United States–Canada
Air Quality Agreement

Progress Report
1996

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Your Comments on this Report Would be Appreciated

Article IX of the Canada-United States Air Quality Agreement assigns the International Joint Commission the responsibility of inviting comments on this report. The Commission will prepare a synthesis of the comments received for the Governments of the United States and Canada and for public release. You may send written comments to either of the following addresses:

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List of Acronyms and Abbreviations

Acronym/ Abbreviation	Full name
AIRMoN	Atmospheric Integrated Research Monitoring Network
ANC	acid neutralizing capacity
AQC	Air Quality Committee
AQMD	Air Quality Management District
ARNEWS	Acid Rain National Early Warning System
ATS	Allowance Tracking System
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAPMoN	Canadian Air and Precipitation Monitoring Network
CASTNet	Clean Air Status and Trends Network
CCT	Clean Coal Technology
CEC	Commission for Environmental Cooperation
CEM	continuous emission monitoring or monitors
CEPA	Canadian Environmental Protection Act
CO	carbon monoxide
CO_2	carbon dioxide
DOE	U.S. Department of Energy
DDT	dichlorodiphenyltrichloroethane
EPA	U.S. Environmental Protection Agency
ETS	emissions tracking system
GAW	Global Atmospheric Watch
GCVTC	Grand Canyon Visibility Transport Commission
IADN	Integrated Atmospheric Deposition Network
IFCS	International Forum on Chemical Safety
IJC	International Joint Commission
I/M	inspection and maintenance
IMPROVE	Interagency Monitoring of Protected Visual Environments
kg/ha/yr	kilograms per hectare per year
km	kilometers
kT	kilotonnes
LEV	low-emission vehicle
LRTAP	UN Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution

Acronym/ Abbreviation	Full name
MOU	Memorandum of Understanding
N_2O	nitrous oxide
NAAEC	North American Agreement on Environmental Cooperation
NAAQS	National Ambient Air Quality Standards
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NAMS	National Air Monitoring Stations
NAPAP	National Acid Precipitation Assessment Program
NAPS	National Air Pollution Surveillance
NARSTO	North American Research Strategy for Tropospheric Ozone
NO_x	nitrogen oxide
NO_2	nitrogen dioxide
NTIS	National Technical Information Service
OTAG	Ozone Transport Assessment Group
OTC	Ozone Transport Commission
OTR	Ozone Transport Region
PAMS	Photochemical Assessment Monitoring Stations
PCBs	polychlorinated biphenyls
PM	particulate matter
$PM_{2.5}$	particulate matter smaller than 2.5 micrometers in diameter
POPs	persistent organic pollutants
ppb	parts per billion
ppm	parts per million
PSD	prevention of significant deterioration
RADM	Regional Acid Deposition Model
RECLAIM	Regional Clean Air Initiatives Market
ROSA	Regional Ozone Study Area
SAMI	Southern Appalachian Mountains Initiative
SLAMS	State and Local Air Monitoring Stations
SO_2	sulfur dioxide
TAF	Tracking and Analysis Framework
$\mu g/m^3$	micrograms per cubic meter
UN	United Nations
UNEP	United Nations Environment Program
VOC	volatile organic compound

Executive Summary

This report builds on the 1992 and 1994 Canada/United States Air Quality Agreement Progress Reports. The report reviews the acid rain control programs, emissions forecasts, and scientific research in both countries; discusses new areas of concern, such as ground-level ozone (smog) and air toxics; and includes the first five-year review of the Air Quality Agreement.

Annex 1 Commitments

Sulfur Dioxide

Acid rain, the principal bilateral air quality issue for many years, is the primary focus of cooperation under the Air Quality Agreement; however, ground-level ozone, air toxics, and inhalable particles are becoming increasingly important areas of concern. Canada fully implemented its Acid Rain Control Program in 1994, and the United States has made substantial progress implementing its program, which will largely be completed by 2000.

Canada's sulfur dioxide (SO_2) reduction program has been successful. Canada has achieved a 54-percent decrease in SO_2 emissions in the 7 eastern provinces from 1980 levels. Emissions decreased from 3.8 million tonnes in 1980 to 1.7 million tonnes in 1994, significantly surpassing the emissions goal for eastern Canada. All major sources targeted by the program have completed technological improvements or programs to reduce SO_2 emissions and to ensure that the 2.3-million-tonne cap will be respected until 2000.

Canada is also committed to permanently capping its national SO_2 emissions at 3.2 million tonnes beginning in 2000. Canada is currently 16 percent under this cap, with national emissions for 1994 reported at 2.7 million tonnes. Current projections beyond 2000 indicate that this cap will be met for some time. A national multi-stakeholder group, however, is developing a National Strategy on Acidifying Emissions to evaluate the need for further emission reductions.

The United States began its first compliance year in 1995 for Phase I of the Acid Rain Program. SO_2 emissions declined sharply in 1995 at the original Phase I 263 electric utility units. Emissions at these large, mostly coal-burning facilities were nearly 5 million tons below 1980 levels, representing a decline in emissions at these units of more than 50 percent since 1980. Emissions reductions at these Phase I units are 95 percent of total 1995 emissions reductions. Additional 1995 reductions of 300,000 tons were achieved by 182 substitution and compensating units—Phase II units that chose to comply with Phase I requirements early. Actual SO_2 emissions levels for all utility units in Phase I decreased to 5.3 million tons from 1980 levels of 10.9 million tons. This represents a reduction of 3.4 million tons more than allowable levels of 8.7 million tons for the first compliance year. In addition, the first annual reconciliation of SO_2 allowances and emissions for Phase I units reported that all Phase I units met their compliance obligations—SO_2 allowances matched SO_2 emissions generated in 1995. No excess emissions were reported for any Phase I utility units.

Nitrogen Oxides

Canada and the United States committed to reductions of nitrogen oxides (NO_x) in Annex 1 of the Agreement. The reduction goals amount to about 10 percent of national NO_x emissions for both countries by 2000: 100,000 tonnes in Canada and 2 million tons in the United States. Both countries are concerned about the role of nitrogen compounds not only in the formation of ground-level ozone but also in acidification processes.

In Canada, measures are in place to reduce NO_x emissions from stationary sources by 125,000 tonnes by 2000, fulfilling Canada's commitments. The measures include, among others, national emissions limits for new fossil-fueled power plants; retrofits at several existing power plants; new source standards for boilers, process heaters, and cement kilns; and a reconstruction of the INCO metals smelter at Sudbury, Ontario.

Canada's "Next Steps" Smog Management Plan, to be developed by 1997, will call for additional measures to reduce NO_x emissions.

The United States is undertaking a combination of measures for stationary and mobile sources to reduce NO_x emissions under the 1990 Clean Air Act Amendments (CAAA). NO_x emissions are expected to be reduced by more than 2 million tons by 2000. A major part of these reductions in NO_x emissions is expected to be achieved through Acid Rain Program reductions of emissions from coal-fired electric power plants.

Compliance Monitoring

Almost all major Canadian sources now have implemented either continuous emission monitoring (CEM) or methods of comparable effectiveness. Canada is in substantial compliance with its obligations in Annex 1.

In the United States, all operating Phase I and Phase II sources have installed CEMs or other acceptable alternatives. There is an unprecedented level of accuracy in the CEMs installed by utilities and nearly full compliance with emissions reporting requirements. Some 98 percent of installed monitors at Phase I units passed the required 10-percent relative accuracy standard; 93 percent achieved relative accuracy standards of less than 7.5 percent. In addition, monitors used at Phase I units were in operation more than 95 percent of the time.

Prevention of Significant Deterioration and Visibility Protection

The U.S. Prevention of Significant Deterioration (PSD)/visibility program was designed to keep areas with clean air clean. Since the 1994 Progress Report, the United States has continued to model and monitor the effects of long-range transport of air pollution on visibility in national parks and wilderness areas, the main areas to be protected in its PSD program.

To fulfill its PSD obligations, Canada believes that its Canadian Environmental Assessment Act (proclaimed 1995), together with provincial permitting and assessment regulations and maximum desirable air quality objectives (the benchmark for assessment of new sources), provides protection comparable to the U.S. PSD program. Discussions are under way between the two governments on the compatibility of the Canadian approach with the U.S. program.

Annex 2 Commitments

Monitoring Networks

Canada and the United States are continuing to integrate data from acidic deposition monitoring networks to ensure that data collected under both countries' programs are comparable and credible. The networks monitor wet deposition and measure air concentrations used to estimate dry deposition. The major networks, the Canadian Air and Precipitation Monitoring Network, the U.S. National Dry Deposition Network, and the U.S. National Atmospheric Deposition Program/National Trends Network are providing comprehensive data collection in North America.

Each country has its own approach to monitoring ground-level ozone concentrations. The two governments have been cooperating in analyzing significant ozone episodes that occurred in the summer of 1995 and are exploring other opportunities for cooperation.

Emissions Inventories

Both countries continue to work together to ensure emissions inventory data consistency and coordination in emissions trends analysis. Canada and the United States have been updating and improving their estimates for the 1990 emissions inventory using the latest information obtained from states and provinces, source measurements, and special study findings. The expanded use of CEM in both countries is expected to improve the accuracy and timeliness of emission data. Numerous tools also have been developed to analyze emissions trends and forecasts.

The countries are continuing to meet semiannually to explore opportunities for enhanced cooperation.

Scientific and Technical Cooperation

Since the last progress report, the two governments have continued to cooperate in atmospheric modeling, deposition monitoring, emissions inventories, effects research and monitoring, control technologies, and market-based initiatives.

Key atmospheric modeling and deposition monitoring findings and developments include the following:

- Wet sulfate deposition (a measure of acidification from SO_2) continues to decrease, correlated with SO_2 emissions reductions. Wet nitrate deposition (a measure of acidification from NO_x) shows no consistent change. Models support the deposition changes based on sulfur reduction and also support the important role of nitrogen in continued acidification and in ozone formation and control.
- Precipitation acidity has shown no consistent change. This is believed to be the result of a widespread decline in calcium and magnesium concentrations in precipitation.
- A U.S. report using the Regional Acid Deposition Model predicts that most of the northeastern United States and lower eastern Canada will experience a 30-percent or greater reduction in total sulfur deposition by 2010.

Significant findings on aquatic ecosystems trends include the following:

- Decreases in sulfur deposition have been accompanied by decreases in sulfate concentrations of surface waters in eastern Canada and the northeastern United States. Decreases in surface-water sulfate led to limited improvements in water quality (e.g., a few waters show increases in pH or decreased acidity (increased acid neutralizing capacity (ANC)). The declining sulfate concentrations are often accompanied by declining concentrations of base cations, including calcium, magnesium, and potassium.
- Results from a field experiment and modeling studies indicate that continued nitrogen deposition at current levels could result, in the long term, in an erosion of the benefits of sulfur emissions controls in both countries. Experimental addition of nitrogen to a forested watershed in Maine shows quick responses to watershed nitrogen saturation and associated decreases in pH and ANC. A watershed model projects that, depending on time to watershed nitrogen saturation, atmospheric nitrogen deposition to some eastern U.S. lakes and streams might play an important role in future lake and stream acidification.
- Continued lake monitoring in the Adirondacks has shown a recent decrease in lake nitrate concentrations. This is a significant change from prior data during the 1980s, which had indicated increasing nitrate concentrations. These data indicate the value of continuous monitoring of changes in surface-water chemistry.

Canadian and U.S. forest health monitoring continues to find no evidence of widespread forest decline associated with acidic deposition. The eastern North American hardwood forest is generally in good health. There is evidence, however, that acidic deposition can cause discernible effects in forests suffering from other forms of stress, including drought or high-elevation temperature extremes. For example, there is birch decline near Canada's Bay of Fundy due to acidic fog and red spruce decline at high elevations. In addition, symptoms of ozone damage were found in 1995 on ozone-sensitive plant species on more that 50 percent of 105 forested ozone monitoring sites throughout the northeastern United States.

In the area of visibility, Canada and the United States are continuing to merge visibility data sets and to cooperate in using models to predict future changes in visibility.

Regarding effects on materials, research into the effects of acid rain on marble and limestone will continue to improve predictive capability.

Health effects research indicates a growing consensus that acidic aerosols and other types of particulate matter (PM) have an adverse health effect on large segments of the population. Since the last progress report, epidemiological studies of the links between health effects and ambient levels of PM have been further validated. Controlled human exposure studies of ozone and acidic aerosols indicate acute effects on lung function; these studies support epidemiological findings. Chronic exposure to acidic aerosols has been associated with decline in lung function in children, but it is not known if the decline is permanent. Ozone exposure related to acid summer haze is associated with increased respiratory

hospital admissions and increased hospital emergency-room visits for respiratory causes.

Regarding quality assurance, bilateral field and laboratory intercomparisons continue to confirm the compatibility of Canadian and U.S. air quality data and to demonstrate steady improvement in laboratory performance.

In technical activities, the two governments are continuing to study, develop, and exchange information on new clean air technologies. In particular, the United States will fund more than $7 billion in projects under the Clean Coal Technology Program over the course of the decade.

The United States continues to use market-based mechanisms to achieve air pollution reduction at a lower societal cost. A report issued by the General Accounting Office in December 1994 estimated that with full interutility trading under the Acid Rain Program's allowance trading system, the annualized cost of SO_2 reductions should be less than $2 billion, compared to an annualized cost of compliance without trading of $4.9 billion. In addition, numerous innovative market-incentive programs are being explored and developed by individual states and regional groupings of states, including California's South Coast Air Quality Management District, the Los Angeles Clean Air Initiatives Market, the Ozone Transport Commission (OTC), and the Ozone Transport Assessment Group (OTAG).

Economic Research

Canada and the United States continue to exchange information on the costs and benefits of clean air controls. A 1995 study on the health benefits of reducing vehicle emissions in Canada found that the benefits ranged from Can$11 billion to Can$30 billion over a 24-year period. In addition, a 1995 study conducted by the U.S. Environmental Protection Agency estimated that the U.S. Acid Rain Program will lead to health benefits in the order of $12-40 billion per year by 2010 as a result of reducing levels of sulfate particles in the air.

Article V Notification

Since the fall of 1994, the two countries have been notifying each other of proposed actions, activities, or projects that could likely cause significant transboundary air pollution. Canada has sent eight formal notifications to the United States, while the United States has sent two to Canada. The United States has also notified Canada of other actions under the Clean Air Act that addressed air pollution.

Additional Areas of Cooperation

Ground-Level Ozone

Ground-level ozone is the main component of smog. It is formed from NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Ground-level ozone is both a regional and transboundary problem.

Canada and the United States are moving forward on two fronts to address this pollutant. Domestically, Canada is completing Phase I of its NO_x/VOC Management Plan and developing its "Next Steps" Smog Management Plan. The goal is to attain the air quality objective of 82 parts per billion (ppb) ozone in Canada. The United States established OTC in the Northeast and OTAG for the entire eastern United States to study and recommend regional control strategies to mitigate interstate pollution and achieve the 120 ppb air quality standard for ozone. The United States continues to make progress in improving air quality levels in ozone nonattainment areas. Of the original 98 classified ozone nonattainment areas, 28 have been redesignated to attainment. Fourteen of these were redesignated in 1995.

Both countries are also reviewing their respective air quality objectives/standards for ground-level ozone at a time when studies indicate that human health effects can occur at even lower concentrations. Cooperatively, the two countries are also engaged in a transboundary ozone management pilot project, known as the Regional Ozone Study Area (ROSA) project. This project will investigate the effectiveness of regional controls on NO_x and VOC emissions in addressing the transboundary flow of ground-level ozone.

Air Toxics

Air toxics are contaminants emitted to the atmosphere that are hazardous to human health or plant and animal life. They tend to persist in the environment for a long time and can also accumulate over time in animals that

consume contaminated food and water. Hundreds of different air toxics have been identified, including heavy metals (e.g., mercury) and organic compounds (e.g., benzene and dioxins). Air toxics can be transported thousands of miles from where they were emitted, making them a transboundary problem as well as a global one.

Canada and the United States both launched domestic programs about 20 years ago to control these pollutants. This report, however, only describes the bilateral and international efforts in which the two countries are engaged to control air toxics. These efforts include the proposed Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin, the North American Commission for Environmental Cooperation initiatives, new protocols to the United Nations (UN) Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution, and UN global work on persistent organic pollutants.

Although none of these international efforts on air toxics is formally linked to the Air Quality Agreement, the Air Quality Committee has decided to report on them to provide a more complete picture of how the two countries control transboundary air pollution.

Article X: Review and Assessment

During 1995 and 1996, Canada and the United States (the Parties) carried out the first five-year review of the Agreement. The review concluded that, overall, the two countries have been successful in fulfilling their obligations as set forth in the Air Quality Agreement, particularly regarding implementation of the acid rain control programs in each country. The Parties agreed, however, that control of transboundary air pollution has not occurred to the extent necessary to fully protect the environment.

Furthermore, the Agreement does not currently focus on other serious transboundary air pollutants, such as ground-level ozone, air toxics, and inhalable particles. The Parties have begun studying regional ozone management, however, and are evaluating what role they might play regarding air toxics.

While the Parties agreed on most aspects of the review, they disagreed about two main obligations: the prevention of air quality deterioration/visibility protection under Article IV and assessment and mitigation under Article V.

The two Parties also invited public input to the review through public hearings held by the International Joint Commission. Sixteen presenters participated in the hearings, with 48 citizens groups, industry associations, provinces, and individuals submitting written comments. The majority of the presenters were from Canada. In summary, comments indicated a consensus that the Agreement provides a good framework for addressing all transboundary air pollution issues. The public, however, expressed the need to give higher priority to air quality and health issues and recommended that the Agreement be expanded to include new annexes on ground-level ozone, air toxics, and inhalable particles.

Note: The text of the 1996 Progress Report uses American spelling throughout (e.g., sulfur instead of sulphur). Future progress reports will alternate the use of Canadian and American spelling. Dollars are US$ unless otherwise indicated.

SECTION 1

Introduction

The 1996 Progress Report focuses on progress made in Canada and the United States in the last two years to fulfill their respective commitments under the Air Quality Agreement.

The report, prepared by the bilateral Air Quality Committee (AQC), builds on the 1992 and 1994 Progress Reports. The 1996 report reviews the acid rain control programs, emissions forecasts, and scientific research in both countries. It also discusses additional areas of concern, including ground-level ozone (smog), inhalable particles, and air toxics. In addition, the report includes the first five-year review of the Air Quality Agreement by both governments and a summary of public meetings on the Agreement held by the International Joint Commission (IJC).

History of the Agreement

Canada and the United States signed the Air Quality Agreement on March 13, 1991, after more than a decade of negotiations. The Agreement signaled the beginning of a new era of environmental cooperation between the two countries. The Agreement currently focuses on acid rain but was designed as a living Agreement to address transboundary air pollution between the two countries.

To help implement the Agreement, the two countries established the AQC. The AQC has focused primarily on meeting the existing commitments in the Agreement, and it has recently started to address issues involving ground-level ozone and air toxics.

The AQC includes two working subcommittees. The Subcommittee on Program Monitoring and Reporting assesses progress towards meeting emissions reduction targets and prepares progress reports. The Subcommittee on Scientific Cooperation ensures the exchange of information and cooperation in such areas as atmospheric modeling and research and monitoring of atmospheric, environmental, and human health effects. The AQC meets at least once a year to provide overall direction to the two subcommittees and to review progress made.

Under the Agreement, the IJC is assigned the responsibility of inviting public comments on the progress reports and synthesizing them for the two countries and the public.

Public Comment on the 1994 Progress Report

In 1994, the IJC published notices, issued a news release, and inserted a comment sheet in the second progress report inviting public comments. In comparison to the 21 written submissions on the first progress report, only 8 were received on the second.

Several respondents to the 1994 Progress Report criticized the Agreement and the AQC for not focusing on air toxics emissions, ground-level ozone, and visibility. Some respondents voiced uncertainty about what actions were taken by the two governments as a result of the 1992 Progress Report review. They commented on wide-ranging issues, including the need to address the following: (1) including more women on the AQC; (2) considering the degree of slippage, if any, on all official targets in the Air Quality Agreement; (3) harmonizing air quality standards on both sides of the border; (4) addressing hazardous waste burning; (5) giving more attention to nitrate and ammonium as acidifying agents; and (6) notifying each government of possible new sources of air pollution in an expanded transboundary region. A copy of the IJC

synthesis of comments on the 1994 Progress Report is available from the IJC.

The AQC and its subcommittees took the comments on the progress reports into consideration during annual activities and in preparing the first five-year review of the Air Quality Agreement (included as Section VI of this report). This progress report responds to as many of these comments as possible within the five-year assessment or elsewhere in the report.

Air Quality Committee: Current Activities

At the 1994 annual meeting of the AQC in Ottawa, the two countries reviewed progress towards the 1995 implementation deadlines in the Air Quality Agreement. They reviewed efforts to reduce sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions, discussed the need for continuous emission monitoring (CEM), and evaluated ways to prevent significant deterioration of air quality and visibility. They also discussed the need to address long-range transport of NO_x and volatile organic compounds (VOCs), the primary causes of ground-level ozone.

Major issues discussed at the 1995 annual meeting in Washington, D.C., included the following:

- Progress on SO_2 and NO_x reductions in both countries.
- Progress of the two governments in carrying out the transboundary ozone study pilot project begun in 1994 and in cooperating in ozone modeling and information sharing.
- AQC review of its role regarding transboundary air toxics in light of the work being conducted under various international efforts on air toxics issues.
- Cooperation and progress in scientific and technical research, including harmonizing emissions inventories.
- Canada's position on compliance with prevention of significant deterioration (PSD)/visibility and the U.S. response.
- Interpretation of assessment and mitigation provisions of Article V.
- Ways of providing public access to notification under Article V and the progress of both governments in providing notification of transboundary air pollution sources.

In addition, the Subcommittee on Program Monitoring and Reporting met in April 1995 in Washington, D.C., to discuss progress towards meeting AQC objectives. The Subcommittee on Scientific Cooperation met in Research Triangle Park, North Carolina, in March 1996 to discuss ongoing cooperation in research and monitoring efforts.

SECTION II

Progress: Specific Programs and Objectives

Overview

This section discusses each country's progress in meeting objectives outlined in Annex 1 of the Air Quality Agreement concerning SO_2 and NO_x—the main components of acid rain.

The emissions reductions outlined in Annex 1 are summarized in Table 1. In this table, and throughout the remainder of this document, Canadian SO_2 and NO_x emissions are expressed as metric tonnes. U.S. SO_2 and NO_x emissions are expressed as short tons. One short ton is equivalent to 0.9 metric tonnes. One metric tonne is equal to 1.1 short tons.

Table 1. Canada-United States SO_2 Emissions Reduction Goals

Canada
SO_2 emissions reduction in 7 easternmost provinces to 2.3 million tonnes[1] by 1994
Maintenance of 2.3-million tonne annual cap for eastern Canada through December 1999
Permanent national cap on SO_2 emissions of 3.2 million tonnes by the year 2000
United States
SO_2 emissions reduction of 10 million tons[1] from 1980 levels by the year 2000[2]
Permanent national cap of 8.95 million tons for electric utilities by the year 2010
National cap of 5.6 million tons for industrial source emissions beginning in 1995

[1]One ton is equal to 0.9 tonnes; 1 tonne is equal to 1.1 tons.
[2]With the exception of sources repowering with a qualifying clean coal technology, sources receiving bonus allowances as part of the Allowance Trading Program, and sources using allowances earned for early reduction efforts earned prior to the year 2000.

Implementation of Control Programs

Canada

Program Goals

Canada has two caps on SO_2 emissions: (1) an eastern Canada cap of 2.3 million tonnes that applies to the seven provinces from Manitoba eastwards, effective from 1994 to 2000, and (2) a national cap of 3.2 million tonnes that takes effect from 2000 onwards.

Canada has surpassed both of these goals. In 1994, SO_2 emissions in eastern Canada were just 1.7 million tonnes, or 26 percent below the cap. National emissions were approximately 2.7 million tonnes, or 16 percent below the cap. Canada expects to be well under both caps for the foreseeable future.

Table 2 illustrates SO_2 reductions achieved by 1994 as well as the provincial emissions limits. Some of the limits are still being amended through ongoing federal/provincial negotiations to reflect the 2,300-kilotonne (kT) limit.

For NO_x reductions, Canada is committed to cutting emissions from stationary sources by more than 100,000 tonnes from projected levels by 2000. This goal will be met on schedule. Currently identified reductions total more than 125,000 tonnes, with the single largest reduction—43,000 tonnes—at the INCO metals smelter in Sudbury, Ontario. New Brunswick also imposed the Canadian Environmental Protection Act (CEPA)

Table 2. Total SO_2 Emissions by Provinces in Eastern Canada[1] (kilotonnes)

	1980 Act.	1988	1990	1992	1994	1994 Emissions Limit
Manitoba						
Primary Metals	463	550	500	555	388	—
Other	21	16	16	10	9	—
Total[2]	484	566	516	565	397	550
Ontario						
Primary Metals	1090	800	729	510	250	—
Power Generation	396	321	195	157	106	—
Other	272	286	268	246	262	—
Total[2]	1758	1407	1192	913	618	885
Quebec						
Primary Metals	641	478	189	218	199	—
Other	457	234	202	182	183	—
Total[2]	1098	712	391	400	382	5005
New Brunswick						
Primary Metals	15	23	6	12	14	—
Power Generation	123	158	141	149	90	—
Other	80	39	34	32	30	—
Total[2]	218	220	181	193	134	1755
Nova Scotia						
Power Generation	125	147	143	143	133	—
Other	68	36	35	34	40	—
Total[2]	193	183	178	177	173	1895
Newfoundland						
Power Generation	18	18	21	18	8	—
Other	38	27	36	57	37	—
Total[2]	56	45	57	75	45	45
Prince Edward Island						
Total[2,4]	5	3	3	4	4	5
Eastern Canada Total						
Primary Metals	2004	1851	1424	1295	851	—
Power Generation	662	644	500	467	337	—
Other	941	641	594	565	565	—
Total[2]	3812	3136	2518	2327	1753	2349[3]

1. Data for 1988, 1990, 1992, and 1994 are taken from reports by the provinces on their SO_2 control programs. The emissions levels represent the best estimate available at the time of writing this report. Note that even historic year estimates may be revised as better inventory data are made available.
2. *Total emissions are more than the sum of Primary Metals and Power Generation.* The difference is mainly sources such as residential and commercial and industrial fuel combustion, except in Newfoundland where the major contributor is petroleum refining.
3. The 1994 Eastern Canada limit is 2,300 kilotonnes. The current total of agreed-to objectives is 2,349 kilotonnes. The remaining 49 kilotonnes will be allocated through amendment of the current federal/provincial agreements.
4. This value includes a component of power generation emissions.
5. This revised emission limit reflects a renegotiated federal/provincial agreement.

guidelines on a new power plant and on a major modification to an existing power plant.

Program Implementation

The federal and provincial governments in Canada share responsibility for implementing programs to control air pollutants, such as NO_x and SO_2, and to address regional air quality problems like smog.

In general, the federal government's role is to address transboundary issues or circumstances where federal sources are implicated. The federal government also provides leadership in developing national emissions standards for new sources. The provinces oversee the protection and management of resources within their boundaries as well as develop and enforce regulations. Coordination among the provinces and the federal government is achieved through the Canadian Council of Ministers of the Environment and the Council of Energy Ministers.

SO_2 Programs

The Eastern Canada Acid Rain Control Program was initiated in 1985 and subsequently formalized in seven federal/provincial agreements. These agreements establish specific SO_2 emissions reduction targets and timetables for each of the provinces. The provinces also agreed to participate in acid rain effects research, monitor ecosystems, and report on progress. The federal government undertook to monitor reductions in transboundary flows of SO_2 from the United States, conduct a wide range of research activities, monitor and model deposition, support research and development projects for SO_2 reduction technologies, and control emissions from federal facilities.

The program's objective was to limit wet sulfate deposition to no more than 20 kilograms per hectare per year (kg/ha/yr) in the eastern provinces. This deposition rate was defined as the acceptable level to protect moderately sensitive aquatic systems. As a first step toward achieving this target, SO_2 emissions in eastern Canada were capped at 2,300 kT by 1994.

The Eastern Canada Acid Rain Control Program focuses on reducing SO_2 emissions at large, nonferrous metal smelters and fossil fuel-burning power plants. The program was fully implemented by 1994 with every province meeting its target and many surpassing their targets by 25 percent or more. Each province in the program determined its own approach for meeting its provincial SO_2 limit; some set targets for large emitters to meet, while others regulated emitters. Industry complied by changing production processes, installing emissions control technology, switching fuel, increasing energy efficiency, and/or closing old plants. Following are examples of industry compliance:

- The Hudson Bay Mining and Smelting Ltd. smelter in Manitoba commissioned a new zinc pressure leaching plant to recover 98-99 percent of the zinc in concentrate form, reducing SO_2 emissions by about 25 percent.
- Once the single largest point source of SO_2 in North America, INCO's Sudbury (Ontario) smelter reduced its SO_2 emissions by 80 percent from 1980 levels. The company decreased emissions from 865 kT to 162 kT in 1994 as a result of a Can$612 million investment to modernize its nickel and copper smelter. INCO's emissions are currently 35 percent below its regulated limit of 265 kT.
- Noranda Metals' Horne copper smelter in Quebec met its regulated limit as a result of its technology development program. In 1994, SO_2 emissions were 156 kT—a reduction of more than 70 percent from 1980 levels.
- Large power plants also have installed scrubbers and/or switched to lower-sulfur coal to meet their respective SO_2 limits. Ontario Hydro, for example, operates two scrubbers at its coal-fired Lambton station at about 90-percent SO_2 removal efficiency. New Brunswick Power has two scrubbers in operation, one at its new Belledune station and one at its retrofitted Dalhousie station, both of which comply with Canada's guidelines for new thermal power plants. Nova Scotia Power began operating the first commercial fluidized bed unit.

NO_x Reductions

Several initiatives to reduce NO_x at stationary sources are now in place or being finalized as a result of provincial actions in Phase I of Canada's NO_x/VOC Management Plan. They are described below. The number in parentheses is the estimated annual NO_x emissions reduction in kT for that particular measure by 2000. The six measures total 125 kT in NO_x emissions reductions:

- Canada's national NO_x emissions limits for new steam-electric power plants were revised in 1993 and went into effect in 1995 under the Canadian Environmental

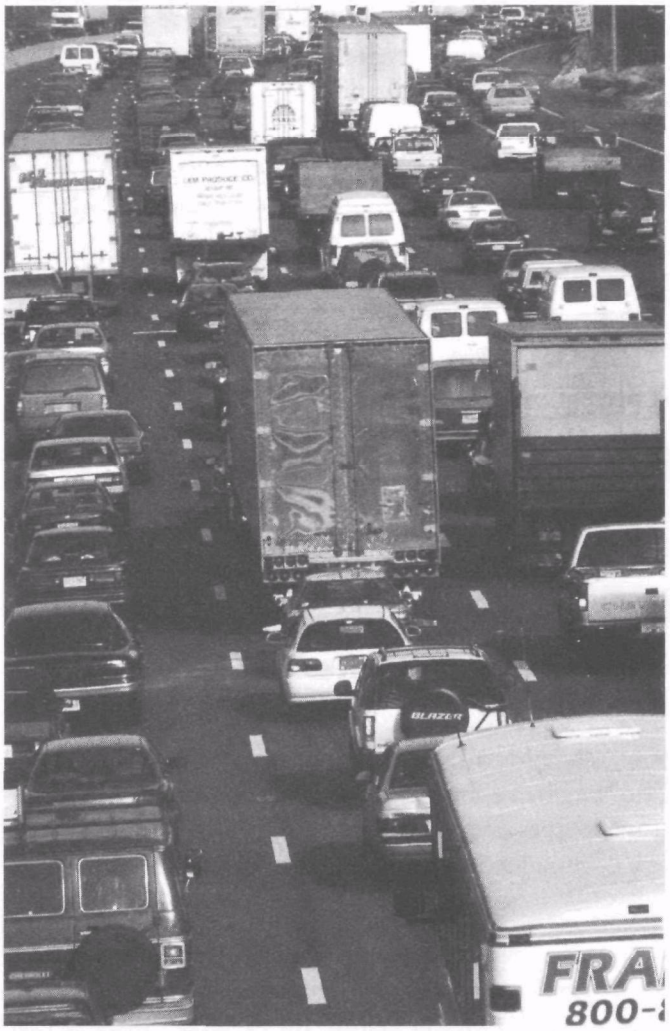

Photo: Steve Delaney, U.S. EPA

Assessment Act. In 2000, the limits will be tightened to less than one-quarter of the current limit (10 kT).

- Retrofits of NO_x emissions controls at existing fossil fuel-burning power plants are proceeding in Quebec, New Brunswick, Ontario, and British Columbia (12 kT).
- New source limits were published in 1992 for gas turbines used to power pipeline compressors and in increasingly popular combined-cycle power plants (20 kT).
- New source limits for other stationary fossil fuel- burning equipment, such as boilers, process heaters, and kilns, are being finalized (40 kT).
- A complete reconstruction of the INCO metals smelter at Sudbury, Ontario, included switching to an oxygen-based process. By excluding atmospheric nitrogen from the furnace, NO_x emissions have been virtually eliminated (43 kT).
- British Columbia has implemented a mandatory vehicle inspection and maintenance (I/M) program, and a number of other provinces are developing regional programs to curb smog problems through I/M, public education, and public transportation.

Regarding mobile-source initiatives, beginning with the 1994 model year, new Canadian light-duty vehicles have met more stringent emissions standards, paralleling those in the United States. These more stringent standards resulted from an agreement between the federal government and automakers.

At their October 1995 meeting, the Canadian Council of Ministers of the Environment endorsed a new Cleaner Vehicles and Fuels Initiative. This important new initiative will accomplish the following:

- Further tighten new vehicle emissions standards in harmony with the United States.
- Introduce new alternative low-emission vehicles starting in 2001 (with 10-percent lower NO_x emissions and 7-percent lower VOC emissions).
- Extend low-sulfur diesel fuel to 100 percent of on-road diesel use starting in 1997.
- Introduce gasoline with reduced benzene and sulfur content starting in 1998.

Monitoring of Canadian Emissions

Compliance monitoring involves measuring or estimating emissions, verifying that the values are appropriate, and reporting the results to authorities on a regular basis. In Canada, emissions may be one of the following:

- Estimated. These are based on industrial process variables, such as combustion parameters, tonnes of ore processed, or sulfur recovered per unit of time.
- Directly measured on a continuous basis. CEM is the actual measurement, on a continuous basis, of pollutants emitted into the atmosphere in exhaust gases from combustion processes.
- Predicted. Predictive emissions monitoring systems or "software CEM" use combustion and process parameters that are inputted into the plant's control system to track and predict emissions.

Under the Agreement, Canada was required by January 1995 to establish at electric utility units greater than 25 megawatts a method of comparable effectiveness to CEM.

Canada was also required to investigate the feasibility of using and implementing CEMs where appropriate.

To ensure compliance with the Agreement, Canada issued a guideline under CEPA stating that all new and modified thermal power plants commissioned after 1995 install CEM systems in accordance with the new Performance Specification and Protocol for Continuous Emission Monitoring of Gaseous Emissions from Thermal Power Generation. Most provinces have regulations that require existing units to install CEM. (For additional discussion see Section VI, Article-by-Article Review.)

For large, base-loaded utility units, all but two plants—Boundary Dam in Saskatchewan and Holyrood in Newfoundland—had installed CEM systems or systems of equivalent effectiveness by the end of 1995. These two provinces are now reviewing the requirements to install CEM systems or use other comparable methods.

Capacity used on a standby or peaking mode presents technical difficulties for CEM. Other estimation methods are more appropriate and have been accepted in Canada.

Most provinces require monitoring in other industries with major combustion sources, such as plants in the pulp and paper, cement, chemicals, steel-making, and smelting sectors.

The application of methods other than conventional CEMs usually depends upon the size and location of the facility, the nature of the fuel, and the type of combustion equipment. Since many of Canada's medium-sized sources are fueled by natural gas, the use of predictive monitoring systems is expected to increase. These systems reduce emissions by optimizing combustion processes.

United States

Program Goals

The U.S. Acid Rain Program to reduce SO_2 and NO_x emissions is well under way. Major goals of the Acid Rain Program established under Title IV of the 1990 Clean Air Act Amendments (CAAA) are:

- Reduction of annual SO_2 emissions by 10 million tons below 1980 levels.
- A 50-percent reduction in utility SO_2 emissions.
- A national cap on utility SO_2 emissions of 8.95 million tons per year.
- A national cap on nonutility SO_2 industrial emissions of 5.6 million tons.

These goals are to be accomplished in two phases—Phase I began in January 1995; Phase II begins in 2000. The Acid Rain Program is also designed to reduce NO_x emissions from coal-fired boilers as part of an overall 2-million-ton NO_x reduction mandated by the Act.

SO_2 Program Implementation

The United States began its first compliance year in 1995 for Phase I of the Acid Rain Program. SO_2 emissions declined sharply in 1995 at the original 263 Phase I electric utility units. Emissions at these large, mostly coal-burning facilities were nearly 5 million tons below 1980 levels, representing a decline in emissions at these units of more than 50 percent since 1980. These Phase I units were responsible for more than half of the 1980 utility SO_2 emissions and represent 95 percent of total 1995 emissions reductions.

Additional 1995 reductions of 300,000 tons were achieved by 182 substitution and compensating units—Phase II units that chose to comply with Phase I requirements early. Actual emissions levels of SO_2 for all utility units in Phase I decreased to 5.3 million tons from 1980 levels of 10.9 million tons, a reduction of 3.4 million tons more than allowable levels of 8.7 million tons in the first year of compliance (see Figure 1). These emissions reduction milestones followed significant levels of allowance trading and 100-percent utility compliance

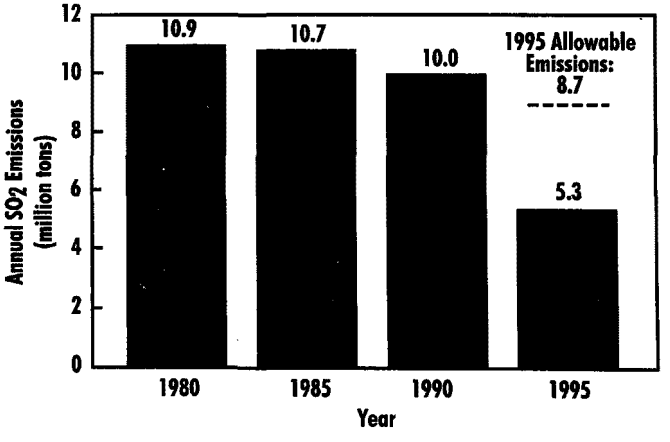

Figure 1. U.S. SO_2 Emissions Reductions at Phase I Affected Utility Units.

Note: Affected utility units include the original 263 Phase I units and 182 substitution and compensating units that chose to comply with Phase I requirements early.

with all Phase I permitting, CEM, and reporting requirements.

Since the Acid Rain Program's major rules were published in January 1993 and the 1994 Progress Report was issued, the U.S. Environmental Protection Agency (EPA) has promulgated additional regulations to foster the Acid Rain Program. These include a final opt-in regulation in April 1995 allowing small utility combustion sources (boilers, turbines, or internal combustion engines) to enter the Acid Rain Program voluntarily.

Allowance Trading

Allowance trading grew significantly during the first year of Phase I compliance. As of March 31, 1996, EPA's Allowance Tracking System (ATS) recorded more than 2,000 allowance transactions involving the transfer of more than 40 million allowances. Of the 40 million allowances, nearly 30 million were transferred by private parties. About 10 percent of these allowances were acquired by electric utility companies from brokers, fuel companies, or other electric utilities. EPA expects that an even more significant portion of the total allowances transferred will become "intrautility" trades (allowances transferred among different plants within the same company).

Allowance purchases through EPA's annual public auction continue to receive support. Some 775,000 allowances have been sold in four auctions, with the average sales price of allowances continuing to drop. In the March 1996 auction, 275,000 allowances were sold with average prices ranging from $64 to $68.

In other program initiatives, EPA's awards of allowances from the Conservation and Renewable Energy Reserve have increased significantly to utilities that reduced emissions through energy efficiency and renewable projects before the CAAA emissions reductions deadlines. In December 1995, EPA awarded more than 8,600 energy efficiency and renewable energy bonus allowances, the largest award of bonus allowances since they began in 1993 and twice the total number of allowances that had been previously awarded.

EPA has also made the first awards of small diesel allowances. The CAAA established the small diesel refinery program to assist small refiners in defraying the capital costs of installing desulfurization equipment at their refineries by providing SO_2 allowances based on the amount of diesel fuel produced.

In another program initiative, EPA awarded its first allowances to industrial sources voluntarily entering the Acid Rain Program. Allocations of 95,882 allowances were awarded to Alcoa units in Newburg, Indiana and Dupont boilers in Johnsonville, Tennessee. Known as the opt-in program, additional combustion sources (e.g., fossil fuel-fired boilers, turbines, or internal combustion engines) not already affected by the Acid Rain Program can participate in allowance trading. Sources can create allowances through emissions reductions and generate revenue through the sale of allowances. Opting in will be profitable if the revenue from selling allowances exceeds the combined cost of the emissions reductions and of participating in the opt-in program.

NO_x Program Implementation

The United States is undertaking a combination of measures for stationary and mobile sources to reduce NO_x emissions under the CAAA. NO_x emissions are expected to be reduced by more than 2 million tons by 2000. A major part of these reductions is expected from Acid Rain Program reductions of emissions from coal-fired electric power plants.

In the first stage of the Acid Rain Program's NO_x reductions, regulations promulgated in April 1995 will reduce NO_x emissions by more than 400,000 tons per year from 1996 to 1999 and by more than 1.2 million tons by 2000. The regulations established standards for Group 1 boilers (defined as coal-burning, dry bottom wall-fired, and tangentially fired boilers).

The Acid Rain Program's proposal for second-stage NO_x reductions was announced in January 1996. These reductions will provide further NO_x reductions by 2000. The proposal presents standards for 195 Group 2 boilers (defined as cell burners, cyclones, wet bottom wall-fired, vertically fired, and fluidized bed combustors) and also proposes tightening existing standards for Phase II Group 1 boilers. Under CAAA requirements, regulations for these second-stage NO_x reductions must be promulgated by January 1, 1997.

Phase I affected units are required to meet the applicable limits by 1996. Phase II affected units are required to meet the applicable limits by 2000. The proposed rule relies upon target performance standards but also allows emissions averaging and the use of alternative, higher emissions limits where meeting the applicable limits is infeasible. Utilities choose the method of compliance which best suits their needs. This approach provides

flexibility, promotes technology development and competition, and provides opportunities to reduce the cost of control.

In other developments, EPA continues to work with states to help them implement stationary-source requirements for reducing ground-level ozone in parts of the United States. Since the issuance of the 1994 Progress Report, states and the District of Columbia in the Ozone Transport Commission (OTC) signed a memorandum of understanding (MOU) to reduce NO_x emissions by 55-75 percent from 1990 levels. The reductions will occur in two phases, 1999 and 2003, and will help significantly reduce smog levels in the northeastern United States as well as help achieve the health-based standards for ozone.

In programs aimed at reducing NO_x emissions from mobile sources, EPA continues to implement regulations established under the CAAA for passenger cars and trucks. In addition to standards reported in the 1994 Progress Report, EPA introduced tailpipe standards for cars in 1994 that will be phased in on car models through 1996. More stringent tailpipe standards will substantially reduce emissions of NO_x and VOCs, the main components of ground-level ozone.

EPA also is developing two major programs that will result in significant NO_x reductions early in the 21st century. The National Low-Emission Vehicle (LEV) Program is expected to achieve nationwide reductions of NO_x emissions of 400 tons per day by 2005. Once the vehicle fleet has turned over, NO_x reductions of 1,200 tons per day are estimated by 2015. In addition, EPA is developing regulations in partnership with the State of California and leading manufacturers of heavy-duty engines. These regulations will establish a consensus plan to reduce emissions from new trucks and buses substantially beginning in 2004. This is expected to result in a 50-percent reduction over current levels of NO_x emissions from heavy-duty engines.

Monitoring of U.S. Emissions

All operating Phase I and Phase II utilities have installed CEMs or acceptable alternatives. There is an unprecedented level of accuracy and compliance in the CEMs installed by utilities and nearly full compliance with reporting requirements. Some 98 percent of installed monitors at Phase I units passed the required 10-percent relative accuracy standard; 93 percent achieved relative accuracy standards of less than 7.5 percent. Monitors used at Phase I units were in operation more than 95 percent of the time.

Worker tests continuous emission monitoring equipment used at a U.S. utility plant.

CEMs and the Emissions Tracking System (ETS) ensure the integrity of the Acid Rain Program, instilling confidence in allowance transactions by certifying the existence and quantity of the commodity being traded. Monitoring also ensures through accurate accounting that the emissions reductions goals of the CAAA are met. Each new and existing electric utility unit greater than 25 megawatts must employ a CEM system; there are alternative monitoring requirements for some natural gas and oil-fired units.

The Acid Rain Program focuses on total emissions. Each regulated unit must account for each ton of SO_2 emitted as well as NO_x and carbon dioxide (CO_2). In addition, each unit must measure volumetric flow, opacity, and diluent gas. Utility units are required to provide electronic quarterly reports to EPA on their emissions. Quarterly reporting of emissions for Phase II units began in April 1995. All Phase I units fulfilled their requirement to report a full year's worth of hourly emissions data.

EPA's ETS records quarterly report data and analyzes each unit's emissions data for quality assurance. These data are then reconciled with the unit's SO_2 allowance holdings during annual reconciliation, under which a unit's SO_2 emissions must match the allowances it holds. By the fourth quarter of 1995, nearly 40 percent of Phase

I and Phase II affected utility units submitted emissions data to EPA by electronic transfer.

EPA certified all Phase I electric utility units in 1995. Most Phase II units are expected to be certified by the fall of 1996. Monitoring tests revealed high performance results.

Annual Reconciliation

The first annual reconciliation of SO_2 allowances and emissions for utility units occurred in early 1996 after the first year of Phase I compliance. All 445 affected utility units met their compliance obligations—SO_2 allowances held matched emissions generated. In 1995, 87 million SO_2 allowances were held by utility units, allowing up to 8.7 million tons of SO_2 to be emitted. However, only 5.3 million tons of SO_2 were emitted—39 percent less than allowed.

All Phase I units and any Phase II units that elected to participate during Phase I must reconcile SO_2 emissions and allowances at the end of each compliance year. Utilities are given until January 30 of the following year to obtain additional SO_2 allowances, if necessary, to cover each unit's emissions for the year. After January 30 (the allowance transfer deadline), the allowances a unit holds in its ATS must equal or exceed the unit's annual SO_2 emissions. Any remaining allowances may be sold or banked for future years. If a unit's emissions exceed the number of allowances held, the unit is out of compliance.

Compliance Assurance Monitoring for Industrial Sources

In addition to Title IV Acid Rain Program CEM requirements for utility sources of emissions, the CAAA included new provisions in Title V, Permits, and Title VII, Enforcement. These provisions require owners and operators of major stationary industrial sources to enhance monitoring of criteria pollutants and certify compliance with regulations. Criteria pollutants are particulate matter (PM_{10}), SO_2, carbon monoxide (CO), nitrogen dioxide (NO_2), ozone, and lead. All major sources covered by Title V would be affected, including electric utility steam generating units, industrial/commercial/institutional steam generating units, municipal waste combustors, petroleum refineries, primary copper, zinc, and lead smelters, steel plants, and pulp mills. Hazardous air pollutants under state regulation also would be affected.

EPA initiated an enhanced monitoring proposal in 1993 that set general monitoring criteria to be followed in demonstrating continuous compliance. EPA withdrew the proposal in April 1995 to allow further review of monitoring approaches.

A revised proposal, named compliance assurance monitoring, was issued in the summer of 1996, taking into account issues raised at a series of stakeholder and focus group meetings. The proposal will establish criteria that define what monitoring should be conducted by a source to provide a reasonable assurance of compliance with emissions limitations and standards. The criteria will include the maximum number of discrepancies that represent acceptable control performance and address the obligation to complete corrective actions as indicated by monitoring results. A final rule is expected to be promulgated in the summer of 1997.

PSD and Visibility Protection

Information Exchange Meetings Between Canada and the United States

Since the last progress report, the National Park Service and Parks Canada cosponsored the second international air issues workshop in June 1995 at Waterton Glacier International Peace Park. In addition to the park services, participants included EPA, Environment Canada, the U.S. Forest Service, U.S. Fish and Wildlife Service, the provinces of Alberta and British Columbia, the state of Montana, and the Confederated Salish and Kootenai Tribes.

Among the recommendations made to continue and expand cooperative efforts were the following: (1) establishing a national lead on air quality at Parks Canada; (2) beginning a newsletter and information exchange; (3) sharing monitoring and research data and establishing a common monitoring program; (4) participating in regional air quality partnerships and programs; and (5) forming park-level working groups, including exchanges of personnel.

Status of Development of PSD and Visibility Programs in Canada

In December 1994, Canada submitted to the AQC a formal response on Canada's obligations under the Air Quality Agreement regarding PSD and visibility. In brief, Canada holds that the Canadian Environmental Assessment Act (proclaimed on January 1, 1995), together with provincial permitting and assessment regulations and maximum desirable air quality objectives (the benchmark for assessment of new sources near pristine areas), provides comparable protection to that provided by the U.S. PSD program.

In general, new point sources or modifications to existing sources under provincial jurisdiction are required to submit to environmental assessment and/or permitting processes. Applications are reviewed under the applicable legislation. Every jurisdiction in the country has formal environmental assessment legislation.

As part of this assessment process, the proponent must undertake the following:

- Justify the need for the project and review alternative options.
- Complete a pollution prevention analysis.
- Analyze pollution control technologies to minimize emissions.
- Evaluate the impact of emissions on the environment, including ambient air quality and visibility.
- Adjust the project as required by the air quality analysis.

New or modified sources in already developed areas are generally assessed against the maximum acceptable air quality objectives. Projects proposed for undeveloped areas, including those that might impact national or provincial parks, are assessed against the maximum desirable air quality objectives to keep clean areas clean. Maximum desirable objectives are comparable to background levels.

In addition, the Canadian Environmental Assessment Act provides the means to ensure that the impact of proposed Canadian sources will be assessed in U.S. territory, including Class I areas, and that possible damages will be mitigated. (Class I areas are areas of special natural, recreational, scenic, or historic value, such as national parks and wilderness areas.)

The United States, however, has indicated its concern that Canada has not fulfilled its PSD/visibility obligations under the terms of the Air Quality Agreement. Further discussions between the two governments are under way. (For additional information, see Section VI, Article-by-Article Review.)

Progress of Existing PSD and Visibility Programs in the United States

The U.S. PSD program was designed to keep areas with clean air clean. The basic goals of the PSD program are the following: (1) ensure that economic growth will occur in harmony with the preservation of existing clean air resources; (2) protect the public health and welfare from any adverse effects that might occur even at air pollution levels lower than the National Ambient Air Quality Standards (NAAQS); and (3) preserve, protect, and enhance the air quality in Class I areas.

Since the 1994 Progress Report, the Interagency Workgroup on Air Quality Modeling, comprised of EPA and federal land managers (National Park Service, U.S. Fish and Wildlife Service, and U.S. Forest Service), has continued to develop air quality modeling tools that will evaluate the effects of long-range transport on national parks and wilderness areas. Since the issuance in 1993 of a first-phase report outlining the use of modeling tools in the air quality permitting process and steps needed for improvement, most of the recommendations have been accomplished.

These accomplishments include developing high-resolution wind fields for better characterizing transport processes and refining meteorological and air quality models to better estimate pollutant levels in parks and wilderness areas. The refined long-range transport analysis techniques were presented for public comment at the sixth EPA modeling conference. These techniques are now being used more routinely in permitting actions around the country, thus improving the scientific basis for decisions concerning air quality impacts in parks and wilderness areas.

A similar though voluntary group, the Southern Appalachian Mountains Initiative (SAMI), has brought together a variety of stakeholders to address visibility as well as ozone and acid deposition issues in the Southeast.

Photo: Air Resources Specialists, Fort Collins, Colorado

Visibility on a good (left) and bad (right) day at Acadia National Park in Bangor, Maine, one of the sites that makes up the U.S. Interagency Monitoring of Protected Visual Environments (IMPROVE) program.

SAMI is focusing on the Great Smoky Mountains and Shenandoah National Parks and the eight Forest Service PSD Class I wilderness areas in the region.

In another development, the Grand Canyon Visibility Transport Commission (GCVTC) has completed the technical assessment of actions to improve visibility on the Colorado Plateau. GCVTC used the assessment to develop regional haze recommendations that were issued in a report to EPA in June 1996. EPA has 18 months to act on the recommendations. The recommendations include: (1) reduction of emissions by vehicles and power plants; (2) encouragement of pollution prevention efforts, including development of renewable energy and energy conservation; (3) exploration of an emissions fee for certain polluters; and (4) minimization of smoke impacts from prescribed areas.

The assessment developed and modeled an emissions inventory, provided air quality and modeling analyses, and evaluated the effectiveness of various emissions management options, including costs, for visibility conditions. GCVTC consists of the governors of western states in the air transport regions and includes ex-officio members from EPA and the federal land managers. The assessment was conducted by committees comprised of representatives from federal and state governments, industry, environmental groups, and academia. GCVTC was mandated under the CAAA.

EPA also has formed an outside advisory committee on ozone, PM, and regional haze implementation programs. This group provides advice and recommendations to EPA on developing new, integrated approaches for implementing NAAQS for ozone and PM as well as for implementing a new regional haze reduction program. The subcommittee is expected to issue a report making recommendations on regional haze reduction in June 1997, with promulgation of any regulations 18 months from the report's issue date.

Visibility monitoring in national parks and wilderness areas is reported in Section III, pages 43-46, of this report.

New Issues Under the Control Programs

Canada

Prior to the Eastern Canadian SO_2 Reduction Agreement in 1985, Canadian scientists predicted that the current SO_2 emissions reductions would likely not be sufficient to protect the more sensitive aquatic ecosystems in Canada (1990 Assessment Report). New scientific evidence since then has confirmed that acidifying emissions are still a serious problem for aquatic and terrestrial ecosystems and human health. (See Section III, pages 35-43 and 47-50.)

As a result, Canada is currently developing a new National Strategy on Acidifying Emissions beyond 2000. The strategy will address the need for further emissions reductions within Canada and the United States to protect the Canadian environment, human health, and visibility. Although the strategy was originally driven by the need to solve the residual acid rain problem, protecting human health from the effects of sulfate particles has become an important consideration. Furthermore, the strategy also will include pollution prevention measures to ensure that areas not currently at risk from acidification will remain so.

The strategy is expected to be submitted to federal and provincial environment and energy ministers in 1997.

U.S. Acid Deposition Standard Feasibility Study

EPA's *Acid Deposition Standard Feasibility Study*, issued in October 1995 and mandated under Appendix B, Section 404, of the CAAA, reported that nitrogen and sulfur play an important role in long- and short-term acidification of surface waters. The report projects that full protection of surface waters might not be realized because of the role of nitrogen in some sensitive watersheds. Although environmental benefits are reported in the study's comparisons of reduction scenarios with and without the Acid Rain Program, additional reductions in nitrogen and sulfur deposition might be necessary to protect the most sensitive resources more fully. (See Section II, pages 21-22, and Section III, page 29, for a more detailed discussion of the study.)

Progress Under Article V of the Air Quality Agreement

Article V, Assessment, Notification, and Mitigation, discusses proposed actions, activities, or projects that, if implemented, would be likely to cause significant transboundary air pollution. Since Article V does not contain implementation procedures, the two governments held discussions to initiate the notification process. From the outset, bilateral discussions were marked by a fundamental disagreement in interpretation of paragraph 1 of Article V that relates to assessment of sources deferring to existing laws, regulations, and policies in both countries. Section VI of this report discusses this matter in more detail.

The two governments began implementing notification procedures in the fall of 1994. The Parties notify each other of major sources of SO_2, NO_2, VOCs, particles, CO, and toxic substances. The identification of possible new sources or modification of existing major sources of transboundary air pollution within 100 kilometers (km) of the border triggers the notification procedure. The Parties recognize, however, that major new sources beyond this zone also could be a concern. Therefore, in November 1994, they agreed to notify each other of any major new source beyond the 100 km limit but did not agree on what criteria to use to decide which sources would trigger notification. All notification information is available to the public on the Internet.

Through formal notification, Canada has notified the United States of eight possible new sources over the last two years, while the United States has notified Canada of two. The United States has also notified Canada of Clean Air Act (CAA) actions addressing air pollution. The United States and Canada consulted on the CAA rulemaking that changed the Detroit-Ann Arbor region's ozone nonattainment status to attainment. The United States also notified Canada about a similar CAA rulemaking on ozone in Ohio.

Market-Based Intruments

Canada

Canada does not have a national emissions trading program like the United States or a tax on SO_2 emissions like Sweden. It is, however, exploring a number of market-based initiatives.

In late 1994, the federal government established the Task Force on Economic Instruments to identify workable options for the implementation of one or more market-based instruments. The task force identified emissions trading programs for NO_x and SO_2 as areas where further work would be required if they were to be considered for implementation in the long term.

The federal government had already begun examining the economic, administrative, and environmental feasibility of an emissions trading program for SO_2 in the Atlantic region. The government found that trading among sources in the Atlantic region can reduce emissions within a regional bubble at a total regional cost significantly less than that of a command-and-control approach. Because of the high proportion of imported sulfur into Atlantic Canada from upwind sources, however, emissions trading limited to Atlantic Canada would have only a marginal impact on regional acidic deposition levels. As a result, Canada is contemplating extending the area under consideration for emissions trading beyond the Atlantic region to include the nearby areas of southern Quebec and Ontario.

A number of industries in Ontario and Quebec are working together on an open-market emissions reduction credit system for controlling NO_x and VOC emissions from mobile and stationary sources in the Windsor-Quebec corridor. The members intend to develop the credit system rules by mid-1996.

United States

The Acid Rain Program under the CAAA represents the world's largest use of market-based mechanisms to achieve environmental protection. Since enactment of the program, the projected cost of compliance with the SO_2 emissions reductions has declined significantly, largely because of the program's flexible, market-based approach. In 1990, EPA estimated the annualized cost of the SO_2 reductions to be $4 billion by 2010, assuming full interutility trading. In December 1994, the General Accounting Office completed an analysis of the program and estimated that with full interutility trading the annualized cost in 2010 should be less than $2.0 billion, compared to an annualized cost of compliance without trading of $4.9 billion.

Some of the cost savings associated with more recent analyses can be linked to lower transportation costs for low-sulfur coal. Other cost savings can be attributed to reductions in costs and improved performance of certain technologies now that they must compete with all emissions reduction options. Clearly, competition between compliance options has had an effect on costs and innovation.

Allowance trading is occurring on two levels, both of which result in significant cost savings to the affected industry.

First, most large utility systems are performing "internal" trades of allowances among the boilers within their systems in order to achieve the lowest cost of compliance for the system. Market watchers speculate that this is the larger share of "trading" that is occurring in the program today. Submissions of trades to be recorded in EPA's ATS are voluntary and will not occur until the parties want the transfer to be "official" for compliance purposes. Therefore, many of these trades are not yet reflected in EPA's tracking system. The second level is the external trading among utilities and various financial entities.

There are numerous other examples of innovative market-incentive programs aimed at achieving pollution reductions under the CAAA. For example, California's South Coast Air Quality Management District (AQMD) is continuing to undertake the most comprehensive ozone nonattainment trading program in the United States with its Regional Clean Air Initiatives Market (RECLAIM) program for the Los Angeles area. Begun in January 1994, RECLAIM sets annual emissions limits on NO_x and SO_2 for 430 sources. These limits would decrease each year to curb the area companies' emissions by 80 percent for NO_x and 65 percent for SO_2 by 2003. AQMD expects that the costs of meeting the goal would be about half that of regular smog control. It is estimated that RECLAIM will save Los Angeles $164.1 million a year.

By the end of 1996, EPA expects to issue guidance for emissions trading of smog-forming pollutants (NO_x and VOCs) that gives states and industry more flexibility in

trading emissions credits without prior state or federal approval. The open-market system, proposed in July 1995, allows industrial sources to create credits by reducing emission rates below recent actual levels required by federal or state rules.

In another market-based trading initiative, the OTC adopted a model rule in February 1996 that implements OTC's NO_x emissions reduction requirement through a market-based "cap and trade" program. OTC was established by the CAAA to coordinate state efforts to reduce ground-level ozone levels across the 12 northeastern states and the District of Columbia. The OTC trading program has the potential to achieve cost savings of nearly $80 million in annualized costs in 2005.

The Ozone Transport Assessment Group (OTAG) is also exploring market initiatives. Comprised of 37 states in the eastern United States, OTAG is expected to report on a regional trading option in the fall of 1996 as part of an effort to reduce ozone transport.

Finally, several states have established or are establishing their own initiatives for market incentives for air pollution reductions. These states include California, Connecticut, Illinois, Massachusetts, Michigan, New Jersey, New York, Oklahoma, and Texas.

Assessment of the Costs, Benefits, and Effectiveness Of Clean Air Controls

Canada

Canada continues to gather data to evaluate the costs, benefits, and effectiveness of clean air controls. In the past, abatement strategies for air pollution were developed based on studies that emphasized either costs or emissions reductions. They were not easily linked to the expected environmental benefits.

To correct this weakness, Canada has developed an integrated assessment model that links control costs, SO_2 emissions forecasts, atmospheric relationships, and geochemical and biological model results with a geographic information system to predict ecological responses. The model allows the user to ask questions such as: "What level of SO_2 emissions is needed to protect all lakes in Canada?" In addition, the model can identify the most efficient and cost-effective way to meet environmental objectives. As a result, it is an important tool for developing the new National Strategy for Acidifying Emissions.

Since there are serious effects of air pollution on human health, a number of studies to assess health costs have been conducted, including the following:

- A 1994 study of the clean air benefits in the Lower Fraser Valley in British Columbia that examined pollutants such as PM_{10}, SO_2, NO_x, and VOCs. The study found that health benefits could be approximately Can$7 billion over a 35-year period.
- A 1995 study on the health benefits from reducing vehicle emissions nationally (e.g., particles, NO_x, VOCs, some air toxics, and benzene) that found that the health benefits ranged from Can$11 billion to Can$30 billion over a 24-year period.

United States

Numerous efforts are under way to evaluate the costs, benefits, and effectiveness of the U.S. Acid Rain Program and the overall CAAA. As mandated by several sections of the CAAA, initial assessments and evaluation of the Acid Rain Program have been completed. Others are under way or planned.

EPA's *Acid Deposition Standard Feasibility Study* (EPA430-R- 95-001a), issued in October 1995 and mandated under Appendix B, Section 404, of the CAAA, was one of the first studies to project environmental effectiveness of the Acid Rain Program. The study indicates that SO_2 emissions reductions will benefit sensitive surface waters such as lakes and streams, particularly in the eastern United States. The study also reports that nitrogen and sulfur play an important role in long- and short-term acidification of surface waters. The report concludes that additional reductions in nitrogen and sulfur deposition might be necessary to fully protect the most sensitive resources. The report also projects that trading of SO_2 emissions allowances under the Acid Rain Program, which is expected to reduce control costs by about 50 percent, will not have detrimental environmental effects.

The report found that scientific uncertainties, particularly with regard to nitrogen, need to be reduced. The report does not recommend setting an acid deposition standard at this time, a view supported by EPA's Science Advisory Board. (An acid deposition standard is a

numerical limitation on the amount of acidic compounds above which adverse impacts are believed to occur to a given ecological resource.) The report does, however, lay the foundation for future efforts to assess appropriate environmental goals in ecologically sensitive regions.

The feasibility study integrated state-of-the-art ecological effects research, emissions data, and source-receptor modeling work. The study also considered implementation and cost issues (see Section II of this report, page 19).

Another EPA study issued in November 1995, *Human Health Benefits From Sulfate Reductions Under Title IV of the 1990 Clean Air Act Amendments,* estimates the total annual value of the health benefits in the United States (in 1994 dollars) resulting from Title IV's sulfate reductions. The study estimates the value to be between $3 billion and $11 billion in 1997, and between $12 billion and $40 billion by 2010 when the program is fully implemented. The study also projected that annual health benefits for eastern Canada resulting from U.S. reductions in SO_2 emissions would be an additional $1 billion in both 1997 and 2010.

Copies of the feasibility and human health benefits studies are available from the Acid Rain Hotline at 202 233-9620.

Other benefits assessments are under way. Section 812 of the Amendments requires EPA to assess the costs and benefits of the entire CAAA. The assessment requirement is both retrospective (1970-1990) and prospective (in terms of projections regarding expected costs, benefits, and other effects of compliance pursuant to the Act). The retrospective report is under review. The prospective report is being developed.

Evaluation of the Acid Rain Program also will be addressed under Section 901 of the CAAA. Under this requirement, the National Acid Precipitation Assessment Program (NAPAP), a federal interagency program established by Congress in 1980, is directed to issue a report to Congress in 1996 and every four years thereafter on costs, benefits, and effectiveness of Title IV. NAPAP is also directed to address deposition rates that must be achieved in order to prevent adverse ecological effects. In support of this mandate, a tool for modeling integrated assessment, the Tracking and Analysis Framework (TAF), is being developed for NAPAP.

TAF has the following goals: (1) integrating credible models of scientific and technical issues into an assessment framework that can directly assess key policy issues and (2) acting as an orderly repository with the capability for storing and analyzing real-world data on emissions, deposition, compliance strategies, and costs, as they become available. TAF is made up of various models which include emissions, atmospheric pathways, lake acidification, visibility, and benefits evaluation.

Since implementation of Phase I of the Acid Rain Program only began in 1995, there is not enough information available at this time to conduct a more comprehensive integrated assessment in 1996. Therefore, the 1996 NAPAP Report to Congress will consider the state-of-science in the effects and benefits areas relevant to acid deposition. The 1996 NAPAP Report to Congress will describe the activities that need to occur in order for TAF to contribute to a more complete assessment of the costs and benefits of Title IV of the CAAA as part of the year 2000 assessment.

In addition, EPA submitted its first report to Congress in 1995 on national SO_2 emissions trends from industrial sources such as coal-burning plants, pulp and paper mills, and petroleum refineries. The report, *National Annual Industrial Sulfur Dioxide Emission Trends, 1995-2015* (EPA454-R-95-001), concludes that industrial SO_2 emissions are expected to decrease 13 percent (to 4.9 million tons) from the 5.6-million-ton cap during the next 20 years. The report also finds that the diesel fuel desulfurization regulations are already having a positive effect on reducing mobile-source SO_2 emissions, demonstrating a 19- percent decrease in diesel vehicle emissions and a 10-percent reduction in overall motor vehicle emissions. A copy of the emissions trends report (publication number PB96-13955) is available from the National Technical Information Service (NTIS) at 703 487-4660 or from INFOCHIEF at 919 541-5285.

SECTION III

Progress: Scientific and Technical Activities and Economic Research

This section discusses each country's progress in meeting the commitments outlined in Annex 2 of the Air Quality Agreement to coordinate and cooperate on air quality modeling, monitoring, and effects research.

Emissions Inventories

Emissions inventories provide the foundation for air quality management programs. They are used to identify the major sources of air pollution, provide data to input in air quality models, and track control strategies.

Accuracy of emission inventories has always been a priority in Canada and the United States. Both countries have been updating and improving their estimates for the 1990 inventory using the latest information obtained from states/provinces, source measurements, and special study findings. The expanded use of CEM in both countries is expected to improve the accuracy and timeliness of emissions data. Numerous tools also have been developed to analyze emissions trends and forecasts. The countries are continuing to meet biannually to increase the level of collaboration in compiling emissions inventories.

Overall, emissions have decreased in Canada and the United States. SO_2 emissions decreased significantly in both countries. In the United States, NO_x and VOCs increased slightly from 1993 levels, due to more vehicle miles traveled and increased wildfires. NO_x and VOC emissions data are expected to show decreases in 1995, when more EPA-mandated mobile-source controls are in place. In Canada, NO_x emissions estimates show a decrease or flattening between 1980 and 1994. Canada has been developing industrial and pollution controls equivalent to those in the United States. These controls have contributed to the emissions reductions. The two governments have continued to work together to ensure emissions inventory data consistency and coordination in emissions trends analysis.

SO_2, NO_x, and VOC Emissions in Canada and the United States from 1980 to 2010

SO_2 and NO_x emissions are the dominant precursors of acidic deposition. They also contribute to fine particle pollution and visibility degradation. NO_x and VOCs are the primary contributors to the formation of ground-level ozone, which is involved in the formation of acidic compounds in the atmosphere.

Methodologies were revised in 1992 for the three pollutants covered in this report. Methods continue to change as new models and data are introduced. The 1996 Progress Report includes data on forest-fire emissions and uses a residential wood-burning model from the U.S. Department of Interior and U.S. Department of Agriculture's Forest Service. The report also uses an EPA growth model incorporating 1991, 1992, and 1993 emissions updates. Emissions estimates for SO_2 from mobile sources were revised using the EPA on-road PM emission factor model. An EPA mobile-source emissions factor model was also used to estimate VOC and NO_x emissions. In addition, EPA's Office of Mobile Sources conducted an extensive off-highway VOC emissions data survey in 1990 that produced more accurate estimates than previous totals.

The emissions estimates for 1980, 1985, 1990, and 1994 and the projected emissions estimates for 2000 and 2010 are described for each pollutant in the following sections. The 1990 and 1994 data reported for both Canada and the United States are preliminary. The 1980 data are included because 1980 is the base year for measuring emissions reductions under the acid rain control programs in both countries. Table 3 summarizes the 1994 emission

Table 3. Emissions Estimates for Canada and the United States, 1994

	SO_2		NO_x		VOCs	
	(million tonnes[1])	(million tons[1])	(million tonnes)	(million tons)	(million tonnes)	(million tons)
United States						
Electric Utilities	13.5	14.9	7.1	7.8	0.0	0.0
Industrial	4.6	5.1	3.7	4.1	10.4	11.4
Mobile	0.0	0.0	9.6	10.6	7.7	8.5
Other	1.0	1 .1	1.0	1.1	3.0	3.3
Total	19.2	21.1	21.5	23.6	21.1	23.2
Canada						
Electric Utilities	0.6	0.7	0.2	0.2	neg.	neg.
Industrial	1.6	1.8	0.5	0.5	0.8	0.9
Mobile	0.1	0.1	1.2	1.3	0.7	0.8
Other	0.4	0.5	0.1	0.1	1.2	1.3
Total	2.7	3.0	2.0	2.2	2.7	3.0
U.S./Canadian Total						
Total	21.9	24.1	23.5	25.9	23.8	26.2

Notes: One ton is equal to 0.9 tonnes; 1 tonne is equal to 1.1 tons; total is not the raw data total of enumerated items due to rounding of numbers.

estimates for Canada and the United States. Figures 2, 3, and 4 summarize the SO_2, NO_x, and VOC emissions estimates for 1980, 1985, 1990, 1994, 2000, 2005, and 2010. The data presented in these figures and Table 3 were obtained from *EPA National Air Pollution Emission Estimates, 1900-1994* (EPA454-R-95-011), published in October 1995, and from Environment Canada (Pollution Data Analysis Division).

SO_2

The principal anthropogenic sources of SO_2 are coal and oil combustion, smelting, and a few industrial processes. As shown in Table 3, electric utilities were responsible for 70 percent of the 1994 SO_2 emissions in the United States and 22 percent in Canada. Industrial sources were responsible for 23 percent of SO_2 emissions in the United States and 60 percent of total SO_2 emissions in Canada.

SO_2 emissions are declining. Overall trends in emissions levels from 1980 to 2010 for Canada and the United States are presented in Figure 2. In 1980, total estimated SO_2 emissions in the two countries were 28.5 million tonnes. In 1985, total estimated SO_2 emissions in Canada and the United States were 24.2 million tonnes. From 1980 to 1994, SO_2 emissions in North America were estimated to decline by 6.6 million tonnes, or 23 percent. SO_2 emissions in the United States in 2000 and 2010 are projected to be 17.4 and 15.7 million tons, respectively. The totals include emissions from banked or unused allowance credits. SO_2 emissions in Canada in 2000 and 2010 are projected to be 2.8 and 2.9 million tonnes,

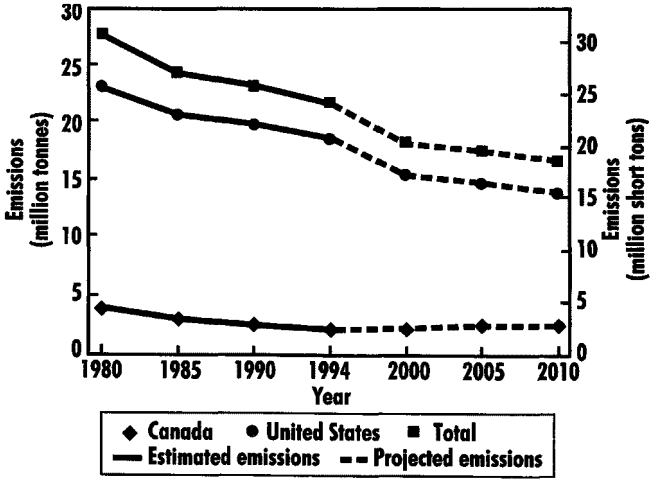

Figure 2. SO_2 Emissions.

respectively. Uncertainty bands on the national annual emissions estimates of SO_2 range from 5 to 10 percent; the uncertainty bands are larger for regional annual emissions estimates.

The United States' SO_2 utility emissions cap of 8.95 million tons is not expected to be achieved until 2010 because utilities in Phase II are projected to use banked allowances gained from significant overcompliance in Phase I.

NO_x

The principal anthropogenic source of NO_x emissions is fuel combustion, which occurs in internal combustion engines, residential and commercial furnaces, industrial boilers, electric utility boilers and engines, and other miscellaneous equipment. As shown in Table 3, mobile sources produced 45 percent of NO_x emissions in the United States in 1994 and 60 percent of emissions in Canada. Electric utilities were responsible for 33 percent of the 1994 emissions in the United States and 10 percent in Canada. Industrial sources were responsible for 19 percent of NO_x emissions in the United States and 25 percent of total NO_x emissions in Canada.

Figure 3 shows the overall trend for anthropogenic emissions of NO_x in Canada and the United States from 1980 to 2010. In 1980, the total estimated NO_x emissions in the two countries were 23 million tonnes. Estimates of NO_x emissions in North America from 1980 to 1994 showed a slight increase of 0.5 million tonnes, or 2 percent. NO_x emissions are expected to decline slightly by 2000, then rise in both countries. NO_x emissions in the United States in 2000 and 2010 are projected to reach 20.7 and 21.6 million tons, respectively. NO_x emissions in Canada in 2000 and 2010 are expected to stay constant at 2.0 million tonnes per year. Uncertainty bands for national annual NO_x emissions range from 10 to 15 percent and are larger regionally.

VOCs

VOCs contribute to the formation of ground-level ozone and acidic compounds in the atmosphere. Anthropogenic emissions of VOCs come from a wide variety of sources, such as mobile sources and industrial processes (e.g., chemical manufacturing, petroleum product production, and industrial solvent use). As shown in Table 3, mobile sources produced 36 percent of VOC emissions in the United States in 1994 and 26 percent of emissions in Canada. Industrial sources were responsible for 49 percent of the VOC emissions in the United States and 30 percent of the total in Canada. There are also important natural sources of these emissions.

VOC emissions in both countries are expected to decline by the year 2000, then remain stable through 2010. Overall trends in VOC emissions levels from 1980 to 2010 for Canada and the United States are presented in Figure 4. In 1985, the total estimated emissions of VOCs in Canada and the United States were 26.2 million

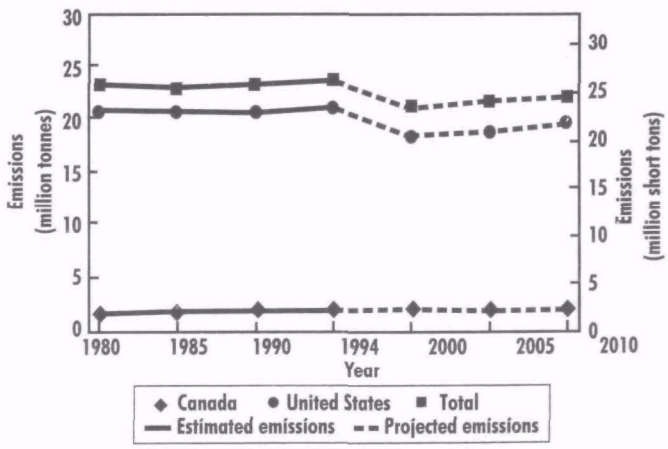

Figure 3. NO_x Emissions.

tonnes. From 1980 to 1994, VOC emissions in North America were estimated to decline by 1.8 million tonnes, or 7 percent. Estimated emissions for the United States are 19.6 million tons in 2000 and 20.3 million tons in 2010. VOC emissions in Canada in 2000 and 2010 are projected to reach 2.7 and 2.9 million tonnes, respectively. Uncertainty bands on anthropogenic and natural emissions of VOCs are large.

Ammonia

Natural and anthropogenic emissions of ammonia are important in the study of acidic deposition. In the atmosphere, ammonia, a nitrogen-containing compound, is converted to ammonium. Ammonium is deposited to the earth, leading to the additional loading of nitrogen and acidification of soil and surface waters. In the atmosphere, however, ammonia can neutralize acidity, lessening the effects of acid fog.

EPA and several international organizations have conducted research on ammonia emissions factors. EPA completed a literature search assessing the most recent information in an EPA report entitled *Development and Selection of Ammonia Emissions Factors* (EPA600-R-94-190). The report recommends several new emissions factors for fertilizer application and updates information on ammonia emissions from selective catalytic and nonselective catalytic converters ("ammonia slip"). The report (publication number PB95-123915) is available from NTIS at 703 487-4660.

EPA will develop a brief research plan that identifies source categories in need of more study. This plan will incorporate research presented at a major international conference on atmospheric ammonia in October 1995. Additional research will focus on the following: (1) the limited test data available for studying large-scale national and global ammonia emissions; (2) significant industrial process changes; and (3) the controversy due to the current emissions factor or activity data.

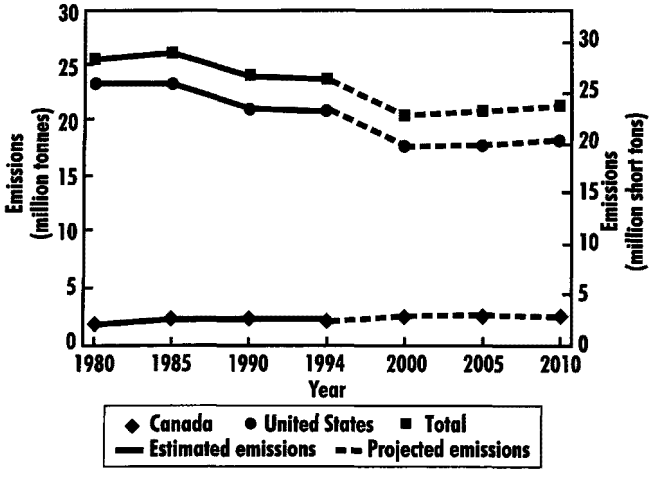

Figure 4. VOC Emissions.

Deposition Monitoring and Prediction

Airborne pollutants are deposited to earth's surface by three processes: wet deposition, dry deposition, and cloudwater deposition. Wet deposition is estimated by measuring and analyzing rain and snow. Dry deposition is estimated by analyzing particles and gases, which can be difficult and costly. Cloudwater deposition usually occurs at higher elevations, which are often cloudy and fog-prone. Cloudwater deposition is also difficult to estimate because it is highly dependent on topography.

Due to the difficulties of measuring dry and cloudwater deposition, the primary focus of monitoring has been on measuring and assessing wet deposition. Work is under way to develop an effective method of combining estimates of dry deposition with wet deposition measurements to provide comprehensive information on regional variations.

Monitoring Networks

Canada and the United States have networks that monitor wet deposition and measure air concentrations to estimate dry deposition. Data from the U.S. and Canadian networks have been combined in this report to provide comprehensive deposition information in North America. Deposition monitoring integration efforts continue.

Canada

In Canada, the Canadian Air and Precipitation Monitoring Network (CAPMoN) and provincial networks report wet deposition data. Several CAPMoN and provincial sites also report dry deposition data. CAPMoN has been providing daily concentration data at some sites for up to 16 years.

United States

In the United States, the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is the largest wet deposition network. It uses a weekly measurement protocol at approximately 200 sites, some with data records dating from the early 1980s. The Atmospheric Integrated Research Monitoring Network (AIRMoN), under the National Oceanic and Atmospheric Administration, is also part of NADP. AIRMoN is the world's oldest wet deposition network. The daily monitoring at these sites is essential for reliable ammonium and nitrate data. The United States also has the Clean Air Status and Trends Network (CASTNet), established in 1987, which reported weekly average concentration data for 52 sites through September 1995. CASTNet supplements the NADP/NTN wet deposition network in areas that do not have monitoring sites, such as mountain and coastal regions. CASTNet operates in collaboration with the dry deposition component of AIRMoN established in 1984.

Findings of Air Pollutant Monitoring Activities (Canada/United States)

Wet Deposition/Concentrations

Wet sulfate deposition and concentration data show a downward trend in Canada and the United States. Nitrate concentration and deposition data show no significant trend.

A comparison of the 1992 and 1993 deposition patterns with those of previous years (presented in earlier reports) shows that the areas receiving the highest deposition (greater than 30 kg/ha/yr sulfate and 20 kg/ha/yr nitrate) are in the parts of southern Canada and northern United States that border the lower Great Lakes. Figures 5 to 8 show the spatial distributions of wet sulfate and nitrate deposition in 1992 and 1993. The patterns vary considerably in size and shape from year to year depending on meteorological and emissions variability. Continued long-term monitoring is needed to quantify the link between emissions reductions and changes in deposition and concentrations and to confirm the effectiveness of further emissions reductions for both SO_2 and NO_x.

For estimating trends, measurements of sulfate and nitrate concentrations in precipitation are more useful than amounts of deposited sulfate and nitrate because pollutant concentrations are less affected by annual fluctuations in precipitation. Figure 9 shows a general trend toward decreasing concentrations of sulfate in rain from the early 1980s to the early 1990s, while Figure 10 shows no such trend for nitrate. This is confirmed by statistical studies in both Canada and the United States.

In the United States, a trends analysis using 1980-1992 wet deposition data showed significant downward trends in sulfate concentrations at the majority of U.S. measurement sites. Most of these sites are located in the north central and western parts of the country. Long-term trends (1983-1992) found sulfate concentrations to be generally decreasing by 0 to 4 percent per year at most sites. Similar results have been found in Canada for 1979-1994. Only a small number showed statistically significant downward trends in nitrate concentrations.

In addition, the U.S. trends analysis showed a widespread decline in calcium and magnesium concentrations (largely in the northeastern United States). The decline appears to have offset the declining sulfate concentrations, resulting in the acidity of precipitation remaining the same. Canada had similar results with a trends analysis using CAPMoN data for 1979-1994. Sulfate and base cation (calcium, magnesium, and potassium) concentrations decreased at most of the sites tested. Nitrate and acidity in precipitation showed no consistent change.

In general, the SO_2 emissions reductions are reflected in reductions in sulfate concentrations in precipitation. A close correlation is found between emissions and declining deposition across all of eastern North America (see Figure 11). In contrast to sulfate, the nitrate wet deposition showed no strong correlation with the NO_x emissions (see Figure 12). This does not mean that such a relationship does not exist but that it cannot yet be detected due to the small change in emissions and the high annual variability of the integrated wet deposition.

Dry Deposition/Concentrations

Dry deposition is an important component of total acidic deposition. Rates of dry deposition fluxes in Canada and the United States are usually determined by calculating dry deposition as the product of a measured air concentration and a modeled deposition velocity (which is a function of the terrain and meteorological data). In Canada, current investigations are focusing on the uncertainties associated with site-specific dry deposition modeling that is being conducted by the dry deposition

Figure 5.

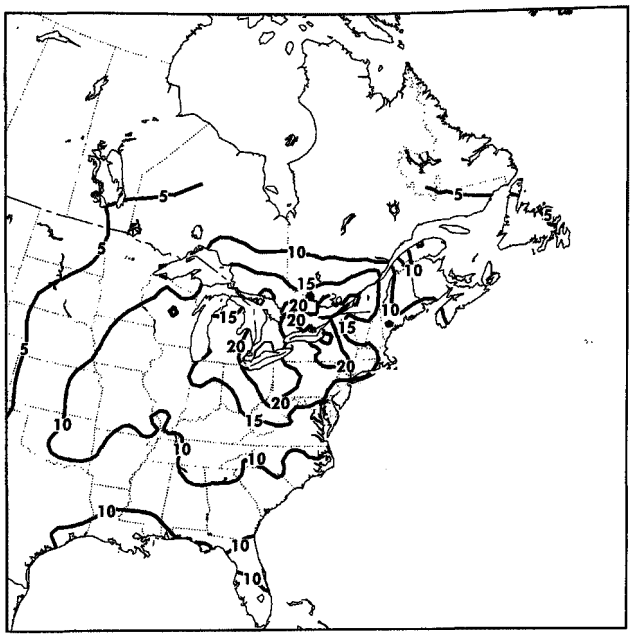

Figure 6.

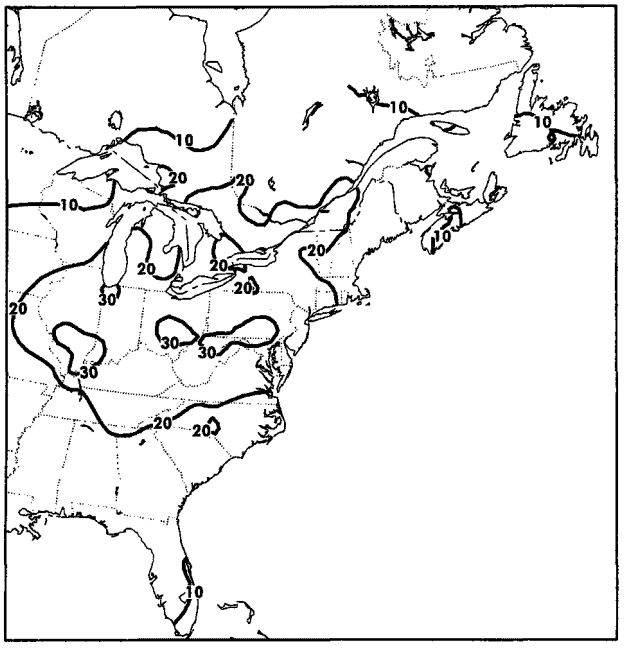

Figure 7.

Figure 8.

Figures 5-8. Spatial Distributions of Wet Sulfate and Nitrate Deposition in 1992 and 1993.

networks in the United States and at one Canadian location. Canadian and U.S. measurement and modeling techniques are routinely compared, and differences (e.g., 14 percent at 2 nearby sites) are used to assess the source of the bias and to determine appropriate methods of merging the data.

Measurements of SO_2 concentrations in air are used primarily for estimating dry deposition. Figure 13 shows a map of air concentrations of SO_2 at Canadian and U.S. sites in 1994. The map confirms results found in previous years that highest concentrations occur in the Ohio River Valley and drop off in all directions, most rapidly to the north into Canada. In general, the concentration pattern has not changed markedly from the 1991 pattern shown in the previous progress report.

Air concentration data for five years (1990-1994) were used in a model to estimate dry deposition. These dry deposition estimates, when added to the wet deposition

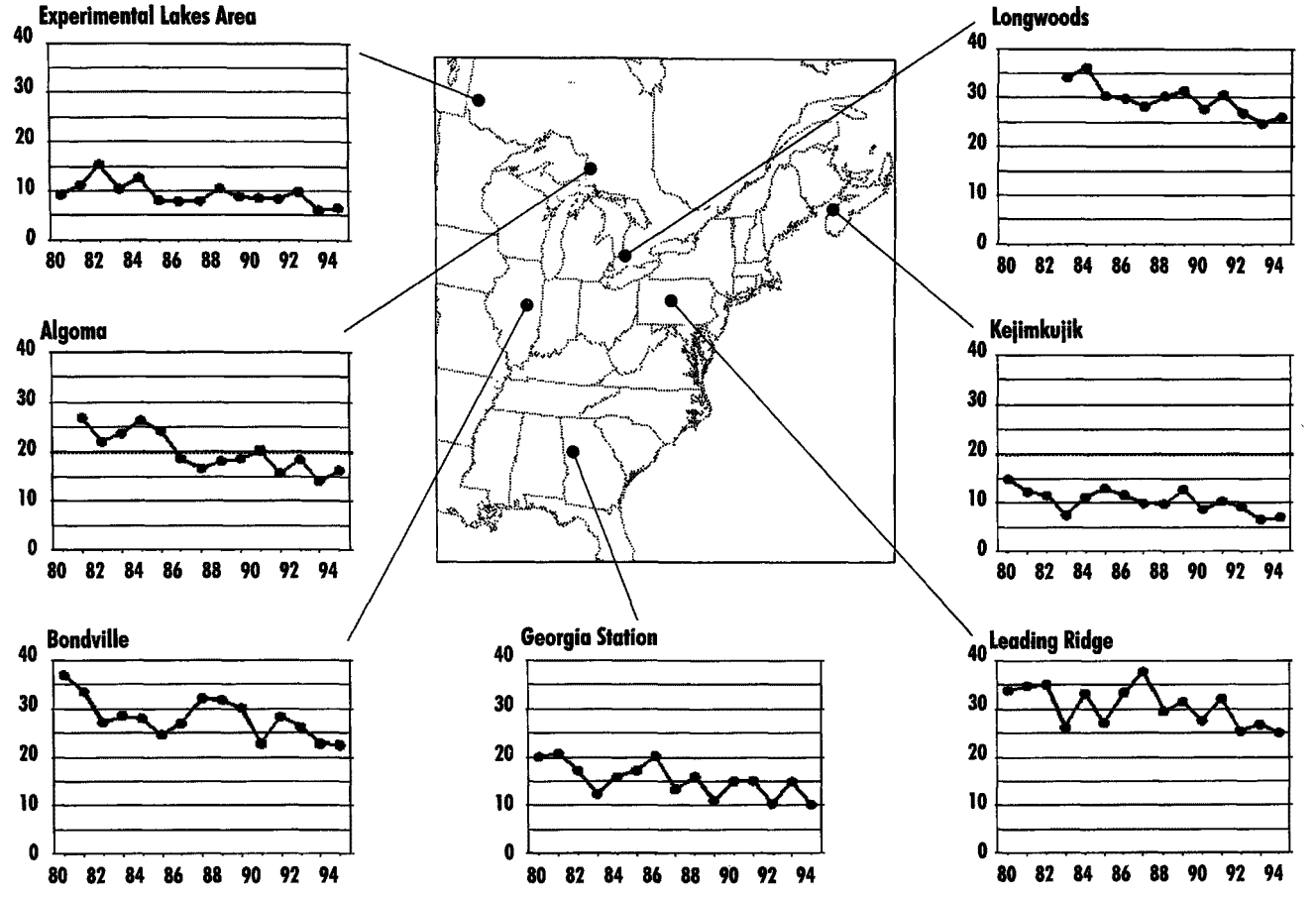

Figure 9. Sea Salt Corrected SO_2 Wet Deposition (kg/ha/yr).

data, provide estimated total sulfur deposition. Analyses of these data are still in progress due to the difficulty of determining trends with data from only five years and the remaining research questions regarding dry deposition monitoring. Results will be reported in the next progress report. The limited data and statistical regression models of total sulfur deposition data (wet plus dry deposition) indicate that there were significant decreases at numerous specific locations between 1990 and 1994.

Predictions (U.S. Models)

A recent U.S. report used the Regional Acid Deposition Model (RADM) to project the change in sulfur deposition upon implementation of the CAAA. The model predicts that most of the northeastern United States and lower eastern Canada will experience a 30-percent or greater reduction in total sulfur deposition from 1990 to 2010.

The report, the *Acid Deposition Standard Feasibility Study*, significantly updates the projection developed by NAPAP in 1990. The report incorporates an updated baseline SO_2 emissions inventory, a decision model-based estimate of SO_2 emissions allowance trading, and the Canadian SO_2 protocol program. The study also uses projections developed from a newer version of the RADM, which corrects errors uncovered during the NAPAP model evaluation. Figures 14 and 15 show 1990 and 2010 annual average total sulfur deposition, respectively, as predicted by RADM for the recent study. Figure 16 shows the percent reduction in predicted annual average total sulfur deposition between 1990 and 2010. The new results on projected total annual sulfur deposition levels are in substantial agreement with the NAPAP 1990 assessment results.

Binational Cooperative Model Evaluation

Phase 2 of the binational cooperative model evaluation, the Eulerian Model Evaluation Field Study, reported in the 1994 Progress Report, was completed. The peer

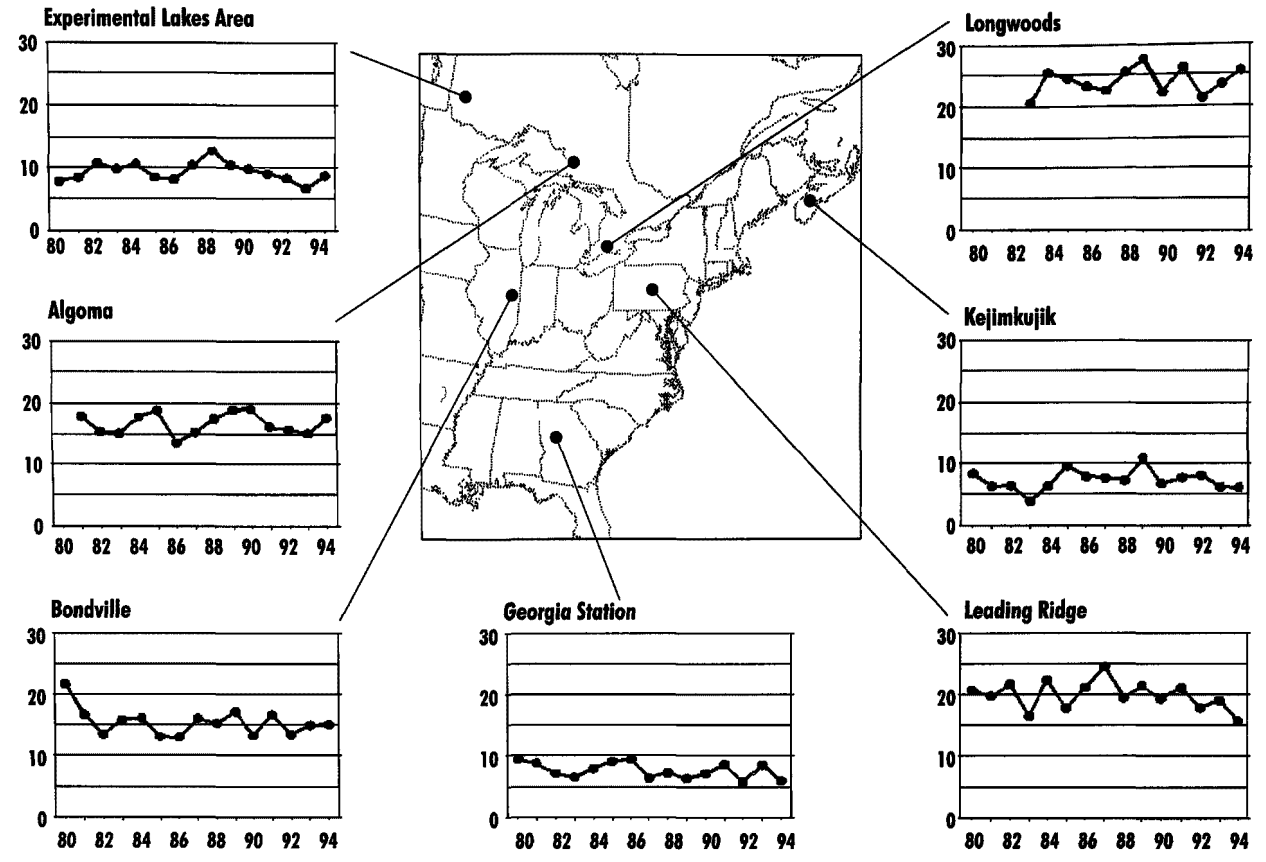

Figure 10. NO_3 Wet Deposition (kg/ha/yr).

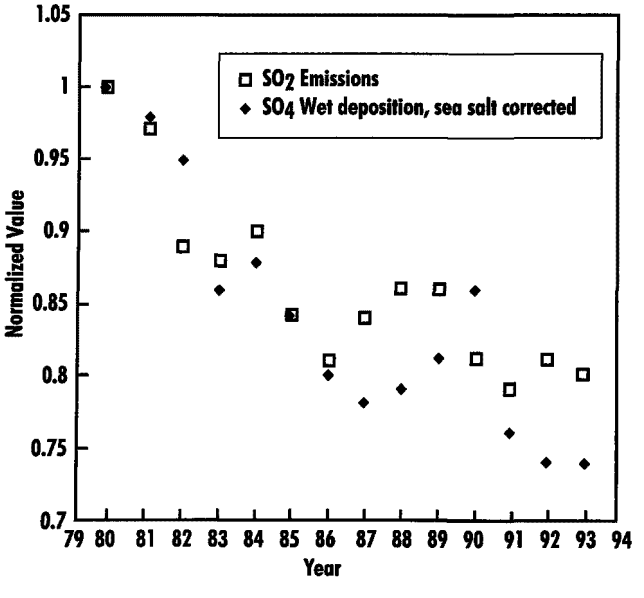

Figure 11. Normalized Annual SO_2 Emissions and Sulfate Wet Deposition, Sea Salt Corrected, Over Eastern North America.

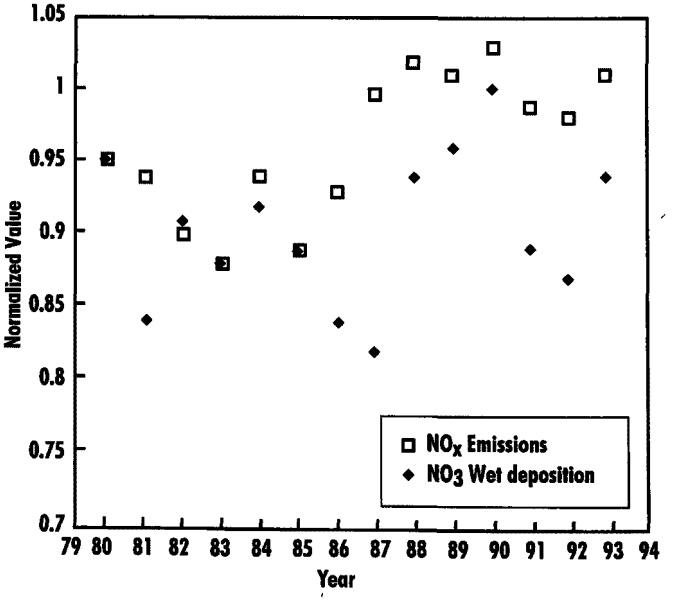

Figure 12. Normalized Annual NO_x Emissions and Nitrate Deposition Over Eastern North America.

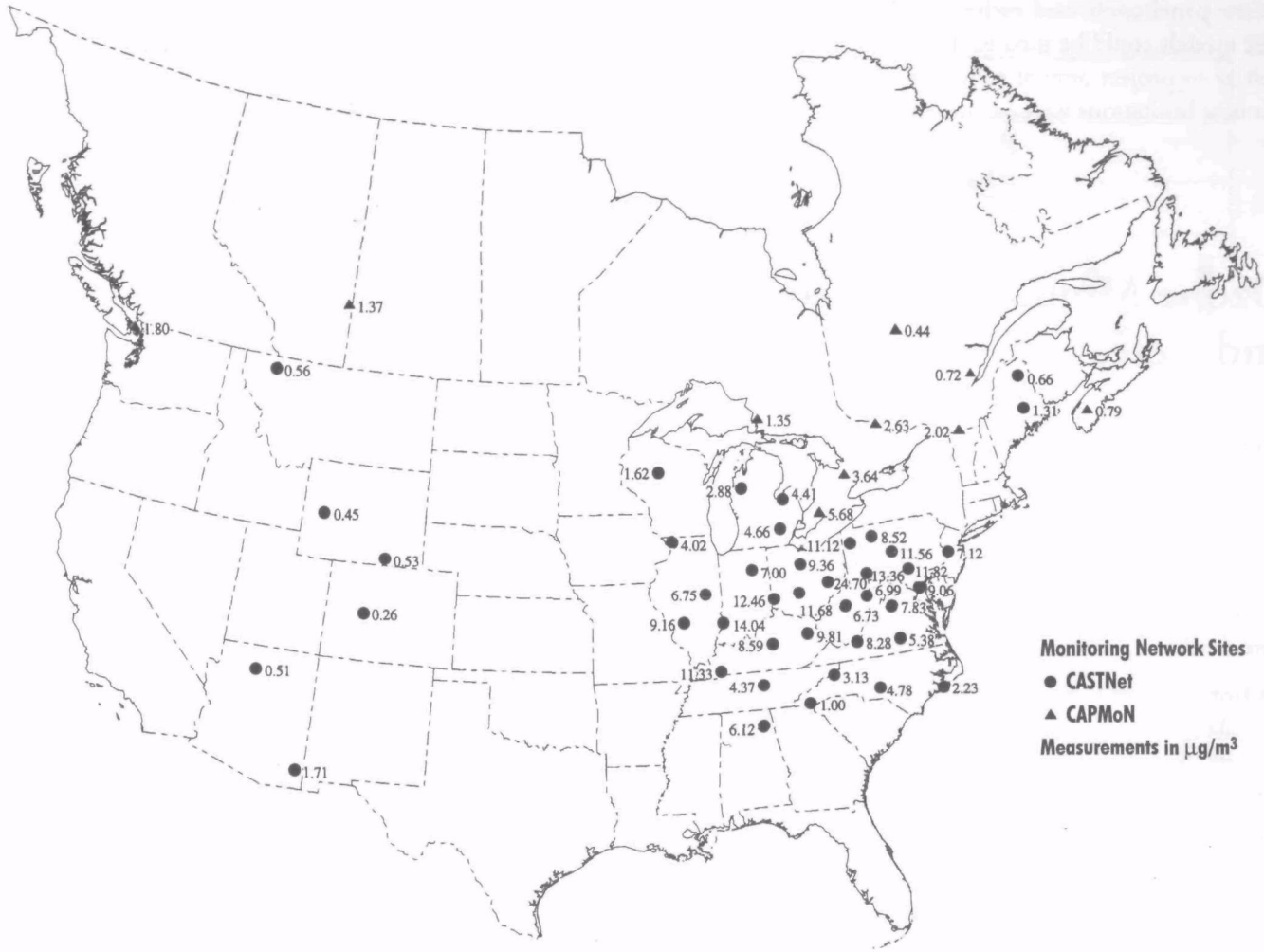

Figure 13. Median 1994 SO_2 Air Concentrations at CAPMoN and CASTNet Sites.

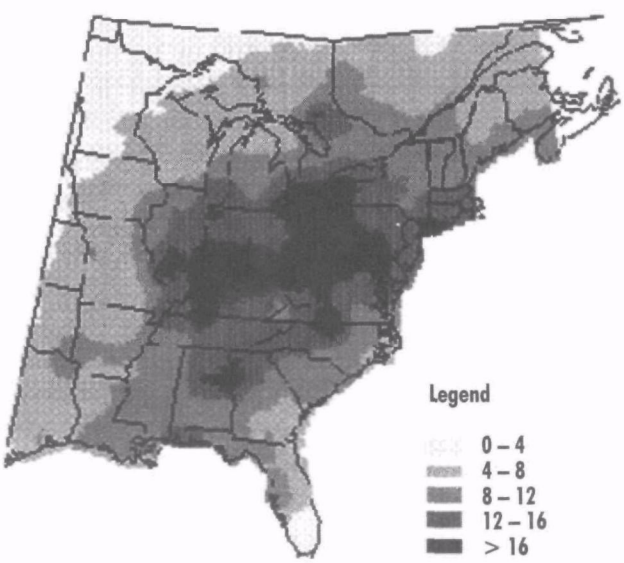

Figure 14. Annual Average RADM-Predicted Total Sulfur Deposition, 1990.

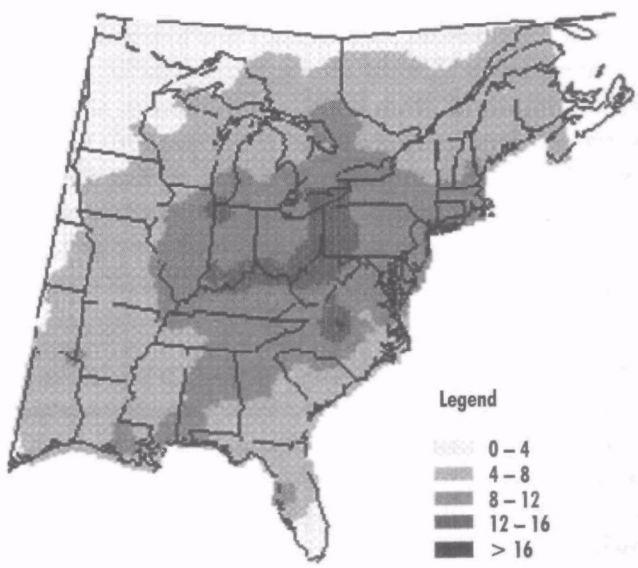

Figure 15. Annual Average RADM-Predicted Total Sulfur Deposition, 2010.

review panel confirmed earlier conclusions that the complex models could be used to develop current estimates as well as to project annual sulfur and nitrogen deposition. No new limitations were identified.

Ozone Monitoring, Trends, and Research

Ozone is formed when NO_x and VOCs react in the atmosphere. Adverse effects of ozone include human health impacts and damaging effects on forests and agricultural crops. Ground-level ozone is the main component of smog. Each country has its own approach for summarizing annual ozone concentrations. Although urban trends are decreasing, nonurban regional trends have not been addressed.

Ozone research and modeling are designed to address critical issues concerning ozone, including its formation, atmospheric interaction (meteorological factors), transport, and duration of exposure levels, particularly during summer episodes.

Monitoring

Canada

Ambient air monitoring in Canada is carried out at 142 National Air Pollution Surveillance (NAPS) sites as well as at a number of additional sites at the provincial, municipal, and industrial levels. The NAPS network is a joint project of federal, provincial, and municipal governments. NAPS data are used to gauge the success of, and the need for, air emissions control policies. The NAPS sites are located primarily in urban locations and include ozone measurements at most sites, with NOx and VOCs monitored at a subset of these.

Background ozone measurements are made at eight CAPMoN sites, which also measure airborne nitrogen compounds and, in some cases, VOCs. Canada has approximately 159 ozone monitoring sites in total, 95 of which monitor airborne nitrogen compounds and 37 of which monitor VOCs. With some of its highest ozone concentration levels reported by nonurban monitoring stations in southern Ontario, Canada recognizes the need for more rural and background monitoring.

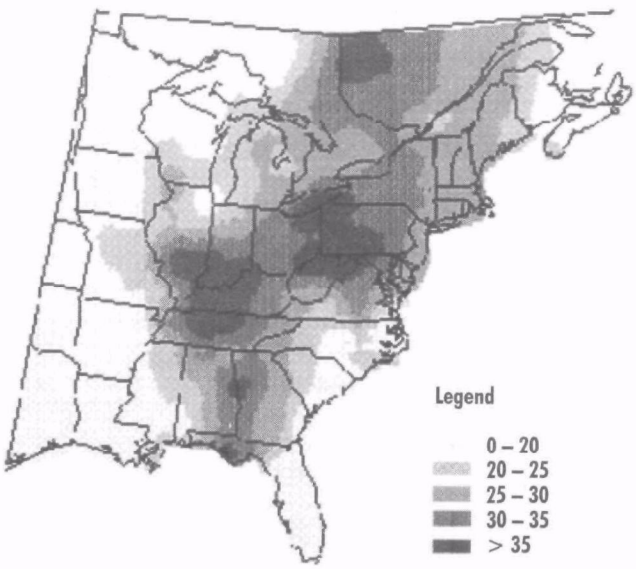

Figure 16. Annual Average RADM-Predicted Total Sulfur Deposition, Full CAAA Implementation, 2010, Percent Reduction From 1990 Control.

United States

The U.S. ozone monitoring program is principally comprised of three related networks: State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), and Photochemical Assessment Monitoring Stations (PAMS). These monitoring networks conform to uniform criteria for monitor siting, instrumentation, and quality assurance. The SLAMS network is designed to locate sites in areas where EPA and states decided monitors are needed, thus allowing states and local agencies to develop networks tailored to immediate monitoring needs. Data from the SLAMS network are used for a variety of purposes, including determining compliance with the NAAQS for ozone. There are currently 553 SLAMS ozone monitors operating in the United States. The NAMS network is a subset of monitors selected from the SLAMS to comply with the CAA requirement to constitute a long-term national network for urban area-oriented ambient monitoring. Used as a systematic, consistent database for air quality comparisons and trends analysis, the NAMS monitors are located in areas of greatest population concentration and highest population exposure. Currently, there are 235 NAMS monitors operating across the United States.

In February 1993, EPA initiated the PAMS program to establish enhanced monitoring networks in all ozone nonattainment areas classified as serious, severe, or extreme. Each PAMS network consists of as many as five

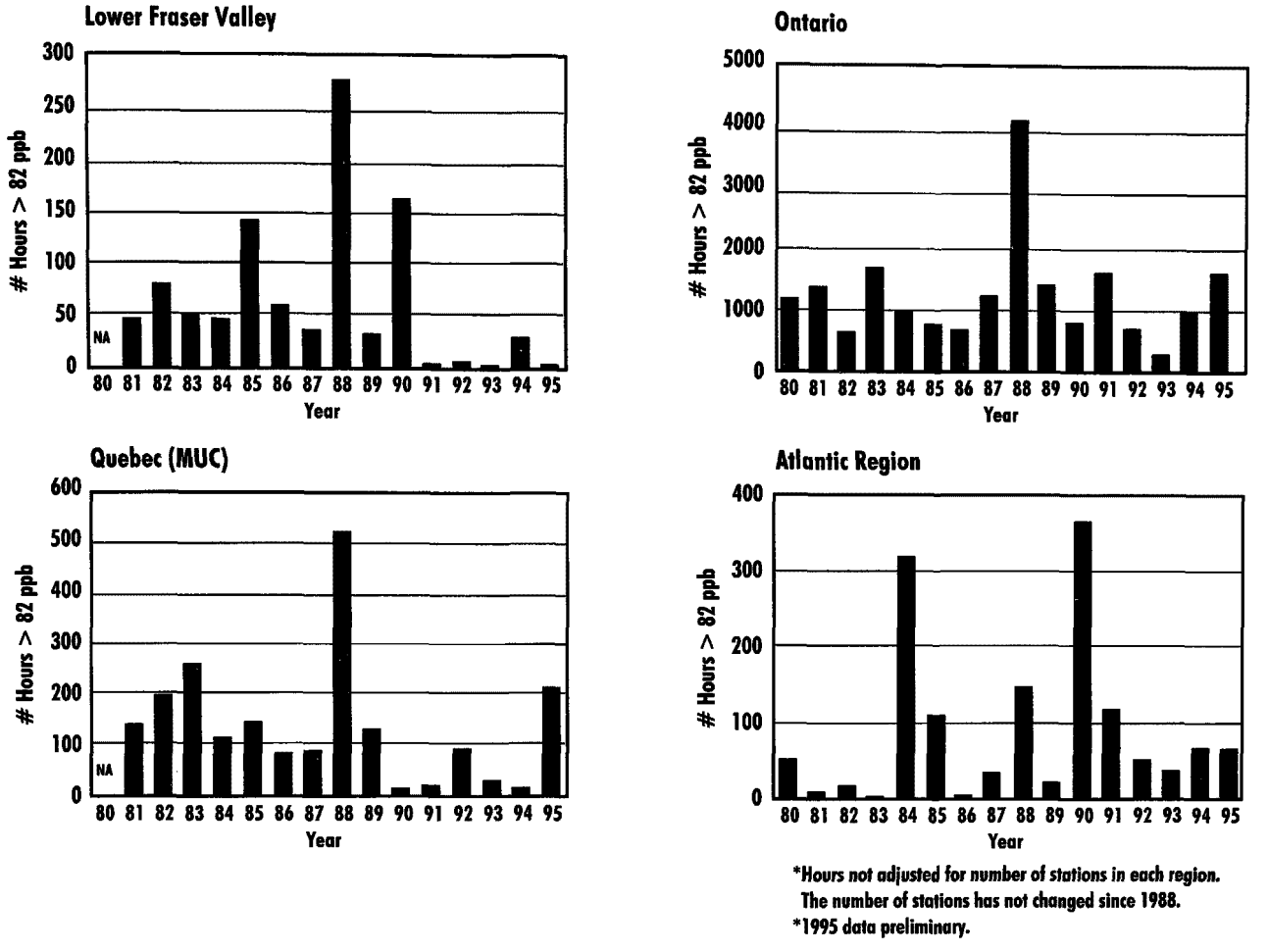

Figure 17. Number of Hours with Ozone Exceedances Greater than 82 ppb, 1980-1995, in Four Canadian Areas.

monitoring stations. About 70 of the expected 100 PAMS surface air quality and meteorology monitoring stations are operating across the nation. The data collected at the PAMS include measurements of ozone precursors. In addition to providing a long-term perspective on changes in atmospheric concentrations in ozone and its precursors, the PAMS program will specifically help to improve emissions inventories, provide input to photochemical grid models, supply information to evaluate population exposure, and provide routine measurements of selected toxic air pollutants.

Trends

Canada

A recent extensive analysis of ground-level ozone concentrations in eastern Canada shows that the heavily populated southern portion of Ontario is exposed to the highest ozone concentrations. In this area, maximum hourly ozone concentrations have exceeded 190 parts per billion (ppb). At some sites, the acceptable air quality objective of 82 ppb can be exceeded on as much as 25 percent of summer days. Trend analysis of summertime average daily maximum ozone concentrations for eastern Canadian sites showed no consistent pattern. At all sites, there was an annual variability in peak ozone levels and in the frequency of hours with ozone concentrations above the maximum acceptable objective.

Figure 17 illustrates similar results, showing the number of hours per year between 1980 and 1995 when hourly average ozone exceeded 82 ppb in the Lower Fraser Valley, the Ontario and Quebec (greater Montreal area) portions of the Windsor-Quebec corridor, and the Atlantic region. The year 1988 stands out as a high ozone year in all the problem regions of Canada as well as in U.S. data. These results emphasize the importance of meteorology in generating high ozone levels and serve as a warning. In a polluted airshed, given the right meteorological

conditions, the number of exceedances encountered in 1988 could occur again in the absence of additional control actions.

United States

U.S. analyses focus on long-term trends and large areas. Figure 18 shows a map of 10-year trends (1985-1994) in maximum ozone concentrations for northern, eastern, and midwestern geographic regions. Nationally, the ozone levels dropped 12 percent compared to 1985. The regions depicted in Figure 18 show a similar pattern; all four had lower ozone levels in 1994 than in 1985. The selected areas also mirror another national statistic: All regions had the highest ozone values in 1988 during the 10-year period, and all but one (New York, New Jersey) observed lowest levels for the period in 1992. Shorter-term urban-scale trends are addressed in Section IV of this report.

Research

The North American Research Strategy for Tropospheric Ozone (NARSTO) research program, initiated in the United States and now including Canada and Mexico, was designed to address ground-level ozone, its formation, the nature of its precursors, and ozone source-to-exposure relationships. NARSTO will provide the structure for a more systematic and coordinated interaction on oxidant modeling than has previously occurred. It is expected that the collective effort of all three countries will significantly enhance understanding and improve efforts to control ground-level ozone. NARSTO will also provide a forum for Canada and the United States to compare and coordinate evaluation efforts for the new ozone models in the same spirit as for acid rain. Research from NARSTO is expected to provide information for future U.S. ozone program initiatives.

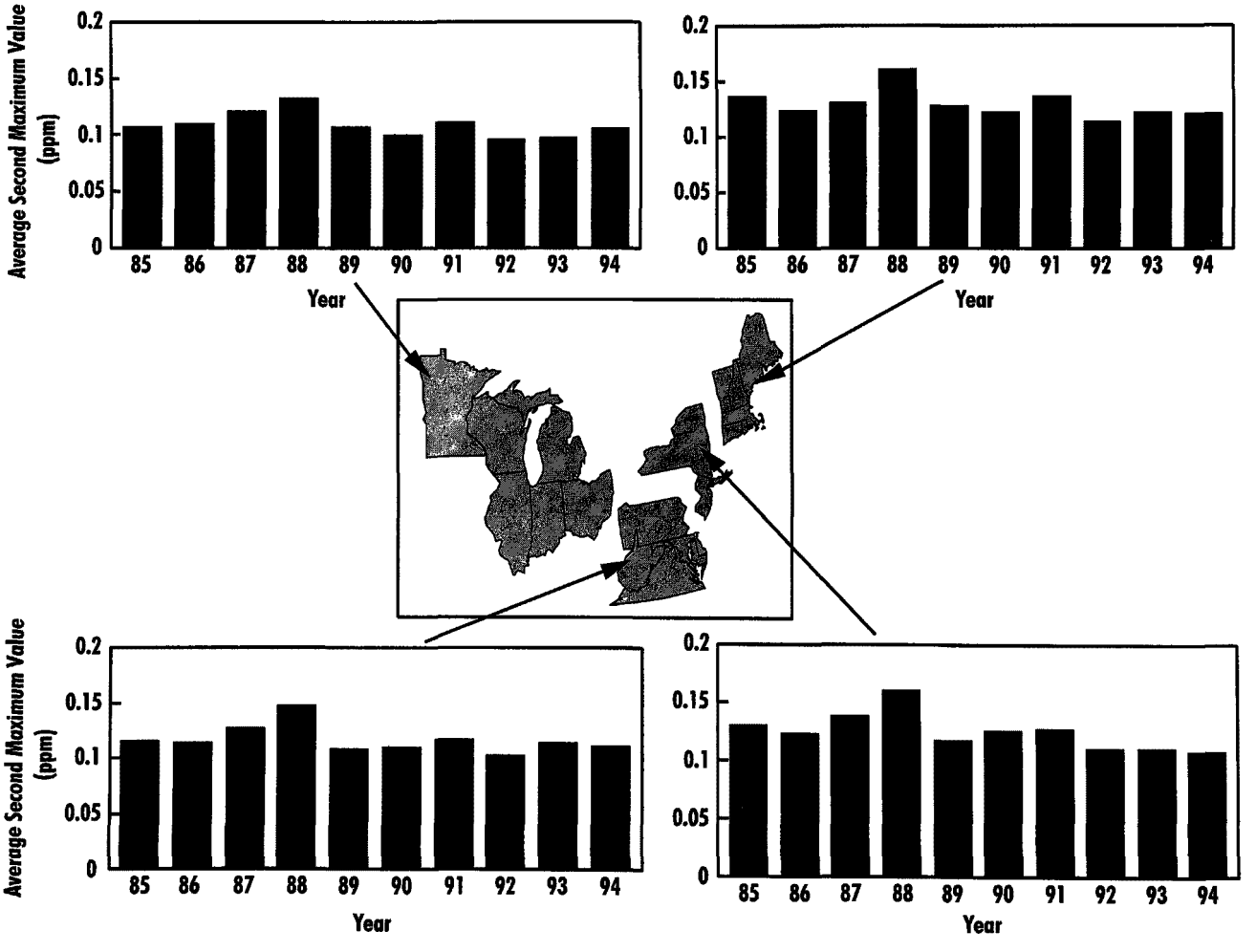

Figure 18. Trend in Average Second Maximum Values (in ppm) for Ozone (by Region for Trend Sites).

The Canadian NO_x/VOC Science Program was established to respond to a number of study initiative questions; the answers will be incorporated in a science assessment to be published in mid-1996. The assessment will focus on three key areas: (1) improving scientific understanding of the formation and loss of ozone; (2) establishing effective oxidant grid-based simulation models; and (3) developing reliable and timely emissions inventories. The science program also includes activities to ensure that an adequate monitoring system is in place to track the effects of pollutant abatement measures and to assess the current ground-level ozone air quality objective.

Aquatic Effects Research and Monitoring

Overall, the data from aquatic effects monitoring indicate that reduced SO_2 emissions are reflected in decreasing sulfate in lake waters. Many factors beyond atmospheric deposition, however, influence lake acidity. Only some waters monitored from 1981 to 1993 exhibit statistically significant improvements in pH or acid neutralizing capacity (ANC); most sampled waters did not. Recent research on watershed nitrogen dynamics indicates that nitrogen could counteract the beneficial impact of SO_2 emissions reductions. Results from fish community surveys in Quebec show that a large number of fish populations have been lost this century due to lake acidification. Monitoring of water birds in Canada suggests that fish-eating birds remain at risk in regions affected by acid rain, but where water chemistry is improving (e.g., Ontario's Sudbury region), waterfowl recovery can follow.

Chemical Trends (Canada and the United States)

Surface-water chemistry has been monitored at many locations since the early 1980s (the most recent data is from 1993) to verify the ecological benefit accruing from emissions control. Some locations (see Figure 19) have statistically significant trends in sulfate levels. Of the 8 sites shown in Figure 19, all but 1 (Kejimkujik in Nova Scotia) showed declining sulfate. An extension (i.e., with more sites and longer records) of an earlier analysis of water quality trends in Nova Scotia, Newfoundland, Quebec, and Ontario yielded results similar to those reflected in Figure 19. Fifty-one percent (of 202 sites) showed decreasing sulfate, 1 percent was increasing, and 48 percent had no significant trend.

Most decreasing sulfate trends occur in Ontario and Quebec where the largest absolute deposition reductions have been observed (see Figure 9). In the Sudbury region of Ontario, which has been affected by emissions reductions at both long-range and local sources, more than 80 percent of monitored lakes have declining trends. Most of this decline occurred by the mid-1980s, however, and has subsequently leveled off or even reversed.

Climatic variation appears to be responsible for a short-term reversal of sulfate trends in lakes from south central Ontario. The presence of wetlands in the drainage basin of lakes appears to be a factor in delaying the response of these systems to reduced deposition. All of the sites with increasing sulfate trends occurred in the Atlantic region, and most sites with no sulfate trend were in the Atlantic region as well.

Thus far, decreases in surface-water sulfate have led to only some improvements in water quality. Just two of the sites in Figure 19 have responded with declining acidity (or increasing ANC). Lac Laflamme in southern Quebec and Constable Pond in the Adirondacks of New York are continuing to acidify (i.e., they have significantly decreasing ANC). Other chemical changes have compensated for declining sulfate without improving acidity, most notably declining base cation (e.g., calcium, magnesium, and potassium) concentrations.

The extended regional analysis showed that 11 percent of monitored sites in Nova Scotia, Newfoundland, Quebec, and Ontario continued to acidify, 33 percent are recovering, and 56 percent exhibit no statistical trend. The greatest difference between these results and those from the earlier analysis is a substantial shift of lakes in Nova Scotia and Newfoundland from the improving class to the class without an acidity trend. In New Brunswick, lakes that continue to acidify have low ANC, whereas lakes with higher ANC show little acidity trend.

In the Adirondacks, declining sulfate trends were remarkably consistent among all lakes monitored, most of which had decreases in base cation concentrations. This was especially true where thin till is the dominant surface geology in the drainage basin. This perhaps indicates that base cation leaching in these systems is strongly influenced by exchange reactions in overlying soils as opposed to mineral weathering, which contributes to deeper

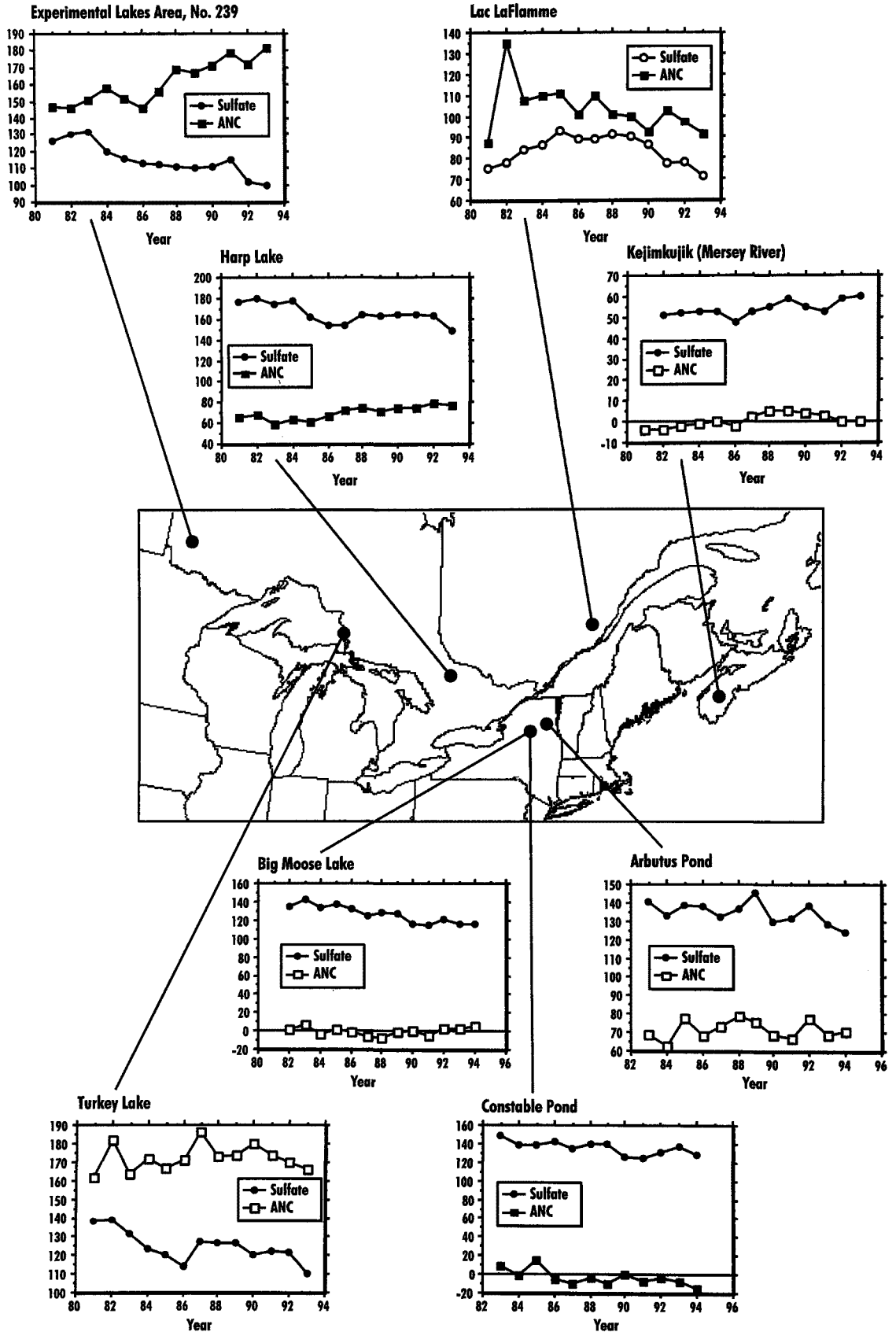

Figure 19. Time Series of Annual Averages of Sulfate and ANC (μeq/l).

groundwaters. Most systems in the Adirondacks show no evidence of change in either ANC or acidity (hydrogen ion) at this time.

Nitrate concentrations decreased recently in the Adirondacks as well. Although an increasing trend was noted in the 1980s, there now appear to be no significant trends in nitrate during 1982-1994. Regional climatic factors might play an important role in this recent phenomenon.

Long-term data from the Hubbard Brook Experimental Forest in New Hampshire indicate that although only small changes in stream pH have been observed, large quantities of base cations have been lost from soils. These losses are apparently due to declines in base cation deposition and leaching by acidic deposition. As a result, response of soil and streamwater chemistry to decreases in acidic deposition might be substantially delayed.

Evaluation of long-term declines in dissolved organic carbon at the Experimental Lakes Area of northwestern Ontario showed that both climate warming and acidification might be causes and that changes in the lakes observed over the last 20 years might have been influenced by a resultant increase in water penetration by ultraviolet light. Both the Hubbard Brook and Experimental Lakes results show that complex ecological interactions must be considered when attempting to relate chemical trends in surface waters to changes in acidic deposition.

Although it is clear that SO_2 emissions reductions are reflected in decreasing sulfate in surface waters, it is equally clear that there are many factors beyond atmospheric deposition that influence acidity trends. The substantial shifts in classification of acidity trends (e.g., from "improving" to "no trend") with just three years of additional data confirm that existing short-term data do not demonstrate future changes reliably; long-term data are required.

Model Application (United States)

Nitrogen Bounding Study

EPA scientists have modeled the potential combined effects of atmospheric sulfur and nitrogen deposition on the chemistry of lakes and streams in the eastern United States. The scientists adapted the Model of Acidification of Groundwater in Catchments to project potential effects on lake and stream chemistry for three regions of the eastern United States (Adirondacks, Mid-Appalachian Region, and Southern Blue Ridge Province). The results indicate that nitrogen can play a very significant short- and long-term role in a watershed and can offset the benefits of sulfur reductions.

EPA scientists conducted model simulations for 50 years into the future. Projections of sulfur and nitrogen deposition levels were based on results expected from implementation of the CAAA as well as other more restrictive deposition reduction scenarios. The extent of potential future effects depends on how rapidly the atmospheric deposition of nitrogen compounds moves watersheds toward a state of nitrogen saturation (i.e., input equals output on an annual basis). The time to watershed nitrogen saturation varies depending on forest age, historic and future levels of nitrogen deposition, future changes in ambient temperatures, water stress, land use, and other variables. Lacking the current capability to accurately estimate the time required to reach watershed nitrogen saturation at regional scales, the nitrogen bounding study instead assumed an encompassing range of times (including never). The study then estimated the potential consequent effects on surface-water ANC. Thus, these modeling analyses effectively bounded the range of possible future deposition levels and water chemistry outcomes.

The model projections (see Table 4) are for specific target populations (i.e., groups of lakes or streams with watersheds of similar size, land, and other characteristics), not for all watersheds in the respective regions. For example, if the Adirondacks watersheds progress no further towards nitrogen saturation, model projections indicate a reduction from 19 percent of the target population being chronically acidic in 1984 to 11 percent in the simulated year. In contrast, if all watersheds modeled move to nitrogen saturation in 50 years, then the percentage of chronically acidic waters is projected to be 43 percent of the target population in the simulated year.

Field Study (United States)

Bear Brook Watershed Manipulation Experiment

Results from this experiment illustrate the rapidity with which some forested watersheds in the northeastern United States might reach nitrogen saturation in response to increased nitrogen loadings.

A paired watershed manipulation experiment has been under way since the mid-1980s at the Bear Brook

Table 4. Projections for Year 2040 for Percentage of Waters with Either Chronic Acidity or High Potential for Episodic Acidity.
Time to watershed nitrogen saturation varies as indicated. Deposition ranges from natural background to levels resulting from implementation of the CAAA.

Target Population	Adirondacks (703 lakes)	Mid-Appalachians (4298 streams)	Southern Blue Ridge (1323 streams)
ANC≤0 μeq/l (Chronic Acidity)			
Observed[1]	19	4	0
N saturation 50 yr.	6–43	0–9	0–4
N saturation 100 yr.	3–26	0–5	0–0
N saturation 250 yr.	0–15	0–4	0–0
N saturation never	0–11	0–0	0–0
ANC≤50 μeq/l (High Potential for Episodic Acidity)			
Observed[1]	55	27	6
N saturation 50 yr.	53-67	5-41	4-16
N saturation 100 yr.	51-57	5-37	4-16
N saturation 250 yr.	44-54	5-28	3-14
N saturation never	44-54	4-23	2-11

[1]1984 for lakes; 1985 for streams
Adapted from EPA Office of Air and Radiation. *Acid Deposition Standard Feasibility Study Report to Congress* (EPA430-R-95-001a), October 1995.

Watershed in Maine. Manipulations of the watershed (i.e., additions of dry ammonium sulfate with distinct isotopic signatures) for both sulfur and nitrogen tripled the annual catchment loading of sulfur and quadrupled the annual loading of nitrogen. In response, there was an increase of stream concentrations and watershed fluxes of hydrogen ions, calcium, magnesium, sodium, potassium, sulfate, nitrate, and aluminum relative to the control; chloride remained nearly unchanged; ANC declined (see Figure 20). No clear trends in dissolved organic carbon or silica were evident. After 5 years of manipulation, average annual sulfate concentration significantly increased by 90 percent (see Figure 20). Nitrate concentrations have also increased markedly, not only during periods of vegetation dormancy but also during the summer growing season, indicating the movement of nitrogen to greater soil depths.

Chesapeake Bay (United States)

Several models were integrated to investigate Chesapeake Bay water quality processes and their sensitivity to external nutrient loading. The models included a watershed model that generated nutrient loadings from subbasins and a hydrodynamic model of the bay that included a water quality model coupled to a sediment chemistry model. Atmospheric deposition to the watershed and water surface was estimated using RADM. The models studies indicated that improvements in dissolved oxygen could be expected based on feasible reductions (20-30 percent of nitrogen and phosphorus) in nutrient loadings.

Biomonitoring (Canada)

Studies of the impact of acidity (low pH) on fish and other biota indicate that species richness and the population of acid-sensitive fish species decline with lower pH. Critical pH levels may vary, and aluminum toxicity plays a key role in certain waters. The inherent variability present in aquatic communities means that longer monitoring records are required to distinguish between random change and change related to pollutant emissions control.

Aquatic biota have been monitored annually since 1987 in 36 lakes and 21 rivers across eastern Canada, representing a broad range of terrain sensitivities and sulfate deposition levels. The data analyzed to date serve as a baseline from which to measure future effects of emissions reductions on aquatic biology. These findings indicate that more acidic rivers (pH<5.0) on the average have 2.3

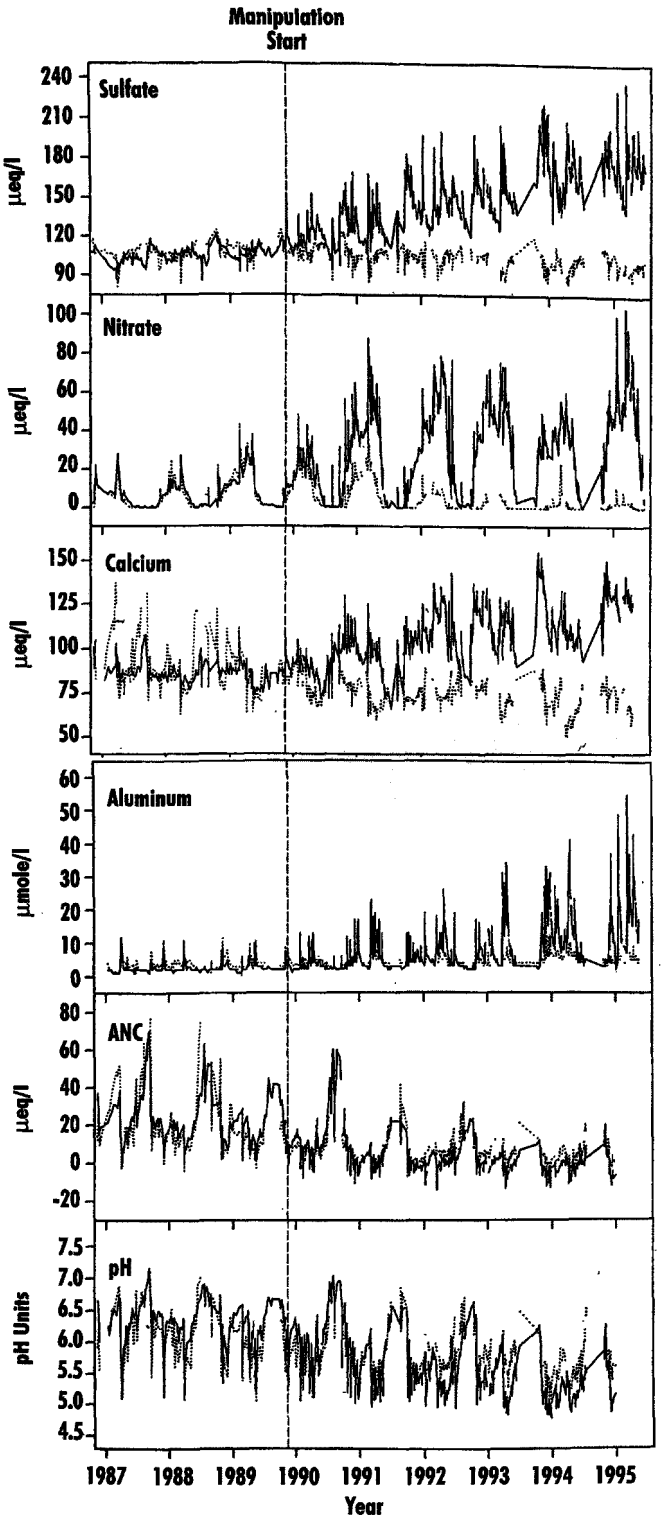

Figure 20. Bear Brook Watershed Manipulation Begun at the End of 1989 with Addition of Dry Ammonium Sulfate to Western Part of Watershed.

Note: Dotted lines represent eastern part of the watershed. Solid lines represent western part of the watershed.

fish species, and more neutral rivers (pH>5.0) on the average have 5.1 fish species. The more acidic lakes (pH<5.6) average fewer species than do the more neutral lakes (pH>5.6). Although the total number of fish caught per unit of effort was actually higher in acidic lakes, the annual variability of the catch was twice that of neutral lakes. Assessments of critical pH levels in Nova Scotia rivers indicated that those with a pH less than 4.7 have lost Atlantic salmon; those between 4.7 and 5.0 have reduced stocks; and those with pH greater than 5.0 support healthy populations.

Acidity and Fish Communities in Quebec

Fish species have been surveyed for 253 lakes in southern Quebec. The lakes vary widely in size, pH, and level of acidic deposition. The regions receiving the highest levels of acidic deposition (>20 kg/ha/yr) experience decline in species richness and biomass with decreasing pH. As long as pH is greater than 6, there are no apparent effects on fish; however, nearly 75 percent of fish species are lost as pH declines from 6 to 5. These survey results indicate large resource losses. By making use of the relationship between fish species richness and pH in two regions (Outaouais and Abitibi) (see Figure 21), Canadian scientists estimated that since 1900 at least 13,500 fish populations have disappeared from the 48,468 sensitive lakes found there.

Fish populations in certain other regions show little effect from acidic deposition. Some effects are attributed to natural organic acidity.

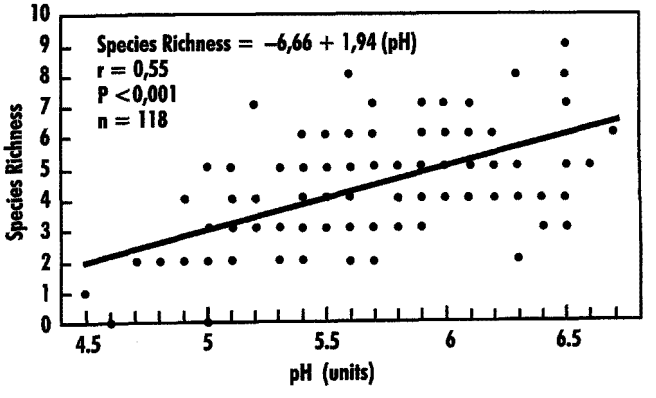

Figure 21. Relationship Between the Number of Fish and pH, 188 Lakes From the Outaouais and Abitibi Hydrographic Regions of Quebec.

The presence of the Canadian water bird, the common loon, is a key indicator of the health of Canadian lakes.

Water Birds

Results of studies suggest that fish-eating birds remain at risk in regions affected by acid rain. Where restoration of aquatic systems is occurring (e.g., Sudbury, Ontario), recovery of waterfowl populations can follow and indicate biological improvements.

Though aquatic ecosystem restoration around Sudbury is at an early stage, improvements in benthic biota (organisms living at the bottom of a body of water) and some fish have been observed. The quality of breeding habitat for some waterfowl species is expected to improve as well. Monitoring of small lakes northeast of Sudbury showed that the combined breeding density of fish-eating species (common loon, common merganser, and hooded merganser) has nearly doubled between 1985 and 1995 (from 30 to 58 breeding pairs/100 km^2). Small lakes are the preferred breeding habitat for many waterfowl species. Breeding densities in the most acidified waters (pH<5.5) have not changed and remain low. Populations in less degraded areas (pH>5.5), generally near the periphery of the region, have increased.

Because the common loon relies on fish, it is a key bioindicator linking the effects of acid rain to higher trophic levels of larger lakes in eastern Canada. The breeding success of the common loon is monitored as part of a national volunteer-based survey. The survey, conducted from 1987 to 1994, found that loons avoid breeding on acidic lakes (pH<5.5) and, when they do breed there, are less successful (fewer chicks fledged per breeding attempt). In Atlantic Canada, however, the number of loons observed breeding between 1988-1995 at the acid-stressed Kejimkujik National Park in southwestern Nova Scotia has remained stable, but production of young varies annually; it is generally low (less than half the level of production in Ontario) and controlled by fish availability.

Forest Health Monitoring

Canadian and U.S. forest health monitoring continues to find no evidence of widespread forest decline associated with acidic deposition. The eastern North American hardwood forest is generally in good health. There is evidence, however, that acidic deposition can cause discernible effects in forests suffering from other forms of stress, such as drought or high-elevation temperature extremes. For example, there is birch decline near Canada's Bay of Fundy due to acid fog and red spruce decline at high elevations. In addition, in 1995, symptoms of ozone damage on ozone-sensitive plant species were found on more than 50 percent of 105 forested ozone monitoring sites throughout the northeastern United States.

Canada

In 1994, forest health monitoring activities in Canada documented changes in tree condition. A series of Acid Rain National Early Warning System (ARNEWS) plots are in declining condition—persistent dieback of more than 15 percent of the crown has occurred for 3 years. These plots are on acid-sensitive soils, with trees not recovering from natural stresses. The plots are on the fringe of the Canadian Shield, also known as the Laurentian Plateau (a huge rocky region that covers half of the land area of Canada and dips into the United States to form the Adirondack Mountains of New York and Superior Uplands of the Midwest). Tree health continues to be affected by insects, drought, and other stresses.

An inexpensive monitoring method has been developed and tested. The method, which has the potential for determining spatial distribution patterns of ozone exposure and for monitoring forests in remote areas, will be incorporated in ARNEWS monitoring activities.

Needle damage (flecking) has been observed on white pine, white spruce, red spruce, and balsam fir in eastern Canada and on Douglas fir in British Columbia. The damage did not appear to be caused by weather, insects, or diseases and resembled pine damage caused by ozone that has been reported elsewhere.

The cause-and-effect relationship between acidic fog and birch damage, suggested in the 1994 Progress Report, has been confirmed. In 1979, the health of birch stands in southwestern New Brunswick began to decline. The spatial distribution of the decline coincided with the presence of acidic fogs with measured pH less than 3.5. Observed damage symptoms included the browning of leaves, premature leaf fall, and twig and branch death. Damage could not be accounted for by the presence of insects and/or diseases. Tree mortality in sample plots was several times the mortality in areas not affected by the acid fog. In addition, the degree of damage and rate of recovery coincided with the frequency of the acidic fogs. The data support a cause-and-effect relationship between the damage and the pollutants.

Soil monitoring shows decreases in soil nutrients in areas of higher pollutant deposition, suggesting a possible impact on forest health. Monitoring data that tracked the health of sugar maple show increased levels of crown transparency in areas of higher nitrate and sulfate deposition.

In other activities, Canada is determining critical loads for forests using models to predict changes in forest condition as a result of sulfate and nitrate deposition. A southern Ontario study calculated critical loads for maintaining long-term acidity levels in upland forests. In the northern part of the study area, part of the Canadian Shield, soils are currently subjected to atmospheric sulfate and nitrogen deposition in excess of critical loads. This sensitivity to acid precipitation is primarily due to shallow and weathering resistant soils and soil parent materials that are mostly granitic. When average dieback levels as measured in the North American Maple Program are superimposed, it is clear that dieback is higher in areas where critical loads are exceeded. Other studies confirm that dieback is also closely related to tree health.

Effects of Sulfate and Ozone on Vegetation

Ambient levels of sulfate and nitrate deposition interact with the developing cuticle of a leaf/needle and alter its structure and chemical composition. This process prematurely and artificially ages the leaf/needle and consequently stunts tree growth. This interaction has been demonstrated on declining red spruce along a 500 km coastal acidic fog/ozone pollution gradient in the Gulf of Maine/Bay of Fundy region. The pollutants also affect how the needle surfaces react to water. This has implications for foliar uptake of acidic ions.

Pollutants also cause needle surfaces to become wet more easily, affecting absorption of acidic ions. A significant correlation between increases in leaf sulfate content due to foliar absorption and a loss of frost hardiness was found in trees exposed to sulfate-containing acidic mist. This correlation further implicates pollutants in the deterioration of red spruce at high elevations in the Appalachians.

Research has also demonstrated effects of ozone fumigation on forest trees, particularly white pine. Studies indicate that younger foliage was more sensitive than older foliage. Concentrations of ozone in fumigation experiments, however, show little effect on the setting of seeds. This indicates that the reproductive capacity of trees, even in the nonattainment areas of eastern Canada, is not affected by ambient levels of ozone.

United States

Results from inventory and monitoring activities conducted through 1994 do not show any evidence of regional-scale forest decline in the northeastern United States. More than 95 percent of some 5,700 trees surveyed throughout New England were classified as "healthy" with respect to tree canopy condition. Approximately 85 percent of the trees also showed no sign of damage such as decay, damaged foliage, or dead tops. Indicators of decay (e.g., conks, rotten wood) were most common, affecting some 9 percent of sample trees. In certain cases, specific damage is commonly associated with certain species (e.g., beech bark disease cankers on American beech trees). Damage levels have not increased noticeably since data collection began in 1993.

Symptoms of ozone damage to ozone-sensitive plant species were found on 58 percent of 71 ozone biomonitoring plots in New England and on 38 percent of 34 visited sites in the Great Lake states (see Figure 22). Damage occurred throughout the region except for the northern and western parts of Maine that are the most remote from population centers. This is an increase from the roughly 10 percent of plots showing damage in 1993. The increase is likely due to changes in the sampling methodology. Sampling across the whole region was restricted to a two-week window in August, thereby maximizing the cumulative effects of ozone damage. These results indicate that ozone levels and climate conditions in 1994 were such that damage occurred in the field, at least

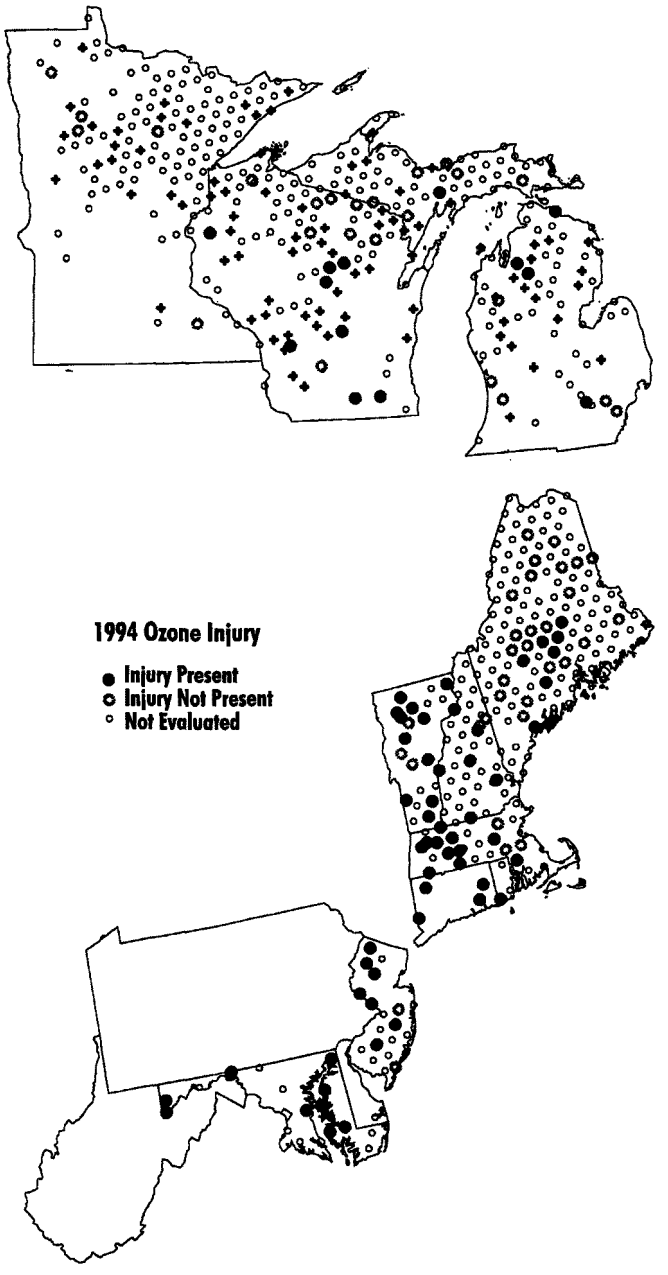

Figure 22. Ozone Injury to Plants.

to sensitive plant species. The effects of ozone damage on growth, productivity, or survival of less-sensitive plant species are not yet clear.

Aluminum-Calcium Interactions

Calcium is a major tree nutrient with key roles in wood formation and maintenance of cell walls. Concentrations of plant-available calcium have been decreasing for six decades in forest soils in the northeastern United States. Proposed explanations include increased uptake due to increased forest growth and increased leaching due to acidic deposition. New research in red spruce forests in the northeastern United States suggests a third explanation: Aluminum is mobilized in the mineral soil, then transported into the forest floor in a form that reduces calcium storage. Aluminum has a high affinity for organic binding sites and is to some degree able to displace calcium, which is then more easily leached from the ecosystem. Increased aluminum saturation also reduces the retention of calcium from atmospheric sources. The loss of calcium eventually can cause reduced growth and stress tolerance in trees. Acidic deposition compounds the effect by increasing the rate at which aluminum is mobilized and available to displace calcium in the plant root zone.

Forest Decline in Northwestern Pennsylvania

High mortality rates have been found in recent years in a specific forested area (40,000 hectares) in the northwestern part of Pennsylvania. This area has experienced droughts in 1988, 1991, and 1995 as well as many years of defoliation by a variety of insects. Sugar maple is a major component of the ecosystem and the most seriously affected species. Mapping and analysis of the affected area indicate that mortality and decline have been greatest on drier sites and on unglaciated, calcium- and magnesium-poor soils. Adjacent sugar maple stands on glaciated, calcium- and magnesium-rich soils are healthy. Decline started earlier, is more severe in higher elevation stands, and occurs across an acidic deposition gradient. Research is under way to examine the interacting factors. Results are expected by 1997.

Visibility

Canada

Canada has been conducting studies on visibility at four monitoring sites across the country to determine which types of aerosols contribute to the deterioration of visibility and the effects different aerosols' chemical classes have on visibility. The four sites are: (1) the lower Fraser River Valley in British Columbia on the west coast, (2) Waterton Lakes International Park on the border of Alberta and

Montana, (3) Egbert in south central Ontario about 70 km north of Toronto, and (4) St. Andrews in New Brunswick on the Maine border. Each of the sites has an Interagency Monitoring of Protected Visual Environments (IMPROVE) module A capability that measures fine mass and absorption and the total amount of light scattered by an aerosol.

Some preliminary findings from the studies include the following:

- The Vancouver area and industrial sources on both sides of the Canadian and American border are the most important sources of aerosols in the Fraser Valley. In addition, and of some importance to parallel studies, a strong aerosol plume from the petroleum refinery area in Anacortes, Washington, has affected the Skagit Valley in the state. This suggests the influence of transboundary transport in visibility reduction in the region.
- About two-thirds of the air pollution that reduces visibility in the Waterton Lakes International Park and Montana's Glacier National Park seems to come from the Canadian side of the border and one-third from the American side. About half of the air pollution from Canada appears to come from sources within Alberta.
- During a period of intense pollution in 1992, testing at Egbert showed that sulfate aerosols were the dominant factor in poor visibility.
- A comparison of monitoring results from Alberta, Ontario, and New Brunswick shows that Egbert has the worst visibility and Waterton Lakes has the best visibility.

Since current models are limited in their ability to deal with humidity, more work is being conducted on the relationship between relative humidity, the growth of sulfate particles, and light scattering.

Current Conditions

A national data set using visibility measurements was created to collect data at airports across the country from 1951 to 1990. The data show that visibility is best in the summer—approximately 120 km in the Yukon and Northwest Territories, as well as northern British Columbia, Alberta, Saskatchewan, and Manitoba. Visibility, however, is only 60 km in lower mainland British Columbia and less than 30 km in the lower Great Lakes region of Ontario as well as in Nova Scotia and New Brunswick on the east coast. In the winter, visibility conditions change. There is a broad band of low visibility, 30 or 40 km, which runs from the Arctic Ocean deep into the prairie provinces.

United States

The current U.S. visibility monitoring program includes about 60 sites in national parks and wilderness areas. The objectives of visibility monitoring are to: (1) document current visibility levels in federally protected areas (i.e., national parks and wilderness areas); (2) gather information needed to identify sources of current visibility impairment; and (3) document visibility trends needed to determine progress towards the national visibility goals of no impairment in protected areas from manmade pollution sources.

Visibility monitoring programs typically photographically document a scene under various levels of visibility. Since quantitative information is difficult to extract from photographs, visibility monitoring also involves the use of instruments that record optical characteristics of the atmosphere to determine the composition and concentration of visibility-reducing aerosols. Optical instruments usually measure either the scattering (i.e., light scattered by molecules) or extinction coefficient (which relates to how well a landscape can be seen). Aerosol monitoring determines the composition of visibility-reducing aerosols to help identify the source type and strength of particles and gaseous precursors to secondary particles.

Visibility monitoring in national parks and wilderness areas has continued under the IMPROVE protocols (see Figure 23). The IMPROVE program published new monitoring and data analysis technical guidance in 1995 and is planning to publish the next edition of its periodic report on visibility, *Spatial and Temporal Patterns and Long-Term Trends of the Chemical Composition of Haze in the United States,* in 1996.

Several special studies also have been undertaken to characterize the cause of visibility impairment. Fieldwork for one of the studies, the Southeastern Aerosol and Visibility Study, was conducted in 1995 in Great Smoky Mountains National Park. The study was designed to enhance understanding of fine particle characteristics under humid summer conditions in the southeastern United States.

Key topics of ongoing and future investigations include the following: (1) measurement and apportionment of

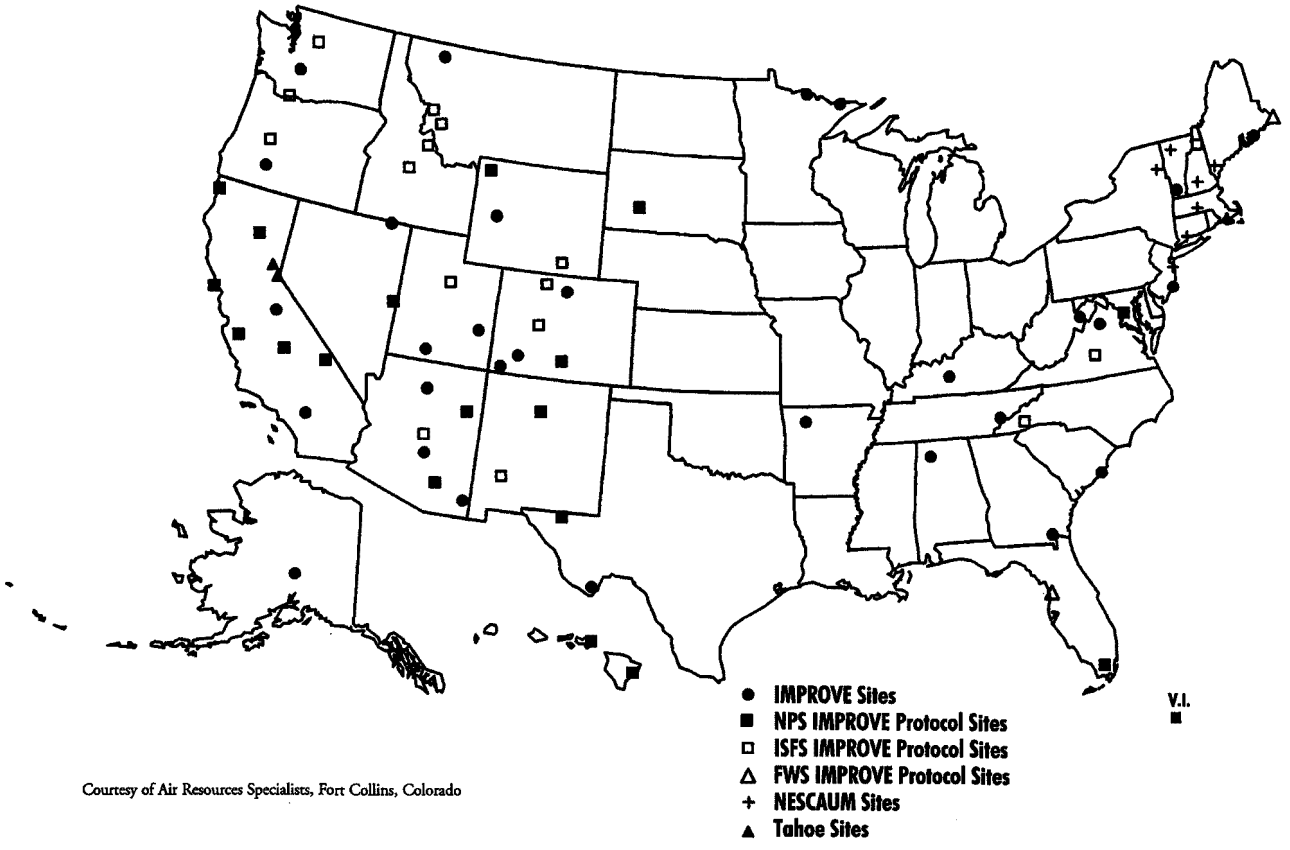

Figure 23. Map of U.S. Interagency Monitoring of Protected Visual Environments (IMPROVE) Sites.

absorption, (2) determination of the acidity of sulfate aerosols, (3) improvement of the understanding of the effect of carbon-based particles on visibility impairment, (4) improvement in the understanding of the effects of water, and (5) development of better assessment techniques to identify source types and regions and to evaluate the effects of changes in emissions.

Current Conditions

Average natural visibility in the West is about 120-160 miles. The best average visibility, at greater than 90 miles, is found only in the Colorado Plateau, central Rockies, and Great Basin regions. Moving east or west from this area, the visibility decreases quite rapidly, to approximately 10-20 miles along the West Coast and to less than 10 miles in much of the eastern United States, where the estimated natural mean visibility is about 70-90 miles. There are differences in visibility in the East and West. Visual ranges are more than six times better in most parts of the West than in most areas east of the Mississippi.

In the East, 60-70 percent of the visibility impairment can be attributed to sulfates. The sulfate contribution to reduced visual air quality decreases further west where organics, nitrates, and soils have larger contributions to visibility impairment. In southern Arizona, New Mexico, and southwest Texas, the sulfate contribution is 40-50 percent; in the Colorado Plateau and central Rockies it is 30-40 percent. In Nevada, Idaho, and Oregon, the sulfate contribution is less than 30 percent. In southern California, the sulfate contribution is 15 percent.

Carbon-based particles contribute approximately 20 percent to manmade visibility impairment in the East, while in most parts of the West they contribute 30-40 percent. In the Northwest, where there is a significant amount of prescribed fire and agricultural burning, the carbon-based particle contribution to reduced visibility is typically 50 percent or greater.

Wind-blown dust is usually the third largest contributor to visibility impairment in the West; nitrates are typically less than 10 percent nationally. The one

exception to these general trends is at the southern California monitoring site, where nitrates often cause more than 50 percent of the visibility impairment.

Seasonal Changes in Visibility Impairment

Figure 24 summarizes annual seasonal averages for four areas of the United States: the Southwest, southern California, the Northwest, and the East. The height of the bar corresponds to the concentration in units of micrograms per cubic meter ($\mu g/m^3$). The height of the shaded patterns is proportional to the contribution of various particles to visibility degradation. In most cases, the summer months are the haziest, and the winter months are the clearest. The relative contribution of each particulate species tends not to vary from season to season.

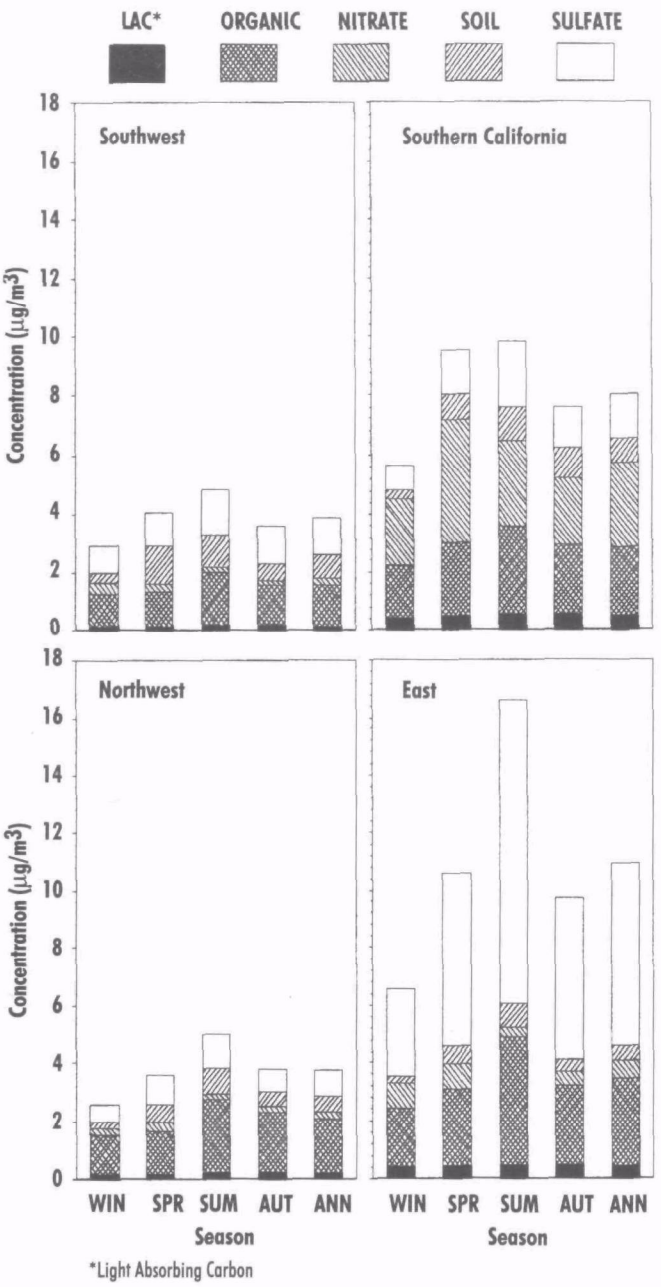

Figure 24. Summary of Season Trends in Visibility Impairment in the United States.

Effects on Materials

United States

Current research on the effects and economic impact of acidic deposition on materials includes studies on degradation of bridges, tall buildings, and cultural resources.

There were difficulties in assessing the impact of acidic deposition on bridge degradation. These difficulties were the result of the inherent variability of estimating bridge condition and local deposition levels and the presence of other unobserved factors.

The tall building study is examining buildings more than 10 stories in Chicago to estimate a relationship between the level of acidic deposition and the annual change in building value, controlling for maintenance expenditures. Results are expected to be available at the end of 1996.

Cultural resources are defined as cultural properties (e.g., historic buildings, monuments, burial markers, artworks, archival documents) for which replacement value understates the societal value. In 1996, results are expected on research measuring the incremental loss of preservation value due to the accelerated decay caused by acidic deposition.

There has also been research on the physical damage to cultural resources, and models of sulfate distribution within limestone and marble have been developed. SO_2 deposition has been found to increase exponentially with relative humidity on unexposed Salem limestone and Shelbourne marble because the relative humidity affects the ability to absorb. Wind speed and turbulence affect the amount of SO_2 delivered to the surface of these materials.

Human Health

Acidic Aerosols and Other Particles

A rapidly growing body of research examines the relationships between particles (also called PM or aerosols) and a range of adverse health effects. PM includes physically and chemically diverse substances that exist as liquid droplets or solids dispersed in the atmosphere. Studies attempt to identify associations between health effects (i.e., a specific symptom, illness, or cause of death) and PM characteristics such as concentration, size, acidity, and chemical components (e.g., some particles are sulfates; some are nitrates; some include metals and other toxics, etc.). In the eastern United States and Canada, PM often contains a large quantity of sulfate aerosols. In the western United States and Canada, where sulfate levels are lower, PM often contains nitrates.

Scientists use several research methodologies to analyze the relationship between human health effects and PM. These include the following:

- **Epidemiologic studies** identify statistical associations between monitoring data on the atmospheric levels of particular pollutants and observed health effects among certain groups of people, such as the population of a particular city or all people over 65.
- **Clinical studies** expose healthy or potentially susceptible individuals (e.g., asthmatics) to measured amounts of laboratory-generated pollutants.
- **Toxicology studies** expose healthy, sick, or aged animals, human tissue, or cells to laboratory-generated pollutants.

The adverse health effects potentially associated with pollution can be acute or chronic. Acute effects include short-term changes in lung function (i.e., the volume of air one is able to exhale or inhale), increased cardiopulmonary hospitalizations, and increased daily rates of mortality associated with episodic pollution. Chronic effects include permanently decreased lung function, increased new cases of bronchitis, and increased mortality associated with long-term exposure.

The relationship between health effects and particulate air pollution was first reported in several epidemiologic studies of various cities in the United States, Canada, and Europe. This research showed that daily increases in particulate levels were associated with increased illness and death, even at levels below current air quality standards. Epidemiologic studies published in the last three years suggest the following:

- Some groups (e.g., the elderly, children, and people with preexisting diseases) are more susceptible to small increases in particulate levels.
- Long-term exposure to particles increases the rates of respiratory and cardiovascular illness and reduces life span in the general population.

Some studies indicate that health effects are associated with fine $PM_{2.5}$ (PM smaller than 2.5 micrometers in diameter), the acidic portions of PM, or its sulfate component. Other studies assert that PM causes health effects in association with other pollutants such as ozone, SO_2, and metals and becomes difficult to distinguish from the effects of weather extremes.

Questions concerning which particles are linked to specific health effects are not yet resolved. There is a growing consensus among scientists, however, that elevated levels of ambient particles are associated with increased rates of illness and death. This consensus is built upon recent epidemiologic studies and a 1995 reanalysis of these data that essentially confirmed the previous analyses.

Results of other recent epidemiologic studies also strengthen the case linking PM and health. These include the following:

- Using daily mortality and total suspended particulate monitoring data for Toronto, Canada, from 1970 to 1990, epidemiologists reported a strong association between daily particulate levels and cardiac deaths.
- A recently published study provides evidence of associations between ambient particulate sulfate and admissions to 168 Ontario hospitals for cardiac and respiratory diseases. Data from several U.S. studies in different cities have indicated similar associations of varying magnitudes (see Figure 25).
- The "24 Communities" joint Canada/U.S. epidemiologic study in 6 Canadian and 18 U.S. communities was specifically designed to examine the associations between acidic aerosol exposures and adverse health effects. The recently reported findings demonstrate that children who are chronically exposed to acidic PM have

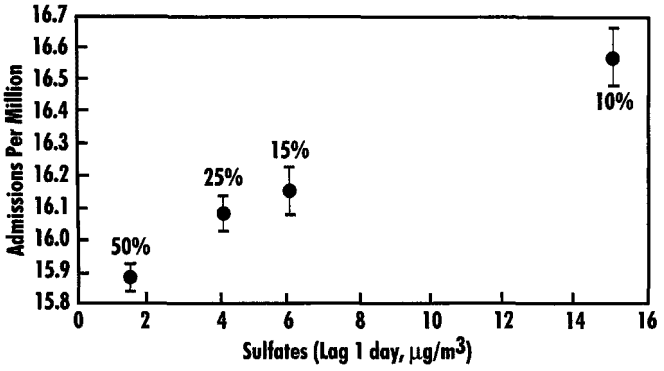

Figure 25. Respiratory Admissions vs. Sulfates in Ontario Hospitals.

lung function lower than predicted for their age group. The study also found an increased risk of "bronchitis" in children residing in high acid PM regions (see Figure 26).

Epidemiologists typically estimate the population's exposure to a pollutant from ambient air data. This approach raises questions about actual exposure, because people spend a great deal of time indoors. Recent studies have answered some of these questions. These studies show that a large percentage of ambient fine $PM_{2.5}$, which includes most acidic aerosols and most sulfates and nitrates, successfully penetrates indoors.

Though larger PM (PM_{10}) is inhalable and has adverse respiratory effects, clinical inhalation studies show that only fine PM penetrates more deeply into the lung. Clinical and toxicology studies provide potential biological bases that support epidemiologic results about the relationship between PM and adverse health effects, such as the following:

- In a recent clinical study, healthy individuals who were exposed to acidic aerosols showed a reduced rate of particle clearance from their airways. A possible consequence of this effect is that their lungs' defense system mechanisms may be compromised.
- Repeated exposure of laboratory animals to acidic PM was associated with changes in airway responsiveness and changes in the animals' ability to clear particles from their lungs.
- Laboratory animal studies show that inhaled acidic particles, when attached to very fine metallic particles, can cause inflammation of the airways.
- Acidic aerosol droplets can exacerbate asthma symptoms in asthmatics.
- Other recent research has identified ultrafine particles (i.e., PM less than 20 nanometers in diameter) as a potentially toxic portion of PM. This research suggests that an extensive number of a small mass of ultrafine particles are inhaled.

Ozone

Stratospheric ozone in the upper atmosphere protects humans from harmful ultraviolet light; ground-level ozone in the troposphere, however, can cause adverse human health effects. These effects have been documented by toxicologists and in clinical studies when human subjects and animals are exposed to laboratory-generated ozone. They also have been reported in epidemiologic studies of children at outdoor camps and the general population.

Among healthy individuals, exposure to ozone can cause a broad range of symptoms, including cough, airway irritation, and chest discomfort when breathing deeply.

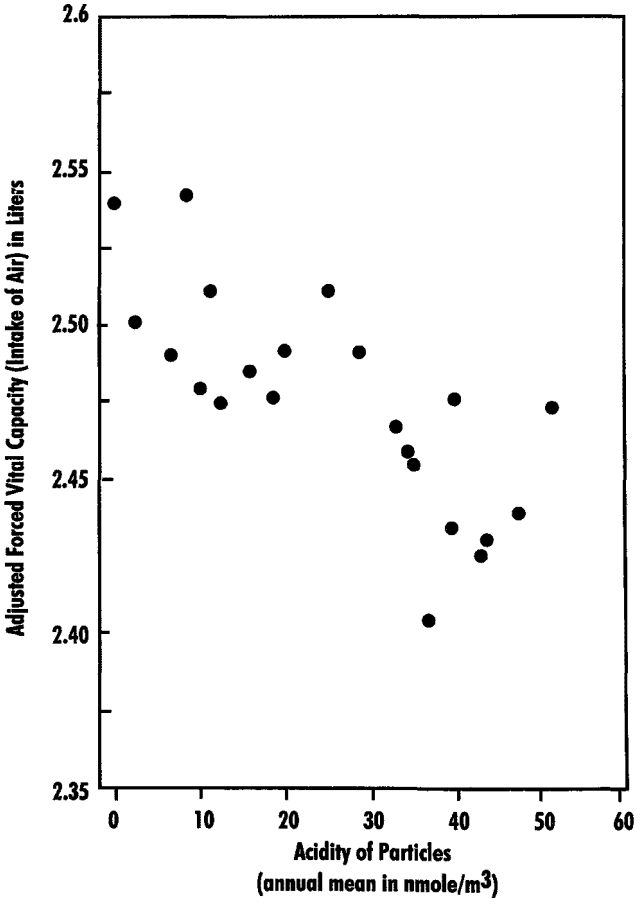

Figure 26. Results of Lung Exposure of Children to High Aerosol Activity in Canadian and U.S. Communities.

Courtesy of Asthma Society of Canada

Canadian child with asthma takes medication to relieve respiratory symptoms on a polluted day.

These respiratory symptoms, which include transient changes in lung function and changes in breathing patterns during exercise, depend upon the duration of exposure, ozone's concentration, and the ventilation volume.

Groups at risk to ozone exposure include children, asthmatics, individuals with chronic lung disease, and healthy individuals who exercise outdoors. The responses of asthmatics are qualitatively similar to those of healthy individuals, but asthmatics' symptoms are typically more numerous and intense. Their increased airway resistance is probably due to bronchial constriction and inflammation. Patients with chronic obstructive pulmonary disease have not been evaluated to the same extent as asthmatics; thus no conclusions can be reached about their relative sensitivity.

Acute effects of ozone exposure are documented in epidemiologic studies. These studies illustrate that emergency-room visits and hospitalization increase when ambient levels of ozone are high:

- Several recent studies indicate that respiratory- related emergency-room visits increase approximately 8 percent when ambient ozone levels increase by 80 ppb to the higher levels. This change of 80 ppb is approximately the difference between background levels and the current 1-hour standard (see Figure 27).
- A seasonal variation in response to ozone exposure has been observed among individuals in nonattainment areas of the United States. The lowest responsiveness occurs after the summer ozone season; the greatest responsiveness is in the early spring.

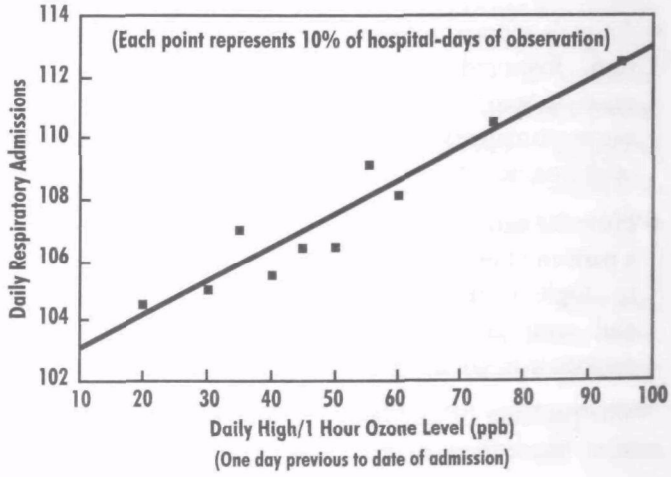

Figure 27. Actual Respiratory Admissions in Ontario.

- Hospitalization for respiratory-related illnesses also appears to increase with elevated ambient ozone levels. In one study in Ontario, Canada, 5 percent of daily respiratory hospital admissions were related to ambient ozone levels. Young children were observed to have the highest sensitivity to ozone, as measured by hospitalization admissions; the elderly have the least.
- Acute changes in lung function also have been observed in children attending summer camps in various locations in North America. A recently published analysis compared the results of six camp studies and concluded that there is strong evidence that children exposed to ozone in natural settings may experience decreases in lung function similar to those observed in clinical ozone exposure studies.

Clinical studies have identified several possible mechanisms that might partially explain these acute health effects. These include the following:

- Ozone exposure increases the airways' allergic responsiveness to allergens and other agents that cause the bronchi to constrict.
- Ozone induces airway inflammation in both healthy humans and asthmatics that persists for up to 18 hours after exposure ceases. There are no chronic mortality studies in animals.
- Ozone impairs the lungs' defense mechanisms, which may increase susceptibility to respiratory infection.

Although chronic effects of ozone exposure, such as structural damage to pulmonary tissue, and persistent inflammation have been observed in a number of animal studies, they have not been studied in humans. The following studies document ozone's chronic effects:

- Animals exposed to ozone exhibit acute lung inflammation. Repeated cycles of acute pulmonary damage and repair in response to repeated incidents of inflammation cause permanent changes in the function and structure of the tissues of the animals' lungs.
- Humans and animals repeatedly exposed to ozone have a pattern of response that is different than their response to single acute exposures. Some acute lung function and symptom responses are diminished while other responses might be worsened.

The presence of ambient PM confounds the results of studies attempting to associate mortality with episodic and long-term ozone exposure. Studies conducted in large North American cities, including New York, Los Angeles, Philadelphia, and Toronto, suggest that ozone exposure might contribute modestly to the overall mortality risk.

Quality Assurance

Bilateral field and laboratory intercomparisons continue to confirm the compatibility of Canadian and U.S. air quality data and to demonstrate steady improvement in laboratory performance. New documentation was produced for methods and analysis.

Field intercomparisons are based on colocated sampling instruments at one or more sites. For example, CAPMoN and NADP/NTN precipitation chemistry measurements are colocated at Sutton, Quebec, and State College, Pennsylvania. The results, accumulated since 1986, show good comparability between Canadian and U.S. sulfate measurements and somewhat lower comparability for nitrate and ammonium. Similarly, a study of colocated CAPMoN and U.S. National Dry Deposition Network air filter pack sampling is under way for sulfur and nitrogen compounds at the Centre for Atmospheric Research Experiments in Egbert, Ontario. The study began in 1990 and continues to confirm the compatibility of the two countries' air quality data. Canadian and U.S. researchers also have participated in American and European intercomparison studies involving atmospheric mercury.

Laboratory comparison studies are conducted annually. These studies help ensure that the chemical analyses carried out in the various precipitation chemistry, aquatics, air toxics, soils, and vegetation laboratories are comparable. Precipitation and aquatic chemistry laboratories conduct comparison studies annually. Approximately 50 Canadian and U.S. laboratories participate in these studies. Study number 38 was recently completed. These studies continue to demonstrate steady improvements in laboratory performance.

In addition, one intercomparison study on nutrients and metals in vegetation is conducted annually. Approximately 30 laboratories participate in this study. The study indicates a steady improvement with time in

laboratory performance and comparability. American and Canadian researchers also have conducted annual intercomparison studies for organochlorines, polychlorinated biphenyl (PCB) isomers, polycyclic aromatic hydrocarbons, and trace metals in atmospheric samples.

Other bilateral quality assurance activities include the publication of a Quality Assurance Program Plan Integrated Atmospheric Deposition Network (IADN) and the production of a manual on laboratory methods for soil and foliar analysis in long-term environmental monitoring programs. Appropriate laboratories and sites in the IADN program are audited on a routine basis. In addition, there is guidance for quality assurance/quality control for the U.S. ozone monitoring program networks SLAMS, NAMS, and PAMS. On a national basis, all quality assurance activities continue to be a high priority in atmospheric research programs.

The United States will be cooperating with Canada through the Global Atmospheric Watch (GAW) of the World Meteorological Organization in a newly established Quality Assurance Activity. The countries will coordinate quality assurance data for GAW stations located in North, Central, and South America. Ozone, precipitation chemistry, and atmospheric optical depth will have quality control criteria and validation criteria for field and laboratory measurements. Communication and scientific investigations are included. Sponsoring agencies include the National Oceanic and Atmospheric Administration's Air Resources Laboratory, EPA, and the U.S. Department of Energy (DOE).

Control Technologies

The Air Quality Agreement commits Canada and the United States to "cooperate and exchange information on development and demonstration of technologies and measures for controlling emissions of air pollutants," particularly SO_2 and NO_x. Both governments are continuing to cooperate and increase information exchange.

Canada, the United States, and Mexico exchange information at the North American Clean Air Technologies Conferences. The first conference was held in Canada in 1994 and the second in the United States in 1996.

Canada

In Canada, developing new control technologies involves many government agencies at the federal and provincial levels as well as major industrial partners, such as metals companies and electric utilities.

At power plants, new technologies to reduce SO_2 emissions—such as fluidized-bed combustion, limestone injection into furnaces, and activation of unreacted calcium—result in large volumes of solid wastes. Environment Canada has conducted extensive studies to characterize and assess pollution control requirements for these wastes and to mitigate or eliminate their adverse environmental effects. For example, Environment Canada is working with Nova Scotia Power on such a study at the Point Aconi Generating Station. Additionally, Environment Canada continues to collaborate with the Canadian Electricity Association, utilities, and industry on a number of projects including technologies to reduce NO_x emissions and flue gas desulfurization wet scrubber technology to reduce SO_2 emissions.

Similarly, the Canadian Coal Gasification Research and Development Committee continues to study integrated coal gasification combined cycle processes as a clean coal technology option for Canada. Environment Canada continues to work with Nova Scotia Power on pilot-scale testing of conventional selective catalytic reductions of NO_x with high-sulfur coal. This project is demonstrating NO_x removal efficiencies in the 86-93 percent range, with no apparent fouling or degradation of the catalyst. Long-term studies of this nature are important in evaluating how well, and how long, conventional selective catalytic reduction resists deactivation from trace metals in coal.

The New Brunswick Department of Energy has collaborated with New Brunswick Power in developing and implementing technology to fully utilize the scrubber wastes produced at the two scrubbed power plants in the province that produce wallboard-grade gypsum. Saskatchewan Power is evaluating NO_x optimization potential at retrofitted wall-fired combustors at its Boundary Dam power station.

Environment Canada is also investigating the formation of nitrous oxide (N_2O), a greenhouse gas, in power plant plumes, further building on work being conducted in the United States. This project illustrates the importance of developing technology that can address multiple pollutants simultaneously.

United States

Progress continues to be considerable in the development of control technologies. In the United States, the Clean Coal Technology (CCT) Program will fund more than $7 billion in projects over the course of the decade. Power-generating and pollution-control technologies are being developed in this cost-shared government/industry research and development program. CCT initiatives under the DOE are intended to increase emissions and cost reductions and operation efficiencies. The CCT Program is expected to demonstrate the utility and merit of new coal-burning processes in a series of full-scale commercial facilities.

The CCT Program emphasizes the mitigation of acid rain precursor emissions. This focus is consistent with the *U.S. and Canadian Special Envoys Report on Acid Rain,* the source of the original 1986 recommendation for a multi-billion dollar clean coal demonstration program.

There are currently 43 active projects in the CCT Program. Eighteen projects have been completed; 8 are in operation; and 16 are in the design phase or under construction. Only one project is in negotiation. Of the 43 projects selected in the 5 completed competitive CCT solicitations, almost all will have had sufficient operating time to be offered commercially by 2000. Once the projects are completed, both sponsors and participants will use the information gained to promote and market the technologies in commercial applications. Total project costs through the 5 solicitations under the program amount to approximately $7.2 billion, with an average industry cost share of 68 percent.

As reported in the 1994 Progress Report, significant clean coal technology achievements are continuing in the following market categories:

- Advanced power generation systems (including fluidized- bed combustion.
- Integrated gasification combined-cycle and other processes.
- Environmental control systems (including advanced flue gas desulfurization technologies and combined SO_2/NO_x control systems).
- Coal process for clean fuels (characterized by production of high-energy density solid, stable compliance fuels and production of coal-derived liquids that can be used as chemical or transportation fuel feedstocks).
- Industrial applications that encompass steel industry, cement industry, and industrial boiler applications.

Finally, Canada and the United States continue to hold an annual meeting on control technologies under a bilateral MOU between DOE and the Canadian Department of Natural Resources. Status reports on their respective CCT programs are given at the annual meeting.

SECTION IV

Additional Areas of Cooperation

Ground-Level Ozone

Ground-level ozone, the main component of smog, is formed when NO_x and VOCs react in the atmosphere. Adverse effects of ozone include human health impacts and damaging effects on forests and agricultural crops. Both Canada and the United States have their own programs to reduce the emissions that cause ground-level ozone, and the two governments are working cooperatively to address transboundary ozone initiatives begun in 1994.

Ongoing Cooperation

Regional Ozone Study Area

In November 1994, the AQC met and formally approved the Regional Ozone Study Area (ROSA) initiative. ROSA is the outgrowth of a transboundary ozone management pilot project initiated by the environmental heads of the two governments in July 1994. The ROSA project is intended to address transboundary ozone transport on a broad regional scale. The source/receptor region of greatest interest for assessment is an area encompassing eastern Missouri and Tennessee on the southwest and New York State and Ontario on the northeast (see Figure 28).

The initial analyses conducted for ROSA included a series of modeling runs directed by EPA staff using the Regional Oxidant Model. These simulations examined the extent to which key source regions in the ROSA contribute to transboundary ozone transport. The simulations also examined the potential effectiveness of regional ozone precursor controls in addressing ozone transport. Due to the expense of conducting these analyses and the need to involve key U.S. states in the process, more comprehensive modeling directed at ROSA study objectives will be developed in conjunction with the U.S. OTAG regional cooperative effort (for further discussion in this section, see page 56). In addition to the OTAG modeling effort, which is slated to continue through 1997, EPA and Environment Canada are cooperating to analyze the ozone episodes of mutual interest that occurred in the summer of 1995.

The ROSA initiative demonstrates that the two countries share priority in expanding cooperation under the Air Quality Agreement to improve the air quality of North America.

Next Steps

In 1996, Canada and the United States will explore opportunities to link their ozone reduction efforts more closely, including possible integration of Canadian Regional Smog Management Plans and transboundary considerations in the OTAG process. As an important step in advancing cooperation under the ROSA initiative, the United States already has invited Canada to participate as an observer in OTAG meetings. There is also an opportunity for the Ontario Regional Smog Management Plan, in particular, to coordinate with and build upon OTAG efforts. It is expected that close linkages will be maintained as the two efforts evolve. Furthermore, the two countries will examine specific elements of a transboundary management process, such as transboundary NO_x emissions trading.

Discussions are under way on possible open-market emissions trading between sources in Ontario and Michigan. Any decision made within OTAG on interstate trading will be important to the development of a broader transboundary trading initiative. A draft emissions trading framework has been prepared by OTAG, and trading concepts will be considered in more detail as the OTAG program evolves during 1996.

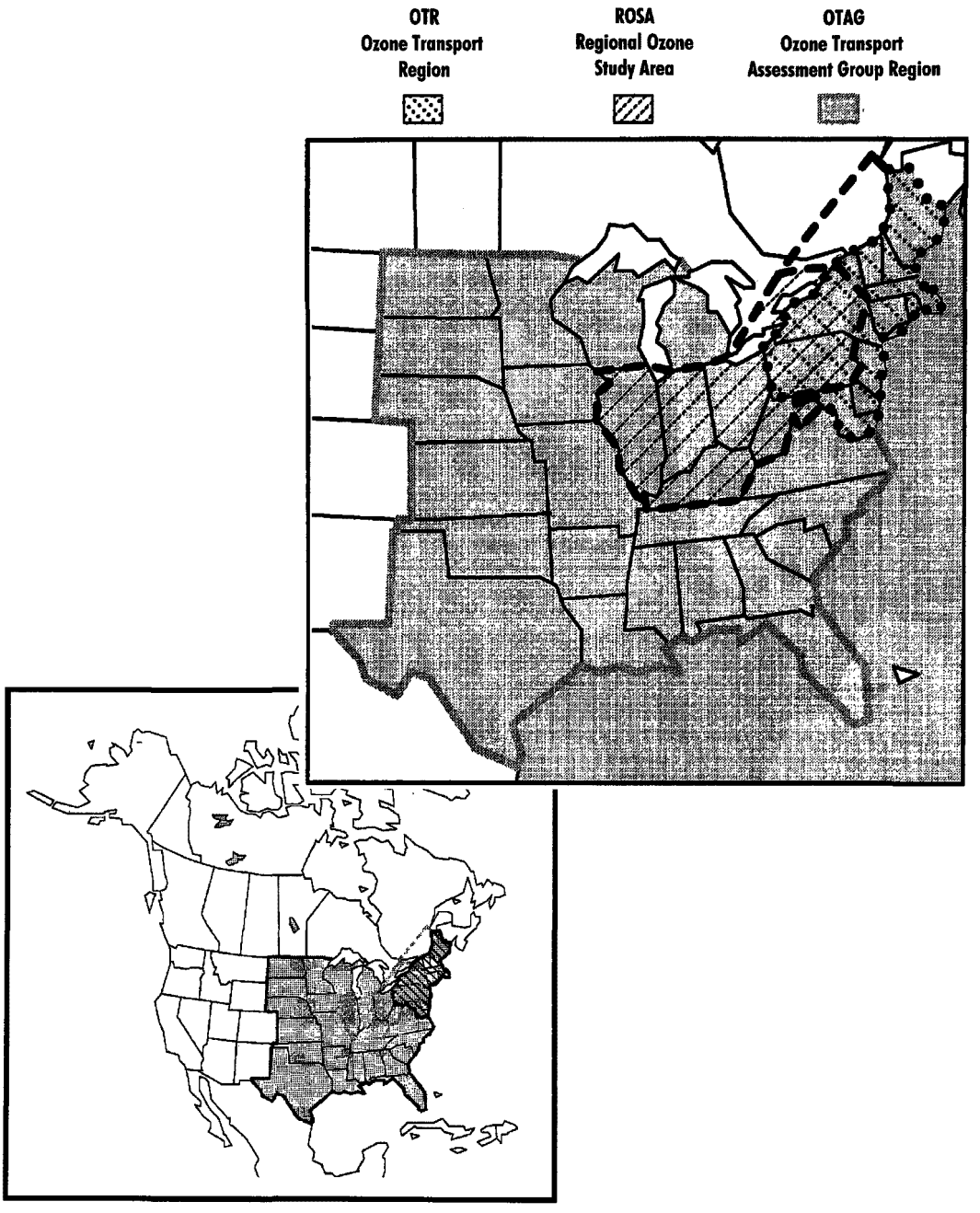

Figure 28. OTAG and ROSA Regions.

Domestic Programs

Following are summaries of the domestic programs both governments are undertaking to reduce ground-level ozone.

Canada

In Canada, ground-level ozone is a particular problem in three regions: the Lower Fraser Valley in British Columbia, the Windsor-Quebec city corridor straddling southern Ontario and Quebec, and the southwestern areas of New Brunswick and Nova Scotia.

As a result, the Canadian Council of Ministers of the Environment adopted a plan in 1990 to reduce NO_x and VOC emissions that cause smog. The main objectives of the NO_x/VOC Management Plan are the following: (1) reduce emissions of ground-level ozone to below the national ambient air quality objective of 82 ppb (1 hour)

in areas with ozone exceedances and (2) establish a national program to prevent air quality from deteriorating in the rest of the country.

The Phase I plan acknowledged that achieving these objectives would likely require additional measures and the need for a second and possibly third phase.

At present, most of the Phase I initiatives are complete (e.g., revised vehicle emissions standards, consumer product reformulation, and gasoline vapor pressure reduction). Others are still being developed. Some provinces have implemented regional control measures, such as vehicle inspection, fuel storage and handling, public education, and strict facility-specific permit provisions. British Columbia has made the most progress, undertaking a program to significantly reduce levels of smog in the Vancouver-Fraser Valley area.

As anticipated, the Phase I measures will not fully resolve the ozone/smog problem in the targeted regions. In addition, a greater understanding of air quality and a broader multipollutant definition of the smog problem have emerged. As a result of recent health studies regarding ground-level ozone, Canada is reviewing its objectives for ground-level ozone.

In the last year, the Canadian Council of Ministers of the Environment has begun developing a "next steps" smog strategy and accompanying plans. The new initiative will begin in 1997 and will build on Phase I measures and science. The strategy will consist of a National Smog Management Plan (led by the federal government) and four Regional Smog Management Plans. The National Smog Management Plan component will consolidate national preventative actions, including new vehicles and fuels standards recently agreed to by federal and provincial ministers. Additional product and process standards and stricter environmental performance limits for new sources are also contemplated.

The four Regional Smog Management Plans will address continuing air quality problems in smog "hot spots." These will be led largely by the provinces and have a strong remedial and airshed management component. The province of British Columbia and the Greater Vancouver Regional District have already developed a plan for the greater Vancouver area. The province has also announced its intention to develop strict vehicle emissions and fuel standards and introduce California-type LEV requirements by 2001. The province of Ontario has issued its discussion paper, "Toward a Smog Plan for Ontario," suggesting NO_x and VOC emissions reduction targets of 45 percent.

Areas Designated to Ozone Attainment, as of July 1996

San Francisco, CA; Miami, FL; Tampa-St.Petersburg, FL; Jersey County, IL; Indianapolis, IN; South Bend, IN; Kansas City, KS/MO; Edmonson County, KY; Lexington, KY; Owensboro, KY; Paducah, KY; Detroit-Ann Arbor, MI; Grand Rapids, MI; Charlotte-Gastonia, NC; Raleigh-Durham, NC; Canton, OH; Cleveland, OH; Columbus, OH; Dayton-Springfield, OH; Toledo, OH; Youngstown, OH; Cherokee County, SC; Knoxville, TN; Memphis, TN; Charleston, WV; Greenbriar County, WV; Huntington-Ashland, WV; Parkersburg, WV.

United States

NAAQS were established in the United States for ground-level ozone to protect public health and welfare. The health and welfare standards are both 0.12 parts per million (ppm), not to be exceeded for more than 1 hour per year. Areas (usually county or metropolitan area wide) where the violations are measured are designated as nonattainment areas. Each designation is based on a submittal to EPA by the state governor.

The U.S. program focuses on reducing the primary ozone-forming pollutants, VOCs and NO_x. Most efforts have been directed toward controlling VOCs, although increasing attention has been given to controlling NO_x for ozone reduction since the 1991 publication of the National Research Council report *Rethinking the Ozone Problem in Urban and Regional Air Pollution.*

The CAAA specified five classifications of nonattainment with the ozone standard: marginal, moderate, serious, severe, and extreme. The classifications are based on the amount of ozone measured in the areas, with the most polluted areas receiving the extreme classification. Increasingly stringent control measures are required for each classification of increasing pollution levels. The more polluted areas have more time to reach full attainment because implementation of the more stringent requirements is expected to be more time-consuming. Of the original 98 classified ozone nonattainment areas, 28 have been redesignated to attainment. Fourteen of these were redesignated in 1995. These redesignations are due to improved air quality levels measured in recent years in the areas.

Regulators are also becoming aware that ozone does not always originate entirely in the area where the violation is measured. Ozone and ozone precursors can be transported by air movements from other areas. The special problems caused by air transport were recognized by Congress in the CAAA when it established an Ozone Transport Region (OTR). The OTR consists of the New England states, New York, New Jersey, Pennsylvania, Maryland, Delaware, and the District of Columbia metropolitan statistical area (which includes a portion of Virginia).

The CAAA also established an OTC comprised of representatives from these 13 jurisdictions. The OTC assesses the formation and transport of ozone precursors in the OTR and recommends regional control strategies to mitigate the interstate pollution. Two of the OTC's most significant actions to date are the adoption of a MOU to control NO_x emissions (NO_x MOU) and a recommendation to adopt a LEV program. The NO_x MOU will achieve significant reductions in NO_x throughout the OTR and will be implemented through a cost-saving trading program. The recommendation for the LEV program has led to negotiations with automakers that may bring cleaner cars not only to the OTR but also to the rest of the nation.

OTAG, another regional cooperative effort that covers an even broader geographic area, is addressing the transport problem in the entire eastern United States. OTAG is organized under the umbrella of the Environmental Council of the States and is chaired by the State of Illinois. It consists of states, EPA, environmental organizations, industry, and others. OTAG is organized into a number of subgroups that meet regularly to explore issues of concern and develop strategies focusing on the interstate nature of the ozone problem. One subgroup explores options for atmospheric models that help predict the effectiveness of areawide control strategies. OTAG has invited representatives from Environment Canada to observe its meetings.

While the current 0.12 ppm ozone standards are being implemented in the United States, they are being reviewed to determine if they need to be revised to reflect the most recent scientific information on the health and vegetation effects of ozone. EPA issued an advanced notice of proposed rulemaking in June 1996 stating its intentions to propose decisions on revised ozone standards in conjunction with its decision on revision of PM standards. EPA will announce a proposed decision on revision of the ozone and PM standards in November 1996.

Air Toxics

Overview

Air toxics are contaminants that are emitted into the atmosphere and transported through the air. They are toxic, persistent, and hazardous to human health or plant and animal life.

Air toxics are released from a variety of sources and processes. They include a large number of compounds and compound classes, such as the following:

- Heavy metals (e.g., mercury)
- Respirable mineral fibers (e.g., asbestos)
- Toxic inorganic gases (e.g., chlorine)
- Hazardous VOCs (e.g., benzene)
- Halogenated organic compounds (e.g., dioxins)

Sources of air toxics vary from large point sources such as waste incinerators, smelting, and fossil-fueled power plants to many small and diverse sources including pesticide applications, motor vehicles, and dry-cleaning facilities.

Certain persistent toxic substances also bioaccumulate in living organisms and have been associated with immune system dysfunction, reproductive deficits, developmental and neurobehavioral abnormalities, and cancer. Air toxics have been detected thousands of miles from where they were emitted. For example, toxic substances have been detected in human breast milk and wildlife tissue in remote areas that have no local discharge or emission sources.

Canada and the United States have identified a range of persistent toxic substances of concern in the Great Lakes. Many of these are pesticides, but polycyclic aromatic hydrocarbons (compounds consisting of hydrogen and carbon arranged in rings), dioxins and furans, and several heavy metals are also of concern. The "atmospheric area of influence" of these substances is broad. Many air toxics are known to originate from sources well beyond the Great Lakes Basin. The two countries are also examining transboundary toxics in the Gulf of Maine, on the West Coast (Vancouver-Seattle region), and in more localized

contexts, such as Detroit-Windsor and surrounding the Trail Smelter in British Columbia.

To control these toxic pollutants, Canada and the United States launched domestic programs about 20 years ago at both the federal and provincial/state levels. At the federal level, control programs were introduced under the respective Clean Air Acts of both countries. These efforts have been enhanced in recent years with the toxic provisions of the CEPA and the CAAA. Both nations have implemented mandatory inventory reporting systems: the Toxic Release Inventory in the United States and the National Pollutant Release Inventory in Canada. Progress implementing these programs is reported in other publications, including the annual CEPA reports in Canada and the National Air Toxics Information Clearinghouse in the United States.

The international efforts described below are intended to provide an overview of the efforts of both governments to control the transboundary transport of air toxics. The United States and Canada are cooperating in the following international efforts that address air toxics: Annex 15 of the United States-Canada Great Lakes Water Quality Agreement, the Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin (Binational Virtual Elimination Strategy), and the North American (Canada, the United States, and Mexico) Agreement on Environmental Cooperation's Resolution on the Sound Management of Chemicals.

International Efforts

Annex 15 of the Great Lakes Water Quality Agreement

Annex 15 on Airborne Toxic Substances states that Canada and the United States "shall conduct research, surveillance, and monitoring and implement pollution control measures for the purpose of reducing atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes Basin ecosystem." The control measures may be aimed at sources anywhere in Canada and the continental United States, not just the Great Lakes Basin.

Scientific work to identify persistent toxic substances is progressing. The IADN is also well established, with five master monitoring stations in place, one on each of the Great Lakes. Eight years after negotiating Annex 15, however, there is not an adequate overview of progress toward reducing and eliminating Great Lakes air toxics of concern. To accelerate action on this front, a Binational Virtual Elimination Strategy for persistent toxic substances in the Great Lakes Basin will be implemented in 1996.

Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin

President Clinton and Prime Minister Chrétien agreed in February 1995 that the two countries should develop a strategy to "address the most persistent toxic substances in the Great Lakes environment."

The strategy follows the framework set out by *Agenda 21: Global Action Plan for the 21st Century* signed by more than 160 nations in 1992. This plan called for phasing out or banning toxic chemicals that pose an unmanageable and unreasonable risk to human health and the environment.

The Binational Virtual Elimination Strategy sets quantifiable reduction targets and time frames for specified persistent toxic substances in the Great Lakes Basin. The strategy describes a process for evaluating the sources and current regulatory framework of the toxics as well as developing options for reductions. The strategy also sets forth principles by which the strategy will be guided, including the commitments to open, interactive public participation and involvement in the international arena to pursue reductions. There is also emphasis on pollution prevention and support of State, Provincial, Lakewide Management Plans for each of the Great Lakes to achieve reductions.

The strategy describes in a technical appendix some of the actions that the countries propose to take to achieve reductions. Although the strategy emphasizes voluntary efforts, all regulatory and nonregulatory efforts will be considered.

North American Agreement on Environmental Cooperation

As a follow-up to the North American Agreement on Environmental Cooperation (NAAEC), the Commission for Environmental Cooperation (CEC) was established to address transboundary and regional environmental concerns in North America. One of the CEC initiatives,

North American Air Monitoring and Modeling, focuses on North American air quality concerns. This initiative is aimed at developing cooperative long-term air quality monitoring, modeling, and assessment programs in North America through the promotion, collection, and exchange of data and through development and application of appropriate models between and among the three countries.

The initial focus of CEC's activities is assessing the compatibility of the air data sets currently generated in North America, determining the quality of emissions inventories, and developing potential partnerships with established organizations that share common objectives.

During 1996, CEC will coordinate the development of regional action plans for the phase-out or management of PCBs, dichlorodiphenyltrichloroethane (DDT), chlordane, and mercury. This work is being conducted as part of the Resolution on the Sound Management of Chemicals signed by Canada, the United States, and Mexico in 1995 under the auspices of the NAAEC.

UN Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution

As part of the UN Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (LRTAP), work is under way to develop protocols on persistent organic pollutants (POPs) and heavy metals.

The POPs protocol is expected to address a short list of substances and industrial chemicals and allow flexibility in implementation. Certain pesticides would be subject to use restrictions while others would be banned. For stationary sources of dioxin and furan emissions, best available technology or best environmental practice requirements may be applied. The protocol would also include an annex setting forth the technical and procedural criteria necessary for additional substances to be covered. It is expected that the POPs protocol will be concluded by late 1997.

The heavy metals protocol will focus on lead, mercury, and cadmium. As with the POPs protocol, a variety of response action obligations would be considered. Although heavy metals are being addressed in parallel with POPs at the Working Group on Strategies sessions, technical work on heavy metals is not as well advanced. It is expected that the heavy metals protocol will not be completed until 1998.

UNEP, International Forum on Chemical Safety, and Other Related Global Chemical Safety Forums

Following a decision by the May 1995 UN Environmental Program (UNEP) Governing Council, an assessment was initiated and draft interim report prepared of the chemistry, toxicology, transport, and socioeconomic factors associated with POPs and recommendations for international actions on POPs. The draft report was presented to the Intergovernmental Conference on the Protection of the Marine Environment from Land-Based Activities in October 1995 in Washington, D.C. The 102 participating governments, including the United States and Canada, recommended that a legally binding global instrument be developed for the reduction and/or elimination of emissions and discharges and, where appropriate, the manufacture and use of POPs. The affected pollutants are PCBs, dioxins/furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor. In addition, the second Intersessional Group meeting of the International Forum on Chemical Safety (IFCS) held in Canberra, Australia, approved the draft report's sections on chemistry, toxicology, and transport. IFCS held two meetings in June 1996 in the Philippines to further develop the socioeconomic portion of the report and to develop recommendations to the UNEP Governing Council's January 1997 meeting on how to proceed towards a globally legally binding mechanism on POPs.

Although none of these international efforts is formally linked to the Air Quality Agreement, the AQC believes it would be useful to assess the magnitude of the air toxics problem and report on the implementation of the current agreements. This will provide a more complete picture of how the two countries control transboundary air pollution. Furthermore, the AQC has decided to track these programs and identify any gaps by the end of 1996. The AQC will then address what role it will play regarding air toxics.

SECTION V

Conclusion

This third progress report under the Canada-United States Air Quality Agreement has focused on the substantial progress the two governments have made in achieving emissions reductions goals and in carrying out long-term programs to reduce the effects of acid rain in both countries.

Canada has achieved a 54-percent decrease in SO_2 emissions in the seven eastern provinces from 1980 levels. Emissions decreased from 3.8 million tonnes in 1980 to 1.7 million tonnes in 1994, significantly surpassing the emissions goal for eastern Canada. In the United States in 1995, the first compliance year for Phase I of the Acid Rain Program, all Phase I affected units met their compliance obligations, with SO_2 allowances held by the units matching emissions generated. SO_2 emissions declined sharply at Phase I electric utility units—decreasing to 5.3 million tons from 1980 levels of 10.9 million tons. This amounted to a reduction of 3.4 million tons more than allowable levels of 8.7 million tons for the first year of compliance. Both countries are also implementing programs to reduce NO_x emissions. In Canada, measures are in place to reduce NO_x emissions from stationary sources by 125,000 tonnes by 2000. In the United States, NO_x emissions from stationary and mobile sources are expected to be reduced by more than 2 million tons by 2000.

In scientific and technical cooperation, this report has documented the commitment of Canada and the United States to expand monitoring and modeling efforts for acidic deposition as well as ground-level ozone. Both countries continue to work together to ensure emissions inventory data consistency and coordination in emissions trends analysis. The two governments are assessing and reporting ecosystem and human health effects from acidic compounds. They are also demonstrating and deploying new pollution control technologies in an effort to reduce pollution and are using different methods for reducing emissions, including energy efficiency, demand-side management, fuel switching, and pollution control equipment.

In addition, the United States has continued to use market-based mechanisms to achieve air pollution reduction at a lower societal cost. At the same time, both governments have continued to exchange information on clean air control costs.

This report also considers the increasing efforts of the two countries, jointly and through individual pollution control programs, to address ground-level ozone (the main component of smog), the deposition of toxic compounds, and other air quality issues of concern. One of the newest outgrowths of this activity is the ROSA project, which is addressing transboundary transport of ozone on a broad regional scale.

Further discussion of the cooperation of the two governments is contained in the first five-year review of the Air Quality Agreement (see Section VI).

SECTION VI

Five-Year Review and Assessment of the Canada-United States Air Quality Agreement

Introduction

Article X, Review and Assessment, of the Canada-United States Air Quality Agreement is intended to ensure that the Parties periodically review and assess the Agreement to determine whether it is working well and is "a practical and effective instrument to address shared concerns regarding transboundary air pollution." This review will weigh the success of this broad charge.

Article X, Paragraphs 1, 2, and 3 of the Canada-United States Air Quality Agreement state:

1. *Following the receipt of each progress report submitted to them by the Air Quality Committee in accordance with Article VIII and the views presented to the International Joint Commission on that report in accordance with Article IX, the Parties shall consult on the contents of the progress report, including any recommendations therein.*
2. *The Parties shall conduct a comprehensive review and assessment of this Agreement, and its implementation, during the fifth year after its entry into force and every five years thereafter, unless otherwise agreed.*
3. *Following the consultations referred to in paragraph 1, as well as the review and assessment referred to in paragraph 2, the Parties shall consider such action as may be appropriate, including: (a) the modification of this Agreement; (b) the modification of existing policies, programs, or measures.*

The five-year review provides a comprehensive assessment of the Agreement and its implementation as required by Article X. It also provides guidance for consideration of any modifications to the Agreement.

The review must address the following two broad questions:

(1) Are the Parties fulfilling their obligations under the Air Quality Agreement? What measures are being taken to do so?

(2) Is the Air Quality Agreement a good mechanism for fulfilling these obligations? What are the strengths and weaknesses of the Agreement?

The 1996 Progress Report responds to the first question, and the following article-by-article review, beginning with Article III, responds to the second question. Articles I and II dealing with definitions and purpose are not reviewed.

Article-By-Article Review

Article III. General Air Quality Objectives

Is the Agreement effectively working to control transboundary air pollution between the two countries?

The General Air Quality Objectives, as set forth under Article III of the Agreement, broadly direct the Parties to control transboundary air pollution between the two countries in accordance with the remaining articles of the Agreement. The Agreement outlines a detailed plan for the reduction of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions in both countries. The Agreement has succeeded in achieving these SO_2 and NO_x emissions reduction goals. The Parties agree, however, that control of transboundary air pollution has not occurred "to the extent necessary to protect the environment," particularly in highly sensitive areas. (The Parties recognize that

Annex 1 was designed to protect only moderately sensitive areas from acidic deposition.)

Furthermore, the Parties recognize that the Agreement and its annexes currently focus on acid rain and do not address other types of transboundary air pollutants, such as ground-level ozone, air toxics, and particles. At present, the Air Quality Committee (AQC) is studying ways of managing ground-level ozone and its precursors and is evaluating what role it might play regarding air toxics, taking into consideration other agreements and pending new protocols (see 1996 Progress Report). The Parties will decide over the next year whether to add new annexes on ground-level ozone, air toxics, and/or particles to the Agreement, or leave their management to other areas.

Article IV: Specific Air Quality Objectives: Annex 1

Are the Parties meeting the specific objectives as set forth in Annex 1? What programs or other measures have been adopted to implement specific objectives?

The Specific Air Quality Objectives, as set forth under Article IV of the Agreement, direct the Parties to adopt programs and other measures necessary to implement emissions limitations or reductions of SO_2 and NO_x in order to reduce the transboundary flow of these acidic deposition precursors. The 1996 Progress Report provides a detailed description of the progress of implementation of the acid rain control programs in both countries.

Two key Annex 1 objectives remain subject to further discussion between the Parties: compliance monitoring and prevention of significant deterioration (PSD)/visibility. While Canada believes that it is fulfilling the compliance monitoring requirements of Annex 1, and almost all major Canadian sources have some type of emissions monitoring system, the United States remains concerned about the uniformity and accuracy of provincial reporting requirements. Canada acknowledges that inventory data need to be improved and is working with the provinces toward that end.

Both Parties also recognize the importance of PSD and visibility, particularly for international, national, state, and provincial parks and wilderness areas. Part C of Title I of the U.S. Clean Air Act (CAA) was developed specifically to address these issues. Canada holds that Canadian air quality objectives for NO_x, SO_2, and particulate matter (PM) are equal to or more stringent than U.S. standards, and the desirable levels are comparable to background levels found in remote areas. Canada believes that the new Canadian Environmental Assessment Act, combined with provincial permitting and environmental assessment legislation, provides comparable environmental protection to the U.S. program.

U.S. concerns center on the enforceability of Canadian requirements and whether implementation procedures for visibility protection and PSD would prevent deterioration in areas that already enjoy air quality surpassing Canadian objectives. The United States is concerned that the outlined Canadian program does not identify the way to achieve reasonable progress similar to the visibility program in the United States. In addition, the United States believes that comparisons should be most appropriately made between Canadian air quality objectives and U.S. PSD increments. PSD increments in the United States can never lead to ambient levels above the national ambient air quality standards.

Article V: Assessment, Notification, and Mitigation

What measures have the Parties taken to implement Article V? What are its strengths and weaknesses?

While both Parties generally agree that the notification clause is functioning adequately, particularly with the establishment of electronic bulletin boards, they are less satisfied with assessment and mitigation. Article V states that "each party shall, as appropriate and as required by its laws, regulations, and policies, assess those proposed actions, activities, and projects within the area under its jurisdiction that, if carried out, would be likely to cause significant transboundary air pollution, including consideration of appropriate mitigation measures."

The Parties' dissatisfaction with the assessment and mitigation clauses stems from the differences in laws and regulations in the two countries. Canadian environmental assessment legislation provides that, effective in 1995, potential damages on U.S. territory caused by all new Canadian sources be assessed, mitigated, and/or compensated. Although the United States informally shares assessment data with Canada, there is no similar U.S. legislation providing assessment and mitigation of U.S. sources into Canadian territory. Canada views this position as going against the spirit and intent of reciprocity in the Air Quality Agreement. The United States views this position as consistent with the language of the Agreement.

Article VI: Scientific and Technical Activities and Economic Research

Are the Parties satisfied with the level of cooperation, coordination, and sharing of scientific and technical information and economic research?

While the level of scientific and technical activities and economic research has been adequate to meet the reporting needs of the Agreement, both Parties conclude that additional research and monitoring activities beyond this level would be helpful in addressing transboundary air pollution issues.

Article VII: Exchange of Information

Are the Parties satisfied with the degree of information exchange? Are there other areas/issues that have not been introduced in an information exchange capacity that should be?

Although the Parties agree that information exchange has been sufficient to meet the Agreement's objectives, both Parties conclude that this cooperation ought to be expanded. Unfortunately, shrinking budgets and travel restrictions on both sides will severely limit the ability of experts to continue or expand this type of cooperation.

Article VIII: The Air Quality Committee

Is the Committee fulfilling its duties? Has the subcommittee structure within the AQC been effective?

The AQC meets formally once a year to assist in implementing the Agreement by reviewing subcommittee progress, providing recommendations, and ensuring that interested stakeholders receive the appropriate feedback. In this regard, and in the publication of biannual progress reports, the AQC fulfills the objectives of the Agreement. The subcommittee structure has been effective in dividing work that must be undertaken to implement the Agreement. The AQC will have to consider how to address future issues to meet the air quality priorities of the two Parties.

The Parties concur that the production of biannual progress reports unnecessarily diverts scarce fiscal and human resources from pressing air issues. Instead, a detailed progress report every five years in the years when there is a five-year review and assessment of the Agreement and short interim progress reports would be more than adequate to satisfy the reporting goals of the Agreement.

Article IX: Responsibilities of the International Joint Commission

Is the International Joint Commission (IJC) fulfilling its duties? What measures has the IJC taken thus far to solicit public comment?

The IJC has successfully been fulfilling its duties under the Air Quality Agreement. The IJC invited and synthesized comments on the 1992 and 1994 Progress Reports for submission to the Parties. Although there were few public comments on the two reports, the IJC served actively in the public participation process. Upon request from the Parties, the IJC held public meetings to solicit input to this five-year review. These public comments have been summarized and included in this document.

Canada would like to see the IJC play a more prominent role, including the conducting of five-year reviews. The United States is satisfied with the current role being played by the IJC in synthesizing and providing public comments.

Article X: Review and Assessment

Are the Parties satisfied with this Article?

The Parties agree that Article X of the Agreement serves a critical function regarding the continued effectiveness and usefulness of the Air Quality Agreement. The involvement of a third party could assist in the review process.

Articles XI: Consultations; XII: Referrals; and XIII: Settlement of Disputes

Although no formal consultations, referrals, or disputes have occurred, do these Articles accommodate a Party's desire for consultation, evaluation, and settlement of matters of concern?

The Parties concur in the affirmative. So far, however, the Parties have sought to resolve matters of concern between themselves and without outside help. It remains to be seen whether matters can be successfully resolved through a formal consultation process under Article XI.

Article XIV: Implementation

What measures have the Parties taken to ensure timely implementation of the Agreement? Are there any barriers to successful implementation?

Both Parties have been successful to date in obtaining the necessary support and funding to establish acid rain programs. Given severe budget constraints and significant funding cuts, however, the monitoring and research programs on both sides of the border are threatened.

The Parties require close coordination and cooperation with state and provincial governments as necessary to implement the Agreement. Differences in each country's federal structure have created some uncertainty in jurisdictional questions. In Canada, the National Air Issues Mechanism is a federal/provincial/territorial effort to manage air issues in an integrated fashion. In the United States, implementation of the Agreement has not required enactment of any additional legislation.

Article XV: Existing Rights and Obligations

The Air Quality Agreement recognizes the rights and obligations of the governments in other international agreements. The AQC considers other important transboundary air pollution issues and discusses the extent to which they may be addressed by other international agreements, such as the NAAEC. The Commission on Environmental Cooperation, established by the NAAEC, is currently working with Canada, Mexico, and the United States to develop a North American model for transboundary environmental impact assessment. In addition, transboundary air toxics are being addressed through other international negotiations (see Emerging Issues in this section).

Emerging Issues

Have the Parties established or considered new objectives?

While the Parties have not yet established new objectives, they are individually studying critical loads/acidic deposition standards and bilaterally discussing ground-level ozone. For example, Canada is evaluating new target loads, based on the critical loads concept, in a new National Strategy on Acidifying Emissions for post-2000. Moreover, both Parties are taking tropospheric ozone issues seriously and are eager to develop a more extensive understanding of this important air issue. Differences between Canada's ozone objective (82 parts per billion) and the U.S. standard (120 parts per billion) and their implementation will be reviewed to address comparable levels of health protection to the public on both sides of the border.

In a manner that is not redundant with efforts in other areas, the Agreement could be expanded to pursue improved understanding of such issues as transboundary contributions to inhalable particulate levels and air toxics (currently being addressed in the Great Lakes Water Quality Agreement and its new Binational Virtual Elimination Strategy). Bilateral efforts to address visibility issues in pristine areas should continue to be encouraged. There are already some efforts under way.

Summary of Public Comments

Canada and the United States asked the IJC to hold hearings to solicit public comments prior to the issuing of the first five-year review. The IJC held two hearings in 1995, one in Ottawa and one in Washington, D.C. Sixteen presenters participated in the hearings, with 48 citizens groups, industry associations, provinces, and individuals submitting written comments. The majority of the presenters were from Canada.

The comments appear to indicate a consensus that the Air Quality Agreement provides a good framework for addressing all transboundary air pollution issues. The public expressed the need, however, to give higher priority to air quality issues due to growing evidence on environmental and human health effects of toxic air pollution.

Many commenting urged both governments to expand the scope of the Agreement to include three new annexes on smog, air toxics, and inhalable PM. They stated that citizens on both sides of the border deserve comparable protection and that the two governments should work cooperatively to establish regionally harmonized, uniformly enforced standards that protect human health. Ground-level ozone was identified as a major transboundary health and environmental problem in southern Ontario and was generally considered to be an issue requiring attention under the Agreement.

In addition, because of concern about government cutbacks, respondents also suggested that new annexes be included in the Agreement to secure expanded monitoring and modeling programs and emissions inventories.

Regarding acidic deposition, many respondents said that more needed to be done to protect sensitive ecosystems.

Others commenting noted that the Agreement lacks a focus on regional or local transboundary air quality issues, particularly in the Detroit-Windsor region, the New Brunswick-Northeastern states region, and the Washington State-British Columbia region. Local citizens groups in the Detroit-Windsor region, for example, emphasized that the Agreement should be used to ensure transboundary cooperative efforts aimed at abating and preventing the flow of transboundary pollutants. There was a suggestion to explore ways by which Canadian jurisdictions have the same recognition as adjoining states under the CAA provisions.

Other respondents suggested that Alaska and the parts of Canada that border Alaska participate in implementing the existing Agreement and in new national or binational arrangements.

Several respondents suggested ways of enhancing the Air Quality Agreement, including the following:

- Stakeholders (i.e., technical specialists, environmental groups, industry, and the general public) should be included on the AQC.
- Regional transboundary air quality committees—with local stakeholders—should be established under the Agreement to ensure better management of local issues.
- A third-party oversight body should be created to monitor the actions of governments under the Agreement, conduct studies, report on progress, and make recommendations on how to improve air quality along the border. A role was suggested similar to one assigned to the IJC by the governments under the Great Lakes Water Quality Agreement.
- Public participation and education are necessary components for effective implementation of the Air Quality Agreement.

Copies of the report on the public hearings held in Canada and the United States, *Synthesis of Comments Received on the Canada/United States Air Quality Agreement*, are available from the IJC.

Conclusion

Overall, Canada and the United States have been successful in fulfilling their obligations as set forth in the Air Quality Agreement. This is particularly the case regarding implementation of the acid rain control programs in each country. The Parties agree, however, that control of transboundary air pollution (outside of scientific cooperation and technical policy information exchange) has not occurred to the *extent necessary to protect the environment more fully.*

Furthermore, the Agreement does not currently focus on other serious transboundary air pollutants, such as ground-level ozone, air toxics, and inhalable particles. The Parties have begun to study regional ozone management, however, and are evaluating what role they might play regarding air toxics.

While the Parties agree on most aspects of this five-year review, they disagree over two main obligations: (1) the prevention of air quality deterioration and visibility protection and (2) certain aspects of assessment and mitigation. Canada and the United States will continue to work at resolving these differences.

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APPENDIX A

United States-Canada Air Quality Committee

Canada

Co-chair:

Tony Clarke
Assistant Deputy Minister
Environmental Protection Service
Environment Canada

Members:

David Egar
Director General
Air Pollution Prevention Directorate
Environment Canada

Phil Merilees
Director General
Research, Atmospheric Environment Service
Environment Canada

Brian Moore
Director
Environment Division
Natural Resources Canada

James Trottier
Deputy Director
U.S. Transboundary Division
Foreign Affairs and International Trade Canada

Larry Lechner
Director
Air and Land Protection Branch
Saskatchewan Environment and Public Safety

Walter Chan
Assistant Director
Science and Technology Branch
Ontario Ministry of Environment and Energy

Conrad Anctil
Direction de la coordination de l'expertise technique
Ministère de l'Environnement et de la Faune, Québec

Derrick Maddocks
Director
Industrial Environmental Engineering Division
Newfoundland Department of Environment and Lands

United States

Co-chair:

Rafe Pomerance
Deputy Assistant Secretary for
the Environment and Development
Department of State

Members:

Abraham Haspel
Deputy Assistant Secretary for
Economic and Environmental Policy
Department of Energy

E. Anthony Wayne
Deputy Assistant Secretary for
European and Canadian Affairs
Department of State

Bruce Hicks, Director
Air Resources Laboratory
NOAA

David Kee, Director
Air and Radiation Division
EPA Region 5

Molly Ross
Staff Assistant
Office of the Assistant Secretary for
Fish, Wildlife, and Parks
Department of Interior

John Seitz, Director
Office of Air Quality Planning and Standards
EPA

Paul Stolpman, Director
Office of Atmospheric Programs
EPA

Subcommittee on Program Monitoring and Reporting

Co-chairs:

Wayne Draper
Associate Director
Transboundary Air Issues Branch
Environment Canada

Brian McLean
Director, Acid Rain Division
Office of Atmospheric Programs
Environmental Protection Agency

Subcommittee on Scientific Cooperation

Co-chairs

Ann McMillan
Chief, Science Assessment
and Policy Integration Branch
Atmospheric Environment Service
Environment Canada

Jim Vickery
Assistant Laboratory Director
Air National Exposure Research Laboratory
Office of Research and Development
Environmental Protection Agency

Terms of Reference

U.S.-Canada Air Quality Committee

1. Review progress made in the implementation of the Agreement, including its general and specific objectives.
2. Prepare and submit to the Parties a progress report within a year after entry into force of the Agreement and at least every two years thereafter.
3. Refer each progress report to the International Joint Commission for action in accordance with Article IX of the Agreement.
4. Release each progress report to the public after its submission to the Parties.
5. Establish reporting subcommittees as required to fulfill the above responsibilities.
6. Meet at least once a year and additionally at the request of the Parties.
7. Not release, without the consent of the owner, any information identified to it as proprietary information under the laws of the place where such information has been acquired.

Subcommittee on Program Monitoring and Reporting

1. Coordinate activities as outlined in paragraph 2 of Annex 2 to the Agreement for the purpose of determining and reporting on air emission levels, historical trends, and projections.
2. Cooperate and exchange information on development and demonstration of technologies and measures for controlling emissions of air pollutants, in particular, acidic deposition precursors, subject to respective laws, regulations, and policies, as set forth in subparagraph 3(d) of Annex 2 to the Agreement.
3. Cooperate and exchange information on their analysis of market-based mechanisms, including emission trading, as set forth in paragraph 3(e) of Annex 2 to the Agreement.
4. Cooperate and exchange information with respect to economic research that the Parties may agree upon for purposes of supporting the general and specific objectives of the Agreement, as set forth in paragraph 3(f) of Annex 2 to the Agreement.
5. Develop and revise, as necessary, recommendations to the Air Quality Committee on operational guidelines for implementation of Article V(2), and cooperate and exchange information regarding implementation of sections 3 and 4 of Annex 1 to the Agreement.
6. Assist the Air Quality Committee in reviewing progress made in the implementation of the Agreement, including its general and specific objectives, as required under Article VIII of the Agreement, with respect to areas within its purview.

7. Prepare necessary input on issue areas within its purview for the reports of the Air Quality Committee required under Article VIII of the Agreement.
8. Support the Air Quality Committee in its preparation of the report required under Article VIII.
9. Establish ad hoc bilateral working groups as may be required to fulfill the above responsibilities.

Subcommittee on Scientific Cooperation

1. Coordinate air pollutant monitoring activities as set forth in paragraph 1 of Annex 2 to the Agreement for the purpose of determining and reporting on air pollutant concentrations and deposition.
2. Cooperate and exchange information on their monitoring of the effects of changes in air pollutant concentration and deposition, with respect to changes in various effects categories, e.g., aquatic ecosystems, visibility, and forests, as set forth in subparagraph 3(a) of Annex 2 to the Agreement.
3. Cooperate and exchange information on their determination of any effects of atmospheric pollution on human health and ecosystems, as set forth in subparagraph 3(b) of Annex 2 to the Agreement.
4. Cooperate and exchange information on the development and refinement of atmospheric models for purposes of determining source receptor relationships and transboundary transport and the position of air pollutants, as set forth in subparagraph 3(c) of Annex 2 to the Agreement.
5. Cooperate on approaches to, and share information and results of research on, methods to mitigate the impacts of acidic deposition, including the environmental effects and economic aspects of such methods, as set forth in paragraph 4 of Annex 2 to the Agreement.
6. Cooperate and exchange information with respect to any other scientific or technical activities that the Parties ask it to undertake to support the general and specific objectives of the Agreement.
7. Prepare the necessary scientific input for the reports of the Air Quality Committee as required under Article VIII of the Agreement.
8. Establish ad hoc bilateral working groups as may be required to fulfill the above responsibilities.

APPENDIX B

Agreement Between the Government of the United States of America and the Government of Canada on Air Quality

The Government of Canada and the Government of the United States of America, hereinafter referred to as "the Parties",

Convinced that transboundary air pollution can cause significant harm to natural resources of vital environmental, cultural and economic importance, and to human health in both countries;

Desiring that emissions of air pollutants from sources within their countries not result in significant transboundary air pollution;

Convinced that transboundary air pollution can effectively be reduced through cooperative or coordinated action providing for controlling emissions of air pollutants in both countries;

Recalling the efforts they have made to control air pollution and the improved air quality that has resulted from such efforts in both countries;

Intending to address air-related issues of a global nature, such as climate change and stratospheric ozone depletion, in other fora;

Reaffirming Principle 21 of the Stockholm Declaration, which provides that "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction";

Noting their tradition of environmental cooperation as reflected in the Boundary Waters Treaty of 1909, the Trail Smelter Arbitration of 1941, the Great Lakes Water Quality Agreement of 1978, as amended, the Memorandum of Intent Concerning Transboundary Air Pollution of 1980, the 1986 Joint Report of the Special Envoys on Acid Rain, as well as the ECE Convention on Long-Range Transboundary Air Pollution of 1979;

Convinced that a healthy environment is essential to assure the well-being of present and future generations in Canada and the United States, as well as of the global community;

Have agreed as follows:

Article I
Definitions

For the purposes of this Agreement:

1. "Air pollution" means the introduction by man, directly or indirectly, of substances into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment, and "air pollutants" shall be construed accordingly;
2. "Transboundary air pollution" means air pollution whose physical origin is situated wholly or in part with the area under the jurisdiction of one Party and which has adverse effects, other than effects of a global mature, in the area under the jurisdiction of the other Party;
3. "Boundary Waters Treaty" means the Treaty Relating to Boundary Waters and Questions Arising along the Boundary between Canada and the United States, signed at Washington on January 11, 1909;
4. "International Joint Commission" means the International Joint Commission established by the Boundary Waters Treaty.

Article II

Purpose

The purpose of the Parties is to establish, by this Agreement, a practical and effective instrument to address shared concerns regarding transboundary air pollution.

Article III

General Air Quality Objective

1. The general objective of the Parties is to control transboundary air pollution between the two countries.
2. To this end, the Parties shall:
   (a) in accordance with Article IV, establish specific objectives for emissions limitations or reductions of air pollutants and adopt the necessary programs and other measures to implement such specific objectives;
   (b) in accordance with Article V, undertake environmental impact assessment, prior notification, and, as appropriate, mitigation measures;
   (c) carry out coordinated or cooperative scientific and technical activities, and economic research, in accordance with Article VI, and exchange information, in accordance with Article VII;
   (d) establish institutional arrangements, in accordance with Articles VIII and IX; and
   (e) review and assess progress, consult, address issues of concern, and settle disputes, in accordance with Articles X, XI, XII and XIII.

Article IV

Specific Air Quality Objectives

1. Each Party shall establish specific objectives, which it undertakes to achieve, for emissions limitations or reductions of such air pollutants as the Parties agree to address. Such specific objectives will be set forth in annexes to this Agreement.
2. Each Party's specific objectives for emissions limitations or reductions of sulphur dioxide and nitrogen oxides, which will reduce transboundary flows of these acidic deposition precursors, are set forth in Annex 1. Specific objectives for such other air pollutants as the Parties agree to address should take into account, as appropriate, the activities undertaken pursuant to Article VI.
3. Each Party shall adopt the programs and other measures necessary to implement its specific objectives set forth in any annexes.
4. If either Party has concerns about the programs or other measures of the other Party referred to in paragraph 3, it may request consultations in accordance with Article XI.

Article V

Assessment, Notification, and Mitigation

1. Each Party shall, as appropriate and as required by its laws, regulations and policies, assess those proposed actions, activities and projects within the area under its jurisdiction that, if carried out, would be likely to cause significant transboundary air pollution, including consideration of appropriate mitigation measures.
2. Each Party shall notify the other Party concerning a proposed action, activity or project subject to assessment under paragraph 1 as early as practicable in advance of a decision concerning such action, activity or project and shall consult with the other Party at its request in accordance with Article XI.
3. In addition, each Party shall, at the request of the other Party, consult in accordance with Article XI concerning any continuing actions, activities or projects that may be causing significant transboundary air pollution, as well as concerning changes to its laws, regulation or policies that, if carried out, would be likely to affect significantly transboundary air pollution.
4. Consultations pursuant to paragraphs 2 and 3 concerning actions, activities or projects that would be likely to cause or may be causing significant transboundary air pollution shall include consideration of appropriate mitigation measures.

5. Each Party shall, as appropriate, take measures to avoid or mitigate the potential risk posed by actions, activities or projects that would be likely to cause or may be causing significant transboundary air pollution.

6. If either Party becomes aware of an air pollution problem that is of joint concern and requires an immediate response, it shall notify and consult the other Party forthwith.

Article VI

Scientific and Technical Activities and Economic Research

1. The Parties shall carry out scientific and technical activities, and economic research, as set forth in Annex 2, in order to improve their understanding of transboundary air pollution concerns and to increase their capability to control such pollution.

2. In implementing this Article, the Parties may seek the advice of the International Joint Commission regarding the conduct of monitoring activities.

Article VII

Exchange of Information

1. The Parties agree to exchange, on a regular basis and through the Air Quality Committee established under Article VIII, information on:

   (a) monitoring;

   (b) emissions;

   (c) technologies, measures and mechanisms for controlling emissions;

   (d) atmospheric processes; and

   (e) effects of air pollutants,

   as provided in Annex 2.

2. Notwithstanding any other provisions of this Agreement, the Air Quality Committee and the International Joint Commission shall not release, without the consent of the owner, any information identified to them as proprietary information under the laws of the place where such information has been acquired.

Article VIII

The Air Quality Committee

1. The Parties agree to establish and maintain a bilateral Air Quality Committee to assist in the implementation of this Agreement. The Committee shall be composed of an equal number of members representing each Party. It may be supported by subcommittees, as appropriate.

2. The Committee's responsibilities shall include:

   (a) reviewing progress made in the implementation of this Agreement, including its general and specific objectives;

   (b) preparing and submitting to the Parties a progress report within a year after entry into force of this Agreement and at least every two years thereafter;

   (c) referring each progress report to the International joint Commission for action in accordance with Article IX of this Agreement; and

   (d) releasing each progress report to the public after its submission to the Parties.

3. The Committee shall meet at least once a year and additionally at the request of either Party.

Article IX

Responsibilities of the International Joint Commission

1. The International Joint Commission is hereby given, by a Reference pursuant to Article IX of the Boundary Waters Treaty, the following responsibilities for the sole purpose of assisting the Parties in the implementation of this Agreement:

   (a) to invite comments, including through public hearings as appropriate, on each progress report prepared by the Air Quality Committee pursuant to Article VIII;

(b) to submit to the Parties a synthesis of the views presented pursuant to sub-paragraph (a), as well as the record of such views if either Party so requests; and

(c) to release the synthesis of views to the public after its submission to the Parties.

2. In addition, the Parties shall consider such other joint references to the International Joint Commission as may be appropriate for the effective implementation of this Agreement.

Article X
Review and Assessment

1. Following the receipt of each progress report submitted to them by the Air Quality Committee in accordance with Article VIII and the views presented to the International Joint Commission on that report in accordance with Article IX, the Parties shall consult on the contents of the progress report, including any recommendations therein.

2. The Parties shall conduct a comprehensive review and assessment of this Agreement, and its implementation, during the fifth year after its entry into force and every five years thereafter, unless otherwise agreed.

3. Following the consultations referred to in paragraph 1, as well as the review and assessment referred to in paragraph 2, the Parties shall consider such action as may be appropriate, including:

(a) the modification of this Agreement;

(b) the modification of existing policies, programs or measures.

Article XI
Consultations

The Parties shall consult, at the request of either Party, on any matter within the scope of this Agreement. Such consultations shall commence as soon as practicable, but in any event not later than thirty days from the date of receipt of the request for consultations, unless otherwise agreed by the Parties.

Article XII
Referrals

With respect to cases other than those subject to Article XIII, if, after consultations in accordance with Article XI, an issue remains concerning a proposed or continuing action, activity, or project that is causing or would be likely to cause significant transboundary air pollution, the Parties shall refer the matter to an appropriate third party in accordance with agreed terms of reference.

Article XIII
Settlement of Disputes

1. If, after consultations in accordance with Article XI, a dispute remains between the Parties over the interpretation or the implementation of this Agreement, they shall seek to resolve such dispute by negotiations between them. Such negotiations shall commence as soon as practicable, but in any event not later than ninety days from the date of receipt of the request for negotiation, unless otherwise agreed by the Parties.

2. If a dispute is not resolved through negotiation, the Parties shall consider whether to submit that dispute to the International Joint Commission in accordance with either Article IX or Article X of the Boundary Waters Treaty. If, after such consideration, the Parties do not elect either of these options, they shall, at the request of either Party, submit the dispute to another agreed form of dispute resolution.

Article XIV
Implementation

1. The obligations undertaken under this Agreement shall be subject to the availability of appropriated funds in accordance with the respective constitutional procedures of the Parties.

2. The Parties shall seek:

(a) the appropriation of funds required to implement this Agreement;

(b) the enactment of any additional legislation that may be necessary to implement this Agreement;

(c) the cooperation of Provincial and State Governments as necessary to implement this Agreement.

3. In implementing this Agreement, the Parties shall, as appropriate, consult with Provincial or State Governments, interested organizations, and the public.

Article XV

Existing Rights and Obligations

Nothing in this Agreement shall be deemed to diminish the rights and obligations of the Parties in other international agreements between them, including those contained in the Boundary Waters Treaty and the Great Lakes Water Quality Agreement of 1978, as amended.

Article XVI

Entry into Force, Amendment, Termination

1. This Agreement, including Annexes 1 and 2, shall enter into force upon signature by the Parties.
2. This Agreement may be amended at any time by agreement of the Parties in writing.
3. Either Party may terminate this Agreement upon one year's written notice to the other Party, in which case any annexes will also terminate.
4. Annexes constitute an integral part of this Agreement, except that, if an annex so provides, either Party may terminate such annex in accordance with the terms of that annex.

Annex 1

Specific Objectives Concerning Sulphur Dioxide and Nitrogen Oxides

1. Sulphur Dioxide

   A. For the United States:[1]

      1. Reduction of annual sulphur dioxide emissions by approximately 10 million tons[2] from 1980 levels in accordance with Title IV of the Clean Air Act[3] i.e., reduction of annual sulphur dioxide emissions to approximately 10 million tons below 1980 levels by 2000 (with the exception of sources repowering with qualifying clean coal technology in accordance with section 409 of the Clean Air Act, and sources receiving bonus allowances in accordance with section 405(a)(2) and (3) of the Clean Air Act.).
      2. Achievement of a permanent national emission cap of 8.95 million tons of sulphur dioxide per year for electric utilities by 2010, to the extent required by Title IV of the Clean Air Act.
      3. Promulgation of new or revised standards or such other action under the Clean Air Act as the Administrator of the U.S. Environmental Protection Agency (EPA) deems appropriate, to the extent required by section 406 of the Clean Air Act Amendments of 1990 (P.L. 101-549), aimed at limiting sulphur dioxide emissions from industrial sources in the event that the Administrator of EPA determines that annual sulphur dioxide emissions from industrial sources may reasonably be expected to exceed 5.6 million tons.

[1]Applies only to reductions in emissions in the forty-eight contiguous States and the District of Columbia.

[2]1 ton = 0.91 tonnes (metric tons).

[3]All references to the Clean Air Act refer to the Act as amended November 15, 1990.

B. For Canada:

1. Reduction of sulphur dioxide emissions in the seven easternmost Provinces to 2.3 million tonnes per year by 1994 and the achievement of a cap on sulphur dioxide emissions in the seven easternmost Provinces at 2.3 million tonnes per year from 1995 through December 31, 1999.

2. Achievement of a permanent national emissions cap of 3.2 million tonnes per year by 2000.

2. Nitrogen Oxides

A. For the United States.[4]

With a view to a reduction of total annual emissions of nitrogen oxides by approximately 2 million tons from 1980 emission levels by 2000:

1. Stationary Sources

Implementation of the following nitrogen oxides control program for electric utility boilers to the extent required by Title IV of the Clean Air Act:

(a) By January 1, 1995, tangentially fired boilers must meet an allowable emission rate of 0.45 lb/mmBtu and dry bottom wall-fired boilers must meet an allowable emission rate of 0.50 lb/mmBtu (unless the Administrator of EPA determines that these rates cannot be achieved using NOx burner technology).

(b) By January 1, 1997, EPA must set allowable emission limitations for:

—wet bottom wall-fired boilers;

—cyclones;

—units applying cell burner technology; and

—all other types of utility boilers.

2. Mobile Sources

Implementation of the following mobile source nitrogen oxides control program to the extent required by Title II of the Clean Air Act:

(a) Light Duty Trucks (LDT) (up to 6000 lbs gross vehicle weight rating (GVWR)) and Light Duty Vehicle (LDV) — standards for model years after 1993:

	5 yrs/50,000 miles (useful life)	10 yrs/100,000 miles
LDTs (0 to 3750 lbs Loaded Vehicle Weight (LVW)) and LDVs	0.4 grams per mile (gpm)	0.6 gpm
Diesel LDTs (0 to 3750 lbs LVW) and LDVs (before 2004)	1.0 gpm	1.25 gpm
LDTs (3751 to 5750 lbs LVW)	0.7 gpm[5]	0.97 gpm

In model year 1994, 40% of each manufacturer's sales volume must meet the above standards. In 1995, the percentage shall increase to 80% and, after 1995, to 100%.

(b) Light Duty Trucks more than 6000 lbs GVWR (after model year 1995):

	Gasoline 5 yrs/50,000 miles	Gasoline and Diesel 11 yrs/120,000 miles
LDTs (3751 to 5750 lbs Test Weight (TW))	0.7 gpm	0.98 gpm
LDTs (over 5750 lbs TW)	1.1 gpm	1.53 gpm

In model year 1996, 50% of each manufacturer's sales volume must meet the above standards. Thereafter, 100% of each manufacturer's sales volume must meet the standard.

[4]Applies only to reductions in emissions in the forty-eight contiguous States and the District of Columbia.

[5]This standard does not apply to diesel-fuelled LDTs (3751 to 5750 lbs LVW).

(c) Heavy Duty Trucks (HDT) of more than 8500 lbs GVWR (after model year 1990):

	Gasoline & Diesel Engines
HDT (Effective model year 1991[6])	5.0 grams per brake horsepower-hour[6] (gbhp-hr)
HDT (model year 1998 and later)	4.0 gbhp-hr

Useful life[6]:

Gasoline Engine	8 yrs/110,000 miles
Diesel Engines	
Light heavy-duty:	8 yrs/110,000 miles
Medium heavy-duty:	8 yrs/185,000 miles
Heavy heavy-duty:	8 yrs/290,000 miles

B. For Canada:

1. Stationary Sources

(a) As an interim requirement, reduction, by 2000, of annual national emissions of nitrogen oxides from stationary sources by 100,000 tonnes below the year 2000 forecast level of 970,000 tonnes.

(b) By January 1, 1995, development of further annual national emission reduction requirements from stationary sources to be achieved by 2000 and/or 2005.

2. Mobile Sources

(a) Implementation of a more stringent mobile source nitrogen oxides control program for gasoline powered vehicles with standards no less stringent than the following:

Light Duty Vehicles (up to 6000 lbs GVWR) (By Model year 1996 for passenger cars) (By model year 1996 for light duty trucks[7]):

	5 yrs/80,000 kilometers (useful life)
Cars and Light Duty Trucks (0 to 3750 lbs LVW)	0.4 gpm
Light Duty Trucks (3751 to 5750 lbs LVW)	0.7 gpm

Medium Duty Vehicles (6001 to 8500 lbs GVWR) (By model year 1997[7]):

	5 yrs/80,000 kilometers (useful life)
0 to 3750 lbs LVW	0.4 gpm
3751 to 5750 lbs LVW	0.7 gpm
Over 5750 lbs LVW	1.1 gpm

Heavy Duty Vehicles (over 8500 lbs GVWR) (By model year 1998[7]):

	8 years/110,000 miles (useful life)
Over 8500 lbs GVWR	4.0 gbhp-hr

(b) Implementation of a more stringent mobile source nitrogen oxides control program for diesel powered vehicles and engines with standards, to the extent possible, no less stringent that the standards for the respective duty classes of gasoline powered vehicles and engines.

[6]As set forth in EPA regulations in effect as of the entry into force of this Agreement.

[7]The government of Canada will propose this effective date; the final effective date is subject to the procedures and outcome of the regulation development process.

3. Compliance Monitoring

   A. Utility Units

      1. For the United States:

         Requirement that, by January 1, 1995, each new electric utility unit and each electric utility unit greater than 25 MWe existing on the date of enactment of the Clean Air Act Amendments of 1990 (November 15, 1990) emitting sulphur dioxide or nitrogen oxides install and operate continuous emission monitoring systems or alternative systems approved by the Administrator of EPA, to the extent required by section 412 of the Clean Air Act.

      2. For Canada:

         Requirement that, by January 1, 1995, Canada estimate sulphur dioxide and nitrogen oxides emissions from each new electric utility unit and each existing electric utility unit greater than 25 MWe using a method of comparable effectiveness to continuous emission monitoring, as well as investigate the feasibility of using and implement, where appropriate, continuous emission monitoring systems.

      3. For Both Parties:

         The Parties shall consult, as appropriate, concerning the implementation of the above.

   B. Other Major Stationary Sources

      Requirement that the Parties work towards utilizing comparably effective methods of emission estimation for sulphur dioxide and nitrogen oxides emissions from all major industrial boilers and process sources, including smelters.

4. Prevention of Air Quality Deterioration and Visibility Protection

   Recognizing the importance of preventing significant air quality deterioration and protecting visibility, particularly for international parks, national, state, and provincial parks, and designated wilderness areas:

   A. For the United States:

      Requirement that the United States maintain means for preventing significant air quality deterioration and protecting visibility, to the extent required by Part C of Title I of the Clean Air Act, with respect to sources that could cause significant transboundary air pollution.

   B. For Canada:

      Requirement that Canada, by January 1, 1995, develop and implement means affording levels of prevention of significant air quality deterioration and protection of visibility comparable to those in paragraph A above, with respect to sources that could cause significant transboundary air pollution.

   C. For Both Parties:

      The Parties shall consult, as appropriate, concerning the implementation of the above.

Annex 2

Scientific and Technical Activities and Economic Research

1. For the purpose of determining and reporting on air pollutant concentrations and deposition, the Parties agree to coordinate their air pollutant monitoring activities through:

   (a) coordination of existing networks;

   (b) additions to monitoring tasks of existing networks of those air pollutants that the Parties agree should be monitored for the purposes of this Agreement;

   (c) addition of stations or networks where no existing monitoring facility can perform a necessary function for purposes of this Agreement;

   (d) the use of compatible data management procedures, formats, and methods; and

   (e) the exchange of monitoring data.

2. For the purpose of determining and reporting air emissions levels, historical trends, and projections with respect to the achievement of the general and specific objectives set forth in this Agreement, the Parties agree to coordinate their activities through:

   (a) identification of such air emissions information that the Parties agree should be exchanged for the purposes of this Agreement;

   (b) the use of measurement and estimation procedures of comparable effectiveness;

   (c) the use of compatible data management procedures, formats, and methods; and

   (d) the exchange of air emission information.

3. The Parties agree to cooperate and exchange information with respect to:

   (a) their monitoring of the effects of changes in air pollutant concentrations and deposition with respect to changes in various effects categories, e.g. aquatic ecosystems, visibility, and forests;

   (b) their determination of any effects of atmospheric pollution on human health and ecosystems, e.g. research on health effects of acid aerosols, research on the long-term effects of low concentrations of air pollutants on ecosystems, possibly in a critical loads framework;

   (c) their development and refinement of atmospheric models for purposes of determining source receptor relationships and transboundary transport and deposition of air pollutants;

   (d) their development and demonstration of technologies and measures for controlling emissions of air pollutants, in particular acidic deposition precursors, subject to their respective laws, regulations and policies;

   (e) their analysis of market-based mechanisms, including emissions trading; and

   (f) any other scientific and technical activities or economic research that the Parties may agree upon for purposes of supporting the general and specific objectives of this Agreement.

4. The Parties further agree to consult on approaches to, and share information and results of research on, methods to mitigate the impacts of acidic deposition, including the environmental effects and economic aspects of such methods.

For More Information

If you are interested in obtaining information on the scientific and technical issues of acid deposition, contact:

In the United States

National Acid Precipitation
Assesment Program
722 Jackson Place, NW
Washington, DC 20503

In Canada

Environment Canada
Science Assessment and Policy Integration Branch
4905 Dufferin Street
Downsview, Ontario M3H 5T4

If you are interested in obtaining information on the acid deposition control program, contact:

In the United States

Acid Rain Division
U.S. Environmental Protection Agency
Mail Code 6204J
401 M Street, SW
Washington, DC 20460

In Canada

Acid Rain Program
Transboundary Air Issues Branch
Environment Canada
351 St. Joseph Boulevard
Place Vincent Massey - 11th Floor
Hull, Québec K1A 0H3

International Joint Commission
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Your Comments on this Report Would Be Appreciated

The International Joint Commission invites your comments on the Progress Report of the Air Quality Committee under the Canada-United States Air Quality Agreement. The Agreement assigns the Commission, an independent organization, responsibility for inviting public comment on the report and preparing a synthesis of the comments received for the Governments of the United States and Canada and for public release.

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Name: _____

Organization (if applicable): _____

Address: _____

City: _____ State/Prov: _____ Postal/Zip Code: _____

Comments:

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