



**Canada • United States**  
Air Quality Agreement

**PROGRESS REPORT 2010**

## THE INTERNATIONAL JOINT COMMISSION REQUESTS YOUR COMMENTS ON THIS REPORT

The International Joint Commission (IJC) is very interested in your views on the important work being carried out under the Air Quality Agreement. What do you think about the ongoing efforts of our two countries to address transboundary air quality; what issues do you think should have the highest priority; and what do you think about the information provided in this report?

Under the Air Quality Agreement, the IJC invites public comment and provides a synthesis of comments to the Governments of Canada and the United States to assist them with implementing the Agreement. The IJC intends to hold a series of public meetings in the summer of 2011 to invite comment on this report. More information including a schedule of the public meetings, will be provided online at **[www.ijc.org](http://www.ijc.org)**.

The IJC invites you to send written comments on this report until September 9, 2011, at either address below:

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## Introduction

Both Canada and the United States committed to reduce the impact of transboundary air pollution through the 1991 Canada–United States Air Quality Agreement (AQA). The Acid Rain Annex, negotiated with the original 1991 agreement, committed both Canada and the United States to reducing acid rain-causing emissions of sulphur dioxide ( $\text{SO}_2$ ) and nitrogen oxides ( $\text{NO}_x$ ). Since this time, there have been large reductions in  $\text{SO}_2$  and  $\text{NO}_x$  emissions on both sides of the border with subsequent reductions in acidification and improvements in air quality. For example, as of 2008, Canada's total  $\text{SO}_2$  emissions have decreased by 47% from 1990 emission levels while the United States has reduced total  $\text{SO}_2$  emissions from covered sources by 51% from their 1990 levels. The Ozone Annex, added to the Agreement in 2000, committed both countries to reducing emissions of  $\text{NO}_x$  and volatile organic compounds (VOCs), the precursors to ground-level ozone, a key component of smog. Between 2000 and 2008, the United States has reduced  $\text{NO}_x$  emissions by 33% in the transboundary ozone region while Canada's total  $\text{NO}_x$  emissions decreased by 32% in the region.

The 2010 Progress Report, prepared by the bilateral Air Quality Committee, is the tenth biennial report completed under the 1991 Canada–United States Air Quality Agreement. The report summarizes key actions undertaken by Canada and the United States in the last two years to address transboundary air pollution within the context of the Agreement. The report presents progress made toward meeting the commitments established in the Acid Rain and Ozone Annexes of the Agreement, and in implementing the underlying Agreement.

To prepare this report, the Air Quality Committee took into consideration the public comments received through the International Joint Commission (IJC) regarding the 2008 Progress Report. A synthesis of comments can be found at the IJC website at <http://www.ijc.org/php/publications/pdf/ID1634.pdf>. The comments received expressed support for the Agreement and its success in fostering cooperation on transboundary air pollution control and satisfaction with the progress made by both countries in reducing emissions of pollutants that cause acid rain and contribute to smog formation. This Agreement continues to provide important opportunities for collaboration between Canada and the United States on air pollution and related issues.







# SECTION 1

## Commitments

### Acid Rain Annex

#### Overview

The Acid Rain Annex to the 1991 Air Quality Agreement established commitments for both countries to reduce the emissions of sulphur dioxide and nitrogen oxides, the primary precursors to acid rain. The commitments include prevention of air quality deterioration, visibility protection, and continuous emissions monitoring. Both countries have been successful in reducing the impact of acid rain on each side of the border. However, despite these achievements, studies in each country indicate that although some damaged ecosystems are showing signs of recovery, further efforts are necessary to restore these ecosystems to their pre-acidified conditions.

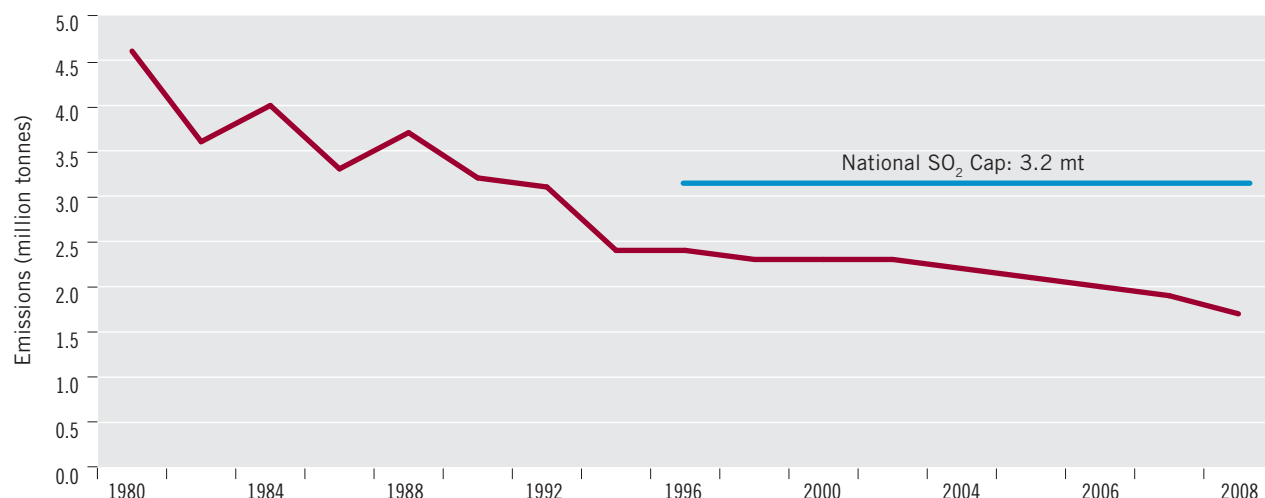
#### Key Commitments and Progress: Sulphur Dioxide Emission Reductions



For more than a decade, Canada has steadily reduced sulphur dioxide (SO<sub>2</sub>) emissions, through the implementation of the Canada-Wide Acid Rain Strategy for Post-2000. The strategy serves as the framework for addressing the remaining acid rain problem in eastern Canada and ensuring that new acid rain problems do not occur elsewhere in Canada.

In 2008, Canada's total SO<sub>2</sub> emissions were 1.7 million tonnes, or about 47% below the national cap of 3.2 million tonnes<sup>1</sup>. This represents more than a 63% reduction from Canada's total SO<sub>2</sub> emissions in 1980 and a 46% decrease from the 1990 emission level (see Figure 1). This overall reduction in national SO<sub>2</sub> emission levels can be attributed to the SO<sub>2</sub> emission reductions undertaken by the four eastern provinces (New Brunswick, Nova Scotia, Quebec and Ontario) targeted by the Acid Rain Strategy.

<sup>1</sup> One tonne is equal to 1.1 short tons.

**Figure 1. Total Canadian Emissions of SO<sub>2</sub>, 1980–2008**

Source: Environment Canada 2010

The largest source of SO<sub>2</sub> emissions in Canada continues to be the non-ferrous smelting and refining sector, which accounted for 39% of national SO<sub>2</sub> emissions in 2008, despite an almost 60% decrease in SO<sub>2</sub> emissions from this sector since 1990. Other key industrial sources contributing to Canadian SO<sub>2</sub> emissions include electric power generation and the upstream petroleum industry, which accounted for 30% and 20%, respectively, of national SO<sub>2</sub> emissions in 2008.

While Canada has been successful in reducing emissions of acidifying pollutants, many areas across Canada have a low capacity to withstand acid

deposition and continue to receive levels of acid deposition in excess of critical loads. A critical load is the maximum amount of acidifying deposition an ecosystem can tolerate in the long term without being damaged.

Despite Canadian emission reduction efforts, the control of acidifying emissions has not occurred to the extent necessary to reduce acid deposition below critical loads and ensure the recovery of aquatic and terrestrial ecosystems.



The United States succeeded in meeting its commitment to reduce annual SO<sub>2</sub> emissions by 10 million tons from 1980 levels by 2000. Additionally, in 2007, emissions of SO<sub>2</sub> from the electric power sector in the United States fell below the 2010 national emission cap of 8.95 million tons for the first time, achieving the U.S. commitment three years early.

Title IV (the Acid Rain Program or ARP) of the *Clean Air Act Amendments of 1990* requires major reductions of SO<sub>2</sub> and NO<sub>x</sub> emissions from the electric

power sector, the highest SO<sub>2</sub> emitting sector. Under the ARP, the SO<sub>2</sub> program set a permanent cap on the total amount of SO<sub>2</sub> that may be emitted by electric generation units in the contiguous United States starting in 1995. The reductions are phased in over time, with the final 2010 SO<sub>2</sub> cap set at 8.95 million tons.

To achieve SO<sub>2</sub> emission reductions, the ARP uses a market-based cap and trade program that allows flexibility for individual combustion units to select their own method of compliance. The number of SO<sub>2</sub> allowances allocated in a given year to a particular unit is determined by *Clean Air Act* provisions, and



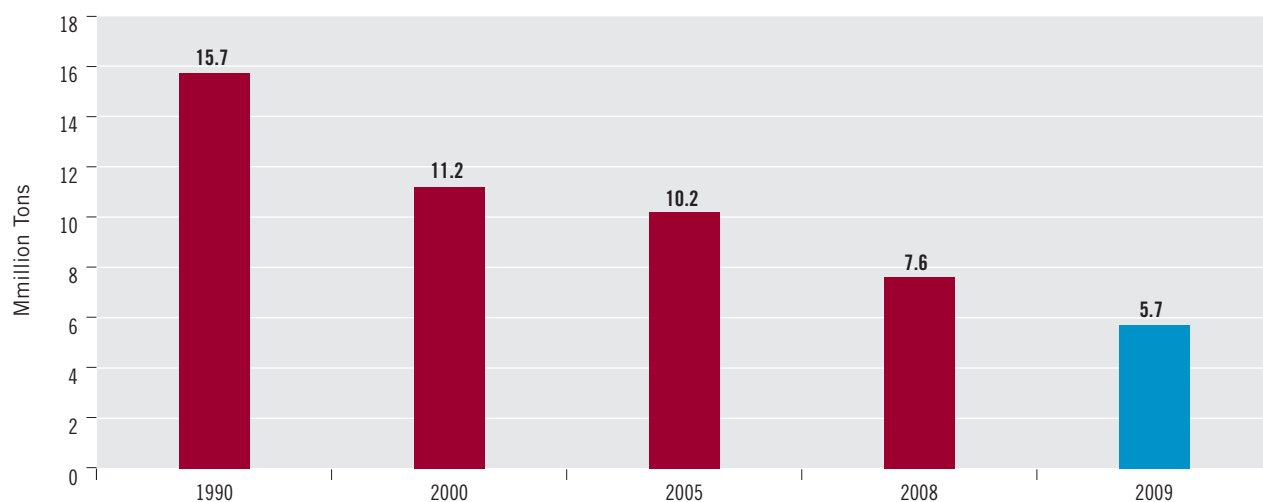
the total allowances allocated each year must not exceed the national cap. Every year, each individual source must hold enough allowances to cover its annual emissions. Unused allowances can be sold (traded) or banked (saved) for future use. The banking of allowances gives sources the flexibility to determine how they will comply with program requirements over time.

In 2009, the ARP's SO<sub>2</sub> program affected 3,572 electric generating units (EGUs). The Environmental Protection Agency (EPA) allocated approximately 9.5 million SO<sub>2</sub> allowances under the ARP. Actual emissions from affected sources were 5.7 million tons of SO<sub>2</sub> (see Figure 2), down from 7.6 million tons in 2008 and well below the 2010 cap of 8.95 million tons. Part of this reduction was due to a lower demand for power in 2009 as well as new add-on

pollution control technology to meet recent federal and state regulations, primarily in the eastern half of the country. Additionally in 2009, the number of banked allowances grew, from about 8.5 million available for 2008 compliance to approximately 12.3 million available for 2010 and future years.

In addition to the electric power generation sector, emission reductions from other sources not affected by the ARP, including industrial and commercial boilers and the metals and refining industries, and the use of cleaner fuels in residential and commercial burners have contributed to an overall reduction in annual SO<sub>2</sub> emissions. National SO<sub>2</sub> emissions from all sources have fallen from nearly 26 million tons in 1980 to less than 11.4 million tons in 2008 (see [www.epa.gov/ttn/chief/trends](http://www.epa.gov/ttn/chief/trends)).

**Figure 2. U.S. SO<sub>2</sub> Emissions from Acid Rain Program Electric Generating Units, 1990–2009**



Source: US EPA 2010

## Key Commitments and Progress: Nitrogen Oxides Emission Reductions



Canada has met its commitment to reduce NO<sub>x</sub> emissions from power plants, major combustion sources and metal smelting operations by 100,000 tonnes below the forecasted level of 970,000 tonnes. This commitment is based

on a 1985 forecast of 2005 NO<sub>x</sub> emissions; in 2008, industrial emissions of NO<sub>x</sub> totaled 664,755 tonnes.

Transportation sources contribute the majority of NO<sub>x</sub> emissions, accounting for nearly 53% of total Canadian emissions, with the remainder generated

by power plants and other sources (see Figure 27: U.S. and Canadian National Emissions by Sector for Selected Pollutants, 2008 on page 45). Additional information on Canadian emissions

can be found at <http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1>. Canada is continuing to develop programs to further reduce NO<sub>x</sub> emissions nationwide.



The United States has achieved and exceeded its goal under the Acid Rain Annex to reduce total annual NO<sub>x</sub> emissions by 2 million tons below projected annual emission levels for 2000 without the ARP (8.1 million tons).

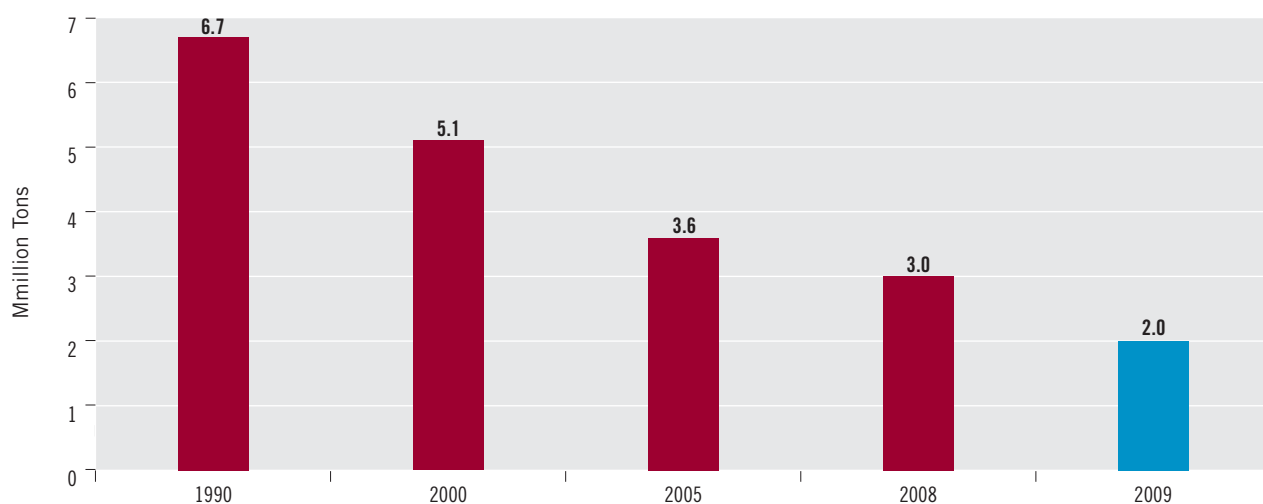
Title IV of the *Clean Air Act* requires NO<sub>x</sub> emission reductions from certain coal-fired EGUs. Unlike the market-based SO<sub>2</sub> program, the NO<sub>x</sub> program under the ARP uses rate-based-emission limits based on boiler type to achieve reductions.

In 2009, 960 coal-fired units were affected by the NO<sub>x</sub> program. All 960 met their NO<sub>x</sub> emission requirements under the ARP. Emissions of NO<sub>x</sub> from all NO<sub>x</sub> program-affected units were 1.8 million tons, and total NO<sub>x</sub> emissions from all sources covered by

the ARP were 2.0 million tons (Figure 3). This level is more than 5 million tons less than the projected NO<sub>x</sub> levels for 2000 without the ARP, or more than double the NO<sub>x</sub> emission reduction commitment under the Acid Rain Annex.

While the ARP is responsible for a large portion of these annual NO<sub>x</sub> reductions, other programs—such as the Clean Air Interstate Rule (CAIR) NO<sub>x</sub> ozone season and annual programs, and state NO<sub>x</sub> emission control programs—also contributed significantly to the NO<sub>x</sub> reductions that sources achieved in 2009. (Note that a court decision in 2008 remanded the CAIR rule to EPA and a replacement was proposed on August 2, 2010. CAIR remains in effect temporarily until the proposed rule is finalized.)

**Figure 3. U.S. Title IV Utility Unit NO<sub>x</sub> Emissions from All ARP Sources, 1990–2009**



Source: US EPA 2010

## Emissions/Compliance Monitoring



Canada has met its commitments to estimate emissions of NO<sub>x</sub> and SO<sub>2</sub> from new electric utility units and existing electricity units greater than 25 megawatts (MW) using a method comparable in effectiveness to continuous emission monitoring systems (CEMS) and to investigate the feasibility of using CEMS by 1995. Continuous emissions monitoring installation in Canada's electric utility sector has been widespread since the late

1990s. In 2010, almost all new and existing base-loaded fossil steam plants with high emission rates have operating CEMS. Coal-fired facilities, which are the largest source of emissions from the sector, have SO<sub>2</sub> and NO<sub>x</sub> CEMS installed at more than 94% of their total capacity. Under Canada's National Pollutant Release Inventory (NPRI) mandatory reporting program, electric power generating facilities are required to report their air pollutant emissions annually.



The ARP requires affected units to measure, record and report SO<sub>2</sub> and carbon dioxide (CO<sub>2</sub>) mass emissions and NO<sub>x</sub> emission rates using CEMS or an approved alternative measurement method. The vast majority of emissions are monitored with CEMS, while the alternatives provide a cost-effective means of monitoring mass emissions for smaller and/or cleaner units. Table 1 shows the amount of SO<sub>2</sub> emissions monitoring using CEMS.

Affected sources are required to meet stringent quality assurance and control requirements and report hourly emission data in quarterly electronic reports to the EPA. In 2009, the average percent of monitoring data available (a measure of monitoring systems' reliability) was 98.4% for coal-fired units. This number is based

on reported monitor data availability for SO<sub>2</sub> monitors (98%), NO<sub>x</sub> monitors (99%), and flow monitors (98.1%).

Using automated software audits, the EPA rigorously checks the completeness, quality, and integrity of monitoring data. The Agency promptly sends results from the audits to the source and requires correction of critical errors. In addition to electronic audits, the EPA conducts targeted field audits on sources that report suspect data. In 2009, source compliance with ARP emission monitoring requirements was 100% for the 3,572 covered units. All emission data are available to the public within two months of being reported to EPA. Data can be accessed on the Data and Maps website maintained by the EPA's Clean Air Markets Division at <http://camddataandmaps.epa.gov/gdm/>.

**Table 1. Units and SO<sub>2</sub> Emissions Covered by Monitoring Method for the Acid Rain Program, 2009**

		Number of Units	Percentage of Units	Percentage of SO <sub>2</sub> Emissions
Coal	CEMS	1042	29.35	98.80
Gas	CEMS	16	0.45	0.04
	Non-CEMS	2277	64.14	0.06
Oil	CEMS	43	1.21	0.16
	Non-CEMS	158	4.45	0.80
Other	CEMS	13	0.37	0.15
	Non-CEMS	1	0.03	<0.01

Note: "Other" fuel units include units that in 2009 combusted primarily wood, waste or other non-fossil fuel. The total number of units in the table excludes 17 affected units that did not operate in 2009.

Source: US EPA 2010



## Acid Deposition Monitoring, Modelling, Maps and Trends

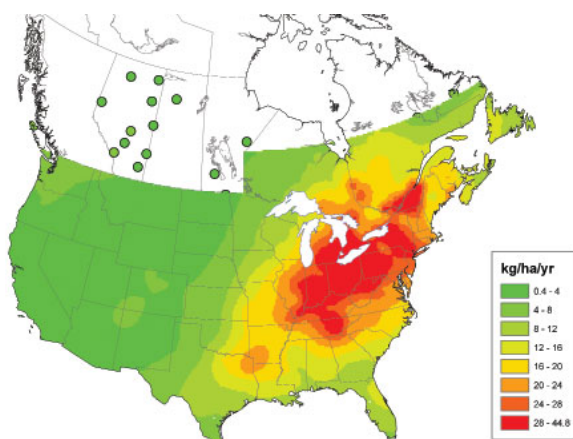
Airborne pollutants are deposited on the Earth's surface by three processes: (1) wet deposition (rain and snow), (2) dry deposition (particles and gases), and (3) deposition by cloud water and fog. Wet deposition is comparatively easy to measure using precipitation monitors, and the concentration of sulphate and nitrate in precipitation is regularly used to assess the changing atmosphere as it responds

to decreasing or increasing sulphur and nitrogen emissions. In Canada, to facilitate this comparison, measurements of wet sulphate deposition are typically corrected to omit the contribution of sea salt sulphate at near-ocean sites (less than 62 miles, or 100 kilometres [km], from the coast).

Figures 4 through 6 show the U.S.–Canada spatial patterns of wet sulphate (sea salt-corrected) deposition for 1990, 2000 and 2007 (the most recent data year). Figures 7 through 9 show the patterns of wet nitrate deposition for the same three years. Deposition contours are not shown in western Canada because Canadian scientists judged that the locations of the contour lines were unacceptably uncertain due to the paucity of measurement sites in all of the western provinces. To compensate for the lack of contours, wet deposition values in western Canada are shown as coloured circles at the locations of the federal/provincial/territorial measurement sites.

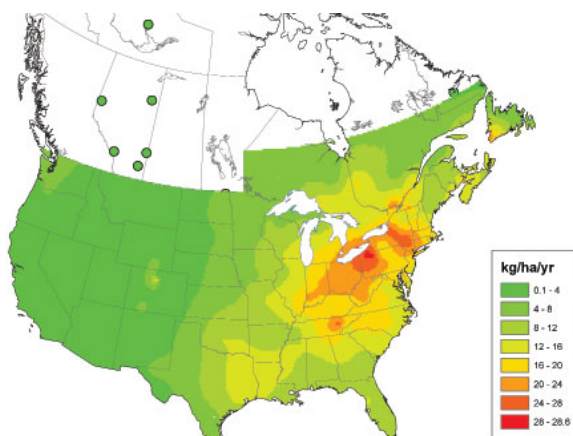
The three maps indicate that wet sulphate deposition is consistently highest in eastern North America around the lower Great Lakes, with a gradient following a southwest-to-northeast axis running from the confluence of the Mississippi and Ohio rivers through the lower Great Lakes. The patterns for 1990, 2000 and 2007 illustrate that significant reductions occurred

**Figure 4. 1990 Annual Wet Sulphate Deposition**



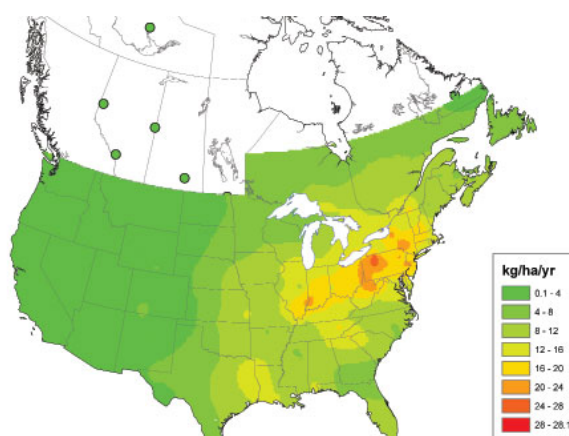
Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

**Figure 5. 2000 Annual Wet Sulphate Deposition**



Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

**Figure 6. 2007 Annual Wet Sulphate Deposition**



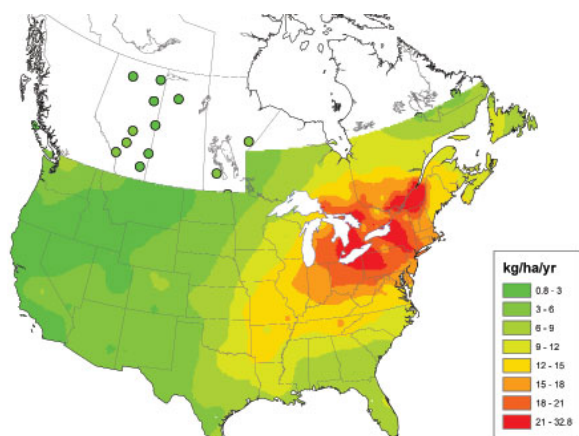
Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

in wet sulphate deposition in both the eastern United States and much of eastern Canada. By 2000, the region receiving greater than 28 kg/ha/yr (kilograms per hectare per year) of sulphate wet deposition had decreased to a small area near the southern shore of Lake Erie, and had disappeared completely in 2007. The regions receiving more than 20 kg/ha/yr of sulphate wet deposition in 1990 had also decreased markedly by 2007 to several small areas mainly in the states of Pennsylvania, New York and Indiana. The wet sulphate deposition reductions are considered to be directly related to decreases in SO<sub>2</sub> emissions in both Canada and the United States. The emission

reductions are outlined in the Key Commitments and Progress: Sulphur Dioxide Emission Reductions section beginning on page 4 of this report. The patterns of wet nitrate deposition (Figures 7 through 9) show a similar southwest-to-northeast axis, but the area of highest nitrate deposition is north of the region with the highest sulphate deposition.

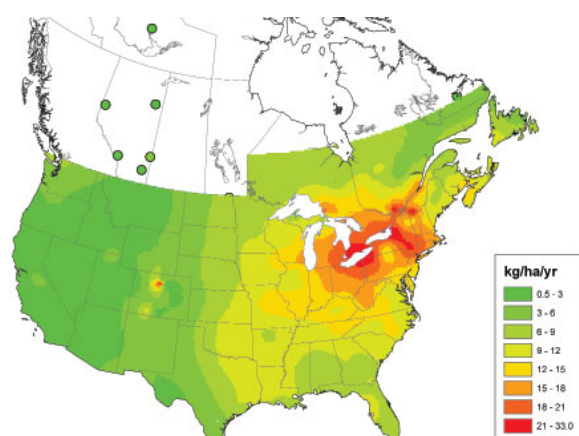
Reductions in wet nitrate deposition have generally been more modest than for wet sulphate deposition, except during the period from 2000 to 2007, when large NO<sub>x</sub> emissions reductions occurred in the United States and, to a lesser degree, in Canada. As a result,

**Figure 7. 1990 Annual Wet Nitrate Deposition**



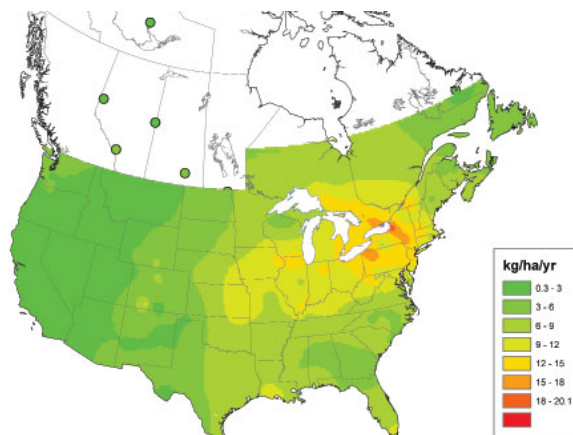
Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

**Figure 8. 2000 Annual Wet Nitrate Deposition**



Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

**Figure 9. 2007 Annual Wet Nitrate Deposition**



Source: National Atmospheric Chemistry (NAtChem) Database ([www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html)) and the National Atmospheric Deposition Program

by 2007 the regions receiving greater than 15 kg/ha/yr of nitrate wet deposition had all but disappeared in the two countries, with the exception of small areas of Pennsylvania, New York and Ontario.

Wet deposition measurements in Canada are made by the federal Canadian Air and Precipitation Monitoring Network (CAPMoN) and networks in a number of provinces/territories, including Alberta, the Northwest Territories, Quebec, New Brunswick and Nova Scotia. Dry deposition estimates are made at a subset of CAPMoN sites using combined air concentration measurements and modeled dry deposition velocities—the so-called inferential technique. In the United States, wet deposition measurements are made by two coordinated networks: the National Atmospheric Deposition Program/National Trends Network (NADP/NTN), which is a collaboration of federal, state and nongovernmental organizations (<http://nadp.sws.uiuc.edu/>), and the NADP/Atmospheric Integrated Research Monitoring Network (AIRMoN), which is a sub-network of NADP funded by the National Oceanic and Atmospheric Administration (<http://nadp.sws.uiuc.edu/AIRMoN/>). Dry deposition estimates in the United States are made using the inferential technique based on modeled dry deposition velocities and ambient air

concentration data collected by EPA, the National Park Service (NPS), and the Clean Air Status and Trends Network (CASTNET) ([www.epa.gov/castnet](http://www.epa.gov/castnet)). Wet deposition measurements in the United States and Canada are comparable, and the data are available from the websites of the individual networks and from a binational database accessible to the public at [www.msc-smc.ec.gc.ca/natchem/index\\_e.html](http://www.msc-smc.ec.gc.ca/natchem/index_e.html).

However, contrary to wet deposition estimates, the comparability of dry deposition velocities calculated by the Canadian and U.S. models is poor, although comparability between the measured air concentration values is reasonable. Studies show that dry deposition can be an important contributor to total deposition; thus ongoing efforts are in place to study the sources of the differences between the modelled dry deposition values. At the Borden research station in Ontario, instruments have been co-located for a number of years as part of an ongoing bilateral inter-comparison study on modelling dry deposition. Recent studies attempt to quantify the sensitivity of both the CAPMoN and CASTNET dry deposition models to a variety of factors that influence the dry deposition velocity, with the goal of refining model parameters for better comparability in future measurements, and reconciling past measurements.

## Preventing Air Quality Deterioration and Protecting Visibility



Canada is addressing the commitment to prevent air quality deterioration and ensure visibility protection by implementing the *Canadian Environmental Assessment Act*, the *Canadian Environmental Protection Act, 1999* (CEPA 1999), and the continuous improvement (CI) and keeping clean areas clean (KCAC) principles that are part of the *Canada-wide Standards for Particulate Matter (PM) and Ozone*.

Federal and provincial environmental assessment regulation requires that air quality be considered for all major new point sources or modifications to existing sources to ensure that Canadian objectives to protect the environment and human health are met. Mandatory provincial reporting processes require new

and existing sources to file notifications, which are reviewed to determine the scale of the environmental assessment appropriate to each case. CEPA 1999 prefers to use pollution prevention in its approach to environmental protection. Implementing similar principles—pollution prevention, CI and KCAC—is also part of the Canada-wide Standards (CWS).

There are numerous locations across Canada where ambient levels of PM and ozone are below the CWS. Actions are required to ensure that levels in these areas do not rise to the CWS, but rather, are reduced over time, and that clean areas are maintained. For example, although Metro Vancouver experiences good regional air quality relative to most other Canadian urban areas, the region adopted an Air Quality Management Plan (AQMP) in 2005 to maintain and



improve air quality in the Lower Fraser Valley airshed. The AQMP aims to minimize the risk to human health from air pollution, improve visibility, and reduce Metro Vancouver's contribution to global climate change. The CWS for  $PM_{2.5}$  (particulate matter less than or equal to 2.5 microns) is being met throughout the Lower Fraser Valley and the eastern part of the Valley is just below the CWS for ozone after having met or exceeded the standard during the past five years. The AQMP therefore supports the CI/KCAC provisions of the CWS. Also, visibility degradation in the Lower Fraser Valley occurs at concentration levels of  $PM_{2.5}$  well below the CWS. The AQMP's emission reduction actions aim to reduce direct emissions of PM and ozone, as well as PM precursors.

The province of British Columbia continues to make progress toward establishing a visibility management framework, through the efforts of the British Columbia Visibility Coordinating Committee (BCVCC), an interagency committee consisting of representatives from different levels of government involved in air quality management in the province. Although the BCVCC has been in existence since 2007, it was formalized in 2009 with the development of official terms of reference.

The BCVCC has established science, visibility index, business case, reporting and pilot project working groups to carry out projects related to visibility management. Science studies include visibility monitoring, the analysis of visibility trends, and understanding the linkage between air pollutant emissions and visibility impairment. Communications

efforts have been directed toward developing a communications strategy on visibility and the creation of a website ([www.airhealthbc.ca/ca/default.htm](http://www.airhealthbc.ca/ca/default.htm)) as a means to promote visibility and educate the public on this issue. Policy work involves the establishment of a visibility goal for B.C. and the Lower Fraser Valley, as well as the development of a metric to determine progress toward meeting the goal. These products will be evaluated and tested through a pilot project in the Lower Fraser Valley to determine if they are viable components of a visibility management framework. Furthermore, a workshop was held in April 2010 to provide direction on bringing a visibility framework to reality in B.C.

In addition to the visibility protection work underway in B.C., work is underway in other parts of Canada. In 2010–2011, a visibility monitoring pilot site will be established in the Rocky Mountains. The site meets the U.S. Interagency Monitoring of Protected Visual Environments (IMPROVE) network's siting requirements, and an agreement is being reached with the National Oceanic and Atmospheric Administration (NOAA) to have an IMPROVE speciation monitor on-site and to carry out laboratory speciation data analysis. This allows for the integration of data from this new site into the IMPROVE database and the extension of the IMPROVE visual range map into Canada. Other locations being considered for future visibility monitoring are on the Atlantic coast of Canada. Ongoing work involves the inter-comparison of IMPROVE data with the CAPMoN speciation samplers at Egbert, Ontario, to ensure data comparability.





The United States has various programs to ensure that air quality is not significantly degraded by the addition of air pollutants from new or modified major sources. The *Clean Air*

*Act* requires major new stationary sources of air pollution and extensive modifications to major existing stationary sources to obtain preconstruction permits. The permitting process is called New Source Review (NSR) and applies both to areas that meet the National Ambient Air Quality Standards (NAAQS) (attainment areas) and areas that exceed the NAAQS (nonattainment areas). Permits for sources in attainment areas are prevention of significant deterioration (PSD) permits, while permits for sources located in nonattainment areas are nonattainment area (NAA) permits.

PSD permits require air pollution controls that represent the best available control technology (BACT). BACT is an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under the *Clean Air Act*. BACT is determined on a case-by-case basis and considers energy, environmental and economic impacts.

NAA permits require the lowest achievable emission rate (LAER). BACT and LAER must be at least as strict as any existing New Source Performance Standard (NSPS) for sources. One important difference between NSR permits and the NSPS program is that NSR is applied on a source-specific basis, whereas the NSPS program applies to all sources nationwide.

The PSD program also protects the air quality and visibility in Class I areas (i.e. national parks exceeding 6,000 acres and wilderness areas exceeding 5,000 acres). The federal land management agencies are responsible for protecting air quality-related values, such as visibility, in Class I areas by reviewing and commenting on construction permits.

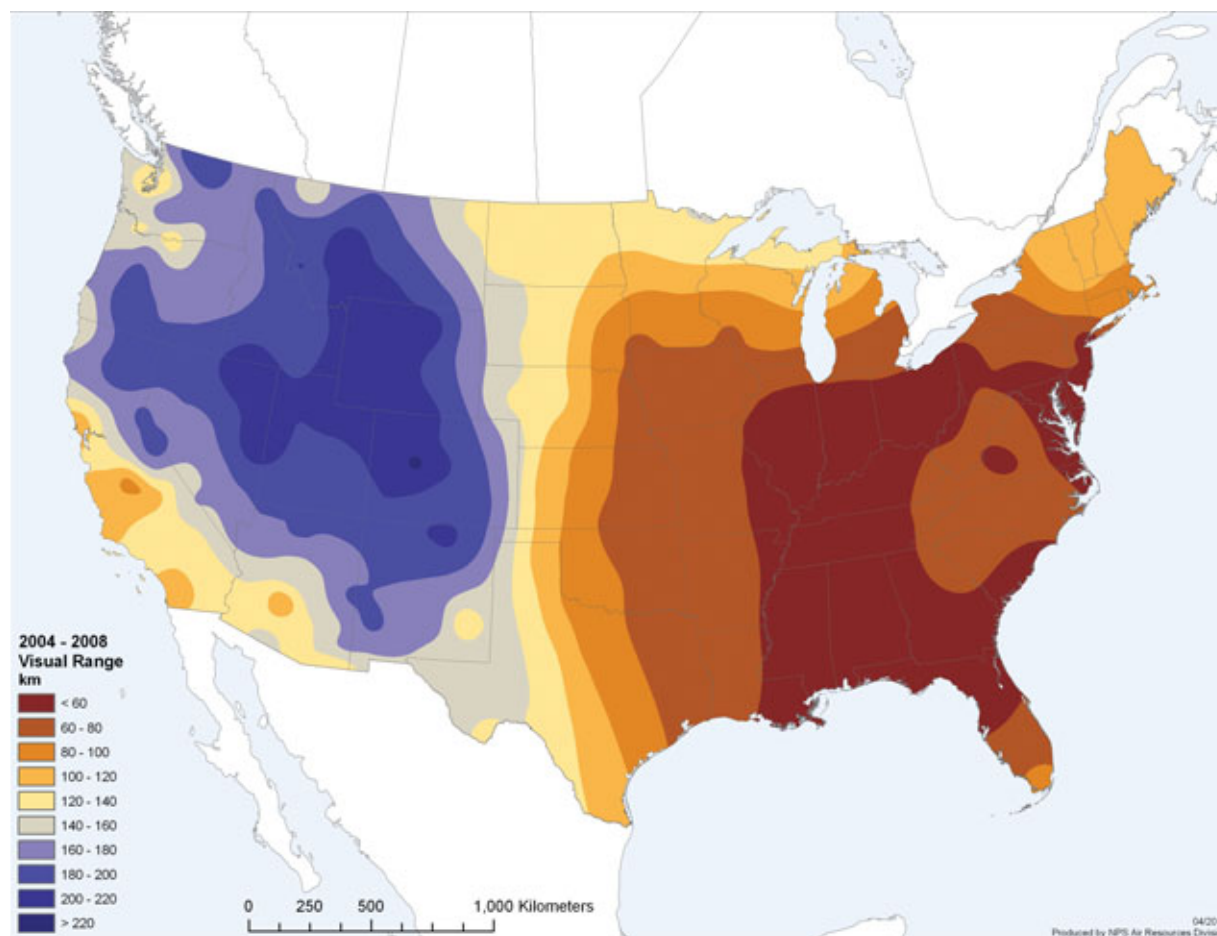
The *Clean Air Act* established the goal of improving visibility in the nation's 156 Class I areas and returning these areas to natural visibility conditions (visibility

that existed before human-caused air pollution); the 1999 Regional Haze Rule requires that states reach that goal by 2064. In July 2005, the EPA finalized amendments to the Regional Haze Rule. These amendments require the installation of emission controls, known as best available retrofit technology (BART), on certain older, existing combustion sources within a group of 26 source categories, including certain EGUs that cause or contribute to visibility impairment in Class I areas. Many of these older sources have never been regulated, and applying BART will help improve visibility in Class I areas. Most of the regional haze SIPs have been submitted, and controls to satisfy the BART requirements are to be operational no later than five years after the SIP is approved.

The first planning period establishes an assessment of expected visibility conditions in 2018. The SIPs are revised every 10 years, and states revise their visibility goals accordingly to ensure that reasonable progress is being made to achieve natural visibility conditions. There is also a reporting check every five years, in which states report their interim progress toward reaching the goals. Additional information on the EPA's Regional Haze Program can be found at [www.epa.gov/visibility/index.html](http://www.epa.gov/visibility/index.html).

Figure 10 shows the annual average standard visual range within the United States for the period 2004–2008. “Standard visual range” is defined as the farthest distance a large dark object can be seen during daylight hours. This distance is calculated using fine and coarse particle data from the IMPROVE network. Increased particle pollution reduces the visual range. The visual range under naturally occurring conditions without human-caused pollution in the United States is typically 45 to 90 miles (75 to 150 km) in the east and 120 to 180 miles (200 to 300 km) in the west. Additional information on the IMPROVE program and visibility in U.S. national parks can be found at <http://vista.cira.colostate.edu/improve/>.

**Figure 10. Annual Average Standard Visual Range in the Contiguous United States, 2004–2008**



Source: US National Park Service 2010 (data from IMPROVE website: <http://vista.cira.colostate.edu/improve/>)

## Consultation and Notification Concerning Significant Transboundary Air Pollution



Canada and the United States are continuing notification procedures, initiated in 1994, to identify potential new sources and modifications to existing sources of transboundary air pollution within 100 kilometres (62 miles) of the Canada–U.S. border. Additionally, the governments can provide notifications for new or existing sources outside of the 100 km (62 mile) region if they believe there is potential for transboundary air pollution. Since the publication of the last Progress Report in 2008, Canada has notified the United States of four additional

sources, for a total of 55 Canadian notifications. The United States has notified Canada of five additional sources for a total of 61 U.S. notifications.

Transboundary notification information is available on the government websites of each country at:

### CANADA

<http://www.ec.gc.ca/Air/default.asp?lang=En&n=162474D9-1>

### UNITED STATES

<http://www.epa.gov/ttn/gei/uscadata.html>



Following guidelines approved by the Air Quality Committee in 1998 for a consultation request by a Party on transboundary pollution concerns, Canada and the United States report ongoing progress on joint discussions concerning Essar Steel Algoma, Inc. (ESAI) in Sault Ste. Marie, Ontario.

### **Essar Steel Algoma, Inc.**

The ESAI is an integrated primary steel producer located on the St. Mary's River in Sault Ste. Marie, Ontario, approximately one mile from the Canada–U.S. border.

The Canada–U.S. Algoma informal consultation group was formed in 1998 to address concerns regarding local cross-border pollution. Representatives from the United States and Canada hold regular discussions to coordinate monitoring programs in the Sault Ste. Marie area and to address progress in abating potential transboundary air pollution from the ESAI facility in Ontario. Air quality monitoring on the Canadian side has been ongoing since the 1960s, and the monitoring on the U.S. side was initiated by the Intertribal Council of Michigan in 2001. Sampling of fine PM and toxic air contaminants continues on both sides of the border.

Canadian and U.S. representatives have continued to meet to discuss progress toward reducing emissions from ESAI and to share results of air monitoring studies. To date, the air measurements recorded at the Michigan sites do not violate U.S. ambient air quality standards, nor do they exceed air toxics levels of concern for long-term exposure. However, several pollutants, including total suspended particulates and coarse particulate matter (i.e. particulate matter less than or equal to 10 microns, or  $PM_{10}$ ), exceed Ontario air quality criteria in the west end of Sault Ste. Marie, Ontario. The U.S. 24-hour NAAQS standard for  $PM_{2.5}$  was significantly reduced in 2006, thus it is possible that Michigan sites could potentially be in exceedance of the new standard.

In 2007, the Inter-tribal Council of Michigan installed a camera, facing toward Sault Ste. Marie, Ontario, as part of the Midwest Hazecam Network (see [www.mwhazecam.net](http://www.mwhazecam.net)). The Inter-tribal Council provided the Ontario Ministry of the Environment (MOE) with photographs documenting red and black particle plumes emanating from ESAI on multiple dates from 2007 to 2009. Ontario MOE staff have documented these emissions events in their reporting system and contacted ESAI regarding previously unreported incidents.

In November 2009, the MOE confirmed that ESAI completed installation of a permanent baghouse for the #7 blast furnace in February 2009. Due to the economic downturn, plans to restart the #6 blast furnace and install permanent controls have been delayed. The furnace is presently idle and ESAI does not have any plans to start the #6 blast furnace in the near future. When it does restart the #6 blast furnace ESAI will have 10 months to have the permanent baghouse operating. During the permanent bag house installation a portable baghouse will be operating. ESAI is currently acquiring all of the mechanical components of the baghouse to ensure it can meet the agreed upon timeline. ESAI initiated the operation of its cogeneration facility earlier this year. The cogeneration facility is fully operational.

Also, ESAI has been ordered to conduct a modelling and monitoring study of the coke ovens, which will result in a determination of the best available technology to reduce fugitive emissions. ESAI has chosen to install individual oven pressure controls on the #9 battery. This retrofit is to be installed and operational by October 31, 2011. The #7 battery will be retrofitted with a mechanized door and jam cleaner, which is to be operational by October 31, 2011, as well. The ESAI bilateral consultation group will continue to monitor and report on this facility.

# Ozone Annex

## Overview



The Ozone Annex was added to the AQA in 2000 to address transboundary ground-level ozone. The annex commits both Canada and the United States to reducing emissions of NO<sub>x</sub> and VOCs, the precursors to ground-level ozone. The commitments apply to a defined region in both countries known as the Pollutant Emission Management Area (PEMA), which includes central and southern Ontario, southern Quebec, 18 U.S. states<sup>2</sup> and

the District of Columbia. The states and provinces within the PEMA are the areas where emission reductions are most critical for reducing transboundary ozone.

## Key Commitments and Progress

### Vehicles, Engines, and Fuels

**New stringent NO<sub>x</sub> and VOC emission standards for vehicles, including cars, vans, light-duty trucks, off-road vehicles, small engines and diesel engines, as well as fuels.**



Emissions from vehicles, off-road equipment, and fuels account for more than 65% of the NO<sub>x</sub> emissions and more than 30% of the VOC emissions in the Canadian PEMA region. Consistent

with its Ozone Annex obligations, Canada has implemented a series of regulations to align Canadian emission standards for vehicles and engines with corresponding standards in the United States.

The *On-Road Vehicle and Engine Emission Regulations* were in effect as of January 1, 2004, and introduced more stringent national emission standards, aligned with U.S. federal standards, for new 2004 and later model year light-duty vehicles and trucks, heavy-duty

vehicles and motorcycles. These regulations were amended in 2006 to introduce new requirements for 2006 and later model year on-road motorcycles. The changes ensure that Canadian emission standards for on-road motorcycles remain aligned with more stringent standards adopted by the EPA. In addition, Canada plans to amend the *On-Road Vehicle and Engine Emission Regulations* to require on-board diagnostic (OBD) systems for on-road heavy-duty engines such as trucks and buses.

The *Off-Road Small Spark-Ignition Engine Emission Regulations* were in effect as of January 1, 2005, and established emission standards, aligned with U.S. federal standards, for 2005 and later model year engines found in lawn and garden machines, light-duty industrial machines, and light-duty logging machines. New regulations are planned to introduce standards to reduce air pollutant emissions from large, off-road spark-ignition (SI) engines, such as forklifts.

<sup>2</sup> Connecticut, Delaware, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New York, New Jersey, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia and Wisconsin.

The *Off-Road Compression-Ignition Engine Emission Regulations* were in effect as of January 1, 2006, and introduced emission standards aligned with U.S. federal standards (Tier 2 and 3), for new 2006 and later model year diesel engines, such as those typically found in agricultural, construction and forestry machines. Environment Canada plans to amend these regulations to incorporate the more stringent U.S. Tier 4 standards.

The proposed *Marine Spark-Ignition Engine and Off-Road Recreational Vehicle Emission Regulations* were published in the *Canada Gazette*, Part I, on December 30, 2006. The proposed regulations will introduce new emission standards, aligned with U.S. federal standards, for new outboard engines, personal watercraft, all-terrain vehicles (ATVs), snowmobiles, and off-road motorcycles to apply to 2011 and later model year vehicles and engines

Regulatory initiatives for fuels include the *Sulphur in Gasoline Regulations*, which limit the level of sulphur in gasoline to 30 milligrams (mg)/kg (equivalent to 30 parts per million [ppm]) as of January 1, 2005; and the *Sulphur in Diesel Fuel Regulations*, which reduce the level of sulphur in diesel fuel used in on-road vehicles to 15 mg/kg (15 ppm) as of June 1, 2006 and the level of sulphur in diesel fuel used in off-road, rail and marine engines to 500 mg/kg (500 ppm) as of 2007. Levels have been further limited to 15 mg/kg (15 ppm) beginning in 2010 for off-road and 2012 for rail and marine engines.

Canada and the United States have agreed to work together under the Canada-United States Air Quality Agreement to reduce transportation emissions by:

- harmonizing national vehicle and engine standards for emissions of smog-forming pollutants;
- optimizing vehicle and engine emissions testing activities, taking advantage of unique testing capabilities, and sharing emissions test data where appropriate to facilitate regulatory administration activities in both countries; and
- sharing information and discussing strategies and approaches on greenhouse gas emissions standards for motor vehicles.

## Stationary Sources of NO<sub>x</sub>

**Annual caps by 2007 of 39 kilotonnes (kt) of NO<sub>x</sub> (as nitrogen dioxide [NO<sub>2</sub>]) emissions from fossil fuel power plants in the PEMA in central and southern Ontario, and 5 kt of NO<sub>x</sub> in the PEMA in southern Quebec.**

In the Canadian portion of the PEMA, the largest source of NO<sub>x</sub> emissions from industry is the fossil fuel-fired power sector. Canada has met its commitment to cap NO<sub>x</sub> emissions from large fossil fuel-fired power plants in the Ontario and Quebec portions of the PEMA at 39 kt and 5 kt, respectively, by 2007. Emissions from power plants in the Ontario portion of the PEMA were approximately 78 kt in 1990. In 2009, NO<sub>x</sub> emissions from Ontario fossil fuel-fired power plants are estimated to be 16.2 kt, or 58% below the cap. Annual NO<sub>x</sub> emissions for 2008 from Quebec fossil fuel-fired power plants in the PEMA are estimated to be 0.109 kt, considerably below the cap.

Ontario's *Cessation of Coal Use Regulation – Atikokan, Lambton, Nanticoke and Thunder Bay Generating Stations* (O. Reg. 496/07) came into effect in August 2007 and ensures that coal is not to be used to generate electricity at Atikokan, Lambton, Nanticoke and Thunder Bay Generating Stations after December 31, 2014. Ontario is planning to phase-out four more coal fired units by the end of October 2010 – two at Nanticoke and two at Lambton – with the remaining units to be phased out by the end of 2014. Lakeview Generating Station was closed in April 2005 (O. Reg. 396/01), eliminating annual emissions of approximately 5,000 tonnes of NO<sub>x</sub> and 15,900 tonnes of SO<sub>2</sub>, upwind of the Greater Toronto Area.

Ontario has been engaged in a number of clean energy projects to offset coal-fired electricity generation. Since October 2003, Ontario has secured contracts representing more than 5,000 MW of new renewable energy supply from large- and small-scale projects across Ontario. More than 1,400 MW of these projects have reached commercial operation and are generating electricity from wind, water, sun and bio-based resources.

To ensure that the 5 kt cap is met for the Quebec portion of the PEMA, Quebec's Draft Air Quality Regulation is introducing a specific cap of 2100 tonnes per year for the Sorel-Tracy plant. This plant is used mainly during peak periods, and it easily met the cap in 2008, with 109 tonnes of NO<sub>x</sub> emissions.

## Proposed National Guideline on Renewable Low-impact Electricity

**Control and reduce NO<sub>x</sub> emissions in accordance with a proposed national Guideline on Renewable Low-impact Electricity.**

A notice of a draft Guideline on Renewable Low-impact Electricity (Green Power Guideline) was published in the *Canada Gazette*, Part I, in 2001. This guideline was developed to provide national guidance on environmentally preferable electricity products and their generation in Canada, and to establish criteria for environmental labelling of qualifying electricity products under the EcoLogo<sup>M</sup> Program. Certification criteria derived from the draft guideline are being used to certify qualifying electricity products. Most Canadian provinces have developed their own specifications and requirements for renewable low-impact electricity. Notably, British Columbia and New Brunswick require their facilities to meet the certification criteria for renewable low-impact electricity, as defined by the EcoLogo<sup>M</sup> Program. The EcoLogo<sup>M</sup> certification criteria for Renewable Low-Impact Electricity are being reviewed and updated to promote continuous improvement in the environmental performance of this industry. Issuance of updated criteria is planned for 2011.

## Measures to Reduce VOCs

**Reduce VOC emissions by developing two regulations—one on dry cleaning and another on solvent degreasing—and using VOC emission limits for new stationary sources.**

The final provision of the *Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations* came into effect in August 2005. The environmental objective of the Regulations is to reduce the ambient tetrachloroethylene (PERC) concentration in the air to below 0.3 µg/m<sup>3</sup> (micrograms per cubic metre). The risk management goal of the Regulations is to reduce tetrachloroethylene

use in dry cleaning in Canada to less than 1,600 tonnes per year. In June 2009, Environment Canada completed a use pattern study and a statistical analysis of the 2006 ambient air concentrations of tetrachloroethylene across Canada, indicating that both the regulatory objective and goal have been achieved.

The *Solvent Degreasing Regulations*, which took effect in July 2003, froze the consumption of trichloroethylene (TCE) and PERC in affected cold and vapour-solvent degreasing facilities for three years (2004 to 2006) at then-current levels based on historical use. Beginning in 2007, the annual consumption levels were reduced by 65% for affected facilities.

## Measures for NO<sub>x</sub> and VOC Emissions to Attain the CWS for Ozone

**If required to achieve the CWS for ozone in the PEMA by 2010, measures will be in place to reduce NO<sub>x</sub> emissions by 2005 and implemented between 2005 and 2010 for key industrial sectors and measures to reduce VOC emissions from solvents, paints, and consumer products.**

The CWS committed provincial jurisdictions to developing implementation plans outlining the comprehensive actions being taken within each jurisdiction to achieve the standards. As the province of Quebec is not a signatory to the CWS, it is not required to develop an implementation plan. However, the following sections describe the measures that Quebec and Ontario have put in place to reduce emissions of NO<sub>x</sub> and VOCs.

Ontario's implementation plan for reducing smog-causing emissions includes the *Industry Emissions—Nitrogen Oxides and Sulphur Dioxide Regulation* (O. Reg. 194/05) which will lead to incremental reductions of NO<sub>x</sub> and SO<sub>2</sub> from facilities in seven industrial sectors. Since 2006, NO<sub>x</sub> and SO<sub>2</sub> emissions from facilities regulated under Regulation 194/05 have shown a downward trend due to a number of factors including lower economic activity and some facility improvements. More significant reductions are expected in 2010, as O. Reg. 194/05 requires a stricter cap. Further details on Ontario's implementation plan can be found at [www.ene.gov.on.ca/programs/4708e.htm](http://www.ene.gov.on.ca/programs/4708e.htm). More information on Ontario's

Regulation 194/05 (*Industry Emissions—Nitrogen Oxides and Sulphur Dioxide*) can be found at [www.ene.gov.on.ca/envision/AIR/regulations/industry.htm](http://www.ene.gov.on.ca/envision/AIR/regulations/industry.htm).

The federal government has worked in collaboration with provinces, territories and stakeholders to create a comprehensive air management system that will effectively reduce ozone-causing emissions. As part of this approach the federal government is considering new national emissions standards for key industrial sectors. In addition further actions on all sources of NO<sub>x</sub> and VOCs could be taken by provinces in areas where air quality is under pressure. Further details can be found in the New Actions on Acid Rain, Ozone and Particulate Matter section of the report.

VOC emissions from manufacturing and using consumer and commercial products, such as cleaning products, personal care products and paints, contribute significantly to the formation of smog. The federal government is therefore taking action to reduce VOC emissions from consumer and commercial products.

Two regulations controlling VOCs in products were finalized in 2009. The *Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations* and the *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* were finalized and published in *Canada Gazette*, Part II on July 8 and September 30, 2009, respectively. A third regulation controlling VOCs in certain consumer products is expected to be finalized in 2010. The VOC concentration limits align with a number of current and upcoming regulations in California and other U.S. jurisdictions. The Canadian regulations are predicted to result in an average annual reduction in VOC emissions by 28–40% in the covered sectors.

Environment Canada is currently examining other product categories to identify additional opportunities for the reduction of VOC emissions.

## Actions by the Province of Quebec

Quebec has made progress in meeting its Ozone Annex commitments by way of several regulatory actions. The Draft Air Quality Regulation, which is an

overhaul of Quebec's current *Regulation Respecting the Quality of the Atmosphere*, contains stricter standards aimed at reducing NO<sub>x</sub> emissions from new and modified industrial and commercial boilers, in accordance with Canadian Council of Ministers of the Environment (CCME) guidelines. In addition, when burners on existing units must be replaced, the replacements must be low-NO<sub>x</sub> burners. The version of the Draft Air Quality Regulation that was published in November 2005 for consultations with interested stakeholders is being revised.

With respect to VOC emissions, proposed standards included in the Draft Air Quality Regulation aim to reduce emissions from the manufacture and application of surface coatings, commercial and industrial printing, dry cleaning, above-ground storage tanks, petroleum refineries, and petrochemical plants.

Quebec's *Regulation Respecting Mandatory Reporting of Certain Emissions of Contaminants into the Atmosphere*, which came into force in 2007, requires Quebec enterprises to report atmospheric releases of certain contaminants. It determines the reporting thresholds, the information that these enterprises will have to provide, and the parameters applicable to the calculation of the quantities of these contaminants. The Regulation allows for improved information on emission sources of air contaminants across the province, including emissions of VOCs and NO<sub>x</sub>. Quebec enterprises whose annual VOC emissions exceed 10 tonnes and annual NO<sub>x</sub> emissions exceed 20 tonnes are required to report their emissions.

Pursuant to its *Regulation Respecting Petroleum Products and Equipment*, Quebec is currently applying provisions aimed at reducing gasoline volatility during the summer months in the city of Montréal and the Gatineau to Montréal section of the Windsor–Quebec City corridor. Quebec is also evaluating the possibility of introducing amendments to the above regulation to address vapour recovery initiatives, including gasoline storage, transfer depots, and service stations, regardless of whether they are new or existing facilities, in the Quebec portion of the Windsor–Quebec City corridor. The city of Montréal is currently enforcing regulatory provisions concerning gasoline vapour recovery in its territory.



## Actions by the Province of Ontario

Ontario has met its commitments under the Ozone Annex to reduce emissions of NO<sub>x</sub> and VOCs in the Ontario portion of the PEMA. Ontario has implemented the following programs, regulations, and guidelines:

- The *Emissions Trading* regulation (O. Reg. 397/01), which establishes caps for NO<sub>x</sub> and SO<sub>2</sub> emissions from the electricity sector.
- The Ontario Drive Clean Program (established under O. Reg. 361/98, as amended by O. Reg. 578/05), which is a mandatory inspection and maintenance program for motor vehicles that identifies vehicles that do not meet provincial emission standards and requires them to be repaired. The Vehicle Emissions Enforcement Unit (Smog Patrol) complements the Drive Clean Program by conducting roadside inspections of heavy-duty and light-duty vehicles.
- The *Recovery of Gasoline Vapour in Bulk Transfers* regulation (O. Reg. 455/94), which requires gasoline facility operators to install, maintain and operate gasoline vapour recovery systems.
- The *Gasoline Volatility* regulation (O. Reg. 271/91, as amended by O. Reg. 45/97), which sets limits for gasoline vapour pressure during the summer.
- The *Dry Cleaners* regulation (O. Reg. 323/94), which requires mandatory environmental training every five years for at least one full-time employee of all dry cleaning establishments in Ontario.
- Guideline A-5: New and Modified Combustions Turbines (1994), which sets limits for NO<sub>x</sub> and SO<sub>2</sub> emissions from new and modified stationary combustion turbines.
- Guideline A-9: New Commercial/Industrial Boilers and Heaters (2001), which imposes a NO<sub>x</sub> emission limit on new or modified large boilers and heaters in industrial installations.
- The *Airborne Contaminant Discharge Monitoring and Reporting* regulation (O. Reg. 127/01), amended by O. Reg. 37/06 in February 2006, which harmonizes Ontario's air emission reporting system with Environment Canada's NPRI.

Beyond the Ozone Annex, Ontario has finalized the *Industry Emissions—Nitrogen Oxides and Sulphur Dioxide* regulation (O. Reg. 194/05) which sets limits on emissions of NO<sub>x</sub> and SO<sub>2</sub> from seven industrial sectors in Ontario. The province also amended the *Air Pollution – Local Air Quality* regulation (O. Reg. 419/05) in 2007 and 2009; this regulation introduced over 50 new and/or updated air quality standards, several of which apply to VOCs. The regulation also requires advanced air dispersion modelling assessments to provide more accurate predictions of impacts from industrial air emission sources.

## NO<sub>x</sub> and VOC Program Updates



- From 2003 to 2008, implementing the NO<sub>x</sub> transport emission reduction program, known as the NO<sub>x</sub> SIP Call, in the PEMA states that are subject to the rule.
- Starting in 2009, implementing the Clean Air Interstate Rule NO<sub>x</sub> ozone season program in the PEMA states subject to the program.
- Implementing existing U.S. vehicle, non-road engine, and fuel quality rules in the PEMA to achieve both VOC and NO<sub>x</sub> reductions.
- Implementing existing U.S. rules in the PEMA for the control of emissions from stationary sources of hazardous air pollutants and of VOCs from consumer and commercial products, architectural coatings and automobile repair coatings.
- Implementing 36 existing U.S. NSPS to achieve VOC and NO<sub>x</sub> reductions from new sources.



The NO<sub>x</sub> Budget Trading Program (NBP) was a market-based cap and trade program created to reduce the regional transport of emissions of NO<sub>x</sub> from power plants and other large combustion sources that contribute to ozone nonattainment in the eastern United States. The NBP was designed to reduce NO<sub>x</sub> emissions during the warm summer months, referred to as the ozone season, when ground-level ozone concentrations are highest.

The NBP was established through the NO<sub>x</sub> State Implementation Plan (SIP) Call, promulgated in 1998. All 20 affected states and the District of Columbia chose to meet mandatory NO<sub>x</sub> SIP Call reductions primarily through participation in the NBP. From the beginning of program implementation in 2003 to 2008, the NBP dramatically reduced NO<sub>x</sub> emissions from power plants and industrial sources during the summer months, contributing significantly to improvements in ozone air quality in the eastern United States. In 2009, the NBP was replaced by the Clean Air Interstate Rule (CAIR) NO<sub>x</sub> ozone season trading program, which required emissions reductions from affected sources in an expanded geographic area and went into effect May 1, 2009.

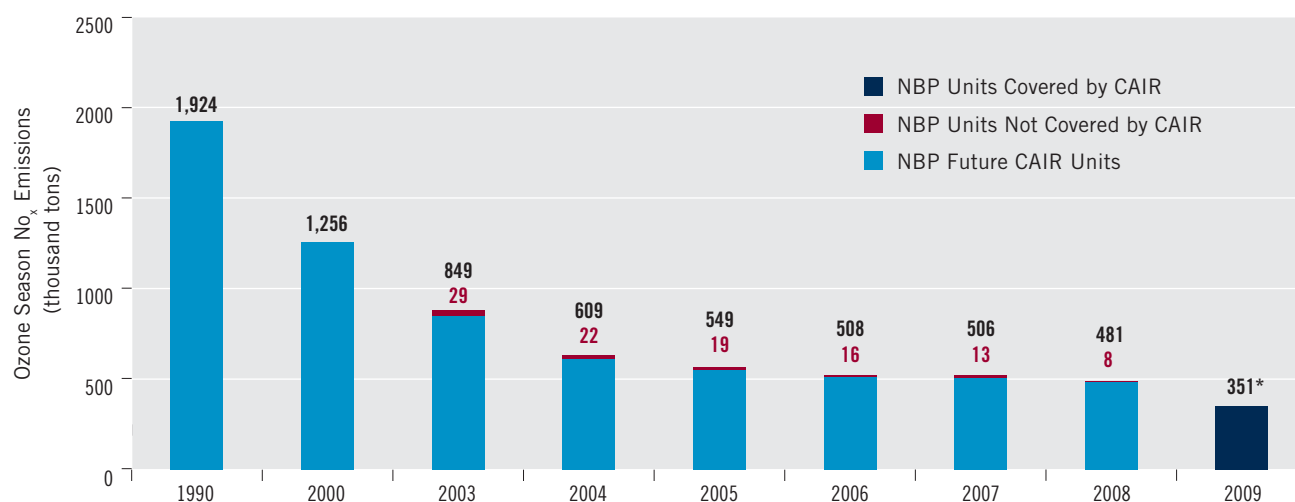
**Emissions Reductions:** In the 2008 ozone season, NBP sources emitted 481,420 tons of NO<sub>x</sub>. This is an overall decrease of almost 25,000 tons from 2007.

Figure 11 shows total ozone season NO<sub>x</sub> emissions from all NBP sources. These data include ozone season emissions prior to the start date of the NBP for some states. For example, the totals in this section include the 2003–2007 ozone season emissions for affected units in Missouri, even though those sources were not subject to the NBP emission reduction requirements until 2007.

**Compliance:** Under the NBP, affected sources must hold sufficient allowances to cover their ozone season NO<sub>x</sub> emissions each year. In 2008, 2,568 units were affected under the NBP. Of those units, only two did not hold sufficient allowances to cover 2008 emissions. Overall, affected sources achieved over 99.9% compliance in 2008.

For more information on the NBP, please visit the program's website at [www.epa.gov/airmarkets/progsregs/nox/sip.html](http://www.epa.gov/airmarkets/progsregs/nox/sip.html). Detailed emissions results and other facility and allowance data are also publicly available on the EPA's Data and Maps website at <http://camddataandmaps.epa.gov/gdm>. To view emissions and other facility information in an interactive file format using Google Earth or a similar three-dimensional platform, go to [www.epa.gov/airmarkets/progress/interactivemapping.html](http://www.epa.gov/airmarkets/progress/interactivemapping.html).

**Figure 11. Ozone Season NO<sub>x</sub> Emissions from NO<sub>x</sub> Budget Trading Program Sources**



Notes: NBP units not covered by CAIR are those units that were included in the NBP but not covered under the 2009 CAIR NO<sub>x</sub> ozone season program.

\*The 2009 total includes only former NBP units now covered by CAIR.

Source: US EPA 2010

## Current CAIR Implementation in NBP States (transition from NBP to CAIR NO<sub>x</sub> Ozone Season Program)

All former NBP states except Rhode Island are in the CAIR NO<sub>x</sub> ozone season program, which also includes six additional eastern states (Arkansas, Florida, Iowa, Louisiana, Mississippi and Wisconsin) and full state coverage in Alabama, Michigan and Missouri. The CAIR NO<sub>x</sub> annual and CAIR SO<sub>2</sub> programs, which address PM<sub>2.5</sub>, apply in all of the CAIR NO<sub>x</sub> ozone season states except Connecticut, Massachusetts and Arkansas, and also include Texas and Georgia. These areas are shown in Figure 12. In a November 2009 rule, the EPA stayed the effectiveness of CAIR for Minnesota, which had previously been identified as significantly contributing to nonattainment of PM<sub>2.5</sub> ambient air quality standards in downwind states. Therefore, the EPA is excluding Minnesota sources and emissions from compliance requirements.

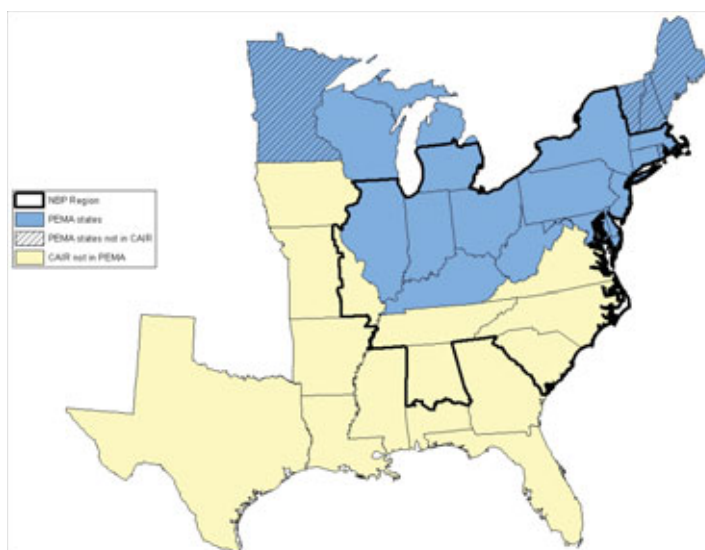
The 2009 CAIR NO<sub>x</sub> ozone season emissions cap for EGUs was at least as stringent as the NBP, and in some states was tighter. The trading budget for any

NBP state that includes its industrial units under CAIR remains the same for those units as it was in the NBP. CAIR also allows sources to bank and use pre-2009 NBP allowances for CAIR NO<sub>x</sub> ozone season program compliance on a 1:1 basis, thereby giving sources in those states the incentive to reduce emissions sooner.

Furthermore, sources outside of the NBP region can buy and use pre-2009 NBP allowances in the CAIR NO<sub>x</sub> ozone season trading program. Finally, in order to be in compliance, NBP sources that did not have enough allowances in their accounts at the end of the reconciliation period to cover their 2008 ozone season emissions surrendered 2009 CAIR allowances at a 3:1 ratio.

In 2009, there were about 3,321 affected units in the CAIR NO<sub>x</sub> annual program and 3,279 in the CAIR NO<sub>x</sub> ozone season program (Figure 13). This covers a range of unit types including units that operate everyday or nearly everyday to provide baseload power to the electrical grid as well as units that provide power on peak demand days only and may not operate at all some years.

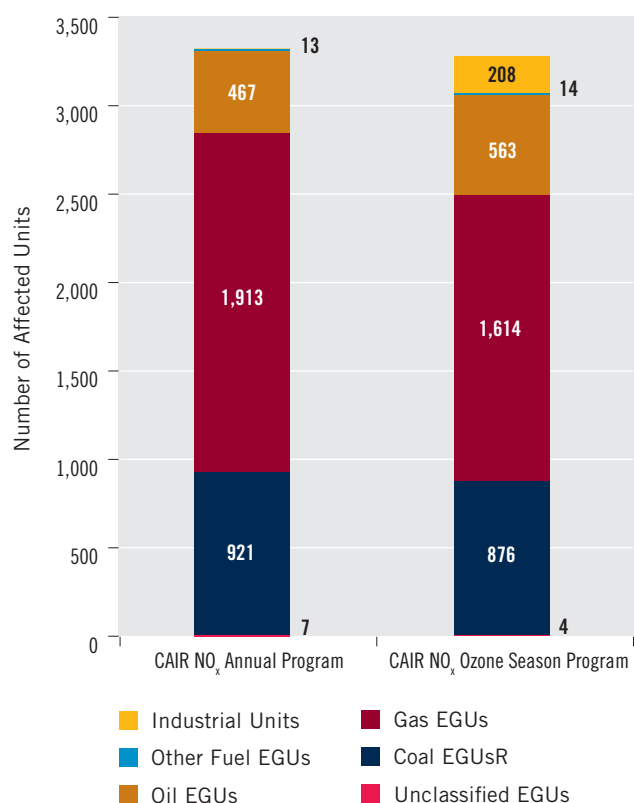
**Figure 12. PEMA Region and the Transition from the NBP to CAIR**



Note: In a November 2009 rule, the EPA stayed the effectiveness of CAIR for Minnesota, which had previously been among the states controlled for fine particles.

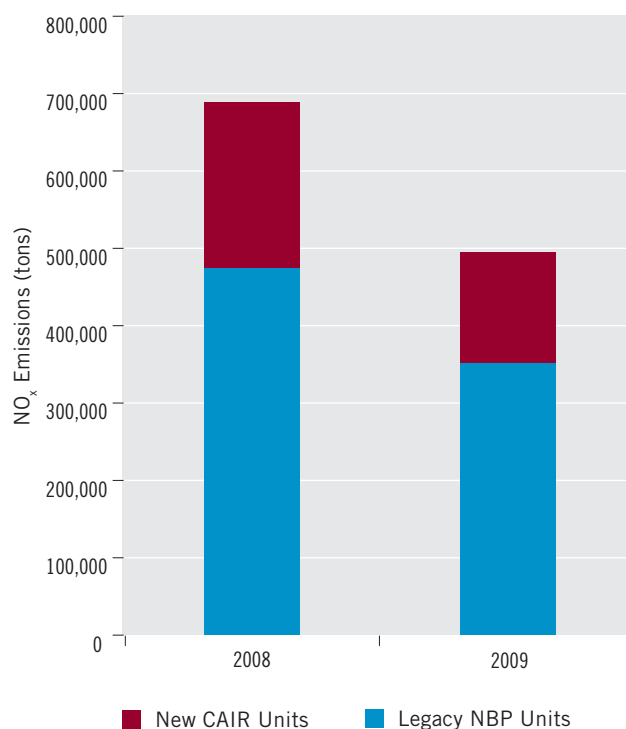
Source: US EPA 2010

**Figure 13. Affected Units in CAIR NO<sub>x</sub> Annual and CAIR NO<sub>x</sub> Ozone Season Programs**



**Emissions Reductions:** Between 2008, the CAIR transition year, and 2009, when compliance became mandatory, ozone season NO<sub>x</sub> emissions fell in every state participating in the CAIR NO<sub>x</sub> ozone season program. Units in the seasonal program reduced their overall NO<sub>x</sub> emissions from 689,000 tons to 495,000 tons (Figure 14). An 11% drop in heat input and a 22% improvement in NO<sub>x</sub> rate accounted for this reduction in total summer NO<sub>x</sub> emissions.

**Figure 14. Ozone Season Emissions from CAIR NO<sub>x</sub> Ozone Season Sources**



## Annual NO<sub>x</sub> Reductions

From 2008 to 2009, NO<sub>x</sub> emissions from units in the CAIR NO<sub>x</sub> annual program region fell from 2.3 million tons to 1.3 million tons, reflecting a 10% drop in energy demand (as measured by heat input) and a 36% improvement in the rate of NO<sub>x</sub> emissions.

In 2009, the total emissions from sources in the annual NO<sub>x</sub> region were about 350,000 tons (21%) below the regional budget. All states participating in the program reduced emissions from 2008 levels. Eighteen states and the District of Columbia had emissions below their allowance budgets, collectively by about 191,000 tons. Another six states (Delaware, Iowa, Louisiana, Michigan, Mississippi and Pennsylvania) exceeded their 2009 budgets by a total of about 37,000 tons.



The introduction of the CAIR NO<sub>x</sub> annual program reduced year-round regional emissions in 2009 as program participants operated NO<sub>x</sub> control devices on EGUs outside the summer months. These emission reduction efforts had a dramatic impact: annual NO<sub>x</sub> emissions from EGUs fell 43%, while power demand (as measured by heat input) from those sources only dropped 10%.

**Compliance:** In 2009, the EPA moved from unit-level compliance under the NBP to facility-level compliance with CAIR. Only one CAIR facility did not hold enough allowances to cover its emissions for both the ozone season and NO<sub>x</sub> annual programs. That facility automatically surrendered a 3-for-1 penalty deduction from the next year's allowance allocation for each program. (Note that a court decision in 2008 remanded the CAIR rule to the EPA and a replacement rule was proposed on August 2, 2010. CAIR remains in effect temporarily until the proposed rule is finalized.)

**New Source Performance Standards:** All of the 36 categories of NSPS identified in the Ozone Annex for major new NO<sub>x</sub> and VOC sources are promulgated and in effect. In addition, the EPA finalized the NSPS for Stationary Compression-Ignition Internal Combustion Engines in July 2006, which is helping these sources achieve significant reductions in NO<sub>x</sub> and VOC emissions. Furthermore, in December 2007, the EPA finalized an additional nationally applicable emission standard—an NSPS for NO<sub>x</sub>, carbon monoxide (CO),

and VOC emissions from new stationary spark-ignited internal combustion engines (for more information on the Spark Ignited Internal Combustion Engine rule, see [www.epa.gov/ttn/atw/nsps/sinsps/sinspspg.html](http://www.epa.gov/ttn/atw/nsps/sinsps/sinspspg.html)).

In February 2006, the EPA promulgated the NSPS for utility and industrial boilers and combustion turbines. The updated standards for NO<sub>x</sub>, SO<sub>2</sub>, and direct filterable PM are based on the performance of recently constructed boilers and turbines. The EPA is currently reviewing the NSPS for petroleum refineries and for equipment leaks at chemical plants and petroleum refineries. The equipment leak standards were completed in October 2007, and the petroleum refineries standard was completed in April 2008.

**VOC Controls on Smaller Sources:** In 1998, the EPA promulgated national rules for automobile repair coatings, consumer products, and architectural coatings. The compliance dates for these rules were January 1999, December 1998, and September 1999, respectively. From a 1990 baseline, the consumer products and architectural coatings rules are each estimated to achieve a 20% reduction in VOC emissions, and the automobile repair coatings rule is estimated to achieve a 33% reduction in VOC emissions. Currently, the EPA is developing amendments to the consumer products rule and the architectural coatings rule based on the Ozone Transport Commission model rules for these categories. Both amended rules will have a compliance date of 2012.

In addition, the EPA had previously scheduled for regulation 15 other categories of consumer and commercial products under section 183(e) of the *Clean Air Act*. To date, EPA has regulated or issued guidance on all 15 categories, including flexible packaging printing materials; lithographic printing materials; letterpress printing materials; industrial cleaning solvents; flatwood panelling coatings; aerosol spray paints; paper, film, and foil coatings; metal furniture coatings; large appliance coatings; portable fuel containers; miscellaneous and plastic parts coatings; auto and light-duty truck assembly coatings; miscellaneous industrial adhesives; and fibreglass boat manufacturing materials.

**Motor Vehicle Control Program:** To address motor vehicle emissions, the United States committed to implementing regulations for reformulated gasoline; reducing air toxics from fuels and vehicles; and implementing controls and prohibitions on gasoline and diesel fuel quality, emissions from motorcycles, light-duty vehicles, light-duty trucks, highway heavy-duty gasoline engines, and highway heavy-duty diesel engines.

On the fuel side, the EPA fully phased in requirements for reformulated gasoline in nonattainment areas in 1995 and implemented low-sulphur requirements for gasoline in 2005 and on-road diesel fuel in fall 2006 (30 ppm and 15 ppm sulphur levels, respectively).

The EPA implemented much tighter PM emission standards for highway heavy-duty engines in 2007 and correspondingly tighter NO<sub>x</sub> standards in 2010. The EPA implemented Tier 2 exhaust and evaporative standards for light-duty cars and trucks from 2004 to 2009. The EPA has also implemented on-board refueling standards and onboard diagnostic systems (OBD II) requirements for these vehicles. In 2004, the EPA published new motorcycle emission standards, which took effect in 2006 and 2010.

**Non-road Engine Control Program:** The EPA has applied engine standards in all five non-road engine categories identified in the Ozone Annex: aircraft, compression-ignition engines, spark-ignition engines, locomotives and marine engines. Non-road diesel fuel was aligned with on-highway diesel fuel at 15 ppm sulphur in 2010. Locomotive and marine diesel fuel has been limited to 500 ppm sulphur since 2007 and will align with on-highway and non-road diesel fuel at 15 ppm in 2012.

The EPA began regulating non-road spark-ignition (SI) engines in 1997 with its small SI engine rule, which applies to lawn and garden engines under 25 horsepower (hp) (19 kilowatts [kW]). Marine outboard engines and personal watercraft engines were first regulated in 1998 and 1999, respectively. Since then, the EPA has implemented tighter standards covering a wider range of SI engines. The EPA published regulations for recreational vehicles and large SI engines in November 2002. These regulations cover snowmobiles, ATVs, off-highway motorcycles, and non-road equipment with engines larger than 25 hp (19 kW). Phase-in of the emission reductions began with the 2004 model year, and full emission reductions will be achieved by the 2012 model year. The EPA's Phase 3 standards for small spark-ignition engines including marine inboard and sterndrive engines began phase-in in 2010.

In addition, the EPA began regulating non-road compression-ignition engines (diesels) with the 1996 model year and has now promulgated more stringent (Tier 4) standards for non-road compression-ignition engines. The Tier 4 standards for non-road diesels will phase in through 2014. New locomotive and marine engine standards (for engines less than 30 litres/cylinder) were finalized in March 2008 and took effect in 2008 for remanufactured locomotive and marine engines. Stringent Tier 3 standards began in 2009 for newly manufactured engines. Even more stringent Tier 4 standards requiring catalytic aftertreatment will phase in for most newly manufactured locomotive and marine engines beginning in 2014.



## Anticipated Additional Control Measures and Indicative Reductions

### National Reductions



In addition to measures to regulate emissions from vehicles, off-road equipment and fuels, the federal government developed an ecoTransport Strategy to further reduce environmental

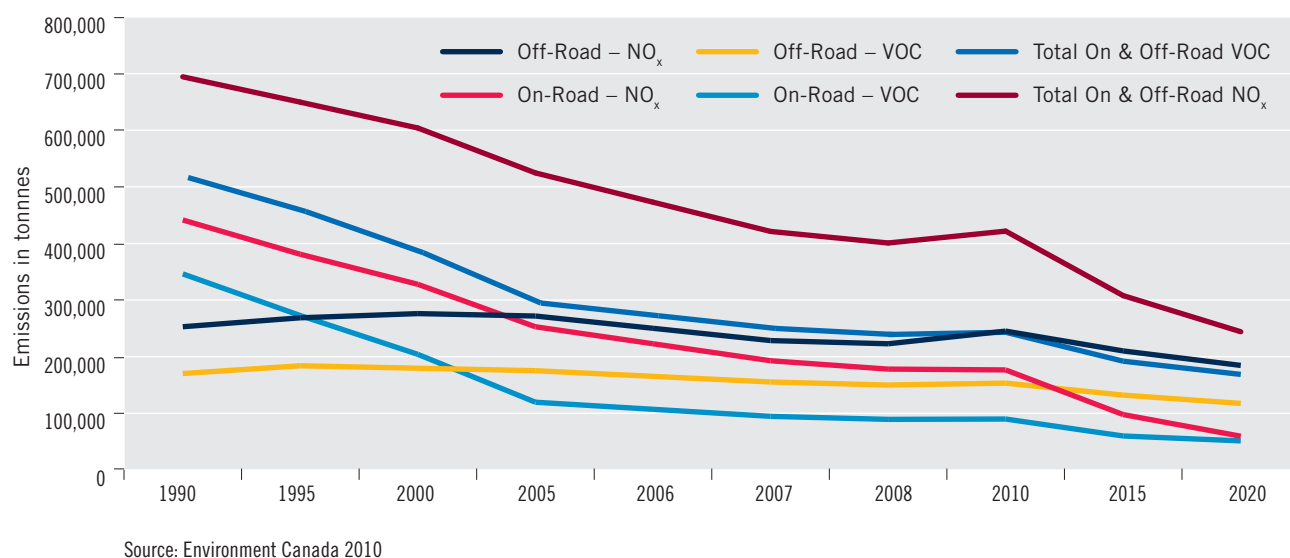
impacts of transportation. The ecoTransport Strategy involves a series of initiatives designed to reduce the amount of fuel consumed, improve transportation efficiency and introduce cleaner transportation technologies. Launched as part of the Government's Clean Air Agenda, this strategy features the following four programs: (1) the ecoMobility Program; which aims to reduce urban passenger transportation emissions by encouraging commuters to use public transit and other sustainable transportation options such as car pooling and biking; (2) the ecoTechnology for Vehicles Program; which involves purchasing and testing a range of advanced technologies, including hydrogen, fuel cell and plug-in electric hybrid vehicles to ensure that the latest clean vehicle technologies are available quickly in Canada; (3) the ecoEnergy for Personal Vehicles Program, which provides decision-making tools to encourage consumers to purchase fuel-efficient vehicles and tips for motorists on

maintaining their vehicles to reduce fuel consumption and air pollution and (4) the ecoFreight program, which works with the freight transportation industry towards greater acceptance of technologies and practices that reduce fuel consumption and air pollution (see <http://www.ecoaction.gc.ca/ecotransport/index-eng.cfm>).

Canada implemented a national vehicle scrappage program in January 2009. By August 2010, 86,000 high-polluting vehicles of model year 1995 and earlier were retired, resulting in a total reduction of 3,900 tonnes of NO<sub>x</sub> and VOC emissions. Canadians in every province are offered a selection of incentives as rewards for retiring their older vehicles that include \$300 per vehicle, free transit passes, rebates on bicycles or replacement vehicles, memberships in car-sharing programs, etc.

Since the federal government published the Regulatory Framework for Air Emissions in 2007, the government has worked with provinces, territories and stakeholders to refine the approach for managing air pollutants. The current proposal includes the establishment of national standards to reduce ozone precursor emissions from industry and other key sources.

**Figure 15. Canadian Transportation NO<sub>x</sub> and VOC PEMA Emissions Projections, 1990–2020**





The proposed reductions in air pollutant emissions and improvements to air quality would occur across the country, including in regions currently in attainment of the CWS for ozone and in the PEMA, as well as where ozone levels still exceed the CWS.

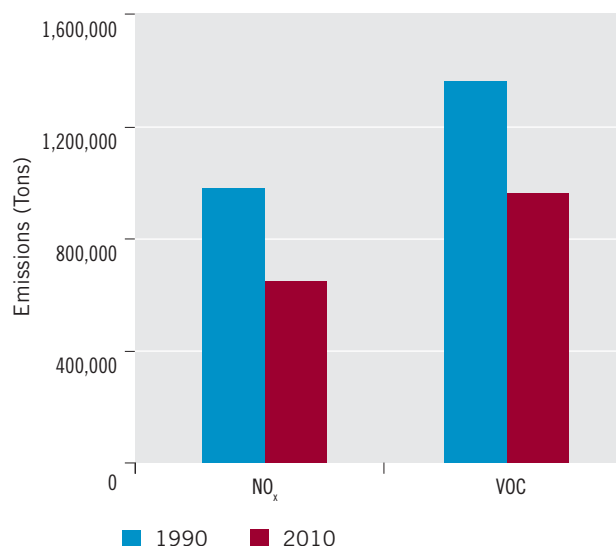
## Quantitative Estimates

In the Ozone Annex, parties provided 2010 NO<sub>x</sub> and VOC emission reduction estimates associated with applying the control measures identified under Part III of the Annex. The parties further agreed to update these reduction forecasts to demonstrate that the obligations are being implemented and to ensure that quantitative estimates reflect any emission estimation methodology improvements. The largest source of NO<sub>x</sub> and VOC emissions in the Canadian PEMA region is transportation. Figure 15 shows that NO<sub>x</sub> and VOC emissions from transportation sources in the PEMA are expected to decrease by 55% and by nearly 63%, respectively, by 2015 from 1990 levels.

Using national emission data and an improved methodology for emission projections, the specific NO<sub>x</sub> and VOC emission reduction obligations in the Annex are estimated to reduce annual NO<sub>x</sub> emissions in the PEMA by 34% and annual VOC emissions in the PEMA by 29% by 2010, from 1990 levels (see Figure 16). Canada is currently in the process of developing new emission projections based on the

2008 emissions data that will take into consideration the impact of the recent economic slowdown and the latest economic projections. These projections will be available later in 2010. The information shown in Figure 16 is the same as that presented in the 2008 progress report.

**Figure 16. Canadian NO<sub>x</sub> and VOC PEMA Emissions and Projections**



Note: Numbers for 2010 reflect all emission categories including those committed in the specific obligations in Part III of Annex 3 Specific Objective Concerning Ground-Level Ozone Precursors.

Source: Environment Canada 2006

## National Reductions



In 2010, the EPA finalized light duty greenhouse gas standards in a joint rulemaking with the U.S. Department of Transportation that will phase in between 2012 and 2016. Because they will reduce fuel consumption, these standards will reduce ozone-forming pollutants and air toxics in addition to carbon dioxide (CO<sub>2</sub>).

In another action, the EPA finalized stringent new standards for ocean going vessels (engines > 30 litres per cylinder) in 2009. These standards, which phase in through 2016 are linked to the joint establishment of Emission Control Areas (ECAs) around the U.S.

and Canadian coasts and internal waters such as the Great Lakes. These standards will impose stringent NO<sub>x</sub> standards for ships operating in the ECA and will greatly reduce PM by reducing the sulphur allowed in fuel used in the ECA. NO<sub>x</sub> emissions are expected to be reduced by 80%, SO<sub>x</sub> by 95% and PM by 85% when the requirements are fully implemented.

## Area-Specific Reductions

The EPA is implementing NO<sub>x</sub> and VOC control measures in specific areas, as required by applicable provisions of the *Clean Air Act*. The measures include NO<sub>x</sub> and VOC reasonably available control technology, marine vessel loading, treatment storage and disposal facilities, municipal solid waste landfills, onboard

refueling, residential wood combustion, vehicle inspection and maintenance, reformulated gasoline, cement kilns, internal combustion engines, large non-utility boilers and gas turbines, fossil fuel-fired utility boilers, and additional measures needed to attain the NAAQS.

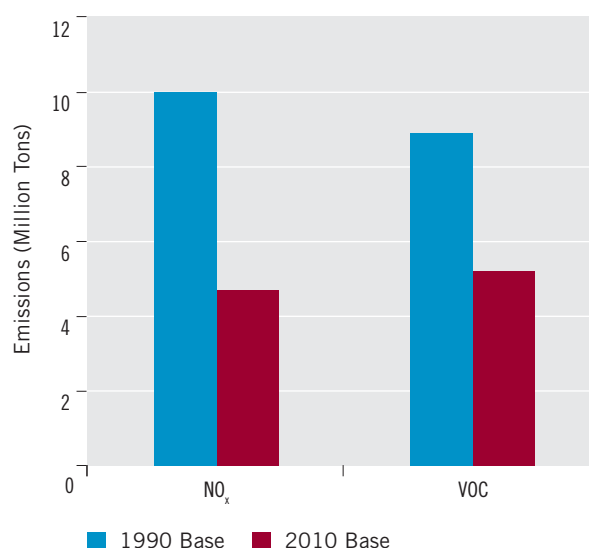
## Quantitative NO<sub>x</sub> and VOC Emission Reductions

In the Ozone Annex, the United States provided NO<sub>x</sub> and VOC emission reduction estimates associated with the application of the control strategies identified under Part III B and Part IV of the Annex. The EPA has updated these estimates using national data sets that were completed in late 2007.

The specific emission reduction obligations (see Figure 17) are now estimated to reduce annual NO<sub>x</sub> emissions in the PEMA by 53% (versus the predicted overall emission reduction rate of 43%) and annual VOC emissions in the PEMA by 41% (versus the predicted overall emission reduction rate of 36%) by 2010, from 1990 levels. Note that the U.S. emissions projections are based on implementation of the Clean Air Interstate Rule. A CAIR replacement rule has not been finalized, thus revised emissions

projections that reflect this new regulation are not currently available. Since CAIR remains temporarily in effect until it is replaced, the U.S. anticipates that the 2010 projected emissions reductions will be comparable to those shown in Figure 17.

**Figure 17. U.S. NO<sub>x</sub> and VOC PEMA Emissions and Projections**



Source: US EPA 2008

## Reporting PEMA Emissions



**Provide information on all anthropogenic NO<sub>x</sub> and all anthropogenic and biogenic VOC emissions within the PEMA from a year that is not more than**

**two years prior to the year of the biennial progress report, including:**

- **annual ozone season (May 1 to September 30) estimates for VOC and NO<sub>x</sub> emissions by the sectors outlined in Part V, Section A, of the Ozone Annex; and**
- **NO<sub>x</sub> and VOC five-year emission trends for the sectors listed above, as well as total emissions.**

Canada and the United States have complied with emission reporting requirements in the Ozone Annex.

Canada's National Pollutant Release Inventory (NPRI) provides a comprehensive emissions inventory for pollutants such as NO<sub>x</sub>, VOCs, SO<sub>2</sub>, total PM, PM<sub>10</sub>, PM<sub>2.5</sub>, and CO that contribute to acid rain, ground-level ozone and components of smog. This comprehensive inventory is based on two components:

- mandatory annual reporting of emissions by more than 8,700 facilities; and
- emission estimates compiled for various sources such as motor vehicles, residential heating, forest fires and agricultural activities.

The information reported by facilities is publicly available on the Environment Canada website at <http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=B85A1846-1>.

The compilation of the comprehensive 2008 air pollutant emissions summaries were completed in early 2010, and the emission data have been included in this 2010 Progress Report. The historical trends (1985–2007) were also updated to reflect the latest emission estimation methods and statistics for various sectors such as on-road and non-road transportation vehicles, and the wood products industry. The Canadian emission summaries are available on Environment Canada's website at <http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=FFE5DABE-1>.

New emissions inventory modelling files for the calendar years 2006 and 2008 are now available and include updated information on the temporal and the spatial allocation of the emissions for various sources and pollutants.

In the United States, the EPA developed the National Emissions Inventory (NEI) as a comprehensive inventory covering emissions in all U.S. states for point sources, nonpoint sources, on-road mobile sources, non-road mobile sources and natural sources. The NEI includes both criteria pollutants and hazardous air pollutants. The emissions data in this 2010 Progress Report include 2008 projections based on extrapolations of 2005 NEI data and also represent monitored, source-reported emissions under the U.S. ARP and NBP through 2009. The U.S. regulations require that states report emissions from large point sources every year and for all sources once every three years. The next comprehensive U.S. emissions inventory will be for 2008 and will be issued in early 2011.

Table 2 shows preliminary Canadian and U.S. emissions in the PEMA for 2008 for  $\text{NO}_x$  and VOCs. Note that U.S. ozone season biogenic VOC emissions are not currently available. However, most of the estimated annual biogenic VOC emissions occur during the ozone season. Figures 18 and 19 show U.S. emission trends in these areas for 1990 through 2008. The trend in the PEMA states is similar to the U.S. national trend. For  $\text{NO}_x$ , most of the emission reductions come from on-road and non-road mobile sources and electric utilities. Over



this same period, the reductions in VOC emissions are primarily from on-road mobile sources and solvent utilization. VOC emissions from non-industrial fuel combustion increased after 1998 and then returned to a downward trend by 2000, but saw a significant spike upward in 2001. The general rise in VOC emissions from 2001 to 2002 is in part due to improved characterization methods for non-industrial fuel combustion (e.g. commercial and institutional sources such as office buildings, schools, hospitals), petroleum refining, solvent utilization, non-road mobile sources, residential wood combustion, and wildfires. Also, there are changes to VOC emissions around 2005 when compared to the 2008 Report due to a correction for VOC emission rates for residential wood combustion and a more complete exclusion of wildfire data.

**Table 2. PEMA Emissions, 2008**

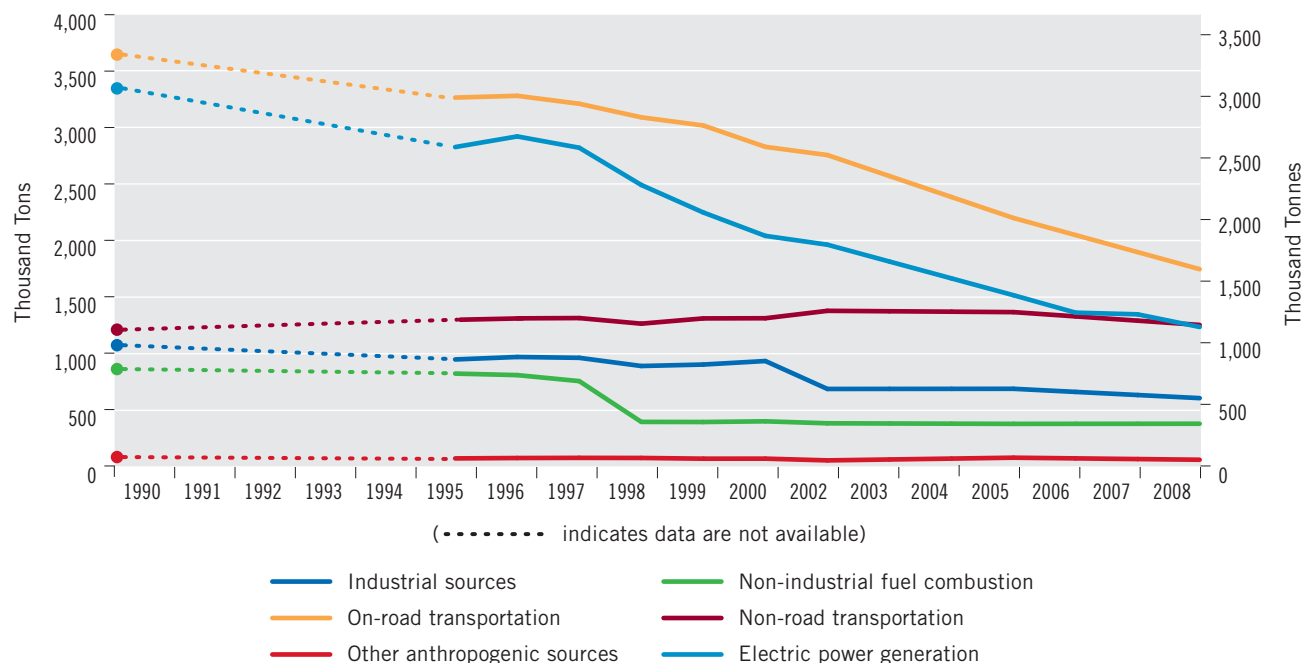
Emissions Category	2008 Annual				2008 Ozone Season			
	NO <sub>x</sub>		VOCs		NO <sub>x</sub>		VOCs	
	1000 Tons	1000 Tonnes	1000 Tons	1000 Tonnes	1000 Tons	1000 Tonnes	1000 Tons	1000 Tonnes
<b>Canadian PEMA Region: Annual and Ozone Season Emissions</b>								
Industrial Sources	91	83	87	79	39	36	37	34
Non-industrial Fuel Combustion	48	43	102	93	12	11	17	15
Electric Power Generation	39	36	0	0	16	15	0	0
On-road Transportation	196	178	98	89	77	70	42	38
Non-road Transportation	245	222	165	150	131	120	84	76
Solvent Utilization	0	0	263	239	0	0	112	102
Other Anthropogenic Sources	6	5	139	126	3	2	83	75
Forest Fires	0	0	0	0	0	0	0	0
Biogenic Emissions	–	–	–	–	–	–	–	–
<b>TOTALS</b>	<b>624</b>	<b>568</b>	<b>854</b>	<b>777</b>	<b>353</b>	<b>321</b>	<b>342</b>	<b>311</b>
<b>TOTALS without Forest Fires and Biogenics</b>	<b>624</b>	<b>568</b>	<b>854</b>	<b>777</b>	<b>353</b>	<b>321</b>	<b>342</b>	<b>311</b>
<b>U.S. PEMA States: Annual and Ozone Season Emissions</b>								
Industrial Sources	608	552	261	236	253	230	109	99
Non-industrial Fuel Combustion	382	346	655	594	159	144	273	248
Electric Power Generation	1,236	1,122	17	16	515	467	7	6
On-road Transportation	1,747	1,585	1,179	1,070	728	660	491	446
Non-road Transportation	1,254	1,138	995	903	523	474	415	376
Solvent Utilization	1	0	1,728	1,568	0	0	720	653
Other Anthropogenic Sources	64	58	552	501	27	24	230	209
Forest Fires*	1	1	14	12	–	–	–	–
Biogenic Emissions*	149	139	4,445	4,038	–	–	–	–
<b>TOTALS</b>	<b>5,443</b>	<b>4,938</b>	<b>9,846</b>	<b>8,932</b>	<b>2,205</b>	<b>2,000</b>	<b>2,245</b>	<b>2,036</b>
<b>TOTALS without Forest Fires and Biogenics</b>	<b>5,292</b>	<b>4,801</b>	<b>5,387</b>	<b>4,887</b>	<b>2,205</b>	<b>2,000</b>	<b>2,245</b>	<b>2,036</b>

\*Data are for 2005.

Note: Tons and tonnes are rounded to the nearest thousand. Totals in final rows may not equal the sum of the individual columns.

Source: Environment Canada and US EPA 2010

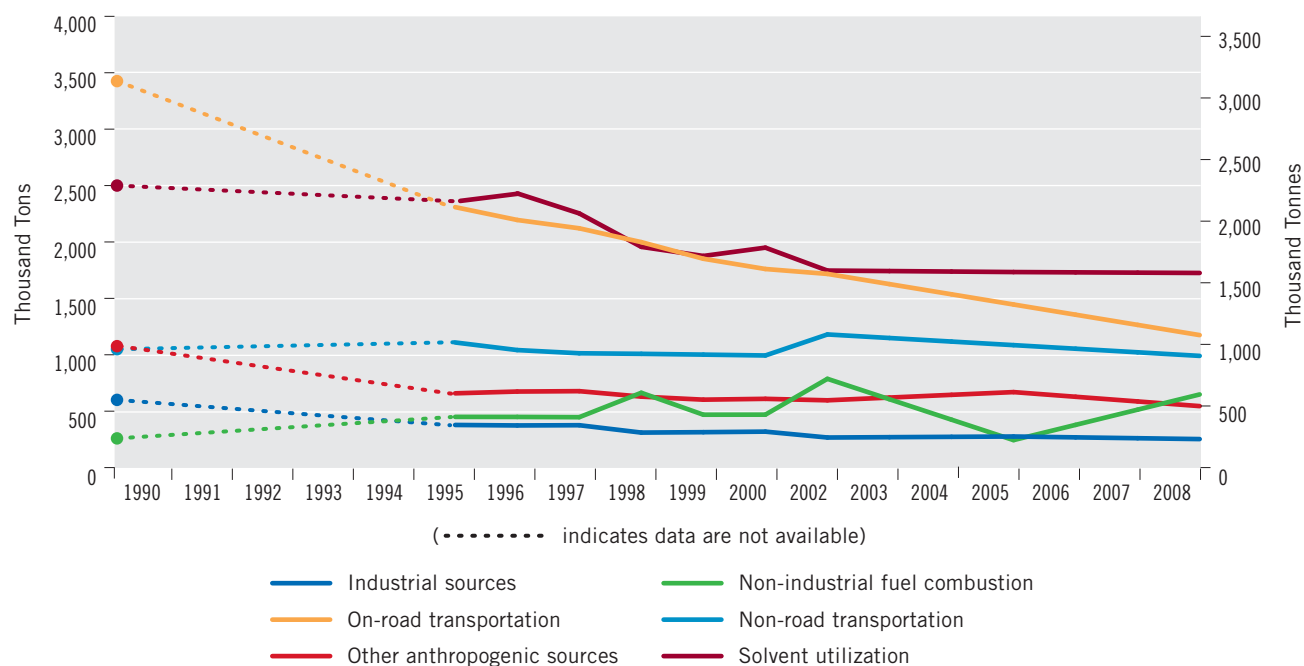
**Figure 18. U.S. NO<sub>x</sub> Emission Trends in PEMA States, 1990–2008**



Note: The scales in Figures 18–19 and 20–21 are significantly different.

Source: US EPA 2010

**Figure 19. U.S. VOC Emission Trends in PEMA States, 1990–2008**

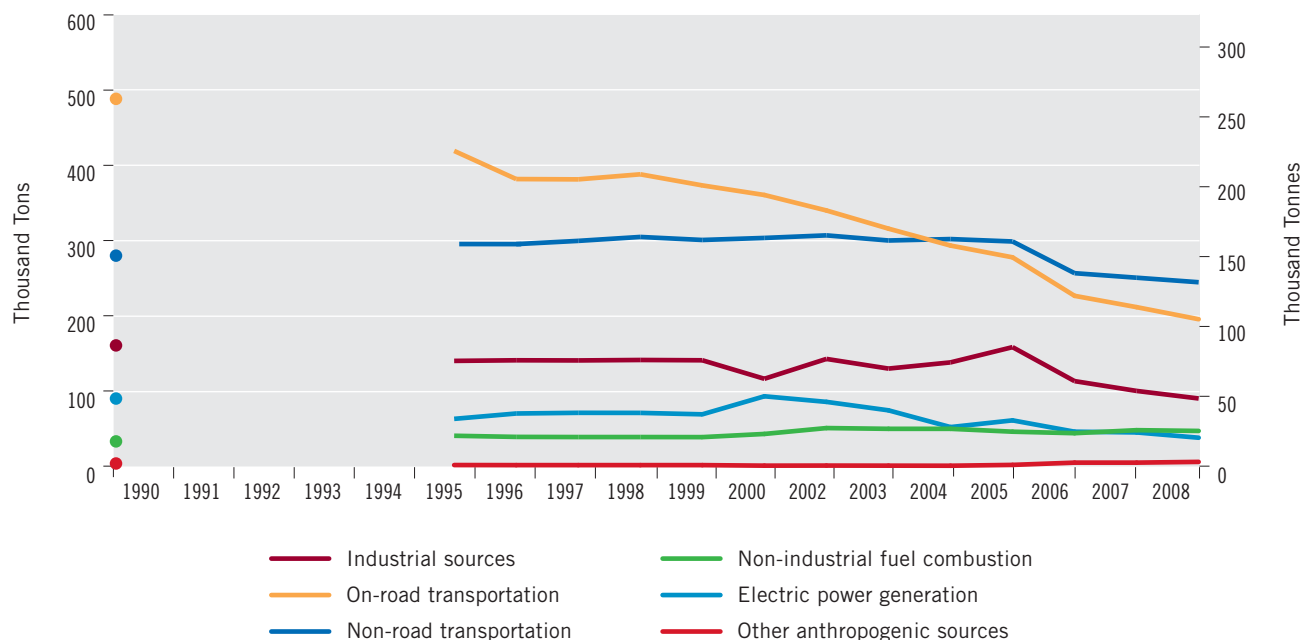


Note: The scales in Figures 18–19 and 20–21 are significantly different.

Source: US EPA 2010



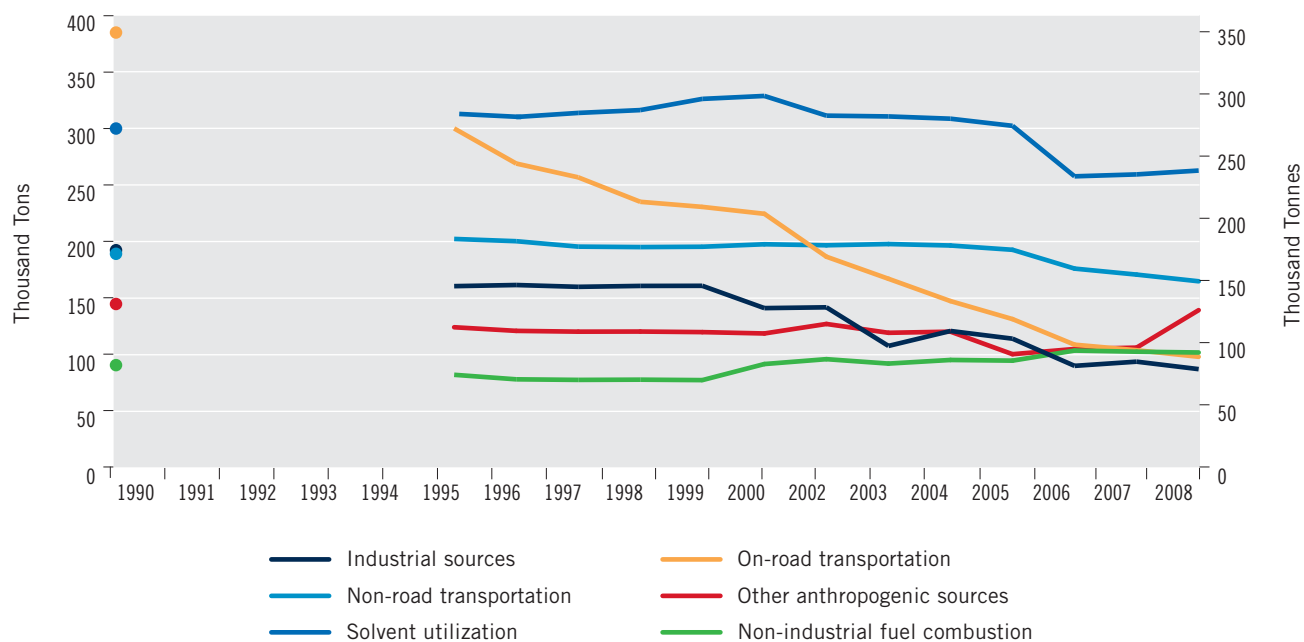
**Figure 20. Canada NO<sub>x</sub> Emission Trends in the PEMA Region, 1990–2008**



Note: The scales in Figures 18–19 and 20–21 are significantly different.

Source: Environment Canada 2010

**Figure 21. Canada VOC Emission Trends in the PEMA Region, 1990–2008**



Note: The scales in Figures 18–19 and 20–21 are significantly different.

Source: Environment Canada 2010



Figures 20 and 21 show Canadian NO<sub>x</sub> and VOC PEMA emission trends for 1990 through 2008. For NO<sub>x</sub>, most of the reductions come from on-road mobile sources and electric power generation, with increases in non-industrial fuel combustion and other anthropogenic sources. Similar reductions and

increases were observed for VOC emissions. VOC emission reductions were primarily from on-road mobile sources, electric power generation, industrial sources and solvent utilization, with a slight increase in non-industrial fuel combustion.

## Reporting Air Quality for All Relevant Monitors within 500 km of the Border between Canada and the United States



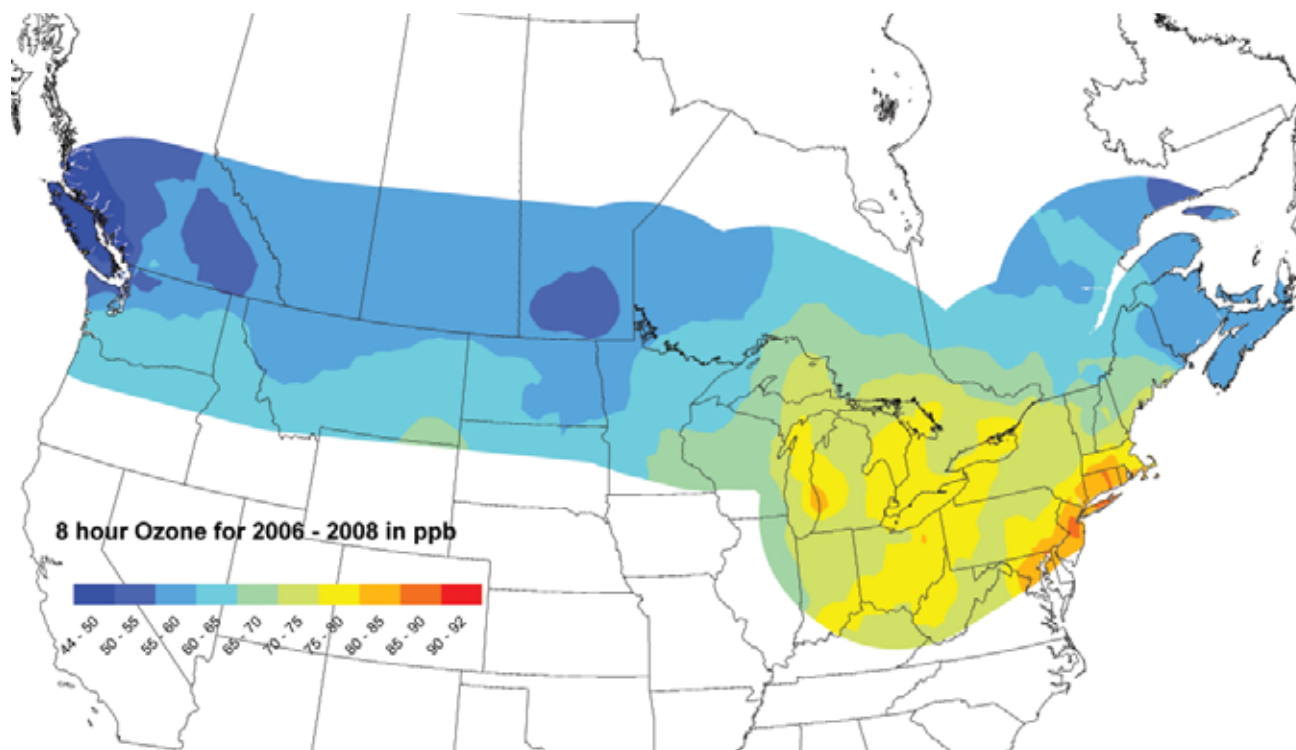
Both the United States and Canada have extensive networks to monitor ground-level ozone and its precursors. Both governments prepare routine reports summarizing measurement levels and trends. The latest quality-assured complete data set from both countries is for 2008.

### Ambient Levels of Ozone in the Border Region

Figure 22 illustrates ozone conditions in the border region in the metrics of national standards. The reference period is 2006 through 2008. Only data from sites within 500 km (310 miles) of the Canada–

U.S. border that met data completeness requirements were used to develop this map. Figure 22 shows that higher ozone levels occur in the Great Lakes and Ohio Valley regions and along the U.S. east coast. Lowest values are generally found in the West and in Atlantic Canada. Levels are generally higher downwind of urban areas, as can be seen in the western portions of Lower Michigan, though the full detail of urban variation is not shown. For ozone, the data completeness requirement was that a site's annual fourth-highest daily maximum 8-hour concentration (parts per billion [ppb] by volume) be based on 75% or more of all possible daily values during the EPA-designated ozone monitoring seasons.

**Figure 22.** Ozone Concentrations along the Canada–U.S. Border  
(Three-Year Average of the Fourth-highest Daily Maximum 8-hour Average),  
2006–2008



Note: Data contoured are the 2006–2008 averages of annual fourth-highest daily values, where the daily value is the highest running 8-hour average for the day. Sites used had at least 75% of possible daily values for the period.

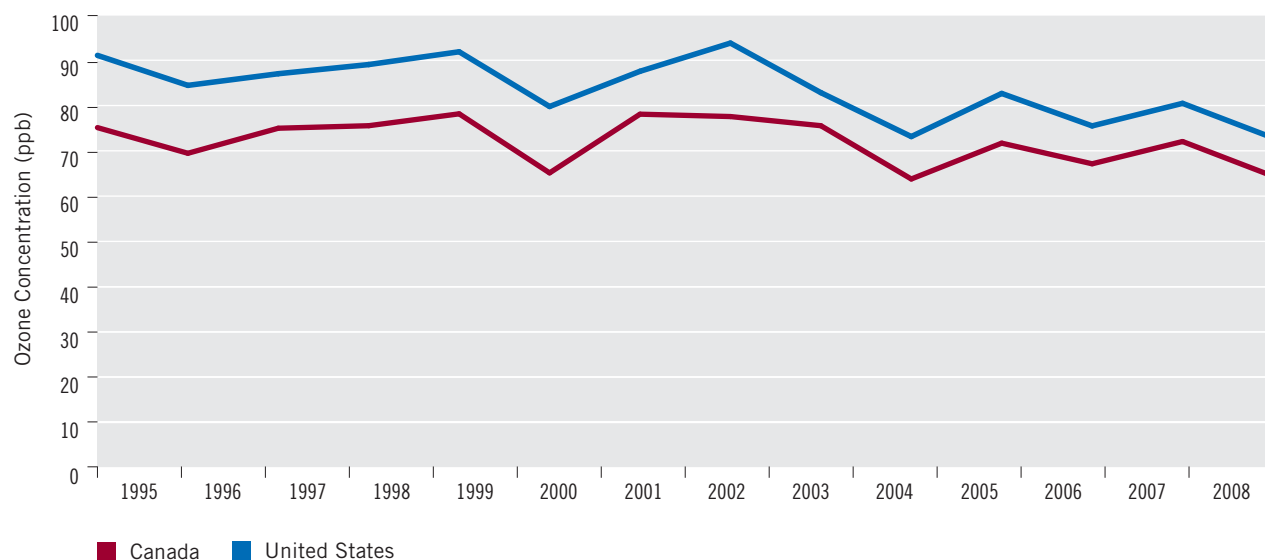
Sources: Environment Canada National Air Pollution Surveillance (NAPS) Network Canada-wide Database, 2008 (<http://www.ec.gc.ca/rnsnpa-naps/Default.asp?lang=En&n=5C0D33CF-1>); EPA Aerometric Information Retrieval System (AIRS) Database ([www.epa.gov/air/data/index.html](http://www.epa.gov/air/data/index.html))

### Ambient Concentrations of Ozone, NO<sub>x</sub>, and VOCs

Annual ozone levels over the 1995–2008 time period are presented in Figure 23, based on information from longer-term eastern monitoring sites within 500 km (310 miles) of the Canada–U.S. border. Ozone levels have decreased over the period with a notable decline in ozone levels since 2002. The lower ozone levels shown for 2004 were due, in part, to the cool, rainy summer in eastern North America. There is also a

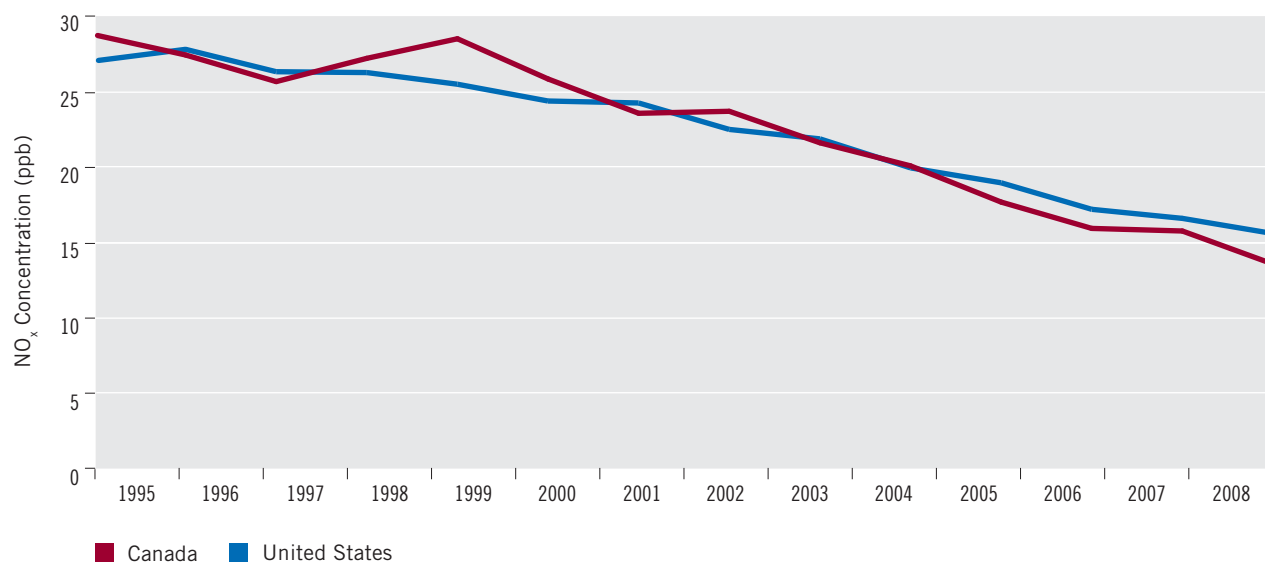
complex regional pattern in ozone level variations, which is not evident from the graph shown in Figure 23. Figures 24 and 25 depict the average ozone season levels of ozone precursors NO<sub>x</sub> and VOCs in the eastern United States and Canada. These measurements represent information from a more limited network of monitoring sites than is available for ozone. Figure 26 shows the network of monitoring sites actually used to create the trend graphs in Figures 23 through 25.

**Figure 23.** Annual Average Fourth-highest Maximum 8-hour Ozone Concentration for Sites within 500 km of the Canada–U.S. Border, 1995–2008



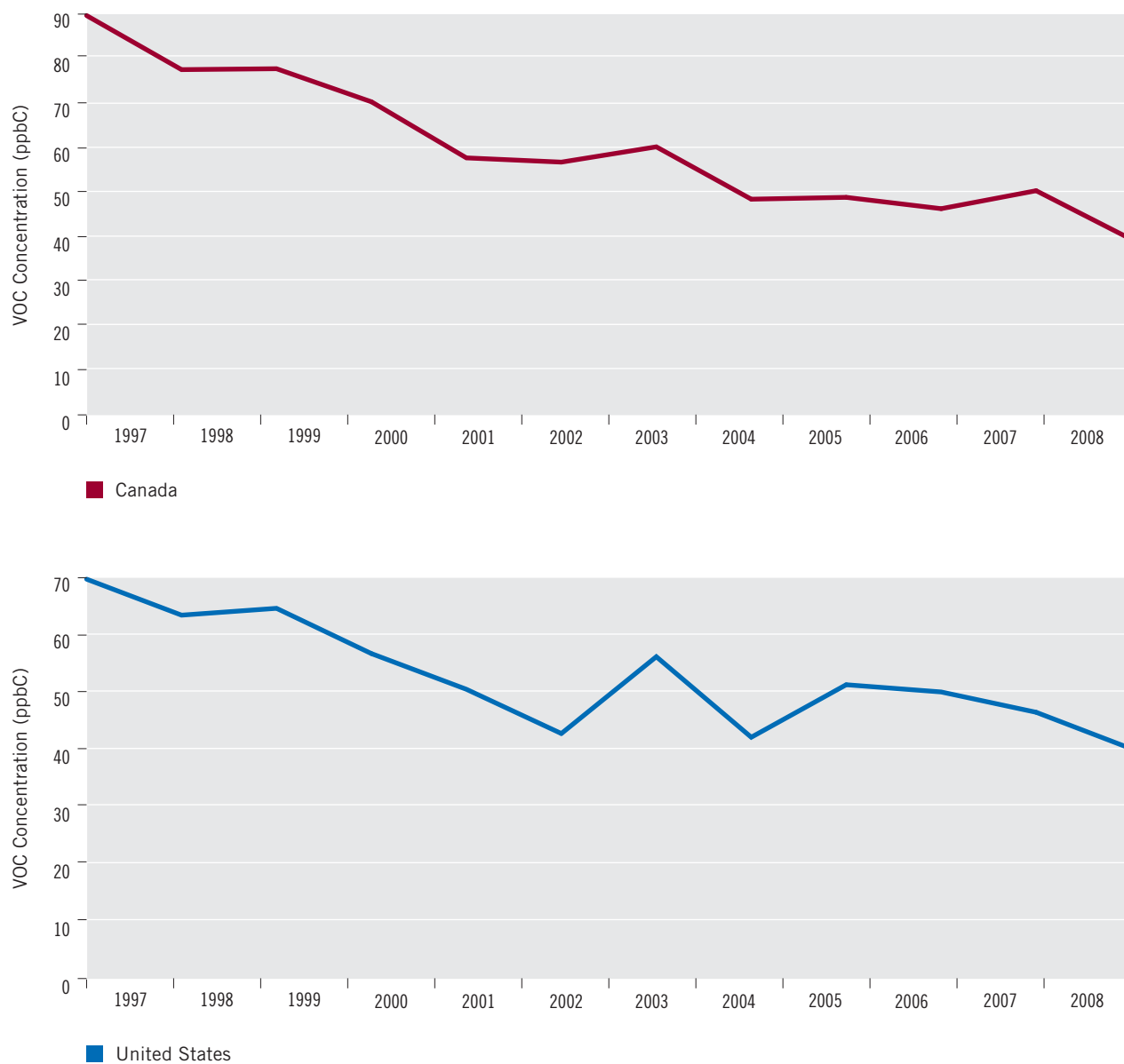
Source: US EPA and Environment Canada 2010

**Figure 24.** Average Ozone Season 1-hour  $\text{NO}_x$  Concentration for Sites within 500 km of the Canada–U.S. Border, 1995–2008



Source: US EPA and Environment Canada 2010

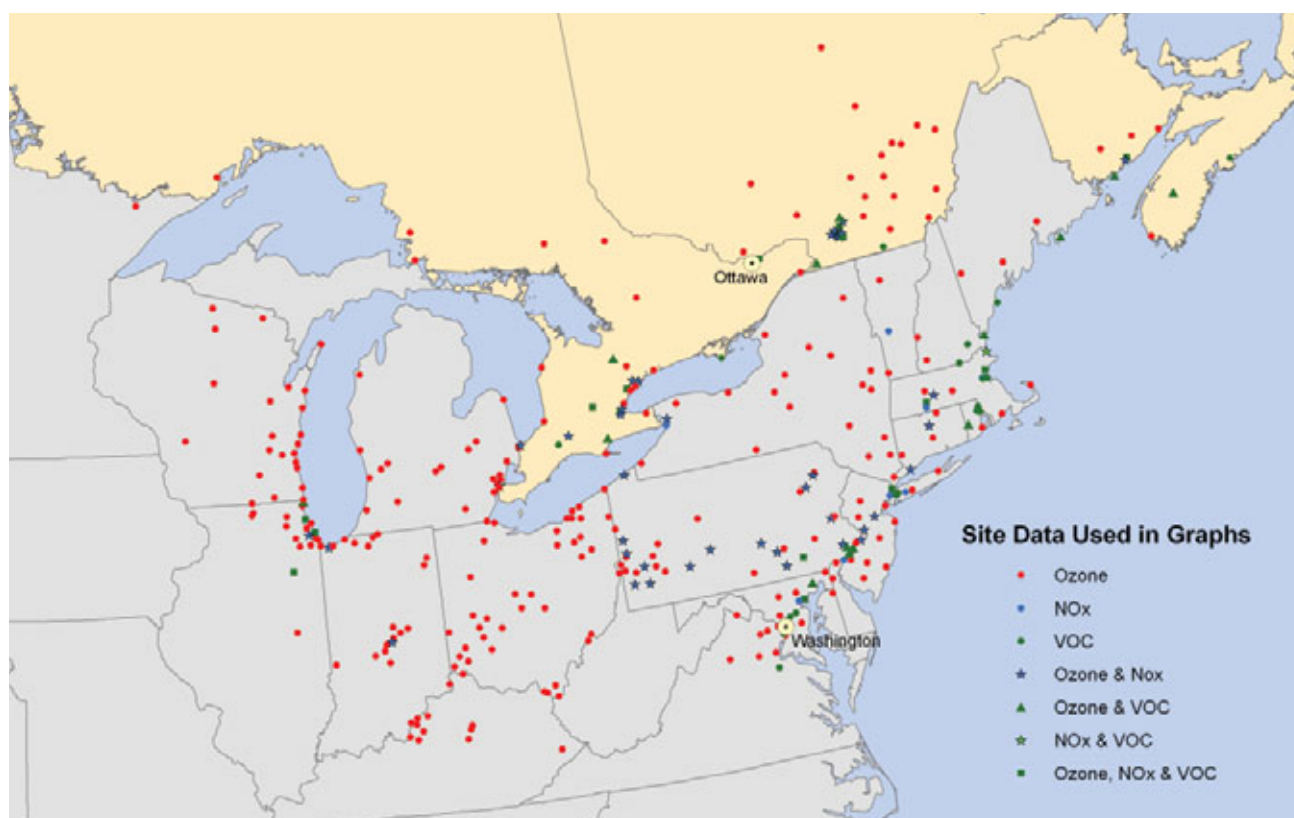
**Figure 25.** Average Ozone Season 24-hour VOC Concentration for Sites within 500 km of the Canada–U.S. Border, 1997–2008



Source: US EPA and Environment Canada 2010



**Figure 26.** Network of Monitoring Sites Used to Create Graphs of Ambient Ozone, NO<sub>x</sub> and VOC Levels



Source: US EPA and Environment Canada 2010

The data in Figures 24 and 25 represent measurements for the ozone season (i.e. May through September). Although NO<sub>x</sub> and VOC concentrations have fluctuated over recent years, because VOC concentrations are influenced by temperature, these fluctuations are most likely due to varying meteorological conditions. Overall, the data indicate a downward trend in the ambient levels of both NO<sub>x</sub> and VOCs. The limited correspondence between composite ozone and precursor trends could reflect the regional complexity of the problem as well as network limitations.

Recently in the United States, there has been much investigation into the relationship between NO<sub>x</sub> emissions reductions under the NO<sub>x</sub> SIP Call and

observed concentrations of ambient ozone in the states participating in the NBP. Generally, a strong association exists between areas with the greatest NO<sub>x</sub> emission reductions and downwind monitoring sites measuring the greatest improvements in ozone. This suggests that, as a result of the NBP, transported NO<sub>x</sub> emissions have been reduced in the East, contributing to ozone reductions that have occurred after implementation of the NBP. More information on the relationship between NO<sub>x</sub> emissions and ambient ozone concentrations in the eastern United States is available in the NO<sub>x</sub> Budget Trading Program 2008 Environmental Results report available at [http://www.epa.gov/airmarkets/progress/NBP\\_3.html](http://www.epa.gov/airmarkets/progress/NBP_3.html).

## New Actions on Acid Rain, Ozone and Particulate Matter



For the past two years the federal government has worked with provinces, territories and other stakeholders to develop a comprehensive air management system (CAMS) framework that could reduce air pollutant emissions from major sources in Canada. The federal Minister of the Environment and his provincial counterparts are currently reviewing the framework and will discuss next steps in the fall of 2010. The proposed CAMS framework includes three key elements:

### Canadian Ambient Air Quality Standards (CAAQS)

New ambient air quality standards for particulate matter (PM) and ground-level ozone would be established under CEPA 1999 and considered as new national standards to replace the existing Canada-wide Standards. There is a recommendation to subsequently develop additional CAAQS for nitrogen oxides (NO<sub>x</sub>) and sulphur dioxide (SO<sub>2</sub>) as our current objectives were last updated in the mid eighties.

### Air Zone Management/Regional Airsheds

The framework recommends the establishment of trigger levels set relative to the CAAQS to ensure proactive measures are taken to protect air quality if it is deteriorating. If pollution levels rise within local air zones (delineated and managed by the provinces), increasingly stringent action would be taken to ensure the CAAQS are not exceeded and do not become “pollute up to” levels. Four air quality trigger levels will drive a range of management actions in an escalating sequence. Airsheds will provide a framework for inter-jurisdictional collaboration and coordination of overall system reporting. Six regional airsheds will be established to understand and coordinate action on transboundary emissions.

### Base-level industrial emissions requirements (BLIERs)

BLIERs would be quantitative or qualitative emissions requirements (emissions-intensity like) proposed at a national level for new and existing facilities in major industrial sectors and three equipment types. These requirements are based on what leading jurisdictions inside or outside Canada are requiring of industry in “attainment areas,” adjusted for Canadian circumstances. The framework already proposes preliminary BLIERs for some air pollutants in nine sectors and one cross-sectoral equipment type. Additional BLIERs would need to be developed and all the proposed levels would still require validation including cost-benefit analysis.

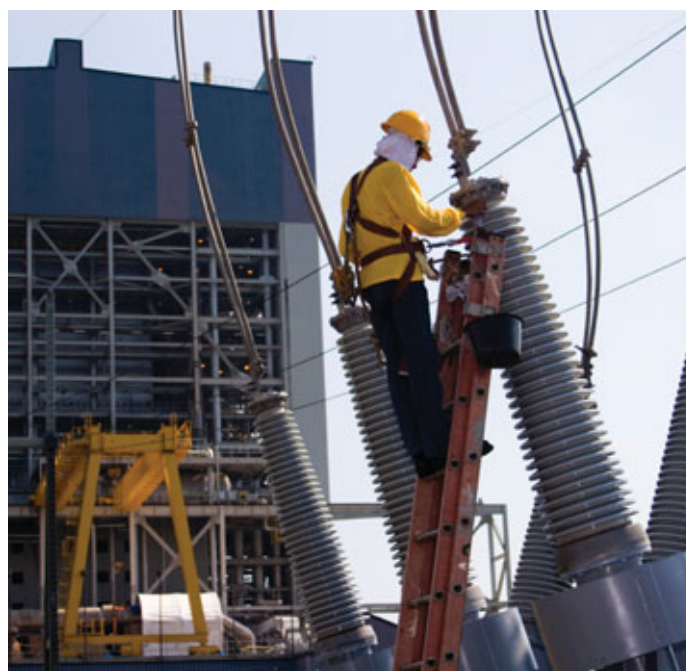
In addition to this new framework and as mentioned previously, several new regulations have been announced which will have coincidental benefits for ground-level ozone, particulate matter and acid rain forming pollutants.

The Government of Canada has proposed greenhouse gas regulations that will apply a stringent performance standard to new coal-fired electricity generation units and those that have reached the end of their economic life. The overall goal of the regulations is to transition from high-emitting coal-fired electricity generation to low- or non-emitting generation such as renewable energy, high-efficiency natural gas, or thermal power with carbon capture and storage. Draft regulations are expected to be published in Canada Gazette early in 2011, final regulations are expected to be published later that year, with the regulations scheduled to come into effect by July 1<sup>st</sup>, 2015.

The proposed regulations are expected to have important co-benefits in reducing air emissions and improving local air quality. Coal-fired generation in 2007 was a major contributor of total particulate matter

(86% of electric utility emissions), sulphur dioxide (95% of electric utility emissions), nitrogen oxide (75% of electricity emissions) and mercury (96% of electric utility emissions). Compared with business-as-usual projections, the following approximate reductions are anticipated:

- Sulphur dioxide emissions from electricity generation are projected to be some 39% lower relative to business-as-usual by 2030.
- Nitrogen oxide emissions from electricity generation are projected to be some 9% lower relative to business-as-usual by 2030. This is some 35% below 2005 levels.
- Mercury emissions from electricity generation are projected to be some 29% lower relative to business-as-usual by 2030. This is some 65% below 2005 levels.



## Ozone Standards and Implementation



In March 2008, the EPA revised the national ambient air quality standards (NAAQS) for ground-level ozone, setting them at a level of 0.075 ppm, based on an 8-hour averaging time. Both the primary standard for the protection of health and the secondary standard for the protection of sensitive vegetation and ecosystems were set at this level. While this action strengthened the standards from the previous 1997 standards level of 0.084 ppm, the new standard reflected a level above the range of 0.060 to 0.070 ppm that was recommended by the EPA's Clean Air Scientific Advisory Committee (CASAC). In response to petitions for reconsideration of the new standards, the EPA Administrator decided to reconsider the ozone standards. The reconsideration was based on the existing scientific and technical record used in the March 2008 review, which included more than 1,700 new scientific studies.

In January 2010, the EPA proposed to further strengthen the primary and secondary ozone standards. Final action on this review of the ozone standards is scheduled for fall 2010. For additional information on the proposed ozone standards and other implementation issues please visit [www.epa.gov/air/ozonepollution/actions.html](http://www.epa.gov/air/ozonepollution/actions.html).

Regarding ongoing implementation of the 1997 ozone standards (established at a level of 0.084 ppm with an 8-hour averaging time), more than 75% of the 126 areas designated as nonattainment in 2005 now attain the standards. A number of national and regional measures—such as the NO<sub>x</sub> SIP Call for electric utilities and other large sources, more stringent requirements for car and truck engines and fuels, and issuance of new standards to reduce emissions from a wide range of sources of toxic air pollutants (and VOCs)—have helped these areas attain the standards. The EPA continues to work with the remaining areas to further reduce emissions and reach attainment.





## Particulate Matter Standards and Implementation

The EPA established the original NAAQS for  $PM_{2.5}$  in 1997 to provide protection from the adverse health effects of fine particles. The primary annual  $PM_{2.5}$  standard was set at a level of 15 micrograms per cubic meter ( $\mu g/m^3$ ) averaged over three years, and the 24-hour standard was set at a level of 65  $\mu g/m^3$  (average of 98<sup>th</sup> percentile value for three consecutive years). The secondary standards for  $PM_{2.5}$ , for protection against urban visibility impairment, materials damage, and other environmental effects, were set at levels identical to those for the primary standards.

In April 2005, the EPA designated 39 areas as nonattainment areas for the 1997  $PM_{2.5}$  standards. Thirty-six of these areas are in the eastern United States (including Chicago, Detroit and Cleveland, located on the Great Lakes); two are located in California; and one area is located in the northwestern United States. States were required to submit state implementation plans to the EPA in 2008. Each plan is to include strategies and regulations for reducing emissions of

$PM_{2.5}$  and its precursors, and demonstrate how the area would attain the standards “as expeditiously as practicable,” presumptively within five years of designation. The EPA can grant extended attainment dates up to ten years from the date of designation for areas with more severe air quality situations. The 2007 Clean Air Fine Particle Implementation Rule provided guidance to the states in developing their plans and can be found at [www.epa.gov/pm/actions.html](http://www.epa.gov/pm/actions.html).

A number of federal and regional programs have been established to reduce emissions of fine particles and important precursor pollutants from key sources such as on-road and non-road vehicle engines and power plants. Examples include the 2000 heavy-duty highway diesel engine rule, the 2004 Clean Air Nonroad Diesel Rule, the 2008 Locomotive and Marine Diesel Engine Rule, and voluntary diesel retrofit programs in many states. Despite legal challenges to the Clean Air Interstate Rule, by 2009 U.S. power plants reduced  $SO_2$  emissions by 4.5 million tons since 2005. Voluntary programs to change out residential wood stoves and reduce wood smoke

emissions have also been successful in a number of cities. Together, these programs have led to important reductions in particle pollution in the United States. Through 2009, 35 of the 39 designated nonattainment areas have air quality concentrations attaining the 1997 PM<sub>2.5</sub> standards.

In October 2006, the EPA completed another review of the PM standards, reflecting findings from scientific studies published since the last review. The level of the annual PM<sub>2.5</sub> standard remained unchanged at 15 µg/m<sup>3</sup>. However, the EPA established a more protective 24-hour standard at 35 µg/m<sup>3</sup> (average of 98<sup>th</sup> percentile values for 3 years). The secondary standards were set at levels identical to those for the primary standards. The existing 24-hour PM<sub>10</sub> standard of 150 µg/m<sup>3</sup> was retained. However, due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the EPA revoked the annual PM<sub>10</sub> standard. The revised standards and related information can be found at [www.epa.gov/pm/standards.html](http://www.epa.gov/pm/standards.html).

Following the issuance of the 2006 standards, a number of parties challenged the EPA's decision not to strengthen the annual standard as recommended

by the CASAC. In February 2009, a federal appellate court remanded the 2006 annual standard back to the EPA. The EPA intends to address the remand of the annual standard in the context of the ongoing review of the PM standards, scheduled for completion in late 2011. More information on the current PM NAAQS review can be found at [www.epa.gov/ttn/naaqs/standards/pm/s\\_pm\\_index.html](http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html).

Following the revision of the 24-hour PM<sub>2.5</sub> standards in 2006, the EPA designated 31 areas as nonattainment areas for the new standard in November 2009. Sixteen of these areas had been designated nonattainment for PM<sub>2.5</sub> in 2005; 15 areas were new PM<sub>2.5</sub> nonattainment areas. In contrast to the previous round of nonattainment designations in 2005, a number of the new areas have high concentrations primarily in the cold weather months, with key contributions from wood smoke emissions. State attainment plans for these 31 nonattainment areas are due in December 2012. Additional information on the 2009 area designations can be found at [www.epa.gov/pm/designations/2006standards/](http://www.epa.gov/pm/designations/2006standards/).





## Related Air Quality Efforts

### New England Governors and Eastern Canadian Premiers

The Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) is a unique international relationship of six New England state governors (from Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont) and five eastern Canadian premiers (from New Brunswick, Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and Quebec). The conference was created in 1973 and addresses many topics, including the environment, economic development, tourism, energy, fisheries, trade and agriculture.

At the June 2009 meeting of the NEG/ECP, governors and premiers of the Acid Rain and Air Quality Steering Committee reported that they have met all of the key action items that were set out in the Acid Rain Action Plan of 1998. These included the following:

- coordinated data collection and management
- development of regional surface water quality and fine particulate matter monitoring programs
- the implementation of a regional forest mapping research project
- increased public awareness and education
- the establishment of appropriate emission reduction targets: a regional 50% reduction of SO<sub>2</sub> emissions by 2010 and a 20–30% reduction in NO<sub>x</sub> emissions by 2007

The Acid Rain and Air Quality Steering Committee is looking to refocus its activities to address current environmental concerns. It will assess current federal standards and processes for airborne pollutants in order to determine whether there is a need to update regional emissions beyond 2010. The committee is also considering initiatives related to wood combustion and expanding public access to information on air quality.

The Transportation and Air Quality Committee, established in 2007 by the governors and premiers, drafted a regional Transportation and Air Quality Action Plan in 2008 that includes recommendations to assist jurisdictions in coordinating efforts toward greenhouse gas (GHG) emission reduction. The Transportation and Air Quality Committee continues to work in the following areas:

- supporting development of environmentally friendly biofuels by assessing new technologies and local feedstocks
- promoting fuel efficiency in all modes of transportation

- expanding alternative transportation and commuter services
- aligning infrastructure funding with energy and climate goals
- seeking new opportunities to enhance regional interconnectivity and efficiency of regional freight networks
- seeking to adopt carbon dioxide and air quality standards, such as the California standards, for cars throughout the region

Further information on the work of NEG/ECP can be found at [www.cap-cpma.ca/](http://www.cap-cpma.ca/) and [www.negc.org/premiers.html](http://www.negc.org/premiers.html).





## Scientific and Technical Cooperation and Research

### Emission Inventories and Trends



The United States and Canada have updated and improved their emission inventories and projections on  $PM_{10}$ ,  $PM_{2.5}$ , VOCs,  $NO_x$ , and  $SO_2$  to reflect the latest information available.

These emissions inventories were also processed for U.S. and Canadian air quality models to support the technical assessment of air quality problems and for the development of air quality management strategies. In the United States, the most recent complete emission inventory data are for the year 2005. The 2008 emission data in this 2010 Progress Report were developed as an interpolation between the 2005 NEI and a 2009 projection inventory. The inventories and projections are available at [www.epa.gov/ttn/chief/eiinformation.html](http://www.epa.gov/ttn/chief/eiinformation.html). The 2009 projection inventory was originally prepared for possible inclusion with the emissions processing and air quality modelling in support of future EPA regulatory analyses (see CAP 2002-Based Platform Version 3, available at [www.epa.gov/ttn/chief/emch](http://www.epa.gov/ttn/chief/emch)). For Canada, the 2008 emissions inventory was developed using the latest emission estimation methods and statistics, and includes the pollutant

emissions information reported by more than 8700 facilities to the NPRI for 2008. The Canadian inventories and projections are available at [http://www.ec.gc.ca/pdb/websol/emissions/ap/ap\\_query\\_e.cfm](http://www.ec.gc.ca/pdb/websol/emissions/ap/ap_query_e.cfm).

Emission data for both countries for 2008 are presented in Figures 27, 28, 29 and 30. Figure 27 shows the distribution of emissions by source category grouping for  $SO_2$ ,  $NO_x$  and VOC. The following observations can be made from this figure:

- $SO_2$  emissions in the United States stem primarily from coal-fired combustion in the electric power sector.
- Canadian  $SO_2$  emissions come mostly from the non-ferrous smelting and refining industry, the upstream petroleum industry and electric power generation utilities. The contribution from electric power generation utilities is lower in Canada due to the large hydroelectric and nuclear capacity in place.
- The distribution of  $NO_x$  emissions in the two countries is similar, with non-road and on-road vehicles accounting for the greatest portion of  $NO_x$  emissions.

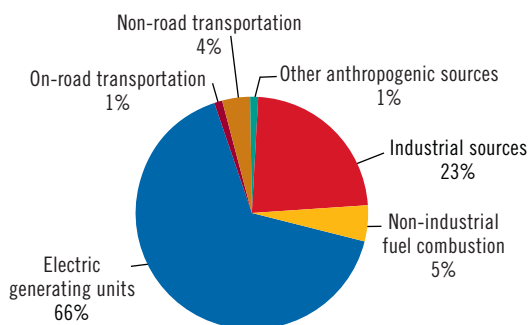


- VOC emissions are the most diverse of the emission profiles in each country. The most significant difference is that most VOCs (31%) in Canada come from the industrial sector. This is the result of the proportionately higher contribution of oil and

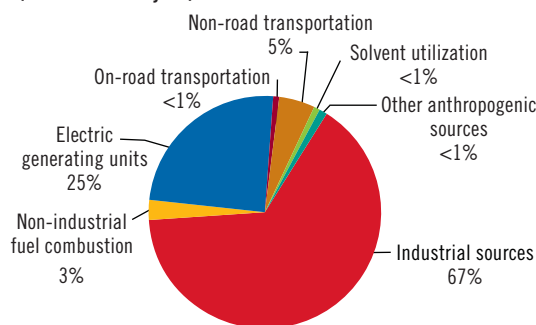
gas production in Canada. In the United States, solvents contribute the highest percentage (28%) of VOCs and on-road vehicles also contribute a sizable percentage (22%).

**Figure 27. U.S. and Canadian National Emissions by Sector for Selected Pollutants, 2008**

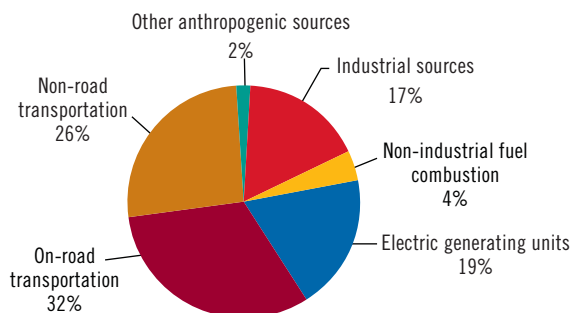
**U.S. SO<sub>2</sub> Emissions – 2008**  
Total: 11.5 million tons/year  
(10.4 million tonnes/year)



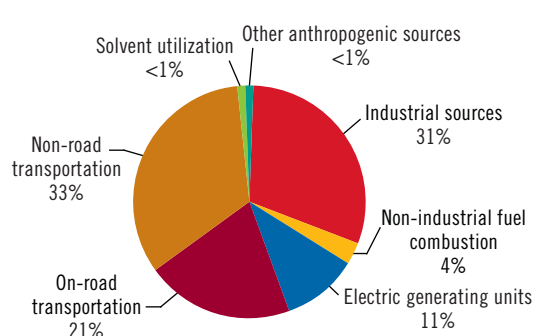
**Canadian Emissions – 2008**  
**Sulphur Dioxide**  
Total: 1.7 million tonnes/year  
(1.9 million tons/year)



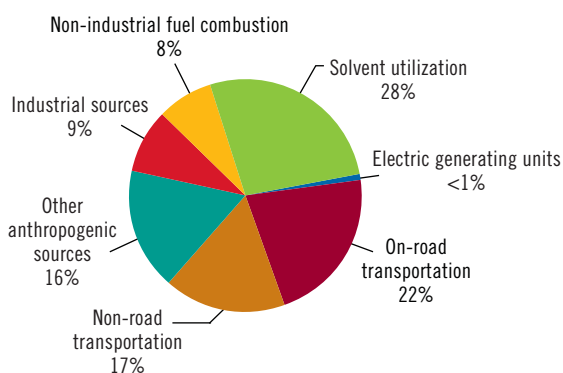
**U.S. NO<sub>x</sub> Emissions – 2008**  
Total: 16.2 million tons/year  
(14.7 million tonnes/year)



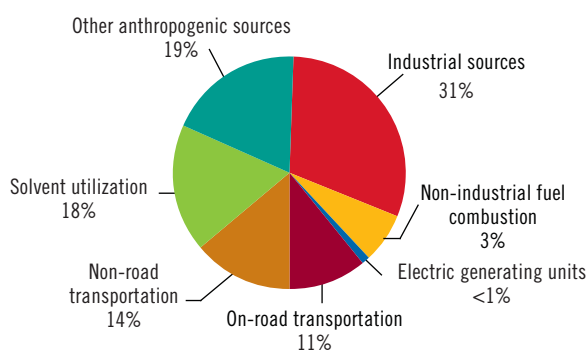
**Canadian Emissions – 2008**  
**Nitrogen Oxides**  
Total: 2.2 million tonnes/year  
(2.4 million tons/year)



**U.S. VOC Emissions – 2008**  
Total: 15.4 million tons/year  
(14 million tonnes/year)



**Canadian Emissions – 2008**  
**Volatile Organic Compounds**  
Total: 2.4 million tonnes/year  
(2.6 million tons/year)

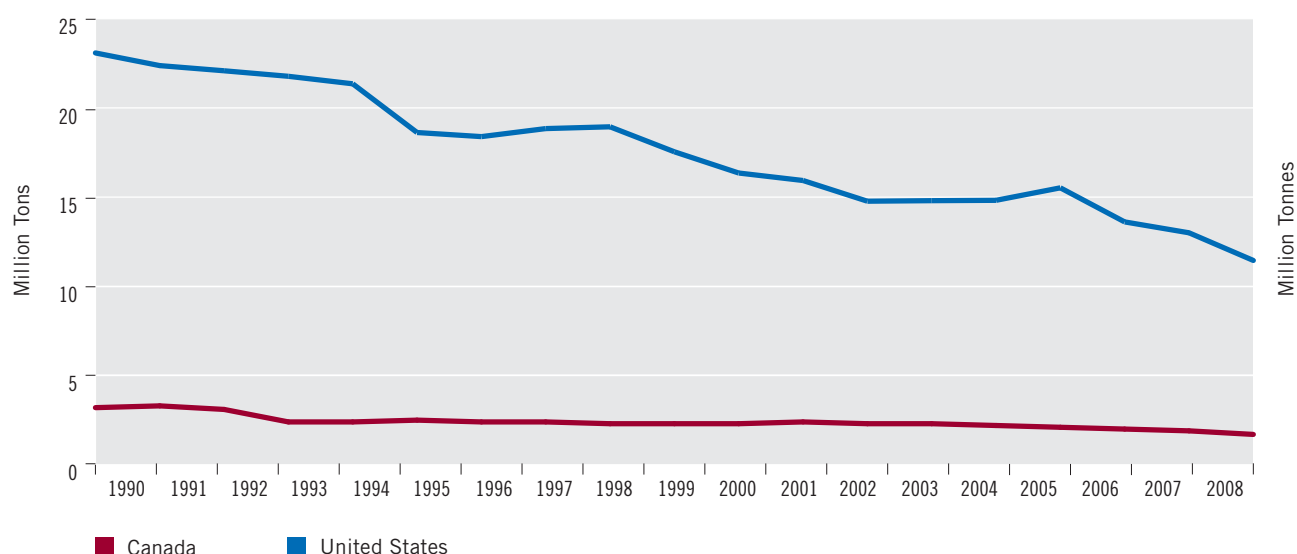


Source: US EPA and Environment Canada 2010

The emission trends reflected in Figures 28, 29, and 30 for SO<sub>2</sub>, NO<sub>x</sub> and VOCs, respectively, show emissions from 1990 through 2008. Both countries have seen major reductions in SO<sub>2</sub> emissions. In Canada, the reductions in SO<sub>2</sub> emissions came from the non-ferrous smelting and refining industry and the electric power generation utilities. For NO<sub>x</sub>, the

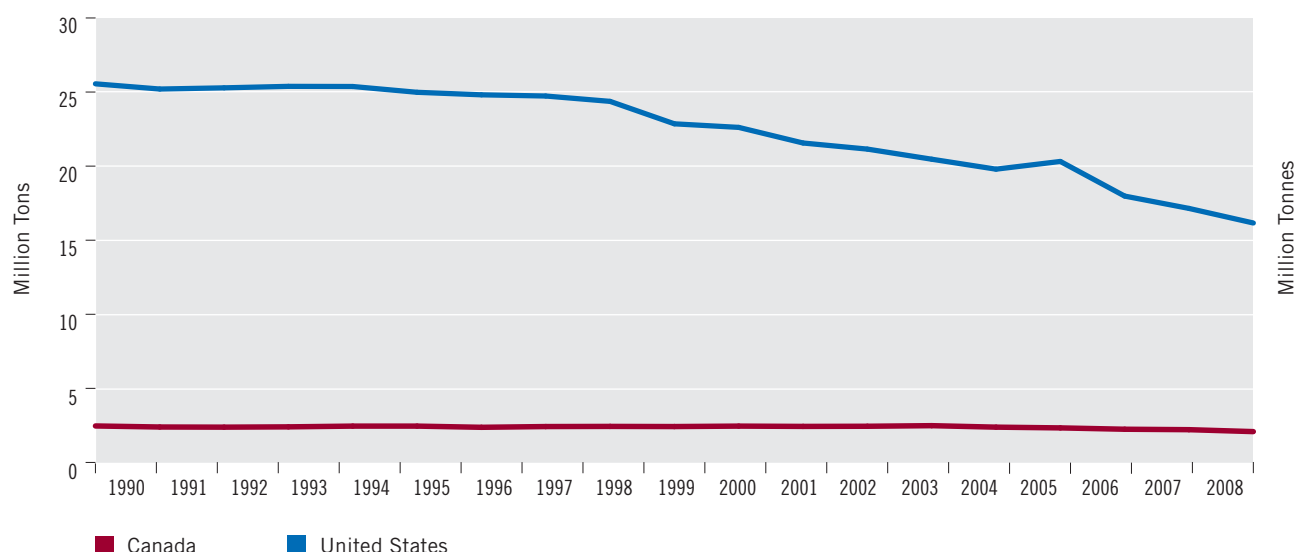
reductions were from on-road mobile sources, electric power generation utilities, and the mining and rock quarrying industry. For VOCs, the reductions came from on-road mobile sources and the downstream petroleum industry, with additional reductions from various industrial sectors such as chemical, pulp and paper, wood products, and iron and steel industries.

**Figure 28. National SO<sub>2</sub> Emissions in the United States and Canada from All Sources, 1990–2008**



Source: US EPA and Environment Canada 2010

**Figure 29. National NO<sub>x</sub> Emissions in the United States and Canada from All Sources, 1990–2008**



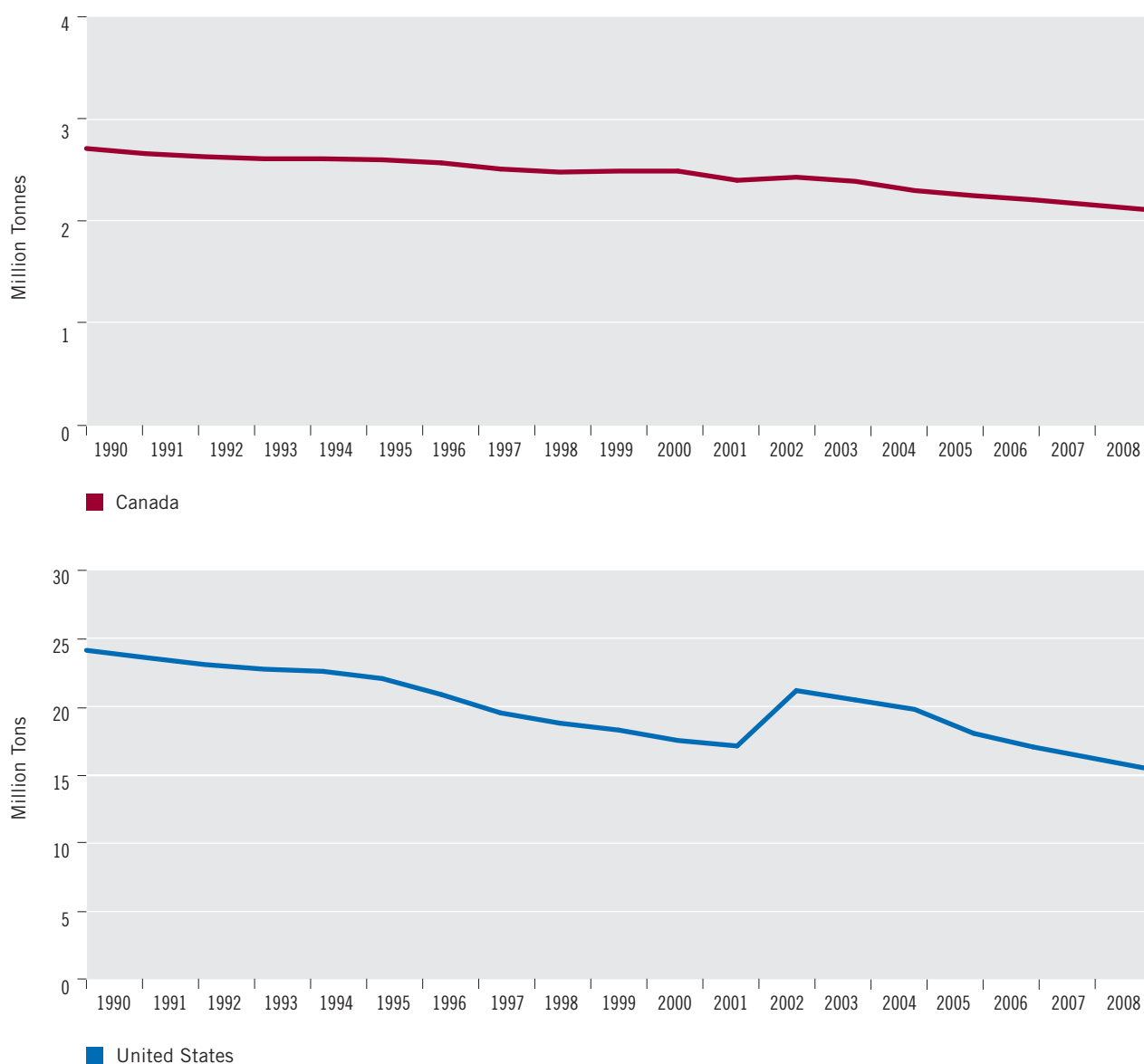
Source: US EPA and Environment Canada 2010



In the United States, there is an overall trend of emissions reduction though an increase in  $\text{NO}_x$  and  $\text{SO}_2$  emissions is shown for year 2005. The most recent version of the 2005 inventory is more comprehensive and includes some method improvements compared with the previous version reported. Some inconsistencies with the projected year data also influence the extrapolations done to develop the trends data series and should be improved when new projected inventory data are available.

In the United States, the major reductions in  $\text{SO}_2$  emissions came from electric power generation sources as well as industrial and commercial fuel combustion sources. For  $\text{NO}_x$ , the reductions came from on-road mobile sources, electric power generation sources and other fuel combustion sources. For VOCs, the reductions were from on-road mobile sources, chemical products manufacturing and use, and waste disposal including burning and wastewater treatment. (As noted earlier, the uptick in VOC emissions in 2002 is due to new and improved characterization methods.)

**Figure 30.**  
National VOC Emissions in the United States and Canada from All Sources, 1990–2008



Source: US EPA and Environment Canada 2010

# Air Quality Reporting and Mapping

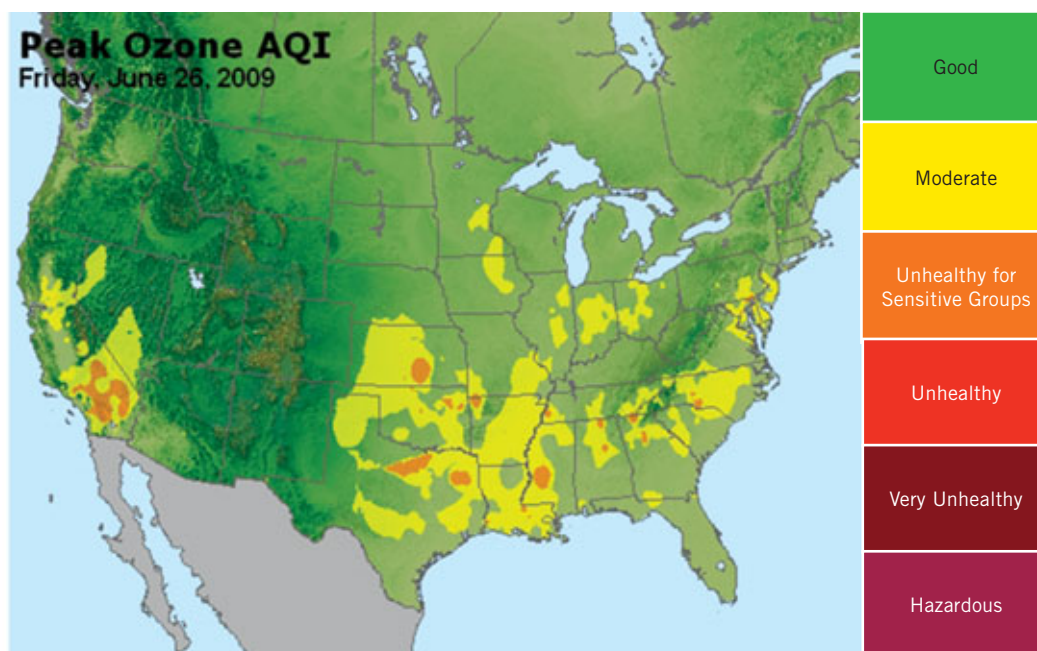


Canada and the U.S. collaborate closely on real-time air quality reporting and mapping through the AIRNow program ([www.airnow.gov](http://www.airnow.gov)), which was initiated by the U.S. EPA more than a decade ago. The AIRNow program provides current and forecasted air quality information for monitoring sites throughout the U.S. and Canada. Each country is responsible for ensuring instrument calibration and comparability of ambient measurements of ozone and PM<sub>2.5</sub>. In 2004, the AIRNow program

was expanded to provide information on PM<sub>2.5</sub> and ozone measurements on a continental scale year-round. Figure 31 is an example of the kind of maps available on the AIRNow website which display pollutant concentration data expressed in terms of the color-coded Air Quality Index (AQI).

Note: The AQI for ozone reflects 8-hour average ozone concentrations. Areas shaded orange (USG) indicate values that are “unhealthy for sensitive groups.” More information on the AQI is available at [www.airnow.gov](http://www.airnow.gov).

**Figure 31. AIRNow Map Illustrating the AQI for 8-hour Ozone**



Note: This map is an illustration of the highest ozone concentrations reached throughout the region on a given day. It does not represent a snapshot at a particular time of the day, but is more like the daily high temperature portion of a weather forecast. The AQI shown in the legend is based on 8-hour average ozone. More information on the AQI is available at [www.airnow.gov](http://www.airnow.gov).

Source: US EPA 2010



Environment Canada continues to expand and refurbish federal and provincial/territorial networks of monitoring stations across the country. Canada maintains two national ambient air quality monitoring networks—the National Air Pollution Surveillance (NAPS) Network, co-managed by federal, provincial, territorial and some municipal

governments, and the Canadian Air and Precipitation Monitoring Network (CAPMoN), operated by Environment Canada. Information about these networks can be found at <http://www.ec.gc.ca/rnsa-naps/Default.asp?lang=En&n=5C0D33CF-1> and <http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1>.

As of 2008, over 300 NAPS air monitoring stations existed, each measuring one or more of the following: ozone,  $PM_{2.5}$ ,  $PM_{10}$ , chemical composition of PM,  $SO_2$ , CO,  $NO_x$  and VOCs. Similarly, 29 CAPMoN sites existed measuring one or more of ozone,  $PM_{2.5}$ ,  $PM_{10}$ , chemical composition of PM,  $SO_2$ ,  $HNO_3$ ,  $NO/NO_2/NO_y$ , total gaseous mercury and wet deposition of major ions and mercury. Of the 29 CAPMoN sites, 16 measured ozone and 13 of the 16 were located within 500 km (310 miles) of the Canada–U.S. border to characterize regionally representative air quality. The ozone monitors at the CAPMoN ozone sites also continue to gather data in real time, in support of the Air Quality Prediction Program, and for distribution to the EPA-led AIRNow program.

Between 2005 and 2009, the federal government invested \$12 million dollars for establishing new monitoring stations and upgrading and replacing monitoring equipment at existing sites. There also were significant investments in the associated laboratories that carry out detailed chemical analysis such as VOC and  $PM_{2.5}$  speciation. As of 2008, there were 200 ozone monitors (60 at rural sites), 140  $NO_2$  monitors and 45 VOC sampling locations (14 at rural sites). There were also 210 continuous  $PM_{2.5}$  monitors reporting to the Canada-wide Air Quality Database.

For the NAPS network, substantial resources were expended in 2008–2009 to convert existing continuous  $PM_{2.5}$  instruments to U.S. Class III Federal Equivalent Method (FEM) instruments. It is planned that the entire network will be converted to FEM instruments by 2011. In addition, there are 41 filter-based samplers reporting  $PM_{2.5}$  on a one-in-three-day basis. Environment Canada has developed a chemical speciation network to characterize  $PM_{2.5}$ . Fourteen sites are now operating across Canada. The speciation network sites report fine ( $PM_{2.5}$ ) and coarse ( $PM_{10-2.5}$ ) mass, major ions, organic and elemental carbon (IMPROVE method), and metals by using ion-coupled plasma-mass spectroscopy (ICPMS) and x-ray fluorescence instrumentation (XRF) and gas-phase species including ammonia and nitric acid. In 2009, levoglucosan (a marker for biomass burning) measurements were added to the  $PM_{2.5}$  speciation program.

For the CAPMoN network, a comprehensive inter-comparison study of commercially available PM instruments was initiated in late 2008. This study was undertaken to assess the best PM monitoring technology to be used at remote locations in harsh Canadian weather conditions—ensuring accurate data, robustness of operation and reliable data telemetry.



The majority of air quality monitoring performed in the United States is carried out by state, local and tribal agencies in four major networks of monitoring stations: State and Local Air

Monitoring Stations (SLAMS), Photochemical Assessment Monitoring Stations (PAMS),  $PM_{2.5}$  Chemical Speciation Network (CSN), and air toxics monitoring stations. In addition, ambient air monitoring is performed by the federal government (EPA, NPS, NOAA, the U.S. Geological Survey, and the U.S. Department of Agriculture), tribes and industry.

Air quality monitoring in the United States supports several air quality management objectives:

- NAAQS attainment/nonattainment determination
- human exposure assessment for health research studies

- public air quality reporting and forecasting (AQI/AIRNow)
- accountability of control strategies (ARP,  $NO_x$  SIP Call, NBP, and CAIR)
- model evaluation
- determination of source receptor relationships
- characterization of regional air masses, transport
- ecological exposure assessments (acidity; nutrients; ozone; mercury; and other persistent, bioaccumulative, and toxic chemicals)
- assessments for toxic air pollutants: trends, hotspots, human health exposure, research

A summary of monitoring networks is provided in Table 3.

**Table 3. U.S. Air Quality Monitoring Networks**

MAJOR ROUTINE OPERATING AIR MONITORING NETWORKS: State / Local / Tribal / Federal Networks				
Network <sup>1</sup>	Sites	Initiated	Measurement Parameters	Source of Information and/or Data
<b>Urban/Human-Health Monitoring</b>				
NCore – National Core Monitoring Network	~80 planned	2011	O <sub>3</sub> , NO/NO <sub>y</sub> , SO <sub>2</sub> , CO, PM <sub>2.5</sub> /PM <sub>10-2.5</sub> , PM <sub>2.5</sub> speciation, surface meteorology	<a href="http://www.epa.gov/ttn/amtic/ncore/index.html">http://www.epa.gov/ttn/amtic/ncore/index.html</a>
SLAMS – State and Local Ambient Monitoring Stations	~3000	1978	O <sub>3</sub> , NO <sub>x</sub> /NO <sub>2</sub> , SO <sub>2</sub> , PM <sub>2.5</sub> /PM <sub>10</sub> , CO, Pb	<a href="http://www.epa.gov/airexplorer/">http://www.epa.gov/airexplorer/</a>
CSN – PM <sub>2.5</sub> Chemical Speciation Network	~200 currently active	1999	PM <sub>2.5</sub> mass, PM <sub>2.5</sub> speciation, major ions, Metals	<a href="http://www.epa.gov/airexplorer/">http://www.epa.gov/airexplorer/</a>
PAMS – Photochemical Assessment Monitoring Network	75	1994	O <sub>3</sub> , NO <sub>x</sub> /NO <sub>y</sub> , CO, speciated VOCs, carbonyls, surface meteorology, upper air	<a href="http://www.epa.gov/ttn/amtic/pamsmain.html">http://www.epa.gov/ttn/amtic/pamsmain.html</a>
<b>Rural/Regional Monitoring</b>				
IMPROVE – Interagency Monitoring of Protected Visual Environments	110 plus 67 protocol sites	1988	PM <sub>2.5</sub> /PM <sub>10</sub> , major ions, metals, light extinction, scattering coefficient	<a href="http://vista.cira.colostate.edu/IMPROVE/">http://vista.cira.colostate.edu/IMPROVE/</a>
CASTNET – Clean Air Status and Trends Network	80+	1987	O <sub>3</sub> , weekly concentrations of SO <sub>2</sub> , HNO <sub>3</sub> , SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , Cl <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> for dry and total deposition, surface meteorology	<a href="http://www.epa.gov/castnet/">www.epa.gov/castnet/</a>
GPMP – Gaseous Pollutant Monitoring Program	33	1987	O <sub>3</sub> , NO <sub>x</sub> /NO/NO <sub>2</sub> , SO <sub>2</sub> , CO, surface meteorology, enhanced monitoring of CO, NO, NO <sub>x</sub> , NO <sub>y</sub> and SO <sub>2</sub> , canister samples for VOC at three sites	<a href="http://www.nature.nps.gov/air/Monitoring/network.htm#data">www.nature.nps.gov/air/Monitoring/network.htm#data</a>

Table 3 (continued)

MAJOR ROUTINE OPERATING AIR MONITORING NETWORKS: State / Local / Tribal / Federal Networks				
Network <sup>1</sup>	Sites	Initiated	Measurement Parameters	Source of Information and/or Data
NADP/NTN – National Atmospheric Deposition Program / National Trends Network	250+	1978	Precipitation chemistry and wet deposition for major ions (SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup> , Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> , H <sup>+</sup> as pH)	<a href="http://nadp.sws.uiuc.edu/">http://nadp.sws.uiuc.edu/</a>
NADP/MDN – National Atmospheric Deposition Program / Mercury Deposition Network	100+	1996	Mercury measured in precipitation and wet deposition	<a href="http://nadp.sws.uiuc.edu/mdn/">http://nadp.sws.uiuc.edu/mdn/</a>
IADN – Integrated Atmospheric Deposition Network	20	1990	PAHs, PCBs, and organochlorine compounds are measured in air and precipitation	<a href="http://www.epa.gov/glnpo/monitoring/air/">www.epa.gov/glnpo/monitoring/air/</a>
Air Toxics Monitoring				
NATTS – National Air Toxics Trends Stations	27	2005	VOCs, carbonyls, PM <sub>10</sub> metals <sup>2</sup> , Hg	<a href="http://www.epa.gov/ttn/amtic/natts.html">http://www.epa.gov/ttn/amtic/natts.html</a>
State/Local Air Toxics Monitoring	250+	1987	VOCs, carbonyls, PM <sub>10</sub> metals <sup>2</sup> , Hg	
NDAMN – National Dioxin Air Monitoring Network	34	1998–2005	CDDs, CDFs, dioxin-like PCBs	<a href="http://cfpub2.epa.gov/ncea/cfm/recordisplay.htm?deid=22423">http://cfpub2.epa.gov/ncea/cfm/recordisplay.htm?deid=22423</a>

## Notes:

1. Some networks listed separately may also serve as subcomponents of other larger listed networks; as a result, some double counting of the number of individual monitors is likely. This list of networks is not meant to be totally inclusive of all routine monitoring in the United States.

2. PM<sub>10</sub> metals may include arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, and others.

The EPA has developed a National Ambient Air Monitoring Strategy for state, local, and tribal agencies and introduced a new multi-pollutant monitoring network referred to as NCore. Monitors at NCore sites will measure particles (PM<sub>2.5</sub>, speciated PM<sub>2.5</sub>, PM<sub>10-2.5</sub>, speciated PM<sub>10-2.5</sub>), ozone, SO<sub>2</sub>, CO, NO, NO<sub>y</sub> and basic meteorology. It is possible that ammonia and nitric acid measurements will also be added after further methods development. Sites are placed in broadly representative urban (about 60 sites) and rural (about 20 sites) locations throughout the country. The EPA collaborates on site selection with individual state and local agencies

and multistate organizations. Where possible, states locate urban NCore sites next to existing monitoring operations, including PAMS or National Air Toxic Trends Stations (NATTS) sites, to leverage existing resources. Similarly, the EPA coordinates with states and other existing monitoring network programs (i.e. IMPROVE, CASTNET) to establish rural-based NCore sites. The objective of this network is to gather additional information needed to support emissions and air quality model development, air quality program accountability, and future health studies. On October 17, 2006, the EPA finalized revisions to the ambient air monitoring regulations that included requirements to reflect



the NCore network, which is scheduled to be fully operational by January 1, 2011. General information on the NCore network is available at [www.epa.gov/ttn/amtic/ncore/index.html](http://www.epa.gov/ttn/amtic/ncore/index.html). More specific information on each candidate NCore site can be viewed or downloaded from <http://ncore.sonomatechdata.com/>.

The EPA has completed transitioning of the carbon measurement at CSN-speciated  $PM_{2.5}$  stations to the IMPROVE protocol to support better comparability between the CSN and IMPROVE networks. This effort was initiated in 2007.

The EPA finalized revisions to monitoring requirements for lead (Pb) in 2008 to support the tightening of the lead NAAQS from  $1.5 \mu\text{g}/\text{m}^3$  (quarterly average) to  $0.15 \mu\text{g}/\text{m}^3$  (rolling three-month average). New monitoring requirements included the establishment of source-oriented lead monitoring sites around lead sources emitting 1.0 tons per year of lead or greater by January 1, 2010, and the establishment of non-source oriented sites in urban areas with populations of 500,000 or more. Information on changes to the lead NAAQS and associated monitoring requirements is available at: <http://www.epa.gov/air/lead/actions.html>.

New ambient monitoring requirements have been established for the recently revised  $\text{NO}_2$  and  $\text{SO}_2$  NAAQS. All new  $\text{NO}_2$  and  $\text{SO}_2$  monitors must begin operating no later than January 1, 2013. EPA also proposed changes to the ozone monitoring requirements to support the 2008 revisions to the ozone primary and secondary NAAQS. Additional details on the  $\text{NO}_2$  and  $\text{SO}_2$  monitoring requirements

and the proposed changes to ozone monitoring requirements are available at: [www.epa.gov/air/airpollutants.html](http://www.epa.gov/air/airpollutants.html).

The NADP, with support from the EPA is operating a new network designed to measure ambient mercury concentrations. The Ambient Mercury Network (AMNet) measures ambient concentrations of speciated mercury at 20 sites throughout the U.S. and Canada. The data from this network will provide status and trends of ambient mercury concentrations, as well as information for model development including validation and source apportionment.

The EPA is also providing support to the proposed NADP Ammonia Monitoring Network (AMoN), which uses passive devices to measure gaseous ammonia concentrations. Currently there are 20 sites collecting two-week samples of ambient ammonia concentrations. These measurements are needed to enhance atmospheric and deposition models, validate emission inventories, and understand the chemistry driving  $PM_{2.5}$  formation. Both efforts aim to utilize the NADP committee structure as a platform for initiation and continued growth. The NADP website contains data, maps, and program information (<http://nadp.sws.uiuc.edu>).

Recent activities related to CASTNET include transitioning its ozone monitoring operations to fully meet the regulatory quality requirements applicable to SLAMS air monitoring data, and real-time reporting of hourly ozone and meteorological data to the AIRNow system for use in forecasting and mapping current air quality conditions. In addition, CASTNET is evaluating monitoring methods that provide highly time-resolved (i.e. hourly) measurements of both gaseous ( $\text{SO}_2$ , nitric acid, ammonia) and aerosol (sulphate, ammonium, nitrate, chloride and other base cations) components. The EPA is investigating several ammonia measurement methods including adding a fourth filter to the current three-stage filter pack, a denuder-filterpack system, and passive ammonia samplers for routine monitoring at CASTNET sites. The website for CASTNET includes program information, data and maps, annual network reports, and quality assurance information (see [www.epa.gov/castnet](http://www.epa.gov/castnet)).



# Health Effects



Health Canada is conducting research and developing tools that will support regulatory and non-regulatory actions for improving air quality and human health.

Studies include investigations of the health risks associated with exposure to air pollutants emitted from industrial and transportation sources; mortality risk associated with long term exposure to air pollutants; and characterization of the spatial variability of ambient air pollutants.

Health Canada is also continuing to develop an air health indicator for tracking changes in health outcomes attributable to changes in air quality. In addition, the development phase of the multi-pollutant Air Quality Health Index (AQHI) is now completed and the index is currently implemented in select communities across Canada. By providing daily and forecasted air pollution information, the AQHI helps Canadians make decisions to protect their health by limiting short-term exposure to air pollution.

Health Canada and Environment Canada are working to finalize a comprehensive Canadian Smog Science Assessment, which will inform future policy actions including a review of the Canada-wide Standards.

## Canadian Health and Exposure Research

### Seniors' Health Study

This study examined the association between exposure to particulate air pollution and changes in cardiovascular function among non-smoking seniors in Windsor, Ontario. Daily indoor and outdoor black carbon and particulate matter  $\leq 2.5 \mu\text{m}$  ( $\text{PM}_{2.5}$ ) samples were collected along with personal samples for  $\text{PM}_{2.5}$ . Findings from this study suggest that increased exposure to black carbon and  $\text{PM}_{2.5}$  can increase blood pressure, heart rate, and several other cardiovascular measures. In general, findings



from this study are consistent with previous evidence suggesting that daily exposure to particulate pollution can have an adverse impact on cardiovascular function in seniors.

### Canadian Census Cohort – Mortality and Air Pollution Study (CCC-MAPS)

In 2009, Health Canada launched a Canadian Census Cohort study in collaboration with Statistics Canada. This study will examine the mortality risk of long-term exposure to air pollution in the Canadian population. Long-form census data on 2.7 million Canadians are currently being linked to vital status information up to 2007. Long-term exposure to  $\text{PM}_{2.5}$  and ozone will be estimated using remote sensing methods, land use regression models and ambient data, as well as an atmospheric exposure model. The relationship between air pollution exposure and cancer incidence and cause-specific mortality will be examined. Results from this study will be used to inform risk management strategies, and will further our knowledge on the chronic effects of long-term exposure to air pollution in specific regions of the country.

### Industrial Emissions and the Exacerbation of Adverse Health Effects in Asthmatic Children

In 2009, Health Canada initiated a study to examine the impact of industrial emissions on respiratory and cardiovascular health in asthmatic children. This study, to be completed in 2010, is being conducted in

collaboration with the McGill University Health Centre, the Hôpital Maisonneuve-Rosemont, the Institut national de santé publique, the Agence de la santé et des services sociaux de Montréal, and the Centre de la santé et des services sociaux de la Point-de-Isle. The objective is to examine the relationship between industrial emissions and respiratory and cardiovascular outcomes among a panel of asthmatic children who live in close proximity to an industrial area in Montréal. A panel of approximately 80 asthmatic children is undergoing daily tests to examine pulmonary function, lung inflammation, blood pressure, and heart rate. Personal and outdoor air monitoring are carried out to assess children's exposure to PM, NO<sub>2</sub>, SO<sub>2</sub>, VOCs and polycyclic aromatic compounds (PAHs). Results from this study will provide much needed information regarding the impact of industrial air pollution on vulnerable populations and will facilitate the development of effective regulatory and non-regulatory strategies to improve air quality.

### **Human Health Effects of Exposure to Air Pollutants in an Outdoor Setting: A Randomized Controlled Cross-over Study**

Health Canada is conducting an epidemiological study entitled "Human Health Effects of Exposure to Air Pollutants in an Outdoor Setting: A Randomized Controlled Cross-over Study" in Sault Ste. Marie, Ontario. This study is designed to investigate the acute cardiovascular and respiratory effects of industrial air pollution in the vicinity of Sault Ste. Marie. Approximately 60 volunteers are participating in this study and each will participate for three weeks under different exposure conditions. One week will be spent at a background site away from industrial emissions, one week will be spent at a site close to industrial emissions, and one week will be spent close to industrial emissions while wearing a helmet designed to filter out criteria air contaminants. Participants will undergo clinical tests to examine the impact of industrial air pollution on measures of cardiovascular health and pulmonary function.

Personal and outdoor exposure to SO<sub>2</sub>, NO<sub>2</sub>, PM, VOCs and PAHs will be assessed and potential relationships between air pollutants and health outcomes will be analyzed. This is a novel study design that is expected to provide much needed information on potential acute health effects of steel industry emissions. Results are expected in 2011.

### **Montréal Congestive Heart Failure Study**

Health Canada is currently conducting a study in collaboration with McGill University and the Montreal Heart Institute to examine the impact of indoor and outdoor air pollution on patients with congestive heart failure. Subjects in this study represent a vulnerable population that may be particularly susceptible to the effects of air pollution. Therefore, it is important that this population is considered when developing regulatory and non-regulatory strategies to address air pollution. Specifically, the study investigates whether daily changes in respiratory and cardiovascular health are associated with changes in exposure to indoor and outdoor air pollution. Results from this study are expected in 2011.

### **Spatial Air Pollution Monitoring Studies**

A number of outdoor monitoring studies have been conducted in urban areas to characterize the spatial variability of ambient air pollutants including NO<sub>2</sub>, SO<sub>2</sub>, ozone (O<sub>3</sub>), VOCs, PAHs and PM. In particular, these studies have examined the effect of land use (e.g. roadways, industry) on ambient air pollution levels and models have been developed to predict air pollution levels in a given region based on land use characteristics. These models will also be used in health studies designed to support the development of strategies to address air pollution, and may also inform land use planning. To date, Health Canada has conducted spatial monitoring studies in Ottawa, London, Windsor, Winnipeg, Hamilton and Toronto with plans to complete studies in Halifax, Vancouver, Calgary and Montréal.

## Canadian Health and Exposure Tools to Support Risk Management

### Canadian Air Quality Health Index (AQHI)

The Air Quality Health Index (AQHI) is a public information tool that helps Canadians protect their health on a daily basis from the negative effects of air pollution. The AQHI is based on epidemiological data and relates air pollution exposures to acute health outcomes. This index employs a linear, non-threshold concentration-response relationship of short-term health risks of the smog mixture using three pollutants ( $\text{NO}_2$ , ground-level ozone and  $\text{PM}_{2.5}$ ) as a surrogate measure of the more complex mixture in the urban atmosphere. The index is expressed on a 1 to 10+ scale, where higher values represent a greater health risk.

In addition to the scale, corresponding health messages have been developed for general and “at risk” populations. The current (hourly) and forecasted (today and tomorrow) AQHI values and their associated health messages are publicly available at [www.airhealth.ca](http://www.airhealth.ca) and on the Weather Network broadcasts and website in locations where the AQHI is available. This information will allow Canadians to make informed choices to protect themselves and those in their care from the short-term health impacts of exposure to air pollution.

The AQHI is now available in 40 communities in 9 provinces, with additional communities to be added as the AQHI is implemented across the country.

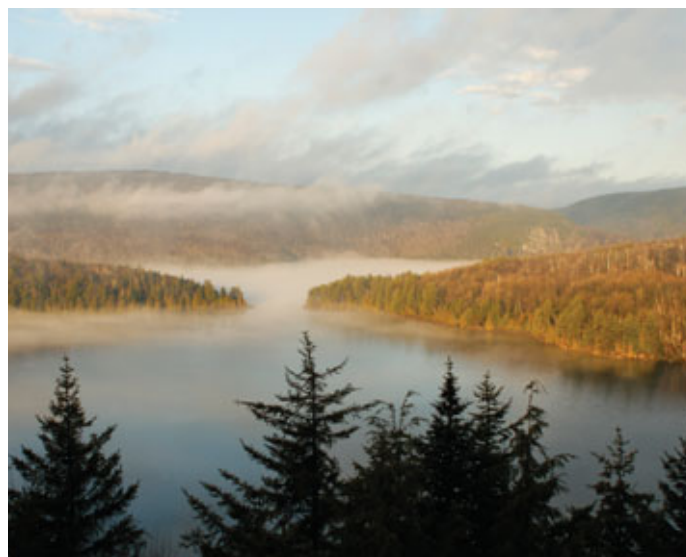
### Air Quality Benefits Assessment Tool (AQBAT)

The Air Quality Benefits Assessment Tool (AQBAT) is a computer simulation program developed by Health Canada to estimate the human health costs and/or benefits associated with changes in ambient air quality. AQBAT was made publicly available in 2006 and has been applied to federal government policy proposals on air quality as well as by a number of municipal governments and consultants in specific policy contexts. An updated version of AQBAT will be released in 2011. The revised version will include

a number of improvements, including updated population, air pollution and baseline incidence data of hospital admissions and mortality; revised concentration-response functions and valuation parameters for selected outcomes; and a mapping capability. Additional outcomes for consideration in this version include life expectancy, quality-of-life impacts in relation to chronic morbidity, and adverse pregnancy outcomes.

### Air Health Indicator (AHI)

The Air Health Indicator (AHI) is defined as the percentage of daily deaths attributable to a specific pollutant exposure. The AHI was developed by analyzing daily air pollution and mortality data for Canada’s 24 largest cities between 1984 and 2004. While Health Canada continues to refine the methodology used by the AHI, it can currently be used to measure trends in air quality management since 1981 as well potential health risks associated with air pollution over this time. The AHI was included in the 2008 Canadian Environmental Sustainability Indicators Annual Report in an assessment of ozone-related mortality from 1990 to 2005 in several Canadian cities. The report can be found at <http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=2102636F-1>.





## U.S. Report on Health Effects of Ozone and PM



The health and welfare effects of ozone are documented and critically assessed in the EPA Ozone Criteria Document and EPA Ozone Staff Paper, finalized and released to the public in

February 2006 and July 2007, respectively. These documents can be found at <http://cfpub.epa.gov/ncea/cfm/recorddisplay.cfm?deid=149923> and [http://epa.gov/ttn/naaqs/standards/ozone/s\\_o3\\_cr\\_sp.html](http://epa.gov/ttn/naaqs/standards/ozone/s_o3_cr_sp.html).

The purpose of the revised EPA Ozone Criteria Document, titled *Air Quality Criteria for Ozone and Other Photochemical Oxidants*, was to critically evaluate and assess the latest scientific information published since the last review of the ozone criteria document in 1996. The 2006 review focused on useful new information that emerged in the last decade, and is pertinent in evaluating health and environmental effects data associated with ambient air ozone exposures. The EPA Ozone Staff Paper is based on key findings and conclusions from this document, together with other analyses, and presents options for the EPA Administrator's consideration regarding review, and possible revision, of the ozone NAAQS.

The new research published in the staff paper suggested additional health effects beyond those that had been known when the 8-hour ozone standard was set in 1997. Since 1997, more than 1,700 new health and welfare studies related to ozone have been published in peer-reviewed journals. Many of these studies have investigated the impact of ozone exposure on health effects such as changes in lung structure and biochemistry, lung inflammation, asthma exacerbation and causation, respiratory illness-related school absence, hospital and emergency room visits for asthma and other respiratory disorders, and premature mortality.

Aggravation of existing asthma resulting from short-term ambient ozone exposure was reported prior to setting the 1997 ozone standard and has been observed in studies published subsequently.

In addition, a relationship between long-term ambient ozone concentrations and the incidence of recent-onset asthma in adult males (but not females) was reported. An additional study suggested that incidence of new diagnoses of asthma in children is associated with heavy exercise in southern California communities with high ozone concentrations. A study in Toronto reported a significant relationship between 1-hour maximum ozone concentrations and respiratory hospital admissions in children under the age of two. Given the relative vulnerability of children in this age category, there is particular concern about these findings. Increased rates of illness-related school absenteeism have been associated with 1-hour daily maximum and 8-hour average ozone concentrations in studies conducted in Nevada. These studies suggest that higher ambient ozone levels might result in increased school absenteeism.

The air pollutant most clearly associated with premature mortality is PM. Repeated ozone exposure, however, is a possible contributing factor for premature mortality, causing an inflammatory response in the lungs that could predispose elderly and other sensitive individuals to become more susceptible to other stressors, such as PM. The findings of other recent analyses provide evidence that ozone exposure is associated with increased mortality. Most recently, new analyses of the 95 cities in the National Morbidity, Mortality, and Air Pollution Study data sets showed associations between daily mortality and the previous week's ozone concentrations, which were robust against adjustment for PM, weather, seasonality and long-term trends. Other recent epidemiological studies have reported associations between acute ozone exposure and mortality, as summarized in the Ozone Criteria Document.

Exposure to PM has been associated with premature mortality as well as indices of morbidity, including respiratory hospital admissions and emergency department visits, school absences, lost work days, restricted activity days, effects on lung function and symptoms, morphological changes, and altered host defense mechanisms. Recent epidemiological studies have continued to report associations between short-term exposures to fine particles and effects





such as premature mortality, hospital admissions or emergency department visits for cardiopulmonary diseases, increased respiratory symptoms, decreased lung function, and physiological changes or biomarkers for cardiac changes. Long-term exposure to fine particles has also been associated with mortality from cardiopulmonary diseases and lung cancer and effects on the respiratory system, such as decreased lung function and chronic respiratory disease.

There are several sensitive or vulnerable subpopulations that appear to be at greater risk to PM-related effects. These include individuals with preexisting heart and lung disease, older adults and children.

## U.S. Report on Health Effects of NO<sub>2</sub>

The health effects of NO<sub>2</sub> have been documented and critically assessed in the U.S. Environmental Protection Agency's Integrated Science Assessment for Oxides of Nitrogen—Health Criteria (ISA). NO<sub>2</sub>-associated exposures and health risks have been assessed in the Risk and Exposure Assessment to Support the Review of the NO<sub>2</sub> Primary National Ambient Air Quality Standard (REA).<sup>3</sup> The purpose of the ISA was to critically evaluate and assess available scientific information to inform the review of the NO<sub>2</sub> NAAQS, while the REA presents analyses of NO<sub>2</sub>-associated exposures and health risks as well as an assessment of potential policy options for consideration with regard to the NO<sub>2</sub> primary NAAQS.

The ISA has concluded that the findings of epidemiological, controlled human exposure, and animal toxicological studies provide evidence that is sufficient to infer a likely causal relationship between respiratory effects and short-term (1–24 hours) NO<sub>2</sub> exposure. The strongest evidence for such a relationship comes from epidemiological studies of respiratory effects including symptoms, emergency department visits and hospital admissions. A number of these studies, most of which were published after the previous review of the NO<sub>2</sub> NAAQS (completed in 1996), have reported associations between short-term ambient NO<sub>2</sub> concentrations and respiratory morbidity in locations with NO<sub>2</sub> concentrations below those allowed by the then-current NO<sub>2</sub> NAAQS. Epidemiological studies are supported by evidence from experimental studies, including controlled human exposure studies that evaluate airway hyper-responsiveness in asthmatic individuals. Enhanced airway responsiveness could have important clinical implications for asthmatics since transient increases in airway responsiveness following NO<sub>2</sub> exposure have the potential to increase symptoms and worsen asthma control. Overall, the ISA concluded that the epidemiological and experimental data sets form a plausible, consistent and coherent description of a relationship between NO<sub>2</sub> exposures and an array of adverse health effects that range from the onset of respiratory symptoms to hospital admission.

<sup>3</sup> The final ISA and REA can be accessed at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645> and [http://www.epa.gov/ttn/naaqs/standards/nox/data/20081121\\_NO2\\_REA\\_final.pdf](http://www.epa.gov/ttn/naaqs/standards/nox/data/20081121_NO2_REA_final.pdf), respectively.

## U.S. Report on Health Effects of SO<sub>2</sub>

The health effects of SO<sub>2</sub> have been documented and critically assessed in the U.S. Environmental Protection Agency's *Integrated Science Assessment for Oxides of Sulfur—Health Criteria* (ISA). SO<sub>2</sub>-associated exposures and health risks have been assessed in the *Risk and Exposure Assessment to Support the Review of the SO<sub>2</sub> Primary National Ambient Air Quality Standard* (REA).<sup>4</sup> The purpose of the ISA was to critically evaluate and assess available scientific information to inform the review of the SO<sub>2</sub> NAAQS, while the REA presents analyses of SO<sub>2</sub>-associated exposures and health risks as well as an assessment of potential policy options for consideration with regard to the SO<sub>2</sub> primary NAAQS.

The ISA has concluded that findings from controlled human exposure and epidemiological studies provide evidence that is sufficient to infer a causal relationship between respiratory morbidity and short-term (5 minutes to 24 hours) SO<sub>2</sub> exposure. The strongest evidence for such a relationship comes from controlled human exposure studies that found that a significant percentage of exercising asthmatics exposed to 5–10 minute peak concentrations of SO<sub>2</sub>, experienced bronchoconstriction and/or respiratory symptoms. In addition, epidemiological studies reported associations between 1-hour daily maximum or 24-hour average SO<sub>2</sub> concentrations and respiratory symptoms, emergency department visits and hospital admissions. A number of these epidemiological studies, most of which were published after the previous review of the SO<sub>2</sub> NAAQS (completed in 1996), have reported associations between short-term ambient SO<sub>2</sub> concentrations and respiratory morbidity in locations with SO<sub>2</sub> concentrations below those allowed by the current SO<sub>2</sub> NAAQS. Overall, the ISA concluded that the controlled human exposure and epidemiological data form a plausible, consistent and coherent description of a relationship between SO<sub>2</sub> exposures and an array of adverse health effects that range from bronchoconstriction and respiratory symptoms to hospital admissions for all respiratory causes and asthma.

## Review of U.S. Ozone, Particulate Matter, NO<sub>2</sub> and SO<sub>2</sub> Air Quality Standards

On March 12, 2008, the EPA promulgated tighter primary and secondary NAAQS for ozone of 0.075 ppm, with an 8-hour average (see “New Actions on Acid Rain, Ozone, and Particulate Matter”). In September 2009, the EPA initiated reconsideration of the 2008 ozone NAAQS final decision. This action is scheduled to be completed in the fall of 2010. For more information on the revised ozone standards and reconsideration of the 2008 ozone NAAQS final decision, please visit [www.epa.gov/air/ozonepollution/actions.html](http://www.epa.gov/air/ozonepollution/actions.html).

In 2007, the EPA initiated the next review of the current PM NAAQS, which is scheduled to be completed in 2011. Additional information, including supporting documents, can be found at [www.epa.gov/ttn/naaqs/standards/pm/s\\_pm\\_index.html](http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html).

Based on the results of NO<sub>2</sub> health effects research as assessed in the ISA and estimates of NO<sub>2</sub>-associated exposures and health risks, the EPA revised the NO<sub>2</sub> primary NAAQS on January 22, 2010, and established new requirements for the NO<sub>2</sub> monitoring network. Specifically, the EPA promulgated a new 1-hour NO<sub>2</sub> NAAQS with a level of 100 ppb, retained the existing annual standard with a level of 53 ppb, and established a requirement that a substantial number of NO<sub>2</sub> monitors be sited within 50 metres of major roads and in other locations where maximum NO<sub>2</sub> concentrations are expected to occur. Additional information, including supporting documents, can be found at: [www.epa.gov/air/nitrogenoxides](http://www.epa.gov/air/nitrogenoxides).

Based on the results of SO<sub>2</sub> health effects research as assessed in the ISA, and on estimates of SO<sub>2</sub>-associated exposures and health risks in the REA, on June 2, 2010, the EPA strengthened the primary NAAQS for SO<sub>2</sub>. The revised standard will improve public health protection, especially for children, the elderly, and people with asthma. These groups are susceptible to the health problems associated with breathing SO<sub>2</sub>. The EPA revised the primary SO<sub>2</sub> standard by establishing a new 1-hour standard at a level of 75 ppb. The EPA's evaluation of the scientific

<sup>4</sup> The final ISA and REA can be accessed at [http://www.epa.gov/ttn/naaqs/standards/so2/s\\_so2\\_cr\\_isa.html](http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_cr_isa.html) and [http://www.epa.gov/ttn/naaqs/standards/so2/s\\_so2\\_cr\\_rea.html](http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_cr_rea.html) respectively.

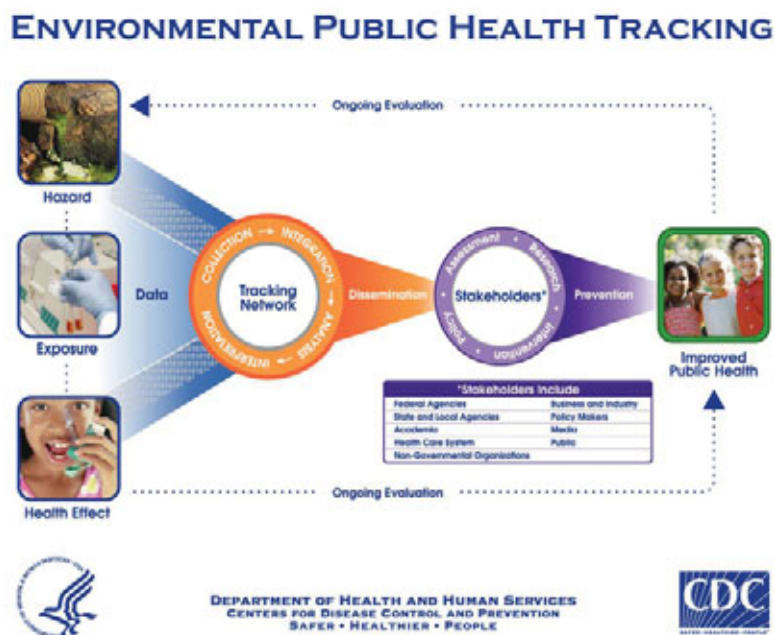
information and the risks posed by breathing SO<sub>2</sub> indicate that this new 1-hour standard will protect public health by reducing people's exposure to high short-term (5 minutes to 24 hours) concentrations of SO<sub>2</sub>. The EPA revoked the two existing primary standards of 140 ppb evaluated over 24 hours, and 30 ppb evaluated over an entire year because they will not add additional public health protection given a 1-hour standard at 75 ppb. Also, there is little health evidence to suggest an association between long-term exposure to SO<sub>2</sub> and health effects. The EPA did not revise the secondary SO<sub>2</sub> NAAQS, set to protect public welfare (including effects on soil, water, visibility, wildlife, crops, vegetation, national monuments and buildings). The EPA is assessing the need for changes to the secondary standard under a separate review. Additional information, including supporting documents, can be found at: [www.epa.gov/air/sulfurdioxide](http://www.epa.gov/air/sulfurdioxide).

## U.S. National Environmental Public Health Tracking

In July 2009, the U.S. Centers for Disease Control (CDC) launched a Web-based National Environmental

Public Health Tracking tool (<http://ephtracking.cdc.gov>) as part of the National Environmental Public Health Tracking Program (<http://www.cdc.gov/nceh/tracking/>). The National Environmental Public Health Tracking Network is a system of integrated health, exposure and hazard information and data from a variety of national, state and city sources (see Figure 32). The Web-based application that was released in 2009 is a surveillance tool that scientists, health professionals and the public can use to track environmental exposures and chronic health conditions. The tool unites vital environmental information from across the country, including air and water pollutants and information for some health conditions such as asthma, cancer, childhood lead poisoning, birth defects and other reproductive and birth outcomes, heart disease, and carbon monoxide poisoning into one resource. The U.S. EPA is collaborating with the CDC to provide air quality data for use in the National Environmental Public Health Tracking Network. Both monitored and modelled data are now available on the Tracking Network to assess possible population exposure to ozone and PM<sub>2.5</sub>, estimate health impacts, guide public health actions, and link to health outcomes in analytic studies.

**Figure 32.** A Conceptual Diagram of the CDC's Environmental Public Health Tracking Program



Source: <http://www.cdc.gov/nceh/tracking/>



## U.S. Health and Exposure Research

The U.S. EPA's Clean Air Research Program ([www.epa.gov/airsience](http://www.epa.gov/airsience)) provides the critical science to develop and implement outdoor air regulations under the *Clean Air Act*, while also providing leadership to the research community in the areas of exposure and health effects of air pollution. The current research program applies integrated, multidisciplinary research approaches to investigate how sources of air pollution impact air quality concentrations. It also examines the resulting human and ecological exposures and health effects. The Clean Air Research Program is transitioning from a pollutant-by-pollutant to a multi-pollutant research approach, which recognizes that people are exposed to and experience health effects from a mixture of air pollutants. As an initial step demonstrating and implementing a multidisciplinary and multi-pollutant research program, the Clean Air Research Program is investigating near-roadway exposures and health effects. The near-roadway research program includes a 2010/2011 exposure and health study that will be conducted in Detroit, Michigan, in collaboration with the University of Michigan. This study will examine potential health effects of air pollution on asthmatic children living near busy highways in Detroit and will enable further investigation into the types of pollutants common near roadways, how people are exposed to them, the extent

and types of exposures, and the severity of certain health effects. More specifically, researchers will evaluate the likelihood of traffic-associated pollution being the cause of severe asthma attacks and respiratory viral infections in children, ages 6 to 14.

Other ongoing research in the EPA's Clean Air Research Program includes the evaluation of alternative exposure metrics, such as air monitoring data alone or in combination with air quality and/or exposure models, for use in epidemiological studies and the investigation of human health impacts related to exposures to specific particulate matter components and size fractions and low concentrations (0.06 ppm) of ozone. Finally, in 2010, the EPA's Clean Air Research Program anticipates awarding grants to fund up to four integrated, multidisciplinary Clean Air Research Centers, which would address priority research areas such as explaining regional and temporal differences in air pollution risk; determining the origins and transformations of multi-pollutant atmospheres and their constituents; defining exposure/concentration-response relationships; assessing susceptibility; understanding PM effects in a multi-pollutant context; and developing greater understanding of PM and ozone health effects.

The U.S. EPA also sponsors exposure and health research conducted by the Health Effects Institute (HEI), which is a nonprofit, independent research organization that provides science on the health effects of air pollution. The HEI is supported jointly by EPA and industry, and periodically by other domestic and international partners. The HEI's research program includes research activities that are consistent with and complementary to the EPA's Clean Air Research Program. The HEI's National Particle Components Toxicity (NPACT) Initiative is a multi-pollutant research program that integrates results from epidemiological and toxicological health studies to provide insights into the relative toxicity of particulate matter components from a variety of sources. In addition, the HEI also recently released its strategic plan for 2010–2015 which includes four core programs: multi-pollutant exposure, epidemiology and toxicology; emerging fuels and technologies; health impacts of air quality actions (accountability); and an international perspective (<http://www.healtheffects.org/>).



# Ecological Effects

## Aquatic Effects and Monitoring

### Declining Calcium Levels in Canadian Fresh Waters



In many Canadian Shield lakes, water concentrations of calcium have been declining to levels that are problematic for some biological populations.<sup>5</sup> The reduction in surface water calcium is an artifact of the long-term (multiple decades) occurrence of acidic deposition. While acid deposition increases calcium leaching from watershed soils and initially increases surface water calcium concentrations, the leaching usually occurs at a rate greater than the

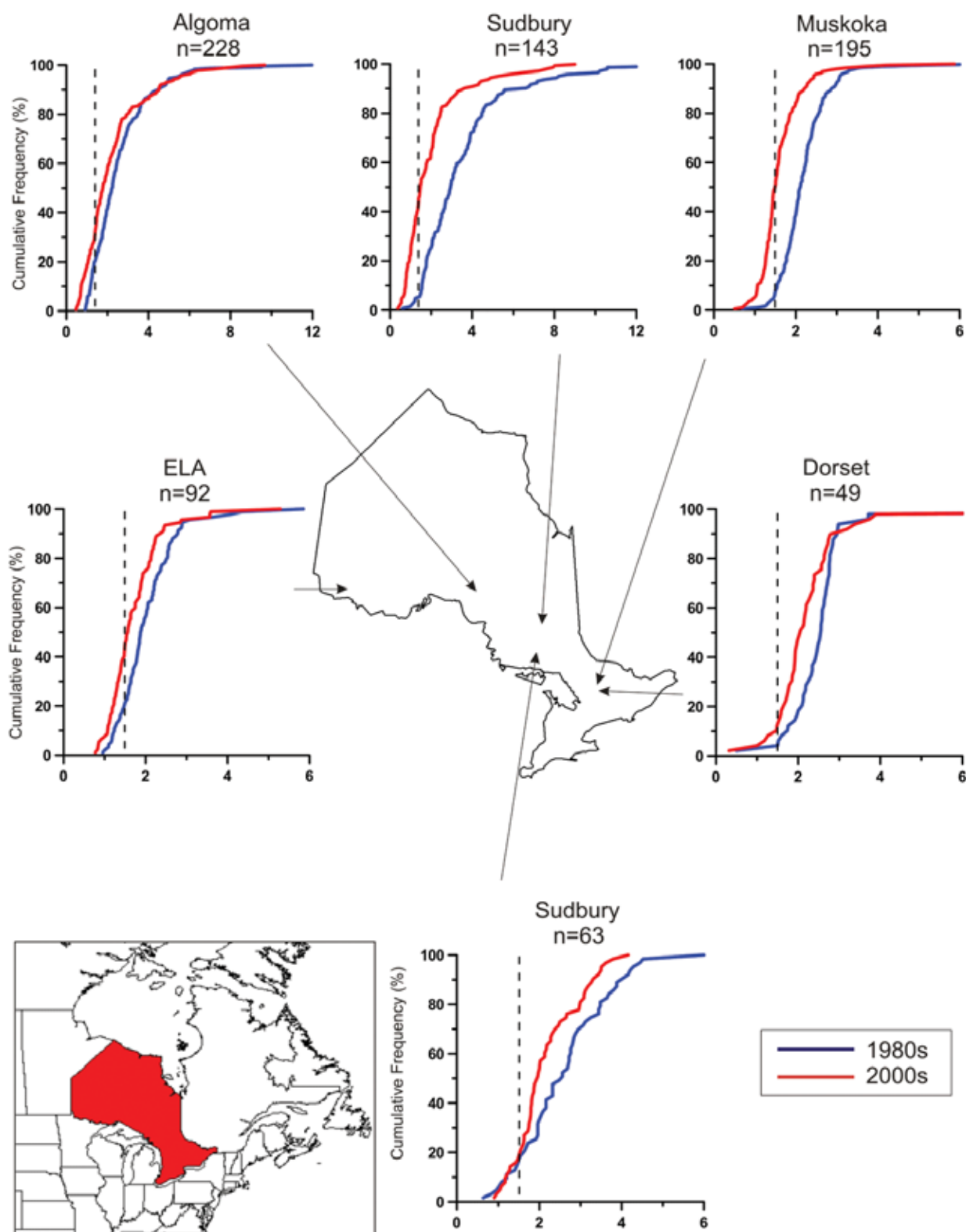
replenishment rate by mineral weathering. This results in a gradual reduction in the pool of exchangeable calcium in catchment soils and eventually leads to reduced calcium concentrations in runoff, particularly when the acidity level of deposition that promotes soil leaching also declines. A clear shift in the distribution of lake water calcium to lower concentrations has been recorded for six regional data sets from Ontario between the 1980s and 2000s (Figure 33). Declining trends in lake calcium have also been observed in other soft water regions of Europe and North America that receive acidic deposition.



<sup>5</sup> Jeziorski A, Yan ND, Paterson AM, DeSellas AM, Turner MA, Jeffries DS, Keller B, Weeber RC, McNicol DK, Palmer ME, et al. 2008. The widespread threat of calcium decline in fresh waters. *Science* 322:1374-1377.



**Figure 33.** Distribution of Lake Water Calcium Concentrations in Six Regions of Ontario between the 1980s and 2000s



Note: Graphs illustrate cumulative frequency distributions of lake water calcium concentrations in six regions of Ontario split between data collected in the 1980s and the 2000s. The vertical dashed line represents an important threshold concentration for daphniid reproduction. (Data adapted from Jeziorski et al.<sup>5</sup>). ELA refers to the Experimental Lakes Area in southern Ontario.

Reduction in surface water calcium concentrations has several ecological implications, although many impacts are not well quantified yet. Populations of calcium-rich zooplankton (e.g. *Daphnia* species) occur in many Canadian Shield lakes. In the Muskoka region of Ontario, the mean calcium concentration of 36 lakes declined 13% between 1985 and 2005. Contemporaneous evaluation of the relative abundance of calcium-rich daphniids in 43 Muskoka lakes showed that they have declined in 60% of the lakes having a present-day calcium concentration less than  $1.5 \text{ mg L}^{-1}$  (the level at which reproduction is delayed), and in

67% of the lakes having present-day calcium between  $1.5$  and  $2.0 \text{ mg L}^{-1}$ . Because calcium-rich daphniids are often the most abundant zooplankton in the lake environment, the population decline may affect the entire food web. Hence, declining calcium levels are expected to affect fish and other aquatic species as well, and the effects may even extend outside of the aquatic environment to the birds and animals that depend on the lakes for food. Studies indicate that even after recovery of lake pH, continued low levels of calcium could prevent full population recovery of the daphniids to pre-impact levels.

## Recovery of Acidified Lakes and Streams



Acid rain, resulting from  $\text{SO}_2$  and  $\text{NO}_x$  emissions, is one of many large-scale anthropogenic effects that negatively affect the health of lakes and streams in the United States and Canada.

Surface water chemistry provides direct indicators of the potential effects of acidic deposition on the overall health of aquatic ecosystems.

Three indicators of acidity in surface waters provide information regarding both sensitivity to surface water acidification and the level of acidification that has occurred today and in the past. These indicators are sulphate ions ( $\text{SO}_4^{2-}$ ), nitrate ions and acid-neutralizing capacity (ANC). Sulphate and nitrate are negatively charged ions with the potential to acidify drainage waters and leach acidic aluminum cations from watershed soils. Aluminium cations are known to be toxic to aquatic life. Assessments of acidic deposition effects dating from the 1970s to the present have shown sulphate to be the primary negatively charged ion in most acid-sensitive waters.

Long-term monitoring networks, such as the U.S. EPA's Long-Term Monitoring (LTM) program, provide information on the chemistry of lakes and streams, which allow us to look at how water bodies respond to changing emissions. The LTM program monitors a total of 170 lakes and streams, representing the major acid-sensitive regions of the northern and eastern

- Sulphate ion concentrations in surface waters provide important information on the extent of base cation (i.e. calcium, magnesium, potassium and sodium) leaching in soils and offer insight on how sulphate concentrations relate to the levels of ambient atmospheric sulphur and atmospheric deposition.
- Nitrogen is an important nutrient for plant growth and, therefore, most nitrogen inputs by deposition are quickly incorporated into biomass during the growing season as organic nitrogen, with little leaching of nitrate into surface waters during the growing season. As atmospheric nitrogen deposition increases, there is greater potential for increased leaching of nitrate into surface waters.
- ANC is a measure of the acid-buffering capacity of water and an important indicator of the sensitivity and the degree of surface water acidification or recovery that occurs over time. Acidification results in a diminishing ability of water in the lake or stream to neutralize strong acids that enter aquatic ecosystems.

United States (New England, Adirondack Mountains, northern Appalachian Plateau, and Ridge/Blue Ridge provinces of Virginia).

Monitoring trends in these indicators make it possible to determine whether conditions in acid-sensitive lakes and streams are improving and heading towards recovery or whether conditions are degrading. Movement toward recovery of an aquatic ecosystem is indicated by increases in ANC levels and decreases in sulphate and nitrate concentrations. Table 4 presents the sulphate, nitrate, and ANC trends ( $\mu\text{eq/L/yr}$ ) represented by the long-term monitoring sites sampled in lakes and streams from 1990 to 2007 for four acid-sensitive regions of the eastern United States. These regional trends were calculated using data from all the sites that were located within the region and had a complete data record for the time period considered. Trends are statistically significant at the 95 percent confidence interval ( $p < 0.05$ ).

U.S. and Canadian  $\text{SO}_2$  emissions reductions included in the AQA commitments have resulted in obvious, significant, and substantial declining  $\text{SO}_4^{2-}$  trends in the surface waters of all regions except the southern Appalachian region. As seen in Figure 34, improving trends in sulphate concentrations from 1990 to 2007 are found in nearly all monitoring sites in New England and the Adirondacks. Results are mixed for the Northern Appalachian Plateau streams, but most streams show some improvement. The regions with declining  $\text{SO}_4^{2-}$  trends have soils that absorb little of the atmospherically deposited  $\text{SO}_4^{2-}$ ; much of the  $\text{SO}_4^{2-}$  input is released to nearby lakes or streams, leading

to acidification of surface waters. In these regions there is a direct relationship between the declining atmospheric deposition of  $\text{SO}_4^{2-}$  and the decrease in  $\text{SO}_4^{2-}$  concentration in surface waters.

However, in the Blue Ridge (Central Appalachians), sulphate concentrations in many individual streams monitored by the LTM program demonstrate degrading trends; improving trends were noted at only 11% of sites. The Southern Blue Ridge region has highly weathered soils that can store large amounts of deposited sulphate. As long-term sulphate deposition exhausts the soil's ability to store additional sulfate, a decreasing proportion of the deposited sulphate is retained in the soil and an increasing proportion is exported to surface waters. Thus, sulphate concentrations in streams are increasing despite reduced levels of  $\text{SO}_2$  emissions and, therefore, reduced levels of sulphate deposition.

Trends in surface water nitrate concentrations are mixed. Trends at several individual LTM sites in lakes and streams indicate flat or slightly degrading nitrate trends (Figure 35). Improving trends for nitrate concentrations were noted at only 24% of sites in New England and the Adirondacks, 52% of sites in the Northern Appalachian Plateau, and 24% of sites in the Blue Ridge. These trends do not appear to reflect changes in emissions or deposition in these areas and are likely a result of ecosystem factors.

**Table 4. Regional Trends in Sulphate, Nitrate and ANC at Long-term Monitoring Sites, 1990–2007**

Region	Water Bodies Covered	Sulphate Trend <sup>a</sup>	Nitrate Trend <sup>a</sup>	ANC Trend
Adirondack Mountains	Lakes in NY	Most <sup>b</sup> improving	Few <sup>b</sup> improving	Many <sup>b</sup> Improving
Catskills/Northern Appalachian Plateau	Streams in NY, PA	Most <sup>b</sup> improving	Some <sup>b</sup> improving	Some <sup>b</sup> improving
New England	Lakes in ME, VT	Most <sup>b</sup> improving	Some <sup>b</sup> improving	Few <sup>b</sup> improving
Ridge / Blue Ridge provinces	Streams in VA	Few <sup>b</sup> improving	Few <sup>b</sup> improving	Few <sup>b</sup> improving

<sup>a</sup> Trends determined by multivariate Mann-Kendall statistical test.

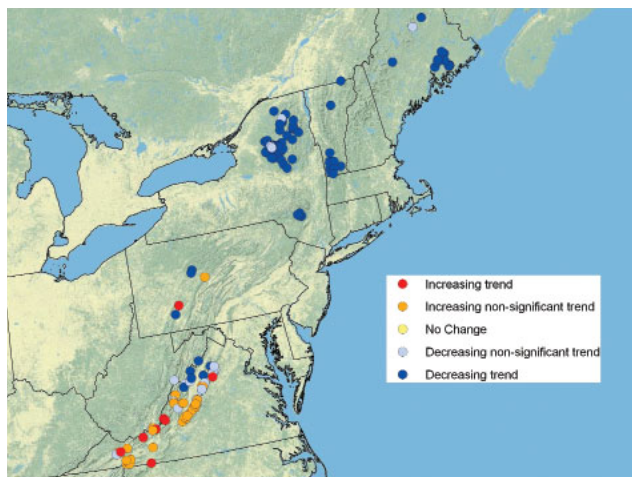
<sup>b</sup> “Most”, “many”, “some”, “few” improving indicate greater than 75%, from 50 to 75%, from 25 to 50%, and less than 25%, respectively, of lakes or streams with statistically significant trend at the 95% confidence level.

Source: US EPA 2010

Declines in sulphate deposition levels are the likely result for many of the improving trends in ANC, but ANC levels still lag declining sulphate concentrations in many of the monitoring sites. From 1990 to 2007, monitoring sites that showed increasing ANC levels (statistically significant improving trend) were in the

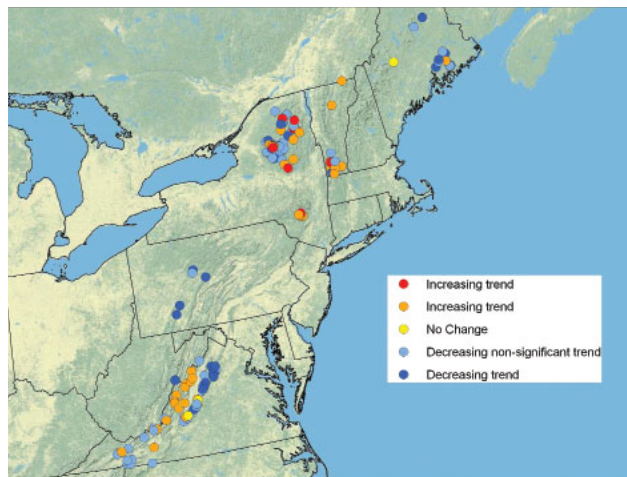
Adirondacks and Catskills (50% of sites). Only a few sites (12% of sites) in New England had statistically significant increasing trends in ANC. Streams in the Appalachian Plateau and Blue Ridge showed few statistically significant trends in ANC (Figure 36).

**Figure 34.** Trends in Lake and Stream Water Chemistry at LTM Sites, 1990–2007 – Sulphate Ion Concentrations



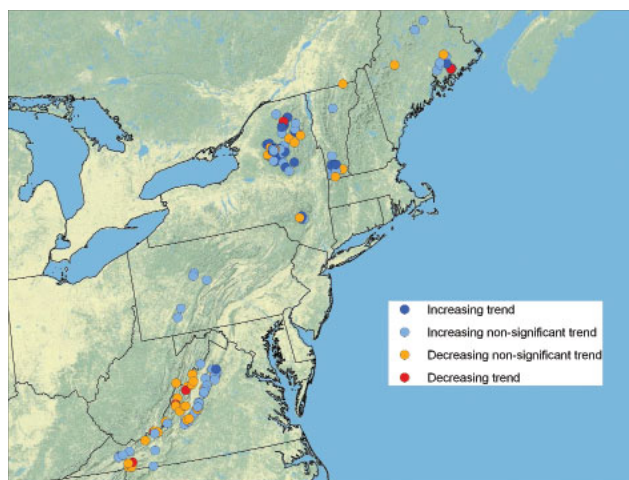
Source: US EPA 2010

**Figure 35.** Trends in Lake and Stream Water Chemistry at LTM Sites, 1990–2007 – Nitrate Ion Concentrations



Source: US EPA 2010

**Figure 36.** Trends in Lake and Stream Water Chemistry at LTM Sites, 1990–2007 – ANC Levels



Source: US EPA 2010

## Critical Loads and Exceedances



A region's critical load is the amount of acid deposition it can tolerate without being adversely affected according to present knowledge. When first utilized in Canada,<sup>6</sup> the critical load was expressed in terms of sulphate deposition only and reported as kg/ha/yr. In order to simultaneously account for both sulphur (S) and nitrogen (N) acidifying inputs (S and N have different atomic weights), the critical load is currently expressed in terms of charge equivalents as eq/ha/yr. The 20 kg/ha/yr wet sulphate target load that was used to guide implementation of a SO<sub>2</sub> emission reduction program in eastern Canada during the 1980s equals 416 eq/ha/yr.

In the 1980s and 1990s, management of the emissions that produce acid deposition in Canada focused on the east where sensitive terrain was coincident with high levels of deposition. Limited survey and monitoring data supported an assumption that acid deposition was not a problem in western Canada. This was in keeping with the fact that western sources were generally distant from sensitive terrain. However, expansion of existing and development of new emission sources in western Canada required that this assumption be re-evaluated. Recent regional surveys of lakes located on the Canadian Shield conducted by federal and provincial authorities<sup>7</sup> have allowed determination of representative aquatic critical loads for northern parts of Manitoba and Saskatchewan. Steady-state critical loads were calculated on a lake-by-lake basis using the Steady-State Water Chemistry (SSWC) model and an acid neutralizing capacity threshold (ANC<sub>limit</sub>) that considered the influence of the high level of dissolved organic carbon (DOC) which is prevalent throughout the region. The critical load for a regional data set was

estimated by the 5<sup>th</sup> percentile value so as to protect 95% of the lake ecosystems. Regional aquatic critical loads ranged from 1.9 to 52.7 eq/ha/yr indicating that very acid-sensitive lakes exist throughout northern Manitoba and Saskatchewan. The lowest regional critical loads occurred in that part of west-central Saskatchewan that is downwind of the rapidly-expanding oil sand industry (as illustrated in Figure 37). Regional critical load exceedances ranged from 54.5 to 909 eq/ha/yr, with the largest (positive) values occurring close to base metal smelters in Manitoba or downwind of the oil sands operations in western Alberta (Figure 38). The exceedances were almost entirely due to sulphate deposition. Nitrogen inputs to the lakes, while significant, were virtually entirely



<sup>6</sup> Canada-United.States. 1983. Memorandum of intent on transboundary air pollution. Report of the Impact Assessment Working Group I, Section 3-Aquatic Effects. 259 p.

<sup>7</sup> Jeffries, DS, Semkin, RG, Gibson, JJ, Wong, I. 2010. Recently surveyed lakes in northern Manitoba and Saskatchewan, Canada: characteristics and critical loads of acidity. J Limnol 69(Suppl. 1):45-55.

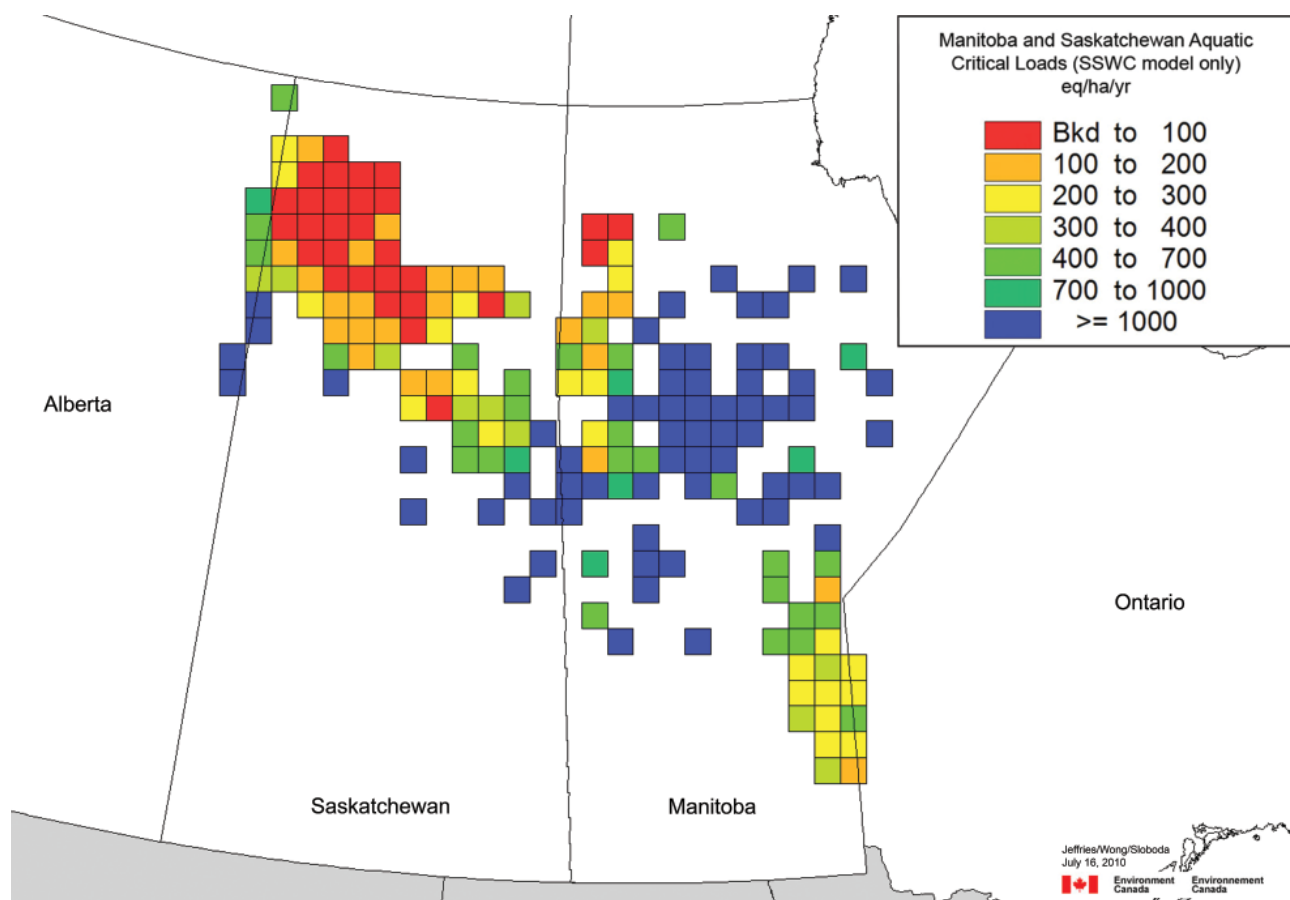


retained within their catchments (lake water nitrate levels were below analytical detection in most cases), meaning that at present, nitrogen deposition is not an acidifying factor.

Lakes having critical loads as low as those observed in northern Manitoba and Saskatchewan will be threatened by long-term acid inputs. However, they

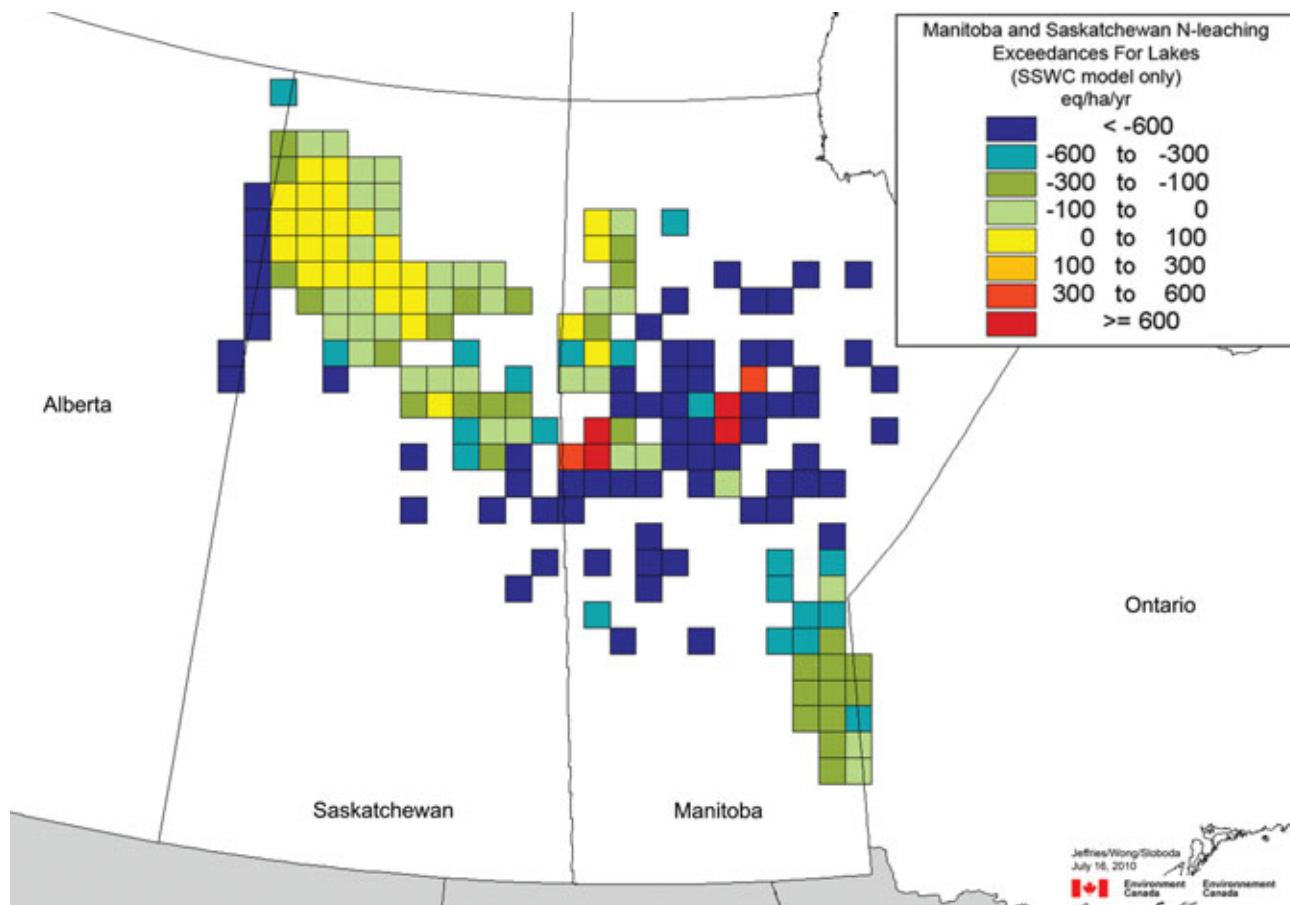
do not presently exhibit obvious symptoms of chemical damage from anthropogenic acidic deposition (i.e. low pH and/or reduced alkalinity). Hence there is still time to protect them from the acidification effects observed in many eastern Canadian lakes.

**Figure 37. Manitoba and Saskatchewan Aquatic Critical Loads for Acidity (Sulphur + Nitrogen)**



Note: Aquatic critical loads (wet and dry deposition in eq/ha/yr for acidity (sulphur and nitrogen) calculated using the SSWC model. "Bkd" in the legend implies background deposition which is ~40–60 eq/ha/yr. The critical load value for a given grid square is the 5th percentile value for all lakes located within the square.

Source: Environment Canada 2010

**Figure 38.** Current Manitoba and Saskatchewan Aquatic Critical Load Exceedances

Note: Current aquatic critical load exceedances (eq/ha/yr) calculated as a grid square's estimated S deposition plus nitrate export (to quantify the N-based component) minus its critical load. Positive exceedance values indicate that 5% (or more) of the lakes in the square are receiving acidic deposition (over the long term) in excess of their neutralizing ability.

Source: Environment Canada 2010



In the United States, the critical load approach is not an officially accepted approach to ecosystem protection.

For example, language specifically requiring a critical load approach

does not exist in the *Clean Air Act*. Nevertheless, the critical load approach is being explored as an ecosystem assessment tool with great potential to simplify complex scientific information and effectively communicate with the policy community and the public.

Between 2002 and 2006, federal agencies and the scientific research community convened workshops and conferences to develop critical load science and

modeling efforts and explore the use of a critical load approach in air pollution control policy in the United States. As a result of these developments, agencies such as the NPS and the U.S. Department of Agriculture (USDA) Forest Service developed specific recommendations for using the critical loads approach as a tool to assist in managing federal lands. Several federal agencies are now employing critical loads approaches to protect and manage sensitive ecosystems. For example, in Rocky Mountain National Park in Colorado, the NPS has entered into a Memorandum of Understanding (MOU) with the Colorado Department of Public Health and

Environment (CDPHE) and the EPA to address harmful impacts to air quality and other natural resources occurring in the park, and to reverse a trend of increasing nitrogen deposition. The MOU requires the NPS to develop a resource management goal to protect park resources and requires the CDPHE to develop an air management strategy that will help to meet park goals.

This approach also provides a useful lens through which to assess the results of current policies and programs and to evaluate the potential ecosystem protection value of proposed policy options. Since 2008, the U.S. EPA has employed the critical load approach to assess the ecological benefits of current air pollution programs, such as Title IV emissions reductions, and to review whether the secondary national ambient air quality standards for oxides of nitrogen and sulphur protect surface waters from acidification.

In addition to activities within federal and state agencies, the scientific research community has recently published many peer-reviewed scientific articles that advance the tools for calculating critical loads in the United States. Figure 39 illustrates critical loads for sulphur plus nitrogen in acid-sensitive lakes in the northeastern Appalachian Mountains and streams in the central Appalachian Mountains. These estimates are based on the recent peer-reviewed work by DuPont et al. (2005)<sup>8</sup> and Sullivan et al. (2007)<sup>9</sup>. Critical load estimates illustrated in Figure 39 include data collected in lakes and streams by EPA-administered surface water monitoring programs, such as the National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program (EMAP), the Temporally Integrated Monitoring of Ecosystems (TIME) program, and the LTM program. The lakes and streams associated with these programs

consist of a subset of lakes and streams that are located in areas most impacted by acid deposition, and many sites provide long term records of surface acidification. For example, the LTM lake and stream sites are monitored 3 to 15 times per year, with some site records dating back to the early 1980s. In New England, the LTM project collects quarterly data from lakes in Maine, Vermont and the Adirondack region of New York.

The NSWS, EMAP and TIME programs employ probability sampling; each monitoring site was chosen statistically from a predefined target population. In New England and the central Appalachian Mountains, the target populations include lakes and streams likely to be responsive to changes in acidic deposition. TIME lakes in Maine, Vermont and the Adirondack region of New York and TIME streams in Pennsylvania, Virginia and West Virginia are monitored annually.

Drawing on the peer-reviewed scientific literature (e.g. Dupont et al. 2005 and Sullivan et al. 2007), critical load estimates for about 1,100 lakes and streams were calculated using a modified SSWC model. The critical load in this study represents the combined deposition load of sulphur and nitrogen to which a lake or stream could be subjected and still have an ANC of 50 µeq/L or higher. This ANC level tends to protect most fish and other aquatic organisms, although some sensitive species may be lost. Critical loads of combined total sulphur and nitrogen are expressed in terms of ionic charge balance as milliequivalent per square metre per year (meq/m<sup>2</sup>/yr). When actual measured deposition of nitrogen and sulphur is greater than the critical load, the critical load is “exceeded,” meaning that combined sulphur and nitrogen deposition was greater than a lake or stream could sustain and still maintain the ANC level of 50 µeq/L or above.

<sup>8</sup> Source: US EPA, 2008 and DuPont J, Clair TA, Gagnon C, Jeffries DS, Kahl JS, Nelson SJ, Peckenham JM. 2005. *Enviro Monit Assess* 109:275-291.

<sup>9</sup> Sullivan T.J., Cosby BJ, Webb JR, Dennis RL, Bulger AJ, Deviney, FA Jr. 2007. Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. *Enviro Monit and Assess* 137:85-99.

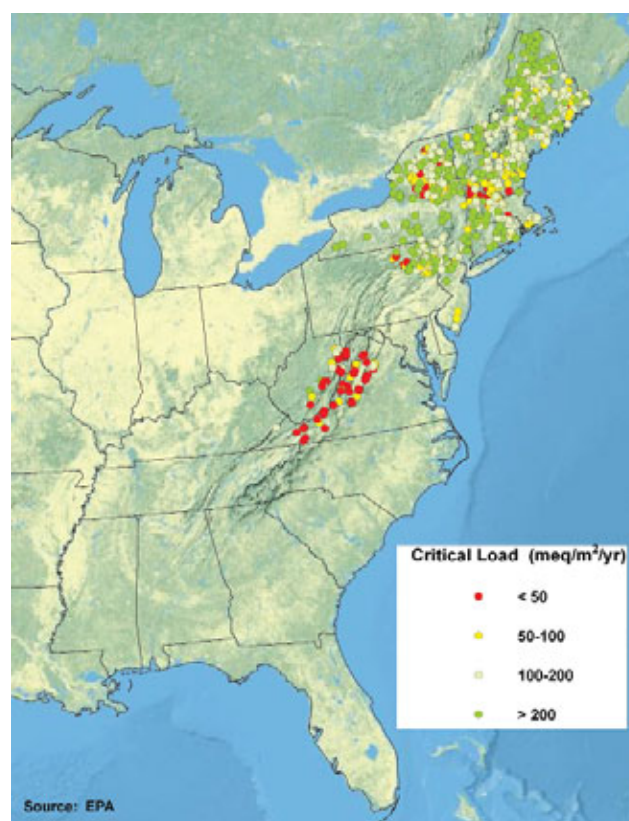
This study compares the amount of deposition lakes and streams can receive—the critical load—to measured deposition for the 1989–1991 (Figure 40) and 2006–2008 periods (Figure 41). Deposition estimates for both periods are based on wet deposition measured values from the NADP network combined with modelled dry deposition values based on the Community Multiscale Air Quality (CMAQ) model. Comparing Figures 40 and 41 provides insight into the improvements resulting from implementing the SO<sub>2</sub> and NO<sub>x</sub> emission reduction commitments in the Canada–U.S. AQA.

Approximately 36% of the lakes and streams for which critical load estimates were calculated in the eastern United States currently receive acid deposition greater than their estimated critical load. This is an improvement when compared to the 1989–1991 period, during which 56% of modelled lakes and streams received acid deposition greater than their estimated critical load. Areas with the greatest concentration of lakes where acid deposition currently is greater than—or exceeds—estimated critical loads include the Adirondack mountain region in New York, southern New Hampshire and Vermont, northern Massachusetts, northeast Pennsylvania and the central Appalachian Mountains of Virginia and West Virginia (Figure 41).

Reductions in acidic deposition have occurred over the past decade, as demonstrated by the deposition maps in Figures 4 through 9 on pages 9–10. However, this comparison of past and current total deposition estimates with critical loads estimates from the scientific literature indicates that acid-sensitive ecosystems in the northeastern United States are still at risk of acidification at current deposition levels. As a result, additional reductions in acidic deposition

from current levels might be necessary to protect these ecosystems, a conclusion supported by other recent analyses, such as *Risk and Exposure Assessment for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur*<sup>10</sup> and the *Integrated Science Assessment for Oxides of Nitrogen and Sulfur Review*<sup>11</sup>.

**Figure 39. Estimated Sulphur + Nitrogen Critical Loads for Lakes in the Northeast and Streams in the Central Appalachian Mountains, United States**



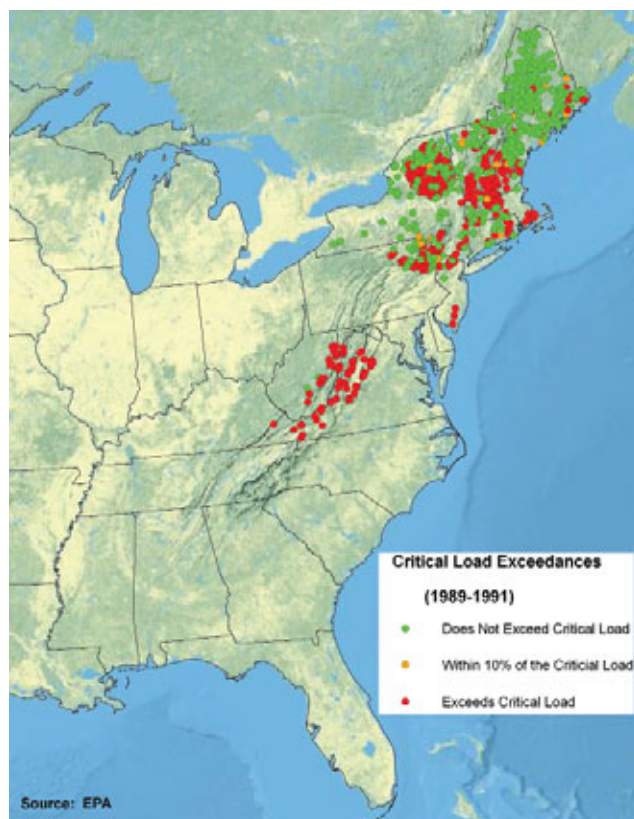
Source: US EPA 2010

<sup>10</sup> [U.S. EPA] (United States Environmental Protection Agency). 2009. Risk and Exposure Assessment for Review of the Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Oxides of Sulfur. EPA-452/R-09-008a. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Health and Environmental Impacts Division, Research Triangle Park (NC).

<sup>11</sup> [U.S. EPA] (United States Environmental Protection Agency). 2008a. Integrated Science Assessment for Oxides of Nitrogen and Sulfur Review. EPA/600/R-08/082F. U.S. Environmental Protection Agency, National Center for Environmental Assessment-RTP Division, Office of Research and Development, Research Triangle Park (NC).

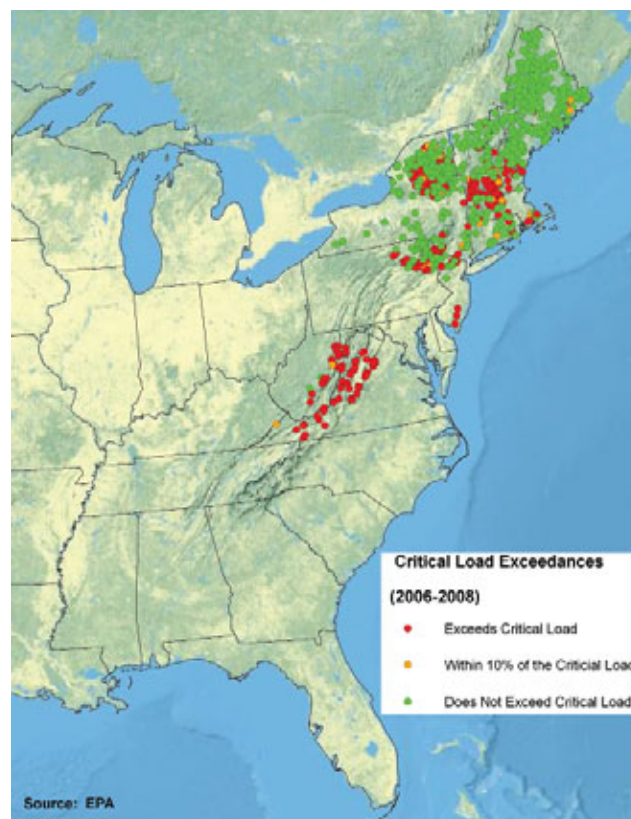


**Figure 40.** Lake and Stream Exceedances of Estimated Critical Loads (Sulphur + Nitrogen) for Total Nitrogen and Sulphur Deposition, 1989–1991



Source: US EPA 2010

**Figure 41.** Lake and Stream Exceedances of Estimated Critical Loads (Sulphur + Nitrogen) for Total Nitrogen and Sulphur Deposition, 2006–2008



Source: US EPA 2010

## Other Related Canadian and U.S. Atmospheric Research

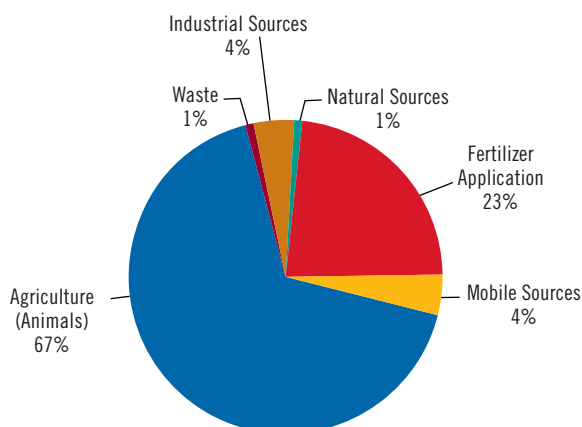
### Ammonia Emissions

Ammonia ( $\text{NH}_3$ ) is listed by the United Nations Economic Commission for Europe (UNECE) *Protocol to Abate Acidification, Eutrophication and Ground-level Ozone* (Gothenburg Protocol) as a chemical whose emissions have a more severe environmental or health impact.  $\text{NH}_3$  is a precursor chemical in the formation of fine particulate matter ( $\text{PM}_{2.5}$ ), a component of the mixture known as smog. As  $\text{NH}_3$  emissions worldwide

are expected to increase in response to agricultural intensification (with agricultural activity accounting for 90% of Canadian  $\text{NH}_3$  emissions in 2007 in the form of livestock and fertilizer application: see Figure 42), the role of ammonia in  $\text{PM}_{2.5}$  formation may proportionally become more important as emissions of other precursor gases level off or decrease due to emissions control policies.

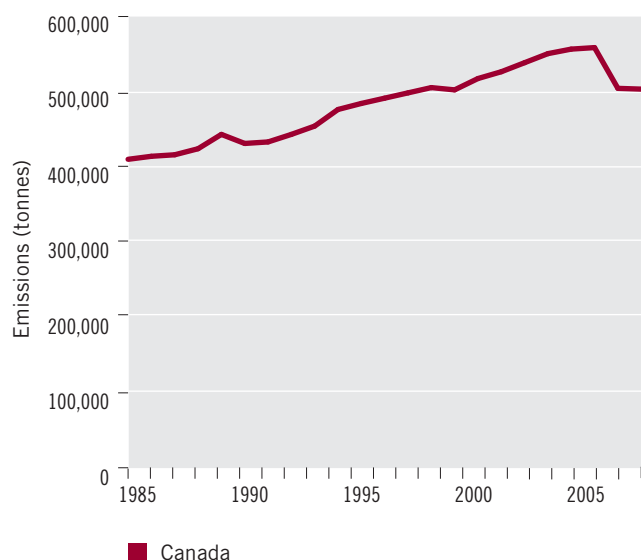


**Figure 42. Canadian National NH<sub>3</sub> Emissions by Sector, 2007**



Source: Environment Canada 2010

**Figure 43. National NH<sub>3</sub> Emissions in Canada, 1985–2007**



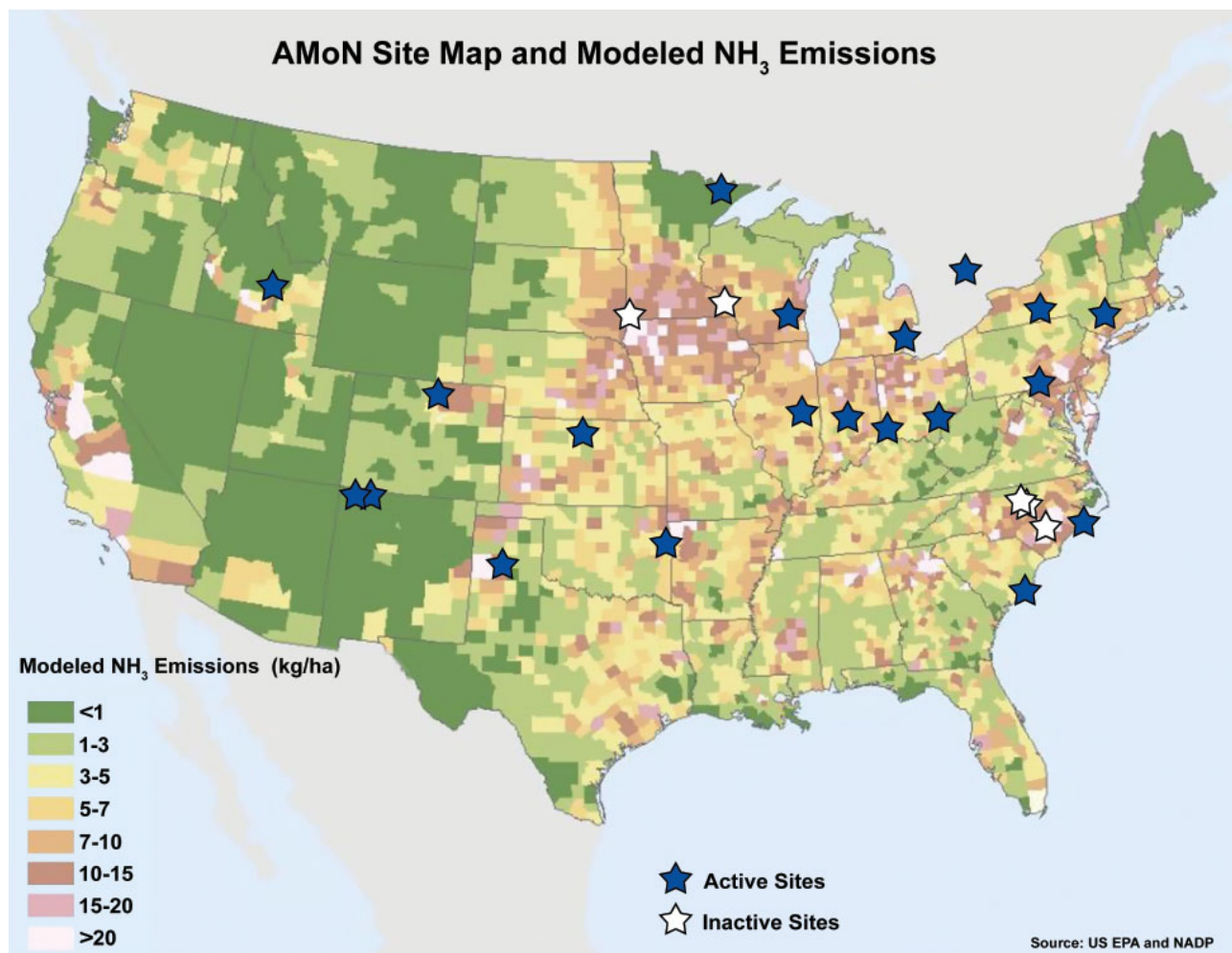
Source: Environment Canada 2010

Figure 43 depicts the Canadian NH<sub>3</sub> emissions trend from 1985 to 2007, where emissions increased approximately 23% in that period.

Similar to Canada, the bulk of the U.S. NH<sub>3</sub> emissions are from agricultural sources, accounting for almost 90% of all emissions in 2007.

To address the need for understanding sources, fate and deposition of NH<sub>3</sub>, both Canada and the U.S. have undertaken initiatives to further the scientific understanding of NH<sub>3</sub>. In the United States, routine monitoring was identified as a necessary measure in understanding spatial and temporal distribution of ammonia concentrations. To address the monitoring need, the U.S. EPA and NADP have developed the Ammonia Monitoring Network (AMoN), where passive samplers were installed at 20 NADP sites across the U.S., in regions of high NH<sub>3</sub> emissions. Figure 44 shows the locations of the NH<sub>3</sub> monitoring sites across the country.

In Canada, an assessment on the role of atmospheric agricultural ammonia in the formation of PM<sub>2.5</sub> was prepared as part of the National Agri-Environmental Standards Initiative (NAESI). The *2008 Canadian Atmospheric Assessment of Agricultural Ammonia* describes the state of the science as well as identifies key knowledge gaps. Atmospheric ammonia research activity is ongoing to address some of the research needs identified by the assessment. One initiative is the launch of a measurement method inter-comparison campaign at the Egbert CAPMoN site in Ontario, with a variety of measurement techniques used in both Canadian and U.S. networks. Additional measurement and modelling work will focus on the Canada–U.S. transboundary region, with a special emphasis on modelling flux and transport across the border, and the impact of NH<sub>3</sub> emissions on PM formation in the source and receptor regions in both countries.

**Figure 44. Ammonia Monitoring Network**

Source: US EPA 2010

## Impacts of Climate Change on Air Quality

Climate change plays an important role in regional air quality, as the latter is dependent on meteorological conditions, which are sensitive to changes in climate. Both Canada and the U.S. are studying the impacts of different climate change scenarios based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) via the coupling of air quality and climate change models. Much of the current work is studying the impacts of a future warmer climate on  $\text{O}_3$  formation, as the effects on PM formation are more complicated and less clear. Studies show that an increase in temperature alone has the potential to increase  $\text{O}_3$ , especially in already-impacted areas, such as urban centres.

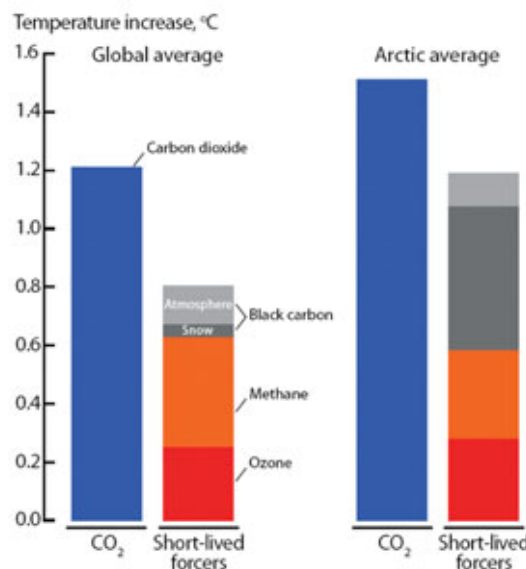
In the U.S., the modelling work has focused on the impacts of climate change on ambient  $\text{O}_3$  and  $\text{PM}_{2.5}$  levels, as well as the combined effects of a changing climate, along with anticipated precursor emissions decreases. Modelling results show that a climate change-only scenario will result in increases in both mean summer 8-hour and 95<sup>th</sup> percentile summer 8-hour maximum concentrations for  $\text{O}_3$ , with the increases mainly in the eastern portions of the country. A climate change and emissions reduction scenario results in overall decreases in both the mean and 95<sup>th</sup> percentile 8-hour maximum  $\text{O}_3$  levels, again with the greatest decreases concentrated in

the eastern parts of the country.<sup>12</sup> These results are reported along with results from other modelling studies in a synthesis report that was developed by the U.S. EPA Global Change Research Program.<sup>13</sup>

In Canada, modelling scenarios are underway to evaluate a regional climate and air quality modelling system against air quality observations for ozone and PM<sub>2.5</sub> for current climate conditions. Further scenarios planned for 2010–2011 will examine “climate change (2050) with current emissions, and climate change (2050) with projected future emissions.” All scenarios are for summer months (June, July and August) over a ten-year period.

A growing area of research involves air pollutants (such as black carbon) that not only have adverse health impacts, but along with other gases such as O<sub>3</sub>, have a climate impact. These compounds are termed collectively as short-lived climate forcers (SLCFs), as their atmospheric lifetime is short in comparison to other greenhouse gases, such as carbon dioxide (CO<sub>2</sub>). A climate forcer affects the Earth’s energy balance by either absorbing or reflecting radiation. Some of the shorter-lived forcers can have significant impacts on regional air quality, and their regulation can lead to nearer-term, measurable benefits for air quality and hence public health, as well as climate benefits. Figure 45 illustrates the radiative impact of SLCFs.

**Figure 45. Radiative Impact of Short-lived Climate Forcers**



Short-lived climate forcers such as black carbon, methane and ozone may have warming effects similar in magnitude to the long-lived greenhouse gases such as CO<sub>2</sub>. Estimates of the warming due to SLCFs are still very uncertain and need to be further refined.

Source: [AMAP] Arctic Monitoring and Assessment Programme. 2009. Update on Selected Climate Issues of Concern: Observations, short-lived climate forcers, Arctic carbon cycle, and predictive capability Oslo (NO). 23 p.

## International Collaboration

### International Transport of Air Pollution

In 2009, the National Academy of Sciences (NAS) completed a study funded by the U.S. EPA, the NOAA, the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF), about the significance of the international transport of air pollutants for air quality, deposition and radiative forcing. This study, entitled “Global Sources of Local Pollution,” included the overarching recommendation to develop and implement an

“integrated pollution source attribution” system. Such a system would focus on improving capabilities within, and integration among, emissions measurements and estimates, atmospheric chemical and meteorological modelling, and observations, including long-term ground-based observations, satellite remote sensing and process-focused field studies. Figure 46 from the NAS study shows the major atmospheric transport pathways affecting North America.

<sup>12</sup> Nolte, C G, Gilliland AB, Hogrefe C, Mickley LJ (2008), Linking global to regional models to assess future climate impacts on surface ozone levels in the United States, J Geophys Res 113, D14307, doi:10.1029/2007JD008497.

<sup>13</sup> [U.S. EPA] United States Environmental Protection Agency. 2009. Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone (An Interim Report of the U.S. EPA Global Change Research Program). Washington (DC): Environmental Protection Agency. EPA/600/R-07/094F, 2009.

**Figure 46. Major Atmospheric Transport Pathways Affecting North America**



The general timescales of transport estimated by the committee from trajectory studies and other sources are: (A) Midlatitudes - Arctic exchange: 1–4 weeks; (B) Midlatitudes - Tropics exchange: 1–2 months; (C) Northern Hemisphere - Southern Hemisphere exchange: ~ 1 year; (D) North America to Western Europe: 3–13 days; (E) Northern Africa to North America: 1–2 weeks; (F) Eastern Europe to Asia: 1–2 weeks; (G) Eastern Asia to North America: 4–17 days.

Source: Global Sources of Local Pollution. NAS Report. 2009

The NAS study will also contribute to a 2010 assessment, co-led by the U.S. EPA, of intercontinental transport in the northern hemisphere by the international Task Force on Hemispheric Transport of Air Pollution under

the Convention on Long-range Transboundary Air Pollution (LRTAP). The assessment is scheduled for release in late 2010.

## Air Quality Model Evaluation International Initiative

Scientists from the U.S. and Canada are participating in an international effort called the Air Quality Model Evaluation International Initiative (AQMEII). The objectives of AQMEII are to promote the international exchange of expert knowledge in regional air quality modelling; identify knowledge gaps in the science; test and develop innovative model evaluation methodologies to improve knowledge about relevant processes and to increase confidence in model performance for better support of policy development; and coordinate research projects on model evaluation and model inter-comparisons.

AQMEII is coordinated by two chairs, one for North America and the other for Europe and is supported by the Joint Research Centre/Institute for Environment

and Sustainability, Environment Canada and the U.S. EPA which act as regional focal points. The first AQMEII workshop was held in Stresa, Italy, in April 2009. A major outcome from the workshop was a plan for a near-term (2010) North American/European (two-continent) air quality model inter-comparison study, using modelling platforms from both continents, that simulates European and North American air quality for all of 2006. A second AQMEII workshop was held in September 2010 in Turin, Italy, to review initial model results and discuss next steps in the inter-comparison activity. Scientific results from this inter-comparison will be published in a February 2011 special issue of the journal *Atmospheric Environment*.



## Conclusion

The United States and Canada continue to successfully fulfill the commitments set forth in the Air Quality Agreement. While the initial focus of the Agreement was on reducing emissions of  $\text{SO}_2$  and  $\text{NO}_x$ , the major contributors to acid rain, the two countries expanded their efforts to cooperatively address transboundary air issues, such as ground-level ozone and particulate matter, over the past decade. The Ozone Annex, added to the Agreement in 2000, committed both countries to reducing emissions of  $\text{NO}_x$  and VOCs, the precursors to ground-level ozone, a key component of smog. Considerable progress has been made to address transboundary ozone pollution in the eastern border regions of each country.

Efforts to address particulate matter levels in the air are important in the United States and Canada. Both countries recognize the significant human health and ecosystem effects (including acid rain and regional haze) associated with  $\text{PM}_{2.5}$  and its precursors. Canada and the United States anticipate negotiating the addition of a Particulate Matter Annex (PM Annex) to the Air Quality Agreement once each country has refined its domestic policy approach for managing emissions of PM and its precursors.

The Air Quality Agreement established a formal and flexible method for addressing cross-border pollution and continues to pave the way for cooperation on a variety of air quality issues going forward.





# APPENDIX A

## Canada–U.S. Air Quality Committee

### Canadian Members

#### Canada Co-Chair:

##### Mike Beale

Associate Assistant Deputy Minister  
Environmental Stewardship Branch  
Environment Canada

#### Members:

##### Daniel Charrette

Environmental Industries Directorate  
Service Industries and Consumer Products Branch  
Industry Canada

##### Lawrence Cheng

Air Policy Development  
Air, Land and Strategic Policy Branch  
Alberta Environment

##### Paul Glover

Healthy Environments and Consumer Safety Branch  
Health Canada

##### Michel Goulet

Direction des politiques de la qualité de l'atmosphère  
Ministère du Développement durable,  
de l'Environnement et des Parcs du Québec

##### Jeffrey Heynen

U.S. Transboundary Affairs Division  
Foreign Affairs and International Trade Canada

##### Marie-Hélène Lévesque

Environmental Policy  
Transport Canada

##### Kimberly MacNeil

Environmental Science and Program Management  
Nova Scotia Department of Environment

##### Louise Métivier

Strategic Priorities Directorate  
Environmental Stewardship Branch  
Environment Canada

##### Glen Okrainetz

Health Protection Branch  
British Columbia Ministry of Healthy Living and Sport

##### Jason Randall

Environment Policy Division  
Energy Policy Branch  
Natural Resources Canada

##### Adam Redish

Air Policy and Climate Change Branch  
Ontario Ministry of the Environment

## Subcommittee on Program Monitoring and Reporting Co-Chair:

**Louise Métivier**

A/Director General, Strategic Priorities Directorate  
Environmental Stewardship Branch  
Environment Canada

## Subcommittee on Scientific Cooperation Co-Chair:

**Dr. Véronique Bouchet**

Manager, Modelling and Integration Research Section  
Science and Technology Branch  
Environment Canada

## United States Members

### United States Co-Chair:

**Daniel Reifsnyder**

Deputy Assistant Secretary for the Environment  
U.S. Department of State

### Members:

**Richard S. Artz**

Air Resources Laboratory  
National Oceanic and Atmospheric Administration  
(NOAA)

**Mitchell Baer**

Office of Policy and International Affairs  
U.S. Department of Energy

**John Bunyak**

Air Resources Division  
National Park Service

**G. Vinson Hellwig**

Air Quality Division  
Michigan Department of Environmental Quality

**Brian J. McLean**

Office of Atmospheric Programs  
U.S. Environmental Protection Agency

**Margo T. Oge**

Office of Transportation and Air Quality  
U.S. Environmental Protection Agency

**Steve Page**

Office of Air Quality Planning and Standards  
U.S. Environmental Protection Agency

**David Shaw**

Division of Air Resources  
New York State Department of  
Environmental Conservation

## Subcommittee on Program Monitoring and Reporting Co-Chair:

**Brian J. McLean**

Director, Office of Atmospheric Programs  
U.S. Environmental Protection Agency

## Subcommittee on Scientific Cooperation Co-Chair:

**Timothy H. Watkins**

Deputy Director, Human Exposure and  
Atmospheric Sciences  
Division, Office of Research and Development  
U.S. Environmental Protection Agency



# APPENDIX B

## List of Acronyms

<b>AHI</b>	Air Health Indicator	<b>CARA</b>	Clean Air Regulatory Agenda
<b>AIRMoN</b>	Atmospheric Integrated Research Monitoring Network	<b>CASAC</b>	Clean Air Scientific Advisory Committee
<b>AMNet</b>	Ambient Mercury Network	<b>CASTNET</b>	Clean Air Status and Trends Network
<b>AMoN</b>	Ammonia Monitoring Network	<b>CDC</b>	Centers for Disease Control
<b>ANC</b>	acid-neutralizing capacity	<b>CCME</b>	Canadian Council of Ministers of the Environment
<b>ARP</b>	Acid Rain Program	<b>CDPHE</b>	Colorado Department of Public Health and Environment
<b>AQA</b>	Air Quality Agreement	<b>CEMS</b>	continuous emission monitoring systems
<b>AQBAT</b>	Air Quality Benefits Assessment Tool	<b>CEPA 1999</b>	Canadian Environmental Protection Act, 1999
<b>AQHI</b>	Air Quality Health Index	<b>CI</b>	continuous improvement
<b>AQI</b>	Air Quality Index	<b>CMAQ</b>	Community Multiscale Air Quality Model
<b>AQMEII</b>	Air Quality Model Evaluation International Initiative	<b>CO</b>	carbon monoxide
<b>AQMP</b>	Air Quality Management Plan	<b>CO<sub>2</sub></b>	carbon dioxide
<b>ATV</b>	all-terrain vehicle	<b>CSN</b>	PM <sub>2.5</sub> Chemical Speciation Network
<b>BACT</b>	best available control technology	<b>CWS</b>	Canada-wide Standards
<b>BART</b>	best available retrofit technology	<b>DOC</b>	dissolved organic carbon
<b>BCVCC</b>	British Columbia Visibility Coordinating Committee	<b>ECA</b>	Emission Control Area
<b>CAIR</b>	Clean Air Interstate Rule	<b>EGU</b>	electric generating unit
<b>CAPMoN</b>	Canadian Air and Precipitation Monitoring Network	<b>EMAP</b>	Environmental Monitoring and Assessment Program

<b>EPA</b>	Environmental Protection Agency	<b>NATTS</b>	National Air Toxic Trends Stations
<b>ESAI</b>	Essar Steel Algoma Inc.	<b>NADP</b>	National Atmospheric Deposition Program
<b>FEM</b>	Federal Equivalent Method	<b>NAPS</b>	National Air Pollution Surveillance (Network)
<b>GHG</b>	greenhouse gas	<b>NARSTO</b>	North American Research Strategy for Tropospheric Ozone
<b>GPMP</b>	Gaseous Pollutant Monitoring Program	<b>NAS</b>	National Academy of Sciences
<b>ha</b>	hectare	<b>NASA</b>	National Aeronautics and Space Administration
<b>HEI</b>	Health Effects Institute	<b>NAtChem</b>	National Atmospheric Chemistry Database
<b>hp</b>	horsepower	<b>NBP</b>	NO <sub>x</sub> Budget Trading Program
<b>IADN</b>	Integrated Atmospheric Deposition Network	<b>NCore</b>	National Core Monitoring Network
<b>ICPMS</b>	ion-coupled plasma-mass spectroscopy	<b>NDAMN</b>	National Dioxin Air Monitoring Network
<b>IJC</b>	International Joint Commission	<b>NEG/ECp</b>	New England Governors and Eastern Canadian Premiers
<b>IMPROVE</b>	Interagency Monitoring of Protected Visual Environments	<b>NEI</b>	National Emissions Inventory
<b>IPCC</b>	Intergovernmental Panel on Climate Change	<b>NH<sub>3</sub></b>	ammonia
<b>ISA</b>	Integrated Science Assessment	<b>NOAA</b>	National Oceanic and Atmospheric Administration
<b>KCAC</b>	Keeping Clean Areas Clean	<b>NO<sub>2</sub></b>	nitrogen dioxide
<b>kg</b>	kilogram	<b>NO<sub>x</sub></b>	nitrogen oxides
<b>km</b>	kilometre	<b>NPACT</b>	National Particle Components Toxicity
<b>kt</b>	kilotonne	<b>NPRI</b>	National Pollutant Release Inventory
<b>kW</b>	kilowatt	<b>NPS</b>	National Park Service
<b>LAER</b>	lowest achievable emission rate	<b>NSF</b>	National Science Foundation
<b>LRTAP</b>	Convention on Long-Range Transboundary Air Pollution	<b>NSPS</b>	New Source Performance Standards
<b>LTM</b>	Long-Term Monitoring	<b>NSR</b>	New Source Review
<b>MDN</b>	Mercury Deposition Network	<b>NSWS</b>	National Surface Water Survey
<b>mg</b>	milligram	<b>NTN</b>	National Trends Network
<b>MOE</b>	Ministry of the Environment (Ontario)	<b>OBD</b>	onboard diagnostic
<b>MOU</b>	Memorandum of Understanding	<b>O<sub>3</sub></b>	ground-level ozone
<b>µg/m<sup>3</sup></b>	micrograms per cubic meter	<b>PAH</b>	polycyclic aromatic hydrocarbon
<b>MW</b>	megawatt	<b>PAMS</b>	Photochemical Assessment Monitoring Stations
<b>N</b>	nitrogen	<b>Pb</b>	lead
<b>NAA</b>	nonattainment areas		
<b>NAAQS</b>	National Ambient Air Quality Standards		
<b>NAESI</b>	National Agri-Environmental Standards Initiative		

<b>PCB</b>	polychlorinated biphenyl	<b>SLAMS</b>	State and Local Air Monitoring Stations
<b>PEMA</b>	Pollutant Emission Management Area	<b>SLCF</b>	short-lived climate forcer
<b>PERC</b>	tetrachloroethylene	<b>SO<sub>2</sub></b>	sulphur dioxide
<b>PM</b>	particulate matter	<b>SO<sub>4</sub><sup>2-</sup></b>	sulphate
<b>PM<sub>2.5</sub></b>	particulate matter less than or equal to 2.5 microns	<b>SSWC</b>	Steady-State Water Chemistry model
<b>PM<sub>10</sub></b>	particulate matter less than or equal to 10 microns	<b>TCE</b>	trichloroethylene
<b>ppb</b>	parts per billion	<b>TIME</b>	Temporally Integrated Monitoring of Ecosystems
<b>ppm</b>	parts per million	<b>UNECE</b>	United Nations Economic Commission for Europe
<b>PSD</b>	Prevention of Significant Deterioration	<b>USDA</b>	U.S. Department of Agriculture
<b>REA</b>	Risk and Exposure Assessment	<b>VOC</b>	volatile organic compound
<b>S</b>	sulphur	<b>XRF</b>	x-ray fluorescence instrumentation
<b>SI</b>	spark-ignition		
<b>SIP</b>	State Implementation Plan		



[illegible]

## Notes

[illegible]

[illegible]

To obtain additional information, please contact:

**In Canada:**

Air Emissions Priorities  
Environment Canada  
351 St. Joseph Blvd.  
12<sup>th</sup> Floor, Place Vincent Massey  
Gatineau, Quebec K1A 0H3

**In United States:**

Clean Air Markets Division  
U.S. Environmental Protection Agency  
1200 Pennsylvania Avenue, NW  
Washington, DC 20460

Environment Canada's website:

[www.ec.gc.ca/Air/default.asp?lang=En&n=83930AC3-1](http://www.ec.gc.ca/Air/default.asp?lang=En&n=83930AC3-1)

U.S. Environmental Protection Agency's website:

[www.epa.gov/airmarkets/progsregs/usca/index.htm](http://www.epa.gov/airmarkets/progsregs/usca/index.htm)

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