

United States – Canada Air Quality Agreement



PROGRESS REPORT

1994



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A Report By The Air Quality Committee

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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Executive Summary

The Canada-United States Air Quality Agreement, now three years old, has successfully drawn together work in Canada and the United States on air quality issues.

This second Progress Report builds on the 1992 Canada-U.S. Progress Report. It reviews acid rain control programs, monitoring, and other scientific activities currently being undertaken by each country individually and together. The report also covers issues not specifically addressed in the original agreement, including ground-level ozone (smog).

Programs to Reduce Acid Rain Emissions

Acid rain, the principal bilateral air quality issue, is the primary focus of work under the Air Quality Agreement. Both countries have made substantial progress in implementing their respective acid rain control programs. In accordance with Annex 1 of the Air Quality Agreement, both countries undertook to reduce emissions of sulphur dioxide (SO₂) and to implement caps on those emissions.

Canada's SO₂ reduction program is well established, with reductions ahead of schedule. Canada has achieved about a 40 percent decrease in SO₂ emissions in the seven eastern provinces from 1980 emission levels, a reduction from 3,800 kilotonnes in 1980 to 2,316 kilotonnes in 1992, substantially meeting its emissions target for eastern Canada two years ahead of schedule. All major sources targeted by the program have or will soon complete technological improvements or programs to reduce SO₂ emissions and to ensure that the 2,300 kilotonne cap will be respected for the 1994-2000 period. Canada is also committed to permanently capping its national SO₂ emissions at 3,200 kilotonnes, beginning in the year 2000. Canada is currently meeting this cap, with estimated national emissions for 1993 reported at 3,040 kilotonnes.

In the United States, Title IV of the 1990 Clean Air Act (CAA) Amendments established a national Acid Rain Program with a primary goal of reducing annual SO₂ emissions by 10 million tons below 1980 levels — a 40 percent decrease in national emissions. Emission reductions begin in 1995, and most reductions will occur by the year 2000. When the Acid Rain Program is fully implemented, a nationwide cap

of 8.95 million tons on utility SO₂ emissions will be maintained. Nonutility industrial sources of SO₂ will also be subject to a national emissions cap of 5.6 million tons.

Since the last Progress Report, the U.S. government and industry have undertaken a major effort to implement the Acid Rain Program. For example, the United States has issued all of its major regulations. The utility industry has installed continuous emission monitors, submitted permit applications and the first electronic reports on emissions, increased use of flue gas desulphurization units, contracted to switch fuel supplies, participated in the SO₂ allowance trading market, and implemented a variety of energy efficiency and conservation programs. During the past two years, over 1 million SO₂ allowances have either been sold at U.S. government auctions or exchanged in private transactions. Overall, the U.S. Acid Rain Program is clearly on track to achieve the goals set forth in the CAA Amendments in a timely way.

Both countries committed to reductions of nitrogen oxides (NO_x) in Annex 1 of the Agreement. In both cases, the reduction goals amount to about 10 percent of national emissions for both countries: 100,000 tonnes in Canada and 2 million tons in the United States. While the NO_x reduction programs in both countries are currently driven more by a concern about ground-level ozone (smog) than acid rain, both countries share a concern about the role of nitrogen compounds in acidification processes. NO_x reduction programs are being implemented in both countries for both stationary and mobile sources, including electric utility plants and passenger cars.

Programs to Address New Air Issues

In 1993, Canada created a National Air Issues Steering Committee made up of federal and provincial/territorial deputy ministers responsible for the environment and energy. The Committee, which has been meeting regularly since its inception, facilitates consultation with industry and nongovernmental organizations on air issues, including acid rain, smog, stratospheric ozone, climate change, and particulate matter/visibility.

In the United States, a new National Science and Technology Council (NSTC) was created in 1994. The Council has a Committee on the Environment and Natural Resources and Subcommittee on Air Quality. The Subcommittee on Air Quality's role is to integrate federal research programs and priorities related to various air quality issues, including acid rain, tropospheric ozone, particulate matter/visibility, and indoor air. The NSTC held its first public forum in March 1994. The forum included industry, the academic community, and other interested parties.

Article V Notification

Canada and the United States have also made headway in other activities that concern notification procedures on transboundary air pollution under Article V of the Air Quality Agreement. The two countries formed a work group and held discussions to address assessment, notification, and mitigation of proposed actions, activities or projects that, if carried out, would be likely to cause significant transboundary air pollution. Based on the discussions, the Air Quality Committee decided that each country would implement its own notification procedures consistent with the intent of Article V. Both countries are also considering the development of an electronic bulletin board on notification that would be accessible to the public.

Scientific and Technical Cooperation

Since the last Progress Report, the two governments have made new inroads in scientific and technical cooperation on topics such as atmospheric modelling, deposition monitoring, emissions inventories, effects research and monitoring, control technologies, and market-based incentives.

Key atmospheric modelling and deposition monitoring findings and developments include:

- The highest levels of wet sulphate deposition for 1988 through 1991 occurred in Ohio, Pennsylvania, and West Virginia, while, in Canada, the southern parts of Ontario and Quebec received more than the Canadian target load of 20 kilograms (kg) per hectare per year. The 20 kg target

load is expected to be reached with full implementation of the Canadian and U.S. acid rain control programs.

- A joint study to evaluate the Acid Deposition and Oxidants Model and the Regional Acid Deposition Model was completed. The study showed that the models could reasonably estimate current and future rates of sulphur and nitrogen deposition. Canadian and U.S. deposition monitoring networks were improved by taking into account information from the models. In addition, nitrogen deposition was added to published quantitative estimates of the relative contributions of Canadian and U.S. source regions to receptor deposition.

Significant findings on aquatic ecosystem trends include:

- Trends observed in the chemical records of lakes and streams in areas that receive high sulphate deposition demonstrate the complexity of the response to SO₂ controls. For example, over the past decade, about one third of monitored lakes in Canada showed evidence of recovery while about half that many continued to acidify. Surveys and other experiments provide some evidence of chemical and biological improvements at locations where deposition has noticeably decreased, but only high-quality, long-term monitoring records will reliably quantify regional responses to SO₂ control.
- Lake monitoring in both Canada and the United States shows that as acidification decreases and lake pH increases, biological populations recover, or can be re-established, relatively rapidly (in less than a decade).
- Studies on the effects of episodic acidification during snowmelt and rainstorms in Adirondack and Appalachian plateau streams in the United States clearly demonstrate that episodic acidification can have serious long-term adverse effects on fish populations even in streams with suitable chemistry during low-flow conditions.
- Lake survey data shows increasing nitrate concentrations in a number of lakes and streams in the Adirondack and Catskill Mountains of New York, the Mid-Appalachian region, Ontario, and Quebec. These locations also receive some of the highest

levels of nitrogen deposition in North America. Maintenance of existing levels or increases of nitrogen deposition over the long term may eventually undermine the ecological benefits derived from SO₂ control programs.

Forest effects studies show that there is no large scale decline in the health of North American forests. For example, the Canada-U.S. North American Maple Project showed that over 90 percent of trees sampled were healthy and mortality rates were normal. However, there are several areas of concern. Over large areas of Ontario and Quebec, sugar maples with no visible symptoms of decline have experienced reduced growth rates over the past 30 years. Forest research has also shown adverse effects from acidic deposition in local instances on certain species of trees. For example, acidic cloud water in high-elevation portions of the eastern United States caused enough winter damage to red spruce foliage to reduce growth rates and cause increased mortality to trees. Similarly, in southeastern New Brunswick, acid fog was found to have caused serious deterioration and death of white birch.

In the area of visibility, a technique has been developed in Canada to extract additional information from historical visibility data. This technique will be used to develop maps describing visibility across Canada by season and by year. These maps will serve as the baseline against which future visibility changes will be determined. Efforts are currently under way to merge the visibility data sets from both Canada and the United States. In other visibility developments, new transport and transformation models were used to predict future changes in visibility. With full implementation of control programs in Canada and the United States, a noticeable improvement in visibility should occur across the eastern United States and eastern Canada.

Reports on materials effects research show clearly that pollutants, especially SO₂, accelerate the degradation of building materials exposed to the atmosphere. There is no evidence of any critical level of pollutant below which corrosion damage does not occur.

In health effects research, a five-year study of more than 10,000 children in 24 North American cities indicates a strong statistical association between decreased lung function

and long-term exposure to ambient acidic aerosols. Significant differences in acute bronchitis between high- and low-acid communities was also evident in this study. Human clinical studies have also suggested that asthmatics might be more sensitive to short-term high-acid aerosol exposures.

Joint activities carried out to ensure that the data collected under both countries' programs are comparable and have credibility. Activities have been expanded to include all three major wet deposition monitoring networks — the National Dry Deposition Network (NDDN), the Canadian Air and Precipitation Monitoring Network (CAPMoN), and the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN).

Several activities are also under way in both countries to develop, demonstrate, and deploy energy technologies to reduce emissions of both SO₂ and NO_x. Among the clean coal technologies being explored by Canada, is the Integrated Coal Gasification Combined Cycle. In the United States, 45 projects are under way in the Clean Coal Technology Program representing a total investment of almost \$7 billion.

Both countries remain interested in the use of market-based mechanisms to achieve air pollution reduction at lower cost to society. The U.S. allowance trading system under the Acid Rain Program is estimated to significantly reduce the costs of compliance by industry in the range of 25 to 50 percent.

In sum, both countries have made significant progress in implementing their respective acid rain control programs. The two countries are also engaged in a host of technical and scientific activities, including technology demonstrations and deployments, the development of emission inventories, atmospheric modelling, depositions and effects monitoring, and effects research. All of these activities are an integral part of air quality management. Both countries are undertaking an analysis of ongoing problems to assess the need for further actions to address air quality problems. In addition, the two countries have established new mechanisms to address air quality research and programs in a more comprehensive and coordinated manner. These activities include examinations of the need for revisions to current air quality standards (e.g., ground-level ozone) and regional loadings programs (e.g., acid rain).

Introduction

HISTORY OF THE AGREEMENT

In 1991, the signing of the Canada-United States Air Quality Agreement signalled the beginning of a new era of environmental cooperation between the two countries. A bilateral Air Quality Committee (AQC) was subsequently established to address problems on the issue of transboundary air pollution.

The Canada-United States Air Quality Committee includes two working subcommittees. The Subcommittee on Program Monitoring and Reporting works on such issue areas as assessing progress toward meeting emission reduction targets and establishing specific implementation procedures, emission inventories, and market-based mechanisms. The Subcommittee on Scientific Cooperation promotes information exchange and cooperation in such areas as atmospheric modelling 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 subcommittees and to review progress made.

The AQC published its first Progress Report in March 1992, one year after the Agreement was signed. The report provided a point of reference for the work of the AQC and for future progress reports. It described the steps that led to the Agreement and the basis for the acid rain programs in each country. It also described the scientific and technical underpinnings of the programs as well as the state of economic research on the subject of transboundary air pollution.

Under Article IX of the Agreement, the International Joint Commission (IJC) is assigned implementation responsibilities. Specifically, the IJC must:

- Invite comments on each progress report prepared by the Air Quality Committee.
- Submit a synthesis of the views received as well as the record of such views if either country so requests.
- Release the synthesis of views to the public after its submission to both governments.

PUBLIC COMMENT ON THE 1992 PROGRESS REPORT

The IJC sent out letters inviting comment on the 1992 Progress Report. Overall, the general public appeared to be confused about the reporting relationship of the Air Quality Committee. Some people thought that it reports to the IJC. In fact, the AQC reports to the "Parties to the Agreement" (the Parties), represented by the United States Secretary of State and the Canadian Minister for Foreign Affairs and International Trade. The IJC is not a "Party to the Agreement," nor is it represented on the AQC. The IJC serves as a knowledgeable third party, responsible for seeking comments on the progress reports prepared by the Committee and assisting the Parties in the implementation of the Agreement.

Several respondents were strongly supportive of the Air Quality Agreement. Several commented, however, that the report failed to mention delays and obstacles in both countries to achieving the goals established in the Agreement. For example, some respondents believed that target reductions for acid deposition are not stringent enough to protect lakes and soils in eastern Canada, even if the terms of the Agreement are fully implemented.

Respondents strongly supported expanding the scope of issues covered under the Agreement to include other air quality problems, including toxic air emissions and ground-level ozone. Governments were encouraged to develop cooperative arrangements under the Agreement to ensure that these priority issues receive the attention they require.

Since some of the emissions that contribute to acid deposition are related to other environmental concerns, including ground-level ozone and greenhouse gas buildup, respondents believed that programs to address these issues should be integrated. This approach might allow cost-sharing among the programs. It also might produce multiple benefits from the same strategies. Moreover, it was suggested that future reports should attempt to quantify the relative contributions of energy conservation, efficiency, and control to emission reductions.

Many of the comments also addressed specific aspects of the emission reduction, effects, and research monitoring programs. The AQC has assessed each comment. This Progress Report responds to as many comments as possible. Some of them have long-term implications related to the workplan of the AQC. For example, expansion of the scope of issues covered under the Agreement is being actively considered, taking into account the state of scientific understanding of air issues and their transboundary implications, and the maturity and compatibility of individual programs. Readers are invited to submit written comments or proposals to the co-chairs of either the Subcommittee on Program Monitoring and Reporting or the Subcommittee on Scientific Cooperation. A copy of the report, *Synthesis of Views on the March 1992 Progress Report of the Air Quality Committee under the United States-Canada Air Quality Agreement*, is available from the IJC.

AIR QUALITY COMMITTEE: CURRENT ACTIVITIES

Since the first Progress Report, the AQC met in November 1992 in Hull, Quebec, and in December 1993, in Washington, DC.

The AQC requires that the subcommittees report on progress, particularly in meeting the emission reduction requirements as set forth in the Agreement and on the initiation of scientific research of mutually high priority. The status of these issues is addressed in sections II and III of this report.

At the November 1992 meeting of the AQC, the two countries addressed a mandate to develop procedures for implementing Article V under the Air Quality Agreement. Article V addresses assessment, notification, and mitigation of sources that have the potential to cause significant transboundary air pollution.

The Subcommittee on Program Monitoring and Reporting met in October 1992 and in April 1993. The Subcommittee reviewed progress of implementation of respective

acid rain control programs and discussed Article V issues and the development of prevention of significant deterioration and visibility protection programs in Canada.

Discussions on Article V were directed at developing steps for ensuring timely and accurate sharing of information on new sources of emissions and their potential impact on each country. The April meeting also initiated discussions on existing ozone regulations and related activities in Canada and the United States. These are summarized in Section IV of this report, which deals with areas of future cooperation.

The Subcommittee on Scientific Cooperation also met in October 1992 and in April 1993. It reviewed the status of Canadian and U.S. research efforts. Topics included atmospheric monitoring and modelling, effects on aquatic systems, forest ecosystems, visibility, materials, human health, and quality assurance/quality control. These meetings also included presentations on ground-level ozone research in both countries.

At the December 1993 meeting of the Canada-U.S. Air Quality Committee in Washington, DC, agreement was reached about implementing Article V. Each country will implement its own notification procedures and advise the other of its intentions through the AQC (Section II of this report deals with progress under Article V). Other discussions at the meeting centred on Canadian and U.S. progress in implementing their respective acid rain control programs, joint efforts on scientific cooperation and information exchange, cooperation on other air issues (including ground-level ozone, toxics, and particulate matter), the status of the UN Economic Commission on Europe Long-Range Transboundary Air Pollution SO₂ Protocol, as well as future efforts.

Notes: The text of the 1994 Progress Report uses Canadian spelling throughout, e.g., sulphur instead of sulfur. Future Progress Reports will alternate the use of Canadian and American spelling. Dollars are US\$ unless otherwise indicated.

Progress: Specific Programs and Objectives

OVERVIEW

In an effort to reduce the impact of acidic deposition on sensitive lakes, streams, forests, materials, visibility, and human health in Canada and the United States, both countries have set out to meet goals to reduce the levels of sulphur dioxide (SO₂) and nitrogen oxides (NO_x) emissions in their respective countries. The emission reductions outlined in Annex 1 of the Air Quality Agreement (see Table 1) identify obligations that Canada and the United States have undertaken in their efforts to reduce SO₂ and NO_x, the primary precursors of acid rain. (Table 1 summarizes the SO₂ Emission Reduction Goals for the United States and Canada. In this table, and throughout the remainder of this document, Canadian SO₂ and NO_x emissions are expressed as metric tonnes [tonnes]. U.S. SO₂ and NO_x emissions are expressed as short tons [tons]. One short ton is equivalent to 0.9 metric tonne. One metric tonne is equal to 1.1 short tons.) This section discusses each country's implementation progress in meeting the obligations of the Air Quality Agreement.

IMPLEMENTATION OF CONTROL PROGRAMS

Canada

Program Goals

Canada's SO₂ reduction program is well established, with reductions ahead of schedule. Canada has cut SO₂ emissions in the seven easternmost provinces, which are the most acid-sensitive, from 3,800 kilotonnes in 1980 to 2,316 kilotonnes in 1992. This is about a 40 percent decrease and substantially meets the emissions target for eastern Canada two years ahead of schedule. New annual SO₂ limits in three eastern provinces, in addition to technological improvements and SO₂ reduction programs, will ensure that Canada meets the 2,300 kilotonne (2.3 million tonne) level for the 1994-2000 period.

Table 1 Canada-United States
SO₂ Emission Reduction Goals

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

¹One tonne equals 1.1 short tons. ²With the exception of sources repowering with a qualifying clean technology, sources receiving bonus allowances, and sources using allowances earned for early reduction efforts earned prior to the year 2000.

Canada is also committed to permanently capping its national SO₂ emissions at 3,200 kilotonnes, beginning in the year 2000. Canada is currently meeting this cap, with estimated national emissions for 1993 reported at 3,040 kilotonnes. Canada is developing a long-term acid rain strategy to ensure that the national cap continues to be met and to ensure that regions within the country are managed according to their environmental sensitivities.

Table 2 illustrates SO₂ reductions achieved by 1992 as well as 1994 emission limits (some of which are still being amended through ongoing federal/provincial negotiations to reflect the 2,300 kilotonne limit).

For NO_x reductions, Canada is committed to a 100,000 tonne reduction in NO_x emissions from stationary sources in the year 2000.

The Canadian Control Program

Canada's control program has focused on reducing emissions at large nonferrous-metal smelters and fossil-fuel-burning power plants. Implementation of the program has taken almost a decade and involved research, development, and demonstration of technologies to control acid gas and other emissions.

In Canada, the implementation of programs to control air pollutant emissions, such as

Table 2 Total SO₂ Emissions by Provinces in Eastern Canada¹ (kilotonnes)

	1980 Actual	1988	1989	1990	1991	1992	1994 Emissions Limit
Manitoba							
Primary Metals	463	550	499	500	543	555	—
Other	21	16	16	16	16	10	—
Total ²	484	566	515	516	559	565	550
Ontario							
Primary Metals	1096	798	776	730	695	506	—
Power Generation	396	321	305	195	167	157	—
Other	272	249	252	241	233	239	—
Total ²	1764	1368	1333	1166	1095	902	885
Quebec							
Primary Metals	641	478	341	189	210	218	—
Other	457	234	205	202	168	182	—
Total ²	1098	712	546	391	378	400	500 ⁵
New Brunswick							
Primary Metals	15	23	23	6	9	12	—
Power Generation	123	158	177	141	130	149	—
Other	80	39	29	34	33	32	—
Total ²	218	210	229	181	172	193	175 ⁵
Nova Scotia							
Power Generation	125	147	146	143	144	143	—
Other	68	36	37	35	33	34	—
Total ²	193	183	183	178	177	177	189 ⁵
Newfoundland							
Power Generation	18	18	25	21	14	18	—
Other	38	27	28	36	48	57	—
Total ^{2,6,7}	56	45	53	57	62	75	45
Prince Edward Island							
Total ^{2,4}	5	3	3	3	4	4	5
Eastern Canada Total							
Primary Metals	2215	1849	1639	1425	1457	1291	—
Power Generation	662	644	653	500	455	467	—
Other	941	617	570	567	535	558	—
Total ²	3818	3110	2862	2492	2447	2316	2349 ³

¹ Data are taken from reports by the provinces on their SO₂ control programs. The emissions levels represent the best estimate available at the time of writing the report. Note that even historic year estimates may be revised as better inventory data is made available.

² Total emissions are more than the sum of Primary Metals and Power Generation, the difference being 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.

⁶ 1992 data are estimates.

⁷ Bilateral agreement only applied to existing sources.

NO_x and SO₂, and to address broader issues, such as regional air quality problems like smog, is a shared responsibility between the federal and provincial governments.

In general, the federal government's role is to deal with transboundary issues or circumstances where federal resources are implicated. The federal government also provides leadership for the development of national emission standards for new emission sources. The provinces have a primary role in overseeing the protection and management of resources within their boundaries, as well as developing and enforcing regulations. Figure 1 shows Canada's compliance strategy for 1980 to 1994.

Coordination among the provinces and the federal government is done through the Canadian Council of Ministers of the Environment (CCME) and the Council of Energy Ministers.

Canada's national power plant emissions guidelines were revised and published in 1993 under the authority of the *Canadian Environmental Protection Act*. These call for stricter control of NO_x at new and existing modified plants and for continuous emissions monitoring for both NO_x and SO₂.

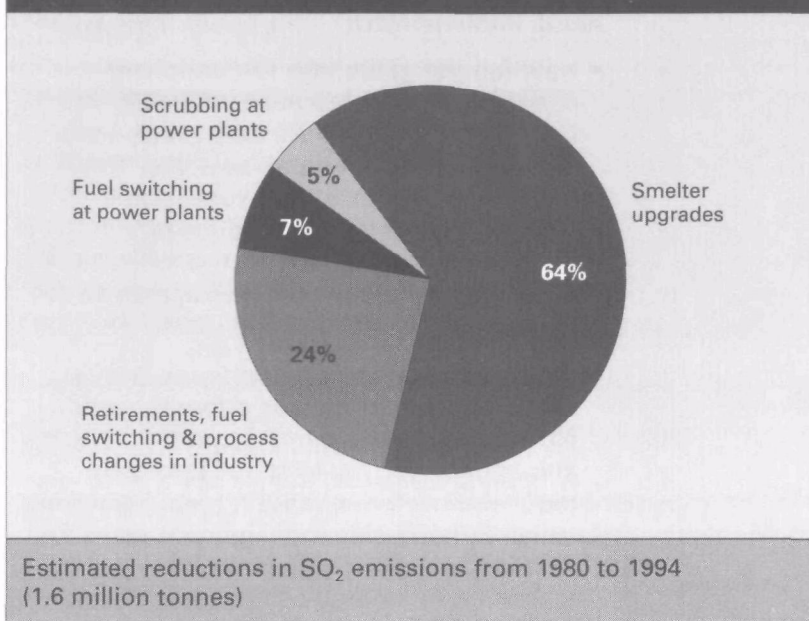
SO₂ Programs

New SO₂ reductions have come largely from the smelting sector (64 percent of all reductions) followed by retiring old plants, fuel substitution, and changes in industrial processes (24 percent).

Highlights of SO₂ programs undertaken in the provinces over the past two years are as follows:

- Canadian electric utilities commissioned three new coal-burning power plants designed to meet national power plant SO₂ emission standards. The first, at Shand in Saskatchewan, is equipped with limestone injection into furnaces and activation of unreacted calcium (LIFAC) SO₂ control system, a North American first, to remove 65 percent of SO₂. The second, at Belledune in New Brunswick, has a conventional 90 percent efficient wet limestone scrubber. The third new power plant, at Point Aconi in Nova Scotia, has the world's largest operating

Figure 1 Canada's SO₂ Compliance Strategies



circulating fluidized-bed unit with limestone injection to capture about 90 percent of SO₂ emissions.

- In the fall of 1993, Inco Ltd. completed a C\$600 million modernization of its Sudbury, Ontario, Copper Cliff complex. This program alone will cut emissions of SO₂ from 865 kilotonnes in 1980 to below 265 kilotonnes in 1994.
- Hudson Bay Mining and Smelting is modernizing its Flin Flon, Manitoba, complex. A new hydrometallurgical pressure leach process will replace the old zinc smelter and a Noranda Continuous Reactor will be used to smelt copper. These programs will ensure that emissions will not exceed the plant's 220 kilotonne limit and will allow for future additional SO₂ capture as a by-product.
- The Noranda Metals Horne smelter at Rouyn-Noranda, Quebec, completed its first round of major SO₂ reductions in late 1989 and is continuing to improve the rate of emissions capture. Its program has cut emissions from 550 kilotonnes in 1980 to below the regulatory limit of 272 kilotonnes.
- Existing power plants in New Brunswick and Ontario, with about 1,300 megawatts of existing capacity, are being equipped with wet limestone scrubbers. The first Ontario scrubber began operation in June 1994.

NOx Reductions

New programs for NOx reduction are being implemented:

- New federal guidelines for stationary combustion turbines were published in December 1992 that are extensively used in new power generation systems. The guidelines are based on overall plant energy efficiency and could result in a 50 to 80 percent reduction in uncontrolled NOx emissions from engines approved for installation after November 1994.
- NOx/volatile organic compounds (VOCs) control initiatives include adopting new NOx emission standards for motor vehicles and appliances; revising building code requirements for enhanced home insulation; using demand-side management plans for power generation; and conducting public education on energy conservation, transportation alternatives, vehicle maintenance, and driving habits.
- The first selective catalytic reduction unit in a Canadian power plant was approved for installation on the gas-fired Burrard power plant in British Columbia.
- Published revised federal guidelines for fossil-fuelled power plants in May 1993 (see Table 3).

Table 3 New Canadian Source Performance Standards for NOx Emissions from New Power Boilers

	Previous (nanograms per joule)	New
Coal	258	170
Oil	127	110
Gas	86	50

British Columbia has already started implementing other reduction programs with the commissioning of inspection and maintenance stations to reduce light-duty vehicle emissions in the Vancouver area. In Ontario, Ontario Hydro published a plan to reduce NOx emissions from power plants by 30 percent by the year 2000. Quebec amended its Air Quality Regulation to include the national prevention elements of the ground-level ozone reduction program. New Brunswick

imposed new national standards on one new power plant and one is undergoing a major modification. It is still too early to quantify the actual reductions based on inventories. A preliminary outlook forecast that includes the effects of the expected emission reductions, however, shows that Canada will meet its commitment to reduce its stationary NOx emissions by 100 kilotonnes by 1999.

Additional initiatives are or will be developed to retrofit existing stationary sources such as power boilers, commercial/industrial boilers, existing turbines, and process heaters in refineries, petrochemical plants, steel foundries, and other industries. New source performance standards are in effect now and implementation is required to be completed in 2000 for these retrofits.

Efforts to reduce NOx emissions in Canada are also aimed at reducing ground-level ozone. NOx emissions from stationary, area, and mobile sources are being inventoried. Control strategies and measures identified by the Canadian Council of Ministers of the Environment NOx/VOC Management Plan are being developed. In addition, VOC emissions, another cause of ground-level ozone, are being addressed. Control initiatives, studies, and scientific knowledge are being developed in an effort to meet Canada's ambient air quality objective of 82 parts per billion (ppb) of ozone by the year 2005.

Progress has been made in programs to monitor industry's compliance in reducing emissions. Compliance monitoring involves measuring or estimating emissions, verifying that the values are accurate, and reporting the results to regulators on a regular basis. In Canada, emissions may be estimated based on process variables such as tonnes of ore processed or sulphur recovered per unit of time, or they can be directly measured on a continuous basis. Continuous emission monitoring (CEM) is the measurement, on a continuous basis, of pollutants emitted into the atmosphere in exhaust gases from combustion processes or as the by-product of industrial processes. The relative cost and site-specific technical factors determine which approach is used.

For Canada's new fossil-fuelled power plants, national guidelines revised in 1993 call for installation of CEM systems and the monitoring of NOx and SO₂. This is to be done in

accordance with *Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation*, also published by Environment Canada in 1993. These CEM specifications draw upon experience gained from development of the U.S. Environmental Protection Agency's (EPA) CEM standards as well as the International Standards Organization standards. The specifications were developed in consultation with the provinces and the electric power industry and are expected to be widely used by these groups as the basis for CEM system installation and operation.

To promote the implementation of CEM at Canadian coal-burning power plants and in other industries, Environment Canada is sponsoring technical seminars that are being well attended by industry and government personnel. Canadian electric utilities and provincial regulators are developing and/or implementing CEM-based compliance monitoring programs at most major coal-burning power plants. For plants that are operated infrequently, alternative methods for reliable emissions estimating are being investigated by government and industry.

In addition to electric power utility plants, alternative emissions monitoring methods are being investigated for other Canadian stationary emissions sources such as metals smelters, natural gas processing plants, combustion turbines and small boilers. As CEM systems become more common, economical, and reliable, their use is expected to grow, particularly when they can also provide opportunities for better industrial process control.

Environment Canada will be publishing the results of its investigations and recommended approaches later in 1994. For small sources, such as boilers, Environment Canada is working with the provinces and industry to develop alternatives to direct monitoring in order to quantify emissions. One alternative being considered is an improved inventory of engines, boilers, and other stationary emissions sources, including fuel use and other parameters.

United States

Program Goals

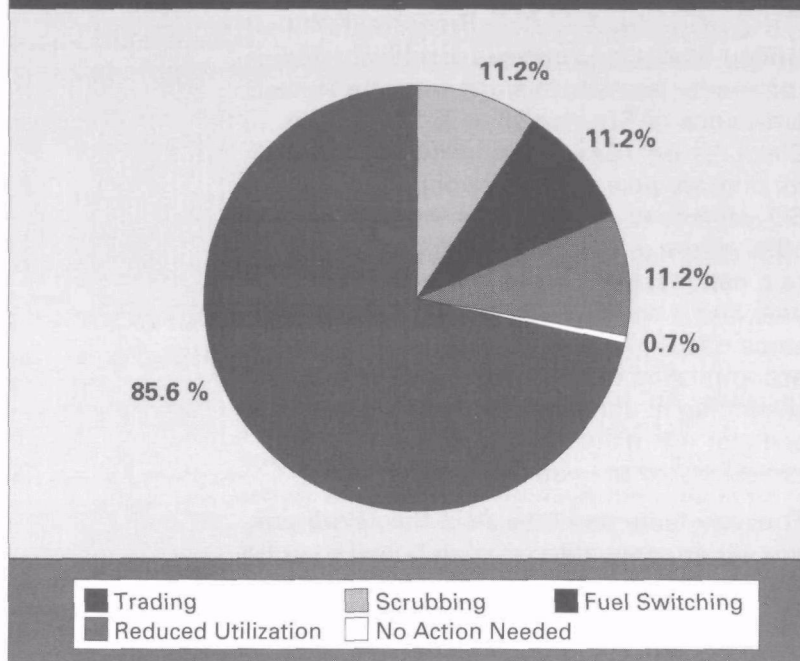
The goal of the Acid Rain Program in the United States is to achieve significant environmental benefits through reductions in emissions of SO₂ and NO_x. Title IV of the Clean Air Act (CAA) Amendments sets as its primary goal the reduction of annual SO₂ emissions by 10 million tons below 1980 levels, with utility emissions subject to a national cap of 8.95 million tons per year and a national cap on nonutility emissions of 5.6 million tons. This goal is to be accomplished in two phases, with Phase I beginning in January 1995. The Act also calls for a 2 million ton reduction in NO_x emissions by the year 2000.

Four key features of the Acid Rain Program are: (1) an innovative, market-based banking and trading system of emission allowances; (2) flexibility for electric utilities to choose the most efficient and cost-effective technologies; (3) a national cap on emissions; and (4) accountability through continuous emission monitoring. EPA is responsible for implementing the Acid Rain Program.

Under the program, SO₂ emissions allowances are allocated to affected utility units based on their historic fuel consumption and a specific emission rate. Each allowance permits a unit to emit one ton of SO₂ during or after a specified year. Affected units must hold a sufficient number of allowances at the end of the year to cover their annual emissions. Once allocated, allowances are fully marketable. In making their compliance decisions, utilities can buy, sell, or bank allowances for future use (Figure 2). Utilities are penalized for noncompliance.

To ensure compliance with the Acid Rain Program, affected electric utilities must file permit applications and measure and report all emissions. Individual units determine their own compliance strategy from among several or a combination of options, such as allowance trading, repowering units, using a cleaner-burning fuel, or reassigning energy production from dirtier units to cleaner ones. Sources can also install scrubber equipment or adopt energy-efficient measures.

Figure 2 U.S. SO₂ Compliance Strategies Reported for Phase I



Phase I begins in January 1995 and affects 110 mostly coal-burning electric utility plants (263 units) located in 21 eastern and mid-western states. Phase II, which begins in the year 2000, tightens the annual allowance allocations for these large plants and also sets allocations for approximately 700 additional plants (approximately 2,100 units). These Phase II plants are generally cleaner than the Phase I plants, and are fired by coal, oil, and gas. The program affects all existing utility boilers and turbines serving generators with an output capacity of greater than 25 megawatts as well as all new utility units.

In 2010, when the Acid Rain Program is fully implemented, a nationwide cap of 8.95 million SO₂ allowances per year on utility units will be maintained.

SO₂ Program Implementation

The U.S. Acid Rain Program has an integrated set of rules and guidance. The major rules were published in January 1993. Phase I of the SO₂ emissions reduction program begins in January 1995 and its implementation is well under way. All 110 Phase I utility sources submitted permit applications. Seventy-two Phase II sources also are considering entering the Phase I program ahead of schedule. All draft permits were issued by August 1993, with final permits issued by August 1994.

EPA reviewed Phase I permit applications from utility plants and concluded that approximately 200,000 excess allowances could be generated under the existing acid rain rules. In November 1993, EPA proposed revisions to the rules for substitution and reduced utilization to correct this problem. A settlement agreement was reached in May 1994 with petitioners who had challenged the January 1993 rules. A revised final rule reflecting the settlement and ensuring that no excess allowances are created is expected to be issued in the fall of 1994.

Allowance Trading

In other implementation initiatives, the allowance trading system is receiving early support from industry. Anticipating the first year of compliance in 1995, utilities have already begun trading emissions allowances. Over 20 two-party and brokered trades have been reported, involving the sale of over 1 million allowances valued at over \$200 million. Announced prices ranged from \$200 to \$300 per ton. Two annual public auctions of allowances have been held. On March 29, 1993, over 150,000 allowances were sold with prices ranging from \$122 to \$450 per allowance. On March 22, 1994, over 176,000 allowances were sold, with prices ranging from \$140 to \$400. The Chicago Board of Trade has been authorized by EPA to run these allowance auctions. The official recording of allowances by EPA's Allowance Tracking System, which opened March 14, 1994, is expected to facilitate more trading in private allowances because it provides validation for the issuance, holding, and transfer of allowances.

Several companies also are providing brokerage services and electronic posting of private bids and offers. Private auctions are expected to occur now that EPA's Allowance Tracking System is in place.

Other program initiatives include EPA awards of the first allowances from the Conservation and Renewable Energy Reserve to utilities that reduced emissions through the use of energy efficiency and renewable projects ahead of the CAA Amendments emissions reduction deadlines. Utilities awarded bonus allowances can sell them, bank them for future use, or use them to comply with EPA's acid rain rules. Unlike some other compliance strategies, energy efficiency and renewable

energy efforts reduce other air pollutants (carbon dioxide, NO_x, toxics, particulates), water contaminants, and solid waste, in addition to SO₂.

NO_x Program Implementation

The CAA Amendments also require additional reductions of NO_x emissions in the United States. The amendments call for a 2 million ton reduction in NO_x emissions by the year 2000. The NO_x reductions will be achieved through a combination of measures for mobile and stationary sources. The CAA Amendments mark the first time that federal laws have required NO_x reductions from existing stationary sources of air pollution. Previous requirements addressed NO_x reduction only through controls on motor vehicles and new utility and industrial sources.

NO_x reductions under the U.S. Acid Rain Program will be achieved in two phases. Under regulations established in March 1994, Group 1 boilers (defined as coal burning, dry bottom wall-fired and tangentially fired boilers) covered under Phase I must meet specific performance standards by January 1, 1995. About one quarter of all Group 1 boilers are covered in Phase I. In 1997, EPA may set NO_x performance standards for all other coal-fired utility boilers (Group 2) as well as more stringent standards for dry bottom wall-fired and tangentially fired boilers if effective low-NO_x burner technology is available.

EPA limits annual emissions of NO_x to 0.050 pounds per million Btu for dry bottom wall-fired boilers, and 0.45 pounds NO_x per million Btu for tangentially fired boilers. These limits for Group 1 boilers are achievable with commercially available technologies. The NO_x rule also establishes procedures allowing utilities to average emissions among certain affected units.

Each affected unit can choose from among several NO_x emission reduction technologies to comply with the applicable proposed emission limitation. These include low-NO_x burner technology, alternative control technologies, fuel switching, and changes to boiler operating parameters. Utilities can select the most cost-effective NO_x emission control strategy. This flexible approach also promotes technology development and encourages market competition among vendors.

On November 25, 1992, EPA provided guidance to states on implementing stationary source NO_x control requirements for reducing ground-level ozone (smog) in parts of the United States that have exceeded the health standards for ozone in urban nonattainment areas and the Northeast. EPA guidance to states is generally consistent with a National Academy of Sciences study required by the CAA Amendments and issued in December 1991. The study concluded that NO_x reduction is necessary for effective reduction of ozone in many areas of the United States. Both Title II of the CAA Amendments and Annex 1 of the Air Quality Agreement focus on NO_x emission reductions from mobile sources, emphasizing new vehicle emission limits.

EPA issued regulations with an emphasis on implementing the mobile source provisions in June 1991. The new NO_x limits for light-duty vehicles (passenger cars and some light-duty trucks) are being phased-in. In model year 1994, 40 percent of each manufacturer's sales volume of passenger cars and light-duty trucks under 6,000 pounds must meet a standard of 0.4 grams per mile (gpm). In 1995, the percentage increases to 80 percent. In model year 1996, 100 percent of these light-duty vehicles must meet the standard. In addition, in model year 1996, 50 percent of each manufacturer's sales volume of light-duty trucks over 6,000 pounds must meet a standard of 0.7 gpm; in 1997, 100 percent of light-duty trucks in this category must meet the standard. For heavy-duty trucks, phase-in of NO_x limits began in 1991, with full implementation by 1998. Other regulations limiting NO_x emissions for nonroad diesel engines (e.g., railroad engines) and farming and construction equipment were issued in May 1994.

Monitoring of U.S. Emissions

Continuous emission monitoring is critical to the Acid Rain Program. It instills confidence in allowance transactions by certifying the existence and quantity of the commodity being traded. Monitoring also ensures, through accurate accounting, that the emissions reduction goals of the 1990 CAA Amendments are met. All Phase I utilities completed certification testing and began submitting quarterly reports to EPA in January 1994. Phase II utilities will complete



Worker tests continuous emission monitoring equipment on an American electric utility plant.

the certification tests for all coal-fired utilities by the end of 1994 and begin submitting quarterly emissions reports by April 1995.

Unlike traditional regulatory programs, which measure specific emission rates, the Acid Rain Program focuses attention on total emissions. The Acid Rain Program requires an accounting of each ton of SO_2 emissions from each regulated unit. Each regulated unit must install a CEM system, which includes an SO_2 pollutant concentration monitor, a NO_x pollutant concentration monitor, a volumetric flow monitor, an opacity monitor, a diluent gas (oxygen or CO_2) monitor, and a data acquisition and handling system for recordkeeping and performing calculations with the data. CO_2 emissions data also are collected for the purposes of gathering information on climate change. All CEM systems must be in continuous operation and must be able to sample, analyze, and record data at least every 15 minutes. All emissions and flow data will be reduced to one-hour averages. Regulated units are required to provide electronic quarterly reports to EPA on their emissions. Each new electric utility unit and each existing electric utility unit greater than 25 megawatts must employ such a CEM system; there are alternative monitoring requirements for some natural gas and oil-fired units.

PREVENTION OF SIGNIFICANT DETERIORATION AND VISIBILITY PROTECTION

Information Exchange Meetings Between Canada and the United States

In 1993, several meetings and conference calls took place between EPA, the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), Environment Canada, and Heritage Canada. Canada and the United States also met in New Brunswick to exchange information on activities regarding air monitoring, acid precipitation monitoring, visibility monitoring, and biological effects research programs in national parks and wildlife refuges. Planning and management issues discussed at the meeting included air quality management, park planning and inter-governmental activities, and both Canadian and U.S. park systems' involvement in the Air Quality Agreement.

Status of Development of Prevention of Significant Deterioration and Visibility Programs in Canada

Canada has established a federal-provincial National Prevention of Significant Deterioration (PSD)/Visibility Working Group. The mandate of the group is to define Canada's response to meeting the PSD/visibility commitment for Canada under Annex 1, paragraph 4, of the Canada-U.S. Air Quality Agreement. Under the mandate, by January 1, 1995, Canada must develop and implement strategies to prevent significant air quality deterioration and protect visibility comparable to the U.S. PSD/visibility program for sources that could cause significant transboundary air pollution.

In Canada, environmental assessment legislation exists at provincial and federal levels, with differences in detail. The federal-provincial Working Group investigated the levels of protection offered by Canadian environmental assessment procedures. The Working Group will determine if existing environmental assessment legislation provides a level of protection comparable with the U.S. PSD/visibility program.

Progress of Existing PSD and Visibility Programs in the United States

Since the 1992 Progress Report, several modelling techniques have been made available to assess the impacts of air pollution sources on Class I areas (national parks and wilderness areas). EPA's PLUVUE II model is aimed at assessing the impact to Class I areas from a single source. In addition, EPA, federal land managers (the U.S. Park Service and U.S. Forest Service), and the FWS have formed the Interagency Workgroup on Air Quality Modelling (IWAQM). This work group has recently completed its Phase I report, which provides information on appropriate "off-the-shelf" methods for estimating long-range transport impacts of air pollutants on federal Class I areas and on regional visibility. These techniques for assessing visibility in Class I areas are continuing to undergo review and further development. Refinements and new developments may be expected in the future.

In monitoring activities since the last Canada-U.S. Progress Report, an analysis of 1988-1991 monitoring data for Class I areas from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network was issued in February 1993. IMPROVE monitoring was established in the mid-1980s by EPA, federal land managers, and certain states.

In other activities, the Grand Canyon Visibility Transport Commission, established under the authority of the 1990 CAA Amendments, has laid the initial groundwork for establishing a database on visibility problems caused by interstate transportation of air pollution in national parks and wilderness areas on the Colorado Plateau in the southwestern United States. The Commission, made up of governors in states in the Air Transport Region and ex-officio members from EPA and agencies managing affected federal lands, has been evaluating regional visibility problems and is working to develop visibility management policy options by November 1995. The Commission has adopted use of the deciview as a measure of haze to gauge the effects of various strategies. The deciview is patterned after the decibel, used to measure sound.

In other programs, EPA, in consultation with representatives from industry, state and local agencies, public interest organizations, and the federal land managers, is in the process

of developing a strategy to implement New Source Review Reform to streamline the present process.

In addition, EPA released a Report to Congress in October 1993 on the impact of the CAA Amendments on visibility in Class I areas. The study reaffirms that the bulk of anthropogenic visibility impairment in the eastern United States is due to sulphates, the majority of which are emitted by power plants. In relatively clean areas of the West, where no single source category dominates visibility impairment, small increases in pollutant levels can markedly degrade visibility. Visibility in Class I areas in the West, therefore, is particularly sensitive to increased levels of pollution.

Implementation of the CAA Amendments is expected to produce increases in annual average visual ranges from 5 to 15 percent in Florida, New England, and just east of the Mississippi River to 25 to 35 percent in the mid-Appalachians and the Ohio Valley. The study also looked at numerous Class I areas in the West. Consistent with relatively slight changes in projected emissions of SO₂, NO_x, and particulates between the years 1988 and 2005, annual average visibility is expected to remain stable in the western United States.

NEW ISSUES UNDER THE CONTROL PROGRAMS

Canadian Air Issues Committee

All jurisdictions within Canada have a long-term objective of resolving, to the extent practicable and economically feasible, acidification and other adverse effects of SO₂ emissions. The key issue for the long-term management of SO₂ emissions in Canada is the nature and timing of jurisdictional commitments for achieving the 3.2 million tonne cap.

A number of important factors will be considered over the next few years:

- Determining the need to further reduce sulphate deposition in eastern Canada beyond levels that will be achieved with current domestic and U.S. programs, establishing target loads, and setting a schedule for compliance.

- Identifying driving forces, other than acidification, to protect the Canadian environment from the impacts of SO₂ emissions. Such driving forces may be, for example, the protection of human health or the deterioration of visibility.
- Determining whether the role of nitrogen in acidification is sufficiently important to warrant further controls to minimize acidification.
- Analyzing the benefits of an SO₂ management system designed to achieve the national cap to determine if it also can be designed to:
 - contain strong cause-and-effect linkages;
 - maximize cost effectiveness;
 - promote pollution prevention;
 - support harmonization commitments in international agreements.

This work is being undertaken by Canada's National Air Issues Steering Committee, which has been meeting regularly since it was established in 1993. Its membership consists of federal and provincial/territorial deputy ministers of environment and energy. In the future, the Committee will deal with emerging air quality issues, including hazardous air pollutants.

U.S. National Science and Technology Council

In the United States, a new National Science and Technology Council (NSTC) was created in 1994. The Council has a Committee on the Environment and Natural Resources and a Subcommittee on Air Quality. The Subcommittee on Air Quality oversees integrated research programs and priorities related to various air quality issues, including acid rain, tropospheric ozone, particulate matter/visibility, and indoor air. The NSTC held its first public forum in March 1994.

Acid Deposition Standards Study

Under Title IV of the 1990 CAA Amendments, EPA is preparing a Report to Congress on the feasibility and effectiveness of setting and implementing acid deposition standards to protect sensitive water and land resources. The purpose of this study is to assess the residual risk to ecosystems following imple-

mentation of the CAA Amendments. 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 study will integrate state-of-the-art ecological effects research, emissions and source-receptor modelling work and also consider implementation and cost issues. The study is expected to be completed in late summer 1994, and then made available for a 30 day public comment period. EPA anticipates delivery of the Report to Congress by January 1995.

PROGRESS UNDER ARTICLE V OF THE AIR QUALITY AGREEMENT

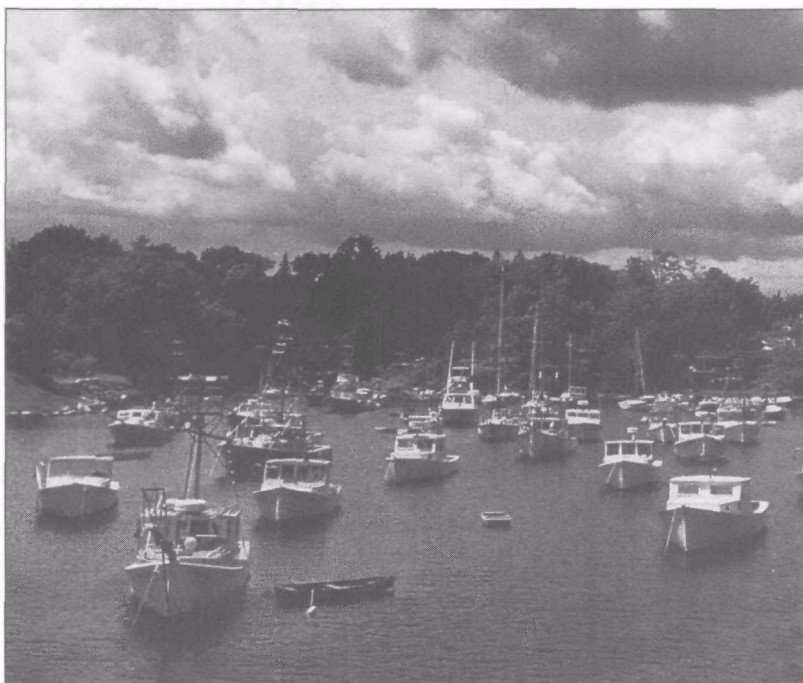
Article V addresses the assessment, notification, and mitigation of proposed actions, activities, or projects that, if carried out, would be likely to cause significant trans-boundary air pollution. The Agreement does not contain specific procedures for implementing Article V. Thus, at the November 1992 Air Quality Committee meeting a working group was formed under the auspices of the Subcommittee on Program Monitoring and Reporting to develop the specific procedures for implementing Article V. At the Committee's request, the Subcommittee was to have a final draft of the procedures for Committee review and approval by the fall of 1993.

During 1993, discussions were held to identify issues associated with implementation of Article V. From the outset, the discussions were marked by a fundamental disagreement on the interpretation of paragraph 1 of Article V, which relates to assessment of sources, as deferring to existing laws, regulations, and policies in the respective countries.

Efforts turned to developing a joint notification procedure. The ensuing discussions were fruitful, and some progress was made in this area. For example, both countries agreed that major sources of SO₂, nitrogen dioxide (NO₂), VOCs, particulates, carbon monoxide (CO), and toxic substances should be subject to notification. Both parties agreed on criteria for determining notification: (1) size cutoff, tons (tonnes) per year of pollutant emitted; and (2) distance from the border. In addition, both parties agreed that information

on sources subject to notification should be available to the public. Canadian and U.S. representatives could not reach agreement on a joint notification process prior to the Air Quality Committee meeting on December 14, 1993.

The Committee concluded that it was probably not practical in the short term to implement joint notification procedures, given the complexities of the legal differences in each country. The Committee decided that each country should develop its own notification procedures and advise the other of its intentions through the Air Quality Committee. Meanwhile, each country will notify the other of proposed actions, activities, or projects, that, if carried out, would be likely to cause significant transboundary air pollution. Serious consideration is also being given to setting up an electronic bulletin board that would be accessible to the public.



Progress: Scientific and Technical Activities and Economic Research

In accordance with Annex 2 of the Air Quality Agreement, Canadian and American scientists have been coordinating and cooperating on acid deposition modelling, monitoring, and effects research for a number of years. Recently, the two countries expanded their cooperative efforts to include ground-level ozone and visibility impairment.

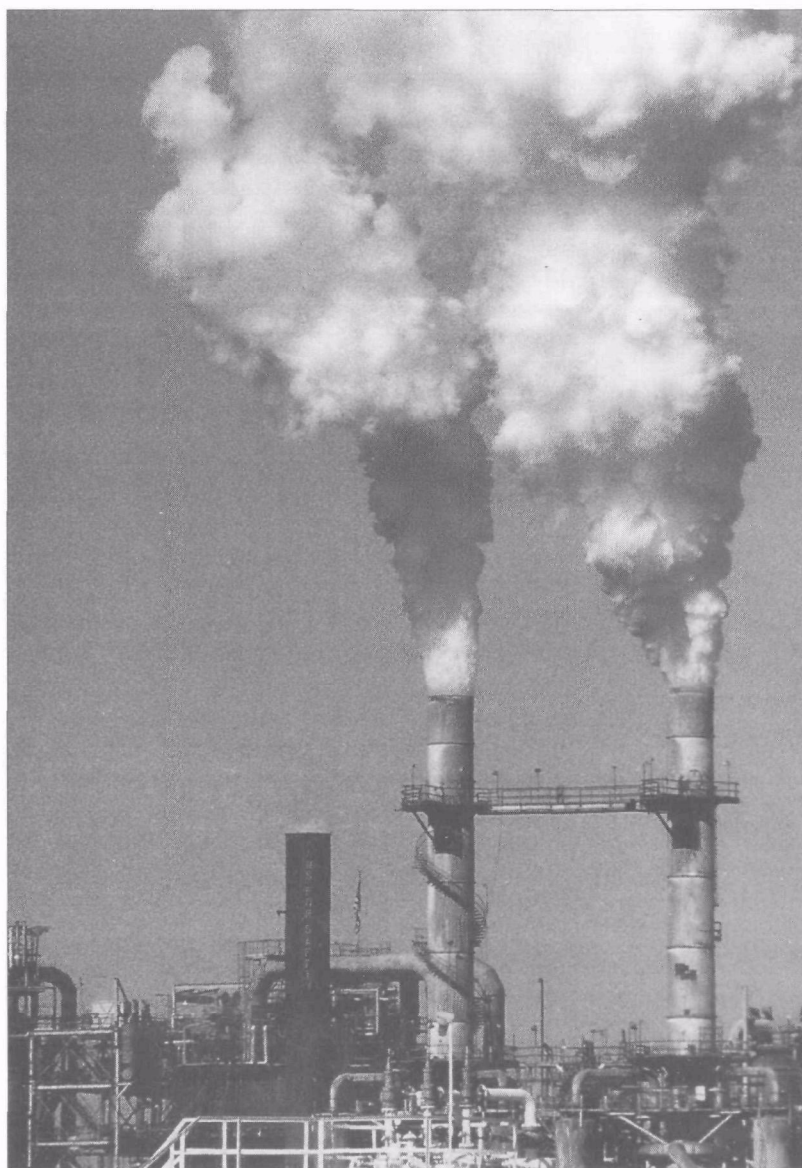
In this section (as elsewhere in the report), the terms acid rain and acid deposition are used interchangeably. "Acid rain" is a shorthand descriptor that has been used for many years and has gained widespread public recognition. The problem of acidification is more complex than the term acid rain would imply. "Acid deposition," therefore, in addition to encompassing wet deposition of acidic species, also includes dry deposition of acidic materials and atmospheric transformation and transport contributing to the impact these materials have on the environment.

EMISSION INVENTORIES

Emission inventories provide the foundation for air quality management programs. They are used to identify the major sources of air pollution, provide data for input into air quality models, and enable the tracking of control strategies. The importance of emission inventories and the accuracy of their estimates 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. Numerous tools also have been developed to analyze trends and forecasts of emissions. Biannual meetings are continuing, emphasizing the need to pursue and increase the level of collaboration between the two countries.

SULPHUR DIOXIDE, NITROGEN OXIDES, AND VOC EMISSIONS IN CANADA AND THE UNITED STATES FROM 1980 TO 2010

Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emissions are the dominant precursors of acid rain. NO_x along with volatile organic compounds (VOCs) are important contributors to the formation of ground-level ozone, which also contributes to the formation of acidic compounds in the atmosphere.



The totals for all three pollutants covered in this report were derived using methodology that has been extensively revised from the methodology used to develop previous estimates. Using the revised methodology, previous estimates have been recalculated. Regarding U.S. mobile sources, the emission estimates were revised using an updated version of the mobile source emission factor model (MOBILE 5). Enhancements include emission factors that were adjusted to account for currently used fuels, the use of nine vehicle speeds (instead of three) to obtain a more accurate model of real-life highway conditions, and the addition of late-model light-duty vehicles.

In addition, EPA's Office of Mobile Sources conducted an extensive off-highway emissions VOCs data survey in 1990 that produced more accurate estimates over last year's totals. Various source categories, including solvent, fossil-fuel, steam-utility, and other point sources, were re-estimated using U.S. Department of Commerce Bureau of Economic Analysis growth factor indicators as well as the application of new control efficiencies, rule effectiveness factors, and updated emission factors.

The emission estimates for the years 1980, 1985, 1990, and 1992 and the projected emission estimates for the years 2000 and 2010 are described for each pollutant in the sections which follow. These estimates and projections of the pollutant emission levels may vary from year to year because of modelling developments. In addition, the 1990 and 1992 data reported for both Canada and the United States are preliminary. The 1980 data are included because 1980 is the base year for measuring emission reductions under the acid rain control programs in both countries.

Table 4 summarizes the 1992 emission estimates for Canada and the United States. The estimates are divided into four major categories, with the data presented both in metric tonnes and short tons. Figures 3, 4, and 5 summarize the SO₂, NO_x, and VOC emission estimates for 1980, 1985, 1990, 1992, 2000, 2005, and 2010. The data presented in these figures and Table 4 were obtained from EPA *National Air Pollution Emission Estimates, 1900-1992*, October 1993, (EPA-454/R-93-032) and from Environment Canada (Pollution Data Analysis Division).

Table 4 Emission Estimates for Canada and the United States, 1992

	SO ₂		NO _x		VOCs	
	(million tonnes ¹)	(million tons ¹)	(million tonnes)	(million tons)	(million tonnes)	(million tons)
United States						
Electric Utilities	14.4	15.8	6.8	7.5	0.0	0.0
Industrial	4.7	5.2	4.0	4.4	10.1	11.2
Mobile	0.0	0.0	9.4	10.3	7.5	8.2
Other	1.5	1.7	0.9	0.9	3.0	3.3
Total	20.6	22.7	21.0 ²	23.1	20.6	22.7
Canada						
Electric Utilities	0.7	0.8	0.3	0.3	negligible	negligible
Industrial	1.9	2.1	0.5	0.5	0.3	0.3
Mobile	0.0	0.0	1.3	1.4	0.7	0.8
Other	0.5	0.6	0.1	0.1	1.0	1.1
Total	3.1	3.4 ²	2.2	2.3	2.0	2.2
U.S./Canadian Total	23.7	26.1	23.1 ²	25.4	22.6	24.9

¹ One ton is equal to 0.9 tonnes; 1 tonne is equal to 1.1 tons.

² Total is not the raw data total of enumerated items due to rounding of numbers.

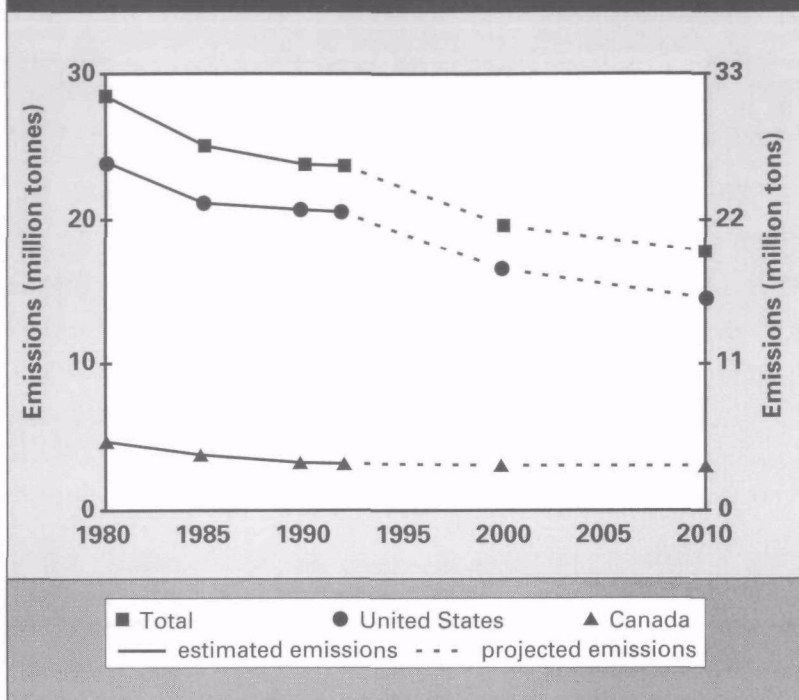
Sulphur Dioxide

The principal anthropogenic sources of SO₂ are coal and oil combustion, smelting, and a few industrial processes. As shown in Table 4, electric utilities were responsible for 70 percent of the 1992 SO₂ emissions in the United States and 23 percent in Canada, while industrial sources were responsible for 23 percent of SO₂ emissions in the United States and 61 percent of total SO₂ emissions in Canada. Canadian SO₂ emissions were approximately 13 percent of the total emissions of Canada and the United States combined in 1992; U.S. emissions were approximately 87 percent of the combined total.

SO₂ emissions are declining. Overall trends in emission levels from 1980 to 2010 for Canada and the United States are presented in Figure 3. In 1980, total estimated emissions of SO₂ in the two countries were 28.5 million tonnes. In 1985, total estimated emissions of SO₂ in Canada and the United States were 25.1 million tonnes. From 1980 to 1992, emissions of SO₂ in North America were estimated to decline by 4.7 million tonnes, or 16.5 percent. SO₂ emissions in the United States in 2000 and 2010 are projected to be 18.3 million tons and 16.3 million tons, respectively. The totals include emissions from banked or unused allowance credits. SO₂ emissions in Canada in 2000 and 2010 are projected to be 3.0 million and 3.1 million tonnes, respectively. Uncertainty bands on the national annual emissions estimates of SO₂ range from 5 to 10 percent; the uncertainty bands are larger for regional annual emissions estimates.



Figure 3 SO₂ Emission Estimates

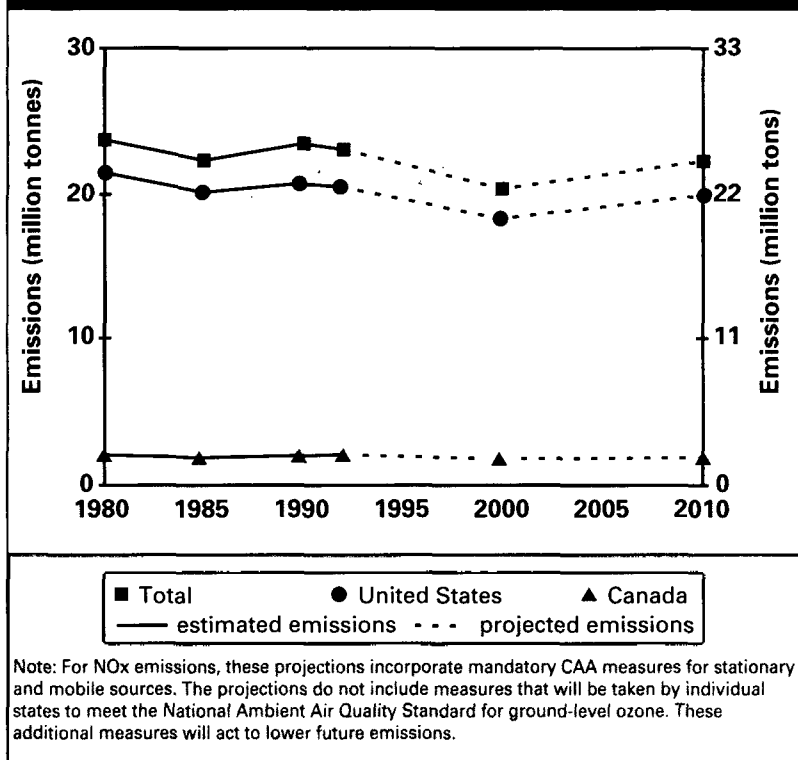


While 8.95 million SO₂ allowances are expected to be allocated by 2010, the United States' SO₂ emissions are expected to exceed the national utility cap of 8.95 million tons because utilities in Phase II are projected to use banked allowances (or credits) gained from greater emission reductions in Phase I.

Nitrogen Oxides

The principal anthropogenic source of emissions of NO_x 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 4, in 1992 45 percent of NO_x emissions in the United States and 60 percent of emissions in Canada were produced by mobile sources. Electric utilities were responsible for 32 percent of the 1992 emissions in the United States and 14 percent in Canada. Industrial sources were responsible for 19 percent of NO_x emissions in the United States and 23 percent of total NO_x emissions in Canada. Canadian NO_x emissions were approximately 9 percent of total emissions in the United States and Canada combined in 1992; U.S. emissions were approximately 91 percent of the combined total.

Figure 4 NOx Emission Estimates



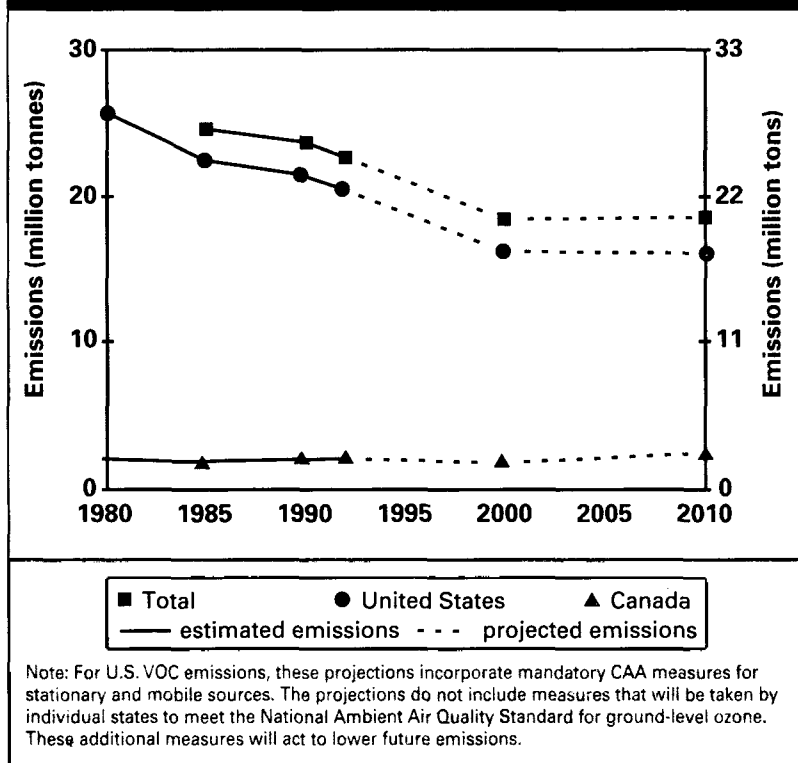
NOx emissions are expected to decline slightly by the year 2000, then rise in both countries. Figure 4 shows the overall trend for anthropogenic emissions of NOx in Canada and the United States from 1980 to 2010. In 1980, the total estimated emissions of NOx in the two countries were 23.6 million tonnes. In 1985, the total estimated emissions in Canada and the United States were 22.3 million tonnes. From 1980 to 1992, emissions of NOx in North America were estimated to decline by 0.5 million tonnes, or 2 percent. Emissions of NOx in the United States in 2000 and 2010 are projected to reach 20.2 million tons and 22.3 million tonnes, respectively. Emissions of NOx in Canada in 2000 and 2010 are projected to reach 2.0 million tonnes and 2.2 million tonnes, respectively. Uncertainty bands for national annual emissions of NOx are in the 10- to 15-percent range, and are larger regionally.

Volatile Organic Compounds

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 4, in 1992, 36 percent of VOC emissions in the United States and 36 percent of emissions in Canada were produced by mobile sources. Industrial sources were responsible for 49 percent of the VOC emissions in the United States and 15 percent of the total in Canada. Canadian VOC emissions were approximately 9 percent of the total emissions of the United States and Canada combined in 1992; U.S. emissions were approximately 91 percent of the combined total. 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 the year 2010. Overall trends in VOC emission levels from 1980 to 2010 for Canada and the United States are presented in Figure 5. In 1985, the total estimated emissions of VOCs in Canada and the United States were 24.7 million tonnes. From 1985 to 1992, VOC emissions in North America were estimated to decline by 2.1 million tonnes, or 8.5 percent. Emissions of VOCs are expected

Figure 5 VOC Emission Estimates



to decline even further after 1992. Estimated emissions for the United States in 2000 are 17.7 million tons and in 2010 are 17.5 million tons. Emissions of VOCs in Canada in 2000 and 2010 are projected to reach 2.1 million tonnes and 2.4 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 for a number of reasons: (1) ammonia is a nitrogen-containing compound and the deposition of ammonia contributes to the total loading of nitrogen in the environment; and (2) in the atmosphere, ammonia can neutralize acidic substances. This Progress Report, however, does not consider the sources, emission trends, or projected emission levels for ammonia.

Nonetheless, research on ammonia emission factors has been conducted by EPA (and certain international groups) and the Agency is currently conducting a literature search so that the latest information can be assessed. Using this information, EPA will develop a brief research plan that identifies source categories in need of more study. Additional categories of research will be based on several factors, including: (1) the limited test data available for studying large-scale national and global ammonia emissions; (2) significant industrial process changes; and (3) controversy due to the current emissions factor or activity data.

Conclusion

An overall trend of decreasing emissions can be seen from this analysis, despite the increases in the estimated emissions for certain individual sources. For example, 1992 saw increased consumption of bituminous coal by electric utilities and industrial boilers and the decreased use of other fuels (e.g., sub-bituminous coal, oil, and gas) in the United States. The result was an estimated net decrease in SO₂ emissions. Total VOC emission estimates in the United States decreased from 1980 to 1992, due largely to changes in automotive fleets. While vehicle miles travelled rose approximately 2 percent each year, the continued replacement of older, less-efficient automobiles

with newer, more-efficient ones yielded a net decrease in the emission estimates of about 10 percent. The same comparison regarding transportation sources can be made for the U.S. NO_x emission estimates. An analysis of the overall trend in the Canadian emission estimates shows a decrease or flattening between 1980 to 1992. Canada has also been developing industrial and transportation pollution controls equivalent to those in the United States. The two countries have been working together to ensure emission inventory data consistency and coordination in emission trends analysis.

ATMOSPHERIC MODELLING

In Annex 2 of the Air Quality Agreement, Canada and the United States agreed to exchange information on the development and application of atmospheric models determining source-receptor relationships and transboundary transport and describing the deposition of air pollutants. This section summarizes results from linear (Lagrangian) and nonlinear (Eulerian) models and describes progress in the evaluation of Eulerian models. These models are used for a number of purposes, including analyses of different emission scenarios and the resulting change in air quality and deposition.

Model Application

Previous studies reported the impact of SO₂ emissions from a given source region on deposition in a receptor region (source-receptor relationship). Since the last Progress Report, similar studies have been conducted for nitrogen using a long-range transport sulphur/nitrogen model and 1980 base-year data. For example, the Canadian contribution to nitrogen concentrations and deposition was found to be greatest at Gander in Newfoundland (60 to 70 percent) and least at Algoma at the eastern end of Lake Superior (7 to 11 percent). Despite the model deficiencies and uncertainties, these matrices provide the first published quantitative estimates of the relative contributions of Canadian and U.S. source regions to nitrogen concentrations and deposition at several receptors in the two countries.

Scientists in Canada and the United States are exchanging information on how to use atmospheric models to anticipate future deposition patterns and how to use the predictions to improve the ability of deposition monitoring networks to detect pattern changes. Canadian and U.S. models have been used to project sulphate deposition patterns following the implementation of various phases of both countries' acid rain control programs (i.e., using the Canadian Lagrangian Long Range Transport Sulphur Model and the U.S. Eulerian Regional Acid Deposition Model [RADM]). The predicted patterns have been used to test the appropriateness of the existing networks and to recommend changes in network design. As sulphur emission control programs are being implemented, deposition monitoring networks are continuing to fulfil the principal goals of detecting and quantifying temporal and spatial changes in deposition. The networks are being modified in accordance with the recommendations of the modelling studies.

Model Evaluation

The two countries have been cooperating in model evaluation using information from the Eulerian Model Evaluation Field Study (EMEFS). Since the last Progress Report, Phase 1 of the evaluation of the two advanced acidic deposition models — ADOM (Acid Deposition and Oxidants Model) and RADM — has been completed. This phase is primarily based on 1988 EMEFS data. Phase 2 will be based on 1990 EMEFS data as well as critical data from the 1988 period; it is to be completed in 1994. Additional cooperative efforts in the further evaluation and application of the advanced models will continue under the Air Quality Agreement.

A peer review panel has confirmed the ability of the models to represent (1) total sulphur loading of the atmosphere; (2) annual sulphur deposition (although there is some seasonal bias, with deposition being underestimated in summer and overestimated in winter); and (3) total nitrogen loading of the atmosphere. The reviewers concluded that the models could be used for developing current estimates as well as projections of annual deposition of sulphur and nitrogen.

The reviewers also concluded that, while both models were adequate for the study of

large-scale and long-distance source-receptor relationships, their complexity will pose a limitation. A valuable application would be for the complex models to serve as a check on the source-receptor matrices produced by simpler but much faster Lagrangian methods. The reviewers agreed that the differences between the simple and complex models' estimates of deposition may be on the order 10 to 15 percent.

MONITORING ACTIVITIES

Coordination of Monitoring Activities

Regional Dry Deposition Estimates

Dry deposition is an important process by which acidic air pollutants are deposited to the Earth's surface. In contrast to wet deposition, dry deposition is very difficult and costly to measure and consequently there have been fewer direct measurements. Thus, 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 modelled deposition velocity. Deposition velocity is modelled as a function of surface characteristics and measured meteorological variables or climatological data.

Air concentration measurements appropriate for estimating dry deposition are taken at multiple locations in both countries. In Canada, the Canadian Air and Precipitation Monitoring Network (CAPMoN) has been providing daily concentration data of SO₂, particulate-SO₄, nitric acid (HNO₃), and particulate-NO₃ at 11 sites for up to 14 years. In the United States, the National Dry Deposition Network (NDDN) was established in 1987 and currently reports weekly averaged concentration data for SO₂, particulate-sulphate (SO₄), nitric acid (HNO₃), particulate-nitrate (NO₃), and ammonia (NH₃) for 50 sites. A map of air concentrations of SO₂ for 1991 at Canadian and U.S. sites is shown in Figure 6. Both networks have observed a gradient in air concentrations with high values occurring closest to areas of greatest SO₂ emissions. There is very little difference between these observations and those reported in the previous Progress Report. These air concentration data, combined with land/vegetation information

Figure 6 Median 1991 SO₂ Air Concentrations at CAPMoN and NDDN Sites



and hourly meteorological or climate data, give an estimate of dry deposition through an inferential model approach. Although Canadian and U.S. approaches to estimating dry deposition are similar, the differences preclude publishing a composite description of dry deposition over eastern North America at this time. To further minimize the differences, Canadian and U.S. measurement and modelling techniques are being compared.

To determine if there could be systematic differences (biases) arising from the use of different methods of sample collection and analysis, collocated NDDN and CAPMoN measurements of air concentrations of various gases have been carried out. Such differences could lead to air concentration and deposition discontinuities across the Canada-U.S. border. With the exception of SO_2 , where a difference of 14 percent was noted, measured differences were found to be small.

In Canada, current investigations are focusing on the advantages and disadvantages of the various models that are available to determine an appropriate and comparable modelling framework. In the United States, recent advances in model design are being applied to the NDDN measurements. The overall goal of the work in both countries is to improve model estimates of dry deposition of all acidifying species by increasing the understanding of the processes involved in delivering gases and particles to the Earth's surface.

Estimating Total Sulphur Deposition

Total deposition is the sum of wet, dry, and droplet deposition. Work is under way to develop an effective way to combine estimates of dry deposition with wet deposition measurements that will provide comprehensive information on regional variations. Also, efforts are being made to achieve greater certainty in the characterization of spatial wet deposition fields of sulphate and nitrate in Canada and the United States. The current method employs interpolation between the sparse measurement sites, using precipitation depth measurements taken only from the acid deposition networks rather than the fuller set of observations provided by national weather services. It is expected that uncertainties in the spatial distributions will be decreased by combining interpolated precipitation chemistry

fields with more detailed observed precipitation amount fields, thereby producing more highly resolved wet deposition fields.

Significant contributions to total deposition can come from fog and cloud water droplet deposition in certain geographical locations. For example, mountain peaks in eastern North America are subject to cloud deposition that may be equivalent to or greater than deposition from precipitation. The United States collected cloud water and calculated cloud water deposition as part of the National Acid Precipitation Assessment Program (NAPAP) from 1986 through 1989. Canada also measured cloud water during this time period as part of the federal/provincial Acid Rain Research and Monitoring Program. In the United States, the Clean Air Status and Trends Network (CASTNET) is reinitiating sampling at some of the previous sites and installing new sites. In Canada, fog chemistry and sulphate deposition are currently being measured in coastal areas in the Atlantic Provinces in order to more accurately describe total sulphate deposition. The work indicates that on average the sulphate deposition from fog is almost equal to that from rain and snow in the New Brunswick Fundy Coast region.

Findings of Air Pollutant Monitoring Activities

Deposition Networks

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is the largest wet deposition network in the United States, operating on a weekly measurement protocol with approximately 200 sites, some with data records dating from the early 1980s.

CASTNET operates wet deposition sites to supplement the NADP/NTN in areas that do not have monitoring sites, such as mountain and coastal regions. The National Oceanic and Atmospheric Administration (NOAA) recently established a daily wet deposition network, the Atmospheric Integrated Research Monitoring Network (AIRMoN). The daily sampling schedule will provide data for addressing the localized effects of emission controls to be used in source/receptor modelling. Wet deposition data from NADP/NTN, CASTNET, and the Canadian CAPMoN and

provincial networks have been combined. The spatial distributions of wet sulphate and nitrate deposition in 1988, 1989, 1990, and 1991 are shown in Figures 7 to 14. Comparing 1988 data with data from 1991 shows in both years an almost total lack of areas receiving more than 30 kg wet sulphate/ha/yr. In contrast, the intervening years (1989 and 1990) show considerable larger areas as having received more than 30 kg/ha/yr, as was the case for the years prior to 1988. A direct comparison of 1988 with 1991 would not have given a realistic assessment of what had actually occurred since the last Progress Report. In all four years, the highest deposition was seen in the states of Ohio, Pennsylvania, and West Virginia (Figures 11 to 14). The highest nitrate deposition was seen in southern Canada in 1988 and in the following years in areas adjacent to the Great Lakes.

Deposition Trends

Figures 15 and 16 show the variability from 1980 to 1991 in the precipitation weighted mean concentration of sulphate and nitrate in Canada and the United States. Deposition is a reflection of both the amount of sulphate in the rainfall (concentration) and the amount of rain in any given area. Because of the greater variability in rain from year to year, trends can be more easily detected in the concentration of sulphate rather than in deposition. A significant downward trend was seen in sulphate concentration in rain at 26 to 33 U.S. NADP/NTN sites over the 1980-1991 period. A Canadian study showed that sulphate concentrations from both Canadian and U.S. sites showed significant long-term trends over the same period with reductions in concentrations being seen early in the decade and with a tendency to level off later in the decade. In contrast, while significant trends were seen for changes in the nitrate concentrations in precipitation, there was no dominant trend in terms of increase or decline.

Between 1980 and 1985, the total SO₂ emissions in eastern North America decreased by about 15 percent, after which they remained approximately constant. NO_x emissions, on the other hand, showed no strong downward trend and exhibited only slight annual variations (i.e., of less than 5 percent) around the mean from 1980 through 1991. In general, changes in SO₂ emissions are reflected in

changes in sulphate concentrations in precipitation. Nevertheless, the ecological response is often a reflection of both the amount and the concentration (deposition) and trends in deposition needed to be investigated. For the period studied, changes in deposition are seen to reflect the changing emission patterns. A statistically significant relationship exists between the SO₂ emissions over eastern Canada and United States and the sulphate concentration trends averaged over all sites in the same area. When sulphate wet deposition is integrated across all of eastern North America and compared with the integrated SO₂ emissions over the same area, a close correlation exists between sulphate deposition and emissions initially showing both emissions and deposition declining (Figure 17 on page 32). However, due to the uncertainty in the data, trends in the latter half of the decade are not obvious. The normalized integrated nitrate deposition showed no upward or downward trend over the decade consistent with the normalized NO_x emissions. Continued monitoring and analysis is needed to quantify the link between reduced SO₂ emissions and subsequent reduced wet sulphate deposition.

EFFECTS RESEARCH AND MONITORING

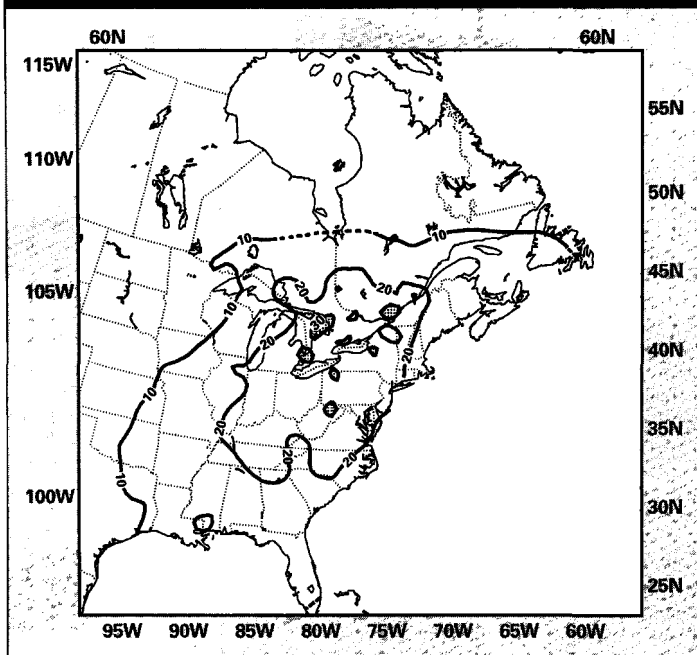
Aquatic Ecosystems Trends

Reduction in North American SO₂ emissions is expected to reduce acidic deposition and result in beneficial changes in the chemistry and biology of lakes and streams that have been adversely impacted by acidic deposition. Some emission reductions have occurred since the 1980s. Assessment of chemical trends observed in surface waters during this period provides a qualitative indication of the response complexity, a verification of whether ecosystems do in fact respond positively, and a baseline for evaluating future changes.

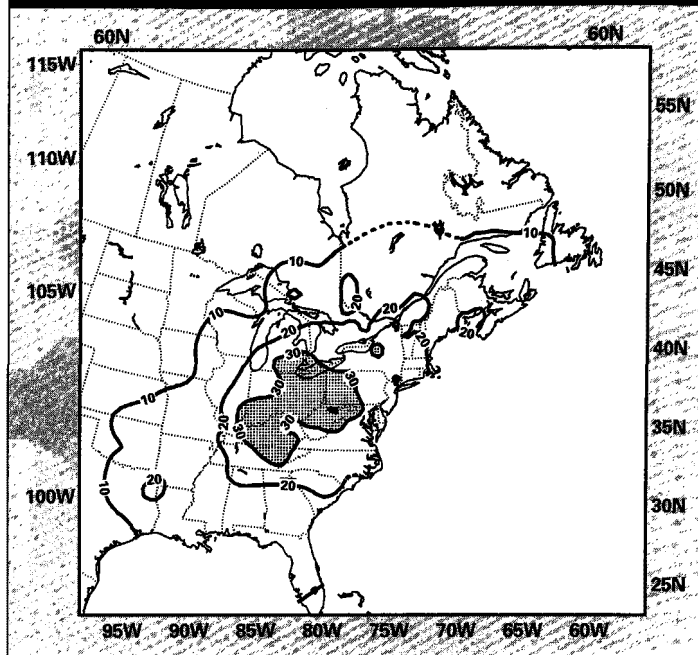
Canada

The 1983-1991 chemical records from 111 lakes or streams in southeastern Canada were evaluated to identify increasing or decreasing trends that were statistically significant at a 95 percent confidence level.

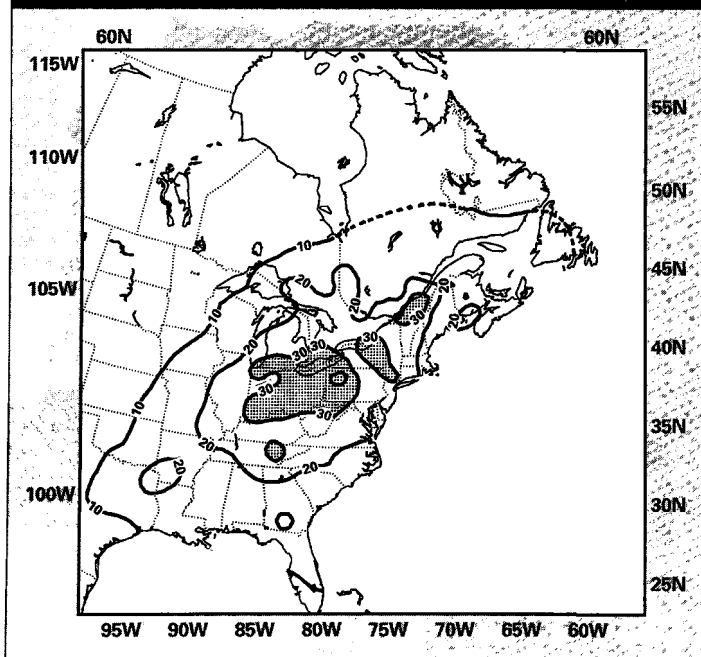
**Figure 7 1988 Wet SO₄ Deposition
Sea Salt Corrected (kg/ha/yr)**



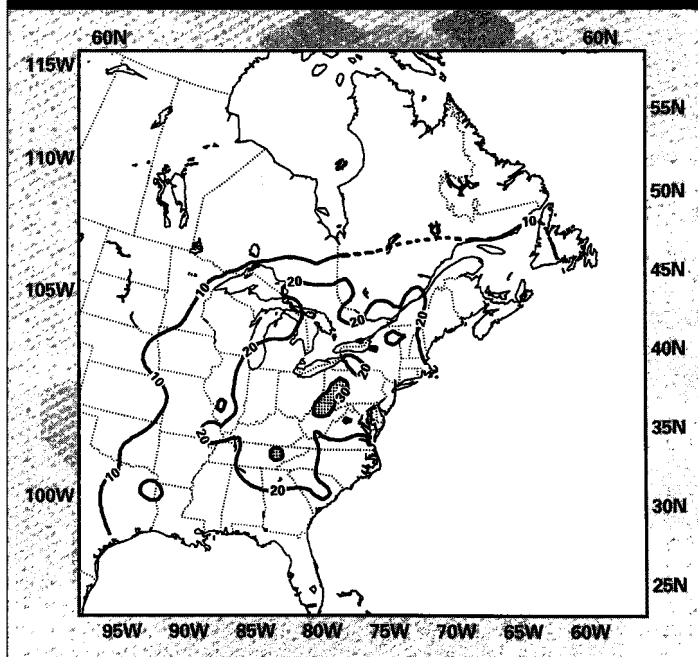
**Figure 8 1989 Wet SO₄ Deposition
Sea Salt Corrected (kg/ha/yr)**



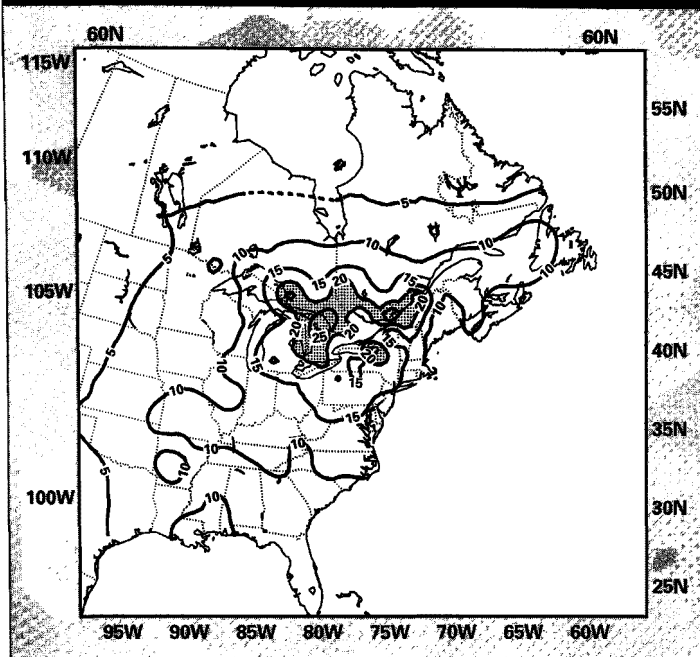
**Figure 9 1990 Wet SO₄ Deposition
Sea Salt Corrected (kg/ha/yr)**



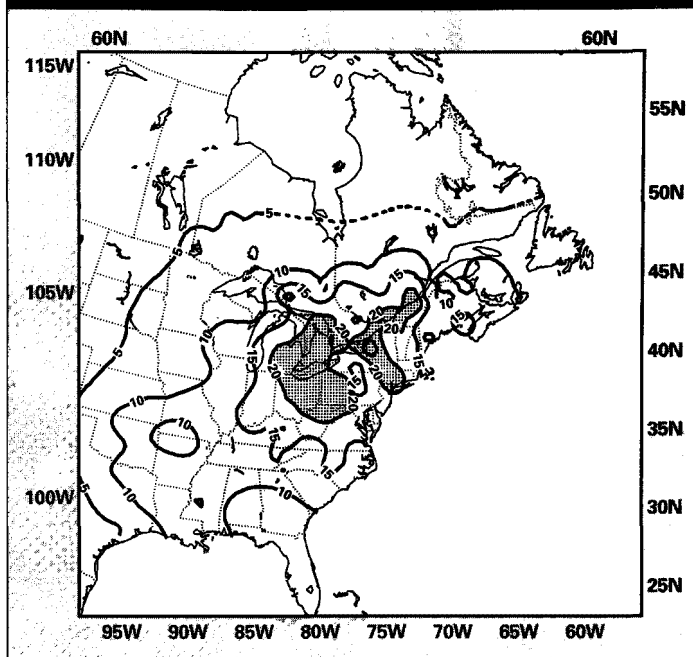
**Figure 10 1991 Wet SO₄ Deposition
Sea Salt Corrected (kg/ha/yr)**



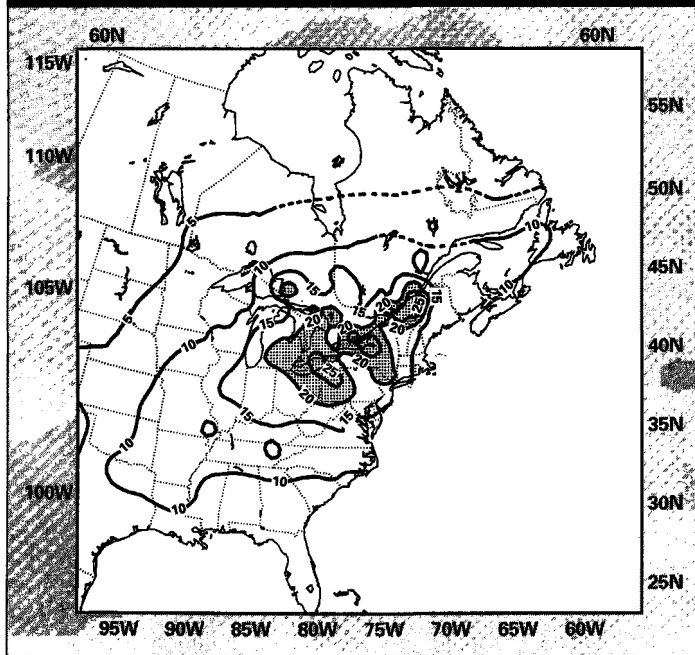
**Figure 11 1988 Wet NO₃ Deposition
(kg/ha/yr)**



**Figure 12 1989 Wet NO₃ Deposition
(kg/ha/yr)**



**Figure 13 1990 Wet NO₃ Deposition
(kg/ha/yr)**



**Figure 14 1991 Wet NO₃ Deposition
(kg/ha/yr)**

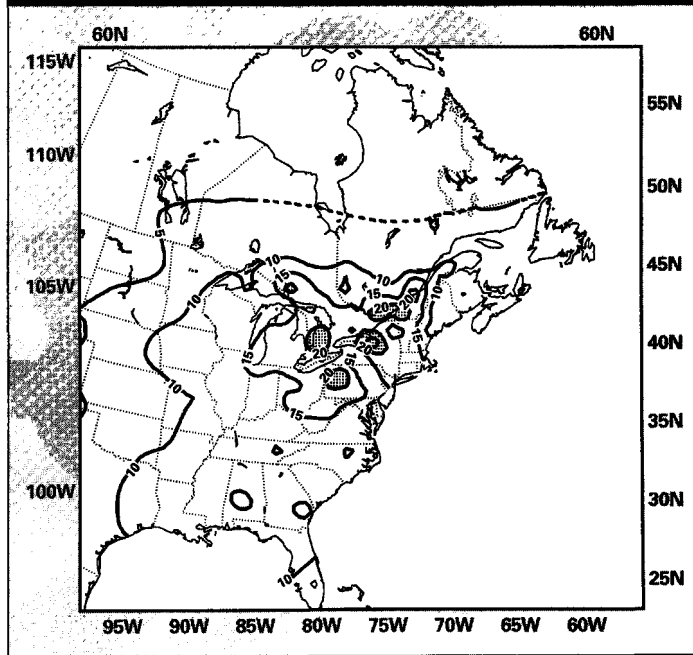
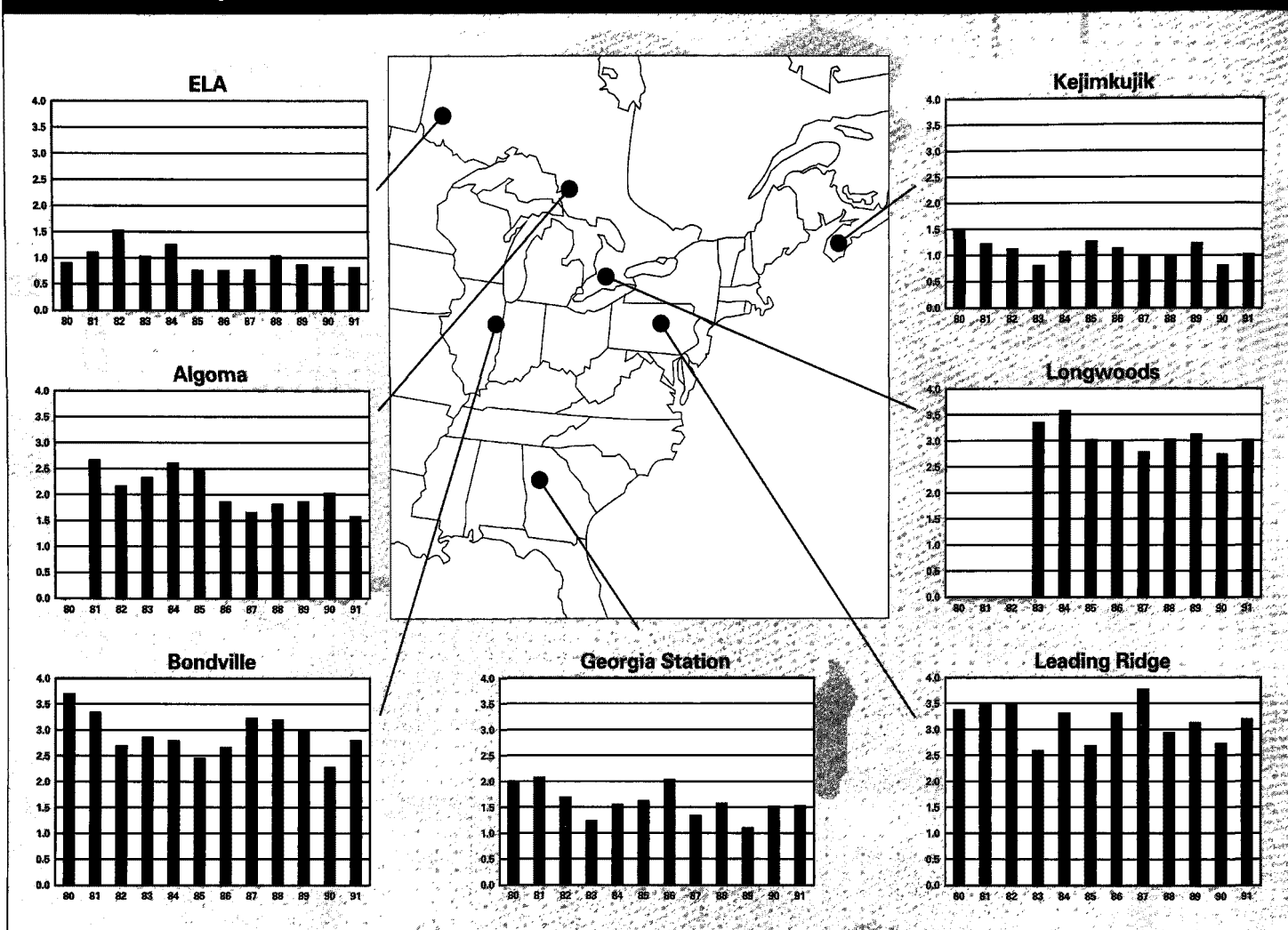


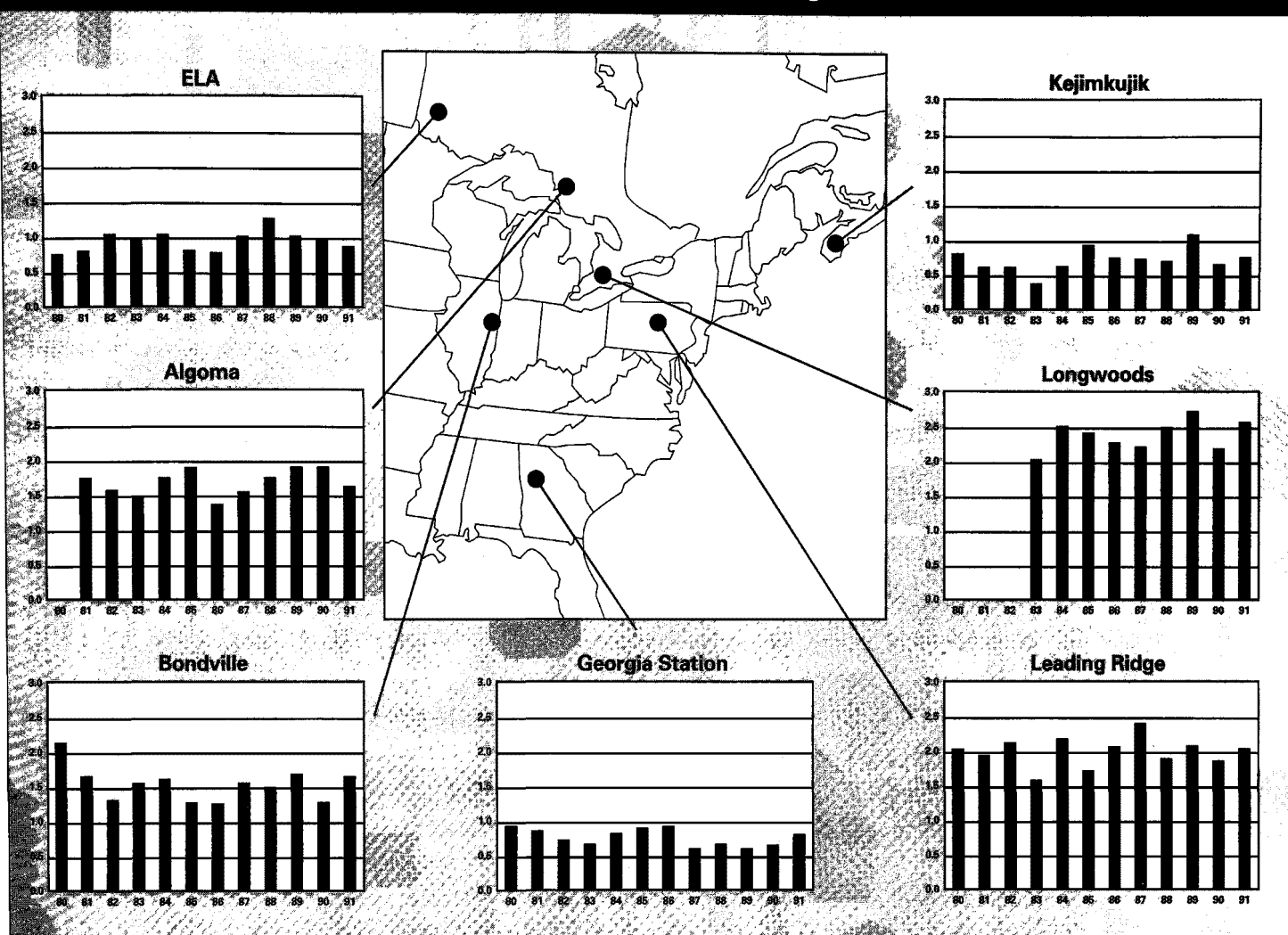
Figure 15 Precipitation Weighted Mean SO_4 Concentration, Sea Salt Corrected (mg/l)



Considering all 111 sites together, 31 percent (mostly in Nova Scotia and Newfoundland, a few in Ontario) are recovering. These sites show an increasing pH and/or acid neutralizing capacity (ANC) trends (regardless of the sulphate trend). Lakes within the Sudbury region of Ontario have also been recovering throughout the 1980s in response to emission reductions from local sources. If these lakes had been included in the statistical analysis, a greater proportion of Ontario's waters would have been classified in the recovering group. Forty-one percent of the sites showed no trend in pH or ANC and no change in sulphate concentration (i.e., from 1983 to 1991, their acidification status was stable). Thirteen percent (mostly in Nova Scotia and Newfoundland) exhibited stable pH and/or ANC but significantly increasing

sulphate. If sulphate continues to increase at these sites and the present compensatory mechanisms fail, these waters might eventually acidify. Fifteen percent of the waters (mostly in Ontario and Quebec) are continuing to acidify (declining pH and/or ANC) despite having stable or declining sulphate levels. Some of the water chemistry trends recognized by this analysis differ from those identified by earlier studies that used a different timeframe. In southwestern New Brunswick, 18 percent of 40 headwater lakes sampled in 1993 had negative ANC compared with 3 percent with negative ANC for the same lakes in 1986. This is to be expected, given the short monitoring period for which records are presently available for evaluation (i.e., short relative to the response times of many catchment processes). Moreover, the results show

Figure 16 Precipitation Weighted Mean NO₃ Concentration (mg/l)



that the regional responses of waters to reductions in SO₂ emissions are not straightforward. Only high-quality, long-term monitoring records will reliably quantify the chemical and biological responses to SO₂ control.

United States

About 80 low-ANC lakes and streams have been monitored in the northeastern and upper midwestern United States since the early 1980s as part of EPA's Long-Term Monitoring Program. Trends in surface water chemistry were calculated for each site through 1989.

Surface waters monitored during the 1980s are generally representative of low ANC systems in these regions, but they were not selected as a statistically representative sample of lakes and streams. Regional trends

monitoring began in 1991 in the Northeast and in 1993 in the Mid-Appalachians to evaluate changes in regional surface water chemistry in response to the emission reductions mandated by the 1990 CAA Amendments. Data from current regional monitoring studies will be available for future reports.

Sulphate concentrations declined in 50 of 53 waters monitored in the northeastern United States. Thirty-four sites (64 percent) had a statistically significant decrease in sulphate (at a 90 percent level of confidence), whereas none had a significant increase in sulphate. Given that sulphate deposition declined in the late 1970s and early 1980s, but has remained relatively constant since then, these results suggest a time lag between decreased deposition and decreases in surface water sulphate. Soils

that have historically become saturated with sulphate, due to high sulphate deposition, are now gradually losing sulphate.

In contrast, nitrate concentrations, increased during the period of record in all 24 of the lakes and streams monitored in two Northeast subregions: the Adirondack and Catskill Mountains of New York. Fourteen of these waters (58 percent) had a statistically significant increase in nitrate, while none had a significant decrease. Similar increases in nitrate did not occur in lakes in Vermont and Maine. Increases in nitrate in Adirondack and Catskill waters occurred even though no pattern is evident in trends in nitrate deposition (Figure 18). Current theories suggest that watersheds in the Adirondacks and Catskills may be moving toward nitrogen saturation. This is due to historically high nitrate deposition and a natural predisposition to nitrogen saturation (because of high soil nitrogen content and the presence of mature forests).

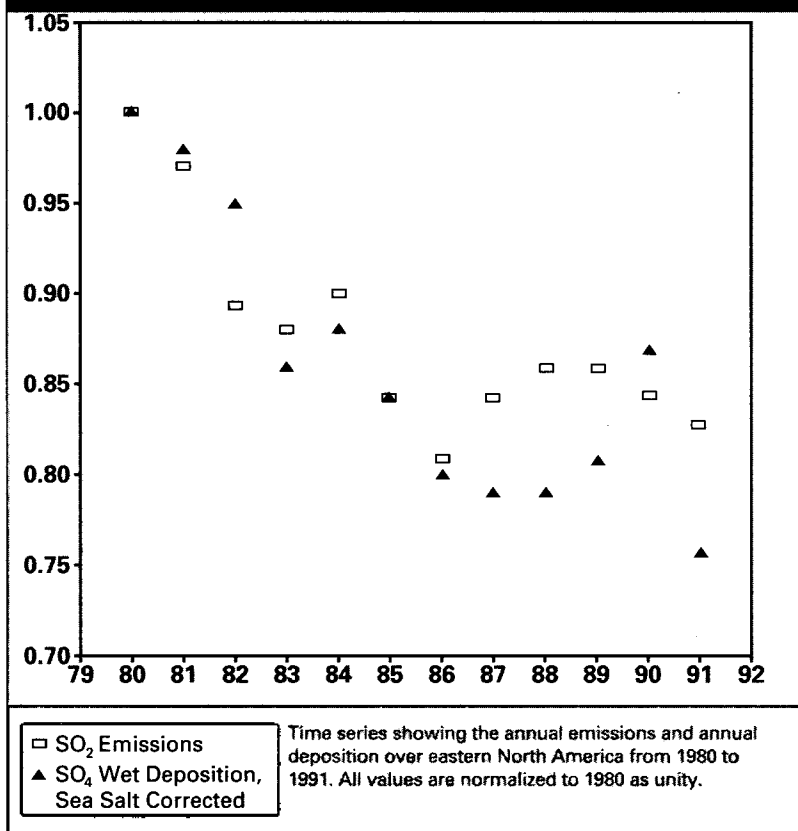
Trends in ANC, pH, and base cations in Northeast surface waters were not nearly as consistent as those for sulphate and nitrate; both increases and decreases occurred with no strong regional pattern. In the Adirondacks, 13 of 16 lakes (81 percent) had decreased ANC, but only 5 (31 percent) had a statistically significant decrease in ANC. In contrast, in New York's Catskills and in Maine and Vermont, 28 of 37 waters (76 percent) increased in ANC; nine sites (24 percent) had a significant increase in ANC. ANC, pH, and base cations are probably affected by several interacting factors, including decreased sulphate deposition and increased nitrate leaching in some areas (which may offset the benefits of declining sulphate), as well as shifts in base cation deposition, aluminum, and organic chemistry.

Long-term monitoring data are also available for 28 lakes in the Upper Midwest. There is some indication of a regional decrease in surface water sulphate during the period of record (16 lakes have decreased, 12 have increased, but all 8 of the statistically significant trends were decreases). Lakes had no measurable changes in nitrate, and there was no consistent pattern in pH, ANC, or base cation trends. Many of the lakes monitored in the Upper Midwest are seepage lakes (with no tributary streams), which receive water directly from precipitation and ground water. Such lakes tend to have long water-turnover times, and thus longer response times. In addition, drought conditions in much of the Upper Midwest during the 1980s complicated interpretation of lake responses to changes in sulphate deposition and aluminum and organic chemistry.

Biological Responses

Many studies have demonstrated that acidification can and has adversely affected aquatic biota. For example, entire lakes were experimentally acidified — two in the Experimental Lakes Area of Ontario and one in northern Wisconsin — to increase understanding of both the direct and indirect effects of acidification on aquatic communities. Changes in lake biology occurred at each pH level over a pH range of 6.1 to 4.7. Acid-sensitive species disappeared and were replaced by fewer acid-tolerant species, resulting in reduced species richness and simplification of the lake's food web. One of the most visible acidification

Figure 17 Normalized Annual SO₂ Emissions and Sulphate Wet Deposition, Sea Salt Corrected, Over Eastern North America



effects was the growth of thick mats of filamentous benthic algae, which covered the shallow, littoral zone beginning when the pH dropped to 5.6. Acidification also caused fish reproductive failures and population declines, primarily as a result of increased mortality of young fish. Analyses of monitoring and survey data have confirmed fish population losses due to acidification from some surface waters in many parts of northeastern North America. For example, in the Adirondack region of New York, 16 to 19 percent of the lakes with adequate historical data appear to have lost one or more fish species as a result of acidification. The estimated number of lakes in Ontario that have either lost their sport fish populations or have residual nonreproducing populations is 228: lake trout, 119; brook trout, 43; smallmouth bass, 52; and walleye, 14. One third of the available Atlantic salmon habitat in Nova Scotia has been lost since 1950 because of acidification. This is a loss to the salmon fisheries of about 9,000 to 14,000 fish per year and is almost equal to the current annual catch.

Information on the recovery of biological communities following improvements in water quality has also become available in recent years. After experimental acidification, the pH in one lake was allowed to gradually increase from 5.0 in 1983 to 5.8 in 1988. Several biotic components recovered rapidly. The extensive mats of filamentous algae, which first appeared at pH 5.6 during acidification, disappeared at pH 5.8. Fish resumed reproduction at pHs similar to those at which reproduction ceased during acidification. Many species of insects and crustaceans that had disappeared during acidification returned.

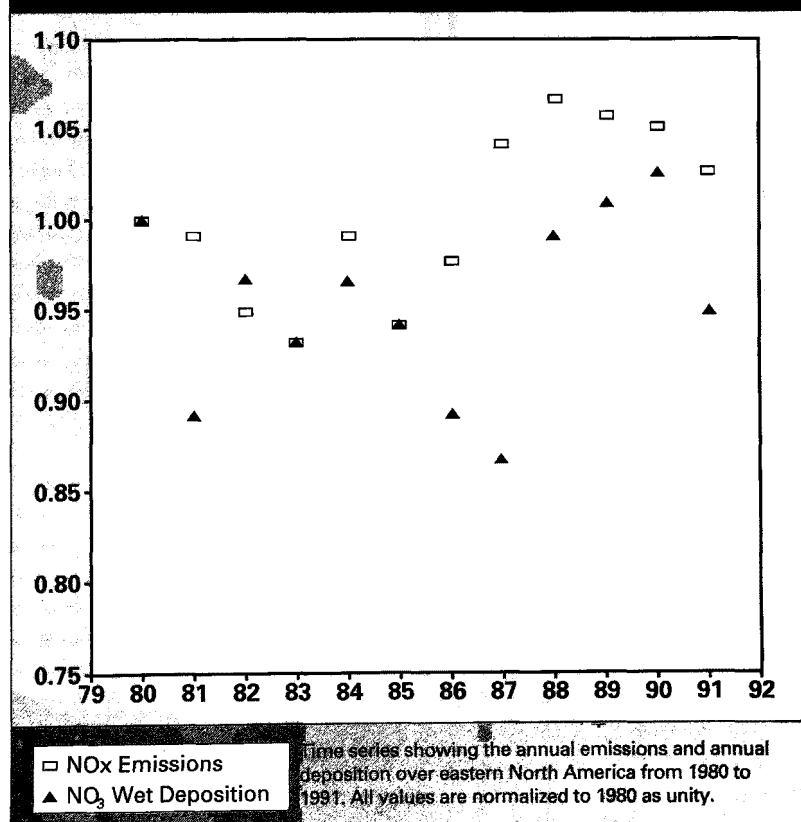
Trends data for lakes around Sudbury, Ontario, also provide evidence of biological recovery. Reductions in emissions of SO_2 and trace metals from the Sudbury smelters during the 1970s and early 1980s have resulted in substantial improvements in water quality in many surrounding lakes. As lake pH increased and concentrations of toxic metals declined, zooplankton and phytoplankton species richness increased and some acid-sensitive species of insects and crustaceans, such as *Epischura lacustris*, reappeared. Organisms with low dispersal activity, however, such as the amphipod *Hyalella azteca*, have not yet recolonized these lakes even though pH levels

have met or exceeded those required for natural populations for several years. Likewise, natural recolonization by fish is likely to be limited and slow, except where lakes are connected directly to unaffected lakes or other areas of refuge. Stocking, however, re-established a naturally reproducing population of brook trout in Joe Lake; brook trout had disappeared from Joe Lake in the late 1950s to early 1960s. Whitepine and Nelson lakes near Sudbury supported remnant populations of large, old lake trout, which resumed reproduction when pH increased to 5.6. Thus, results from these studies suggest that many biological populations will recover or can be re-established relatively rapidly (in less than a decade) when acidification is reversed.

Historical Lake Acidification in North America

Evaluation of the fossil remains of aquatic organisms buried in lake sediments can provide indirect evidence of past lake chemistry

Figure 18 Normalized Annual NO_x Emissions and Nitrate Wet Deposition Over Eastern North America



since certain species tolerate only a limited range of conditions. Recent studies show that lakes with low base cations and ANC are the most likely to have experienced acidification due to acidic deposition, whereas lakes with historically higher pH levels have exhibited little change or even become more alkaline. For example, in a comprehensive study of this type conducted in 1991, 80 percent of a target population of Adirondack lakes with present-day $\text{pH} \leq 5.2$ have undergone large declines in pH and ANC and concomitant increases in aluminum, but only 30 to 45 percent of lakes with current pH between 5.2 and 6.0 were so affected. Similarly, all lakes in the Sudbury area of central Ontario that presently have $\text{pH} < 6.0$ show evidence of extensive past acidification, whereas those with current pH between 6.0 and 7.0 have changed little from their historical pH levels.

Quebec Lake Survey

Between 1986 and 1990, the chemistry of 1,253 Quebec lakes within the 10 to 2,000 hectare(ha) size class and south of 51°N was measured. At the same time, fish surveys were completed on 253 lakes from the 20 to 200 ha size class. The lakes chosen for the chemical sampling were statistically representative of the lake population within the size class, with the lakes covered by the fish survey being a subset.

Results of the chemical survey show that 19 percent of the lakes (or 6,150 of the total population of 31,800 lakes in the size class) have $\text{pH} \leq 5.5$, and 52 percent (16,500 lakes) have $\text{pH} \leq 6.0$. These low pH lakes are located mostly south and east of Noranda, north of Quebec City, and in northeastern Quebec. Sulphuric acid (H_2SO_4) introduced through the atmosphere is mainly responsible for the acidity of lakes in southwestern Quebec, while the acidity of northeastern lakes is due mainly to natural organic acids. Hence, chemical recovery of acidic lakes following emission reductions will occur primarily in southwestern Quebec.

Fish surveys conducted in the southwestern regions where H_2SO_4 is of greatest importance showed that the number of species present decreases with decreasing pH: from 100 percent of all 32 identified species at $\text{pH} = 6.0$, to 72 percent at $\text{pH} = 5.5$, to 28 percent at $\text{pH} = 5.0$, and to 0 percent at $\text{pH} = 4.5$.

At $\text{pH} \leq 5.0$, fish reproduction is limited and younger age classes are often absent.

Implementation of control measures at the Noranda smelter in 1989 has resulted in a decrease of more than 60 percent in SO_2 emissions compared with 1980. Compared with 1982 levels, 1991 sulphate concentrations in lakes near the smelter have decreased by >50 percent, and lakes >200 km away have decreased 0 to 20 percent. There was no change in ANC during this time period, however. Although the decrease in sulphate is encouraging, findings indicated that repetition of the lake survey in the mid-1990s will be needed to verify an attendant improvement in the acidity status of these lakes.

Episodic Response Project

Aquatic ecosystems can be adversely affected not only by chronic acidification, but also by short-term (episodic) decreases in pH that occur during snowmelt and rainstorms. EPA conducted an Episodic Response Project (ERP) in 1993 that studied the effects of episodic acidification on fish in 13 streams in the Adirondack and Catskill Mountains in New York and the Northern Appalachian Plateau in Pennsylvania.

ERP results clearly demonstrate that episodic acidification can have long-term adverse effects on fish populations. Streams with suitable chemistry during low flow, but low pH and high aluminum levels during high flow, had substantially lower numbers and biomass (weight) of brook trout than were found in non-acidic streams. Streams having acidic episodes showed significant mortality of fish. Some free-living brook trout avoided exposure to stressful chemical conditions during episodes by moving downstream or into areas with higher pH and lower aluminum. This movement of fish only partially mitigated the adverse effects of episodic acidification, however, and was not sufficient to sustain fish biomass at levels that would be expected in the absence of acidic episodes. These findings indicate that stream assessments based solely on chemical measurements during low flow conditions will not accurately predict the status of fish communities in small streams.

Atmospheric deposition of sulphate and nitrate contributed significantly to the

occurrence of acidic episodes, with low pH and high aluminum levels, in the ERP streams. In addition, naturally occurring organic acid from decomposing vegetation also commonly contributed to episodic pH depressions. Sulphate and nitrate pulses, however, augment these natural processes to create episodes with lower pH and higher aluminum concentrations than would occur from natural processes alone. Yet even in streams with high enough background or base flow concentrations of sulphate and nitrate to cause natural pH depression, episodic atmospheric deposition still causes a significant additional depression of the pH. This effect is noted even though the apparent stream concentrations of sulphate and nitrate remain relatively constant during the episode.

Nitrogen Deposition and Water Acidification

While SO₂ emissions have declined throughout North America, NO_x emissions have remained fairly constant. Existing levels (or increases) of nitrogen deposition over the long term could eventually undermine the ecological benefits derived from the SO₂ control programs.

The most important technical question concerning nitrogen-based ecosystem acidification is the mobility of nitrogen. When nitrogen contributes to acidification, the nitrogen deposition in excess of that immobilized for the nutrition of terrestrial and aquatic biomass is leached into ground and surface waters as nitrate. This situation implies a change in the "normal" functioning of the nitrogen cycle from a virtually closed internal cycle to an essentially open cycle where excess nitrogen is leached — a state commonly referred to as nitrogen saturation. The development of nitrogen saturation involves a complex interaction of processes in a watershed's nitrogen cycle, not just an increase in atmospheric input. Increasing or chronically high nitrate concentrations in runoff waters or alteration of characteristic seasonal patterns indicate that a watershed may be at or progressing toward nitrogen saturation and nitrogen-based surface water acidification. In addition to concerns about acidification, there are concerns that high nitrate concentrations may possibly contribute to eutrophication (increase in input

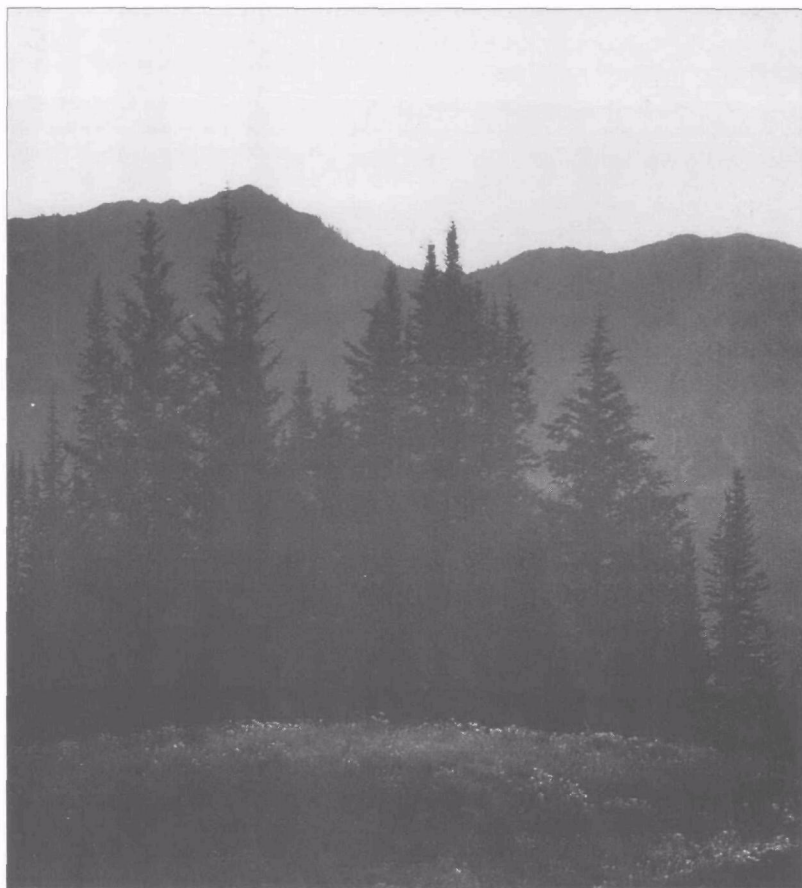


of nutrients leading to a growth in algae) in estuarine areas and near coastal waters. High nitrate concentrations alone are believed unlikely to cause freshwater eutrophication.

Lake survey data from eastern Canada and data from long-term monitoring projects in the 1980s and 1990s in the United States confirm that there are watersheds in both countries that are likely retaining less nitrogen than they did in the past. Nitrate can be a major contributor to episodic acidification, particularly during spring snowmelt when biological uptake of nitrogen is minimal. Increasing trends in nitrate have been observed in some lakes and streams in the Adirondack and Catskill Mountains of New York, the Mid-Appalachian region, Ontario, and Quebec. These locations also receive some of the highest levels of nitrogen deposition. Although the link between saturation and deposition must still be considered circumstantial, preliminary model analyses suggest that high levels of nitrogen deposition can reduce the time required for watersheds to reach nitrogen saturation. Future aquatic research and monitoring would be necessary to better quantify which ecosystems are becoming saturated and why, and to determine deposition levels at which nitrogen saturation occurs.

Forest/Soils Studies

Research has shown that acidic deposition directly affects tree foliage and soil chemistry and that it has contributed to the decline of high-elevation spruce forests in the eastern



United States. Acidic deposition is suspected as a contributing factor in the increased dieback and decline in birch forests in eastern Canada. Monitoring of forests, research on ameliorating symptoms, and studies on forest productivity continue in both countries.

Forest health in both countries has been assessed by comparing the crown condition, mortality, and growth rates using various monitoring systems. Methods and results varied. All systems showed that changes in crown condition and mortality reflected the combined effects of insects, diseases, and air pollution. Growth rates in one monitoring system studied were found to correlate with levels of pollutant deposition on soils where nutrients were limited.

A number of Canadian and U.S. networks have been established to monitor forest health by assessing damage to forests caused by acid deposition. Results to date indicate that there is no large scale decline in the health of Canadian and U.S. forests that can be directly attributed to acidic deposition.

Joint Studies — North American Maple Project

This monitoring program was established in 1988 by Canada and the United States in response to reports of widespread decline in sugar maples. The program measures the condition of tree crowns in managed (sugar bush) and unmanaged (non-sugar bush) stands. Results from 1988 to 1992 show that over 90 percent of the trees sampled were healthy, and mortality rates were normal. The condition of sugar maples in sugar bushes was not significantly different from that of sugar maples in unmanaged stands, nor was tree condition affected by different zones of deposition. Changes in tree condition were caused by natural factors, specifically drought and insects. The monitoring system tracked these events and the data show that trees recovered from these stresses after two to three years. Other Canadian and U.S. networks designed to monitor forest health have looked for damage to forests caused by acid deposition.

Canada — National Networks

In 1984, Forestry Canada's Acid Rain National Early Warning System (ARNEWS) was established to monitor forest health. ARNEWS is designed to detect forest damage by assessing a common set of measurements from permanent sample plots, supplemented by additional surveys.

U.S.-State Networks — Forest Health Monitoring

The U.S. Forest Health Monitoring (FHM) Program is a cooperative effort between federal and state resource agencies to collect, analyze, and report on the health of all forested lands in the United States. The program has three objectives: (1) detection monitoring; (2) evaluation monitoring; and (3) intensive site ecosystem monitoring. Over 1,000 plots in 14 states have been studied and results through 1992 do not show any extensive unexplained forest or tree decline. The system is sensitive enough to have detected the effects of known pests, such as American beech bark disease and hemlock looper.

U.S.-State Networks — Hardwood Tree Health Survey

The State of Vermont first conducted a statewide survey of hardwood tree health in 1986, reporting that 22 percent of the upper canopy hardwood trees had >10 percent crown dieback, and 2.9 percent of the standing hardwood trees were dead. By 1991, the percent of upper canopy hardwood trees with >10 percent dieback had declined to 14 percent. Nearly 25 percent of the trees that had >10 percent dieback in 1986 were dead by 1991 (5.5 percent of the standing hardwood trees). The study concluded that the health of surviving trees had improved from 1986 to 1991 because of decreased insect populations and increased precipitation since 1986.

Responses to Air Pollution Studies

Canada — White Birch Decline

Severe foliage browning and premature leaf-fall in southeastern New Brunswick in the mid-1980s have resulted in serious deterioration and mortality of white birch. The damage was not caused by insects or diseases, but occurred in areas with a high frequency of summer fog that has been measured below pH 3.0. The sensitivity of birch was confirmed by clonal transplant tests. Since 1989, there has been a reduction in foliage browning and a regreening of surviving trees. The improvement in the condition of surviving trees since 1989 is correlated with a reduction in the frequency of fog, indicating a cause-and-effect relationship between damage and acid fog. A similar condition may be developing in the Wawa area of Ontario.

Canada — Ontario Maple

Observations of maple decline have been monitored by health surveys focusing on visual symptoms. In addition, the Ontario Ministry of the Environment and Energy has also examined the growth rates of maples throughout the province. Dendrochronological (tree ring growth) data have showed that sustained reduction in growth has occurred concurrently with increasing pollution levels. Growth reductions were in proportion to the wet sulphate and nitrate deposition being received by each study site. Reductions of

forest health were greater on soils with poor buffering capacity. Tree growth, however, was also affected by climatic stresses and outbreaks of defoliating pests.

United States — Red Spruce Decline

Unexplained increases in mortality of high-elevation red spruce in the eastern United States were reported in the early 1980s. At the time, examination of the climate, pest history, and stand dynamics did not explain the change in spruce condition. Research begun in the later part of the 1980s has, to date, indicated that winter injury to spruce foliage is clearly associated with growth damage and mortality to trees. Both laboratory and field evidence indicated that increased levels of acidic deposition associated with cloud water increased the susceptibility of red spruce foliage to winter injury. Aluminum interference with plant nutrient uptake and increased levels of cation leaching from nutrient-poor ecosystems were documented in some ecosystems. The level of acidic deposition in these ecosystems is consistent with the level required to cause damage.

Canada — Critical Loads for Forest Soils

Canada is developing critical loads for forests using a dynamic model to predict chemical and physical biomass (weight) changes in upland forests as a result of acid sulphate/nitrate loading. The term critical load refers to a quantitative estimate of the maximum exposure to a pollutant that a soil can sustain without significant damage. The model forecasts long-term reductions in site productivity at current levels of pollution. The model will be used to estimate critical loadings for Canadian forests. Numerical estimates are expected to be available for public discussion by the end of 1995.

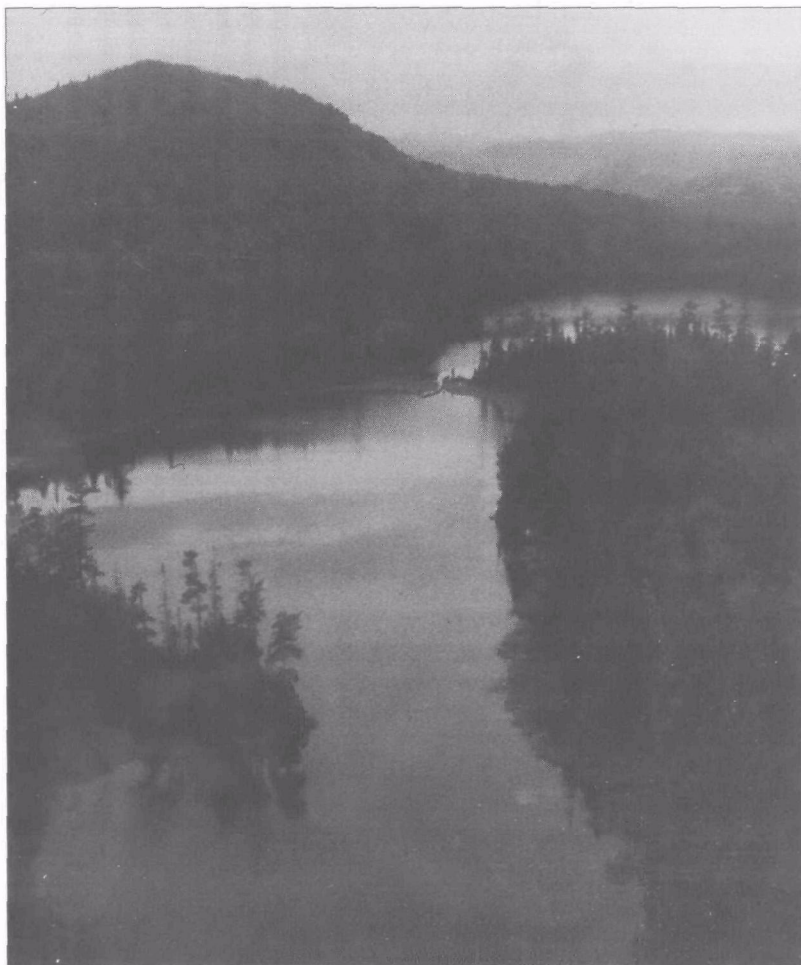
Canada — Remediation Studies

One hypothesis concerning the reason for forest decline is that tree nutrition is impaired by acid deposition, which leaches base cations, principally potassium, calcium, and magnesium. Consequently, during the period 1988 to 1991, fertilization treatments for restoration of

soil cation levels were applied to several sites in Ontario and Quebec with declining forests. Generally, declining trees showed a greater response than healthy trees, but the response to the fertilizer treatments varied among sites and among declining and healthy trees. This indicates that the causes of decline and the response to fertilizers were specific to individual sites. Thus, there would appear to be little benefit in fertilizing extensive areas to avoid damage from air pollutants.

Canada-United States — Effects of Nitrogen Deposition

Continued deposition of nitrogen will increase the amount of nitrogen in forest ecosystems and, depending on the nature of the soil, will increase the capacity for nitrification and the movement of nitrogen to surface water. Vegetation growth can be expected to increase where nitrogen is limiting and where deposition does not interfere with nutrient uptake



and/or introduce additional stresses. Continued nitrogen deposition will affect mycorrhizae (fungi), insects, pathogens, and wildlife. Research on nutrient cycling is continuing in both countries to assess long-term impacts of increased nitrogen deposition on soils and vegetation.

Visibility

Annex 1, Section 4 of the Canada-United States Agreement on Air Quality recognizes that the prevention of significant air quality deterioration and the protection of visibility are important to both countries. This annex requires the United States to apply Part C of Title 1 of the U.S. Clean Air Act to sources that would cause significant transboundary air pollution. The annex requires Canada, by January 1995, to develop and implement means of preventing significant air quality deterioration and protecting visibility comparable to those called for in the U.S. legislation. Since the last Progress Report, several areas of research have been initiated in Canada to meet this obligation.

Canadian Airport Visibility Data

A technique has been developed in Canada to extend the range for capturing airport visibility data. The new approach enables the development of visibility estimates at distances greater than 24 km (15 miles). Maps of the visibility across Canada by season and by year give a historical record of median visibility in Canada since 1951. This will serve as the baseline against which visibility changes in the future will be determined. Efforts are under way to merge the historical visibility data sets in Canada and the United States.

Visibility Reduction Testing

Environment Canada has been testing techniques by which visibility reduction can be linked to the aerosol types that scatter and absorb light. During the 1992 Egbert Aerosol Study, measurements were made of particle size. These in situ measurements were made at the same time and place as light scattering measurements. The results are being used to determine the amount of particle growth attributable to humidity, aerosol scattering and absorption properties, and a radiation balance for the scattering process.

Monitoring Aerosols

In addition to the above studies, routine sampling of visibility-reducing aerosols was initiated in Glacier/Waterton Lakes International Park by Canada and the United States. One sampling site is now operating on the Canadian side at Waterton, Alberta, and one on the United States side in Glacier National Park.

In British Columbia, a significant effort to understand visibility reduction in the lower Fraser Valley (near Vancouver, B.C.) is under way. The Pacific '93 field experiment was expanded to include aerosol movement in this region. In addition, the Province of British Columbia, in cooperation with the regional offices of Environment Canada and the University of British Columbia, are analyzing data from 10 Interagency Monitoring of Protected Visual Environments (IMPROVE) sampling stations located in the lower Fraser Valley. While the intensive phase of this measurement program lasted only for the summer of 1993, an ongoing program of monitoring in the valley involving in situ and optical sampling will be carried on in the future.

Modelling Visibility Changes

In the past, simple sulphate dispersion and transformation models were used to estimate ambient sulphate concentrations that influence visibility. Water vapour, however, also has been found to contribute significantly to light extinction. Thus, computations of visibility degradation need to consider the availability of water vapour simultaneously with the amount of sulphate. More complex models have been developed to produce new estimates of visibility degradation attributable to sulphate aerosols in Canada and the eastern United States. These new models combine relative humidity predictions from meteorological models with data from the chemistry and transport models to more accurately predict the amount of light extinction (a measure of visibility reduction).

U.S. estimates of the current visibility degradation in the East (using a perceptible measure of degradation, termed deciview) and future visibility degradation, assuming full implementation of Canadian and U.S. control programs, have been calculated. This assessment indicated that a noticeable improvement in visibility

should occur across the eastern United States (Figure 19) for the 1985 base year, with most of the change occurring in the warm seasons.

Materials

While joint effects research is not currently being conducted concerning the degradation of materials due to acid rain, both countries participate in a United Nations-ECE Cooperative Programme entitled "Effects on Materials Including Historic and Cultural Monuments." The following presents an overview of the main findings after four years of an exposure program that started in 1987.

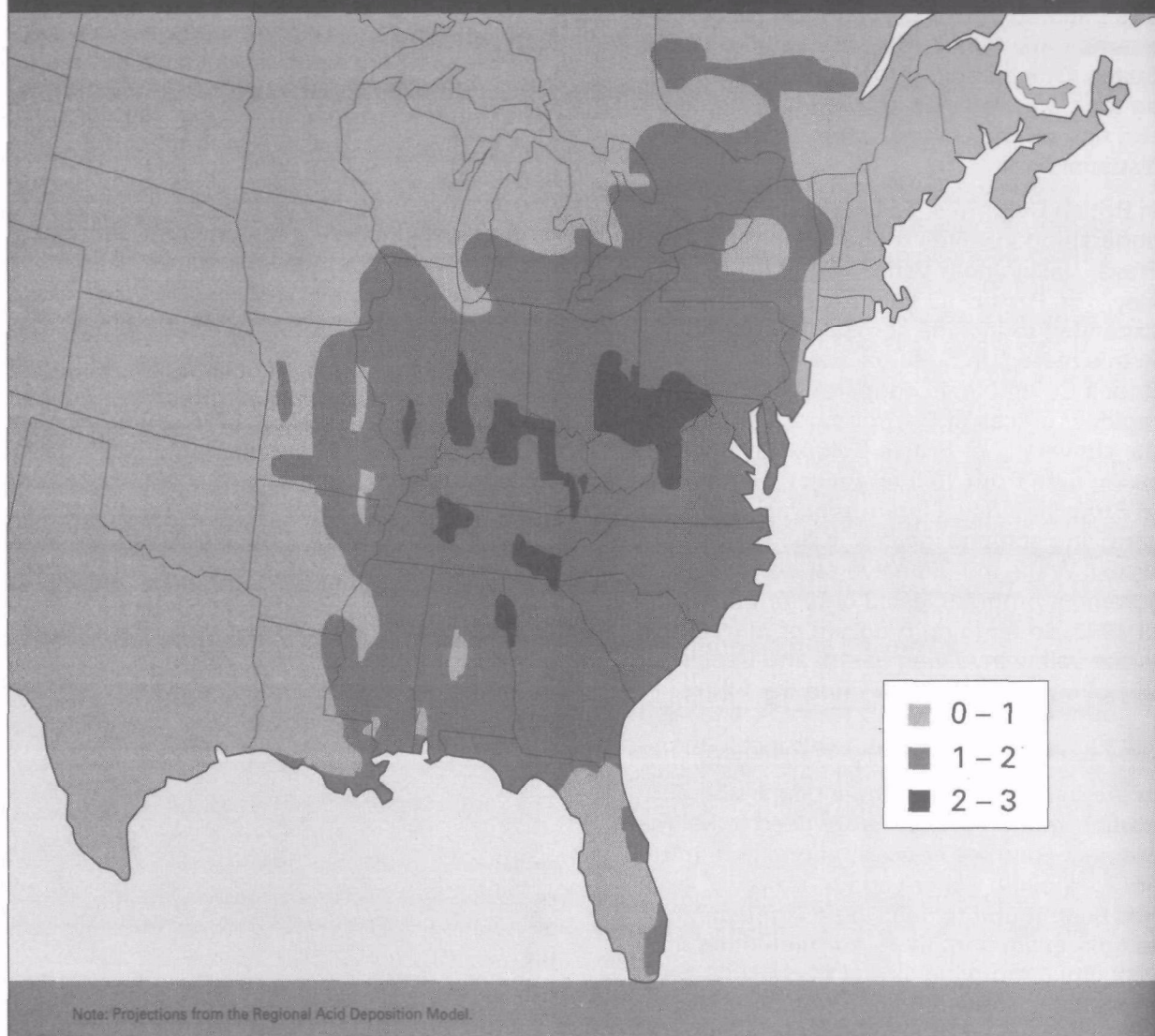
As expected, for all materials exposed, great differences in the corrosion rates have been measured, and the observed degradation is more severe at polluted sites than at rural sites with background pollution. For some materials, like carbon, steel, or nickel, the effects of pollutants are obvious after the first year; for other materials like copper or paints, the effects appear only after four years. For most materials, SO₂ has the strongest corrosive effect. Wet deposition expressed as rain acidity or conductivity has a corrosive effect on certain materials, which, in general, is less severe than the effect of dry deposition.

The dominant effect of SO₂ is evident for zinc, which is commonly used to coat steel to reduce corrosion. Sheltered and unsheltered copper (e.g., shed roofs, decorative items) also have a high corrosion rate during the first year at rural sites. At polluted sites, corrosion increases after the first year due to the formation of a rough and porous layer that accelerates the corrosion. Sheltered and unsheltered cast bronze (commonly used for statues) are less sensitive to humidity than copper.

The analysis performed so far has shown that SO₂ significantly contributes to the degradation of unsheltered sandstone and limestone materials, commonly used in buildings and monuments. The damaging effects of acid rain on wood panels with alkyd paint and those panels with primer and acrylate paint are not yet well understood.

Materials (e.g., nickel, copper, and tin) react differently to SO₂. SO₂ appears to corrode nickel extensively. While the evaluation of copper and tin is not yet completed, it appears

Figure 19 MODELLED IMPROVEMENT IN VISIBILITY FOR THE AVERAGE DAY, 1985-2010 (Improvement is expressed in terms of deciviews)



that SO_2 does not have the same strong corrosive effect on tin as it does on many other materials. The amount of copper corrosion seems to be related to the conductivity (e.g., higher SO_2 concentration) of rain.

These results, obtained for plain flat samples, show clearly that pollutants, particularly SO_2 , enhance the degradation of building materials exposed to the atmosphere. In northern climates, materials already incur heavy degradation due to, for instance, extreme temperatures, many freeze-thaw cycles in winter, and considerable humidity in summer. The further degradation causes evident damage in cities like Montreal, where even newer bronze statues have evidence of the typical stages of degradation (e.g., streaked

brown, black, blue-green surfaces resulting from the combined action of acid deposition, de-icing salts, corrosive dust). Older limestone buildings are either washed by acid rain and lose their details or they retain most of the deposited pollutants in protected areas and then form a crust of gypsum that forms scales and then flakes off the surfaces. Some recently constructed metallic structures embedded in cement have corroded to the point of splitting the concrete.

As confirmed by the results of the ECE Cooperative Programme, even at low deposition loads all materials are subject to degradation due to the pollutants. Materials in Canada might be more susceptible to pollutant degradation because the complex interaction of

pollutants with harsh climactic elements causes faster degradation than in locations with more favourable climates but identical pollution levels.

Human Health

The major new finding since the issuance of the 1992 Progress Report is that long-term ambient exposures to acid aerosols have been linked to a decrease in lung function in children. In addition, significant progress has been made on methods to measure acid aerosols and on elucidating possible mechanisms involved in health effects. New research initiatives on the effects of ozone-acid mixtures have uncovered complex relationships suggestive of a possible synergism.

Preliminary results of a five-year study of 24 North American cities, designed specifically to determine the health risk posed by long-term exposure to ambient acidic aerosols, have recently been published. The study included administering a questionnaire and lung function tests to more than 10,000 children between the ages of 8 and 12. In each community, acid aerosol monitoring was performed for one year. The results of the study indicate a strong statistical association between decreased lung function and long-term exposure to ambient acidic aerosols. The annual mean strong acidity in cities ranged from 0.5 to 52 nanomoles/m³. Previous studies have suggested possible adverse health effects due to long-term exposures of airborne acidity, but they had not measured ambient acidity directly. The independent effects of ozone were also assessed, and they were found to be small. These data provide further evidence that airborne particulate matter, specifically acidic particles, have a detrimental effect on normal lung function, growth, and development.

Human clinical studies have examined the short-term effects of acidic aerosol exposures and have generally focused on asthmatics as a sensitive population. These studies suggest that asthmatics may be more sensitive to short-term high-acid aerosol exposures. Further work is in progress to determine the extent of this association.

Although the effects of H₂SO₄ on clearance of particulates from the lung has been recognized, new studies in animals have expanded the knowledge base by showing that H₂SO₄

inhibits the ability of lung defence cells to kill bacteria; a significant problem in people with chronic bronchitis is lung infection. Earlier animal studies gave rise to a hypothesis that acidic aerosols may cause chronic bronchitis if exposures are sufficiently high for extended durations. Data from the 24-city study indicate significant differences in acute bronchitis between high- and low-acid communities. Also H₂SO₄ alters the biochemistry of mucus. This constellation of effects is poorly understood at present, but represents an area of concern.

New research has illustrated the importance of acid aerosol composition and the number of particles, in addition to the mass of hydrogen ion. Acid sulphate aerosols in the ambient air are a mixture of H₂SO₄ and ammonium bisulphate (NH₄(H)SO₄). Several studies in humans and animals have shown that H₂SO₄ is more potent, but the reasons are only now becoming understood. Even at equivalent hydrogen ion (H⁺) concentrations, H₂SO₄ was more potent than NH₄(H)SO₄. Other studies using guinea pigs showed that responses were dependent on both number concentration and mass concentration of H₂SO₄. These interdependencies may be responsible for some of the anomalies within the acidic aerosol database; they indicate that monitoring to predict effects needs to encompass more than mass of H⁺. Knowledge of exact causative factors associated with the aerosol could be important to the development of effective control strategies.

Interactions of ozone and H₂SO₄ were studied in 1993 as part of the development of a revised *U.S. Ozone Criteria Pollutant Support Document*. The results show that the interaction is dependent on the exact nature of the exposure and the endpoint. Even when one endpoint is examined, both antagonism and synergism have been observed, depending on the concentrations of ozone and H₂SO₄. In addition, ultra-fine H₂SO₄ caused more effects than fine H₂SO₄ in mixtures with ozone.

Acidic aerosols are a subfraction of ambient total suspended particulate matter. Recent ambient air monitoring data from a number of studies have demonstrated that acidic aerosols are concentrated in the fine (<2.5 µm) and ultra-fine (<0.1 µm) fractions (µm=micrometre). Because of their size, these aerosols are more likely to enter the respiratory system and bypass many of the body's natural defence mechanisms.

Significant progress has been made in characterizing personal exposures to particulate matter, including acidic aerosols. This information will be important in developing exposure estimates and assessing risks resulting from ambient acidic aerosol concentrations.

In summary, many of the new findings raise important questions concerning the potential health risk posed by ambient airborne acidity. The data confirm the potential for ambient acidic aerosols to affect lung health in children and for important interactions between acidic aerosols and other ambient pollutants to adversely impact on human health. The impact of and regulatory issues related to acidic aerosols will be considered under the technical/peer reviews for ambient particulate matter in standard/guideline setting by the respective agencies in both countries.

QUALITY ASSURANCE

A variety of activities are being carried out to ensure that the data collected under both countries' programs are comparable and have credibility. For example, routine laboratory comparison studies are being conducted to ensure that the data produced for terrestrial, atmospheric, and aquatic programs are comparable. For the terrestrial program, six studies have been completed, and they show continual improvement in the laboratory measurement process. The most recent study included 23 laboratories analyzing plant tissues for metals and nutrients.

Similarly, three comparisons are being carried out annually to support the atmospheric and aquatic programs. Laboratories are requested

to analyze about 25 different constituents in 10 different water samples. These test samples include natural rainwaters and soft surface waters collected from Canadian and U.S. acid rain watersheds. Thirty-three studies have been completed since December 1982, with over 130 Canadian and U.S. laboratories participating in the studies. The results of these studies are maintained on a database and are available for further analysis.

In other activities, sampling equipment has been co-located to compare Canadian and U.S. measurement techniques. At Egbert, Ontario, almost two years of CAPMoN and NDDN measurements are available. Median values associated with all measurements collected from the fourth quarter of 1990 to the third quarter of 1992 are listed in Table 5. The NDDN and CAPMoN differences are very small (less than or equal to the precision determined for collocated sites within NDDN) for sulphate, ammonium, and total nitrate. Larger differences are noted for SO₂.

An expansion of this activity is now under way. Wet deposition sampling equipment was installed at Scotia Range, Pennsylvania, during the first quarter of 1993. This site was selected because it will permit comparison of all three major wet deposition networks in North America. Precipitation samples are collected according to network-specific schedules (NADPN/NTN and NDDN are weekly and CAPMoN is daily) and analyzed by the network laboratories. There is no sample splitting among laboratories. This effort represents the best chance for assessing overall network comparability, since it covers both field and laboratory operations.

Table 5 Comparison of Canadian CAPMoN and U.S. NDDN Filterpack Measurement of Acidifying Air Pollutants (micrograms per cubic metre)

Egbert, Ontario	Sulfate ($\mu\text{g}/\text{m}^3$)	Nitrate ($\mu\text{g}/\text{m}^3$)	Ammonium ($\mu\text{g}/\text{m}^3$)	Nitric Acid ($\mu\text{g}/\text{m}^3$)	Sulphur Dioxide ($\mu\text{g}/\text{m}^3$)	Total Nitrate ($\mu\text{g}/\text{m}^3$)
Mean NDDN ¹	3.93	2.39	1.73	1.34	5.90	3.78
Mean CAPMoN ²	3.92	2.31	1.75	1.39	6.60	3.70
Median AD	0.14	0.26	0.08	0.13	0.73	0.24
Median APD	3.94	14.77	6.05	12.75	14.74	5.62

¹ NDDN: National Dry Deposition Network (United States)

² CAPMoN: Canadian Air and Precipitation Monitoring Network

Note: Average value over the time period, running from fourth quarter, 1990 through third quarter, 1992. Concentrations in $\mu\text{g}/\text{m}^3$ at 273° kelvin, using median values for absolute difference (AD) and absolute percent difference (APD).

CONTROL TECHNOLOGIES

Canada

Work in Canada is ongoing to develop, demonstrate, and deploy technologies to reduce emissions of SO₂ and NO_x. This work involves many government agencies at both the federal and provincial levels and major industrial partners such as metals companies and electric utilities. For example, at several Canadian smelters, intensive industrial research has led the way to major modernization programs that feature advanced techniques for milling, beneficiation, smelting, and capturing SO₂ as a useful by-product. At power plants, new technologies — such as fluidized-bed combustion (FBC) and limestone injection into furnaces, and activation of unreacted calcium (LIFAC) — result in large volumes of solid wastes; Environment Canada has conducted extensive studies to characterize and assess pollution control requirements for these wastes. In order to mitigate or eliminate the adverse environmental effects associated with such residues, Environment Canada has published a report called *Interim Recommended Practices for the Management of Solid Residues from Circulating Fluidized Bed Combustion (CFBC)*.

Environment Canada also published *Environmental Codes of Practice for Steam Electric Power Generation-Operations Phase* and *Environmental Codes of Practice for Steam Electric Power Generation-Decommissioning Phase*. These are the fourth and fifth in a series of five documents developed for steam electric power plants. These documents are intended to show that adverse environmental impacts associated with the operation of electric generating stations can be mitigated.

Additionally, Environment Canada has collaborated with the Canadian Electrical Association, utilities, and industries on varied projects including combining technology to reduce NO_x emissions with flue gas desulfurization wet scrubber technology to reduce SO₂ emissions, identifying additives that enhance the formation of larger gypsum crystals in SO₂ scrubbers, and investigating NO_x formation in power plant plumes. Similarly, the Canadian Coal Gasification R&D Committee is studying integrated coal

gasification combined cycle (IGCC) as a clean coal technology option for Canada. Environment Canada is also working with Nova Scotia Power on pilot scale testing of conventional selective catalytic reduction (SCR) of NO_x in a high-sulphur content Canadian coal.

Government-industry sponsored research programs on a range of SO₂ and NO_x emission control technologies applicable to Canadian sources are continuing. In many cases, these programs draw directly on developments or industry experience in the United States and other countries.

United States

Considerable progress has been made in the development of control technologies. In the United States, the Clean Coal Technology (CCT) Program will fund almost \$7 billion in projects over the course of the decade. The power-generating and pollution-control technologies developed in this government-business research and development program are initiatives aimed at emission reductions and cost and operation efficiencies. The initiative, lead by the U.S. Department of Energy, is intended to demonstrate the utility and merit of new coal-burning processes in a series of full-scale commercial facilities.

The CCT Program continues to place emphasis on 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.

All five competitive solicitations under the CCT Program have been completed. There are currently 45 active projects in the CCT Program. Three projects have been completed, 21 are in operation, and 16 projects are in the design phase or under construction. The remaining five projects are in negotiation. Of the 45 projects selected under the first three CCT solicitations, almost all will have had sufficient operating time by the year 2000 to be offered commercially. Once the projects are completed, both sponsors and participants will use information and experience gained to promote and market the technologies in commercial applications. Total project costs through the five solicitations under the

program amount to approximately \$6.9 billion, with the average industry cost share being 66 percent.

Achievements to date (by market category) under the Clean Coal Technology Program are summarized below:

- *Advanced power generation systems.* Development of a commercial replication of the atmospheric circulating fluidized-bed combustion (ACFB) technology at 100 megawatt (MW) scale was a direct result of demonstrating the technology under the program at the Colorado-Ute Electric Association Nucla Station between 1988 and 1991. At the time of demonstration it was the largest ACFB plant at 110 MW. While ACFB was finding its way into the marketplace, operations began under the program on the first U.S. application of pressurized fluidized-bubbling-bed combustion (PFBC) at utility scale (70 MW). Approximately three years of pioneering work led to the establishment of a sound database. As work on the PFBC unit nears completion, construction of a circulating bed version is set to get under way so that this alternate approach also can be evaluated. Seven different approaches to integrated gasification combined cycle, an inherently efficient and clean technology, are in various stages leading to full-scale system integration and analysis. The projects in place cover a broad spectrum of gasifier types, coals, sorbents, diluents, oxygenates, and operating conditions. To further expand the technology options being explored, selections under round 5 include an indirect coal-fired cycle, a second generation PFBC, a coal-fired diesel, and an integrated gasification fuel cell.
- *Environmental control systems.* Two advanced flue gas desulfurization technologies in operation have been routinely achieving over 95 percent SO₂ capture and producing wallboard-grade gypsum. Several combined SO₂/NO_x control systems are in operation and exceeding design goals. One of these systems is achieving 96-percent SO₂ reduction and 94 percent NO_x reduction while producing 93 percent pure sulphuric acid and no solid waste. Six NO_x control options covering the full range of boiler

types are in the later stages of scale up. Three of these systems have been adopted for commercial use by the host utility. At least one commercial sale to an operation other than the host utility has been realized for one of the technologies. As emissions reductions are realized over the next 15 years, opportunities to use other technologies as they become available will increase.

- *Coal process for clean fuels.* These technologies are 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. Both the Rosebud Syncoal coal upgrading project and the ENCOAL mild gasification project are producing products at the target capacity of 1,000 tons per day. Testing of the solid and liquid products by potential users is in progress.
- *Industrial applications.* This category encompasses the steel industry, cement industry, and industrial boiler applications. Dealing with coke oven emissions is the key concern of the steel industry. An early effort under the program to control coke oven gas emissions was slowed by an unrelated shutdown of the coke ovens. Another effort to substitute coal for at least 40 percent of the coke has proceeded to construction. A third project aimed at eliminating the need for coke is in negotiation. Complete success was realized for a coal-fired cement kiln application that may have broader application in the paper production and municipal waste incineration areas. Cement kiln waste was used to achieve 90 percent SO₂ reduction, produce fertilizer, convert the kiln waste to cement feedstocks, and eliminate all waste streams. Cement, municipal waste, and paper production plants in the United States and abroad are actively considering adoption of this technology.

Finally, Canada and the United States continue to hold an annual meeting on control technologies under a bilateral Memorandum of Understanding. Status reports on their respective CCT programs are given at the annual meeting.

MARKET-BASED MECHANISMS

Canada

Canada's acid rain program has substantially achieved the SO₂ emissions reductions required under the Canada-U.S. Air Quality Agreement. However, discussions are under way between the federal government and several provinces on the feasibility of applying economic instruments as a cost-effective way of achieving emissions reductions.

United States

The Acid Rain Program under the 1990 Clean Air Act (CAA) Amendments represents the largest use of market-based mechanisms to achieve environmental protection in the world. Innovative market-based approaches, some in combination with traditional command-and-control approaches, are believed to reduce the overall costs of compliance and stimulate innovation in pollution reduction methods. The market-based emissions allowance system under the Acid Rain Program has been estimated to reduce costs of compliance. The reductions are considered significant given that costs of compliance with Phase I of the Acid Rain Program have been projected to increase from \$1 billion in 1997 and \$1.3 billion in 2000 to \$2.1 billion in 2005. In 2010 costs are expected to reach \$2.2 billion for SO₂ compliance. The potential cost savings from a market-based system range from 25 to 50 percent. Over 326,000 emission allowances were sold during public auctions in March of 1993 and 1994; also, more than a dozen two-party and brokered trades have been reported involving the sale of over 1 million allowances valued at about \$200 million. Further trading and additional private auctions are expected to occur now that EPA's Allowance Tracking System is in place.

There are numerous other examples beyond the U.S. Acid Rain Program of innovative market incentive programs aimed at achieving pollution reductions under the CAA Amendments. One example is EPA's Cash for Clunkers Program, which by encouraging fleet turnover promotes the removal from service of older vehicles that tend to be more polluting. Vehicles can be sold to program sponsors, which can include participating state

and local governments or industries such as power companies, petroleum refineries, and steel mills. Vehicle owners are encouraged to participate in the program by the opportunity to avoid high maintenance bills that older vehicles tend to incur. Since newer models meet more stringent emission limits, drivers can put their profits toward purchases of new cars and still net important emissions reductions.

By retiring older "dirty" vehicles, sponsors earn emissions credits to offset their own emissions requirements or to sell to other companies. EPA guidelines establish methods to calculate credits and to ensure that the program removes dirty in-use vehicles from the nation's roads, rather than from the nation's junk yards.

Some states, including Massachusetts and California, have established initiatives in the area of market incentives for air pollution reductions. In each case, the goal is to ensure pollution reduction while providing for flexibility and financial incentives to stimulate innovation and technological advancement. Massachusetts recently unveiled a statewide emissions banking and trading program allowing companies that reduce air pollution below regulatory requirements to trade or sell the additional reductions to companies that need those credits to build or expand their own operations in the state. Under the CAA Amendments, any new source of air pollution, such as a factory, must find offsetting pollution reductions amounting to 120 percent of what is expected to be emitted.

Finally, California's South Coast Air Quality Management District (AQMD) has developed an emissions trading program called the Regional Clean Air Initiatives Market (RECLAIM) for the Los Angeles area. The program would set annual emissions limits for over 450 major NO_x emitting sources and approximately 40 major SO₂ emitting sources in Los Angeles, Orange, Riverside, and San Bernardino counties, the air basin suffering the worst air pollution in the United States. The limits on NO_x and SO₂ would decrease each year to curb the area companies' emissions by 80 percent and 65 percent respectively by 2003. Companies would choose their own cost-effective compliance plans, and those companies reducing emissions beyond their annual limits could sell

pollution credits to others. AQMD expects that the costs of meeting the goal would be about half that of regular smog control. Approximately 400 businesses would save an estimated \$93 million a year.

ASSESSMENT OF THE COSTS, BENEFITS, AND EFFECTIVENESS OF CLEAN AIR CONTROLS

Canada

Canada has achieved its required SO₂ emissions reductions by relying on a mix of regulations, voluntary approaches, and public education, with each province determining its own cost-effective mix depending on the nature of the SO₂ sources in its jurisdiction. This approach has resulted in about a 40 percent reduction in SO₂ emissions from 1980 levels.

However, scientists are predicting that parts of Canada will still be acidified after the year 2000. As a result, Canada is now developing a new National Strategy on Acid Rain for the post 2000 period to protect acid-sensitive areas. An economic analysis of the various measures to reduce SO₂ emissions will be central to the development of the new strategy.

United States

Numerous efforts are under way to evaluate the costs, benefits, and effectiveness of the Acid Rain Program in the United States. Research efforts in the 1980s created baselines in various areas, particularly acid rain impact areas, with which to track and compare data following implementation of the CAA Amendments. The Acid Rain Program, in particular, benefits from years of research that can be used to compare current and future data. Furthermore, because the Acid Rain Program

is one of the first attempts at environmental protection using a market-based approach, it lends itself to analysis of the effectiveness of market-based approaches compared with traditional command-and-control approaches.

Under the directive of several different sections of the CAA Amendments, assessment and evaluation of the Acid Rain Program are planned and are currently under way. Section 812 of the Amendments requires EPA to assess the costs and benefits of the entire CAA. 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). Since acid rain legislation was new to the act upon passage of the 1990 Amendments, the Section 812 analysis is particularly relevant to the Acid Rain Program, and numerous efforts to assess and forecast the costs and benefits of the Acid Rain Program have been initiated.

Evaluation of the Acid Rain Program also will be addressed under Section 901 of the CAA Amendments. Under this requirement, the National Acid Precipitation Assessment Program (NAPAP) will issue a report to the Congress in 1996 and every four years thereafter on costs, benefits, and effectiveness of Title IV. The Acid Deposition Standard Study, under Appendix B, Section 404, of the CAA Amendments, will also provide insight to the environmental effectiveness and costs of the Acid Rain Program.

Furthermore, efforts to effectively track and evaluate the environmental impact of the Acid Rain Program (e.g., deposition of acidic compounds and surface water chemistry) are ongoing. Finally, regarding Title II (mobile sources) of the CAA Amendments, EPA is required to make a determination by the end of 1999 on the need to further reduce NO_x emissions from vehicles with more stringent emission standards.

Areas of Future Cooperation — Ground-Level Ozone

ONGOING COOPERATION

The initial focus of the Canada-U.S. Air Quality Agreement was acid rain. Annex I of the Agreement specifies emissions reduction targets and timeframes for attaining them. The overall purpose of the Agreement, however, is to provide a practical and flexible instrument to deal with shared problems of transboundary air pollution. The Air Quality Committee is responsible for informing each country about the other's activities in areas relating to air quality.

The two subcommittees under the Air Quality Committee met in April 1993, in Washington, DC. At the meeting, the Subcommittee on Program Monitoring and Reporting reviewed existing ozone regulations and activities in Canada and the United States, and the Subcommittee on Scientific Cooperation reviewed existing ozone research efforts in both countries. This marked the beginning of information-sharing under the Air Quality Agreement on the issue of ground-level ozone.

Both governments agreed that joint Canada-U.S. scientific research on air quality modelling, transboundary flows, and pollutants effects on health should continue so that the best solutions can be selected. The North American Research Strategy on the Tropospheric Ozone Program was identified as the vehicle of choice to ensure a consistent approach. It also was agreed that inventory analysis and appropriate airshed modelling are important components of future efforts to find permanent solutions to present ambient air quality problems.

The Ozone Transport Commission's plan for ozone reduction in the eastern region will also help focus on the priority actions required to address ground-level ozone problems in the Windsor-Quebec Corridor and Southern Atlantic Region.

At a meeting in the fall of 1993, Canada and the United States agreed to produce a report on the progress of implementation of the U.S. Clean Air Act Amendment actions and Canadian NOx/VOC Management Plan requirements in the neighbouring regions.

EXISTING GROUND-LEVEL OZONE PROGRAMS

The following programs relating to ground-level ozone were reported at the April 1993 meeting of the bilateral Subcommittee on Program Monitoring and Reporting.

Canada

In Canada, the National Ambient Air Quality Objective (NAAQO) is 82 ppb (0.82 ppm) maximum averaged over 1 hour. This is not a standard but a target for national and regional measures to reduce NOx and VOC emissions. Some provinces have adopted the objective as a standard.

Three regions in Canada periodically experience ozone levels above the national objective: the Lower Fraser Valley (LFV) of British Columbia, the Windsor-Quebec Corridor (WQC) portion of Ontario and Quebec, and the South Atlantic Region (SAR) around Saint John, New Brunswick.

Elements of an emission reduction program were adopted in a NOx/VOC Management Plan adopted by the Canadian Council of Ministers of the Environment (CCME) in 1990. The Canadian plan is comprised of three parts: (1) a national prevention program to implement NOx and VOC emissions reductions in selected industrial and mobile source sectors in all of Canada, along with a public education campaign to help consumers reduce the impact of their everyday activities on the environment; (2) a regional remedial program (addressed to the high-ozone areas of the LFV, the WQC, and the SAR) to implement new NOx and VOC emission limits in existing stationary facilities and develop local transportation management programs; and (3) a scientific program to complete inventories, analyze the data, develop and validate models, improve monitoring networks, understand meteorological factors, and develop scenarios to assess future emission reduction requirements.

In addition, the Canadian government plans to implement mobile source and energy efficiency standards for appliances and buildings. Provincial and local jurisdictions will implement other point and area sources and limits. All requirements of the program have been or will be developed through the multi-stakeholder process involving governments, industry, and environmentalists working together to select consistent and cost-effective measures.

United States

In the United States, the National Ambient Air Quality Standards (NAAQS) were established for ozone to protect public health and welfare. The health and welfare standards are both set at 0.12 ppm (120 ppb) averaged over one hour with no more than one expected exceedance per year. Areas in the United States that do not meet the ozone NAAQS are required by law to be formally designated by EPA as nonattainment (NA) areas for that pollutant. Each designation is based upon a submittal by the appropriate state governor.

The CAA also provides a system to classify or group NA areas according to the severity of the problem. The classification system is contained in Section 181(a) of the 1990 CAA Amendments and is composed of six categories (Table 6). Ozone control programs and other requirements are tied directly to the designation and classification of an NA area. Dates by which the U.S. Congress expects air quality to meet standards (attainment dates) are also prescribed (see Table 6) and vary with the severity of the NA problem.

The CAA requires a three-part approach to address ozone: (1) national rules established by the federal government (e.g., automobile

tail pipe standards); (2) mandatory area-specific rules and progress requirements adopted by states, increasing in stringency with the ozone classification; and (3) reductions needed to meet the NAAQS by a prescribed date.

States must implement ozone control requirements to bring NA areas into attainment with NAAQS. The United States is in the process of reviewing its ozone standard. A decision to retain or revise the current standard will be made in the next few years.

CONCLUSION AND NEXT STEPS

This second Progress Report under the Canada-U.S. Air Quality Agreement documents major efforts in both countries toward achieving emission reduction goals. This report also focuses on scientific and technical activities undertaken by both countries to assess, monitor, and mitigate air pollution. In both countries, government and industry have moved forcefully and expeditiously toward achieving these goals. Both countries are committed to conducting ongoing monitoring and technical activities in order to report on the status of the acidic deposition problem. In addition, the two countries continue to study the effects of acidic compounds on human health. Both countries also are demonstrating and deploying new pollution control technologies in an effort to reduce pollution while using indigenous fuels for energy production.

The two countries share an interest in various air quality problems beyond acidic deposition, including tropospheric ozone (smog) and the deposition of toxic compounds. Both countries have designed pollution control programs

Table 6 Classification of U.S. Ozone Nonattainment Areas

Classification	Concentration	Attainment Date	Years Given to Attain
Marginal	0.121 up to 0.138	Nov. 15, 1993	3 years
Moderate	0.138 up to 0.160	Nov. 15, 1996	6 years
Serious	0.160 up to 0.180	Nov. 15, 1999	9 years
Severe-15	0.180 up to 0.190	Nov. 15, 2005	15 years
Severe-17	0.190 up to 0.280	Nov. 15, 2007	17 years
Extreme	0.280 and above	Nov. 15, 2020	20 years

to reduce levels of ozone and air toxics. The two countries are currently reviewing their standards for ground-level ozone, with Canada expecting to complete its review in 1994 and, in the United States, issuance of a final decision in 1997.

Canada and the United States have embarked on long-term programs to reduce the effects of acid rain in the two countries. In 1995, emission reductions in the United States under the new Acid Rain Program will commence and will increase reductions already achieved. In 1995, Canada will report on its efforts to protect visibility and to prevent significant deterioration (i.e., "keeping clean areas clean").

In the United States, Phase II sources will install continuous emission monitors and

develop strategies for Phase II reduction. In both countries, different methods of reducing emissions will continue to be employed, including energy efficiency, demand-side management, fuel switching, and pollution control equipment. Similarly, deposition, air concentrations, surface waters, and forests will continue to be monitored and results will be compared with past estimates. Both countries will continue to assess the health effects associated with acidic deposition and ground-level ozone. Finally, both countries are in the process of assessing the need for and consequences of further emission reductions to protect critically sensitive ecosystems.

United States-Canada Air Quality Committee

Canada

Co-chair

Tony Clarke
Assistant Deputy Minister
Environmental Protection Service
Environment Canada

Members

François Guimont
Acting Director General
Pollution Prevention Directorate
Environment Canada

Phil Merilees
Director General
Research
Atmospheric Environment Service
Environment Canada

John Lowe
Director
International Trade and
U.S. Relations Division
Natural Resources Canada

David McLellan
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Larry Lechner
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Derrick Maddocks
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Newfoundland Department of
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United States

Co-chair

Rafe Pomerance
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Bruce Hicks
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Molly Ross
Special Assistant to the Assistant Secretary
for Fish, Wildlife and Parks
Department of Interior

SUBCOMMITTEE ON PROGRAM MONITORING AND REPORTING

Co-chairs:

Wayne Draper
Associate Director
Air Issues Branch
Environment Canada

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

SUBCOMMITTEE ON SCIENTIFIC COOPERATION

Co-chairs:

Keith Puckett
Acting Director
Environmental Integration Services Branch
Atmospheric Environment Service
Environment Canada

Jack Puzak
Deputy Director
Office of Modeling, Monitoring Systems
and Quality Assurance
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. Release 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 either Party.
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 fulfil 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 trans-boundary transport and deposition of air pollutants, as set forth in subparagraph 3(c) of Annex 2 to the Agreement.
5. 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, 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 fulfil the above responsibilities.

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

The Government of the United States of America and the Government of Canada, 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 the United States and Canada, 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 within the area under the jurisdiction of one Party and which has adverse effects, other than effects of a global nature, 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 the United States and Canada, 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 under 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, regulations or policies that, if carried out, would be likely to significantly affect transboundary air pollution.
4. Consultation 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 trans-boundary 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 subparagraph (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 in to 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 30 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 90 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 those 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 State and Provincial Governments as necessary to implement this Agreement.
3. In implementing this Agreement, the Parties shall, as appropriate, consult with State or Provincial 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 tons² from 1980 levels in accordance with Title IV of the Clean Air Act³ 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 sections 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.

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 States¹:

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 low 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 6,000 lbs gross vehicle weight rating (GVWR)) and Light Duty Vehicles (LDV) — standards for model years after 1993:

¹ Applies only to reductions in emissions in the 48 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.

	5 yrs/50,000 miles (useful life)	10 yrs/ 100,000 miles
LDTs (0 to 3,750 lbs Loaded Vehicle Weight (LVW) and LDVs)	0.4 grams per mile (gpm)	0.6 gpm
Diesel LDTs (0 to 3,750 lbs LVW) and LDVs (before 2004)	1.0 gpm	1.25 gpm
LDTs (3,751 to 5,750 lbs LVW)	0.7 gpm ⁴	0.97 gpm

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

- (b) Light Duty Trucks more than 6,000 lbs GVWR (after model year 1995):

	Gasoline 5 yrs/ 50,000 miles	Gasoline and Diesel 11 yrs/120,000 miles
LDTs (3,751 to 5,750 lbs Test Weight (TW))	0.7 gpm	0.98 gpm
LDTs (over 5,750 lbs TW)	1.1 gpm	1.53 gpm

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

- (c) Heavy Duty Trucks (HDT) of more than 8,500 lbs GVWR (after model year 1990):

	Gasoline and Diesel Engines
HDT (effective model year 1991 ⁵)	5.0 grams per brake horsepower-hour ⁵ (gbhp-hr)
HDT (model year 1998 and later)	4.0 gbhp-hr

Useful life⁵:

Gasoline Engines	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 6,000 lbs GVWR) (By model year 1996 for passenger cars; by model year 1996 for light duty trucks⁶):

	5 yrs/80,000 kilometres (useful life)
Cars and Light Duty Trucks (0 to 3,750 lbs LVW)	0.4 gpm
Light Duty Trucks (3,751 to 5,750 lbs LVW)	0.7 gpm

Medium Duty Vehicles (6,001 to 8,500 lbs GVWR) (By model year 1997⁶):

	5 yrs/80,000 kilometres (useful life)
0 to 3,750 lbs LVW	0.4 gpm
3,751 to 5,750 lbs LVW	0.7 gpm
Over 5,750 lbs VWR	1.1 gpm

⁴ This standard does not apply to diesel-fuelled LDTs (3,751 to 5,750 lbs LVW).

⁵ As set forth in EPA regulations in effect as of the entry into force of this Agreement.

⁶ 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.

Heavy Duty Vehicles (over 8,500 lbs GVWR) (By model year 1998⁶):

	8 yrs/110,000 kilometres (useful life)
Over 8,500 lbs GVWR	4.0 gpm - 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 than the standards for the respective duty classes of gasoline-powered vehicles and engines.

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

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 emission 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
Assessment Program
722 Jackson Place, NW
Washington, DC 20503

IN CANADA

Environmental Integration
Services Branch
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4

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

IN THE UNITED STATES

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

IN CANADA

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

International Joint Commission
Commission mixte internationale

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 international 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.

Your comments would be appreciated on the form below or by letter and should be sent to one of the following addresses:

**Secretary, Canadian Section
International Joint Commission
100 Metcalfe St.
Ottawa, Ontario K1P 5M1**

**Secretary, United States Section
International Joint Commission
1250 23rd Street, NW, Suite 100
Washington, DC 20440**

Name:

Organization (if applicable):

Address:

City:

State/Prov.:**Postal/Zip Code:****Comments:**