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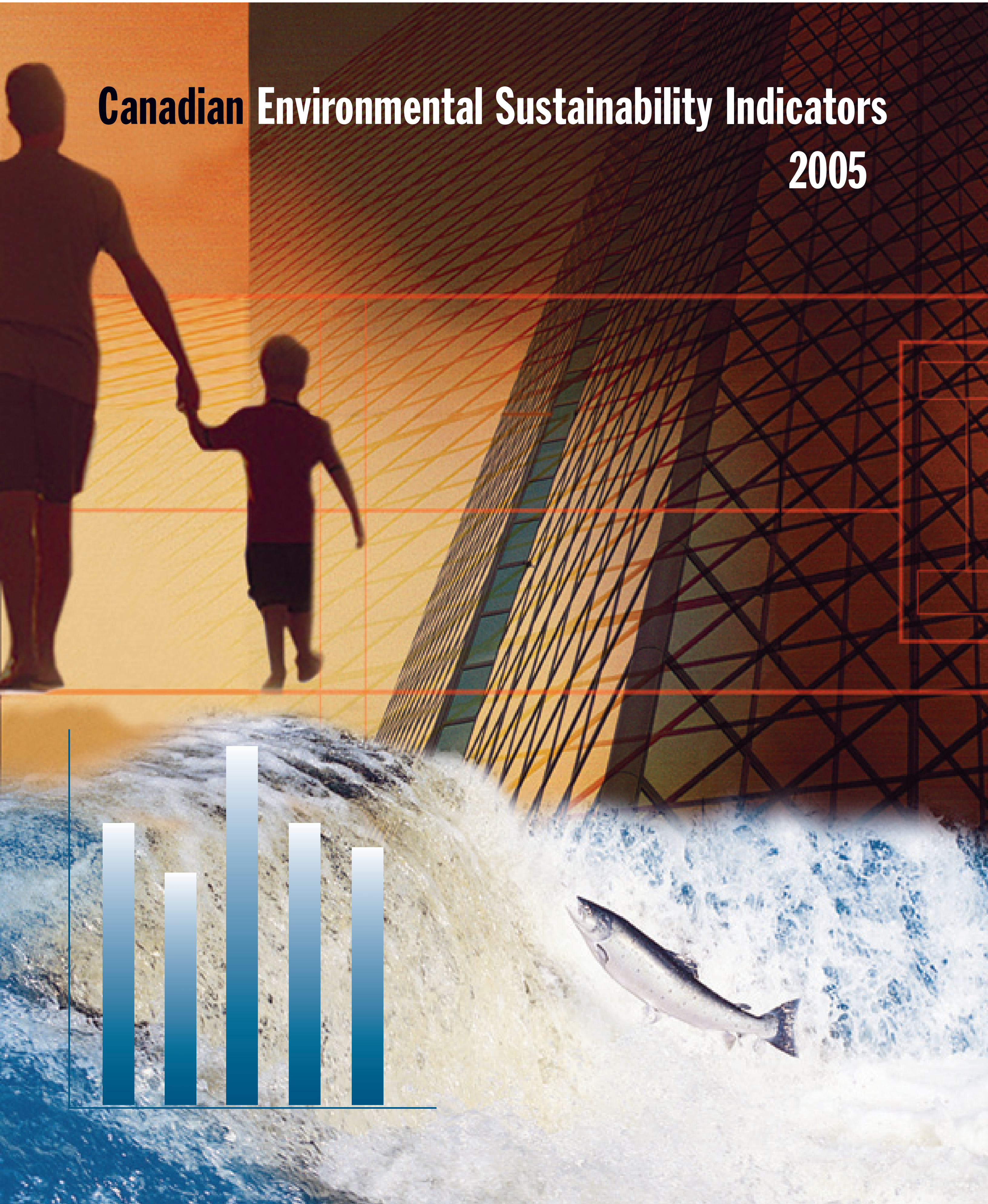
Canadian Environmental Sustainability Indicators 2005



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Canada

Canadian Environmental Sustainability Indicators 2005

Environment Canada
Statistics Canada
Health Canada

Executive summary

Canadians' health and their social and economic well-being are fundamentally linked to the quality of their environment. Recognizing this, in 2004 the Government of Canada committed to establishing national indicators of freshwater quality, air quality and greenhouse gas emissions. The goal of these new indicators is to provide Canadians with more regular and reliable information on the state of their environment and how it is linked with human activities. Environment Canada, Statistics Canada and Health Canada are working together to develop and communicate these indicators. Reflecting the joint responsibility for environmental management in Canada, this effort has benefited from the co-operation and input of the provinces and territories.

Air quality: The air quality indicator presented in this report focuses on human exposure to ground-level ozone, a key component of smog. Ground-level ozone significantly harms human health and the quality of the natural environment. Using observations from 79 primarily urban monitoring stations across Canada, this indicator presents a seasonal average concentration, adjusted for the number of people living near the monitoring stations. The national concentration of ground-level ozone increased 16% from 1990 to 2003. Stations in Southern Ontario had the highest average concentrations in 2003 and the most rapid rise from 1990.

The pollutants that lead to ground-level ozone (nitrogen oxides and volatile organic compounds) are emitted primarily during fossil fuel combustion mainly in and around urban areas, especially by motor vehicles and thermal-electric power plants. Weather conditions—especially hot, stagnant air—and the movement of pollutants from other urban regions in Canada and the United States can boost the observed concentrations.

This indicator will be complemented by a measure of fine particulate matter in future reports. Health Canada will evaluate how measurements of the different air pollutants can be combined to produce an integrated air health indicator.

Greenhouse gas emissions: The greenhouse gas indicator presented in this report focuses on total emissions of greenhouse gases countrywide. Emissions rose 24% from 1990 to 2003, and in 2003 were 32% above the target set by the Kyoto Protocol for 2008 to 2012. Thermal-electric power generation, motor vehicle use and fossil fuel production were the principal sources of the emissions increase. In contrast, while total emissions rose, emissions per unit of gross domestic product fell 13% from 1990 to 2003. The expansion of the Canadian economy, however, more than offset gains in emissions efficiency, resulting in a net increase in total emissions. Greenhouse gas emissions also grew faster than the Canadian population over the same period, resulting in a rise in emissions per person.

Freshwater quality: Good quality water is fundamental to ecosystems, human health and economic performance. The preliminary water quality indicator presented in this report focuses only on the ability of Canada's surface waters to support aquatic life over the period 2001 to 2003. For the 345 sites selected across the country, water quality was rated as "good" or "excellent" at 44% of the sites, "fair" at 31% and "marginal" or "poor" at 25%. Water quality in Canada is under pressure from a range of sources, including agriculture, industrial activity and human settlements.

This is the first time that an index to measure water quality has been applied systematically across Canada. As a result, there is no trend information yet. These preliminary results do not represent the quality of all freshwater in Canada. They apply only to the selected monitoring sites, located mainly in southern Canada, that met data quality standards. Improvements are planned to the monitoring network, the water quality guidelines and the analysis that will enable a better assessment of surface water quality in the future.

These three indicators raise concerns—about Canada's environmental sustainability, our health and well-being, and our economic performance. The trends for air quality and greenhouse gas emissions are pointing to greater threats to human health and the planet's climate. The water quality results show that guidelines are being exceeded, at least occasionally, at most of the selected monitoring sites.

These indicators are connected in fundamental ways:

- Some of the same substances are involved.
- Some of the same economic forces drive the changes in the indicators.
- The indicators reflect stresses in the same regions of the country.

One of the biggest challenges will be the transition from reporting these indicator results separately to reporting them as a set that is integrated with other information on the environment, measures of economic performance and indices of social progress. The long-term goal is better decision-making that fully accounts for environmental sustainability.

This is the first of an annual set of reports on the Canadian Environmental Sustainability Indicators. Over time, the indicators will be further developed, with increasingly robust analyses to track the changes in water quality, air quality and greenhouse gas emissions. Improvements will be made to make these indicators clearer, more relevant and more useful to decision-makers and the public. The indicators will benefit from better monitoring capabilities, new scientific knowledge and guidelines, as well as improved data management and analytical methods. Future reports will be supported with an online information system that will enable users to examine regional and sectoral details and conduct their own analyses.

The Statistics Canada website (www.statcan.ca) provides electronic versions of this report and access to additional information related to the indicators.

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1 Introduction

The health of Canadians and the country's social and economic progress, both now and in the future, are fundamentally linked to the quality of the environment. Recognizing this, the Government of Canada announced in the October 2004 Speech from the Throne its commitment to working with its provincial and territorial partners to build sustainable development [1] systematically into its decision-making. To accomplish this, more reliable and more accessible information is needed to guide the actions of Canadians and their governments.

As part of this, Canadians need clearly defined environmental indicators—measuring sticks that can track the results that have been achieved through the efforts of governments, industries and individuals to protect and improve the environment. Following expert advice, three environmental indicators were selected by which the federal government and its partners can track progress and be held accountable in striving for cleaner water, cleaner air and lower greenhouse gas emissions.

The indicators in this first annual report are as follows:

The **air quality indicator** tracks Canadians' exposure to ground-level ozone—a key component of smog and one of the most common and harmful air pollutants to which people are exposed. The use of the seasonal average of ozone concentrations reflects the potential for long-term health effects.

The **greenhouse gas emissions indicator** tracks the annual releases of the six greenhouse gases that are the major contributors to climate change. The indicator comes directly from the greenhouse gas inventory report prepared by Environment Canada for the United Nations Framework Convention on Climate Change and the Kyoto Protocol. The data are widely used to report on progress toward Canada's Kyoto target for reduced emissions.

The **freshwater quality indicator** reports the status of surface water quality at selected monitoring sites across the country. For this first report, the focus of the indicator is on the protection of aquatic life, such as plants, invertebrates and fish. This new indicator uses the Water Quality Index, endorsed by the Canadian Council of Ministers of the Environment, to summarize the extent to which water quality guidelines are exceeded in Canadian rivers and lakes.

These Canadian Environmental Sustainability Indicators supplement traditional health and economic measures, such as gross domestic product, so that Canadians can better understand the relationships that exist among the economy, the environment, and human health and well-being. They are intended to help those in government who are responsible for developing policy and measuring performance, as well as offering all Canadians more information about the trends in their environment. This report is not intended as a summary or evaluation of policies and management activities to address the issues measured by the indicators.

1. Sustainable development is defined in federal legislation as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

These indicators respond to the May 2003 recommendations of the National Round Table on the Environment and the Economy that the federal government establish a small set of easily understood environmental and sustainable development indicators to track factors of importance to Canadians (NRTEE 2003). Environment Canada, Statistics Canada and Health Canada are collaborating, on behalf of the Government of Canada, to develop and communicate these indicators.

The indicators are in different stages of development. This is the first time a national water quality indicator has been assembled from the different federal, provincial and joint monitoring programs across the country. The air quality indicator draws on a well-established national network of monitoring sites, but differs from existing indicators by weighting the results to reflect human population exposure. The greenhouse gas indicator is the most developed: it comes directly from the inventory developed by Environment Canada in response to international climate change requirements. For the first time, these core environmental indicators have been brought together in a single report.

This report and these indicator results are only a first step. Over the coming years, improvements will be made to their accuracy, relevance and usefulness to decision-makers and the public. Sources of these improvements include further scientific research on the linkages between air quality and human health, new surveys of businesses and households and their actions regarding the environment, and more integrated and representative national monitoring networks. The indicators are also a starting point for a publicly accessible information system where the underlying environmental data can be used and linked to social and economic information—with the goal of supporting decisions that better take these linkages into account.

For each indicator, this report presents the latest status and, where possible, the trends over time, an interpretation of what the indicator trends mean, and plans for future improvements. The report concludes with a discussion of how the indicators are linked.

This report does not stand alone. The Statistics Canada website (www.statcan.ca) provides electronic versions of this report and access to additional information related to the indicators.

2 Air quality

- Ground-level ozone, a key component of smog, has been linked to health issues ranging from minor respiratory problems to hospitalizations.
- The national seasonal average concentration of ozone increased 16% from 1990 to 2003. Most monitoring stations are located in urban areas in southern Canada.
- The highest seasonal average ozone concentrations in 2003 were all recorded at stations in Southern Ontario; concentrations in this region had also grown the fastest since 1990.

2.1 Context

Ground-level ozone, a key component of smog, has significant negative effects on human health, on the natural environment and, consequently, on economic performance. Other important air pollutants include fine particles, sulphur oxides and carbon monoxide.

Ozone is not emitted directly as a pollutant. It is a colourless gas formed by chemical reactions involving nitrogen oxides (NO_X) and volatile organic compounds (VOCs) in the presence of sunlight (Warneck 1988). Ozone concentrations may vary from location to location and from hour to hour, depending on sunlight intensity, weather conditions and the movement of air over various distances.

Ozone occurs naturally in the air we breathe and is found throughout the atmosphere (see Box 1). Human activities boost the formation of ground-level ozone, however, by increasing the concentrations of NO_X and VOCs. These ozone precursors may be emitted locally or transported by the movement of air from other regions or countries.

Most NO_X come from human activities such as burning gasoline in motor vehicles and burning fossil fuels in homes, industries and power plants (Environment Canada n.d.a). Canadians contribute to VOCs in the air primarily by producing oil and gas, by driving off-road vehicles as well as light-duty motor vehicles and trucks, and by burning wood in stoves, furnaces and fireplaces in their homes. Evaporation of gasoline and other liquid fuels and solvents also adds VOCs to the air (Environment Canada n.d.a).

BOX 1

Stratospheric versus ground-level ozone

While ozone in the stratosphere is the same gas found at ground level, it has very different effects. High in the atmosphere, it forms the 'ozone layer,' which protects life on earth by preventing some of the suns' ultraviolet rays from reaching the earth's surface, thereby reducing negative effects such as skin damage. Mixing of the atmosphere can occasionally increase harmful ozone levels at the earth's surface (CCME 2004).

Forests, grasslands and swamps produce VOCs naturally; the relative importance of these natural sources varies from region to region (Conway 2003).

Ground-level ozone can be hazardous to people, depending on the amount inhaled, and can increase breathing and heart rates. Other observed health effects include aggravated asthma attacks, more severe problems with bronchitis and emphysema, and pain during inhalation. These effects are linked to more emergency room visits, hospitalizations and absenteeism, lower labour force participation and higher health care costs (Willey et al. 2004).

Children are especially sensitive to air pollution and are affected more severely by it than adults are: children grow rapidly; their bodies are developing; they breathe in more air in proportion to their body size; and they are exposed in different ways—for example, by playing for long periods outdoors (CIHI et al. 2001).

Studies have also shown that air pollution may contribute to problems with pregnancy such as early fetal loss, preterm delivery and low birth weight (Schwartz 2004). Ozone has likewise been shown to be more toxic to the elderly and to those with pre-existing health conditions (CCME 2004).

The air quality indicator attempts to capture the trends in long-term ozone concentrations at national and regional levels, and to take account of when and where people are exposed to the pollutant (see Box 2).

2.2 Status and trends

2.2.1 National status and trends

In general, the health impacts of ozone worsen as concentrations increase. Seasonal ground-level ozone concentrations averaged approximately 40 parts per billion (ppb) in Canada in 2003 (Figure 1) and concentrations rose 16% from 1990 to 2003.

When examining this statistically significant trend, it is difficult to separate naturally formed ozone from that resulting from human activities. The changes in the concentrations of the gases that react to form ozone are one explanation for the higher ozone concentrations.

However, from 1990 to 2001 the concentrations of NO_X and VOCs declined in urban areas (Environment Canada 2004a). This decline may be largely due to a drop in emissions from road transportation (Environment Canada n.d.a).

On their own, the lower the NO_X and VOC concentrations are, the better for human health and the environment. However, the relationship between NO_X and ground-level ozone is complex. At low

BOX 2
The air quality indicator

Air quality data are collected by instruments at monitoring stations across the country. Most stations are located in urban areas in southern Canada. The air quality indicator is calculated as follows:

1. Hourly observations of ozone concentration as recorded by the monitoring instruments at each station are analysed to determine the eight-hour period of the day when the station's maximum average concentration occurs—generally in the afternoon and evening.
2. The average concentrations are calculated from the data recorded during these eight-hour periods at a given station and then averaged over all days in the 'ozone season' (April 1 to September 30). Ozone concentrations tend to be higher during these months, at the same time as Canadians are most active outdoors.
3. To calculate the national and regional averages and trends, the average values for all the stations are combined. Because some stations are in the middle of some of Canada's biggest cities and others are in remote areas, census data are used to estimate the number of people within 40 kilometres of each station. These population estimates are used to weight the station observations when calculating averages and trends.

Thus, the indicator uses the seasonal average of daily eight-hour maximum average concentrations, which is population-weighted to calculate trends and averages across stations. The results of these calculations are referred to in this report as 'average concentrations.'

For a map of the monitoring locations used in the indicator trend calculation and additional details on the indicator, see Appendix 1.

concentrations, NO_X contributes to ozone formation, but at high concentrations it also reacts with ozone and actually removes it from the atmosphere. This effect is most pronounced in areas with a large number of motor vehicles, typically urban centres (Health Canada and Environment Canada 1999). Thus, lowered NO_X concentrations may actually reduce this effect and result in locally higher ozone concentrations. More work is needed to evaluate this phenomenon and other alternative explanations for the overall trend in ground-level ozone. For example, the same meteorological conditions associated with higher average temperatures in the years 2001 to 2003 may also have influenced the observed upward trend.

2.2.2 Regional status and trends

Ozone concentrations vary substantially across the country (Map 1). The stations with the highest average ozone concentrations (greater than 50 ppb) in 2003 were all located in Southern Ontario. Ground-level ozone is also a concern in rural areas, particularly those influenced by significant long-range ozone movement. Some stations in rural areas across the country reported concentrations of 40 to 50 ppb.

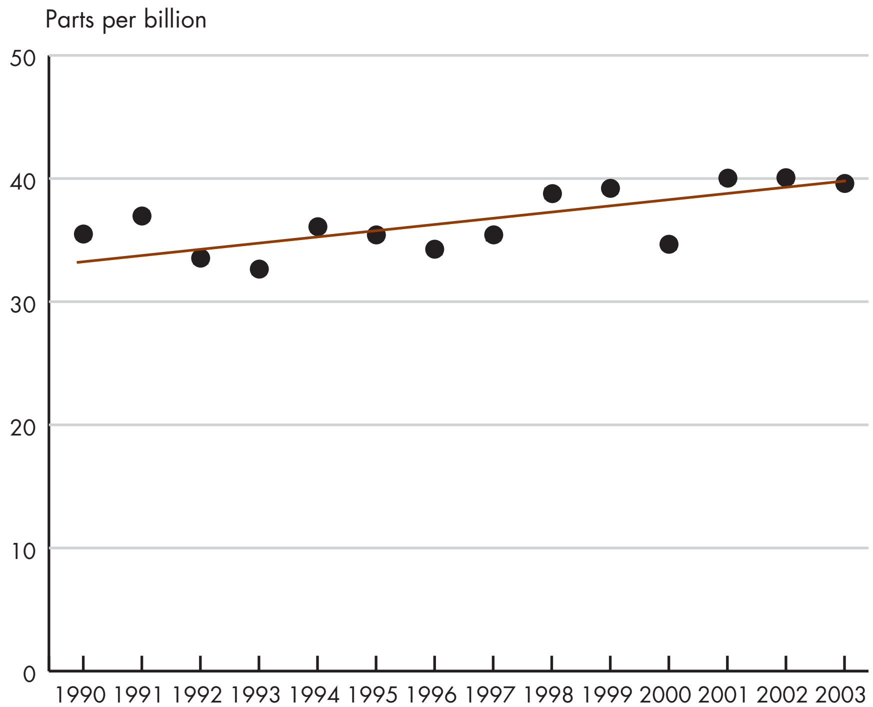
When long-term trends in average ozone concentrations were examined for five regions in the country, all regions exhibited statistically significant increases from 1990 to 2003. Southern Ontario, home to approximately 30% of Canadians (Statistics Canada 2002), saw the highest concentrations and fastest rise (Figure 2).

The sharper growth of ozone concentrations in Ontario has not been examined in detail. Ontario and Quebec, because of their proximity to U.S. emission sources, are most affected by long-range movement of ozone and its precursors. However, the available evidence suggests that U.S. emissions have dropped (US-EPA 2004). More work is needed to explain these phenomena.

2.3 What's next?

Future reports will address other air pollutants as well as ground-level ozone. Air contaminants that pose human health risks include, among others, fine particles, sulphur oxides, and carbon monoxide. Of these, fine

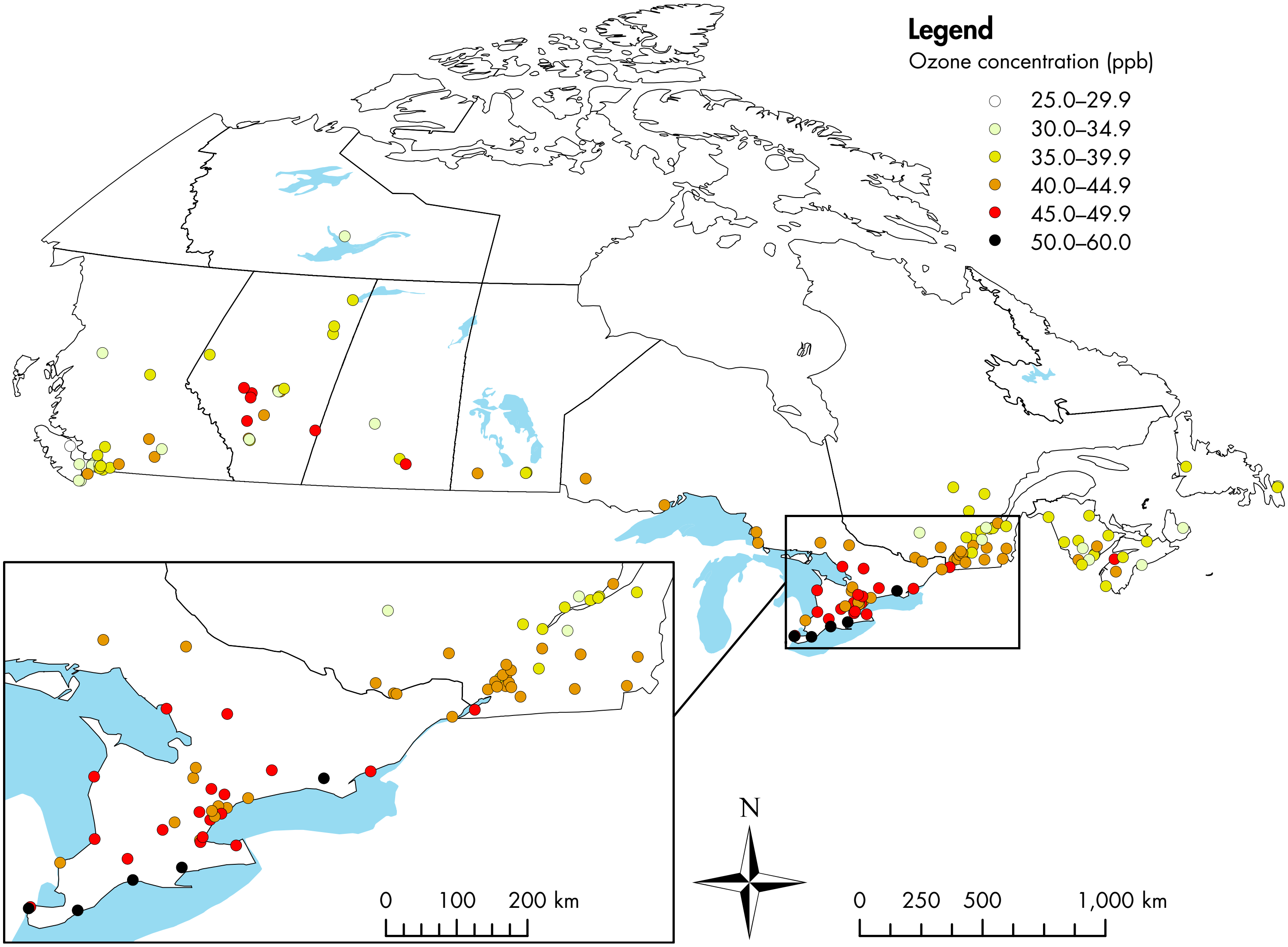
Figure 1 National seasonal average ground-level ozone concentration, Canada, 1990 to 2003



Notes: Results are weighted by population. Both the linear regression and yearly means are shown. Based on 79 monitoring stations. See Appendix 1 (Map A1) for station locations.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

Map 1 Seasonal average ground-level ozone concentration at monitoring stations, Canada, 2003



Note: Number of monitoring stations is 154.
Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

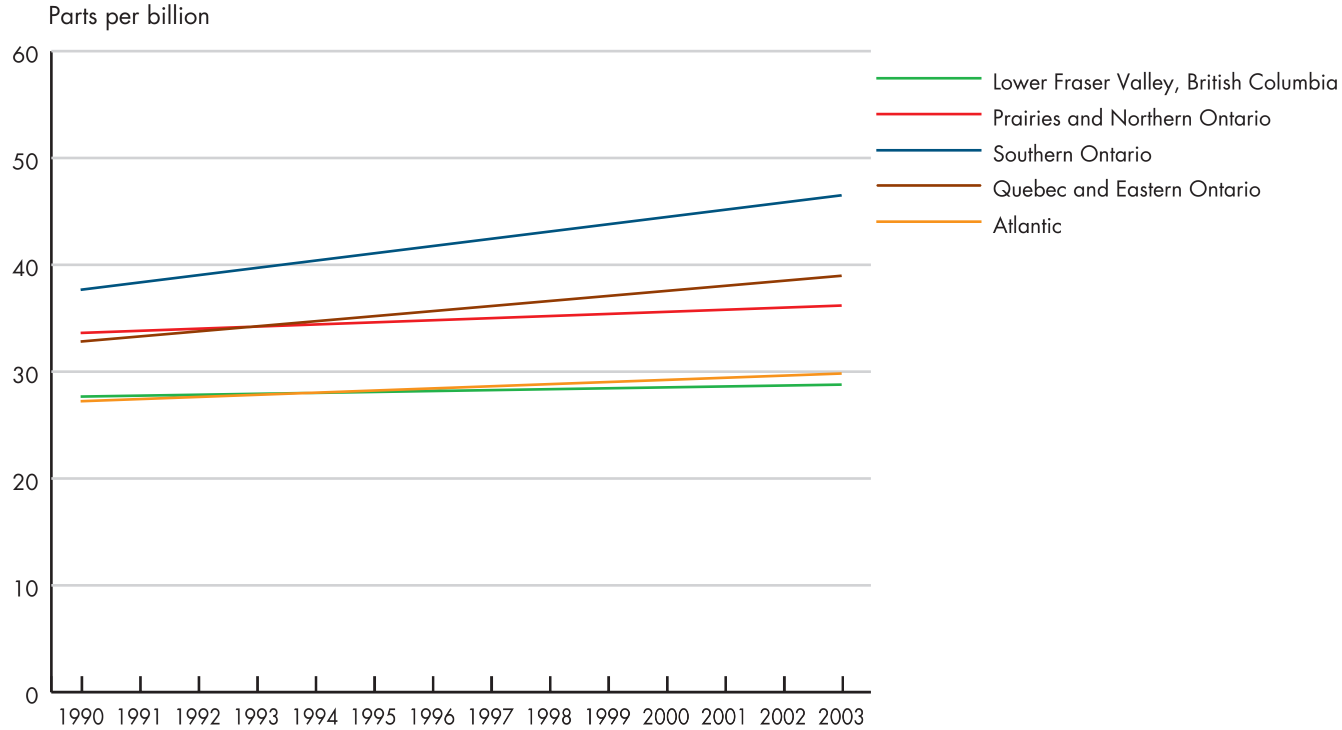
particulate matter [2] ($PM_{2.5}$) is one of the more harmful. These tiny particles can be inhaled deep into the lungs and have been linked to a variety of respiratory problems, such as aggravation of asthma, chronic bronchitis and decreased lung function, as well as premature death (Liu 2004).

The following improvements are planned for the air quality indicator:

Monitoring: Environment Canada will continue to invest in new instruments to fill gaps in pollutant coverage at existing monitoring facilities, and will establish new stations. Further investment will include new instruments that monitor ozone and particulate matter. New stations

2. Airborne particulate matter (PM) is one of the major components of smog. Particulate matter includes microscopic particles in the air that are divided into two size ranges: $PM_{2.5}$ and PM_{10}. The term $PM_{2.5}$ refers to 'fine' particles less than 2.5 micrometres in diameter—about 1/20th the width of a human hair.

Figure 2 Seasonal average ground-level ozone concentrations, selected regions, 1990 to 2003



Notes: Results are weighted by population. Only linear regression lines are shown; yearly means are not shown. Based on 74 monitoring stations. See Appendix 1 (Map A1) for station locations.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environmental Accounts and Statistics Division.

will be set up in more remote locations to ensure better estimates of the trends. The networks will also be assessed for improvements to better measure the ozone concentrations that affect the population. For the purposes of this indicator, the monitoring network should ideally provide balanced coverage of the Canadian population and the sources of ozone and its precursors.

Continuous monitoring for fine particulate matter started in the late 1990s. Each year, more stations were included. Data on fine particulate matter are available for earlier years, but they are discontinuous and obtained from very few locations. As more monitoring equipment is installed and methods for comparing results from different monitoring systems are improved, a more robust national picture and trend will emerge, and a national indicator of concentrations of fine particulate matter will be established.

Analysis: Ground-level ozone observations weighted by population are being used on an interim basis for the air quality indicator. Future work will examine improvements to this method.

Health Canada scientists are examining the feasibility of a broader indicator based on the health risk caused by exposure to the combined effects of several air pollutants because, among other reasons, a combination of different pollutants may produce an even stronger adverse effect than any single pollutant. This indicator could be based on linking deaths due to heart and lung problems with air pollutants present at particular locations and times. The indicator would incorporate ground-level ozone, fine particulate matter and pollutants such as carbon monoxide, nitrogen dioxide and sulphur dioxide. By focusing on the association between exposure and consequences—deaths or hospitalizations—the new indicator would provide governments with better information for policy decisions.

Surveys: Survey work and analysis will make for more accurate estimates of emissions leading to ozone formation. This will also improve estimates of human exposure and therefore strengthen empirical links between that exposure and observed health effects. Gaps remain in the information on behaviours that contribute to emissions (e.g., vehicle choice and use of wood-burning stoves) and to exposure to air pollutants (e.g., timing of outdoor activities). Filling these gaps by way of new or modified data collection and analysis will contribute to better estimates of the effects of ozone exposure on the labour force and society.


3 Greenhouse gas emissions

- In 2003, Canada's total greenhouse gas emissions reached an estimated 740 megatonnes (carbon dioxide equivalent), up 24% from 1990.
- Canada's 2003 emissions were 32% above the target to be achieved in the period 2008 to 2012 according to the Kyoto Protocol.
- Emissions per person rose 9% from 1990 to 2003; emissions per unit of gross domestic product fell 13%.
- The energy sector (including road transportation, fossil fuel industries and thermal electricity and heat production) accounted for 81% of total Canadian emissions in 2003 and 91% of the growth in emissions from 1990 to 2003.
- Alberta and Ontario had the highest emissions of all provinces in 2003. Saskatchewan, New Brunswick and Alberta had the highest percentage increases in emissions compared with 1990.

3.1 Context

Naturally occurring greenhouse gases (GHGs) help to regulate the planet's climate by trapping solar energy that is radiated back from the Earth. Emissions from human activities over the past 200 years have amplified this natural process, and scientists predict that this trend will continue (Environment Canada 2005a).

Not all GHGs occur naturally. Some, such as hydrofluorocarbons and sulphur hexafluoride, are generated only by industrial processes. Others, such as carbon dioxide, methane and nitrous oxide, come from both natural and human sources.

The main concern is due to the increased atmospheric concentration of GHGs resulting from human activities such as burning fossil fuels (oil, coal and natural gas) and deforestation. Global atmospheric concentrations of the six main GHGs (see Box 3) rose by more than 50% during the past three decades (WRI n.d.). Canada's share of global GHG emissions is approximately 2%, although Canadians make up only 0.5% of the planet's population (Environment Canada 2005a).

Emissions of GHGs have been discussed and estimated by scientists and governments for more than a decade. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme and the World Meteorological Organization (IPCC n.d.). Originally consisting of more than 300 of the world's leading experts, the IPCC was formed to investigate climate change. The panel concluded that a doubling of GHGs in the atmosphere would lead to serious consequences for the world's social, economic and natural systems (Houghton et al. 1990). The IPCC estimated that a doubling of CO_2 would lead to an average global temperature increase of 1.4°C to 5.8°C by 2100 (IPCC 2001).

According to several federal government reports (e.g., Lemmen and Warren 2004), if GHG emissions continue

BOX 3

The greenhouse gas emissions indicator

The national greenhouse gas emissions indicator comes directly from Environment Canada's GHG inventory report (Environment Canada 2005a), which contains emissions estimates for sources categorized by economic sector. [i] It includes estimates for six GHGs: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons.

The emissions estimates and sector definitions used for reporting are based on methodological guidance provided by the Intergovernmental Panel on Climate Change (IPCC) and reporting guidelines under the United Nations Framework Convention on Climate Change. The estimates for each sector are generally calculated by multiplying some measure of the amount of GHG-producing activity by the quantity of GHG emitted per unit of activity (e.g., carbon dioxide released per litre of gasoline burned). Emissions estimates for different gases are converted to their equivalent in carbon dioxide based on their impact on global warming compared with carbon dioxide.

For a more detailed description of the indicator and how it is calculated, see Appendix 2.

i. For the purposes of estimating and reporting GHG emissions, the IPCC has identified sectors of economic activity.

to grow, serious consequences will be seen globally, nationally, regionally and locally. A rise in global temperatures could affect, for example, the severity of heat waves, the migration of insects and infectious diseases, water availability and crop yields. Extreme weather events could become more frequent. Sea levels are expected to rise. Indications of these effects have already been seen throughout Canada, especially in the North, where changes have been observed in ice cover, permafrost stability and the distribution of wildlife. At the national level, the social and economic impacts of increased extreme weather events such as drought, flooding and severe storms may be among the most serious of the possible consequences of climate change. Agriculture, forests, tourism and recreation could be affected, as could related supporting industries and towns.

3.2 Status and trends

3.2.1 National status and trends

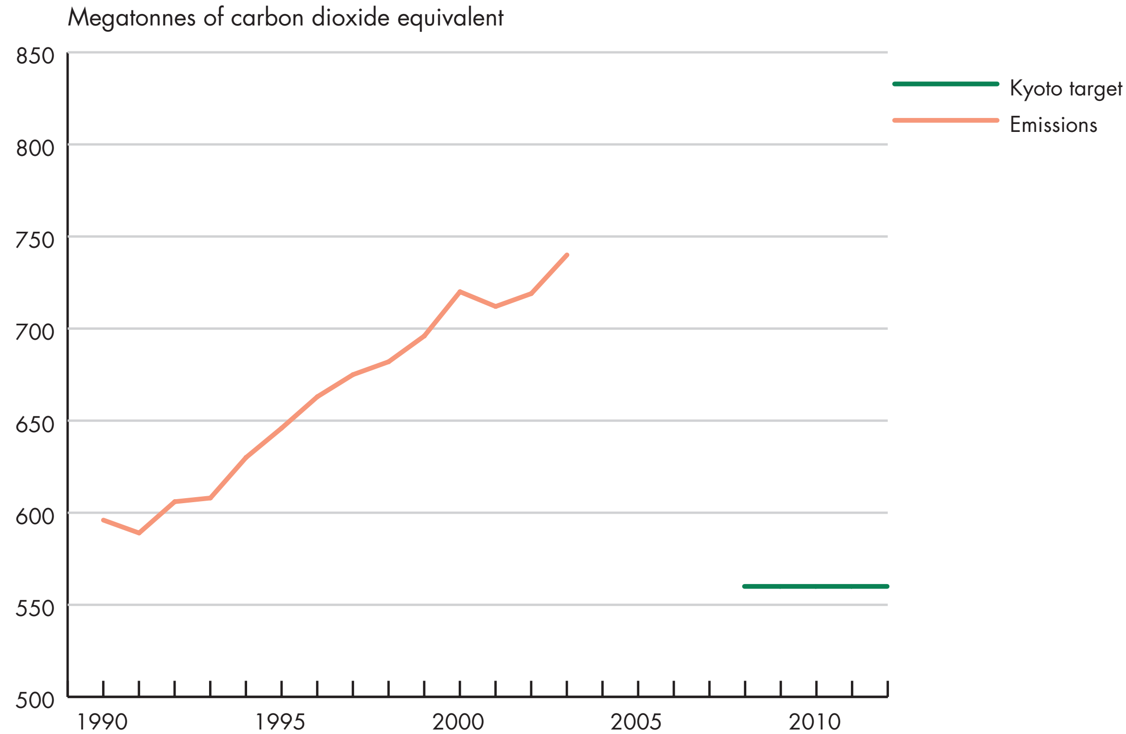
Canada's GHG emissions were an estimated 740 megatonnes (carbon dioxide equivalent) in 2003, up 24% from 596 megatonnes in 1990. The trend in estimated emissions and the target to which Canada has committed under the Kyoto Protocol—6% below the 1990 baseline by the period 2008 to 2012—are shown in Figure 3. The Kyoto Protocol specifies penalties for countries that do not meet their emissions reduction commitments (Environment Canada 2005a).

Almost 80% of the 2003 emissions are attributed to carbon dioxide, 13% to methane and 7% to nitrous oxide. Sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons accounted for less than 2% of Canada's emissions. Each gas's share of total emissions did not change significantly over the period (Environment Canada 2005a).

As a result of its size, low population density, northern climate and resource base, Canada is one of the highest per capita emitters in the world. Canadians use energy to heat, cool and light their homes, offices and factories, and they use energy to transport goods and people over long distances. The economy relies on energy-intensive industries such as mining, refining, steelmaking, forestry, pulp and paper, and petrochemicals (Government of Canada 2001). Emissions rose 9% from 1990 to reach 23 tonnes per person in 2003. This amount of carbon dioxide would fill 47 houses, each with 1,500 square feet (140 m^2) of floor space.

In contrast, Canada's GHG emissions per unit of economic activity (as measured by gross domestic product) dropped 13% from 1990 to 2003 (Figure 4). Efficiency improvements in the energy sector partly explain this gain. Without these improvements, total emissions would have been an estimated 52 megatonnes, or 7%, higher (Natural Resources Canada 2005). Despite these gains, rapid growth in the economy has meant higher total emissions.

Figure 3 Greenhouse gas emissions, Canada, 1990 to 2003



Source: Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003.*

3.2.2 Sectoral status and trends

Estimates of GHG emissions are developed and reported for the following major sectors: energy, industrial processes, solvent and other product use, [3] agriculture and waste. [4] The energy sector accounted for 81% of total emissions in 2003 (Figure 5). From 1990 to 2003, emissions from this sector rose 28%, accounting for 91% of total growth in Canada's emissions. Within the energy sector, the growth resulted primarily from thermal electricity and heat production (27% of the increase), road transportation (23%), and fossil fuel industries (13%). Emissions from some sources, such as energy use in mining, rose more rapidly, and thus have become more important in the overall total (Environment Canada 2005a).

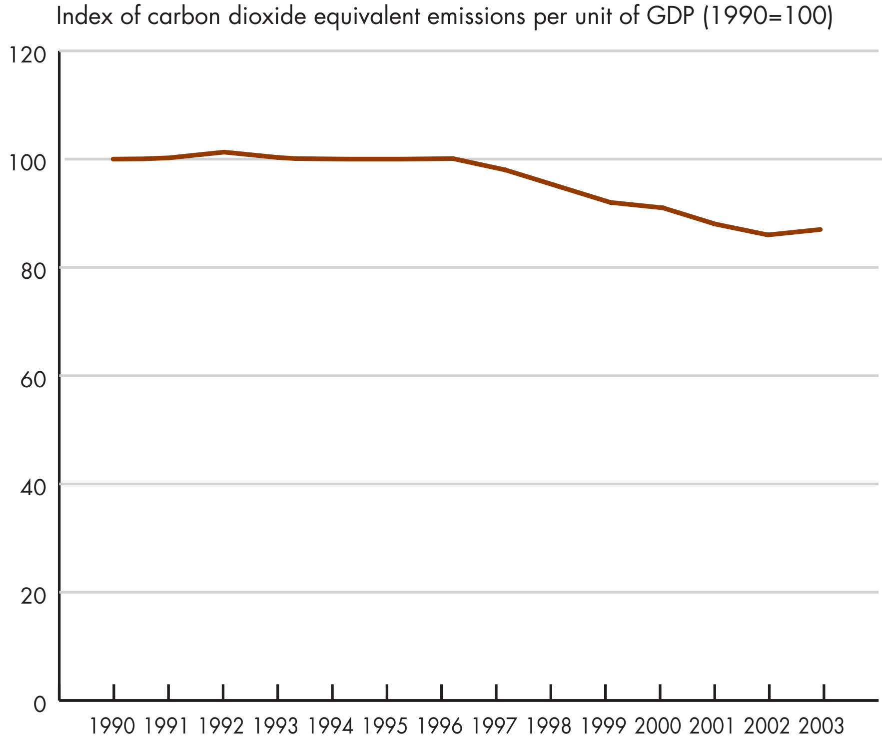
Industrial processes, the only sector with lower estimated emissions, saw a decline of 4% from 1990 to 2003. This sector emits GHGs from the production of minerals, chemicals and metals; from the use of halocarbons and sulphur hexafluoride; and from other industrial processes. Emissions were reduced through technological change at several industrial facilities (Environment Canada 2005a).

The overall increase in emissions was driven by three categories of activity, all in the energy sector.

Thermal electricity and heat production: Electric utilities and industries that generate heat and electricity accounted for 18% of Canada's total GHG emissions in 2003, a 40% rise from 1990 levels. The growth in emissions was driven by the rising demand for electricity and the relative increase in the use of fossil fuels, particularly coal, for electricity generation. Total annual electricity production climbed 21% from 1990 to 2003,

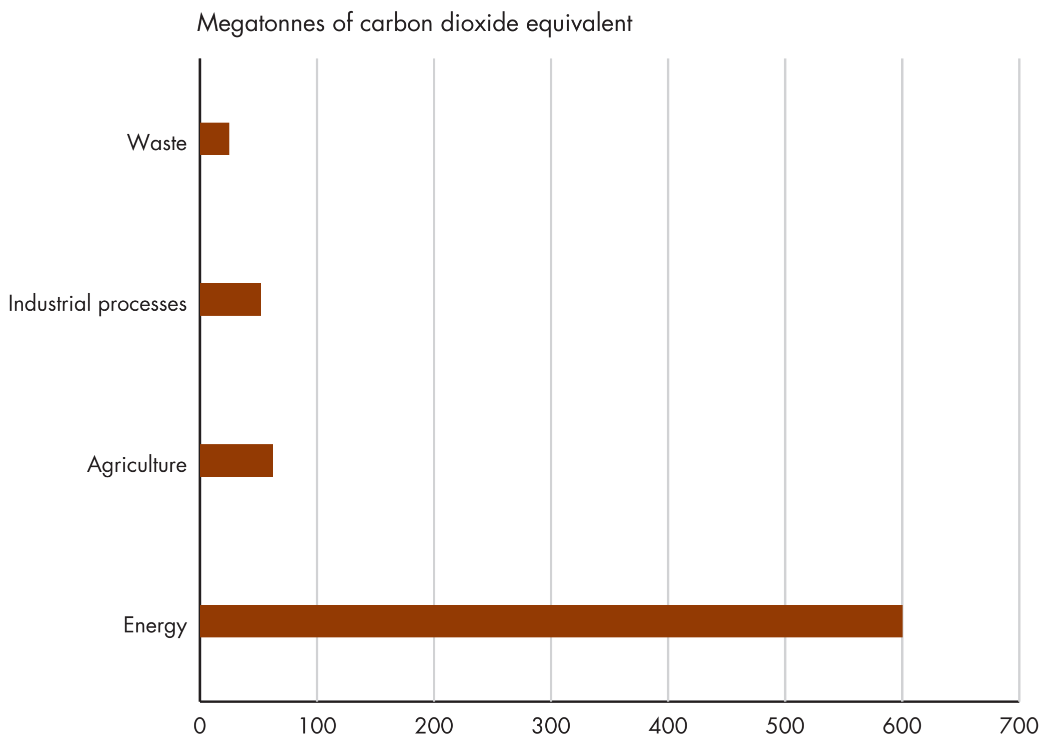
3. This sector had very low emissions and made a very small contribution to the growth in emissions relative to other sectors. Hence, it is not discussed further or presented in the figures.
4. Emissions and removals from land use, land use change and forestry, while reported, are not included in the national inventory totals or in the GHG indicator.

Figure 4 Greenhouse gas emissions per unit of gross domestic product, Canada, 1990 to 2003



Sources: Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003*; Statistics Canada. CANSIM table 380-0017.

Figure 5 Greenhouse gas emissions by sector, Canada, 2003



Note: The 'solvent and other product use' sector is not included because, by comparison, it had very low emissions.

Source: Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003.*

although the population rose just 14% (Environment Canada 2005a).

Road transportation: Moving people and goods accounted for 19% of total emissions in 2003 and for 31% of the growth in emissions since 1990. Canadians are increasingly dependent on road transportation. From 1990 to 2003, the number of vehicles rose 8% faster than the number of people. There was also a shift in the types of vehicles used for personal transportation from automobiles to vans, sport-utility vehicles and light-duty gasoline-powered trucks. These heavier vehicles emit, on average, 40% more GHGs per kilometre than do automobiles. Total GHG emissions from light-duty gasoline trucks rose 93% from 1990 to 2003; emissions from cars fell 8%. Another major contributor was heavy-duty diesel vehicles, whose emissions jumped 71% from 1990 to 2003 (Environment Canada 2005a).

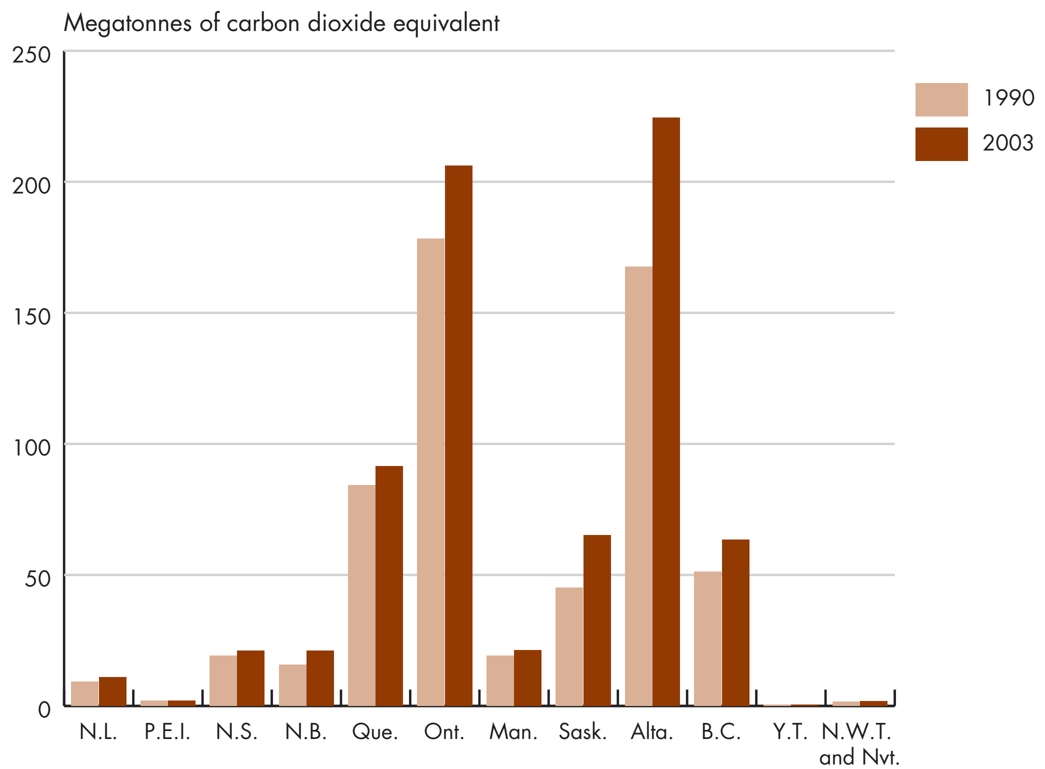
Fossil fuel industries: This category includes exploration, production and basic processing of crude oil and natural gas, as well as combustion of fossil fuels during the production of refined petroleum products. Fossil fuel industries accounted for 10% of total GHG emissions in 2003, up 39% from 1990 levels due to the combined domestic and foreign demand for fossil fuels. During this period, exports of crude oil and natural gas jumped 466% and 132%, respectively, contributing about one-half of the total increase for this category (Environment Canada 2005a).

3.2.3 Regional status and trends

Greenhouse gas emissions vary from region to region (Figure 6). The geographical distribution of emissions is linked to the location of natural resources, population and heavy industry. Total emissions rose in all provinces and territories except for the Yukon, where they dropped slightly (Environment Canada 2005a).

In 2003, Alberta and Ontario reported the highest emissions. Alberta produced 64% of Canada's energy and accounted for approximately 25% of Canada's emissions in that year. Saskatchewan (45%), New Brunswick (33%) and Alberta (33%) had percentage

Figure 6 Greenhouse gas emissions, provinces and territories, 1990 and 2003



Source: Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003.*

increases in emissions from 1990 to 2003 that exceeded the national average (Environment Canada 2005a).

3.3 What's next?

Several steps to improve the GHG emissions inventory will directly improve the quality of the indicator reported through this initiative. Environment Canada's Greenhouse Gas Division is continuously planning and implementing improvements. The priorities take into account the results of annual quality assurance and quality control procedures, reviews and verifications of the GHG inventory, including the annual external examination of the inventory by an international expert review team (Environment Canada 2005a).

Analysis: Areas for improvement include better estimation methods and more data on key variables used in the calculations. Planned improvements to the inventory include:

- refined estimates in the energy sector for sources such as the bitumen industry, upstream oil and gas, and manufacturing and construction sectors
- upgrades to the model for estimating transportation emissions
- investigation of additional sources from the minerals sector
- better estimates of nitrous oxide emissions from agricultural soils
- refined estimates of methane emissions from landfill wastes
- continued implementation of a full quality assurance and quality control plan
- refinement of the uncertainty analysis.

Mandatory GHG emissions reporting was established in 2005, the result of a collaboration among federal, provincial and territorial governments to develop a harmonized system of GHG reporting. Launched on March 15, 2005, the system is being implemented in phases. The first phase required facilities generating 100 kilotonnes or more of carbon dioxide equivalent emissions to report their 2004 emissions by June 1, 2005. These facility data will be used by Environment Canada as an additional input for improving future emissions estimates.

In addition to improvements to the inventory itself, data and analysis from Statistics Canada's Greenhouse Gas Emissions Account will be used in later indicator reports to help understand the economic forces driving the indicator trends. Using Statistics Canada's national input–output model, this account produces highly detailed emissions estimates for 122 industries, 473 commodities and 126 consumption categories. It could be used, for example, to compare the direct GHG emissions by households (e.g., from natural gas heating) with the indirect GHG emissions due to the goods and services the households consumed (Statistics Canada 2001).

Surveys: Information to provide context for the greenhouse gas emissions indicator will be developed from a survey of Canadian households regarding their environmental practices, such as driving habits and use of wood-burning stoves. Preliminary results of this survey should be available in 2006.

4 Freshwater quality

- This new indicator provides a preliminary assessment of surface water quality with respect to protecting aquatic life (e.g., fish, invertebrates and plants). It does not assess the quality of water for human consumption. It is based on information gathered from 2001 to 2003 from 345 selected monitoring sites across the country.
- Freshwater quality was rated as "good" or "excellent" at 44% of the sites, "fair" at 31% and "marginal" or "poor" at 25%.
- Almost all of the selected sites are located in southern Canada in areas of human activity, including human settlements and agricultural regions and, to a lesser extent, areas potentially influenced by acid deposition, industrial facilities and dams.
- This preliminary indicator will be revised in future reports to reflect improvements in monitoring and analysis.

4.1 Context

Water of good quality and in appropriate quantities is fundamental to ecosystems, human health and economic performance. In Canada, water is mostly used by households and in industries such as electricity generation, agriculture, manufacturing, petroleum extraction and mining. Every year, tens of billions of cubic metres of water are withdrawn from surface and groundwater sources (Statistics Canada 2003). Intensive and competing water uses can lead to local shortages and compromise water quality (Environment Canada 2004b).

Every day, primary manufacturing and service industries, institutions and households discharge hundreds of different substances, directly or indirectly, into rivers and lakes. At least 100,000 tonnes of toxic pollutants were directly discharged to Canada's surface waters in 2003 (Environment Canada 2005c; Statistics Canada 2005). Some substances, such as ammonia and other nutrients, are released in large quantities; other, more toxic substances, such as mercury, are released in much smaller but nevertheless significant amounts (Environment Canada 2005c; UNEP 2002).

Many more pollutants make their way indirectly to water bodies after being released into the air or onto the land. Aquatic ecosystems receive airborne pollutants transported over long distances, such as sulphur dioxide and nitrogen oxides which cause acidification, heavy metals (e.g., lead and mercury) and organic compounds (e.g., polychlorinated biphenyls [PCBs] and pesticides) (Environment Canada 2001). On land, untreated runoff from agricultural and urban areas also degrades water quality (Harker et al. 2000; Marsalek et al. 2001).

Water quality degradation can affect both aquatic life and human uses of water. For example, higher concentrations of nutrients (e.g., nitrogen or phosphorus) may result in uncontrolled plant growth and reduce the amount of dissolved oxygen available for fish and other aquatic animals. Economic activities such as freshwater fisheries, tourism and agriculture can be undermined by degraded water quality. The indicator presented in this first report focuses on water quality for the protection of aquatic life. It does not assess the quality of water for human consumption.

Water quality is difficult to define and assess for the purpose of reporting nationally because water chemistry is complex and depends on many physical and chemical properties that vary naturally from place to place and over time. These properties can affect the suitability of water for aquatic organisms—which themselves vary from place to place and have varied sensitivities to different substances. Evaluating whether water quality is degraded is further complicated because natural processes such as heavy rain, melting ice and snow, soil erosion, and weathering of bedrock also influence levels of certain substances in water (e.g., nutrients and metal ions). These natural phenomena maintain both the habitat for a wide range of indigenous species and the conditions underlying other ecosystem processes. These processes vary considerably across the country, making for a diverse mix of aquatic ecosystems.

To report on water quality, experts have measured specific substances in water, and compared the observed concentrations against scientifically established thresholds for potential adverse effects. This is the basis of the Water Quality Index (WQI) endorsed by the Canadian Council of Ministers of the Environment[5] (CCME) in 2001 and used in this report to produce the water quality indicator (see Box 4). This Index can be calculated using the results of ongoing water quality monitoring programs managed by federal and provincial governments.

4.2 Status

4.2.1 National status

Water quality data from a mix of federal, provincial, and joint monitoring programs were assessed by regional experts and assembled into a national dataset to calculate this indicator. Almost all of the 345 monitoring sites included had water quality measurements that exceeded one or more water quality guidelines at least once. On balance, water quality, measured using the WQI to assess its suitability to protect aquatic life, was rated as good or excellent at 44% of the sites; fair at 31% and marginal or poor at 25% (Figure 7). This summary does not include the Great Lakes, which were measured using a different sampling approach (see Box 5).

These initial results should not be interpreted as representing the state of all freshwater in Canada: they apply to the water quality at the selected sites, and are based on data collected from 2001 to 2003. All sites, whether small rivers or large lakes, are weighted equally in this summary. Almost all the sites are in southern Canada, and in areas of human activity, and were therefore potentially affected by human settlements, farms, industrial facilities, and dams, as well as acid precipitation. These are typically places where water quality has been a concern.

Different water quality variables were measured at different locations across the country depending, in part, on the priorities of the various monitoring programs and the potential human influences in the area. Nutrients (in particular phosphorus) and metals (such as copper, iron, lead and zinc) frequently exceeded the water quality guidelines used to assess the protection of aquatic life.

Water quality experts most often identified urban development and agricultural activities as key potential causes of degraded water quality. Pulp and paper facilities, mines (including oil sands), forestry, acid rain, and dams or other diversions were also considered important stressors at some sites (Environment Canada regional water quality experts 2005).

Natural phenomena also contributed to water quality measurements exceeding guidelines. For example, glacial flow, seasonal snow melt and heavy rainfall can lead to high levels of suspended sediments that are rich in nutrients and metals. As well, the naturally acidic water of bogs and other wetlands can result in lower pH and higher concentrations of metals at downstream sites. These factors illustrate the need to develop and implement water quality guidelines that take account of naturally occurring substances and conditions at individual sites.

Detailed work at specific sites will be required to separate the causes of changes in water quality or to determine the reasons why water quality samples exceed guidelines. More study is needed across Canada to link

5. The Canadian Council of Ministers of the Environment brings together the Ministers of the Environment from the federal government and all provincial and territorial governments.

BOX 4

The Water Quality Index

The CCME WQI is a method that allows experts to translate large amounts of complex water quality data into a simple overall rating for a given site and time period. It provides a flexible method for assessing surface water quality that can be applied across Canada.

The WQI is based on a water quality index developed by British Columbia in 1995. This version was then modified through research, testing and consultation by a CCME task group.

The Index combines three different aspects of water quality: the 'scope,' which is the percentage of water quality variables with observations exceeding guidelines;[i] the 'frequency,' which is the percentage of total observations exceeding guidelines; and, the 'amplitude,' which is the amount by which observations exceed the guidelines. The results are converted into a qualitative scale that is used to rate sites as follows:

Rating	Interpretation
Excellent (95.0 to 100.0)	Water quality measurements never or very rarely exceed water quality guidelines.
Good (80.0 to 94.9)	Measurements rarely exceed water quality guidelines and, usually, by a narrow margin.
Fair (65.0 to 79.9)	Measurements sometimes exceed water quality guidelines and, possibly, by a wide margin.
Marginal (45.0 to 64.9)	Measurements often exceed water quality guidelines and/or by a considerable margin.
Poor (0 to 44.9)	Measurements usually exceed water quality guidelines and/or by a considerable margin.

Water quality guidelines are numerical values for physical, chemical, radiological or biological characteristics of water that, when exceeded, show a potential for adverse effects. Guidelines are often based on toxicity studies using a standard set of test organisms found in aquatic ecosystems in Canada. Water quality guidelines can be adjusted to reflect site-specific conditions such as a different species composition or background levels of naturally occurring substances, such as phosphorus. Guidelines are also specific to how the water is used, be it for supporting aquatic life, drinking, recreation, irrigation or livestock watering. In this report, the WQI is used to assess the suitability of bodies of surface water (rivers and lakes) for the protection of aquatic life (CCME 2001).

For a more detailed description of the indicator, how it is calculated, and the location of the sites see Appendix 3.

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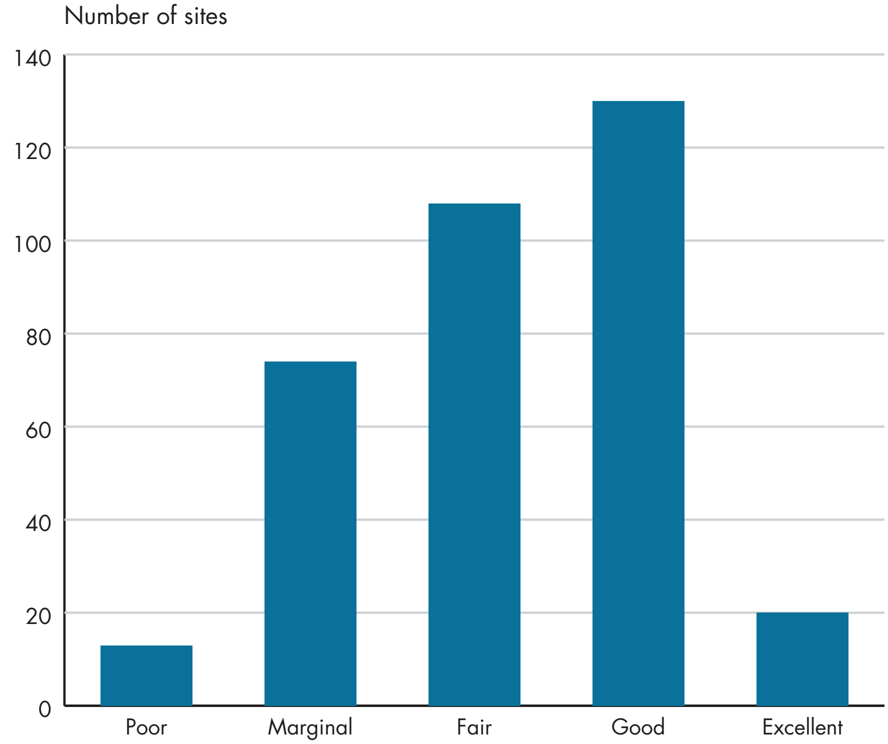
i. The formula for calculating the scope, and hence the WQI, is modified in the province of Quebec. Future work will resolve the differences between the two versions of the Index.

Figure 7 Status of freshwater quality at selected sites, Canada, 2001 to 2003



Notes: The results are for surface water quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption. Number of sites is 345. Observations for the Great Lakes are not included, but appear in Box 5. See Appendix 3 (Map A2) for site locations.

Source: Data assembled by Environment Canada from federal, provincial and joint water quality monitoring programs.

BOX 5

The Great Lakes: A special case

The Great Lakes watershed is heavily farmed and industrialized. It is home to more than 10 million Canadians (Statistics Canada 2002), which puts enormous pressure on water quality. Historically, the Great Lakes have been degraded by excess nutrients and the accumulation of toxic contaminants in the water and the sediments. Some aspects of water quality (e.g., phosphorus concentrations) have been substantially improved in parts of the Great Lakes by human intervention (EC and US-EPA 2003).

Because of the area of the lakes (about 92,200 square kilometres in Canadian territory) and the nature of the surface water quality monitoring program (each lake was sampled at multiple sites once every three years, rather than by multiple samples at the same site every year), water quality there was assessed differently from other sites across the country (see Appendix 3 for additional details).

The WQI was calculated over the period 2003 to 2004 for nine basins: Lake Superior, Georgian Bay, Lake Huron, Lake Erie (the western, central, and eastern basins), Lake Ontario, and Hamilton Harbour and Toronto Harbour in Lake Ontario. Water quality was rated as excellent in two basins, good in five, fair in one and marginal in one. By contrast with measurements of surface water, significant levels of contaminants (including mercury and PCBs) continue to be found in the sediments of the Great Lakes (EC and US-EPA 2003). These observations reflect the historical accumulation of pollutants.

the water quality ratings to specific human activities and natural processes.

4.3 What's next?

This first report provides information on the status of water quality in Canada as it relates to the protection of aquatic life. The preliminary indicator reported here will be revised in future reports.

The ideal indicator would permit managers to separate the effects of natural and human-caused changes in water quality. It would apply a consistent approach to selecting which variables and guidelines to use so that results could be aggregated and compared across the country, by watershed and over time. It would be based on a statistically chosen set of monitoring sites that provided a representative sample of water bodies in Canada with respect to different beneficial uses.

The following improvements are planned in relation to monitoring, analysis and surveys:

Scope and monitoring: The need to protect aquatic life is relevant to every region of Canada. However, most systematic, long-term monitoring efforts are focused on developed or settled areas, largely in the south. Over the next four years, Environment Canada, working with provincial and territorial counterparts, will enlarge the current water quality monitoring network to more broadly represent the distribution of water bodies throughout the country. The first step will be to identify the areas of Canada, usually rural, remote and northern, that are under-represented in the national indicator, and set priorities for increased monitoring activity.

Environment Canada and Statistics Canada will review the suite of water quality variables measured in different jurisdictions across Canada. The goals will be to ensure local and ecological relevance and to understand the implications of combining WQI values calculated using different variables. Investments may be needed to measure more variables at some locations. Options will also be explored for incorporating information on the number and distribution of aquatic organisms into the indicator. This would provide further context and validation of the results.

Given the importance that people attach to clean water for consumption, the suitability of water bodies as sources of drinking water will be built into the water quality indicator in the future. Health Canada will lead the development of a method and identify the data required for the calculation of an index of source water quality. Other major economic and social uses of water, including recreation and agriculture, will also be incorporated into the indicator over time.

Analysis: How well the WQI rates water quality depends directly on the use of appropriate water quality guidelines with which monitoring data can be compared. Guidelines used in the WQI computation should be locally relevant, meaning appropriate to the local organisms and local water characteristics. For example, hardness and temperature can affect the toxicity of some substances of concern. As well, the natural background levels for some substances (e.g., phosphorus and metals) can exceed existing national or provincial guidelines. In coming years, Environment Canada, in consultation with the provinces and territories, plans to assess the relevance of the water quality guidelines to local conditions and, where necessary, develop site-specific guidelines using nationally consistent methods and protocols for calculating the water quality indicator.

Work is also planned on the methods for calculating the WQI, compensating for the unbalanced geographical distribution of monitoring sites, and examining trends in the WQI over time. Options for more consistently choosing variables and guidelines among jurisdictions are being evaluated to address the inconsistencies noted above. A more systematic approach to selecting sites to include in the indicator calculation and to choosing what weight to give them will be implemented for the next report. To develop a clear picture of the trends in water quality, ways of using annual data are being considered.

Surveys: The effects on water quality of households and industry practices, such as the disposal of liquid wastes, as well as the needs of households and industry for high quality water, will be more thoroughly documented by national surveys developed and administered from 2005 to 2009, including surveys of households, industrial water use, and agricultural water use. A survey of municipal water treatment plants is expected to support development of the methods for evaluating source water quality by Health Canada.


5 Connecting the indicators

Linking the indicators and connecting them to other socio-economic and environmental information can guide policy decisions that better address economic performance, quality of life, and environmental sustainability. This first report offers a limited analysis of these connections. In future reports, the analysis will be strengthened as the indicators are improved, additional information (e.g., from surveys) is added, and the analytical tools are developed to make the links quantitative and more closely tied to policy analysis. This report focuses on building the foundation of environmental information required to compile the indicators. Details of the social and economic dimensions still need to be added to this base.

The indicators span a range of concerns: local water and air quality may change from year to year, while greenhouse gas emissions and the related issue of climate change evolve globally over decades. Despite these differences, they are connected in fundamental ways:

- Some of the same substances are involved.
- Some of the same economic forces drive the changes in the indicators.
- The indicators reflect stresses in the same regions of the country.

For example, the pollutants that combine to form ground-level ozone (nitrogen oxides and volatile organic compounds) are emitted from transportation and energy production—activities that are essential to Canadians' lifestyles but that are also major sources of greenhouse gas emissions. In turn, nitrogen oxides and sulphur oxides, both by-products of burning fossil fuels, fall as acid precipitation. This affects the water in sensitive lakes and rivers, notably in parts of eastern Canada, and harms their aquatic organisms (Environment Canada 2005b).

Agricultural fertilizer use and poor manure management have been linked to high concentrations of nutrients, such as nitrogen and phosphorus, in some water bodies (Environment Canada 2001). Agricultural activities also contribute to emissions of methane and nitrous oxide, both potent greenhouse gases (Environment Canada 2005a).

With the water quality data now available, it is impossible to identify precisely the regions of Canada where the stresses on aquatic systems are greatest. In future reports, it should be possible to determine where these regions are and whether they coincide with areas exposed to high concentrations of air pollutants, including ground-level ozone and other components of smog. It should also be possible to better describe the influence of transboundary pollution flows on the Canadian air and water quality indicators.

Federal government reports (e.g., Lemmen and Warren 2004) have concluded that Canada may face environmental, economic and social costs if domestic and international efforts fail to reduce greenhouse gas emissions. Effects on water resources could include reduced water supply and diminished water quality, although these would vary among regions. If extreme weather events become more frequent and intense, damage to settlements and agricultural crops could be severe. Forest productivity and wildlife could be harmed. Continually increasing emissions could lead to pollution-related health problems, heat-related morbidity and mortality, and higher incidence of water-borne and vector-borne diseases.

Even though the indicators are interconnected, they tell different stories. For example, the air quality indicator examines links to human health. In contrast, the preliminary water quality indicator in this report is focused on protection of aquatic life.

One part of the economic dimension of the indicators is the cost associated with reducing water and air pollution. For example, governments, businesses and households need to spend to treat the water that they plan to use, and then spend again to reduce their impact on that water. Statistics Canada (2004) estimated that Canadian businesses invested $428 million in 2002 to prevent and control water pollution. Significantly more was invested that same year on protecting air quality: $1,531 million. Further reducing the impacts of businesses on water and air pollution could raise costs for Canadian firms.

Another key consideration is the socio-economic cost of the pollution itself. For example, Health Canada has estimated, based on data from eight cities (Quebec, Montreal, Ottawa, Toronto, Hamilton, Windsor, Calgary and Vancouver), that 5,900 premature deaths each year in these cities are attributable to air pollution (Judek et al. 2004). Economists have tried to estimate the social costs of poor health due to air pollution. A monetary estimate of all the health impacts—health care costs, lost productivity, and pain and suffering—runs to the billions of dollars per year in Canada (Chestnut et al. 1999).

In future reports, the linkages between the environmental indicators and socio-economic information will be strengthened. Measuring the efficiency of energy use is of particular interest because of the multiple benefits: lower economic cost, less air pollution and acid precipitation, and lower greenhouse gas emissions. Future work will also focus on modelling the benefits of cleaner air and water and anticipating the effects of climate change. This work will aid in the development of policies that combine economic and social perspectives with those of environmental sustainability.

6 Conclusions

The three indicators reported here raise concerns for Canada's environmental sustainability, the health and well-being of Canadians, and our economic performance. The trends for air quality and greenhouse gas emissions are pointing to greater threats to human health and the planet's climate. The water quality results show that guidelines are being exceeded, at least occasionally, at most of the selected monitoring sites across the country.

A challenge for future reports will be to refine and clarify the three indicators and to add detail to the results. This first report is an essential step toward tracking environmental quality in three critical areas for long-term decision-making. It lays the foundation for consistent national reports on water quality and for a better understanding of the links between air quality and human health. This information is complemented with estimates of Canadian trends in greenhouse gas emissions. Improvements are already planned for each of the three indicators.

The air quality indicator builds on the base of an established national monitoring network. However, the task of linking policy measures to air quality and then to human health effects is formidable: ozone levels are influenced by complex factors, including weather and transboundary flows of pollutants. The approach taken in this report—analysing the observed concentrations in relation to where people live—is just a start. It will benefit from refinements in future reports. Ground-level ozone is only one component of air pollution. Systematic measurements of other pollutants, especially fine particulate matter, will need to be analysed. Their cumulative effects must then be integrated into a comprehensive air health indicator.

The greenhouse gas emissions indicator is the best developed of the three indicators. It clearly shows a rise in Canada's emissions since 1990, and helps to pinpoint the key sources of the increase—fossil fuel production and consumption. Further development and improvements are underway for this indicator.

This year's effort to assemble water quality information from across the country demonstrates that jurisdictions can co-operate to sketch a national picture of water quality. Revisions and improvements to the preliminary indicator for future reports will require a better understanding of how well particular monitoring sites represent the quality of water bodies or watersheds in which they are located and how they relate to all the rivers and lakes in Canada. A more accurate national indicator will rely on choosing variables and developing water quality guidelines that better match the ecological diversity of Canada's water bodies.

Reports will be produced annually on a continually improving set of indicators with increasingly robust analyses to track the changes in water quality, air quality and greenhouse gas emissions in Canada. The indicators will benefit from enhanced monitoring capabilities, new survey results for both water quality and air quality, new scientific knowledge and guidelines, as well as improved data management and analytical methods. Future reports will be supported with an online information system that will allow users to examine regional and sectoral details and conduct their own analyses.

One of the biggest challenges will be the transition from reporting these indicator results separately to reporting them as a set that is integrated with other information on the environment, measures of economic performance and indices of social progress. The long-term goal is better decision-making that fully accounts for environmental sustainability.

Appendix 1
Description of the air quality indicator

Canada has a co-ordinated air monitoring network that includes stations from across the country. A national database of concentrations of air pollutants contains information provided by the National Air Pollution Surveillance (NAPS) network, a federal–provincial–territorial co-operative network focused on urban air quality (Environment Canada 2003). This network is, in turn, complemented by information from the Canadian Air and Precipitation Monitoring Network, a federal network that measures rural and background levels of air pollutants.

From 1990 to 2003, 244 ozone monitoring stations reported observations for the database. The data used to calculate the ground-level ozone indicator in this report were taken from stations that monitored ozone and that had sufficiently complete data for 1990 to 2003. Seventy-nine stations had adequate data for analysing trends from 1990 to 2003 (Map A1). For the 2003 status summary, 154 stations met the criteria.

The monitoring stations were grouped into five clusters for the regional trend analysis. The British Columbia region includes only stations inside the Greater Vancouver Regional District and the Lower Fraser Valley. One station in central British Columbia and four in northeastern Ontario were included in the national trend analysis, but were not assigned to any region for the regional analysis.

The stations used in the calculation of the ozone concentrations were chosen based on the quality and completeness of their data; they were not chosen to be a statistically designed sample to estimate population exposure to ozone. One consequence is that some regions weigh more heavily in the calculation of trends than they should simply based on population size. More work is needed to make the estimates of population exposure more accurate and to assess how well the network of stations represents the Canadian population.

The number of observations and the relatively long time series support a solid statistical analysis. However, the measured ozone concentrations vary within each day, within each week, and by day of the year. Concentrations are also influenced by weather systems and movement of pollutants from other parts of the world—in particular, from the United States. As a result, more work is required to disentangle these sources of variability to better understand what drives the observed trends.

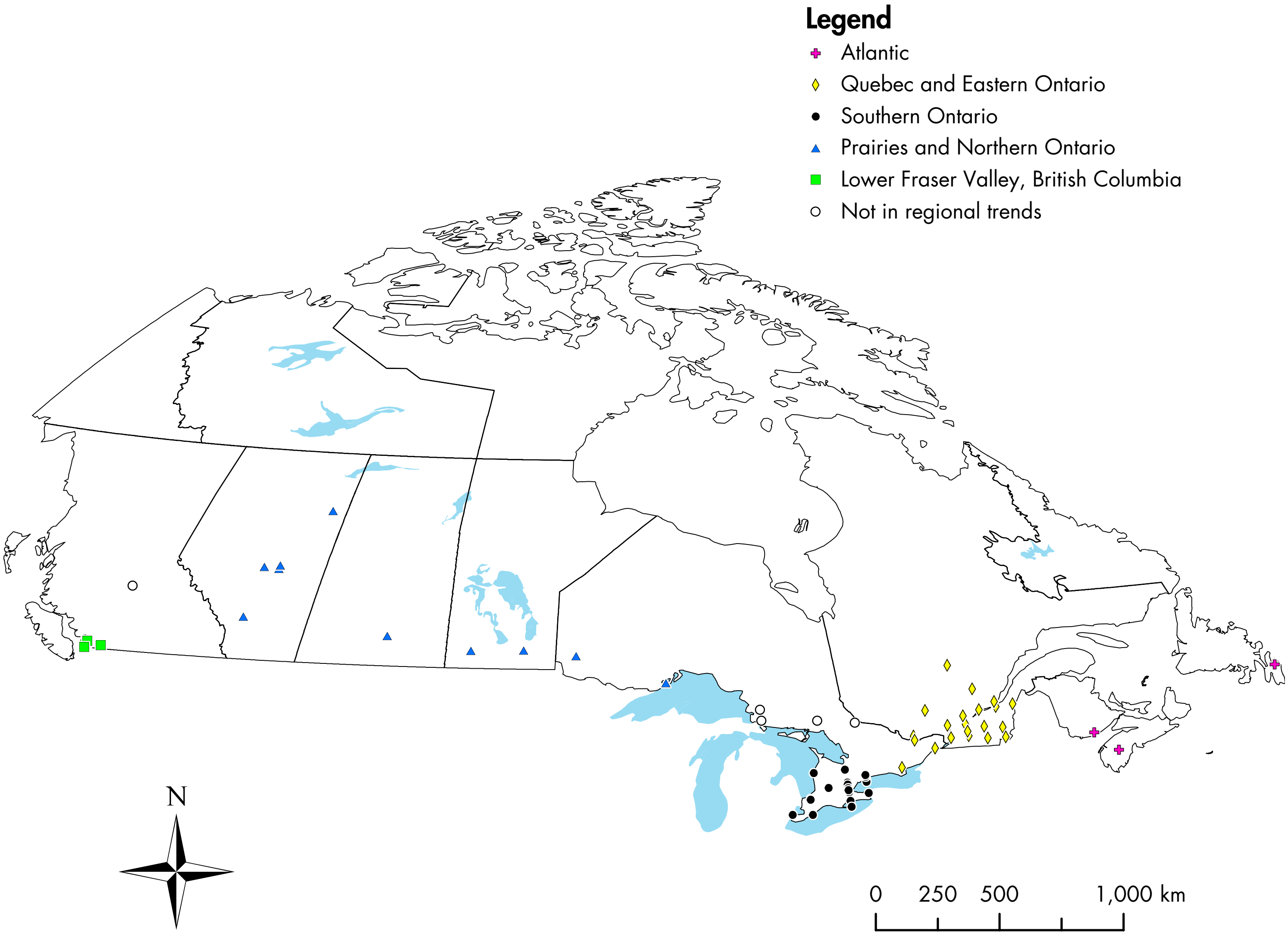
The possible measurement error for ozone concentrations at individual stations is conservatively estimated to be less than ±10% (Dann and Conway 2005). Selected monitoring stations are subject to federal audits. Agencies contributing data to the NAPS database may perform additional audits and strive to adhere to established quality assurance and quality control standards to maintain national consistency.

A nationally consistent and accessible database of observations, a good time series, relatively precise estimates for individual monitoring stations, and documentation of the methods and approach all contribute to the quality of the database. Planned improvements include integrating other air pollutants and reducing the time required to report the results.

This indicator is only one of many possible ways to measure air quality. Considering the availability of high quality data and the significant health impacts, the National Round Table on the Environment and the Economy (2003) recommended using this averaged concentration of ground-level ozone, weighted by population, as the air quality indicator.

This indicator estimates the average seasonal exposure of Canadians to ground-level ozone. Other methods reported elsewhere are also used to assess and report on ground-level ozone in Canada. For example, air quality indices (some using ozone alone, others incorporating additional pollutants) are used to forecast and report on the hourly and daily air quality in communities across the country. Both the Canada-wide Standard for Ozone and the indicator used in this report are based on daily eight-hour maximum average concentrations. The standard focuses

Map A1 Locations of monitoring stations used for air quality indicator trends



Notes: Regional clusters were defined by Environment Canada. Numbers of stations per region are: Atlantic (3); Quebec and Eastern Ontario (25); Southern Ontario (21); Prairies and Northern Ontario (14); Lower Fraser Valley, British Columbia (11); Not in regional trends (5).

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

on the fourth highest value averaged over three years. [6] Adverse health effects can occur at concentrations below the level specified in the standard; it does not provide a full account of potential health risks.

These other indices are not designed to estimate the long-term average exposure to ozone, as is the air quality indicator used in this report.

Further details on the indicator are provided on a website managed by Statistics Canada (www.statcan.ca).

6. Annual national summaries for ozone and $PM_{2.5}$ levels and trends in relation to the Canada-wide Standards are published on the Canadian Council of Ministers of the Environment website at www.ccme.ca/ourwork/standards.html?category_id=60.

Appendix 2
Description of the greenhouse gas emissions indicator

The greenhouse gas indicator, related data and trends information come directly from *Canada's Greenhouse Gas Inventory Report, 1990–2003*, an annual report submitted by Environment Canada as required under the United Nations Framework Convention for Climate Change (UNFCCC) and the Kyoto Protocol (Environment Canada 2005a). Emissions are estimated according to the procedures and guidelines prescribed by the Intergovernmental Panel on Climate Change (IPCC).

The indicator estimates Canada's total annual emissions into the atmosphere of six major greenhouse gases. While there are approximately 25 other natural and human-produced greenhouse gases that qualify as 'climate-changing,' only these six are released in sufficient quantities to be included in the Kyoto Protocol (Houghton et al. 2001).

Carbon dioxide (CO_2) is emitted partly as a result of human activities such as fossil fuel combustion, deforestation and industrial processes.

Methane (CH_4) emissions result from sources such as livestock; incomplete combustion of biomass; leakage from natural gas transportation and delivery systems such as pipelines; coal mining; and decay of organic waste in landfills.

Nitrous oxide (N_2O) is released by cultivating soil, using nitrogen-based fertilizers, producing nylon, and burning fossil fuels and wood.

Sulphur hexafluoride (SF_6): The electric power industry emits this synthetic gas when installing, servicing and disposing of equipment such as circuit breakers, gas-insulated substations and switchgears. Sulphur hexafluoride is also used during primary magnesium production.

Hydrofluorocarbons (HFCs) and **perfluorocarbons** (PFCs) are human-produced halocarbons used, for example, in refrigeration equipment, fire extinguishers and air conditioners. Emissions of these gases occur when this equipment is used and when it is discarded.

The total emissions estimate is calculated by adding the individual estimates for each of these six gases. The estimates are all converted to an equivalent amount of carbon dioxide by multiplying the estimated emissions for each gas by a weighting factor called 'global warming potential.' This potential represents the amount of warming over 100 years that results from adding one unit of each gas to the atmosphere, compared with the effect of adding one unit of carbon dioxide. Each unit of methane, for example, is multiplied by 21 and each unit of nitrous oxide is multiplied by 310 to determine their carbon dioxide equivalents.

The emissions for each GHG are estimated by summing the individual estimates for different activities. In general, measurements of the amount of activity (e.g., kilometres driven or amount of a given product manufactured) are multiplied by the emissions per unit for that activity. Estimates of emissions per unit of activity, also known as emission factors, are based on measurements of representative rates of emission for a given activity level under a given set of operating conditions (US-EPA 1996). Some emission factors can be calculated for individual industrial facilities; most are more general and are derived from national or international averages.

The indicator does not include emissions from naturally occurring sources (e.g., organic matter decay, plant and animal respiration, and volcanic and thermal venting) and absorption of emissions by natural sinks, such as forests and oceans. Emissions and removals from some types of land, such as forests and wetlands, and changes in land use are excluded from the indicator as well.

Environment Canada's Greenhouse Gas Division developed and compiled these data from several sources, including Statistics Canada (e.g., statistics on energy, livestock, crop production and land), Natural Resources Canada (e.g., statistics on mineral production and forestry), and Agriculture and Agri-Food Canada (e.g., some agricultural parameters), as well as other sections of Environment Canada (e.g., data on landfill gas capture, HFC use and PFC use). Environment Canada engineers and scientists estimate emissions using methods developed by IPCC as well as methods and models developed in-house specifically for estimating Canadian emissions (Environment Canada 2005a).

The draft inventory is reviewed by an interdepartmental working group that includes representatives of provincial, territorial and federal government departments working in air pollution measurement and estimation. Emissions estimates for the various sectors are also reviewed by experts from the organizations that provided the source data, such as Statistics Canada, Natural Resources Canada, and Agriculture and Agri-Food Canada. Finally, the information submitted by Canada each year to the UNFCCC Secretariat is subject to external review by a team of experts, and a report of their findings is published by the UNFCCC. The inventory underwent an in-depth review in Canada in 2003 and a 'desk' review in 2004 and 2005.

Sources of uncertainty about the estimated emissions include the definitions of which activities are incorporated in the estimates, methods for calculating emissions, data on the underlying economic activity, and the scientific understanding. Uncertainty information is used to set priorities to improve the accuracy of future inventories and to guide decisions about which methods to use. The uncertainty about estimates for individual gases, individual sectors or specific provinces will be higher than for the overall national estimate (Environment Canada 2005a). There is no accepted quantified measure of the statistical accuracy of the emissions estimates.

Quality assurance, quality control and verification procedures are part of preparation of the inventory: they take the form of internal checks and external reviews and audits, and follow international standards. Activities based on these reviews are intended to further improve the transparency, completeness, accuracy, consistency and comparability of the national inventory. The detailed documentation, uncertainty estimates, international reporting guidelines, domestic and international scrutiny, and reliance on Statistics Canada energy survey results all contribute to the quality of the GHG estimates.

Further details on the indicator in this report are also provided on a website managed by Statistics Canada (www.statcan.ca).

Appendix 3
Description of the water quality indicator

The national freshwater quality indicator is based on the Water Quality Index (WQI), which is endorsed by the Canadian Council of Ministers of the Environment (Neary et al. 2001). The WQI is described further on the council's website (www.ccme.ca/ourwork/water.html?category_id=102).

In this report, the WQI was calculated for 345 locations across Canada, and the results were combined nationally. The set of monitoring sites was assembled from existing federal, provincial and joint water quality monitoring programs (Map A2). These monitoring sites were established for many different reasons, including regulatory requirements, compliance with interprovincial or international agreements, and the need to manage local water quality issues. For example, some small lakes in the Maritimes are being monitored because they are located in acid-sensitive areas.

The monitoring sites included in the calculation of the national indicator met minimum requirements for the timing of the sample collection (from 2001 to 2003) and the number of samples taken (12 for rivers and 6 for lakes over the three-year period). Most of the 345 sites (19 on lakes and 326 on rivers) were located in southern Canada and in areas of human activity. They were therefore potentially affected by human settlements, farms, industrial facilities and dams, as well as acid precipitation. Consequently, the monitoring sites are not statistically representative of Canada as a whole. They were originally chosen for monitoring because they are in areas where there is concern about the effects of human activities on water quality—and because they are readily accessible. The territories, Saskatchewan, northern Ontario, northern Quebec, and Labrador are large areas that now have little or no representation in the water quality indicator. However, several monitoring programs do exist in these areas. For future reports of the indicator, sample collection and coverage will be expanded to move closer to a representative and geographically balanced network.

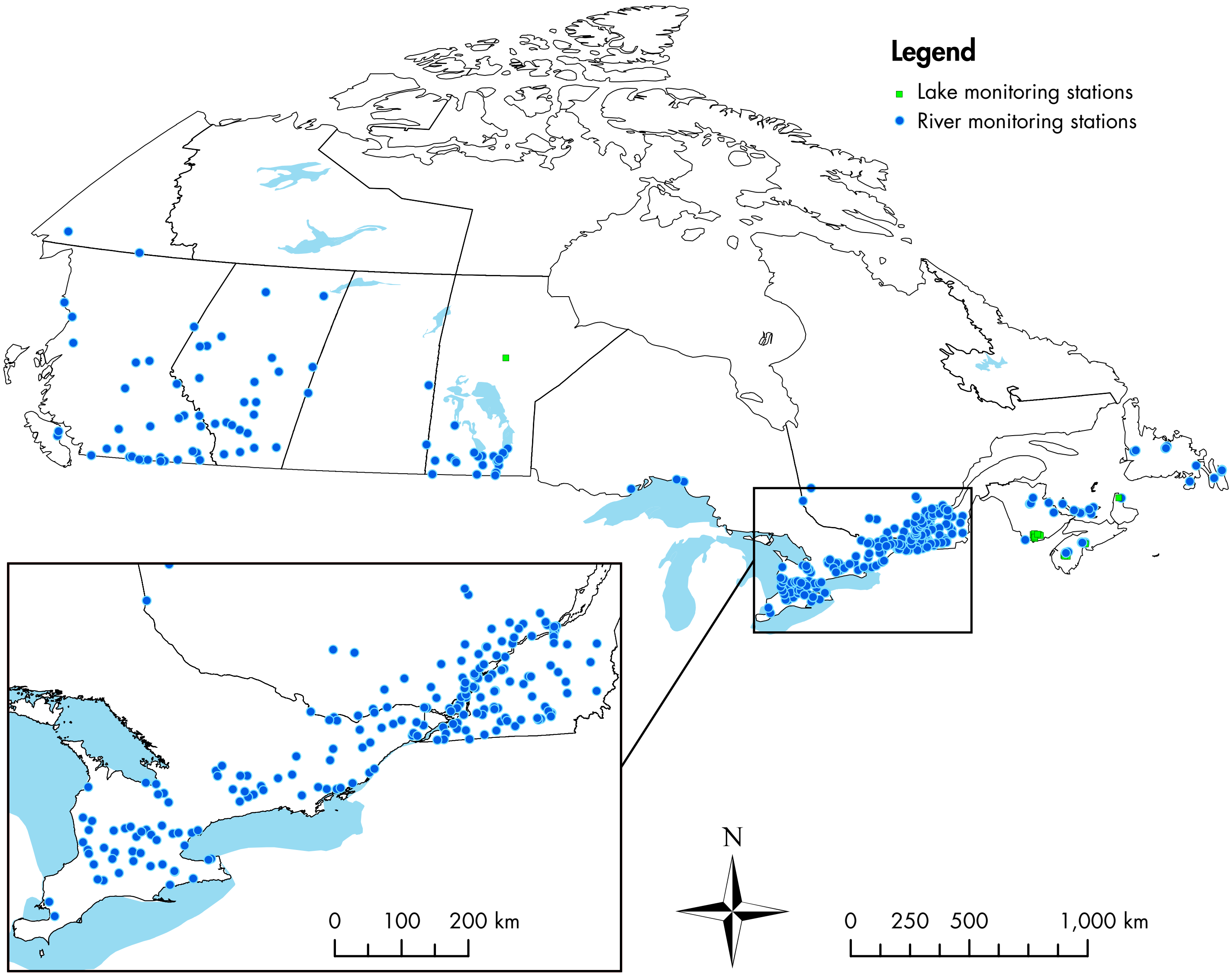
Running waters included in this analysis range from small streams, such as Prince Edward Island's Bear River, which has an average flow of 0.3 cubic metres per second and drains an area of about 15 square kilometres (Environment Canada n.d.b), to powerful rivers such as the St. Lawrence, which discharges 9,850 cubic metres per second and drains an area of about 1.3 million square kilometres (Natural Resources Canada n.d.). The lakes also vary considerably in size—from Pebbleloggitch Lake (0.33 square kilometres) in Nova Scotia to Sipiwesk Lake (454 square kilometres) in Manitoba (Natural Resources Canada n.d.). Future modifications to the monitoring network and analysis of WQI results need to account for this variation, possibly by adjusting the weights of the different water bodies in the analysis.

The range of water quality variables incorporated into the WQI calculations includes:

- nutrients (e.g., phosphorus and nitrogen)
- metals (e.g., arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium, silver and zinc)
- physical characteristics (e.g., pH, dissolved oxygen, turbidity and total suspended solids)
- major ions (e.g., chloride and sulphate)
- some organic compounds (e.g., pesticides).

Different subsets of these variables were selected and applied either uniformly throughout different jurisdictions and regions or, in the case of British Columbia, at individual sites. Environment Canada and its provincial counterparts chose which variables to use in the calculation based on which variables had been measured, the human activities of concern, and the availability of suitable water quality guidelines. The choices were made by drawing on local knowledge and advice provided by provincial, territorial and federal water quality experts. The variables used in the WQI calculations reflect some of the main stressors on water quality across Canada noted above. Water quality

Map A2 Locations of monitoring sites used for the freshwater quality indicator



Sources: Data assembled by Environment Canada from federal, provincial and joint water quality monitoring programs; Statistics Canada, Environment Accounts and Statistics Division.

guidelines were selected from national, provincial and site-specific sources.

For the Great Lakes case study, the WQI was calculated using data collected by Environment Canada's Great Lakes Surveillance Program. Conducted on a three-year rotation, this program took measurements for Lake Erie, Lake Huron and Georgian Bay in April 2004, and for Lakes Ontario and Superior in April 2003. Fifteen variables were included in the calculation of the WQI, but not all of them were available for all lakes.

The national dataset assembled from provincial and federal sources is generally sufficient for this preliminary indicator. Additional work will be required on several aspects, such as the representation and distribution of sites across the country, the consistency with which variables are used in the calculations, the implementation of locally relevant guidelines, and public accessibility of the data. How different variables are combined to produce the index values will also be reviewed and refined.

Further details on the indicator are provided on a website managed by Statistics Canada (www.statcan.ca).

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References

Canadian Council of Ministers of the Environment (CCME). 2004. *Guidance Document on Achievement Determination: Canada-wide Standards for Particulate Matter and Ozone*. Winnipeg, Manitoba.

Canadian Council of Ministers of the Environment (CCME). 2001. *Canadian Environmental Quality Guidelines*. Winnipeg, Manitoba.

Canadian Institute for Health Information (CIHI), Canadian Lung Association, Health Canada and Statistics Canada. 2001. *Respiratory Disease in Canada*. Ottawa, Ontario: Health Canada.

Chestnut, L.G., D. Mills and R.D. Rowe. 1999. *Air Quality Valuation Model Version 3.0 (AQVM 3.0). Report 2: Methodology*. Prepared for Environment Canada and Health Canada. Boulder, Colorado: Stratus Consulting.

Conway, F. 2003. *Atmospheric Science of Ground-Level Ozone: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone: Final Draft*. Working paper prepared for the Canadian Council of Ministers of the Environment. Ottawa, Ontario: Environment Canada.

Dann, T. (Environment Canada, Environment Technology Centre) and F. Conway (Environment Canada, Science Assessment and Integration Branch). 2005. Personal communication. Ottawa, Ontario. September 21.

Environment Canada. n.d.a. Criteria Air Contaminants Database. www.ec.gc.ca/pdb/ape/canada2000_e.cfm (accessed October 24, 2005).

Environment Canada. n.d.b. "Water level and streamflow statistics" for station 01CD005. Water Survey of Canada. www.wsc.ec.gc.ca/staflo/index_e.cfm?cname=flow_daily.cfm (accessed October 24, 2005).

Environment Canada. 2005a. *Canada's Greenhouse Gas Inventory 1990–2003*. Greenhouse Gas Division. Ottawa, Ontario.

Environment Canada. 2005b. *2004 Canadian Acid Deposition Science Assessment: Summary of Key Results*. Meteorological Service of Canada. Ottawa, Ontario.

Environment Canada. 2005c. *National Pollutant Release Inventory 2003*. www.ec.gc.ca/pdb/npri/npri_dat_ rep_e.cfm (accessed October 24, 2005).

Environment Canada. 2004a. *National Air Pollution Surveillance (NAPS) Network: Air Quality in Canada, 2001 Summary and 1990–2001 Trend Analysis*. Report EPS 7/AP/36. Ottawa, Ontario.

Environment Canada. 2004b. *Threats to Water Availability in Canada*. NWRI Scientific Assessment Report Series, No. 3, and ACSD Science Assessment Series, No. 1. Burlington, Ontario: National Water Research Institute.

Environment Canada. 2003. *National Air Pollution Surveillance (NAPS) Network: Annual Data Summary for 2002*. Report EPS 7/AP/35. Ottawa, Ontario.

Environment Canada. 2001. *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada*. NWRI Scientific Assessment Report Series, No. 1. Burlington, Ontario: National Water Research Institute.

Environment Canada and the U.S. Environmental Protection Agency (EC and US-EPA). 2003. *State of the Great Lakes 2003*. Prepared for the Governments of Canada and the United States of America. Ottawa, Ontario and Washington, D.C.

Environment Canada regional water quality experts. 2005. Personal communications. Various locations across Canada. July and August.

Government of Canada. 2001. *Canada's Third National Report on Climate Change: Actions to Meet Commitments Under the United Nations Framework Convention on Climate Change*. Environment Canada Catalogue no. En21-125/2001E. Ottawa, Ontario: Minister of Public Works and Government Services.

Harker, D.B., P.A. Chambers, A.S. Crowe, G.L. Fairchild and E. Kienholz. 2000, "Understanding water quality." In *The Health of Our Water: Toward Sustainable Agriculture in Canada*. D.R. Coote and L.J. Gregorich (eds.). Ottawa, Ontario: Agriculture and Agri-food Canada.

Health Canada and Environment Canada. 1999. *National Ambient Air Quality Objectives for Ground-level Ozone: Science Assessment Document*. Report by the Federal–Provincial Working Group on Air Quality Objectives and Guidelines. Ottawa, Ontario: Environment Canada.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden and D. Xiaosu (eds.). 2001. *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, England: Cambridge University Press. 944 pp.

Houghton, J.T., G.J. Jenkins and J.J. Ephraum (eds.).1990. *Scientific Assessment of Climate Change*. Report of Working Group I to the Intergovernmental Panel on Climate Change. Cambridge, England: Cambridge University Press. 365 pp.

Intergovernmental Panel on Climate Change (IPCC). n.d. *Mandate and Membership of the IPCC*. www.ipcc.ch/about/about.htm (accessed October 25, 2005).

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate Change 2001: Synthesis Report. Summary for Policymakers*. IPCC Third Assessment Report. Geneva, Switzerland. 184 pp.

Judek, S., B. Jessiman, D. Stieb and R. Vet. 2004. *Estimated Number of Excess Deaths in Canada Due to Air Pollution*. Health Canada, Air Health Effects Division, and Environment Canada, Meteorological Service of Canada. www.hc-sc.gc.ca/ahc-asc/media/nr-cp/2005/2005_32bk2_e.html (accessed October 24, 2005).

Lemmen, D.S. and F.J. Warren (eds.). 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*. Climate Change Impacts and Adaptation Directorate. Ottawa, Ontario: Natural Resources Canada.

Liu, L. 2004. *Human Health Effects of Fine Particulate Matter: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone*. Working paper prepared for the Canadian Council of Ministers of the Environment. Ottawa, Ontario: Health Canada.

Marsalek, J., M. Diamond, S. Kok and W.E. Watt. 2001. "Urban Runoff." In *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada*. Environment Canada. NWRI Scientific Assessment Report Series, No. 1. Burlington, Ontario: National Water Research Institute. 47–50.

National Round Table on the Environment and the Economy (NRTEE). 2003. *Environment and Sustainable Development Indicators for Canada*. Ottawa, Ontario.

Natural Resources Canada. n.d. "Rivers." *The Atlas of Canada*. http://atlas.gc.ca/site/english/learningresources/facts/rivers.html (accessed October 25, 2005).

Natural Resources Canada. 2005. *The State of Energy Efficiency in Canada: Report 2005*. Office of Energy Efficiency. Natural Resources Canada Catalogue no. M141-7/2004. Gatineau, Quebec.

Neary, B., K. Cash, S. Hébert, H. Khan, K. Saffran, L. Swain, D. Williamson and R. Wright. 2001. *Canadian Water Quality Guidelines for the Protection of Aquatic Life. CCME Water Quality Index 1.0 Technical Report*. Canadian Council of Ministers of the Environment. Winnipeg, Manitoba.

Schwartz, J. 2004. "Air pollution and children's health." *Pediatrics*. 113, 4: 1037–1043.

Statistics Canada. 2005. *Human Activity and the Environment: Annual Statistics 2005*. Statistics Canada Catalogue no. 16-201-XIE. Ottawa, Ontario.

Statistics Canada. 2004. *Environmental Protection Expenditures in the Business Sector, 2002*. Statistics Canada Catalogue no. 16F0006XIE. Ottawa, Ontario.

Statistics Canada. 2003. *Human Activity and the Environment: Annual Statistics 2003*. Statistics Canada Catalogue no. 16-201-XIE. Ottawa, Ontario.

Statistics Canada. 2002. *A National Overview – Population and Dwelling Counts, 2001 Census*. Statistics Canada Catalogue no. 93-360-XPB. Ottawa, Ontario.

Statistics Canada. 2001. *Econnections 2000: Linking the Environment and the Economy*. Statistics Canada Catalogue no. 16-200-XKE. Ottawa, Ontario.

United Nations Environment Programme (UNEP) Chemicals. 2002. *Global Mercury Assessment*. Inter-organization Programme for the Sound Management of Chemicals. Geneva, Switzerland.

U.S. Environmental Protection Agency (US-EPA). 2004. *The Ozone Report: Measuring Progress through 2003*. Report 454/K-04-001. Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (US-EPA). 1996. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*. Fifth edition. Report AP-42. Research Triangle Park, North Carolina.

Warneck, P. 1988. *Chemistry of the Natural Atmosphere*. San Diego, California: Academic Press.

Willey, J., N. Gilbert and N. Lyrette. 2004. *Human Health Effects of Ozone: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone*. Revised Version. Working paper prepared for the Canadian Council of Ministers of the Environment. Ottawa, Ontario: Health Canada.

World Resources Institute (WRI). n.d. *Climate Analysis Indicators Tool*. http://cait.wri.org (accessed October 25, 2005).

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