with. With respect to flood warning, the Authority is going to have to respond more rapidly as weather systems affecting our watersheds become less cyclonic and more thunderstorm-related. Erosion control is another major area where many changes can be expected. Because of urbanization, the stream systems have become unstable, and climate change is simply going to aggravate the situation. For instance, intermittent thaws during the winter are becoming more frequent in the watershed. These thaws have a tendency to destabilize the banks along rivers and streams, thereby increasing erosion rates that allow the rivers to meander more quickly. This presents a potential hazard to infrastructure since river and valley systems are used as major corridors. Sanitary sewers, for instance, are located in the river valley system to utilize the benefits of gravity flow. Close to half a million dollars per year is being spent just in the City of Toronto to deal with erosion at water mains and sanitary sewers. We expect those costs to increase substantively due to climate change.

The social aspects cannot be ignored either. The river valley systems are one of the major natural or open space areas in the city. Many public access issues exist concerning regional trails along the rivers and streams and foot bridges. Tens of thousands of dollars per year are spent to fix foot bridges and pathways and we can look forward to an increase in costs associated with climate change. Terrestrial impacts and water impacts are also important and were discussed previously (Auld, this volume).

I think that we have the ability to acknowledge or at least address climate change in many areas. We need to take the opportunity to bring the issue to the forefront, bring it down to the grassroots level. Certainly aspects that the Authority deals with, watershed and subwatershed management, are directly related and linked into official planning processes. I believe that the willingness exists within conservation authorities, and also within municipalities, to try and implement flexibility within official planning processes (e.g., watershed plans, Offical Plans, and Official Plan Amendments) and in our design standards to accommodate future changes in the climate. There are some steps that the TRCA could take right now. For example, the Authority currently promotes regeneration activities associated with replanting areas or naturalizing concrete channels. While we continue to promote the planting of native trees and shrubs, we have not given a great deal of thought to assessing whether those species that we are fervently telling everybody to plant are flexible enough to accommodate global climate change.

In closing, many opportunities exist to get the global climate change message down to the people in a more effective manner. The TRCA will encourage this through its watershed management strategies.

I think that we have the ability to acknowledge or at least address climate change in many areas. We need to take the opportunity to bring the issue to the forefront, bring it down to the grassroots level. Certainly aspects that the Authority deals with, watershed and subwatershed management, are directly related and linked into official planning processes. I believe that the willingness exists within conservation authorities, and also within municipalities, to try and implement flexibility within official planning processes (e.g., watershed plans, Offical Plans, and Official Plan Amendments) and in our design standards to accommodate future changes in the climate.

Perspectives from the City of Toronto Public Works

Remarks by Kevin Loughborough
City of Toronto Public Works

I wanted to offer perhaps a little pep talk for what is happening at the City of Toronto regarding the air quality issue. We have recently been inundated with requests from council for reports on air quality. Two reports were before council in 1997 prior to amalgamation, one before the City of Toronto council and the other before Metro council. They were both brought forward this year and the amendments and the additions that councilors made to those reports were almost as many pages as the reports themselves. Air quality is a very hot issue. Another issue is the burning of waste oil that is happening right now in 47 locations in the City of Toronto. The alternative to burning is to re-refine the oil, a much more environmentally friendly way of dealing with that part of our transportation infrastructure. These issues are driving the activities of City staff. As well, we are going through an amalgamation process currently and we're looking for ways to develop partnerships. This kind of workshop networking activity is really helpful for the municipal staff; we need all the help we can get.

...the City disposes of garbage in landfills and that garbage decays and produces methane. The methane used to be burned off as waste material, but now it is being used to generate electricity. The methane gas is actually a cleaner source of power than the coal-burning Lakeview generating station on Lake Ontario just west of Toronto. In this case, we have integrated considerations for climate change and odour control with the management of an explosive gas at our landfill site.

We have been pursuing the integration theme in our infrastructure projects and are discovering and capitalizing on some great opportunities. For instance, the City disposes of garbage in landfills and that garbage decays and produces methane. The methane used to be burned off as waste material, but now it is being used to generate electricity. The methane gas is actually a cleaner source of power than the coal-burning Lakeview generating station on Lake Ontario just west of Toronto. In this case, we have integrated considerations for climate change and odour control with the management of an explosive gas at our landfill site. The project generates over $2 million in revenue for the City.

Another activity that we are examining is the deep water cooling project, a massive retrofit of downtown building cooling systems. The project would integrate our water treatment plant with our building cooling systems. They are separate now, but if we bring them together we could reduce electricity use in that sector by 90%. Instead of burning coal and generating emissions at the Lakeview plant, typically used to meet peak summer space-cooling electricity demands, the natural cold water resource just off our waterfront would be used to air condition downtown buildings. The project is just completing its environmental assessment.

Transportation systems are clearly the key to the air quality solution. At the City, we have been pursing the Sheppard subway and the Spadina LRT with the Toronto Transit Commission.

With respect to water efficiency, the City is retrofitting our existing water infrastructure and we are looking at widely distributing retrofit toilets that replace 13 litre toilets with toilets that only consume 6 litres per flush. That resolves itself in needing less water pumped up through several pressure districts (Toronto is on the side of a hill). Works and Emergency Services are using about $40 million worth of energy per year. They would benefit if pumping needs were reduced through more efficient toilets and shower heads. Consumers would also benefit as efficient shower heads would lower hot water demands and associated heating costs.

In closing, these are just a few examples of how the City of Toronto is integrating its systems. Whether one deals with infrastructure or air issues, a wealth of opportunities come about through integration.

SECTION 6: EMISSIONS AND MITIGATIVE ACTIONS

Toronto-Niagara Region Study
on atmospheric change

Mitigation: If we thought we had to, we could

Ken Ogilvie
Pollution Probe

I would like to begin by working backwards when talking about mitigative actions, as there are many of them. While I will address some of them, the fundamental question that we need to ask ourselves concerns if we are prepared for the benefits because, as most everyone knows, quite often changes have benefits. My message is that, if we really wanted to or we really thought we had to deal with most of the air quality issues, and I won't say all of them because I'm most familiar with smog and to some extent CO_2 emissions, we could knock back emissions enormously. Some of them would take some time, but we know how to get there and other types of emissions can be reduced rather quickly. The analogy would be if climate change and other atmospheric issues were as serious in our collective minds as winning World War II, and we just had to make the right investments, then there are many things we could do. I would like to touch upon a few of these actions in my presentation.

...if climate change and other atmospheric issues were as serious in our collective minds as winning World War II, and we just had to make the right investments, then there are many things we could do.

ELECTRICITY PRODUCTION

Imagine that we wanted to see a very significant drop in our CO_2 emissions and a concurrent decrease in the pollutants causing smog. We know that electricity production in Ontario generates about 18% of the province's CO_2 emissions. We also know that varying amounts of other pollutant emissions in Ontario, such as 22% of the SO_2, 10% of the NO_x, 10% of the mercury, and an unspecified amount of particulates, can be attributed to this activity. Fortunately, we may see an improvement in the quality of our air within a few years when Lakeview will probably be retired, taking coal-fired emissions down with it. When dealing with electricity, one cannot overlook the huge problem south of the border. One of the studies that Pollution Probe undertook, in collaboration with the Institute for Environmental Studies (IES) at the University of Toronto, produced a report on "Emissions from Coal-Fired Electric Stations" (Lourie and Love Environmental Management Consulting, 1998). In Phase one, we developed scenarios by quantifying emissions for 5 major pollutants (NO_x, CO_2, SO_2, fine particulates, and mercury) that currently exist or will likely exist in the year 2010. This included a business as usual scenario that assumed lower NO_x and SO_2 emissions would result as the U.S. Clean Air Act Amendments go into place.

However, if you look at coal-fired utilities from the U.S. Midwest to the east coast of Canada, you will find that over 90% of those emissions originate from the Great Lakes states and the Ohio Valley. So, even if emissions are reduced locally, this will not solve all of our problems. Nevertheless, I think we have a pretty good quantification of most emissions from coal-fired utilities that are of direct concern to human health, and we know that there are technologies available that can reduce these emissions. If all of the 312 operating plants in the Ohio Valley through to the east coast of Canada were fitted with the best available emission control technology, an 80% reduction in emissions of SO_2 and NOx, a 50% reduction in particulate matter, and a 93% reduction in mercury emissions could be expected. The latter value may be a bit aggressive, but certainly a significant mercury reduction is possible, whereas only about a 16% reduction in CO_2 emissions would occur with the increased efficiency associated with some of the technologies.

If all of the 312 operating plants in the Ohio Valley through to the east coast of Canada were fitted with the best available emission control technology, an 80% reduction in emissions of SO_2 and NO_x, a 50% reduction in particulate matter, and a 93% reduction in mercury emissions could be expected.

The only solution that significantly lowers CO_2 levels would be retiring really old but still functional plants. By the year 2010, if all plants older than 40 years were taken out of service, there would be a 60% reduction in CO_2 emissions. Now that energy would have to be replaced with other sources if consumption had not been reduced, but natural gas and other supply options would significantly lower emissions. The solutions addressed in Phase 2 of the Pollution Probe/IES study focus on some of the policy options and "how to get there". Included is a study on the cost of implementing the best available control technologies or new source performance standards. I think that this work will demonstrate that the costs are, in fact, a reasonable investment considering the kind of benefits that would be realized. There are huge barriers to implementing change given large vested interests, economics and so on, but we certainly know that coal-fired utilities pump out a tremendous amount of pollution. I would be hard-pressed to think that the benefits on a broad societal basis would not exceed the costs of phasing out as much coal-fired capacity as reasonable within a decade or two.

TRANSPORTATION

While emissions reduction in the electricity generation sector seems relatively easy to deal with, my experience suggests that transportation is a much tougher sector. As a member of the Ontario Round Table on Environment and Economy, we developed a strategy for sustainable transportation in Ontario, the CO_2 Collaborative (Ogilvie, 1995). Senior decision-makers from the automotive industry through to city administrators, were asked to come together, not to try to find how to stabilize CO_2, but to look at the options that were in front of them for the development of transportation within their own set of vested interests. In this mechanism, it was felt that they would give more collectively to a broader endeavour to lower emissions through options that they could see as being implementable. So, the process wasn't driven backwards from policy, and what we ended up with was an integrated set of 12 recommendations. Thirty of 32 very senior people signed onto it, and yet we all recognized that, if we did all of these things collectively, total emissions would not be reduced. While per capita emissions would drop significantly, total CO_2 emissions would probably go up because population is the major driver. The integrated set of solutions seemed to work well together, consisting of everything from transit-oriented development and land use planning involving compact mixed use, through to relatively simple things like vehicle inspection and maintenance programs and cleaner fuels. The actions are listed in the final report, and there are many others who have also completed studies documenting similar and other types of solutions.

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The solutions are not as drastic or as undesirable as some might feel. It is not necessary to mandate a lot of things to achieve significant per capita reductions. Much progress could be made if we thought that the issue was so serious that we had to reduce emissions. Then it would be possible to push much harder by implementing policy measures like gasoline taxes and CAFE standards, and also by rebuilding infrastructure and toll roads. It might be difficult, but if we thought that was our only choice, if our whole system was going to change without taking this action, we would do it without hesitation. Again, if I can use an analogy from the Second World War, perhaps once you have made the investment, you might find that your company is doing rather well afterwards because of the innovation and the investment that you have made. Some people would focus upon the distributive impacts of having to adjust to the new realities, but the system would probably flow around that and, in the end, we would be quite healthy economically and much healthier in terms of the environment.

So it is doable. Transportation represents about 32% of CO_2 emissions in Ontario. Other than the population driver, the per capita consumption can be lowered quite rapidly and perhaps we can go much further. In the CO_2 Collaborative report, we didn't even assume that we were going to substitute some of the newer technologies like fuel cells and so forth. A lot of those technologies could be driven a lot faster if governments put appropriate incentives in place and if everybody was pushing as they did during the Second World War. If education and communication were unilaterally focused on achieving this goal, then you would achieve a broad level of public support. The linchpin that exists today is we do not face a war-time type of national emergency or response. So, just considering emissions from electricity and transportation, there is 50% of Ontario's CO_2, with the transportation sector contributing 40-60% of the NO_x emissions, 10% of the PM_{10} and perhaps a higher level of $PM_{2.5}$. A number of other health benefits and maybe even some better living conditions would be associated with such emission reductions.

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BUILDINGS

Moving onto buildings, but ignoring fuel use and opportunities for retrofits in industry, there are tremendous technologies sitting on the shelf not used for energy efficiency in homes and buildings. Heather Auld (this volume) commented on some of these measures earlier. However, one must watch out for another type of linkage, where solving an energy efficiency issue could aggravate indoor air quality. This linkage is recognized at Pollution Probe where we recently hired a new director of environmental health from the Lung Association, Ian Morton. A whole range of new solutions emerge when one examines product labelling, building code standards, building retrofits, and so on, in terms of technologies that are beneficial for both indoor air quality and other air issues. There are some really good emissions reductions to be made in the buildings and residential sector. Although I am not certain of the specific numbers, even if this sector accounts for 15-20% of CO_2 emissions, that brings us up to 60-70% of the province's CO_2 emissions when added to energy production and transportation.

COMMUNICATION

So the message that I wanted to leave with you is that we know "the answer", if the issue was as important as the Second World War. But how do we get people to believe that we should implement these things? Certainly we have heard about the importance of personalizing the health message. There is an even stronger incentive to do something associated with children's health, another issue for which Pollution Probe has been reviewing the literature and polling results. We have just established a child health program at Pollution Probe that will assess and communicate, in a fair and reasonable way, the kind of health impacts that children face regarding both indoor and outdoor air quality. Unfortunately, when it comes to issues like smoking in the house or second hand smoke, a lot of people know they are damaging their own health and they may even know that they are damaging their children's health, but they still won't change. Similarly, people know that during smog alerts and air quality advisories their health is threatened but, despite this recognition, studies show that their behaviour does not change very much. So there are limits to what you can do in terms of education, even in terms of bringing the health threat out to people. We know that people will change a bit more if they are aware that their children's health is also threatened, but there are still large numbers of people that won't change even in the face of strong evidence. At the end of the day, if we do not have a national emergency, hopefully we will have policymakers that treat things like the Kyoto target as serious policy issues, and are prepared to apply the measures required to achieve at least the modest reductions that are necessary.

Unfortunately, when it comes to issues like smoking in the house or second hand smoke, a lot of people know they are damaging their own health and they may even know that they are damaging their children's health, but they still won't change. Similarly, people know that during smog alerts and air quality advisories their health is threatened but, despite this recognition, studies show that their behaviour does not change very much. So there are limits to what you can do in terms of education, even in terms of bringing the health threat out to people.

There is a whole range of actions that are not merely theoretically debated, but are in fact being applied right here in Canada. For instance, through the Toronto Atmospheric Fund, the City of Toronto has tapped into our tremendous capacity to deal with emissions of greenhouse gases by implementing landfill methane gas recovery, lighting retrofits and many other projects. Economically, I think we are benefiting tremendously from these things, and we can go a lot further. Yet despite all of this, we face the challenge of even supporting the Toronto Atmospheric Fund, which is a terrible shame. This points to a limited level of understanding of air issues amongst not only the general public, but also among some politicians who are probably in need of even more education than the average person. According to public opinion polls, the average person is very concerned about atmospheric issues and, while confused about a lot of things, people express a willingness on a collective basis to act and even pay for some of the solutions.

Thus another challenge is to better inform the general public and at least the key policymakers. One of the vehicles to do this is through scientific research, conferences and public forums. This is one of the reasons why Pollution Probe co-organized a workshop on *Climate Variability, Atmospheric Change and Human Health*, with IES, York University's Centre for Applied Sustainability, and Environment Canada (Ogilvie *et al.*, 1997), and why it is so important to get key research efforts like the TNR study going. We tend to underestimate the power of the new information that emerges from research. Issues can get stale and in fact even deaths due to smog are only going to drive the agenda so long without fresh information. It is the research community that can, and must, come up with this information. Groups like Pollution Probe, at the end of the day, probably do not have anywhere to go without that research and, while we

We tend to underestimate the power of the new information that emerges from research. Issues can get stale and in fact even deaths due to smog are only going to drive the agenda so long without fresh information. It is the research community that can, and must, come up with this information.

cannot do the research, we can make good use of it and interpret it in the best societal interest that we can think of. However, if we don't have this research, and note that it does not have to be a profound or earth-shattering breakthrough every second day, it will be really difficult to keep the issue alive with the press and the public. Having arrived at Pollution Probe after 20 years in government, I have come to recognize that environmental groups are really one of the key vehicles for communicating with the public. Although the public does not necessarily believe everything we have to say, they do place a great deal of faith in the fact that at least we are not tied in directly with any vested interests, and that we are simply motivated by the need to try and solve a specific environmental issue. The public is swayed by the kind of views that are expressed by health or environmental groups, scientists, doctors, and other recognized experts who participate in the public forum.

In closing, I believe that groups like Pollution Probe are the vehicle for clearly communicating this information and creating ways for the scientific community to communicate with the public. This is what I have been trying to offer with the TNR study as it moves forward, and hopefully Pollution Probe amongst others will be helpful vehicles for communicating science to the public in ways that a peer-reviewed scientist would feel uneasy with. Not because it is incorrect, but because it is just not stated in such rigorous technical terms so as to satisfy your colleagues from a scientific perspective.

REFERENCES

Lourie and Love Environmental Management Consulting 1998. *Emissions from Coal-Fired Electric Stations*. Pollution Probe, Toronto, Ontario.

Ogilvie, K. (ed.) 1995. *Report of the Ontario Transportation and Climate Change Collaborative*. Report submitted to the Ontario Round Table on Environment and Economy.

Ogilvie, K., Bell, D., White, R. and Chiotti, Q. (eds) 1997. *Climate Variability, Atmospheric Change and Human Health Conference Proceedings*, November 4-5, 1996, Pollution Probe, Toronto, Ontario.

The Six Percent Solution: A Contribution from IES 1002s to the Toronto-Niagara Region Study

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With assistance from Philip Byer, Brian Gibson, and Rowan Sage

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INTRODUCTION

This is a brief report on the activities of a core graduate course given at the Institute for Environmental Studies (IES), University of Toronto, during the spring term, January-May 1998. The 16 graduate students and 4 instructors took the task of assessing the dimensions of, and prospects for, reaching the 6% Kyoto target in the Toronto-Niagara Region (TNR).

The course forms the second half of a two part required sequence of courses for IES students, which can also be taken by other students in recognized collaborative programs at the University. The course is designed to engage students in an interdisciplinary approach to problem solving, within the general framework of rational decision-making. The fall session attempted to cover a wide range of relevant tools, including environmental ethics, the basics of decision-making, some toxicology, and fundamental concepts of ecology, with substantial reference to both the Kyoto deliberations (which nicely coincided with the class) and to the controversies around the closure of nuclear plants in Ontario. Given that, and also the knowledge that the TNR study was about to be underway, we decided to focus on achieving the 6% target in the TNR.

In this paper, I would like to first give some sense of the process by which the students approached this task and second, give you a brief summary of the results of their work. The main contributions of the course instructors were to (1) subtly, and sometimes not so subtly, advise and direct the students as to how to go about the task; (2) try and get the students to think about themselves as a research team, or multiply-tasked teams; and (3) mark and critique their papers. The vast bulk of the work, all the original ideas presented in this summary, and almost all of the tables are from the students. Behind this sketch are 16 detailed sectoral papers and 16 final assessments of the mitigation options.

INITIAL SCOPING

... it is interesting to point out that these students...were somewhat disconcerted early on. The source of the frustration was not just the magnitude of the problem, but a whole range of things that we, as researchers, take for granted. For example, the students were concerned that the selected Toronto-Niagara Region did not match available data sets and that the data were poor or not focussed on their topic of concern.

The initial lead in the course was given by myself and one other colleague, in part because of my participation in the earlier November 1996 TNR consultation, and in part because I have somewhat more of a climate impacts background than the other instructors. We spent the first two weeks of the course filling in some of the background, including leading some discussions on the dimensions of the problem as a research task. Most people attending this TNR study workshop are very familiar with how to conduct a research project. However, it is interesting to point out that these students, whose backgrounds were primarily geography but also included economics, business, political science, sociology, and even the Ontario Institute for Studies in Education, were somewhat disconcerted early on. The source of the frustration was not just the magnitude of the problem, but a whole range of things that we, as researchers, take for granted. For example, the students were concerned that the selected Toronto-Niagara Region did not match available data sets and that the data were poor or not focussed on their topic of concern. If you think this makes you unhappy, you should have been in our early classes.

There was quite a bit of early discussion about whether the TNR was a good way to carve out the problem, given the differing political jurisdictions, geographical features, and so on (see Chiotti, this volume, Figure 1). The students were somewhat uneasy about it at first, but with good grace finally got started. The course was organized so that there would be three assignments during the term. The first essay was a scoping paper about the dimensions of the problem while the second essay, due mid-term, was a more in-depth study of one sector or "component" of the problem. The final assignment was to build on the previous two essays, and determine the best way of reaching the 6% target.

Initially the students were placed in small teams that would work together on the initial papers and occasionally present their results to full class sessions. Later on, the full class more or less took over as the forum for discussion and collaboration. Nevertheless, we stressed throughout that the students were to do individual work which ought to take into account what their colleagues were finding - this was a very difficult situation to handle, and is one of the complexities of marking in the university.

Before describing results, I should emphasize that the students focussed very specifically on achieving the 6% target, and spent almost no time on impacts of climate change. If it had been a full year course devoted just to this case study, we would have done so, I think, and that would have "closed the loop" more fully, and made some of the social and political dimensions of the situation more overt. I will come back to this point later in the paper.

One of the advantages of working in the TNR was the fact that there were three or four basic studies in hand of the City of Toronto or Metro Toronto. Among the most important of these were:

1. *Realizing Toronto's Target for Greenhouse Gas Emission Reductions -- Current Trends and Outlook* (1997) (The Torrie Report)
2. *Canada's Second National Report on Climate Change* (1997)
3. *Climate Variability, Atmospheric Change and Human Health Conference: Proceedings*, November 4-5, 1996. (Ogilvie *et al.*, 1997)
4. Several of the Reports on the GTA Planning Effort, including alternative projections of transportation and urban growth trends; in particular the various discussions of nodal growth vs. other kinds of possible growth patterns for the region. A useful summary is *GTA Urban Structure: An Analysis of Progress Towards the Vision* from the Canadian Urban Institute (1997).

Of special early importance was Appendix B of Environment Canada's 1997 *Trends in Greenhouse Gas Emissions*, whose Ontario figures were presented to the class in the third week by one of the students, and it became the first "song sheet" from which everyone began to sing (Table 1). It reminded us of the importance of getting some common materials to work with early on in the process. The discussions were shadowed by 6 main issues of concern or perceived impediments to getting to the 6% solution:

1. The continuing uncertainty about the general energy production mix in Ontario, given the supposedly temporary closure of the 7 nuclear reactors in 1997, and the proposed opening up of the electricity market, including the likely loss of interest in demand management (at least in lowering demand);
2. The growth in regional truck transport, replacing rail;

3. The growth in regional car traffic;
4. (2) and (3) as part of the loss of control over urban sprawl in the province, and the continuing cheap price of gasoline;
5. Uncertainty about political coordination in this inter-jurisdictional context; and
6. Political/public will to respond to the issue.

INITIAL FINDINGS

The results of the first scoping paper were collated into Table 2 (Khan 1998a). The team identified 5 major emission sectors and their relative contribution of TNR emissions:

- Transportation (33%)
- Industrial (28%)
- Commercial/Residential/Institutional (18%)
- Power Generation (17%)
- Landfills/Waste (4%)

It was noted that there were opportunities for emission reductions across these sectors, but that they varied, and some were obviously more intractable than others.

There was a controversy about conversion factors used for the TNR with respect to power generation. At issue was whether one just counts the Lakeview Generating Station as the TNR contributor, giving a regional contribution of 12% of the Ontario figures, or whether you incorporate the electricity used in, but generated outside, the region. In the latter case, the class estimated that the TNR consumes 46% of Ontario emissions based on figures provided for the Ontario Hydro "Central Region" which roughly corresponds to the TNR (Ontario Hydro, 1990). It was the latter number that became the consensus figure.

There was a controversy about conversion factors used for the TNR with respect to power generation. At issue was whether one just counts the Lakeview Generating Station as the TNR contributor, giving a regional contribution of 12% of the Ontario figures, or whether you incorporate the electricity used in but generated outside the region. In the latter case, the class estimated that the TNR consumes 46% of Ontario emissions based on figures provided for the Ontario Hydro "Central Region" which roughly corresponds to the TNR (Ontario Hydro 1990).

For industrial fuel consumption, 60% of Ontario industry was assumed to be in the TNR. The TNR comprises about 50% of Ontario's population (Statistics Canada, 1997) and this was used as a conversion factor for the commercial/residential, transportation, and landfills.

Table 1. Greenhouse gas emission estimates in Ontario from 1990-1995

Source	1990 All gases ($ktCO_2$)	1991 All gases ($ktCO_2$)	1992 All gases ($ktCO_2$)	1993 All gases ($ktCO_2$)	1994 All gases ($ktCO_2$)	1995 All gases ($ktCO_2$)
Industrial Processes						
Natural Gas Distribution	650	700	770	810	870	920
Upstream Oil andGas	535	564	664	713	744	795
Cement/Lime Production	3690	3020	3040	2850	3190	3230
Undifferentiated Industrial Processes	4360	4540	4810	5100	4660	4890
Coal Mining	0	0	0	0	0	0
Chemical Production	11000	10000	10000	9200	11000	11000
SUBTOTAL	20300	18800	19300	18700	20500	20800
Fuel Combustion-Stationary						
Power Generation	26300	27800	28500	18500	16200	22000
Industrial	33300	33200	32200	31400	31500	30700
Commercial	8430	8870	9400	9990	9600	10100
Residential	16600	16100	16700	18700	19400	18500
Agriculture	806	901	1740	977	890	1060
Public Administration	616	475	532	601	636	514
Steam Generation	181	132	141	244	301	257
Producer Consumption	5120	5440	5850	6040	5560	5470
Other	2360	2490	3310	3460	3510	4060
Fire Wood (residential)*	310	350	290	310	280	280
Fire Wood (industrial)	37	37	35	46	40	62
SUBTOTAL	94000	95600	98700	90200	87900	92900
Fuel Combustion-Mobile						
Automobiles	22100	21600	21900	22900	23400	23300
Light-duty Gasoline Trucks	8170	8250	8730	8910	9520	9800
Heavy-duty Gasoline Trucks	678	649	631	624	612	578
Motorcycles	65	64	65	67	68	67
Off-road Gasoline	1040	1020	942	769	799	997
Light-duty Diesel Automobiles	267	268	259	280	289	286
Light-duty Diesel Trucks	279	248	268	280	309	348
Heavy-duty Diesel Vehicles	7460	6670	6960	7590	8260	9190
Off-road Diesel	2260	2070	2010	2080	2170	2300
Air	3210	2890	2660	2710	2780	3060
Rail	1700	1830	1800	1790	1770	1570
Marine	942	1050	947	743	761	669
Other	686	720	737	793	741	758
SUBTOTAL	48900	47400	47900	49500	51400	52900
Incineration						
Municipal Solid Waste	159	162	164	164	164	167
SUBTOTAL	159	162	164	164	164	167
Agriculture						
Livestock/Manure	4100	4100	4000	3800	4000	4000
Fertilizer Use	320	330	360	390	400	400
Soils (Net Source	99	420	480	519	659	583
SUBTOTAL	4520	4850	4840	4710	5060	4960
Micellaneous						
Prescribed Burning*	87	94	85	21	9	9
Wastewater/Compost	140	140	140	150	160	160
Landfills	6100	5800	5900	5900	6000	6600
Anaesthetics/Propellants	160	160	160	160	160	170
SUBTOTAL	6480	6190	6290	6270	6370	6870
PROVINCIAL TOTALS*	**175000**	**174000**	**178000**	**171000**	**172000**	**179000**

Source: Environment Canada (1997)

- Due to rounding, individual values may not add up to totals

* Provincial totals do not include CO_2 from the combustion of biomass

- Soda ash use is not included in provincial Non-Energy line

Table 2. Projected Toronto-Niagara Region greenhouse gas emission estimates (kilotonnes of CO_2 equivalent)

Sources of GHG Emissions	1990 Ontario Emissions	TNR Conversion Factor	1990 TNR Levels	% Total TNR Emissions	1990-2010 % Increase	2010 TNR Emissions
Power Generation	26300	46%[a]	12098	17%	30%[b]	15727
Industrial	33300	60%[c]	19980	28%	10%	21978
Commercial/ Residential/ Administration	25646	50%[d]	12823	18%	30%	16670
Personal Mobile[e]	31375	50%	15688	22%	30%	20394
Commercial Mobile	10944	50%	5472	7%	30%	7114
Other	6581	50%	3291	4%	30%	4278
Landfills	6100	50%	3050	4%	30%	3965
TOTAL	**140246**		**72402**	**100%**		**90126**

Source: modified from Khan, 1998

NOTES:

[a] factor changed from 12% based on TNR usage levels and group concensus
[b] based on increased population estimated by Statistics Canada
[c] estimate by IES students addressing this sector
[d] based on percentage of Ontario residents living in the TNR
[e] based on sum of automobiles, light-duty gasoline trucks, motorcycles and off-road vehicles

TNR emissions were 72,402 $ktCO_2$ in 1990. In a business as usual scenario, TNR emissions for 2010 are expected to be 90,126 $ktCO_2$ - the target of 6% below 1990 levels is 68,057. That means that approximately 22,000 $ktCO_2$ must be found overall.

Following this scoping exercise, the students proceeded to their technical papers. A summary table of their findings (Table 3) shows roughly the sectoral breakdowns, sectoral strategies, and some of the comments contained in the detailed papers. The topics chosen, in alphabetical order with authors in brackets, were:

- Commercial Sector (Patricia Beaulieu)
- Economic Incentives (Jamie McFadyen)
- Economic Incentives - Pollution Taxes and Permits (Hernan Mladinic)
- Economic Incentives in Personal Transportation (Eric Khan)
- Electricity Generation (Ken Corcoran)
- Energy Sector (Ashij Kumar)
- Freight Transportation (Sung Ho Lee)
- Industrial Stationary Fuel Combustion (Silvio Abate)
- Landfills (Christine Ferguson)

- Passenger Transport/Land Use (Susan Pereverzoff)
- Public Education (Michelle Balog)
- Public Transit/Ridesharing (Natasha Amott)
- Retrofitting Buildings - University of Toronto (Tanuja Kulkarni)
- Retrofitting Residential (Maja Saletto Jankovic)
- Tradeable Emissions Permits (Chris Gore)
- Transportation – Fuels (John Georgakopoulos)

Among the themes addressed in these papers was the examination of the possibility of achieving the 6% target overall simply by focusing on massive reductions in one sector or by focusing on two, three or more sectors. Other themes included whether or not technological change by itself would be sufficient, whether some form of emissions permits (particularly in the power generation and industrial sectors) was useful, and the complicated question of how much (if any) "command and control" was required.

Singling out one or two outcomes of the second paper, one can see from Table 3 that there are incremental gains throughout the sectors in increasing energy efficiency. There was also substantial interest in the potential for big obvious technological gains to be made in different sectors. These included the introduction of an Integrated Gasification Combined Cycle (IGCC) into the coal fired generating stations, and a change in the transportation sector fuel mix to combinations of gasoline with Liquified Petroleum Gas (LPG) and Compressed Natural Gas (CNG) in the short term, and Hydrogen and Electricity in longer term. These options were assessed for their potentials and obstacles in the detailed papers.

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There were various attempts at assessing the incremental possibilities of different sectoral strategies. For example, Khan (1998a) in trying to get to a 35% reduction in emissions in the automotive sector, which would meet the 6% target for the sector, assessed each possibility and other jurisdictional successes (Table 4). The papers also stressed some of the difficulties associated with reducing emissions. In studying the commercial sector, Beaulieu (1998a) noted that while a lot had been written on potential technical solutions for efficiency and other gains, little has been said about the costs of implementation. Other students focused on the inexorable trends we face. Pereverzoff (1998) notes that increases in population and transportation use (30% increases or more) over the period will cancel out technology gains. Truck transport is expected to increase 35% or more (Lee, 1998).

Table 3. Summary of potential GHG reductions within various sectors

Sector/ Reference	Strategy	Estimated TNR Emission Reductions ($ktCO_2$) by 2010	Comments
Landfills *Ferguson (1998)*	Gas capture Central composting	1162 1820	Expensive Legislation and market required Expensive
Commercial *Beaulieu (1998)*	Retrofit and design	969	Economically attractive Needs incentive/regulation
Residential *Jankovic (1998)*	Insulation, heat and water, equipment, light, appliances	2689-4382	Retrofit of envelope, expensive Retrofitting of old apartments not included in figures
Residential *McFayden (1998)*	Economic incentives	n/a	
Institutional *Kulkarni (1998)*	Retrofit technology	48	Expensive Decision-makers are conservative
Industry *Abate (1998)*	Increase efficiency Pre-combustion CO_2 Post-combustion	1107-2198 6593-10989	Cheap and easy 2-10% efficiency decrease 18-35% efficiency decrease
Industry *Gore (1998)*	Tradable emission permits	n/a	Any level of reduction theoretically possible Proposed global strategy
Power generation *Kumar (1998)*	IGCC technology	5111-7077	Good efficiency and CO_2 reduction Costs attractive
Power generation *Mladinic (1998)*	Tradable permits		Permits technologically and economically feasible
Corcoran (1998)	Hydraulic purchases, renewables	n/a	Costly to provider and consumer
Freight transportation *Lee (1998)*	Demand management Intermodal technology	2419 1475	Negative economic impact
Transportation *Georgakopoulos (1998)*	Gas/H/Electrical % mix 70/15/15 60/20/20 50/25/25	7494 9310 11126	Expensive Small % conversion currently possible Expensive Larger conversion as medium-term solution Expensive More feasible as long-term solution
Transportation *Pereverzoff (1998)*	Traffic calming and land use	1139	Success depends on comsumer choice
Khan (1998)	Economic instrument	5893-8464	High set-up costs Not mutually exclusive
Arnott (1998)	Increase AVO to 1.33	500	Cheap Need employer support
Education *Balog (1998)*	Formal and non-formal public education strategies	n/a	

Source: Modified from Kumar, 1998

Table 4. **Automobile sector strategy-greenhouse gas emission reduction estimates**

Strategy	Factors/Assumptions Considered	Emission Reduction Estimate
1. Variable Road Pricing	• Singapore Plan resulted in 75% reductionin vehicular traffic • Stockholm study found a 73% reduction in CO_2 emissions • Assume TNR will achieve a 50% emission decrease due to road pricing (considering greater disposable incomes of TNR residents and to be conservative) • Assume work-related commutes generate 10% of total annual TNR GHG emissions	5%
2. Inspection and Maintenance Programs	• OECD study estimates that an inspection and maintenance program will yield a 25% reduction	25%
3. Physically Restraining Traffic	• Assume that 2% of total greenhouse gas emissions arise from personal transportation in the downtown core during weekday busines hours • Assume additional 2% emission reductions resulting from changes in personal travel patterns from motor vehicle commute to public transit	4%
4. Priority Lanes for Carpooling	• Assume the number of motor vehicle commuters opting to forego single passenger travel and join car pools to reduce personal costs is 1%	1%
Cumulative Benefit		35%

Source: Modified from Khan, 1998

STRATEGIES FOR IMPLEMENTATION

For the third paper, students were asked to provide strategies to meet the targets, discussing the economic, social, and environmental tradeoffs. They were also asked to look at the relationship between a set of short-term strategies to meet the targets by 2010, and longer term approaches (including meeting the 2010 targets retroactively), which open up different possibilities.

Within this structure, the students produced a range of different approaches, including:

- Short-term/long-term
- Aggressive/non-aggressive
- Sectorally focused/cross-sectoral
- Multiple phase entry/distributed impact
- Regulatory initiatives/economic incentives/technological changes/equity across sectors.

Very generally, there was a consensus around a non-aggressive short-term strategy, an aggressive short-term strategy, and a very aggressive short-term strategy. Disagreements emerged about regulatory vs. non-regulatory approaches, whether industry should be targeted for reductions and the citizenry left alone (or vice versa), and so on. There was a rough agreement that, in the short term, the equitable approach across all sectors is best for political reasons and that energy efficiency was the easiest partial solution.

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For example, Pereverzoff (1998b) proposed 3 strategies. Strategy 1 emphasized energy efficiency and technological solutions, including the implementation of IGCC in the Ontario Hydro coal-fired plants, substantial retrofitting of residential and commercial buildings, and fuel switching in automobiles (Table 5). Strategy 2 was a more aggressive attempt to get people away from their cars, rather than changing the fuel mix. It included a range of land use, car-pooling and traffic calming options (Table 6). Strategy 3 was purely a technological strategy, targetting the industrial, power generation, and transportation sectors, while avoiding the public. It relied on post-combustion removal of CO_2 and other technologies, some of which are still in the research and development phase (see Table 7).

Table 5. Reductions from Pereverzoff's Strategy 1 (emphasizing energy efficiency and technological solutions)

Sector	1990 ($ktCO_2$)	2010 BAU ($ktCO_2$)	Reduction Method	Reduction ($ktCO_2$)	2010 after reductions
Power Generation	12098	15727	IGCC (coal)	5081-7137	8590-10646
Industrial	19980	21978	Retrofits	1107-2198	19780-20871
Commercial	4120	4847	Retrofits	969-2927	1920-3878
Residential	8300	9960	Retrofits	2689-4648	5312-7271
Institutional	246	283	Retrofits	48	235
Transportation	24450	31785	Gas 45%/ CNG 55%	7550	24235
Landfills	3050	3965	Do nothing	-	3965
Industrial Processes	6240	6864	Do nothing	-	6864
Agriculture	2700	3510	Do nothing	-	3510
TOTAL	**81184**	**98919**		**17444-24508**	**74411-81475**

Source: Pereverzoff, 1998b

Table 6. Reductions from Pereverzoff's strategy 2 (more aggressive attempt to get people away from their cars)

Sector	1990 ($ktCO_2$)	2010 BAU ($ktCO_2$)	Reduction Method	Reduction ($ktCO_2$)	2010 after reductions
Power Generation	12098	15727	IGCC (coal)	5081-7137	8590-10646
Industrial	19980	21978	Retrofits	1107-2198	19780-20871
Commercial	4120	4847	Retrofits	969-1920	2927-3878
Residential	8300	9960	Retrofits	2689-4648	5312-7271
Institutional	246	283	Retrofits	48	235
Transportation	24450	31785	Carpooling Land use Inspection Road pricing	500 520-1950 2036-3054 1020	24261-27709
Landfills	3050	3965	Composting	592-1820	2145-3373
Industrial Processes	6240	6864	Do nothing	-	6864
Agriculture	2700	3510	Do nothing	-	3510
TOTAL	**81184**	**98919**		**14562-24295**	**73624-84357**

Source: Pereverzoff, 1998b

Table 7. Reductions from Pereverzoff's strategy 3 (purely technological)

Sector	1990 ($ktCO_2$)	2010 BAU ($ktCO_2$)	Reduction Method	Reduction ($ktCO_2$)	2010 after reductions
Power Generation	12098	15727	IGCC (coal)	5081-7137	8590-10646
Industrial	19980	21978	Post-combustion Retrofits	6593-10989 1107-2198	8791-14278
Commercial	4120	4847	Do nothing	969-1920	2927-3878
Residential	8300	9960	Do nothing	-	9960
Institutional	246	283	Do nothing	-	283
Transportation	24450	31785	Freight	590	31195
Landfills	3050	3965	Gas capture	592-1162	2803-3373
Industrial Processes	6240	6864	Do nothing	-	6864
Agriculture	2700	3510	Do nothing	-	3510
TOTAL	**81184**	**98919**		**14932-23996**	**74923-83987**

Source: Pereverzoff, 1998b

Detailed discussion also ensued around long-term strategies, especially how to consolidate gains made in the short-term strategies. Elements of proposed long-term strategies are listed below:

- On-going formal and informal education through community-based initiatives, media dissemination, etc.
- Tradable emissions permits

Toronto-Niagara Region Study on atmospheric change

- Economic incentives for the residential sector including financial assistance for upgrades
- Research and development
- technologies for gas capture from landfills
  - IGCC technology for power generation
  - post-combustion removal of CO_2 from industry sources
  - alternative fuels for automobiles
  - energy-efficient technology
- Demand management
  - shift dependence away from heavy-duty trucks towards railways
  - stress inter-modal transportation
- Renewables including solar, wind, and biomass
- Long-term land use strategies including land-use changes focusing on reducing urban sprawl

...we could be playing out the global argument in miniature, the TNR as a "developed region". What ought the share for the TNR really be, given its importance in the country? If Ontario and Alberta are the big emitters, will they have to cut back more than 6%? What percentage of Canadian emissions does the TNR produce? Should the TNR be able to use its productive wealth to buy-off emissions from elsewhere? Do emissions count that are generated outside the region, but which keep the region going?

REFLECTIONS AND CONCLUSIONS

Partly because the instructors had already committed the TNR to a 6% reduction, there was little discussion about the wider political context within which the reduction was to be carried out. For example, there was no discussion about whether the TNR should or must take on more than 6%, given the fact that it has emissions levels greater than a number of provinces.

In this sense, we never engaged the fact that we could be playing out the global argument in miniature, the TNR as a "developed region". What ought the share for the TNR really be, given its importance in the country? If Ontario and Alberta are the big emitters, will they have to cut back more than 6%? What percentage of Canadian emissions does the TNR produce? Should the TNR be able to use its productive wealth to buy-off emissions from elsewhere? Do emissions count that are generated outside the region, but which keep the region going? The questions are endless.

It was clear in the class that we were also recapitulating the larger syndrome that focusing on a short time horizon for meeting targets inevitably focuses attention on sectors. It was very hard for the students, as it is for the rest of us, to break out of the sectoral approach and make cross linkages or even try a completely different approach, for instance by looking at carbon sinks. The closest that anyone came to such a breakout was in the area of public education, and that was in part due to having OISE students in the room. Due to time constraints, there was little chance to sit back and reflect on the possibilities.

There was, as I said earlier, no real attempt on anyone's part to link the potential impacts to the mitigation options as a political selling point, nor was there much mention of other atmospheric issues, except in terms of some of the costs and benefits. Overall, there was a shared concern, captured very well by Gore (1998b):

> *[that the challenge] should be to identify how the TNR can meet its 2010 goal, while simultaneously not limiting the freedom and creativity to explore social and economic changes which will maintain and continue to reduce the levels of GHG which the TNR achieves. Not only do decision-makers need to scope this issue to the year 2010, but to a year they cannot even conceive of."*

I conclude with the thought that the difficulties our students experienced are in many ways similar to what would be faced by any mitigative component of a TNR study. The sectoral and time limitations on creative exploration of linkages, alternative approaches, and so on, should be heeded as a warning. At the same time, the work that these students have done is a substantial resource for the TNR study, and greatly to their credit.

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REFERENCES

Abate, S. 1998a. *Technological Options for the Reduction of Industrial Stationary Fuel Combustion in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Abate, S. 1998b. *Short Term and Long Term Greenhouse Gas Emission Reduction Strategies for the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Amott, N. 1998a. *Ridesharing and Greenhouse Gas Reductions in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Amott, N. 1998b. *Strategies to Reduce Greenhouse Gas Emissions in the Toronto-Niagara Region: Discussion Paper.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Balog, M. 1998a. *Public Education Strategies to Assist in Achieving a 6% Reduction of Greenhouse Gas Emissions in the TNR by the Year 2010.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Balog, M. 1998b. *Implementation Strategies for the Toronto-Niagara Region to Meet the Kyoto Commitment.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Beaulieu, P. 1998a. *Technical Solutions for the Reduction of Greenhouse Gas Emissions from the Commercial Sector in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Beaulieu, P. 1998b. *Strategies for Reducing Greenhouse Gas Emissions in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Canadian Urban Institute 1997. *GTA Urban Structure: An Analysis of Progress Towards the Vision.* Canadian Urban Institute: Toronto, Ontario.

Corcoran, K. 1998a. *Opportunities for and Implications of Reductions of Greenhouse Gas Emissions from Electricity Generation in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Corcoran, K. 1998b. *An Analysis of Two Proposed Strategies for Meeting the Requirements of the Kyoto Protocol within the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Environment Canada 1997. *Trends in Canada's Greenhouse Gas Emissions.* Environment Canada: Toronto.

Ferguson, C. 1998a. *Landfill Methane Emissions in the TNR: A Strategy for Reduction.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Ferguson, C. 1998b. *Reaching the Kyoto Target: A Case for the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Georgakopoulos, J. 1998a. *Technological Options for Reducing Greenhouse Gas Emissions in the Toronto-Niagara Region's Transportation Sector.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Georgakopoulos, J. 1998b. *Strategies for the Toronto-Niagara Region to Achieve a 6% Reduction in Greenhouse Gas Emissions from 1990 Levels.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Gore, C. 1998a. *Understanding Potential Reductions in Greenhouse Gas Emissions for Industries in the Toronto-Niagara Region: The Case for Tradeable Emission Permits.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Gore, C. 1998b. *Meeting the Kyoto Target: A Report on Potential Strategies to Reduce Greenhouse Gas Emissions 6% Below 1990 Levels in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Government of Canada 1997. *Canada's Second National Report on Climate Change.* Queen's Printer: Ottawa, Ontario.

GTA Task Force 1996. *The Economics of Urban Form.* Report prepared by Dr. P. Blais and Berridge Lewinberg Greenberg Dark Gabor Ltd. Office of the GTA: Toronto, Ontario.

Jankovic, M S. 1998a. *Technical Solutions for a Residential Sector.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Khan, E. 1998a. *Reducing Transportation Emissions within the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Khan, E. 1998b. *Strategies for Achieving the Kyoto Commitment in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Kulkarni, T. 1998a. *Technical Solutions for Institutions to Decrease CO_2 Equivalent Emissions.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Kulkarni, T. 1998b. *Discussion Paper Considering Four Strategies for the Toronto-Niagara Region to Meet a 6% Reduction Below 1990 Levels for CO_2 Equivalent Gas Emissions.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Kumar, A. 1998a. *Technical Mitigation Options: Addressing CO_2 Reductions from the Energy Sector within the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Kumar, A. 1998b. *Strategies for Meeting the Reduction in Greenhouse gas Emissions within the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Lee, S H. 1998a. *Greenhouse Gas Mitigation Measures in Freight Transportation.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Lee, S H. 1998b. *Greenhouse Gas Mitigation Measures in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

McFayden, J. 1998a. *Reducing Emissions in the Residential Sector: The Role of Economic Incentives.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

McFayden, J. 1998b. *Greenhouse Gas Emissions in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Metropolitan Toronto Planning Department 1993. *Transit 2020: A Vision for An Integrated Rapid Transit Network.* Metropolitan Toronto: Toronto.

Mladinic, H. 1998a. *Power Generation and Economic Incentives: Reducing Greenhouse Gas Emissions in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

McFayden, J. 1998a. *Reducing Emissions in the Residential Sector: The Role of Economic Incentives.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Ogilvie, K., D. Bell, R. White, and Q. Chiotti (eds) 1997. *Climate Variability, Atmospheric Change and Human Health Conference Proceedings*, November 4-5, 1996. Pollution Probe, Toronto, Ontario.

Ontario Hydro 1990. Providing the Balance of Power. Ontario Hydro, Toronto.

Pereverzoff, S. 1998a. *Reduction of Passenger Transport Emissions Through Land Use Changes.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Pereverzoff, S. 1998b. *Meeting the Kyoto Protocol: Potential Strategies in the Toronto-Niagara Region.* Unpublished IES1002S paper, Institute for Environmental Studies, University of Toronto.

Statistics Canada, CANSIM 1997. *Matix 6231.* Statistics Canada, Ottawa, Ontario.

Torrie, Smith, and Associates 1997. *Realizing Toronto's Target for Greenhouse Gas Emission Reductions – Current Trends and Outlook.* International Council for Local Environmental Initiatives (ICLEI), Toronto.

Perspectives from the Centre for Sustainable Transportation

Remarks by Richard Gilbert
Centre for Sustainable Transportation

I want to touch on four matters relevant to adaptation to or mitigation of climate change. Three concern transportation while the other relates to the heating and cooling of buildings.

The first transport issue is the movement of freight. Freight traffic is responsible for about 30% of the environmental impact of all transport. This traffic is growing, as are its impacts. Passenger traffic has been growing too, but its overall environmental impacts have been more or less constant since the early 1970s. Technological improvements to private automobiles have roughly offset the increase in traffic. This has not occurred for truck traffic, or for freight trains. Trains still carry more freight in Canada than trucks, and with much less environmental impact, but their environmental performance has not been improving in the way that car performance has improved.

In terms of progress towards sustainability, transportation rates among the worst sectors. Although truck traffic accounts for almost all of the worsening performance, the impacts of aviation are also growing. Given present trends, freight will account for some 40% of transport's impact by 2010 and about 50% a decade or so later. Any attempt to mitigate the environmental impacts of transport should have some focus on the movement of freight.

In terms of progress towards sustainability, transportation rates among the worst sectors. Although truck traffic accounts for almost all of the worsening performance, the impacts of aviation are also growing. Given present trends, freight will account for some 40% of transport's impact by 2010 and about 50% a decade or so later. Any attempt to mitigate the environmental impacts of transport should have some focus on the movement of freight.

The second transport issue is air quality inside vehicles. Specific pollutants within cars have been recorded at up to 18 times ambient levels. This is not a well-researched matter. Air quality inside vehicles may be worsening as vehicle sealing technology improves, enabling manufacturers to improve overall energy efficiency by reducing the size and power of vehicle heating and cooling systems.

A worrisome aspect of in-vehicle air quality could be the greater exposure of children as they spend more and more time inside vehicles. A workshop participant remarked about moving to the suburbs to get better air. The main effect of moving to the suburbs on children may be that they spend more time in cars. They are ferried to school, hockey and soccer games, and are taken to shopping malls because there is no one at home to care for them. This combination of factors, poorer in-vehicle air quality and greater exposure as children spend more time in cars, have not yet been assessed together. A third factor, climate change, could interact with the other two factors. Serious examination of these issues is required. It could well result in recommendations to improve in-vehicle air quality and to keep children out of cars. However, the simplest way to reduce in-vehicle air quality may be to reduce the number of vehicles on the road.

A worrisome aspect of in-vehicle air quality could be the greater exposure of children as they spend more and more time inside vehicles. The main effect of moving to the suburbs on children may be that they spend more time in cars. This combination of factors, poorer in-vehicle air quality and greater exposure as children spend more time in cars, have not yet been assessed together.

The third transport issue concerns non-work trips. Although much of the discussion during this workshop has been about work trips, these are now less than 30 per cent of all trips in the Toronto-Niagara Region and the proportion is declining. Almost all of the growth in automobile use comprises non-work trips. All trips are significant. Greenhouse gases are emitted whenever a trip is made using fossil fuel, whatever the time of day or night. Ground-level ozone is formed whenever the sun is shining. In-vehicle pollution may be only a little bit higher during rush periods. The focus on work trips could detract from the much more intractable challenges posed by freight transport.

The non-transport issue I want to touch on is the heating and cooling of buildings, which may be the largest end use of fossil fuel in the Toronto-Niagara Region. A speaker noted that there is much potential to reduce fossil fuel use for these purposes. One way of doing this is to install district heating and cooling. The International Council for Local Environmental Initiatives (ICLEI) has showed that district heating can be a key factor in a city's achievement of low per-capita greenhouse gas emissions.

Toronto has one of the largest district heating systems in North America, operated by the Toronto District Heating Corporation (TDHC). Collective systems provide good opportunities for reducing emissions. Last year the TDHC, which provides steam heat for most buildings in the downtown, installed a new boiler that replaced half its steam capacity. Use of this boiler reduces NO_x emissions by more than 80% compared with its predecessor. Part of the improvement lies in boiler technology and economies of scale, while part lies in sophisticated control features not readily available to building managers.

The TDHC's most exciting venture from the perspective of mitigating climate change and its effects is the Deep Lake Water Cooling (DLWC) project. The cooling of buildings in downtown Toronto is the largest use of electric power in Ontario. It causes Toronto Hydro to have a different peaking cycle from the rest of the province; electricity use peaks here in the summer rather than the winter. Reductions in cooling invariably mean reductions in emissions of CO_2, NO_x, and other pollutants because electric power generation at the margin is from coal.

Toronto (and the Toronto-Niagara Region generally) lies next to a huge reservoir of water at 4ºC, the temperature at which water is most dense. When surface water is cooled to this temperature in the winter it sinks. As a consequence, and because summer warming penetrates only to about 60 metres, all the water below about 70 metres in Lake Ontario has stabilized at 4ºC - and the lake is up to 250 metres deep. Any water drawn from this reservoir would be replaced by natural cooling during the following winter. and thus is a completely renewable resource.

Under the DLWC project, cold water will be supplied by deep lake water instead of on-site chillers and a district cooling system will be established. When installed, the DLWC system will reduce electricity use for cooling, and thus fossil fuel use for this purpose, by more than 75%. As well, it will obviate the need for cooling towers on downtown buildings, which are a source of heat, humidity, noise, and possibly disease.

The TDHC, working with the City of Toronto, plans to make use of this renewable resource to replace much of the electromechanical cooling of buildings in downtown Toronto. Each building now manufactures its own chilled water. It is then pumped to occupied spaces where air is blown over the cold water-filled pipes to provide air conditioning. Under the DLWC project, cold water will be supplied by deep lake water instead of on-site chillers and a district cooling system will be established.

Also exciting is the double use of the deep lake water, which will also be used in the municipal water supply. A new 2.6-kilometre-long inlet for the Toronto Island Filtration Plant will allow cold, 70-metre-deep water to be drawn in. After being purified and pumped ashore the cold lake water will pass through heat exchangers before joining the municipal supply. The environmental assessment for the DLWC proposal has just been completed and approved. When installed, the DLWC system will reduce electricity use for cooling, and thus fossil fuel use for this purpose, by more than 75%. As well, it will obviate the need for cooling towers on downtown buildings, which are a source of heat, humidity, noise, and possibly disease.

Many communities in the Toronto-Niagara Region could reduce the environmental impacts of heating and cooling buildings by installing district heating and cooling systems. With climate change, the need for cooling could become especially important. The need for renewable energy to provide that cooling becomes even more important. DLWC projects serving many parts of the Toronto-Niagara Region could make a significant contribution to reducing fossil fuel use and thus to reducing the extent of climate change and its impacts.

Toronto-Niagara Region Study on atmospheric change

An Analytic Framework to Estimate the "Co-Benefits" of Climate Policy Options

Remarks by Jay Barclay
Environmental Protection Service, Environment Canada

INTRODUCTION

This presentation will complement the interesting perspectives that Ken Ogilvie and Richard Gilbert have offered. I begin with an overview of Canada's response to the Kyoto Protocol, outline some work that is being initiated to examine the benefits of possible actions to reduce greenhouse gas emissions, and highlight recent literature on this topic.

CANADA'S GREENHOUSE GAS POLICY DIRECTION POST-KYOTO

Following the commitments to reduce greenhouse gas emissions that were negotiated in Kyoto in December 1998, Canada's First Ministers called for a process to examine the implications, including costs and benefits, of the agreement. In response, Canada's Energy and Environment Ministers recently launched a process to develop a national implementation strategy on climate change. The purpose of this process is to look at the implications for Canada of addressing the commitments made in Kyoto and to identify the options for addressing these commitments. A number of sectoral and horizontal "issue tables" are being established to deal with a broad range of issues, including modelling and analysis, credit for early action, enhanced voluntary actions, electricity, transportation, and action at the municipal level. This strategy is expected to be complete by the end of 1999.

The intention is to provide Ministers, who will be debating the options available to Canada to reduce GHG emissions in late 1999, with information to help them recognize that actions to reduce GHG emissions can address a number of other issues, particularly local air quality and human health concerns.

ESTIMATING THE BENEFITS OF TAKING ACTION

Environment Canada is initiating some work as part of the overall process, in partnership with Health Canada, to examine the environmental and health benefits of a range of actions that could be taken to address Canada's greenhouse gas commitments. The hope is that our efforts might inform and influence the decision process of developing and choosing actions that would reduce greenhouse gas emissions. Our initiative will provide some information on how specific actions might affect other environmental and particularly atmospheric issues, including the link to human health that a number of speakers have already mentioned.

This is a work in progress because we are still developing our work plan, building on recent literature and examining ways to tap and enhance the modelling and analysis capabilities that exist within Environment Canada and Health Canada. I think the approach we are developing fits very well with the objectives of the Toronto-Niagara Region study and, given the expertise assembled at this workshop, I'm quite interested in your comments or questions on the approach we are proposing.

What we are trying to do at the national level is something that the Toronto Niagara Region study will hopefully do in much more depth and will provide a richness of information on a regional level. Such an effort will complement the broader national approach. The intention is to provide Ministers, who will be debating the options available to Canada to reduce GHG emissions in late 1999, with information to help them recognize that actions to reduce GHG emissions can address a number of other issues, particularly local air quality and human health concerns. If successful, the same information will be useful in the public outreach process that is part of the development of a national implementation strategy on climate change.

One approach we are developing is to identify a number of screening or evaluation criteria that the sectoral issue tables could use in identifying actions that might provide a bigger "bang for the buck" by also reducing other environmental emissions. This is a very preliminary list of criteria that will be subject to considerable review and modification as we attempt to "operationalize" them for use. As a starting point, it is useful to bear in mind that the Kyoto Protocol provides for a number of "flexibility" or implementation mechanisms for Parties to address their commitments, including international emissions trading, joint implementation and the Clean Development Mechanism. But if one is also interested in addressing local air quality and related environmental concerns, then obtaining these benefits requires action at the local level. This reality provides an important perspective on the rationale or approach to dealing with the climate change commitments that we have made.

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The criteria we have identified to date include the importance of taking actions that will reduce energy combustion-related emissions, particularly those in urban areas, due to the direct linkage to human health effects. Some energy forms are preferable from an environmental perspective because they produce fewer or no emissions. Similarly, it may be important to do things that also deal with secondary pollutants such as ammonia that are involved in the particulate issue. Actions which reduce the creation and transportation of pollutants upwind from sensitive eco-regions provide another possible criterion that can be used to help judge the effectiveness of potential actions in providing a range of benefits.

The approach we are developing follows the traditional damage function concept, as illustrated in Figure 1. An analytic framework is being developed that would be used to trace through how a specific measure that would change pollutant levels at a certain source (whether it be an area or point source) will, through atmospheric transportation and related processes, change things like air quality, water quality, and ecosystem health. These changes will in turn affect some key things that policy makers may be concerned about such as human health, land productivity and the durability of built infrastructure. It might also be desirable to assign some monetary values to these effects, rather than stopping at physical impacts, to express the impacts in terms that are commensurate with estimates of the costs of specific actions.

The left side of the chart identifies some of the tools that we might use to operationalize this framework. The starting point for a number of these analytic tools is Environment Canada's Regional Discharge Information System (RDIS), which provides historical estimates of criteria air contaminants from point and area sources. RDIS could also allow us to do some area mapping of emissions. Work is required to incorporate greenhouse gas inventory data into this system.

Environment Canada has developed a model called AERCo$t™ that uses the RDIS system as a base and estimates how specific strategies change emissions of selected pollutants and at what cost. We are looking at adding greenhouse house reduction strategies to this model. Our Emissions Forecasting Model (EFM) is used to produce forecasts for criteria air contaminants, and with some modifications will be able to provide projections for specified policy options or scenarios.

Information on changes in emissions at source would be an input into the Unified Model presently under development at Environment Canada's Atmospheric Environment Service. This model would help to estimate how air quality might change in a world of reduced emissions. Finally, at the end of the process, the Air Quality Valuation Model (AQVM) used by Environment Canada and Health Canada will take information on changes in air quality and related factors and will estimate changes in physical parameters such as reduced morbidity. AQVM then will apply values from the literature to translate the effects into monetary terms. To complete the picture, the right hand side of the figure provides the parameters that need to be addressed through the various steps in the framework.

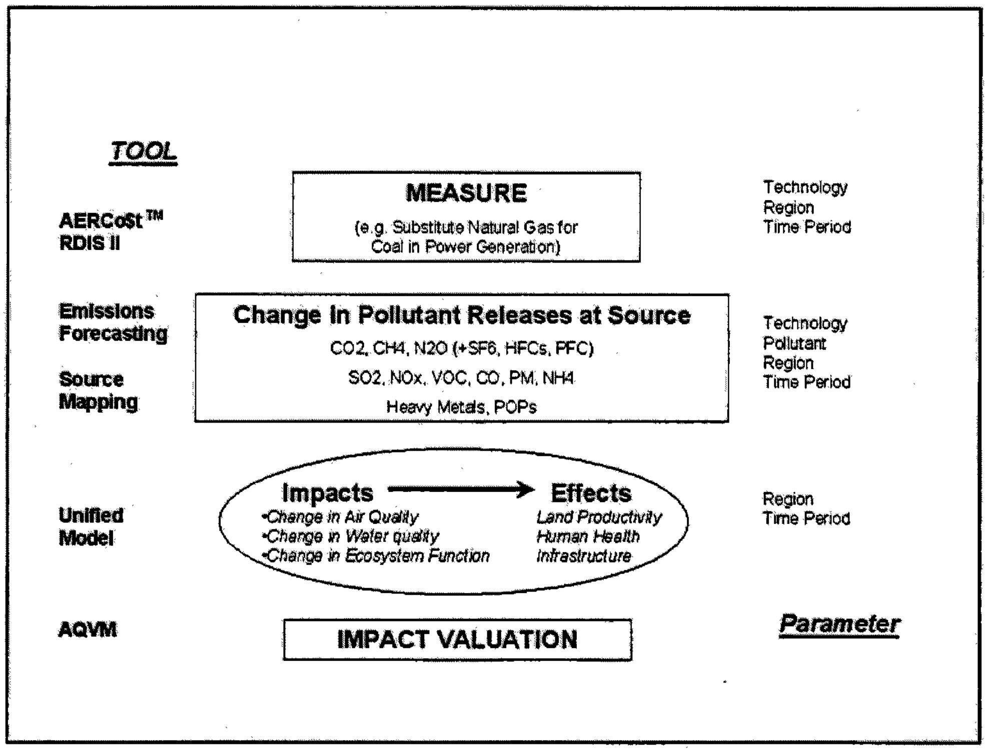

Figure 1. Analytic framework for estimating environmental and health benefits

Perspectives from Toronto Hydro

Remarks by Joe Berta
Toronto Hydro

The subject of my talk is the CO_2 policies and plans of Toronto Hydro. In September 1997, I was retained by Toronto Hydro to put together a policy and plan for them. What we've been doing is integrating with the Toronto Atmospheric Fund (TAF), the City of Toronto, and with our customers - Toronto Hydro is very customer-focused. Everyone is talking about deregulation and the potential for the CO_2 issues to get thrown off the table, however Toronto Hydro actually views them as an opportunity. If we're the only game in town that's offering you energy at a good value plus reduced CO_2 emissions, we're hoping that you are willing to pay a little bit of a premium for it.

Toronto Hydro focuses both internally and externally when dealing with the CO_2 issues. With respect to the work of Peter Timmerman's students (see Timmerman *et al.*, this volume), I am satisfied with some of the education-related strategies that our utility has adopted. Toronto Hydro looks at both the long- and short-term. We hold workshops on renewable energy, wind and solar. We also have experts come into the city who work with community groups to find out what their needs are, and explain things to them like how a solar panel works, how a wind turbine works, and what run of the river is. We want these groups to be informed and educated on about some of the upsides as well as the downsides of these technologies. An educated consumer in our mind is the best ally and asset that we have.

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We also look at the issue internally by promoting and implementing energy conservation. For fleet vehicles, this includes sending the vehicle that has the right equipment and is the right size for the job. Toronto Hydro itself has been amalgamated like the rest of the city. So we've been trying to figure out who we are, what we are, and where we want to be. In terms of some of the station modifications, we have been revamping and changing our business practices to reduce energy consumption.

Toronto Hydro is working with its key accounts to find out what they need to better manage their energy bills. That provides both CO_2 reductions and energy savings for the customers and a customer service from our end. We're looking at renewable energy. For instance, we have a demonstration project working with TAF and the City of Toronto at the Trinity

Bellwoods Park where a photovoltaic array will be built. A solar powered phone has been installed at High Park and, at Riverdale Farm, an existing windmill has been connected to pump groundwater into a duck pond. The utility also has a net billing program where customers are encouraged to install photovoltaics on roofs and have any unused energy credited to their bill.

The utility is also looking at securing a large portion of renewable energy from Ontario Hydro and marketing it to Toronto customers. We believe that a considerable number of customers are willing to purchase green energy and pay a premium for it. We believe that renewable energy and CO_2 adds to local employment benefits.

The utility is also looking at securing a large portion of renewable energy from Ontario Hydro and marketing it to Toronto customers. We believe that a considerable number of customers are willing to purchase green energy and pay a premium for it. We believe that renewable energy and reducing CO_2 adds to local employment benefits.

Partnerships are an important part of Toronto Hydro's approach. We work in partnership with TAF and Public Works at the City of Toronto, as well as with community groups and corporations. Toronto Hydro has endorsed the recommendations of the Ontario Clean Air Alliance and is looking to establish a green fund to help install renewable components on public institutions within the city. As well, the utility is a founding member of the ICLEI Solar Century.

Toronto Hydro is also involved in carbon recycling. In North York, the former North York Hydro was able to plant one tree for every customer they had. We are currently investigating the potential for doing that for all of Toronto. The utility has a bill insert encouraging customers to call LEAF, a community group, which then advises them or arranges where trees should be planted for shading during the summer and for solar gain in the winter.

With so many projects and partnerships, one of the problems we have is resource allocation and time. Where do you want to allocate? Which marketplace is the biggest bang for your buck? Is it commercial or industrial users, or is it the residential market where it is a longer-term process of trying to establish broad support and commitment? These are some of the questions we will be dealing with in the future at Toronto Hydro.

Perspectives from the City of Toronto Atmospheric Fund (TAF)

Remarks by Lois Corbett
Toronto Atmospheric Fund, City of Toronto

I was in Kyoto and I saw a bunch of people sitting around the Canadian delegation that didn't actually know much about climate change. Unfortunately, they also left this big long process not knowing much about climate change, so I congratulate Peter Timmerman, his colleagues, and his students on their impressive work (see Timmerman *et al.*, this volume). There is a graduate class in Calgary that undertook a very similar exercise and they presented their results to the Canadian Energy Research Institute in early May 1998. They looked at the 80 measures that were originally outlined in the National Action Plan for Climate Change and slapped 14 criteria together to rank them. They too came up with some very creative and innovative ways of valuing these measures. So that's 32 students in Calgary saying we can deal with climate change, and we have 16 students here in Toronto saying we can do it in our region. Maybe we should get these two bunches of youngsters together and give them the implementation process plan that unfortunately Jay Barclay and his Environment Canada colleagues have to work out for their Minister.

I think it is really important to take the issue out of the research arena, the laboratory and the computer models, right down to the floor of council chambers.

I want to talk about the role of the Atmospheric Fund in trying to support the type of work and other actions that can happen at the local level. I also want to make four brief points about what groups like the Toronto Atmospheric Fund need from the Toronto-Niagara Region study. We need to take the TNR out of the conference room and into the council chambers. Every year around budget time I fight with councilors, now 56 of them, trying to get their support for a relatively progressive financing institution call the Toronto Atmospheric Fund. With your abilities, skills, persuasion and research, we won't just be a few lonely voices down in council; we will actually be spreading the word about climate change. I think it is really important to take the issue out of the research arena, the laboratory and the computer models, right down to the floor of council chambers. There are councils all through the Toronto-Niagara Region, not just that mega-council down the street. I'm going to tell you, the research community, what to do, but I'm not going to tell you how to do it because I'm not sure I would know how to translate your message, for example, into a five minute deputation - and that's all you get at council. But you may want to start thinking about how you turn the value and the insight of all the work that we've done into a five minute message that a former appliance salesman from North York can understand. That is a huge challenge and the source of one of my research questions. How could you find out what it would take to guarantee the political support of 56 councilors and one mayor on the climate change issue? If you could wrap that up in a nice package for some of the activists, this study would be really important. Of course you can't do that so the question becomes how do you get the message about what we do know out to those people who are making significant, important decisions that affect the daily lives of their residents?

In this day and age, the municipal level of government is not insignificant. The Toronto government, the one I'm most familiar with, is a $5 billion operation. The City of Toronto itself spends about $80 million on energy, so there is one customer that, with a vision and enough leadership, could reduce its own need and have a significant impact on emissions. Taking the study and work out of the laboratory and into the council chambers would produce many opportunities for the research community to provide leadership and build partnerships at the local level of government.

Assuming we took Peter Timmerman's University of Toronto class (see Timmerman *et al.*, this volume) and say the things they have studied are fine with us; we don't need to study anymore and we have got enough of a roadmap. The activist community will need to rely on the research community's expertise to make a convincing argument that this is an issue that the local government, in an area that they don't necessary regulate in, can take some steps in, affect some change, and actually move the agenda forward. We also need to integrate the policies and measures suggested during conferences such as this with the local government's agenda, while recognizing the current world of regulatory reform that exists in Canada. Now is the time to start paying attention to the local level of government because everything is being downloaded and sooner or later the responsibilities will stop somewhere. While the local level of government may not have jurisdiction today, for example, over smog precursors, it may become an increasingly important resource base for organizing and implementing measures that are needed to reduce such pollutants.

The activist community will need to rely on the research community's expertise to make a convincing argument that this is an issue that the local government, in an area that they don't necessary regulate in, can take some steps in, affect some change, and actually move the agenda forward. We also need to integrate the policies and measures suggested during conferences such as this with the local government's agenda, while recognizing the current world of regulatory reform that exists in Canada.

Through my many years of experience in the activist community, I have noticed that it is not just Toronto anymore that wants to be active on these issues at the municipal level. Most local politicians when conducting their early polling find that environmental issues are a concern to their residents and their local constituents. As participants in this study, I think that we need to help inform whatever bit of their environmental agenda they have allocated to the climate change issue. That's my pitch in trying to involve these people. As frustrating and as crazy as they can be sometimes, I think that we do have to start building the bridges. Fortunately, there is already an active grassroots environmental community in the Toronto region that is quite literate in the subject of climate change.

We have spent the last four years at the Toronto Atmospheric Fund building a community of support because we know that we can't get the mayor's ear on climate change unless other people are interested. When the mayor goes on a walking school bus tour and the "little people" talk to him about climate change, how they like the program so much, and how they get lots of good exercise, then he actually gets a message about the value of funding public education around climate change activities. He gets the political message about not taking TAF's capital away, which is always good for TAF, but he along with the children get the message that they are going to see benefits in their lives from these activities. When we first received the walking school bus proposal at the Toronto Atmospheric Fund about two years ago, we had one of our engineers from city works review it. He didn't think that TAF should fund the proposal because it really wasn't a climate change or a greenhouse gas reduction project. It really was all about people and parents being concerned about their children's safety and building up the social network of neighbours who would know each others' kids and on every other day would walk 20 of them to school. So in his eyes, it was much more of a social program than an environmental program. We responded by saying "So, what's your point?"

The activist community will need to rely on the research community's expertise to make a convincing argument that this is an issue that the local government, in an area that they don't necessary regulate in, can take some steps in, affect some change, and actually move the agenda forward. We also need to integrate the policies and measures suggested during conferences such as this with the local government's agenda, while recognizing the current world of regulatory reform that exists in Canada.

We know that climate change is very much a political, economic and social issue. We have to build the integrations around those themes as well as from the environmental and human health perspectives. I think now the challenge is for Peter Timmerman's students to blatantly point out the question "Should the Toronto region have to do more than the rest of the country". I look forward to seeing how we can use the work generated through the TNR study, and especially some of the innovative mitigative measures that have been brought forward.

Toronto has an internationally acclaimed reputation as being a leader on environmental issues and particularly on this environmental issue - how do we reduce greenhouse gases, how do we work on climate change? We've earned that reputation both by doing a few things, talking a lot about what we do (we are from Toronto after all), and saying that the city government level must have an integrated path forward. The issue cannot stay within the domain, for example, of the engineers within public works. It has to be an issue that is addressed within urban planning, transportation and waste management, energy management, the social confines of the department of public health, and people concerned about livelihood and welfare of Toronto residents.

The issue cannot stay within the domain, for example, of the engineers within public works. It has to be an issue that is addressed within urban planning, transportation and waste management, energy management, the social confines of the department of public health, and people concerned about livelihood and welfare of Toronto residents.

We can move forward by learning from some of the mistakes that we have made and by doing exactly what we have done in this workshop; seeing how all of the different angles, issues, measures and layers of government might come together to make some progress on this important environmental issue.

SECTION 7: WORKING GROUP SUMMARIES

Toronto-Niagara Region Study

on atmospheric change

Working Group Questions

On the second day of the workshop, participants were split into 4 working groups (Natural Environment Impacts and Adaptation, Human Health Impacts, Economy and Infrastructure Impacts and Adaptation, Emissions and Mitigation). Participants of a fifth working group, on atmospheric science and modelling, requested to be distributed among the other four as the subject was relevant to all themes. The four working groups were asked to address the three topics listed below.

1. Assessment of research and gaps within respective working group themes concerning the linkages among atmospheric issues, their cumulative effects, and integrated responses.
   - Identify significant research activities or findings missed in Day 1 discusssions and/or the background material relevant to the working group theme (brainstorm and document all suggestions)
   - Identify and list significant research or knowledge gaps (brainstorm and document all suggestions)
   - Identify the two or three most important research gaps

2. Identification of research projects, programs or expertise that could contribute to the Toronto-Niagara Region Study on Atmospheric Change by providing information on the linkages among atmospheric issues, their cumulative effects, and integrated responses (related to the working group theme).
   - Brainstorm and document suggested projects, programs or areas of expertise
   - Identify how each project, program or area of expertise might address the priority research gaps identified in the first task

3. Development and scoping of one or two initiatives that incorporate on-going or new work and expertise into the Study to address priority research gaps.

During the first of two plenary reporting sessions, the working groups reported difficulties addressing these topics without a greater understanding of the goals, objectives and purpose of the Toronto-Niagara Region Study. The following goal statement and primary deliverable were suggested and debated during the plenary session.

Goal Statement: *"The development and/or promotion of adaptive and/or mitigative response strategies to reduce vulnerability to atmospheric change in the Toronto-Niagara Region."*

Primary Deliverable: *"In 2 years, a report including public participation, on the effects/impacts of probable atmospheric change scenarios over the next 25 years including:*

- *Recommended actions to minimize or adapt to critical impact*
- *Questions concerning responses where public discussions are required*
- *Research required to develop better answers*
- *How alternative means of meeting Kyoto obligations can contribute to long term goals*

Following the first plenary discussion, working groups reconvened and continued deliberating on the original three topics. Considerable variation is apparent in the following working group reports that summarize the discussions. Each group addressed the topics and reported on findings in a unique manner and often included valuable recommendations for implementing the broader TNR Study. The editors retained this variation (and therefore value) in the proceedings instead of requesting rapporteurs to conform to a generic structure.

Natural Environment Impacts and Adaptation Working Group Summary

***Soonya Quon** (rapporteur)*
Environmental Adaptation Research Group, Environment Canada

***John Lawrence** (facilitator)*
National Water Research Institute, Environment Canada

INTRODUCTION

The facilitator reviewed the charge to the working groups, and requested that each participant introduce him or herself, area of interest/research, and mention something notable from the previous day's session. Some of the key points were:

- There continues to be a lack of integration in climate change and environmental research after 10 years of talking about it
- There needs to be linkages made between air issues
- Human health is a significant driver in dealing with air issues
- Communication technology allows decisions to be made more quickly than they once were; consequently, deadlines have become more urgent, sooner
- Atmospheric change is a global phenomenon; therefore, air issues in the TNR must consider context (scale of TNR study must be put in context)
- Non-work trips (cars) contribute a great deal to the air problems in the TNR
- There is too much focus on Kyoto; it is simply a milestone in the course of longer term goals for mitigation of and adaptation to climate change

The working group discussed the implications of tying the TNR Study to Kyoto objectives. The potential 'top-down' approach to meeting Kyoto objectives may prevent the degree of public involvement desirable in the TNR Study. Consequently, if the TNR Study becomes too closely tied to meeting Kyoto objectives (e.g., to access funding opportunities) it may be at the expense of public involvement. It was agreed that the Kyoto objectives should be linked with TNR research objectives and needs *after* these are identified.

TOPIC #1: ASSESSING RESEARCH GAPS

- There is a *lack of formal integration of indicators of environmental health.* There is little involvement of atmospheric scientists, and disparate groups work separately to establish indicators. Politicians prefer single indicators, the simpler the better. State of the Lakes Environmental Conference (SOLEC) led to the listing of many environmental health or integrity indicators which are being reduced and combined.

- Atmospheric change scenarios and trajectories of climate change (produced by general circulation models- GCMs- or other models) help anticipate impacts on the natural environment, identify possible adaptations and required research. However, scenarios cannot reduce or relieve the uncertainty of the future changed climate and variability of climate; what is *needed is some consensus on probable regional scenarios produced about the climate of the next 50 years.*

- *Historic (analogue) periods, including periods of extreme climatic anomaly, need to be examined for parallels and trends that can inform the future.* This would involve mining or cataloguing data sets from particular historic periods, and investigating the socio-economic-environmental impacts of climate during those times, as well as how the impacts were dealt with, with a focused purpose (e.g., examining for effects on natural ecosystems). There is a need to examine what data are available, and identify appropriate periods for examination (correlated with or in exceedance of the projections of GCM scenarios). Examination of historic periods can help us select the most appropriate indicators of environmental effects.

Other needs

- Discussion of whether we need better baseline climatology led to a recognition that rather we *need more integration of existing climate data* than collection of more baseline information. Such an integration of data should be in a form and combination useable to researchers, although it was generally agreed that any data integration will have broad usefulness for several research disciplines. We need to identify where links have already been made. *Integration requires overcoming a fear factor*; that is, some professionals fear appearing uninformed when communicating with professionals of other disciplines.

- Need to identify the *current state of the TNR* with regard to land ownership, planning and legislation, economic patterns, and the values and expectations of the stakeholders in the Region.

- Need to *quantify air quality issues and ecosystem effects*. However, it was observed that many such effects are not quantifiable, or have not yet been able to be quantified. An example of a specific research project might be to map the vegetation (types, communities, density) gradient outward from the TNR urban centre as a quantifiable illustration of the effects of urbanization (and related air issues) on biodiversity and natural ecosystems.

- Need to recognize the *sources of influencing factors of atmospheric change*, which requires cross-disciplinary dialogue among scientists

- Need to recognize the TNR as only a part of the climate system; the *TNR Study needs to be couched in a national or global context.*

The ***priority need*** *was decided to be the further investigation (mining) of historical data. Challenges to or clarification of this include:*

- There may be too much information; how do we decide to narrow a focus on any particular area of historical data?
- The availability and quality of historical data sets depends on the local collectors' interest; consequently, biological data sets especially may be spotty. Atmospheric data may be more consistent and more broadly available.
- The historical investigation of a given period needs to integrate the historical socioeconomic, ecological and climatological conditions.

TOPICS #2 AND #3: IDENTIFICATION OF RESEARCH PROJECTS, PROGRAMS AND EXPERTISE / DEVELOPMENT AND SCOPING OF ONE OR TWO INITIATIVES

The identification of our current level of knowledge and directing future research needs especially from historic data sets might be facilitated by a matrix. Such a matrix might compare key air issues or air emissions sources with the components of the natural environment (i.e., aquatic, terrestrial, and human systems).

Examples of the possible historic data set investigation include:

- Land use vs. runoff, extreme events and biodiversity

- Climate and atmospheric change vs. hydrological response, lake levels, water supply and demand, aquatic ecosystem health, shorelines, extreme events (and infrastructure)
- Atmospheric change vs. vegetative response, trends, indicator species and associations
- Socioeconomic trends vs. vegetation, hydrology, aquatic ecosystems and wildlife
- Hydrologic system examined for: socioeconomic response to climate extremes, health of aquatic systems (with indicators such as fisheries, wetlands), water supply during anomalous periods, levels of hospital admissions, water level fluctuation and the effect on shoreline properties, storm events and effects on infrastructure.

CONCLUSIONS

The session managed to identify three broad but key needs required in order to further investigation of the response of the natural environment in the TNR to atmospheric change as a contribution to the research plan of the TNR Study (the relationship between these suggestions is depicted in the figure below):

1. Need to develop probable future scenarios through modelling for the regional scale (TNR), with some degree of consensus and the level of consensus identified, within the next few months.

2. Need to establish means of public consultation. This might take the form of a *public forum* seeking to identify values about the natural environment, and what form or degree of naturalness stakeholders wish to see, within the next quarter of the fiscal year. Public outreach might take the form of the proposed *millenium document* to be released within two years, which could include a) key findings of relations and processes from historical reviews, and b) the presentation of a regional probable future scenario, associated likely impacts to the natural environment, opportunities for adaptation and mitigation and a specification of the kinds of decisions that stakeholders need to make (e.g., decisions about what is valued in the natural environment)

3. Need to give research priority to historical data investigation, the mining of existing data sets for patterns and trends of action/adaptation, and for responses by natural and socioeconomic systems under extreme climate events; findings from these

investigations should be offered in the proposed millenium report to be prepared within two years.

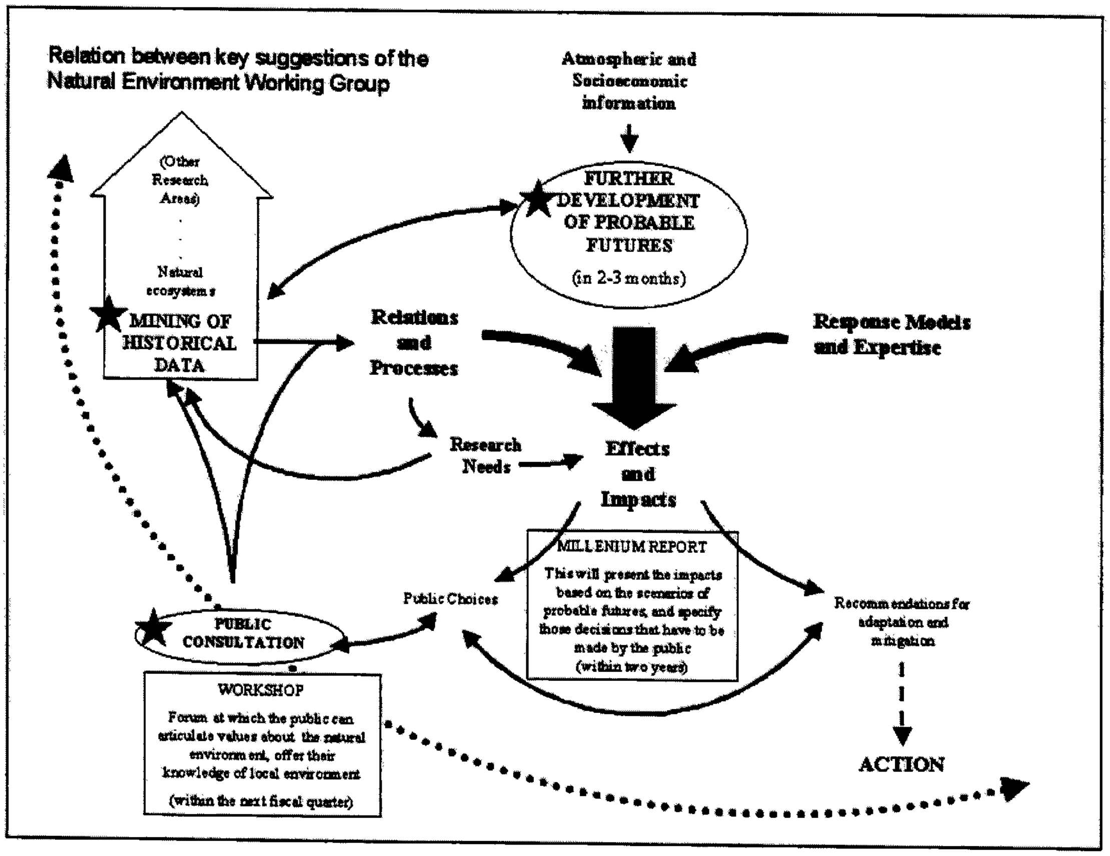


Figure 1. Relation between key suggestions of the Natural Environment Impacts and Adaptation working group

Economic and Infrastructure Impacts and Adaptation

Grace Koshida *(rapporteur)*
Environmental Adaptation Research Group, Environment Canada

Pamela Kertland *(facilitator)*
Atmospheric Environment Service, Environment Canada

ASSESSMENT OF RESEARCH GAPS

The working group members brainstormed to identify and list significant research or knowledge gaps related to economic and infrastructure impacts and adaptation for the Toronto-Niagara Region (TNR). The research or knowledge gaps were grouped into the following categories:

1. Energy and atmospheric change;
2. Costs of atmospheric change on all sectors/activities in the TNR;
3. Vulnerability of "essential" services to atmospheric change and extreme weather events;
4. Water/aquatic resources and atmospheric change; and
5. Infrastructure and atmospheric change

Specific research activities or topics for each category are listed below.

1. Energy and atmospheric change

- changes in energy demand (winter heating and summer cooling) under atmospheric change
- changes in energy supply (energy mix changes (i.e., proportion of fossil fuel, nuclear and alternative sources of energy))
- impact on atmospheric change on energy distribution systems
- develop a "worst case" scenario for the TNR
    - ⇒ with the import of "dirtier" energy sources from outside Ontario, determine the impacts of air quality in the TNR airshed
- assess the costs of environmental externalities of energy production and how these may change with atmospheric change

⇒ identify the most benign (i.e., in terms of emissions, environment impacts) sources of energy for the TNR in the future

- assess how non-atmospheric drivers such as land use planning and transportation systems affect both energy sources and energy types

2. Costs of atmospheric change on all sectors/activities in the TNR

- assess the costs over time of atmospheric change for all sectors/activities in the TNR
- integrate costs, if possible
- does an economic model exist for the TNR study area and what are the required data inputs?
- challenges exist on how to calculate the economic values of some sectors, commodities (e.g., ecosystems, human health)
- assess the different costs between chronic long-term effects of atmospheric change vs. impacts of acute episodes

  ⇒ different sectors/activities in the TNR are more sensitive to long-term effects (e.g., day-to-day exposure to weather elements for construction) while others seem to be more sensitive to acute episodes (e.g., human health to extreme air pollution episodes)

  ⇒ determine the differences in types and levels of costs

  ⇒ determine whether policies can address both the chronic and acute effects

3. Vulnerability of "essential" services/infrastructure to atmospheric change and variability

- determine how vulnerable "essential" services in the TNR, such as water supply and sewage systems, electricity distribution systems and communication systems are to atmospheric change and extreme weather events

4. Water/aquatic resources and atmospheric change

- determine the use, and barriers to, behavioural adaptive strategies such as water conservation in the TNR
- assess how water infrastructure such as water intake pipes can be affected by atmospheric change

- ⇒ impacts on water quality, frequency of lake turnover (water temperature)
- ⇒ subsequent impacts on water use (e.g., deep water cooling)

- assess how water transport systems may be affected
  - ⇒ estimate costs of replacing existing infrastructure to deal with future hydrological conditions
  - ⇒ impacts of more extreme precipitation events (e.g., erosion, damages, changes in IDF (intensity duration frequency) curves)
- assess how inland fisheries, wetlands and other aquatic resources in the TNR may be affected by atmospheric change and variability
- determine how flood regulation may be affected by changes in hydrological conditions in the future

5. Infrastructure and atmospheric change

- assess how atmospheric change can affect the dominant modes of transport in the TNR (e.g., automobile travel, trucking, rail, coastal marine)
- determine how existing National Building Codes might have to be modified in the future under atmospheric change
- identify the barriers to changes in various infrastructure systems and standards
- assess how atmospheric change can affect social infrastructure in the TNR (e.g., recreational beaches, marinas)

SPECIFIC RESEARCH INITIATIVES

The working group members scoped out the following initiatives to address two priority research gaps.

1. Energy

Goal: To develop a long-term strategy for sustainable energy use and management in the TNR

Process: Develop a short list of potential research areas and distribute to key stakeholders (see potential research areas). Meet with interested stakeholders to approach for input, partnerships, obtain seed funding ($5K/stakeholder), prepare report for stakeholders.

Product (after 2 years): Report for stakeholders (state of knowledge on current energy use/mix, potential impacts of atmospheric change; identification of next steps/research needs, scenarios of possible futures, identification of potential mitigation and adaptation options)

Key stakeholders: ICLEI, Federation of Canadian Municipalities, 20% Club members, CEA, Municipal Electrical Association, Ontario Hydro, cities with >100,000 population with a hydro utility, Solar Energy Society, Natural gas suppliers, Better Building Associations, Pollution Probe, Energy Probe, etc.

Potential research areas:

- energy demand changes due to atmospheric change (summer/winter)
- energy demand changes due to non-atmospheric factors (e.g., technology, user demand changes)
- impacts on energy demand management (identify barriers, market/acceptance of conservation initiatives)
- assess costs of infrastructure changes to deal with energy demand and supply changes
- future supply reliability, changes in energy mix (hydroelectric, nuclear, fossil fuels, other renewables, proportion of energy imports and exports)
- changes in air pollution emissions in the TNR with changes in energy mix
- vulnerability of energy transmission and generation to extreme weather events (e.g., storms, wind, icing)
- sector-specific mitigation and adaptation options for transportation (barriers to implementing energy-efficient technologies), space heating and cooling (indoor air quality synergies), industrial and miscellaneous use (district heating and cooling)
- develop an energy vision for the year 2020, backcast exercise for energy futures
- effects of atmospheric change on storage and disposal of waste from energy production (e.g., nuclear, fly-ash)
- analyze opportunities to reduce waste through integration of energy systems and mode changes (on a local basis) and implications for air quality

- determine costing of different energy sources
- assess health risks of different energy mixes (air pollution, fossil fuel use)
- quantify the cost-benefits of household-level energy production (e.g., solar, wind)
- assess environmental externalities of energy use
- energy thru-put analysis on a city basis
- barriers to implementing new energy technologies

2. Water

Goal: To determine sensitivity of water supply systems to atmospheric change.

Potential research areas:

- effects of atmospheric change on water infrastructure
  - ⇒ extreme events such as flooding
  - ⇒ effects of non-atmospheric factors such as population and land use changes
  - ⇒ update project IDF curves
- water supply
  - ⇒ assess resiliency of existing water supply to atmospheric change and population change for the TNR
  - ⇒ effects of surface temperature changes on drinking water quality (taste, odours)
- basin ecosystems
  - ⇒ effects of atmospheric change and urban change on basin ecosystems
  - ⇒ changes in base flows and effects on recreation, wetlands and fisheries in the TNR area
- impacts of future demands for interbasin water transfers and competing water demands in the TNR

Human Health Impacts Working Group Summary

Abdel Maarouf *(rapporteur)*
Environmental Adaptation Research Group, Environment Canada

Karen Smoyer *(facilitator)*
Department of Earth and Atmospheric Sciences
University of Alberta

INTRODUCTION

Eight participants attended the "human health" working group, representing a mix of university and government researchers. The group realized that regional-scale health issues and initiatives to examine impacts of climate change and other air issues have already been identified in previous symposia and publications, e.g. the Great Lakes-St. Lawrence Basin Symposium (May 1997) and the Canada Country Study (1997). The discussion and deliberations were then focused on: a) the requirement for computer models; b) research initiatives in view of fiscal constraints and scope of the TNR study; and c) recommendations to the TNR study Executive Committee for deliverables that can be achieved within 2 years.

REQUIREMENT FOR COMPUTER MODELS

Three types of computer models have been identified as needed for human health impacts and adaptation studies:

1. Short-term regional-scale atmospheric models which use "downscaling" techniques to generate a variety of predictors in addition to simple averages. Variables such as maximum and minimum temperatures, persistence/duration and frequency of weather conditions and pollution concentrations would be most useful.

2. Long-term large-scale GCM to provide scenarios of future climates and associated atmospheric conditions.

3. Integrated assessment models that take into consideration various atmospheric and socio-economic variables at the regional scale. These models would serve as a science-policy interface to provide decision makers with scenarios of regional atmospheric change impacts, as well

as mitigation and adaptation options, e.g. at five-year intervals, from the present time to 2020 and beyond.

RESEARCH INITIATIVES

Two research studies are currently underway and expected to generate useful findings for the TNR study.

1. Historical Analogues

(Principal Investigator: Grace Koshida, Environment Canada)

Daily and seasonal analyses of atmospheric variables (including climate and air pollution) for years known to have been hot/dry and smoggy (e.g. 1988 or 1987-1989) versus years with relatively mild and low-pollution summers (e.g. 1986 or 1984-1986). Morbidity and mortality statistics in the TNR would be examined to assess impacts and adaptation, and provide recommendations for urban planners and policy makers.

2. Toronto-Windsor Corridor Study

(Principal Investigator: Dr. Karen Smoyer, University of Alberta)

This is an air-mass based approach analyzing 17 years (1980-1996) of heat stress events and mortality statistics in the region. The research study will include climate change, demographic change and other socio-economic indicators.

The study may be expanded to include air quality data, downscaling (of climate change impacts), morbidity statistics, urban heat island effect and energy demand/consumption.

RECOMMENDATIONS

Workshop participants believe that within a 2-year time frame a set of deliverables can be achieved for the benefit of the public, stakeholders, research community and policy makers.

1. Plain Language Summary (6 months)

A plain language, "flashy" 2-page summary of what is known about climate change, the atmospheric environment (in general) and human health impacts in Canada and the TNR, based on:

- the Canada Country Study (mostly climate change effects);
- Health Canada & Environment Canada joint research (Burnett, Brook, *et al.*) indicating that poor air quality is detrimental to health and quality of life;
- air quality and other atmospheric change issues (climate change, UV radiation, acid rain, etc.) need to be studied in a holistic fashion to determine their synergistic and cumulative effects on human health.

The summary would also inform stakeholders and other interested parties that a multi-disciplinary group of researchers (list them) are working together to examine the overall atmospheric change impacts with emphasis on the TNR, to inform the public and policy makers of the health impacts and possible mitigation / adaptation options, and to identify knowledge gaps and the next steps of the TNR study. There should be contact information so that interested parties and/or potential funding sources can get in touch with us. This summary could be posted on the TNR web site and updated periodically as new information becomes available.

The group also recommended the follow action steps for the TNR study:

1. Disseminate the findings of all on-going TNR research within a 2-year time frame.
2. Identify a set of mitigation and adaptation actions for the benefit of the public, urban planners, industry, policy makers, etc.

Emissions and Mitigation

Lorraine Craig *(rapporteur)*
Environmental Adaptation Research Group, Environment Canada

Phil Byer *(facilitator)*
University of Toronto

INTRODUCTION

The working group process was guided by the agenda which identified three main topics for discussion: identification of knowledge gaps pertaining to emissions and mitigation in the TNR; identification of research projects to address the knowledge gaps; and development of TNR research studies. In addition to addressing these topics, there was also general discussion about the overall objectives of Toronto-Niagara Region study and ways to promote the study among stakeholders and decision-makers in the Toronto Niagara Region. To assist the group in identifying priority projects, the working group chair sought clarification of the goals and objectives of the Toronto-Niagara Region study in plenary following the morning break. The goals and objectives were discussed in plenary and a handout was provided to all working groups specifying the overall objective of the study and describing a deliverable on the effects/impacts of atmospheric change. This handout was used as the basis for identifying priority emissions and mitigation research projects for the TNR study.

COMMENTS ON THE GOALS OF THE TNR STUDY

The following suggestions, comments and issues were identified concerning the wording of the study objectives and deliverables:

"The development and/or promotion of adaptive and/or mitigative response strategies to reduce vulnerability to atmospheric change in the Toronto-Niagara Region."

- The concept of risk reduction should be built into this statement.

"In 2 years, a report including public participation, on the effects/impacts of probable atmospheric change scenarios over the next 25 years including:

- *Recommended actions to minimize or adapt to critical impact*
- *Questions concerning responses where public discussions are required*
- *Research required to develop better answers*
- *How alternative means of meeting Kyoto obligations can contribute to long term goals*

- The form and the extent of public participation proposed in the TNR study is ambiguous. This needs to be clearly defined. Mechanisms for effective public participation in the TNR study could be tested as a research project.
- The report should also report on uncertainties in the estimates of impacts and the range of possible impacts of atmospheric change.
- Is 25 years the best timeframe for the study?

VISION OF THE TORONTO NIAGARA REGION STUDY

A clear picture or a narrative identifying what the Toronto-Niagara region study is about is needed as a basis for integration and as a means of building interest and support for the project among stakeholders and the public residing within the TNR. There was discussion about ways to do this for example, should Lake Ontario be the focus, should human health be the focus, should the study be about linking science and policy. There was discussion of the geographic boundaries of the study and whether the study should also include those who are impacted by climate change outside of the region for example residents, industry and government of Alberta and northern communities. Some members of the group felt that the study should be built only on the interests of stakeholders and decision-makers within the Toronto-Niagara region. It was stated that the study should focus both on improving air quality while at the same time strengthening the economy in the TNR. Another suggestion was that the study should be packaged from the perspective that individuals, communities and industries in the Toronto Niagara region play a part in contributing to poor air quality and therefore should have a role to play in developing solutions.

The group identified the need to expand support for the study beyond the groups represented at the workshop and expressed concern with the seemingly Environment Canada directed scientific focus for the study. It was noted that the study should not be purely an academic exercise but that it could be part of a consensus-building process that involves stakeholders and decision-makers at all stages. It was suggested that based on lessons learned from the Hamilton Air Quality Initiative, the implementation of recommendations should be considered at the early stages of conceptualization of the Toronto-Niagara region study and the affected groups should be identified and involved at the outset.

WHAT DO WE CURRENTLY KNOW ABOUT EMISSIONS AND MITIGATION?

The group engaged in a brainstorming session to identify what we currently know about emissions and mitigation. The following points of fact were identified:

- Emission measures are based on estimates; some measures are more certain than others
- We have a report on what Toronto has been able to achieve regarding emissions reductions and we have sectoral data.
- Coping with the increase in energy demands associated with population growth is our greatest challenge
- We know something about carbon sinks.
- We know something about technologies to drive down emissions, for example Stelco is aware of all new and emerging technology to control emissions
- Ontario Hydro is a shambles compared to two years ago
- We know about single issue impacts on the TNR

WHAT ARE THE RESEARCH NEEDS?

Following the identification of what is known about emissions and mitigation, the group identified the following key questions that remain to be answered?

- What impact will proposals for electricity restructuring have on emission quantities?
- What is the contribution of truck and diesel emissions to air quality in the TNR?

- How much beyond voluntary is required to meet the Kyoto targets? What incentives are required? What are the relationships between regulatory and non-regulatory regimes?
- What strategies can be used to promote behaviour change towards less reliance on automobiles?
- Need for more research to develop technological innovations to clean up emissions related to transportation and industry.
- Need information to evaluate cost-effectiveness of new emission control initiatives.
- Need accurate data on emissions at the regional level.
- Need to identify what measures of atmospheric change impact are most meaningful to people (# of deaths, litter, etc.)
- Need for information on the regulatory environment to guide decision-making. For example will there be land use planning between now and 2010?
- How can we best cope with growth and change in the Toronto-Niagara region? What is the impact of growth and change on emissions?
- What are the components of a model processing plant, for example for steel manufacturing?
- What are the linkages between land use planning and transport? For example what is the link between technological innovation in vehicle design, design of public transport systems and commuting behaviour?
- Where is the best location for housing, industry?
- What are the levels of emissions by fuel type related to anthropogenic activity in the Toronto Niagara region?
- What have been the successes of emission reduction initiatives?
- What impact will deregulation have on emissions? What impact will it have on industry and municipalities?
- How do economic instruments affect emissions in all sectors?
- What benefits does undeveloped land have on air quality? What role does agriculture play in terms of air quality preservation?
- What share of meeting the Kyoto targets should be the responsibility of the Toronto-Niagara region?

IDENTIFICATION OF RESEARCH PROJECTS

Some members of the group expressed the need for more clarity on the overall study objectives in order to identify priority research initiatives.

The following research projects were identified prior to clarification of the objectives of the TNR study at the midday plenary:

- Review of success stories in emission reduction to identify what works, why and where? This effort would include the use of emission reduction technology, the use of incentives, how to build citizen involvement etc.
- Review of existing data sources to identify the true levels of emissions and air quality in the TNR.
- Review of case studies to determine how deregulation affects emissions.
- Review of fuel consumption data in the region (home fuel, automobile use, etc.).
- Research to develop technology to move water through pipes more efficiently. This would enable district energy systems by moving heat from industry and cold lake water to the city core where large heating and cooling demands exist.

Based on the clarification of TNR objectives provided in the handout developed during the midday plenary, the following projects were identified as priority emissions and mitigation research projects for the TNR study:

1. Review of emission reduction case studies

This project would identify success stories in emission reduction from around the world to identify factors associated with success of these various initiatives. The project would involve a literature review and interviews with individuals involved in the implementation of the initiative. A number of overall theme areas were identified including technological innovation, economic incentives, and public education strategies. Specific case studies were suggested including residential retrofitting, natural gas vehicles in New Zealand, carbon tax in Scandinavia. It was suggested that the project begin with a process to identify critical sectors that present opportunities for mitigation in the TNR as a means for selecting relevant case studies. For example mitigation success stories may be selected in the areas of promoting car pooling or use of public transportation, or initiatives specific to key industries in the TNR such as steel manufacturing, electricity generation. The purpose would be to identify the current state of knowledge regarding effective mitigation for each critical issue, to identify what is possible in terms of levels of emission reduction, to develop mitigation scenarios, and to identify criteria for measuring effectiveness of mitigation strategies.

2. Existing and projected emissions and air quality in the TNR

The goal of the project would be to determine current and projected regional emissions by sector and fuel type. A review of best available data sources of emissions (including process emissions not included in National Pollution Release Inventory and mobile emissions) by sector and fuel type would be undertaken. A review of current modelling approaches using existing emission and monitoring data to characterize regional air quality at present and 25 years from now would be undertaken. Emissions would include all criteria and toxic pollutants. The results would identify priority pollutants, sources of contaminants in the TNR and from outside the TNR, present opportunities for improvement and identify data collection needs to better characterize emissions and air quality in the TNR.

3. Urban vs. Suburban study of individual and industry contributions to emissions

This proposed study would aim to build a community focal point for the TNR study by identifying the extent to which individuals and local industries in a specific geographic area of the Toronto Niagara Region contribute to atmospheric change in the TNR. The study would involve estimating the footprint of emissions for urban and suburban residents with particular lifestyles and would aim to answer the question is the suburban environment cleaner than the urban environment? Point source and non-point sources of emissions would be identified and recommendations would be made for mitigation strategies for individuals, communities and industries in each specific location.

APPENDIX A: Glossary of Commonly Used Abbreviations

Toronto-Niagara Region Study on atmospheric change

Glossary of Commonly Used Abbreviations

AOGCM	Atmosphere-Ocean General Circulation Model
AQVM	Air Quality Valuation Model
CAA	Clean Air Act
CCC GCM II	Canadian Climate Centre Second generation General Circulation Model
CCME	Canadian Council of Ministers of the Environment
CCPA	Canadian Chemical Producers Association
CCRM	Canadian Regional Climate Model
CCSG	Climate Change Study Group
CEC	Commission on Environmental Cooperation
CEPA	Canadian Environmental Protection Act
CFC	Chlorofluorocarbons
CFC	Chlorofluorocarbons
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COA	Canada-Ontario Agreement
CSD	Census Subdivision
DLWC	Deep Lake Water Cooling
DTR	Diurnal Temperature Range
EARG	Environmental Adaptation Research Group
EFM	Emissions Forecasting Model
EMAN	Ecological Monitoring and Assessment Network
EMCO	Ecological Monitoring Coordinating Office
ENSO	El Nino-Southern Oscillation
GCM	General Circulation Model
GHG	Greenhouse gas
GLSLB	Great Lakes-St. Lawrence Basin
GNP	Gross National Product
GWP	Global Warming Potential
H_2O	Water
H_2O_2	Hydrogen peroxide
H_2S	Hydrogen sulphide
H_2SO_4	Sulphuric acid
HAP	Hazardous Air Pollutant
HCFC	Hydrochlorofluorocarbons

HCl	Hydrochloric acid
HFC	Hydrofluorocarbons
HNO_3	Nitric acid
HO_2	Hydroperoxyl
ICLEI	International Council for Local Environmental Initiatives
IEA	Integrated Environmental Assessment
IES	Institute for Environmental Studies
IGCC	Integrated Gasification Combined Cycle
IJC	International Joint Commission
IPCC	Intergovernmental Panel on Climate Change
LANDSAT	Land Remote Sensing Satellite
LPG	Liquid Petroleum Gas
MOA/MOU	Memorandum of Agreement/Understanding
MOE	Ministry of the Environment
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards (in the United States)
NAICC	National Air Issues Coordinating Committee
NAO	North Atlantic Oscillation
NAPCC	National Action Program on Climate Change
NGO	Non-Governmental Organization
NH_3	Ammonia
NH_4	Ammonium
NMHC	Non-methane hydrocarbons
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NO_x	Nitrogen Oxides
NPRI	National Pollutant Release Inventory
O_2	Oxygen
O_3	Ozone
OCAA	Ontario Clean Air Alliance
OCAC	Ontario Climate Advisory Committee
ODS	Ozone depleting substances
OH	Hydroxyl radical
PAH	Polycyclic aromatic hydrocarbons
PAN	Peroxyacetyl nitrate
PCA	Principal Components Analysis
PCB	Polychlorinated biphenyls
PM	Particulate matter

PM_{10}	Inhalable particulate matter
$PM_{2.5}$	Respirable particulate matter
PNA	Pacific/North America
POI	Point-of-Impingement
POPs	Persistent Organic Compound
ppb	Parts per billion
QBO	Quasi-Biennial Oscillation
RDIS	Residual Discharge Information System
SO_2	Sulphur dioxide
SO_4	Sulphate
SO_x	Sulphur oxides
SST	Sea Surface Temperature
TAETG	The Acidifying Emissions Task Group
TAR	Third Assessment Report
TDHC	Toronto District Heating Corporation
TNR	Toronto-Niagara Region
TRCA	Toronto and Region Conservation Authority
TSP	Total Suspended Particulate
TWC	Toronto-Windsor Corridor
ULYSSES	Urban LifestYles, SuStainability and Integrated Environmental ASsessment
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	U.S. Environmental Protection Agency
UV-B	Ultraviolet-B Radiation
VOC	Volatile Organic Compound
WQC	Windsor-Quebec City Corridor

APPENDIX B: University of Toronto 209Y Independent Study Course Student Posters

DESCRIPTION

A University of Toronto undergraduate independent study course (209Y) was offered in the 1997/98 autumn academic term that examined several themes to be adressed in the Toronto-Niagara Region Study on Atmospheric Change. Under the direction of ***Dr. Quentin Chiotti***, the course instructor, each student prepared a poster that summarized his or her research findings for display during the May 1998 workshop. The text and selected graphics from each poster are included in Appendix 2.

Toronto-Niagara Region Study on atmospheric change

Climate Change, Air Quality and Hospital Admissions for Asthma

Nancy Wu
University of Toronto

AIR QUALITY AS A CONTRIBUTOR TO ASTHMA

Elevated amounts of ground-level ozone (smog) present major health concerns. Smog production by a series of photochemical reactions dependent on temperature and sunlight, contribute to elevated amounts of ground-level ozone. These reactions have been anthropogenically accelerated by the burning of fossil fuels (particularly from motor vehicles), a major source of the reactant nitrogen oxides, and volatile organic compounds Smog is a potent irritant to the respiratory system producing coughing and difficult or painful breathing. Continuous exposure may even cause lung damage.

EFFECTS OF CLIMATE CHANGE ON ASTHMA

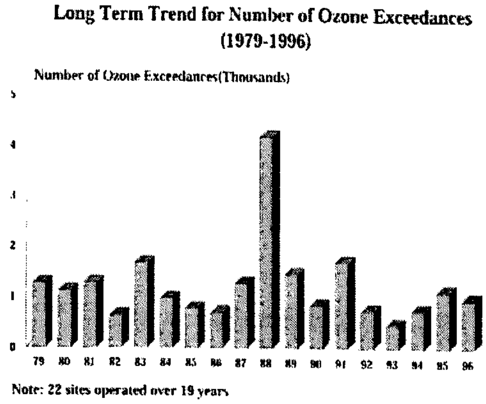
Climate change will cause alterations in atmospheric conditions leading to changes in the frequency of stalled air masses and other weather patterns which will ultimately influence the occurrence of air pollution episodes. Air quality in Ontario is expected to worsen under the influence of climate change.

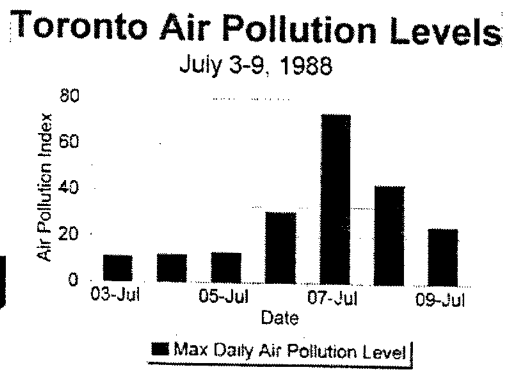
MEASURE OF ASTHMA OCCURANCES

In the literature it was commonly found that researchers use hospital admission rates as a measure of the frequency of asthma occurrences. However the human health working group in a 1996 Environment Canada led Workshop on Climate Variability, Atmospheric Change and Human Health, recommended that non-traditional sources such as pharmacy databases for prescription and over-the-counter sales of medications for asthma be used to as an indictor for the impact of climate change on asthma. Unfortunately, it was discovered that this method was not feasible because the information was not readily available. As well, health experts challenged the usefulness of such data. Thus, it was decided that the hospital admission data needed to be re-examined more closely. From a review of this literature, it was found that:

- There is a positive association between air quality and hospitalization for asthma.
- Ozone is a major contributing factor for asthma occurrences.
- Children and the elderly compose the greatest frequency of hospital visits for asthma.

Summer Of 1998, Air Mass Stagnation And High Temperatures: Of the ozone exceedance levels between 1979-1994, values in 1988 were nearly triple that of other years. Since the summer of 1988 was extremely hot, it was believed that high temperatures was an important condition for high ozone exceedance levels to occur. However, the summer of 1995 was also very hot, yet the ozone exceedances remained relatively low. For the Great Lakes region, 1995 was in fact hotter than 1988, ranked as the fifth hottest summer in the past fifty years (1948-1998), compared to a ranking as the ninth hottest summer.





This suggests that there is no clear relationship between temperature and ozone levels. Upon further investigation, it was suggested by climatologists from the Ontario Ministry of the Environment that the unusually excessive ozone levels for 1988 was due to a high pressure system that Toronto experienced for several days, particularly July 3-10, 1988, creating an accumulation of pollution. Examining newspaper weather forecasts during this period revealed that a major cause of the problem was a high pressure system stalled over southeastern United States, causing warm air to flow over southern Ontario. On July 7th, the temperature rose to 37.5°C and the air quality shot up to 74. An air pollution level above 50 poses health threats to people with respiratory ailments. Thus one can hypothesize that smog episodes are exacerbated by high temperatures with the stagnation of high pressure air masses.

Heat, smog choke Metro

What a sizzler!

The temperature soared to a record 37.6C (99.68F) at Pearson International Airport yesterday, and it reached 36.2C (97.16F) downtown, shattering another record. Today was more of the same, with a high of 37C predicted. Some relief may be felt by Sunday, when temperatures are expected to dip to 30C.

To add to the misery yesterday, the air pollution index soared way past the "acceptable" 32 mark and beyond the health hazard level of 50 to peak at 74 downtown, 84 in Oakville and 86 in Mississauga. The smog cloud, too, is expected to remain in place until Sunday.

(excerpt from The Toronto Star, July 8, 1988)

FUTURE IMPACTS OF AIR QUALITY ON HUMAN HEALTH

Due to changes in demographic structure, the composition of the populations most vulnerable to asthma today may be very different in the future. Therefore it is important to first identify the vulnerable groups at risk today, and then consider changes in demography. Air pollution can sometimes trigger the onset of asthma in people who are genetically predisposed to get the disease, and other high-risk groups such as the elderly and children. Comparing population pyramids for the year 1991 and the projected year of 2021 shows a significant increase in the numbers of vulnerable people most at risk to asthma - children and the elderly - in an absolute and percentage basis.

Population at high risk to asthma in the Greater Toronto Area, 1991 and 2021

	1991	2021
Elderly (age 65+)	392,000 (12.2%)	796,000 (17.1%)
Children (0-14)	647,000 (20.1%)	1,139,000 (24.4%)

CONCLUSIONS AND RECOMMENDATIONS

Should We Worry About Wheezing?: A closer examination of the summer of 1988 unveiled that dangerous ozone exceedance levels were caused by a combination of high temperatures with the stagnation of high pressure air masses. Given that the likelihood of such climate change, we can anticipate that the reoccurrence of dangerous ozone exceedence levels will not only be possible, but highly probable. Furthermore, in consideration of meterological conditions occuring again due to vulnerable groups at risk to asthma, and projected changes in the demographic structure of the Metropolitan Toronto Area, policy makers in the public and private sector, and health care professionals in particular, would be well advised to take notice of these observations.

The Impacts of Atmospheric Change on Biodiversity in the Toronto-Niagara Region

Shona Adamson
University of Toronto

INTRODUCTION

Studies indicate that 7% of Canada's biodiversity is at high risk, and 25% is at some risk of being lost. More specifically of the approximately 12,222 species found in the Mixedwood Plains Ecozone, 4% or over 480 species are said to be at risk as defined by the Committee on the Status of Endangered Wildlife in Canada. Much of the risk facing these species is a direct result of atmospheric changes and stresses.

According to Canadian experts at the Atmospheric Change and Biodiversity workshop held in July 1996, the Carolinian forest (present in the Toronto-Niagara region) was predicted to be the third most threatened biome in Canada from atmospheric stress.

CLIMATE CHANGE

One hypothesis introduced at this workshop was that the biodiversity found in the Carolinian forest was expected to be most sensitive to changes in climate. This claim was substantiated with evidence found in national literature for North America. However, when looking specifically at the Mixedwood Plains Ecozone (which encompasses the Toronto-Niagara Region) there was very little evidence to agree with this educated guess.

National evidence did suggest that the species most at risk in North America due to climate change included:

- Peripheral species that are on the contracting edge of their species range as the leading edge will be pushed northward due a rise in temperature.

  Specific examples of this in North America include:

  - A northward shift of the Northern Boreal forest as a result of a 2°C warming in that area in the last 100 years. This is also a consequence of increased photosynthetic activity from CO_2 fertilization.
  - A 2° northward shift in the range of the Edith's Checkerspot butterfly in South Eastern North America.

- Populations of zooplankton and other drifting animals in the California current have also experienced a northward shift in their species range. This has resulted in a 80% decline in population as a result of a increase in surface water temperature of 1.2 - 1.6 °C. This has also resulted in a decline in various bird and fish populations, higher in the food chain by up to 40%.

- Other species at risk form climate change include geographically localized species who exist in extremely limited habitats. This risk exists in the Mixedwood Plains Ecozone which due to climatic fluctuations in the last five thousand years has resulted in the spatial segregation of many populations of species and forced them to become restricted to special habitats. Human development of this region has further fragmented the distributions of these species to the extent that they are at risk of extirpation in the event of even small climatic changes.
  - Highly specialized species who have a close association with only one other species are also at great risk from climate change, an example of this in the Mixedwood Plains Ecozone is the Kirtland Warbler which will only make its nest in jackpines. This bird is currently on the endangered species list.

ACIDIC DEPOSITION

A second atmospheric stress which the group stated would only be of slight risk to the biodiversity found in the Carolinian forest biome is acidic deposition. Evidence suggests that acidic deposition can cause:

- Damage to trees and forest stands, an example of this is the serious damage that was afflicted on the Carolinian forests in the Eastern United States (which is the same tree types found in the Mixedwood Plains Ecozone). Acid rain which occurred throughout the 1970's and 80's caused serious dieback of the forests and resulted in a increased susceptibility of these stands to continuing atmospheric concentrations of air pollutants.

- A rise in the pH of aquatic ecosystems. This is a particularly serious problem in lakes, where it is responsible for killing plants and other aquatic organisms. Crayfish in the lakes of the Mixedwood Plains Ecozone are presently not at risk but it is stated that an increase in acidification could alter this status.

STRATOSPHERIC OZONE DEPLETION

A third atmospheric stress, stratospheric ozone depletion and increased UV-B radiation was expressed as having no impact on the biodiversity in this region according to experts who attended the workshop. Evidence from the EMAN study of the Mixedwood Plains Ecozone however, suggests that exposure to increased ultraviolet radiation can have various injurious effects upon snails and their habitats.

In general terms stratospheric ozone depletion and increased UV-B radiation has the following adverse effects on biodiversity:

- Increased incidence of skin cancer
- Increased incidence of cataracts, causing blindness.
- Weakened immune response
- Reduction in flowering activity in plants and therefore productivity
- Alteration of the chemical composition of plants.

OTHER ATMOSPHERIC ISSUES

Three other atmospheric issues considered in the Toronto-Niagara Region Study (smog, HAPS, and suspended particulate matter) were predicted by the workshop participants to be of moderate risk and slight risk respectively to biodiversity in the Mixedwood Plains Ecozone. According the group these were expected to contribute half of the risk attributed to this biome. However, no evidence was found at a national or regional level of these stresses having any impact on biodiversity. This demonstrates that more research is needed in order to eliminate the great uncertainty and misunderstanding that exists regarding this issue.

CONCLUSIONS

The inventory of the species found in the Mixedwood Plains Ecozone completed by EMAN is an excellent first step in rectifying the lack of knowledge about the impacts of atmospheric change on biodiversity in the TNR, if not globally. Presently, there is no firm estimate of the number of species which exist worldwide, with estimates falling between 3 and 30 million. More work has to be completed at an international level to find out how many species exist before it can be determine how they are impacted by atmospheric change.

The Mitigation of Air Pollutants (Smog and Greenhouse Gases) by Encouraging Changes in Modes of Transportation Through the Clean Air Commute Campaign

Morvarid Madani
University of Toronto

An interview was conducted during the month of February, 1998, to find out about the University of Toronto's participation in the 1997 Clean Air Commute. 23 U of T faculty & staff members were asked 11 questions:

1. What inspired you to participate in Pollution Probe's Clean Air Commute Week?
2. What environmental or atmospheric issue(s) did your actions help?
3. How were you commuting to work before the Clean Air Commute Week?
4. How did you clean air commute?
5. How convenient was it for you to change your commuting habits for the week?
6. Did you continue your actions after Commute Week was over?
7. How long did you continue to clean air commute after Commute Week was over?
8. Why did your actions stop?
9. Any suggestions on how it could be made easier to clean air commute?
10. Did you find the Clean Air Commute promotional materials useful in educating you about the issue of smog?
11. Will you participate in this year's Commute Week? (if not, why?)

It was found that all of the individuals interviewed were already clean air commuters. However, when asked about what motivated them to participate in the Clean Air Commute Week, 8 responded that it was because they were already clean air commuters, 12 believed that the environment is a critical issue and that they would like to help promote clean air in the city and raise awareness, and 3 participants answered that they participated because *"everybody else was doing it"*.

> ***" I didn't change my routine for the Clean Air Commute Week since I was already a clean air commuter; however, this was true for all participants in my office. Those who have cars and do/usually drive continued to drive and did not participate."***

When the 23 faculty & staff members were asked what environmental or atmospheric issues their actions helped, 11 hoped to reduce air pollution produced by car emissions, 5 would like to reduce smog levels, and all wanted to improve air quality in general. 16 of the participants said that they *"would like to see less cars on the road and reduce the congestion downtown which produces air* *pollution*". 2 people expressed their concerns about the overuse or wasting of our natural resources.

> ***" I am a clean air commuter because I would like to help make the air in Toronto cleaner. I live in an apartment downtown, and every morning, when I wake up and look out the window, I see a brown ring of fumes above the lake. We have to do something about the air quality in Toronto."***

When asked about how they were commuting to work before the Clean Air Commute Week, 14 used public transportation (TTC, Go bus/train), 8 participants cycled to work, and 9 always or sometimes walked to work. One person took his car to a parking lot and then cycled to work, and another one drives to work, but always makes sure that his car is tuned and his tires are inflated correctly.

As expected, when the 23 faculty & staff members were asked about how they clean air commuted during the Clean Air Commute Week, they all stated that they used the same modes of transportation as they usually do. They also responded that they kept their commuting habits all year around, including those who use bicycles!!!

Then, the interviewees gave suggestions on how it could be made easier to clean air commute. 15 out of the 23 U of T faculty & staff members stressed the importance of a better public transportation system to make it easier for people to leave their cars at home. One individual said: "*It is necessary to improve public transportation systems in the suburbs; most people use their cars to go to work because it would take too long to use public transportation*". Another one said: "*I have recently moved to a new place, and it is necessary for me to take the car; otherwise it would take me 3 hours to commute to work*". 5 people suggested car-pooling networks and 9 interviewees said that they would like to see things get better for cyclists, as in more and safer bike paths and more bike parking areas on campus. Other suggestions, such as reducing the number of cars allowed on roads, reducing the number of parking spaces downtown, and higher gas taxes, were also made.

Finally, when asked whether they will participate in this year's Clean Air Commute Week, all 23 stall members answered yes, except for one who would like to, but doesn't see how, considering the fact that she lives far and it would take her 3 hours to commute using public transportation. And one of the interviewees responded: "*Yes, I will participate; but I am already one of the converted.*"

The results of this interview raise an important question: Is the Clean Air Commute Week campaign effective in encouraging non-clean air commuters to change their commuting habits? As it can be observed, all of the U of T respondents who participated in the Clean Air Commute Week were already clean air commuters. Canadians love their cars and they don't have much will in giving them up. It is doubtful that clean air commuting will ever become the norm, unless governments at all levels find the courage to legislate in such a way that driving a car becomes two or three times as expensive as it is now, and the public transportation system gets a whole lot better at the same time. But meanwhile, it is crucial to raise public awareness about the harmful effects of the automobile.

> *" I believe that air pollution is a serious problem, and I find the need to educate people about the issues. It is important to raise public awareness because as long a people don't understand, we can't do much."*

An Examination Of Cycling As An Alternative Transportation Mode To Reduce Air Pollutants (Smog And Greenhouse Gases) In Toronto

Zaheer Abbas Karim
University of Toronto

INTRODUCTION

Bicycles are a non-polluting mode of transport. The use of cleaner modes of commuting, including bicycles, can help reduce emissions which contribute to climate change and smog. As an environmental science student, I am interested in seeing the expansion of bicycle use in Toronto. Two key issues may influence this expansion: (i) the role of atmospheric issues in motivating behavior; and (ii) the identification of incentives which could influence the expansion of bicycle use. Understanding the motivations behind cycling may also provide insights towards the significance of climate change in stimulating other mitigative and adaptive responses.

RESAERCH METHOD

Two target groups were examined: community based transportation organizations (CBTOs) and individual bicycle users. The selection process was through networking and personal contacts. Two separate surveys were administered and although the sample sizes were small, the study still yields useful results. CBTOs were surveyed to determine their level of awareness, priority, and importance of atmospheric issues and bicycle transportation. The mandates for the CBTOs were also examined. Bicycle users were then surveyed for their viewpoint regarding motivating factors, user attitudes, obstacles they face, the role of CBTOs, and their perception for cycling in the future.

SUMMARY OF KEY RESULTS

Community Based Transportation Organizations:

Three organizations were surveyed: CBN (Community Bicycling Network), TAN (Transportation Action Now), and TEA (Toronto Environmental Alliance). These were chosen because they reflect a broad spectrum of CBTOs that deal with transportation issues, including cycling.The topics put to each organization were:

1. Description of the organization's mandate
2. How the mandate has changed
3. Motivating environmental issues
4. Importance of reducing greenhouse gas (GHG) emissions
5. Issues perceived to be the most important to be addressed
6. Incentives that will increase the number of bicycle commuters
7. What the future holds for bicycle transportation

Smog reduction was identified as a motivating factor by all respondents, whereas climate change was not identified by any of the CBTOs. Yet reducing GHG emissions were valued very high by 2 of the 3 respondents:

CBTO	CBN	TAN	TEA
Score (out of 10)	8	6	9

Bicycle lanes were identified as the main barrier to cycling. The CBTOs also mentioned that the approach of society towards bicycle transportation must change if it is to be recognized as a legitimate socially valued form of transportation. The CBTOs are generally optimistic about the future of cycling, however, it very much depends on factors such as fossil fuel pricing and other costs incurred by non-bicycle commuters.

Bicycle Users:

Ten bicycle users were surveyed to complement the examination of CBTOs. The questions put to each user were:

1. Purpose for cycling
2. Major difficulties faced in using a bicycle
3. Motivating environmental issues
4. Importance of reducing GHG emissions with regards to your decision to use bicycles
5. Importance/effectiveness of CBTOs
6. What the future holds for bicycle transportation

Bicycle users in general are either commuters or just casual recreational users, with little overlap between the two. Most of the people who filled this survey commuted to work/school via bicycles. However these commuters also use bicycles for recreational purposes on weekends and holidays. The major difficulties to cycling identified were safety, parking, and accommodation at work. Safety was the biggest issue among users since many automobile drivers are careless and bicycle rights are rarely enforced by police.

Health, budgetary reasons, air quality, and smog reduction were the dominant motivations prompting individuals to cycle. As in the case of CBTOs, climate change or reducing GHG emissions were not identified as motivational factors in their decision to cycle. In fact, reducing GHG were ranked five or less by 6 of the 10 users. Those who do not commute to work put less emphasis on environmental issues and more emphasis on personal fitness and recreation.

Regarding CBTOs, most respondents were not part of a group and were skeptical about them, but the few users who were members found them to be very effective and supportive. The future and growth of bicycle transportation is positive according to some users, while others have a very pessimistic view due to limitations such as distance, facilities, carrying load, and winter weather.

CONCLUSION

The scientific message of climate change does not seem to have reached the CBTOs, just as it has not reached the bicycle users. The fact that the message on smog is being received may be because it is a more tangible concept. The responses of CBTOs to the importance of reducing GHGs suggests that in some ways they are aware of the link and the role that bicycling can play. This message has not reached most users, however, who are driven by other factors. Furthermore, a number of obstacles continue to plague cyclists and limit bicycle use; barriers that must be sufficiently combated in order to facilitate the expansion of bicycle transportation in Toronto, and help reduce emissions which contribute to climate change and smog.

Toronto-Niagara Region Study on atmospheric change

An Examination Of Cycling As An Alternative Examining The Extent Of Heat Related Mortalities For The Toronto-Niagara Region

Vanita Economou
University of Toronto

THE 1995 HEAT WAVE

For the Great Lakes - St. Lawrence Region, the summer of 1995 was the fifth warmest summer on record since 1948. It was also the year of the intense heat wave which left over 500 dead in Chicago. The extreme heat sustained for 4 days in mid July was never experienced by Chicagoans before. Temperatures soared and reached highs above 33C. The region was made to feel like a sauna because of compounding high humidity. Another heat wave was experienced at the end of July causing the city to declare a heat emergency, but the severity of this heat wave was not as pronounced as the one experienced in mid July. The elderly were the most vulnerable segment of the population to heat stress, with **65%** of the victims **over the age of 60**. This deadly heat sequence was not merely a climate driven event, but exacerbated by socioeconomic and geographical factors. Many elderly avoided opening their windows or visiting cooling centres in fear that they would be robbed. The vast number of deaths were in the poorer, inner city neighbourhoods of Chicago and not the wealthier outlying suburbs.

WARMEST 10 SUMMERS
1948-1997
(provided by Env. Canada)

Rank	*Year*
1	1955
2	1949
3	1973
4	1959
**5	1995
6	1991
7	1983
8	1952
9	1988
10	1975

Heat is a serious public health hazard that is deadlier than most people realize. Health officials in big cities ought to look at heat and heat stress as a significant health hazard. The TNR was negatively impacted by a similar heat wave, resulting in crowded hospital emergency rooms, deaths of pets left unattended in overheated automobiles, and extensive losses to the poultry industry. However, Toronto did not experience mortalities at the same level as Chicago.

WHY WAS TORONTO LESS VULNERABLE TO HEAT RELATED MORTALITIES COMPARED TO CHICAGO?

Heat stress and heat related mortalities start to significantly increase when a **temperature threshold of 33C** is attained. In the summer of 1995, Toronto exceeded this threshold for only 5.4% of the days. Toronto did experience sustained high temperatures in mid July but of a lesser magnitude than Chicago. On average, temperatures were 4C warmer in Chicago than Toronto. This difference may not sound very significant, but the body becomes increasingly sensitive to temperature changes when conditions are extreme as in the case of intense heat waves.

COULD THE TNR BE VULNERABLE TO MORE HEAT RELATED MORTALITIES IN A FUTURE UNDER CLIMATE CHANGE?

With climate change, temperatures are expected to increase as will the incidence of heat waves. In the *Impact of Climate on Canadian Mortality: Present Relationships and Future Scenarios,* produced by Kalkstein and Smoyer, heat related mortalities were modeled under various climate change scenarios. It was found that current mortality rates will drastically increase under climate change. The question then follows: **What scenario is most likely to occur in the TNR?**

Under General Circulation Models (GCM's) for the Great Lakes - St. Lawrence Region a summer temperature increase of 4C is likely to occur. This is comparable to Chicago temperatures which were 4C warmer than Toronto during the 1995 heat wave. Under Kalkstein's and Smoyer's models, a 4C rise in temperature translates into **100 deaths per 100 000** attributable to weather. The present day estimate is **7 deaths per 100 000** attributable to weather.

WHAT ABOUT A DEMOGRAPHIC SHIFT?

Kalkstein and Smoyer did not take into account a demographic shift when developing their mortality forecasts. The following demographic statistics are worth noting:

- In 1991 the elderly (over 65) comprised 12% of the total TNR population
- In 2021 the elderly are predicted to comprise 17% of the total TNR population
- The total number of elderly will double in 2021

This demographic shift will impact the extent of heat related mortalities in the TNR. A greater elderly population will therefore increase the number of deaths attributable to heat.

CONCLUSION

With climatic change and global warming, the summers for the TNR will become increasingly warm and will foster increasing incidences of heat waves. The TNR's location is such that infrequent but extreme heat waves are possible. The vulnerable elderly population of the TNR is also increasing, yielding greater projected mortalities. It was established that Toronto's weather conditions differed from those of Chicago during the 1995 heat wave which lessened vulnerability to heat related mortalities. Toronto and Chicago possess very different socioeconomic and geographical conditions which also explains the difference in vulnerability between the two cities.

Returning to the initial question, "Could the TNR be vulnerable to more heat related mortalities in a future under climatic change?", the answer would be yes but a qualified yes. The models forecast dramatic increases in mortality and the TNR's increasing elderly population will also foster greater mortality. However the TNR's socioeconomic and geographical setting is such that the vast mortality experienced in Chicago during the 1995 heat wave will likely not be experienced in the TNR.

The Risk of Malaria Occuring in the Toronto-Niagara Region Due to Greenhouse Gas Induced Climate Change

Leily Razavi
University of Toronto

CLIMATE CHANGE AND MALARIA

Global warming could have profound effects on the health of the world population and it is expected to claim more of its victims through an indirect influence, such as vector-borne diseases like malaria. With a doubling of carbon dioxide (CO_2), the proportion of the world's population exposed to malaria could increase from 45% to 60%. This could result in a global increase of 50 to 80 million cases per year to the 500 million cases that currently occur. Climate change scenarios have shown that malaria could expand into southern Ontario on a seasonal basis.

Warmth and access to water are the necessary conditions for the malarial mosquito survival and the plasmodium's ability to live in the body of mosquito; therefore main daily temperature associated with a $2XCO_2$ may allow for the future development of malaria in Toronto, specifically, the development of both P.vivax (14.5°C, temperature required for development of parasite inside mosquito) and P. falciparum (16-19°C) in the mosquito and transmission of both vivax and falciparum malaria.

THE GEOGRAPHY OF MALARIA

Although formerly found throughout much of the world, with seasonal outbreaks extending into the temperate zones, malaria is now generally restricted to tropical and subtropical regions. Sub-Saharan tropical Africa is the major focus of malaria in the world with high morbidity and mortality in preschool children. The following map demonstrates all countries reporting transmission of malaria to the World Health Organization in 1983.

HISTORICAL INFORMATION

Malaria has been one of the plagues of humanity since the beginning of human life, and its influence on historical and cultural development cannot be exaggerated. Its earliest history is hidden in obscurity but it has certainly existed in warmer part of Africa and Asia since time immemorial. It was assumed that the disease was caused by vapors and mists arising from swamps and marshes. These theories persisted for more than 2000 years until the discovery of malarial parasite in red blood cells in 1880 by Laveran. Indeed, the names for this disease malaria (mal, bad; aria, air) and paludism (palus, marsh) reflect these beliefs.

Although malaria is not, and has not been for many years, indigenous in Canada; the following passage from Geographical and Historical Pathology (pgs:226-227) has been cited as evidence of the existence of malaria in Canada in the 19th century: *"For Canada, as well as for the whole inland basin of the continent, Kingston is the northern limit of endemic malaria."*

RECENT EVIDENCE

For evidence that there could be a shift in the distribution of malaria, one need look no further than New York City or even Toronto. In August 1993, 3 cases of P. falciparum malaria in people without recent travel histories or blood-borne exposure were reported in New York City. Malaria was probably transmitted to these patients by local anopheline mosquitoes that had fed on infected human hosts. Furthermore, in the summer of 1997, a Toronto woman contracted the disease without ever having left the country.

Woman contracts malaria in Toronto
Transmission by local mosquito a rare occurrence
BY LESLIE PAPP
MEDICAL REPORTER

> *A Metro woman has contracted malaria from a local mosquito in what doctors say is the first such infection found in Canada in modern time. "Mosquitoes in southern Ontario can transmit malaria -- all they need is some opportunity," Dr. Kevin Kain, director of the Toronto Hospital's tropical disease unit, said in an interview yesterday.*
> *(excerpt from The Toronto Star, November 28, 1997)*

Local health authorities believe that she may have been infected locally. Malaria is not unheard-of in Canada, with 744 cases having been reported last year, but contracting malaria without ever having left the country has never been reported in Canada before. This fact and the fact that Canada has one of the biggest biting insect rates per capita in the world, demonstrates that it is possible for a mosquito to bite an infected neighbor, then pass it onto an unsuspecting individual.

CONCLUSION

It is important to address climate's role because the control of an infectious disease requires an understanding of the causative agent, the vector, the host and the environment in which transmission occurs. However it should be appreciated that the risk from malaria is not merely a function of environmental and ecological factors. These only establish whether transmission would be possible and hence whether there is a health hazard.

The risk of disease depends on additional factors: the vulnerability of the human community and the capacity and capability of health-protection agencies. Since Canada has the infrastructure to combat malaria, both by eliminating mosquito breeding sites and by treating cases, it is unlikely that the disease will become a major health threat in Canada. Nevertheless, local malaria transmission in such unlikely settings as Toronto or New York City illustrates the need for continued timely surveillance for infectious diseases that are currently not considered to be a threat to public health.

An assessment of the effects of El Nino upon snowboarding activities at Mt. St. Louis Moonstone

Gus Kokkoros
University of Toronto

HISTORICAL CONTEXT: CLIMATE IMPACTS AND ADAPTATION

The ski industry in southern Ontario has been known to be extremely vulnerable to past climate, especially in terms of warm winter temperatures and reduced, if not unpredictable, snow precipitation and cover. Poor skiing conditions can be particularly costly for ski resort operators during peak periods, such as the festive holiday break in December and University/school breaks in February and March. For example, mild conditions during the 1979 festive holiday reduced skier activity by 40% and some individual resort operators lost up to $2.5 million. After unusually poor conditions in the late 1970s and early 1980s, however, many ski resort operators invested in expensive state-of-the-art snow-making equipment, and introduced other adaptive measures such as the heightening of runs (up to 200 metres increase in elevation at Mt. St. Louis Moonstone between 1996-1998) and the addition of chair lifts. Some resorts such as Horseshoe Valley and Blue Mountain even expanded their businesses into summer months offering activites such as mountain bike trails and golf courses.

EL NINO AND THE WINTER OF 1997-1998

Back in the fall of 1997, climatologists and meteorologists were predicting that the winter of 1997-1998 would be influenced by one of the strongest El Nino's since 1982. Not surprisingly, the Great Lakes - St. Lawrence Basin region experienced record setting temperatures, resulting in the warmest winter in the past 50 years, with mean temperatures reaching 3.65 C° above the average. Spring-like conditions existed through parts of the winter, as well as decreased snow precipitation and a shorter length of season.

RESEARCH METHOD

Given the recent history of the ski industry and the anticipated weather conditions in southern Ontario, an opportunity presented itself to observe how the current ski industry would be impacted by, and how they would adapt to, warm winter conditions. These observations could be used to develop a model that would be useful to research scientists in projecting future impacts on this industry due to climate change. Instead of measuring the effects as a direct monetary value, it was thought that an index of enjoyability would be a better reflection of impacts. This index, or model, should reflect the wide range of conditions that could influence the level of enjoyment experienced by the snowboarder. The higher the enjoyment, the more likelihood of the snowboarder returning to the resort. The model and assessment of impacts are based on my participatory observations during the 1997-1998 winter season, as a snowboard instructor at Mt. St. Louis Moonstone.

Observations were logged each day that I was in attendance, and included weather conditions, snow conditions on runs, and the general skill levels of patrons for the day. The model presented represents the accumulation of observations over the past snowboarding season.

The model:

I. Weather
- Bone freezing
- Wet weather
- Chilly conditions
- T-shirt weather

II. Base conditions
- Ice
- Groomed granular
- Sugar
- Packed powder
- Groomed powder
- Powder

III. Skill level
- Beginner
- Intermediate
- Advanced

Based upon the model, the conditions of the past season can be described as follows:

- Weather conditions: In general this season didn't gnash it's teeth as a usual Canadian winter. Days of the coldest type (bone freezing) were very infrequent. Over the course of a typical week, cold conditions and snowfall tended to come in spurts. What was left was a combination of more chilly and wet days.

- Snow base: Snowmaking made a significiant contribution to the snow base. Fortuitously, night-time temperatures usually dropped below -4C, a temperature at which point snowmaking could take place without adding costly chemicals. As a result, for much of the season the most common snow cover was groomed granular.

- Skill level: The more advanced the rider, the greater the tollerance level for a broader range of weather and snow base conditions, in order to realize an enjoyable outing.

POSTSEASON ASSESMENT

Despite the warm weather conditions throughout much of the winter, the economic impact upon the ski industry was not severe.

Resorts weather El Nino
BY FRANCES KATZ
SPECIAL TO THE STAR

Despite El Nino, ski resort operators aren't complaining about this year's business. "It's not been a doom-and-gloom story for alpine resorts," said Jack Lynch, co-ordinator of the ski reporting program for Ontario Tourism in Barrie.

"[The season] hasn't been a disaster by any means," said director of operations for Mount St. Louis Moonstone, Andre Huter. With investment in increased snowmaking capacity

this season, the resort was among the first to open at the end of November. "We got in enough snowmaking before Christmas to squeak through the holidays.

(excerpt from The Toronto Star, March 18, 1998)

Contrary to the expectation of low attendance, the season was on par with last season's attendance, and may have been even higher. In summing up these unexpected results, Andre Huter of Mt. St. Louis Moonstone stated: "Its never luck, simply the hard work and years of reinvesting to keep the next year promising." While the industry was able to do relatively well this past season, despite the warm conditions, a repeat of this success may not be certain under future climate variability and change. As Professor Wall from the University of Waterloo states: "Many ski areas can withstand a bad week, month or even a season and may expect this under current operating conditions. However, the juxtaposition of several poor seasons may be critical." In order to remain viable in the future, snowboarders and ski resort operators may be well advised to consider these observations.

Health Impacts From Stratospheric Ozone Depletion

Karen Sequeira
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WHAT IS THE PROBLEM?

The atmospheric issue of stratospheric ozone depletion caused by anthropogenic emissions will result in an increase in UV-B radiation which will effect human health by increasing the prevalence of skin cancers and cataracts. These health impacts will be noted on a population and community scale as opposed to an individual one, and since the Toronto-Niagara Region is so densely populated, the number of people that could be affected may be staggering. By taking adaptive measures, both behavioural and through legislation, it is possible to ameliorate the effects and make the atmospheric stress less.

THE OFFENDERS: WHAT DO THEY DO?

The Stratospheric layer is a band which extends from 15-50km above the Earth's surface. It contains the molecule Ozone (0_3) which is very important because it acts as a shield, preventing ultraviolet radiation from reaching the Earth. Ultraviolet radiation is divided into three bands: UV-A (320-400 nm), UV-B (290-320 nm) and UV-C (100-290 nm). Most of the ultraviolet radiation below 200 nm is absorbed by oxygen to form ozone, which in turn absorbs all ultraviolet radiation below 290 nm.

In the mid-1970's it was noted that the stratospheric ozone concentrations were falling in the region over Antarctica. The formation of this ozone hole at the South Pole was attributed to the presence of synthetic organic halide compounds entering the stratosphere. These compounds are chlorofluorocarbons (CFC's) which have been used in refrigerators, automobile air-conditioners, and aerosol propellants and other halons from pesticides and dry cleaning. They are stable in the troposphere, but in the stratosphere they are cleaved by UV radiation, forming radicals that react with ozone to convert it into molecular oxygen.

More recently, it was noted that the Arctic region also showed some ozone loss. In the polar regions, the ozone levels reach a minimum in the early spring when increased sunlight provides the energy needed to cleave halides in the lower stratosphere. About two months later, the hole disappears due to the influx of ozone from the equatorial regions. The geographical extent of the depletion of ozone includes Southern Ontario where the cumulative decrease is 5% since 1980.

In 1987 the Montreal Protocol set the stage for the phase-out of compounds which played a role in stratospheric ozone depletion. Projections then suggested that the maximum ozone loss would be around 1997-2000, however recent projections suggest that there will be a delayed turnaround.

HEALTH IMPACTS

Over the past two decades, there has been an increase in the cases of non-melanoma and melanoma skin cancers, probably a reflection of the increased sun exposure, especially during the months of low ozone concentrations. The probability of incidence of non-melanoma skin cancer is related to the cumulative lifetime exposure to solar radiation-especially the UV-B band, while for melanoma skin cancer it is correlated with the amount of exposure as a child. It can be noted that the majority of an individual's lifetime sun exposure occurs before the age of twenty.

The vulnerable persons at risk for developing skin cancer show the following physical and occupational characteristics: blue eyes, red/blond hair, pale-skin, they develop many freckles, have an outdoor occupation, have an indoor occupation and in their leisure time expose themselves to high levels of solar radiation, or have had a high level of solar exposure as a child.

Cataracts are an opacity of the eye resulting from long-term or chronic exposures to high levels of sunlight. Through the action of squinting, the eyebrows and eyelids significantly reduce the amount of solar radiation reaching the eye. With an increase in the amount of UV-A and UV-B penetrating the earth, the crystalline lens will absorb the radiation, and it will start thickening. This results in visual opacities varying from slight to complete opaqueness.

Cataracts are expected to show an increase in children, whose lenses are more transparent than adults, allowing about 4% of solar radiation from 300-340 nm to enter. Persons particularly at risk include those who have outdoor occupations, and those who spend their leisure time exposed to high levels of sunlight.

ACTIONS THAT CAN BE TAKEN

The ultimate effects of depleting stratospheric ozone will depend upon the rate at which society will respond. In the short term, the effects may be ameliorated through behavioural changes such as remaining indoors during the peak hours of sunlight irradiance from lla.m. to 2p.m., when one is most likely to become suntanned or burned.

If it is necessary to go outdoors, it is pertinent to wear protective clothing, a wide-brimmed hat and sunglasses that will protect the eyes and face from sunlight exposure, and a sunscreen with a protection factor of 15 or greater.

APPENDIX C: Workshop Program

ATMOSPHERIC CHANGE IN THE TORONTO-NIAGARA REGION:
TOWARDS AN INTEGRATED UNDERSTANDING OF SCIENCE, IMPACTS AND RESPONSES
May 27-28, 1998

PROGRAM

WEDNESDAY, MAY 27, 1998 (Placer Dome Classroom - Room B142)

8:30	Welcoming remarks **Rodney White,** *University of Toronto*
8:35	Opening remarks **Brian Mills,** *Environment Canada*
8:45	**The TNR Study: Setting and Research Framework** **Quentin Chiotti,** *Environment Canada*
9:15	**The Science and Policy of the Interaction of Air Issues** *Presenters:* **Jim Young and Dan Hrebenyk,** *SENES Consultants* *Panel Discussion* ***David Yap,*** *Ontario Ministry of the Environment* ***Don McKay,*** *Environment Canada*
10:15	*HEALTH BREAK*
10:30	**Adapting to the impacts of atmospheric change on the natural environment in the TNR** *Presenter:* **Tom Hutchinson,** *Trent University* *Panel Discussion* ***Deborah Ramsay,*** *Niagara Escarpment Commission* ***Adam Fenech,*** *Environment Canada*
11:20	**Adapting to the impacts of atmospheric change on the economy and infrastructure of the TNR** *Presenter:* **Heather Auld,** *Environment Canada* *Panel Discussion* ***Donald Haley,*** *Toronto and Region Conservation Authority* ***Kevin Loughborough,*** *City of Toronto Public Works*
12:15	*LUNCH (provided outside of plenary room)*
1:30	**Impacts of atmospheric change on human health in the TNR** *Presenters:* **Jeff Brook,** *Environment Canada* **Karen Smoyer,** *University of Alberta* *Panel Discussion* ***Franca Ursitti,*** *City of Toronto* ***Kirsty Duncan,*** *University of Windsor*
2:35	**Responding to atmospheric change: mitigative actions** *Presenter:* **Ken Ogilvie,** *Pollution Probe* *Panel Discussion* ***Richard Gilbert,*** *Centre for Sustainable Transportation* ***Jay Barclay,*** *Environment Canada*
3:15	*HEALTH BREAK*

3:30	**Meeting the Kyoto Challenge: The Role of the TNR Study** *Presenter*: **Peter Timmerman**, *University of Toronto* *Panel Discussion* ***Lois Corbett***, *City of Toronto Atmospheric Fund* ***Joe Berta***, *Toronto Hydro*
4:20	**Day 1 Wrap-Up** **Ian Burton**, *Environment Canada*
4:30	***Reception and Poster Display***
6:00	***DINNER/SOCIAL (Debates Room, Hart House)*** **The Hamilton-Wentworth Air Quality Initiative** Speakers: **Eric Loi**, *Ontario Ministry of the Environment* **Rosemary Foulds**, *Regional Municipality of Hamilton-Wentworth*

THURSDAY, MAY 28, 1998 (Placer Dome Classroom - Room B142)

8:30	**Charge to Working Groups** **Brian Mills**, *Environment Canada* ***Working GroupTasks***: Identification of research priorities, objectives and workplans for the Toronto-Niagara Region Study
8:45	**Working Groups (Breakout rooms)** *Atmospheric Science and Modelling* *Natural Environment Impacts and Adaptation* *Economic and Infrastructure Impacts and Adaptation* *Human Health Impacts* *Emissions and Mitigation*
10:15	*HEALTH BREAK*
10:30	**Working Groups continued**
12:30	*LUNCH (provided outside of plenary room)*
2:30	**Rapporteur Reports (Placer Dome Classroom - Room B142)** Chair: **Quentin Chiotti**, *Environment Canada*
3:30	**Open Discussion: Next Steps**
4:15	**Workshop Wrap-up** **Terry Allsopp**, *Environment Canada*

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