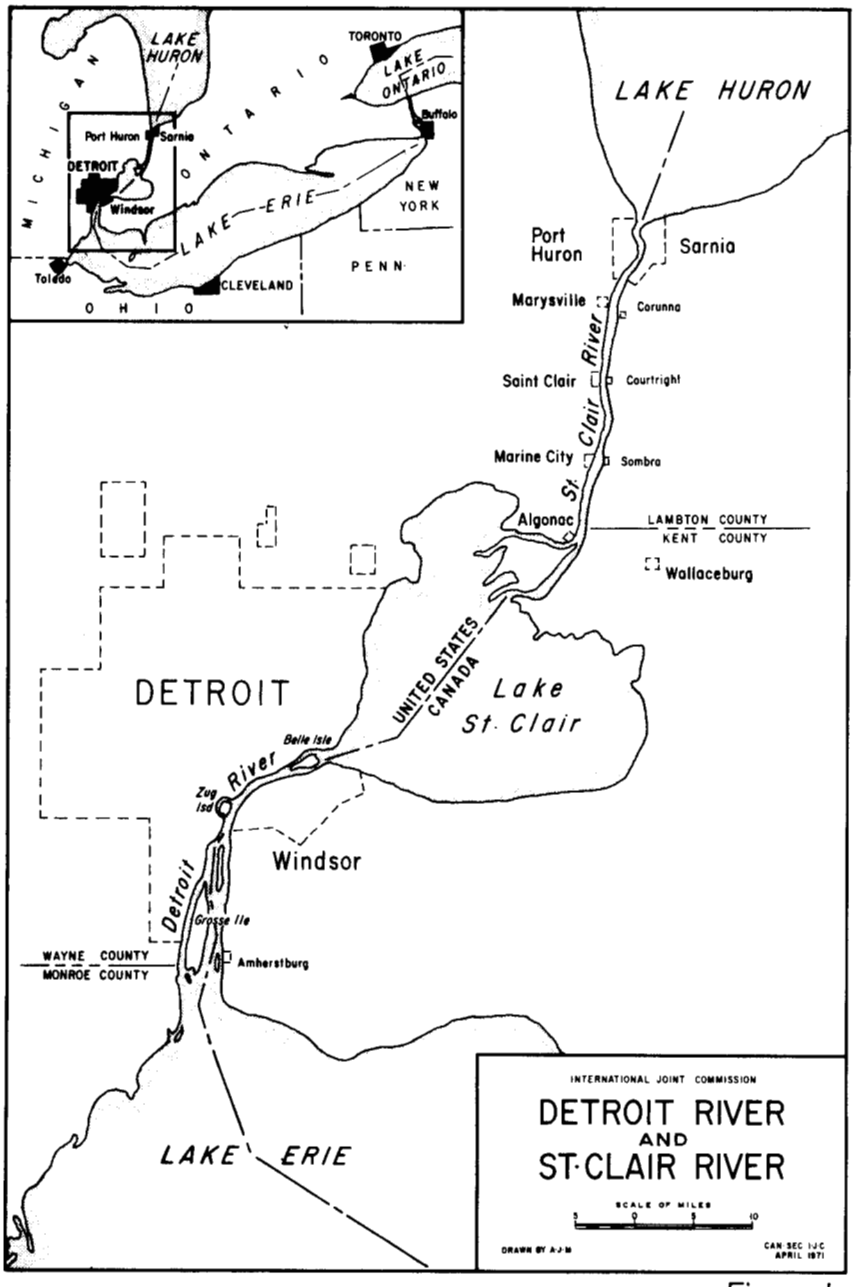
TRANSBOUNDARY AIR POLLUTION

Detroit and St. Clair River Areas

INTERNATIONAL JOINT COMMISSION
CANADA AND UNITED STATES
1972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Toledo
CLEVELAND
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Sarnia
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Corunna
Saint Clair
Courtright
St. Clair River
Marine City
Sombra
Algonac
LAMBTON COUNTY
KENT COUNTY
Wallaceburg
DETROIT
UNITED STATES
CANADA
Lake St. Clair
Belle Isle
Zug Isd
River
Windsor
Detroit
Grosse Ile
WAYNE COUNTY
MONROE COUNTY
Amherstburg
LAKE ERIE
INTERNATIONAL JOINT COMMISSION
DETROIT RIVER
AND
ST. CLAIR RIVER
SCALE OF MILES
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DRAWN BY A.J.M
CAN-SEC IJC
APRIL 1971

Figure 1

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CANADA AND UNITED STATES

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Chapter I

INTRODUCTION

The International Boundary between Canada and the United States passes through the Detroit and St. Clair Rivers. Atmospheric emissions principally from metallurgical industries, powerplants burning fossil fuels, oil refineries, and chemical industries along both banks of the Detroit and St. Clair Rivers are transported by the winds across the International Boundary and deteriorate the ambient air quality in the other country. Under such circumstances it is impossible for a regulatory agency to achieve acceptable air quality in its jurisdiction by requiring a reduction or curtailment of emissions if transboundary movement of air contaminants persists.

Transboundary air pollution is not a new problem in the Detroit River area. The Canadian Government in 1934 informed the Government of the United States that substantial quantities of sulphur dioxide and smoke from the industrial area of Detroit were drifting across the International Boundary and causing a serious problem in Canada. It was also pointed out that the maximum concentration exceeded the maximum found during this Commission's inquiry (1928–1931) into damage from air pollution in the State of Washington resulting from the operation of the smelter at Trail, British Columbia.

THE 1949 REFERENCE

After representations regarding air pollution in the Windsor-Detroit area and vessels as a source of this pollution, the Governments of Canada and the United States in 1949 agreed that the International Joint Commission be requested to determine if the cities of Detroit and Windsor were being polluted by smoke, soot, fly ash, and other impurities, and to ascertain the extent to which vessels plying the Detroit River were responsible. The terms of the reference limited the Commission to make recommendations only on measures to reduce emissions from vessels plying the Detroit River.

The six Commissioners in an interim report, dated October 22, 1952, expressed the opinion that this reference diverted attention from the more serious aspects of the air pollution problem by emphasizing pollution from vessels. The abatement of pollution from vessel traffic would not render air free from the hazards of contaminants from other major sources. They recommended that the terms of reference be amended so as to permit the development of recommendations covering the major sources of pollution as well as vessels. No governmental action resulted from this recommendation at that time.

The Commission, in its 1960 Report under the 1949 Reference, concluded that the air over and in the vicinity of the cities of Detroit and Windsor was being polluted on both sides of the International Boundary to an extent which was detrimental to the general welfare of the citizens in both countries. The major factors responsible were the relatively high levels of dustfall, airborne particulates and sulphur dioxide from industrial installations and from the combustion of large quantities of fuel at other sources on land. The solid fuel consumption by vessels was 1.5 percent of the total fuel burned in the area. However, the intermittent air pollution from vessels was a visible source and its effects were evident in a narrow belt adjoining both sides of the Detroit River.

The most serious contributing factor to the level of pollution was the flow of considerable amounts of particulates from the Zug Island area of the United States into the general vicinity of Windsor. The transboundary flow of contaminants was augmented by emissions from vessels. During the period 1952 to 1957 smoke emission objectives for vessels plying the Detroit River were formulated by the Commission on an annual basis for use by local authorities. They were made progressively more stringent each year until the Commission was satisfied that the reduction of emissions from vessels had reached a point where further improvement could only be achieved by further reduction of the number of hand-fired vessels through conversion or retirement.

The Commission in its 1960 Report recommended that both Governments adopt these objectives and take appropriate action to ensure that they were met. The two Governments in 1961 authorized the Commission to maintain surveillance of vessel performance with regard to smoke emissions.

During the Commission's surveillance activities there was no relaxation in the voluntary smoke abatement programs of the vessel operators and owners. The city of Detroit and the Canadian Department of Transport implemented regulations which were consistent with or more stringent than the Commission's objectives. This enabled the Commission to conclude in 1966 that the actions required of the IJC for purposes of the 1949 Reference on air pollution were completed. The Commission then requested that its responsibility with regard to

surveillance of vessel smoke emissions be terminated. The two Governments concurred.

CANADIAN STUDIES

Meanwhile, in 1963 the Canadian Departments of Transport and National Health and Welfare, as well as the Ontario Department of Health had conducted a study to assess the effect of transboundary pollution on the Canadian side of the Detroit River. The 24-hour average of iron concentrations were of the same magnitude as the highest found anywhere in the U.S. National Air Sampling Network. The highest pollution levels were found when the winds were blowing from the direction of the Zug Island industrial area on the Detroit side of the River.

CURRENT REFERENCE

Finally, under provisions of the Boundary Waters Treaty of 1909, the Governments of Canada and the United States on September 23, 1966, requested the International Joint Commission to inquire into and report on the following questions:

1. Is the air over and in the vicinity of Port Huron-Sarnia and Detroit-Windsor being polluted on either side of the International Boundary by quantities of air contaminants that are detrimental to the public health, safety or general welfare of citizens or property on the other side of the International Boundary?
2. What sources are contributing to this pollution and to what extent?
3. What preventative or remedial measures would be most practicable from economic, sanitary, and other points of view?
4. What is the probable total cost of implementing the measures?

The full text of the Reference from the two Governments is in the Appendix.

On the shores of the Detroit River there are extensive metallurgical industries and large power utilities while on the banks of the St. Clair River there are chemical industries, oil refineries, and powerplants. Thus, in Windsor and Detroit the air pollution complaints were concerned principally with soiling and visible particulates while in Port Huron and Sarnia the complaints emphasized objectionable odours. Also, the prevailing winds in the Detroit River area blow from the United States into Canada while in the St. Clair River area Lake Huron exerts a strong influence on the channelling of land-lake breezes parallel to the River and to the Boundary. For these reasons the air pollution in each region is discussed separately in Chapter VII and Chapter VIII.

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Chapter II

CONDUCT OF THE INQUIRY

In accordance with its usual procedure in such investigations the Commission on November 30, 1966, established the International St. Clair-Detroit River Areas Air Pollution Board. The senior officials appointed by the Commission to the Board were from the Occupational Health Division of the Canadian Department of National Health and Welfare (the air pollution control sector was later transferred to the newly created federal Department of the Environment), the Air Management Branch of the Ontario Department of Health (later transferred to the newly created provincial Department of the Environment), the United States National Air Pollution Control Administration (later the Air Pollution Programmes Office of the Environmental Protection Agency), and the Air Pollution Control Section of the Michigan Department of Health.

The Board was directed to review and so far as possible make use of relevant information and technical data which had been or might be acquired by agencies in the two countries. The Board was also directed to undertake the necessary investigations and studies and to advise the Commission on the specific questions set out in the Reference.

Initial public hearings were held by the Commission in Port Huron, Michigan, and Windsor, Ontario, on June 20 and 21, 1967. The purpose of these hearings was to receive testimony and evidence from interested persons and groups regarding the questions set out in the Reference and to obtain additional guidance in planning the field investigations.

An aerial inspection of the St. Clair and Detroit River areas was made in February 1967. The Commissioners toured the affected areas on June 19 and 22 of 1967.

During the course of the investigation the Board submitted eight semiannual progress reports. In addition, the Commission was kept informed of the activities of the Board through correspondence and informal meetings. At the conclusion of the studies, the Board in

January of 1971 submitted to the Commission a detailed report on the air pollution in the St. Clair and Detroit River areas. It confirmed the obvious existence of significant transboundary air pollution.

After an initial review, the Commission released the Board's report to the public on February 4, 1971. It was given wide distribution. Notices of the public hearings to be conducted by the Commission were published in accordance with its Rules of Procedure and were also mailed to many persons known to be interested. Public hearings were held in Sarnia and Detroit on March 10 and 11, 1971.

On March 15, 1971, the Commission requested the Board to amplify some sections of the report and update advice on some of the information presented at the hearings. The Board complied with this request on May 28, 1971.

During the Commission's extensive deliberations on transboundary air pollution in the St. Clair and Detroit River areas it has considered all of the Board's reports, the written and oral testimony received at its public hearings, and supplementary information obtained from various sources in Canada and the United States, including the resolution pertaining to transboundary air pollution adopted by the Conference of Great Lakes Governors and Premiers at Mackinac Island on August 17, 1971.

Chapter III

THE BOARD'S INVESTIGATION

The Commission established the International St. Clair-Detroit River Areas Air Pollution Board to undertake through appropriate agencies in Canada and the United States the necessary investigations on behalf of the Commission. The Board was directed to advise the Commission on the technical matters it would have to consider in its report to the two Governments. The senior officials appointed by the Commission to the Board were from agencies of the two Federal Governments, the Province of Ontario and the State of Michigan.

The Board, with the concurrence of the Commission, established a number of committees drawn from industry, the academic community, and governmental agencies. The composition of the committees is in the Appendix. The expertise of this multidisciplinary investigation encompassed engineering, chemistry, physics, medicine, meteorology, and phytotoxicology.

The Board's investigation involved a meteorological study of the two areas, the measurement of the contamination of air masses crossing the International Boundary, the identification and quantification of the sources of transboundary air pollution, and the determination of the effects of transboundary air pollution.

The thorough planning of the study, careful selection of a network of sampling sites on both sides of the boundary, delays in procuring specialized instruments and equipment as well as the shortage of scientific and technical personnel postponed the commencement of field studies until December 1967. The analysis, correlation, evaluation, and reporting on the information collected during the succeeding 12 months took an additional year. Although all of the massive amount of collected data was considered, detailed analysis was performed only to the extent necessary to permit reliable conclusions.

AIR QUALITY MEASUREMENTS

Air quality measurements were made at 80 aerometric sampling locations. Because the emissions from the industries and large fossil

fuel combustion units mainly consisted of particulates, sulphur oxides, and odours, emphasis was placed on these contaminants. In addition the gaseous and volatile pollutants received special attention in the St. Clair River area. For completeness of the survey, rather than for indications of transboundary movement, nitrogen oxides, carbon monoxide, hydrocarbons, and oxidants were measured. Other pollutants such as sulphates, polycyclic hydrocarbons, sulphuric acid, and fluorides were measured at some locations. In addition, samples of suspended particulates collected in the Detroit River area were analyzed for a number of metals.

The concentrations of suspended particulates were measured using high-volume samplers. Each sample was for a 24-hour period starting at midnight. The particulates thus collected included some of every size occurring in a day with the possible exception of large particles. The results were expressed as micrograms per cubic meter ($\mu g/m^3$). At most of the 53 stations one sample was taken every 3 days.

Dustfall samples were collected over monthly periods. The data expressed as tons of dustfall per square mile per month (tons/mi^2-mo) represent the sum of the soluble and insoluble solids.

Fluoride monitoring stations consisted of specially designed sequential samplers. Sampling was done for six 4-hour periods every third day. The results were reported as 4-hour averages in parts per billion (ppb) of fluoride.

Atmospheric sulphur dioxide concentrations were measured at 26 locations. At the Canadian sites, sulphur dioxide was measured by continuous recording of electroconductivity analyzers, except at one station where a continuous coulometric analyzer was used. The data reported are average values for 1-hour periods. All but three U.S. stations measured sulphur dioxide by continuous coulometric analyzers and reported data as average 1-hour periods. The others used sequential samplers and spectrophometric techniques. Although some discrepancies were believed to exist between the electroconductivity and coulometric methods of measurement, the annual readings remained the same after the electroconductivity instruments in Canada were replaced by the coulometric type.

Hydrogen sulphide was sampled at 10 stations using an automatic sequential tape sampler. The results were reported as 2-hour averages.

METEOROLOGICAL OBSERVATIONS

Meteorological observations were used for the development of dispersion models. This enabled the Board to ascertain the frequency of the transboundary flow of contaminants and to predict pollution levels.

Wind direction and speed data were collected at 15 locations. This information was obtained at stations established by the Board as well as those of the weather services and the military. Temperatures of the lower atmosphere were routinely measured at instrumented towers in Sarnia and Windsor. Pilot-balloon wind measurements and tethered-balloon temperature soundings were made during periods of intensive study. Detailed meteorological observations were made in conjunction with the flights of an aircraft which directly measured the trans-boundary flux of pollutants. The meteorological data collected during the sampling period was compared with long-term records collected at permanent national meteorological stations and existing state and provincial air quality stations. The meteorological conditions for 1968 were found to be representative of the long-term average.

EMISSIONS INVENTORY

A detailed inventory of the quantity of particulates, suphur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide emissions from all sources was compiled for the year 1967, the last full year for which complete data was available.

The emissions due to fuel combustion were calculated by determining the quantity of each fuel sold to each industry and utility as well as the quantity sold by retail dealers. Emissions from mobile sources were computed by gathering data on traffic volumes as well as the fuel consumed by automobiles, trucks, trains, ships, and aircraft. The emissions from burning refuse were determined by procuring data on the quantity of each type of refuse generated and the method of disposal.

Questionnaires were sent to all large companies to obtain data on emissions due to fuel consumption and process losses. Where emission data could not be obtained from companies, emissions were estimated by data obtained from publications and from state and local air pollution control agencies. In addition, observations were made on some processes.

All point sources, that is individual sites that emitted 100 tons or more of any single pollutant a year, are identified in the Board's report to the Commission. Sources which emitted less than 100 tons of a pollutant were grouped into areas which inversely varied in size according to the quantity of the emissions. The results of the emission survey are summarized in the Board's report in a table reflecting the quantity of contaminants from 16 source categories for each county in both countries.

TRANSBOUNDARY POLLUTION STUDIES

Meteorological factors, actual pollution measurements, and source emission inventories were used to evaluate the extent and quantity of air contaminants transported across the International Boundary.

Pollution roses, graphic displays of combined pollution measurements and coincident wind data, were constructed for the sites which measured suspended particulates, soiling index, and sulphur dioxide. The pollution roses showed the frequency of wind direction along with selected pollution levels at a particular receptor location. They indicated not only the origin of the pollutants but also the frequency of the transboundary flow of pollutants.

Dispersion models were used to compute the average annual concentrations of contaminants due to transboundary pollution. A dispersion model is a mathematical description of the transport and dispersion of pollutants from the time they are emitted to the atmosphere until they reach a receptor. It quantitatively determines the contribution of each individual source or groups of point or area sources to the pollution at a specific site with each meteorological condition. It weighs each concentration by the frequency of the associated meteorological conditions and then sums the weighted concentrations for all source-receptor combinations and all meteorological conditions. By this method the Board estimated the average annual pollution concentration for each receptor.

Direct measurements of the transboundary flux of sulphur dioxide and suspended particulates were taken during 13 flights of an instrumented aircraft along the Detroit and St. Clair Rivers. On the basis of these measurements and concurrent meteorological data, estimates were made of the quantity of pollutants that crossed the International Boundary.

Detailed case studies of measured high pollutant concentrations were made at four locations where extensive meteorological data were available. The purpose of these thorough analyses was to verify that the high concentrations of contaminants were caused by a transboundary flow of pollutants.

IMPACT STUDIES

Statistical medical data on the effects of air pollutants on human health and welfare in the Detroit and St. Clair River areas are not available at this time. However, the observed effects on human health, particularly during adverse meteorological conditions in other areas, are well documented in scientific, medical, and governmental publications.

The effects of air pollution on materials were determined by placing a static "Effects Package" at 11 locations. The monitoring components consisted of silver, steel, and zinc plates; dyed fabrics; rubber strips; nylon hose; sulphation candles; sticky paper; and dustfall buckets. The results were compared with several areas in the United States where similar studies were made.

Air pollution damage to vegetation was assessed by observing over a 10-week period the accumulation of leaf injury and the suppression of growth. Tobacco, pinto bean, geranium, petunia, begonia, and gladiolus were grown under controlled conditions in a laboratory and then transferred to specially constructed plant shelters at six locations. A control shelter with activated carbon filters was installed at the Grosse Ile site.

The effect of particulates traversing the Boundary on visibility was determined by hourly visual range data obtained at the City and Metropolitan Airports in Detroit. Only those cases without precipitation or fog and with a relative humidity of less than 70 percent were considered. Hourly observation data for the study period December 1967 to November 1968 was analyzed by constructing a wind rose for those hours when the visibility was less than a given distance and the obstructing phenomenon was smoke or a combination of smoke and haze. Comparable information was not available for the St. Clair River area.

REDUCTION OF EMISSIONS

The Board considered possible techniques of reducing particulate and sulphur dioxide emissions from powerplants, steel mills, foundries, cement plants, and petroleum refineries, the major sources of pollution. No attempt was made to deal with each individual source. Cognizance was taken of the current collection efficiencies, the feasibility of additional or more efficient measures, the success of emission controls in other areas, interim measures, fuel substitution, fuel switching, and the development of new techniques.

A mathematical model was utilized to ascertain the reduction of emissions of particulates and sulphur dioxide necessary to achieve desirable ambient concentrations. The sources were categorized on an area basis. Alternative remedial measures that would achieve the required reduction were examined. These included additional equipment, flue gas scrubbing, fuel switching, and fuel substitution.

The estimated annual costs associated with alternative measures were based on fuel price differentials, cost of equipment, and operating charges. Much of the cost data on industrial processes was derived from literature on the modification of similar plants. The costs of removing sulphur dioxide from flue gases, by necessity, were based on experimental work conducted in other areas, fuel substitution or fuel switching. The annual cost of eliminating the open burning of refuse was based on the costs of sanitary landfill.

Chapter IV

PUBLIC HEARINGS

A few months after receipt of the Reference from the Governments of the United States and Canada the Commission held pre-investigation hearings in Port Huron and Windsor. The purpose of these hearings was to provide an opportunity for all persons and organizations, public and private, to express their views on the problem and to convey relevant information to the Commission.

After the Board submitted their report to the Commission, public hearings were conducted by the Commission in Sarnia and Detroit. The purpose of these hearings was to afford opportunity for all interested individuals, organizations, and governmental agencies to comment on the Board's report and to offer additional related information which the Commission could consider in developing its own report to the two Governments.

In accordance with the Commission's Rules of Procedure, notices of the four public hearings were published in the Canada *Gazette* and the U.S. *Federal Register* and in local newspapers in both countries. Notices were also mailed to many individuals, known associations, and to elected representatives in the region.

Statements were made by elected representatives from both countries, officials from governmental agencies, industrial representatives, state and provincial organizations, and concerned individuals. All those interested were given opportunity to express their views orally or present documentary evidence. The names of those who testified at the hearings or submitted briefs are set out in the Appendix.

Verbatim transcripts of all hearings and all written submissions made at or subsequent to the hearings are on file and available for examination at the offices of the Commission in Ottawa and Washington.

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INITIAL HEARINGS

The initial public hearings were conducted by the Commission in the Henry McMorran Memorial Auditorium at Port Huron, Michigan, on June 20, 1967, and in Cleary Auditorium at Windsor, Ontario, on the following day.

Because these hearings were preliminary to the actual field investigation, those who testified generally supported the investigation and expressed the need to control the emission of pollutants to the atmosphere. Elected representatives and governmental officials from both countries offered to cooperate with the Commission's Board in their investigation.

The major points made by those who appeared before the Commission at Port Huron are summarized and paraphrased in the following paragraphs:

U.S. County officials emphasized the fact that air pollution levels had increased steadily over the last 10 years resulting in continuous complaints, especially from older citizens, of odours, nuisances and damage to property values.

Ten years ago complaints of air pollution were generally from the immediate area of Port Huron about sources in Sarnia. Complaints are now being received from Marine City and East China Township to the south and from Lexington, Michigan, to the north, a distance of 50 miles.

Foul odours that occur on the United States side allegedly emanate from the Chinook Chemical Corporation near Sombra, Ontario. The plant began operations about a year previously and odours began about the same time. The odours have been sufficiently severe to cause the East China Township Board to take official note of the situation and pass a resolution seeking a correction of the adverse conditions.

Since 1966 the City of Port Huron received 45 written or verbal complaints concerning air pollution, but this does not represent a complete picture. Many citizens have indicated that they have given up hope of correcting the sources.

Southeastern Gas Company reported that on December 4, 1966, it received over 200 calls complaining of strong gas odours in the area of Port Huron. These complaints were traced to sources other than gas company mains and trunk lines.

Air pollution in Port Huron has become considerably worse in the last 6 years. Within the last 2 years Fargo, 18 miles north of Port Huron, has experienced odours common to Port Huron.

The Lambton Industrial Society, formed several years ago to assess and control industrial emissions in the Sarnia area, reported that sulphur dioxide measurements taken in Sarnia in 1963 were, on an annual basis, well within the standards prescribed in the United States by the Department of Health, Education and Welfare.

The salient points put forth at the initial hearing in Windsor are summarized and paraphrased as follows:

Fluoride is one of the two most hazardous air contaminants in the production of phosphate fertilizers, smelting of aluminum, steel, and other metals. Medical literature on air pollution is lacking in fluoride data. Fluoride

standards have been set in Europe and should be set also in the United States.

The city of Windsor is experiencing severe air pollution problems caused by excessive emissions from the Detroit area, the Zug Island-Ecorse area in particular. The degree of transboundary pollution has shown a marked increase during the last 6 years. Effluents from the stacks remain aloft until reaching Canada where they are diffused to ground levels. Due to prevailing westerly winds in the Detroit-Windsor area, the air flows from the United States to Canada are about four times longer than from Canada to the United States.

Canadian studies conducted in the Windsor area from September 20 to November 15, 1963, showed that suspended particulates, as determined by high-volume samplers, were excessively high with an extreme value of 776 micrograms per cubic meter of air. The average sampling was in excess of 200 micrograms for the 56 days of record.

Concentrations of iron range from 91 to 213 grams per cubic meter. This is equivalent to 9½ to 19 tons a day being emitted from the Ecorse area and falling on the Windsor area.

The reddish plume associated with the Ecorse industrial area can be seen crossing the river. On some occasions the plume is a dense pall covering a large part of the Ojibway area of Metropolitan Windsor and constitutes a hazard to navigation on the Detroit River.

Observations made by the city of Windsor on numerous occasions indicate that shipping has had to use radar and other navigation aids to negotiate the Detroit River, and at times emissions have been so dense that traffic using Highway 18B has had to stop.

An agreement worked out between the city of Detroit-Wayne County and United States Steel provides for a reduction of particulates by over 54 tons per day within 2½ years. The reddish plume which floats across the river will no longer be observable or detrimental to the people of Canada.

There has been difficulty experienced by control agencies to procure the kind of technical and professional help needed to do the job on an accelerated basis.

The city of Detroit and Wayne County have for many years desired to develop the capability of measuring the quality of air in many sampling locations, but have been frustrated in this ability because of limited funding. Through the mechanism of grant programs of the Federal Government the problem has been overcome to a great extent.

It is clear that the prevailing winds and the heavy industrial installations in the so-called down river area are the primary factors in contaminating the air in the Windsor area.

Some air quality standards recently proposed may be more restrictive than required, and furthermore, take no account of society's ability to pay the cost or the ability of technology to accomplish the improvements.

On April 11, 1967, Great Lakes Steel Corporation agreed with the State of Michigan and Wayne County that all steelmaking facilities at the Ecorse plant would be equipped with adequate air pollution control equipment by April 30, 1970.

FINAL HEARINGS

On February 4, 1971, following receipt of the Board's report on air pollution in the Detroit River and St. Clair River areas, the Com-

mission released a statement to the press which contained highlights of the Board's report and announced the dates and places of public hearings.

The final hearings were held in the Sarnia Public Library and Art Gallery on March 10, 1971, and at Detroit in the Rackham Memorial Building on March 11, 1971. The statements presented at Sarnia are summarized and paraphrased as follows:

Since the start of this air pollution study there have been some improvements on both sides of the St. Clair River. There is better cooperation between Canadian and U.S. citizens.

The Port Huron City Government is still receiving complaints from some of its citizens with respect to air pollution, but they have been reduced in number. The air pollution in the Port Huron-Sarnia area is caused by a number of industrial enterprises and power utilities on both sides of the border.

There is a problem. We are faced with a degree of air pollution that requires positive action which, as our industrial complex expands, will have to be accelerated.

The conversion by the Canadian Polymer Corporation of its powerplant from a coal-burning unit to natural gas has had the salutary effect of reducing both sulphur dioxide and particulate pollution.

If we are to be successful in reasonably balancing the need for economic progress and a high quality environment, it is imperative that environmental quality standards be uniform and applied on a large scale, preferably an international one.

The Detroit TB and Respiratory Disease Association suggests that a Citizen's Advisory Council be established to report to the Commission.

An epidemiological study should be funded and involve the citizens of the Lambton and St. Clair Counties, concentrating on respiratory conditions of these citizens.

The Board's report presents a mandate to the people on both sides of the St. Clair River to join in concrete and untiring efforts to correct the abuses of our atmospheric environment now so starkly exposed, and to discover positive solutions to the problems posed by the apparent conflict between technological and human needs.

Increased studies are needed to determine more accurately the relationship between air pollution and health, especially respiratory diseases.

The cost of implementing abatement measures will be high, but so, too, is the cost of losses in productivity due to diseases of the respiratory system and more important the cost of human suffering.

The main concern in assessing air pollution should be its effect on health.

The disparity between the air quality standards as prescribed by the Province of Ontario and proposed by the State of Michigan is a major concern, according to a Canadian industry witness. A spokesman for the Detroit Edison Company testified, however, that a comparison shows that the Ontario standards and the proposed U.S. Federal Government secondary standards are quite compatible.

The control of sulphur oxides emissions is a very difficult problem. Low-sulphur fuels are not available in significant amounts at the present time. Desulphurization of coal is still 5 to 10 years away. Flue gas desulphurization technology is being explored and is still several years away.

Since the initial hearings, 4 years ago, complaints continue to be filed with the St. Clair County Health Department against trimethylamine malodours

originating from the Chinook Chemical Company in Sombra, Ontario. Those complaining allege that they are being deprived of the full enjoyment of their properties due to the emissions. The frequency of these adverse conditions has lessened, but they continue to be a source of irritation and concern.

An official from the Ontario Air Management Branch described the pollution control programs in Sarnia and Windsor that had been completed since the Board's emission survey or are underway as a result of regulations, cooperation by the companies concerned and Ministerial Orders. The emissions or particulates, sulphur oxides and odours have been reduced in the five major chemical plants and the three large oil refineries in Sarnia and the 10 principal industries in Windsor by additional control equipment, fuel switching and plant shutdowns.

An Ontario official explained that it was necessary to treat the area as a unit regardless of political boundaries. On behalf of the Department he recommended the formation of a committee composed of the heads of the air pollution control agencies of Ontario, Michigan, and Wayne County to investigate and propose procedures: for the integration of air quality monitoring and meteorological networks; for joint action under adverse meteorological conditions to prevent the build up of pollutants; for dealing with the major sources of transboundary air pollution on a uniform basis; for making joint recommendations to legislative bodies on such subjects as sulphur limitation in fuels; for dealing with complaints about specific sources of pollution in the other jurisdiction; and for making expertise of one agency available to the other agencies that do not have the same capabilities.

One of the major problems in the control of air pollution is the prevention of episode conditions. Such conditions can occur during prolonged periods of inversions or stagnation. Inasmuch as one cannot control meteorological conditions, one must therefore reduce emissions to the atmosphere if the quality of the ambient air is to be preserved.

At this time controls have not been developed to desulphurize flue gases from industrial and utility-type coal-burning powerplants. An acceptable system may be developed within 1 or 2 years.

Statements and testimony received at Detroit are summarized as follows:

The Board's investigation revealed fluoride pollution in the Port Huron, Grosse Ile, Belle Isle, Windsor, and Sarnia areas.

Of the 105 major Wayne County point sources listed in the Board's report, 79 are now in compliance. Of the 26 remaining point sources, 17 are now under commitment to be in compliance within the next 2 years.

It was suggested that great improvement in air quality could result from switching from coal to natural gas as fuel for boilers and steam-generating plants. A witness suggested that it is unrealistic to assume that any widespread fuel switch could take place unless major new supplies of natural gas were made available for use in the Wayne County area.

The prime emphasis at this time should be placed on the reduction of particulates and sulphur oxide concentrations.

A witness from Windsor testified that if the city of Windsor is to survive and provide quality environment for its citizens, an environment in which they can live without endangering their own health or the health of their families, it is imperative that the air pollution on the Detroit side of the River be substantially reduced.

Although the record of air pollution control in Wayne County has been impressive, the levels of air contamination have not shown a corresponding reduction except in isolated instances. This indicates that although major point sources may be easily discernible, other thousands of less obvious pollution sources must also be corrected in a planned and orderly manner.

There should be some uniformity of effort on the method of measurement of contamination as well as the setting of standards. Measurement techniques are an important ingredient in determining and utilizing data and comparing data and deriving any specific recommendations therefrom.

Numerous individuals, including residents of Windsor, attended the hearing in Detroit and expressed concern, disgust, and outright antagonism for the air pollution conditions on the Canadian side of the Boundary from sources in the United States. In general terms their pleas were for definitive action without further delays and an international citizens committee to advise the Commission. A witness suggested that reparations, based on the Trail Smelter case of the 1930's, might be considered.

Chapter V

TRANSBOUNDARY AIR CONTAMINANTS

An air contaminant is a solid, liquid, gas or odour, or a combination of any of them that may contribute to or create air pollution. Sulphur dioxide, particulate matter, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxides constitute, on a mass weight basis, approximately 98 percent of air pollution. Particulate matter and sulphur dioxide are the two principal contaminants on the basis of mass weight and are also the only two which were readily identifiable as transboundary pollutants.

Carbon monoxide, hydrocarbons, and nitrogen oxides, for the purpose of this report, were not identified as transboundary contaminants for several reasons. Although their concentration in the ambient air can be measured, their source is a matter of speculation. For example, the concentration of carbon monoxide can exceed 50 ppm (parts per million) in city streets with dense traffic. Yet, a few hundred yards away it is barely detectable. The quantities of these contaminants emitted by various sources can be calculated with reasonable accuracy. However, because of their dispersion characteristics a specific source-receptor combination cannot be identified. The problem of identifying a particular source of these contaminants with their concentration at a specific location is further complicated by their known long-distance transportation capabilities, photochemical reactions, and the mobility of vehicles which are significant sources of these contaminants.

PARTICULATE MATTER

The minute particles of liquid and solid matter dispersed in the atmosphere are called particulates. Particles larger than 50 μm (micrometers) are described as dustfall because they usually settle rapidly onto receptors not far from their source. Aerosols are the suspended particulates which range in size from a fraction of a μm to less than 50 μm.

The chemical composition and physical characteristics of particulates are dependent on their source. The incomplete combustion of

fossil fuel in steam-electric plants, commercial buildings and residences, as well as incinerated wastes, emit extremely fine carbon particles. Particulates derived from the combustion of solid fuels also contain fine ash particles composed of alumino-silicates and silica.

Prominent in the Detroit River area are the emissions from iron and steel plants. In addition to particulates produced by combustion, the emissions consist of metallic oxides such as iron and manganese oxides as well as fluxes which contain limestone and fluorspar. The catalyst dust from oil refineries contains alumina and silica.

Cement plants emit limestone, shale, and some cement. Fertilizer plants are likely to emit gaseous and particulate fluorides. Fluorides are sometimes used in steel processes as fluxes. Fluorides are ubiquitous in the atmosphere because they exist in most rocks and soils. Fine carbon particulates are emitted from diesel vehicles, ships, and aircraft. Particulate emissions from automobiles consist mainly of lead oxides, chlorides, and bromides.

SULPHUR DIOXIDE

Sulphur dioxide is a gas which at high concentrations has an irritating, choking effect. At low concentrations it may not be noticeable. It is formed by burning combustible materials containing sulphur such as coal and oil and by the oxidation of metal sulphides such as copper, lead, nickel, and zinc sulphides.

The bulk of sulphur dioxide in the atmosphere of most cities is produced by the combustion of fossil fuels. It is the most common gaseous pollutant produced by steam-electric plants, space heating and industrial activities.

ODOURS

Volatile substances which evoke an unfavourable olfactory response are classified as odorous substances. Hydrogen sulphide has a strong unpleasant odour. Unlike other odour-producing substances, it can be measured at concentrations which produce a barely detectable olfactory response. The techniques for measuring the other odour-producing substances at low concentrations are not available. An example is trimethylamine emissions from one plant in the St. Clair River area. Petroleum refineries and chemical plants are the principal source of odours in these areas.

EFFECTS

There is medical evidence that the combined presence of particulates and sulphur dioxide have a synergistic effect on health. However,

studies on particulate concentrations in the absence of sulphur dioxide are less conclusive. Similarly, sulphur dioxide is not thought to be harmful at low levels.

The Ontario Air Pollution Index, described in Chapter VI, is based on concurrent sulphur dioxide and particulate concentrations. Studies have shown that when the Index reaches 50, patients with chronic respiratory diseases may experience an accentuation in symptoms; and at 100, the air pollution has mild effects on healthy people and might seriously endanger those with severe cardiac or respiratory diseases.

The United States Department of Health, Education, and Welfare, in their documents on air quality criteria, report that sulphur dioxide concentrations of 0.2–0.25 ppm (24-hour mean) combined with particulate concentrations of 750 $\mu g/m^3$ (24-hour mean) may increase the death rate. Deaths would likely occur in aged persons or individuals with some predisposing respiratory condition. Sulphur dioxide concentrations of 0.04–0.05 ppm (annual mean) combined with 100 $\mu g/m^3$ of particulate matter may be associated with increased frequency and severity of respiratory ailments.

Odours rarely, if ever, have any direct effect upon health. However, they are aesthetically undesirable and may cause somatic illness because of their objectionable properties. This response can be attributed indirectly to the apprehension many persons have concerning the presence of any unknown constituent in the atmosphere. The constituents of the odours emitted in the Detroit River and St. Clair River areas are not considered to cause damage to vegetation or property.

Particulates in the atmosphere, in addition to the adverse health effects, restrict visibility. Smoke or extremely fine carbon particles contribute to most of soiling effects of pollution and haze. The deposition of particulate matter on buildings, motor vehicles, furnishings, and fabrics increases cleaning costs. Frequently the particles contain adsorbed acidic materials which accelerate corrosion. These repugnant consequences damage property and are detrimental to the general welfare of the affected communities.

Ozone and PAN (peroxyacetyl nitrate) produce adverse effects on vegetation. The United States Department of Health, Education, and Welfare report on air quality criteria points out that some plants, an integral part of the environment, are more sensitive to sulphur dioxide than humans. Adverse effects on vegetation were noted when the mean annual concentration of sulphur dioxide was 0.03 ppm.

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Chapter VI

AIR QUALITY STANDARDS

The desirability of a uniform standard for assessing air quality has been recognized for some time in Canada and the United States. The air quality standards in both countries were based on experiences in other parts of the world, extensive consultation, independent research, and investigation. The standards provide a basis for enforcement programs and indicate the need and extent of surveillance programs. The air quality in the Detroit River and St. Clair River areas was determined by comparing the measured concentration of the contaminants in the atmosphere with the Ontario criteria and the U.S. secondary standards set out in this chapter.

The setting of air quality regulations and their enforcement in Canada is primarily a provincial responsibility. In the United States the Federal Government is required to set air quality standards while emission regulation and enforcement is primarily a state and local responsibility. The Government of Canada has announced the proposed national air quality objectives for adoption by all provinces.

ONTARIO

In 1967 the Government of Ontario passed the Air Pollution Control Act. The control of air pollution and enforcement of the Act became a total provincial responsibility. The purpose of the Act was to control the emissions of any pollutant so that it would not cause injury to health or discomfort to persons, loss of enjoyment of the normal use of property, interfere with the normal conduct of business, or cause damage to property. The Regulations which came into effect on January 1, 1968, established standards for contaminants emitted from stationary sources on a point of impingement and also enumerated 15 criteria for desirable ambient air quality. In 1971 the Ontario Legislature passed An Act to Protect the Natural Environment. The Regulations made under the Air Pollution Act of 1967 remained in force.

Regulations promulgated in 1970 made provision for the preparation of an "Air Pollution Index" for any area in Ontario. The Index is based on continuous measurements of sulphur dioxide and suspended particulate matter because epidemiological studies indicated a relationship between the severity of health effects and the concentration of these two contaminants. The Air Pollution Index provides the public with a day-to-day knowledge of pollution levels. The Regulations also made provision for the Minister to order the curtailment or shutdown of any source not essential to public health or safety should air pollution reach a level which would be injurious to health.

An Air Pollution Index of less than 32 is considered acceptable. When the Index reaches 32 and adverse meteorological conditions are expected to remain for 6 hours, owners of the sources of pollution are advised to make preparations for the curtailment of their operations. When the Index reaches 50 and adverse weather is forecast to continue for at least 6 hours, the Minister of Environment may order major sources to curtail their activities. If the abatement action does not succeed in lowering the pollution level and the Index rises to 75, the Minister may order sources to make further curtailment in operations. When the Index reaches 100, the air pollution episode threshold level, the Minister may require the curtailment of all sources not essential to public health or safety.

As a comparison the calculated Air Pollution Index during the air pollution episode at London, England, in 1962 was 580. During adverse meteorological conditions at New York in 1962 and 1963, the calculated Index was 420 and 330 respectively. The calculated Index during the episode at Birmingham, Alabama, in 1971 was 175.

UNITED STATES

The United States Environmental Protection Agency on April 30, 1971, established national air quality standards for six major pollutants—particulate matter, sulphur oxides, carbon monoxide, photochemical oxidants, nitrogen oxides, and hydrocarbons as required by the Clean Air Act of 1970. The states are required to prepare plans that would result in the standards being met by 1975.

The Act requires that Federal standards provide for protection of public health and also protection against other adverse effects. Thus, two types of standards emerged, primary and secondary, both dealing with the effects of air pollution on man's total environment. Primary standards protect the public health, and secondary standards protect against effects of contaminants on soil, water, vegetation, materials, animals, weather, visibility, and personal comfort and well-being.

The Clean Air Act also provides that within 9 months after the national primary standard is set, states must submit plans to meet it. If a state fails to submit a plan, or if a plan is inadequate, the Administrator of the Environmental Protection Agency issues a Federal plan for the state. States may be allowed up to 27 months to submit plans to achieve secondary standards. The plans submitted by the State of Michigan for achieving the Federal primary standards have been approved.

WAYNE COUNTY

By virtue of enabling legislation of the State of Michigan, the Wayne County Board of Health in 1968 adopted and promulgated the Wayne County Air Pollution Control Regulations with countywide jurisdiction. The County Regulations provide the Air Pollution Control Division with legal authority to prevent, abate, and control air pollutants from all sources, existing and potential, within Wayne County. Following the establishment of the National Air Quality Standards in April 1971, the Board of Health in July 1971 and in March 1972 adopted new restrictions and provided more stringent limits to its regulations including sulphur content in fuels and emissions of smoke and dust into the atmosphere.

The Air Pollution Control Division of Wayne County originated the M.U.R.C. Index, an acronym which means Measure of Undesirable Respirable Contaminants. It is a measure of the airborne microscopic particulates and dirt which contribute to murkiness of haze. It is a modification of COH, the coefficient of haze, expressed in terms which provide the public with a frame of reference similar to temperature and humidity. When the M.U.R.C. Index is from 0 to 30 there is extremely low contamination; 31 to 60, low contamination; 61 to 90, medium contamination; 91 to 120, heavy contamination; and over 120, extremely heavy contamination. The M.U.R.C. Index fits established contamination scales and reflects an approximate concentration of suspended particles in the atmosphere.

CANADA

The Clean Air Act which was passed in the House of Commons and received Royal Assent in June 1971 was designed to protect public health and welfare by setting limits for air pollution contaminants. The maximum acceptable level corresponds in concept to the secondary air quality standards of the United States and to air quality objectives in use by some provinces in Canada. When this level is exceeded, control action by a regulatory agency is necessary.

TABLE 1. SUMMARY OF AIR QUALITY STANDARDS

Unit of measurement	Sampling time	ONTARIO criteria	UNITED STATES		CANADA		IJC objective
			Primary	Secondary	Acceptable	Desirable	
	PARTICULATE MATTER						
$\mu g/m^3$	24 hours	90	260	150	120	. . . .	120
	1 year*	60	75	60	70	60	60
	SULPHUR DIOXIDE						
ppm	1 hour	0. 25	. . . .	. . . .	0. 34	0. 17	0. 25
	3 hours	. . . .	. . . .	0. 50	. . . .	. . . .	. . . .
	24 hours	0. 10	0. 14	0. 10	0. 11	0. 06	0. 10
	1 year**	0. 02	0. 03	0. 02	0. 02	0. 01	. . . .

* Geometric mean.
** Arithmetic mean.

$\mu g/m^3$ —micrograms per cubic meter.
ppm —parts per million of air.

The maximum desirable level defines long-term goals for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology. The Canadian Department of the Environment in October 1971 proposed National Air Quality Objectives for five major air pollutants—sulphur dioxide, particulate matter, carbon monoxide, photochemical oxidants, and hydrocarbons.

SUMMARY OF AIR QUALITY STANDARDS

Table 1 is a summary of the Ontario criteria, the United States primary and secondary standards and the acceptable and desirable objectives proposed by the Government of Canada for the two principal contaminants, particulate matter and sulphur dioxide. For convenience, the transboundary air quality objectives proposed by the Commission and set out in Chapter XI of this report are also listed in Table 1.

Chapter VII

AIR POLLUTION IN THE DETROIT RIVER AREA

Metropolitan Detroit, with a population of four million, encompasses the entire United States shoreline of the Detroit River. (See verso of title page.) The projected population for the year 2000 exceeds seven million. Metropolitan Detroit has more than 4,700 manufacturing enterprises. About 70 percent of the population reside in the highly industrialized Wayne County. This County accounts for 35 percent of all the automobile manufacturing in the United States.

The city of Windsor, nestled in the gentle upstream arc of the Detroit River, is opposite Detroit's industrial complex. Windsor has a population of 212,000. The population of Essex County, including the city of Windsor, is expected to increase from 295,000 to 460,000 by the year 2000. Windsor's manufacturing facilities, like Detroit's, are located near the River.

TOPOGRAPHY

The Detroit River, 30 miles in length, connects Lake St. Clair and Lake Erie. It flows in a narrow valley about 25 feet below a wide flat plain. The terrain, some 20 miles to the southeast, is only 50 feet above the river banks. On the Michigan side of the River the plain rises 200 feet in 15 to 20 miles. The nearest hills, 50 miles away, are in Michigan and the highest point is about 1,000 feet above the River. The surrounding topography has no effect on the retention or dispersion of air pollutants.

METEOROLOGY

The winters and summers in the Detroit River area are moderated by its proximity to the Great Lakes. It is in the zone of prevailing westerly winds. Because the area is near the summer position of the polar front, storm systems that generally move eastward are accompanied by northward and southward displacements. Consequently,

spring and summer winds are less consistent in direction than those of the fall and winter.

The wind roses shown on Figure 2 are a graphic comparison of the wind direction frequencies which occurred during the investigation. Due to the bend of the Detroit River and the east-wind orientation of the Boundary, the winds in the vicinity of Windsor blow from one country to the other with almost equal frequencies. However, in the southern portion of the area where the U.S. side of the Boundary is highly industrialized, the winds blow more frequently from the United States to Canada than in the reverse direction.

Pollutants emitted from near-ground levels are transported away from the source by winds. Stronger winds generally cause a greater mechanical mixing, a greater diffusion of pollutants and, consequently, a reduction in the concentration of contaminants. The average wind speed at Detroit City Airport is 10 miles per hour. The wind is calm 5 percent of the time.

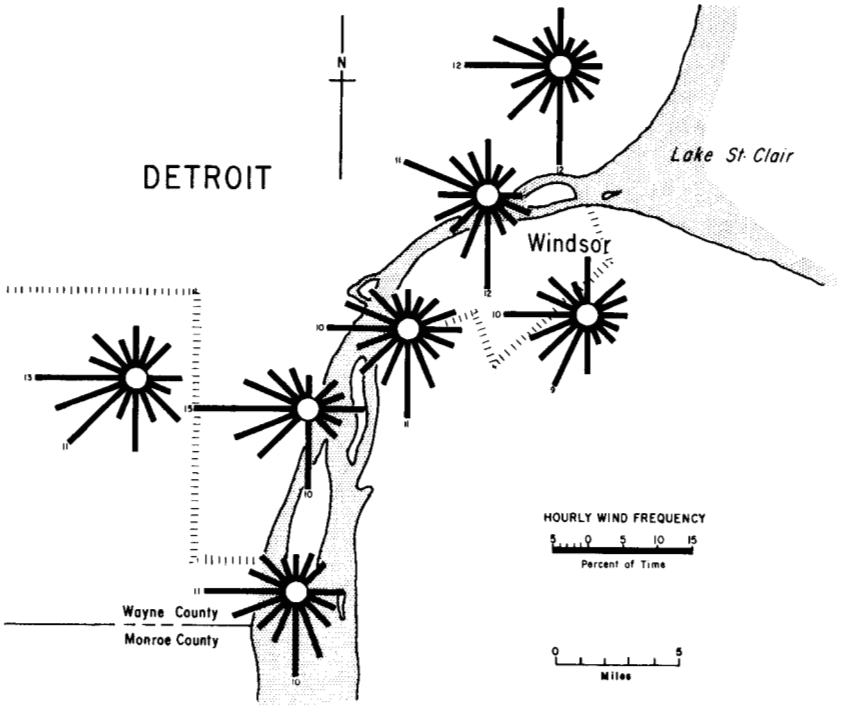

FIGURE 2 DIRECTION AND FREQUENCY OF WINDS IN DETROIT RIVER AREA DECEMBER 1967-NOVEMBER 1968

When the air temperature decreases with height the warm air near the ground and the contaminants emitted into it rise and disperse high in the atmosphere. This unstable condition reduces the concentration at or near ground level. When the temperature within a layer of air increases with height the phenomenon is called an *inversion.*

The air in this inverted warmer layer becomes stable and stagnant, inhibiting the normal rise and dispersion of pollutants. Thus, the pollutants are retained and accumulate in the lower layer of air. During a prolonged inversion there is an excessive accumulation and concentration of contaminants. Such a condition is known as an *episode.*

Three types of inversions occur in the Detroit River area. Ground-based temperature inversions are frequent. Data collected by the Board indicate that, on an annual basis, brief ground-based inversions occur on 100 to 180 days a year. On a clear night the air cools faster in the layer near the ground than aloft. A ground-based inversion develops and remains until morning. After the sun rises, the air near the ground becomes warmer and the temperature inversion breaks down. However, should a cloud cover develop prior to sunrise and persist during the day the inversion may continue as long as the cloud cover remains.

Advection inversions occur in areas near large bodies of water such as Lake Erie and Lake Huron. During the spring and early summer, the air over the lake's surface is cooled by the water. During the day the air of the land and especially over cities like Detroit is warmed and rises. As the warm air rises it is replaced by air from over the lake, thus creating an inversion in the lower layer of the atmosphere.

A third type, the subsidence inversion, occurs aloft and is associated with large high-pressure areas. The sinking motion of the air not only forces the ground layer of warm air upward but also prevents it from going completely aloft. The high pressure also prevents the ground layer of air from spreading outward. Thus, a subsidence inversion acts as a cap on the pollutants being emitted and prevents their dispersion into the higher layers of the atmosphere. Subsidence inversions are serious because the high-pressure areas often remain stationary for prolonged periods and are accompanied by calm or light winds. Such episodes or inversions lasting 4 days or more have occurred in the Detroit area 18 times from 1936 to 1965.

AIR QUALITY

The criteria used to establish air quality standards are based on the effects of air contaminants in the light of existing knowledge. The air

quality in the Detroit River area was determined by comparing the measured concentration of contaminants in the atmosphere with the standards described in Chapter VI.

The average annual concentrations of particulates and sulphur dioxide measured in the Detroit River area during the investigation are shown on Figures 3 and 4. During an inversion or a period of atmospheric stagnation the average daily concentrations are much higher and more dangerous.

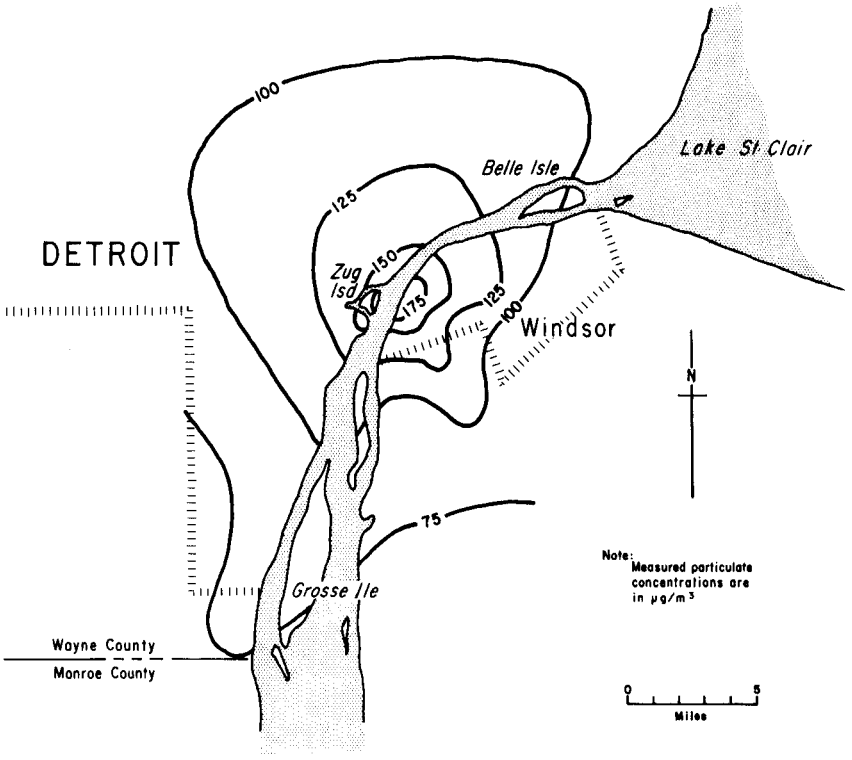

FIGURE 3 MEASURED PARTICULATE CONCENTRATIONS IN DETROIT RIVER AREA

Three of the 13 observation sites in the Canadian portion of particulate concentration are 60μg/m^3 (micrograms per cubic meter of air); for a 24-hour period 90 μg/m^3. The Ontario criterion was exceeded at all stations except one, and it was 15 miles west of Grosse Ile. Approximately 13 square miles in the city of Windsor had a mean annual concentration greater than 125 μg/m^3. Over a square mile of the business section in the city had a mean annual concentration exceeding 175 μg/m^3. Three of the 13 observation sites in the Canadian portion of the area were in the city of Windsor. The Ontario criterion for a

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24-hour period was exceeded in 75 percent of the 276 samples collected at these three sites. The maximum observed suspended particulate concentrations at the same three stations were 537, 326, and 471 $\mu g/m^3$. Similar values were obtained at the five stations south of Windsor and opposite Zug Island.

The U.S. secondary standard for the mean annual concentration of suspended particulates is 60 $\mu g/m^3$ and for a 24-hour period 150 $\mu g/m^3$. In Metropolitan Detroit the mean annual concentration which exceeded 125 $\mu g/m^3$ covered an area of 22 square miles in the locality north and northeast of Zug Island. Ten of the 21 sampling stations in Detroit were located within 5 miles of the Detroit River shoreline and from Grosse Ile to Belle Isle. Half of the 1,350 daily samples taken at these stations over a period of a year were greater than 90 $\mu g/m^3$. Maximum daily averages ranged from 179 to 416 $\mu g/m^3$. The highest values were obtained during the winter and spring months.

Fluoride concentrations were measured at two sites in Detroit and one south of Windsor. Maximum 24-hour values were above the 1.0 ppb (parts per billion) level—the Ontario criterion. At the site south of Windsor and opposite Zug Island, 1 percent of the 200 4-hour samples exceeded 2.7 ppb.

Particulates above 200 micrometers in size settle from the atmosphere as dustfall. The Ontario criterion for dustfall is 20 tons/mi^2-mo (tons per square mile for a 30-day period) and an annual average of 13 tons/mi^2. Based on data obtained at 38 sites the average dustfall concentration exceeded 30 tons/mi^2-mo over nearly all of Windsor and over 25 square miles of northeast Detroit. Heavy dustfall occurred in the commercial and industrial areas of both Detroit and Windsor. At two sites in Windsor maximum monthly values were 68 and 107 tons per square mile. In Detroit three sites had corresponding values of 61, 82, and 123 tons per square mile. The heaviest dustfall occurred in Detroit, south of the city centre. Here the annual average was 62 tons per square mile or five times the Ontario criterion.

Sulphur dioxide concentrations are shown on Figure 4. They are the arithmetic mean of 7,099 samples obtained at five stations in the Windsor area and 27,082 samples obtained at 10 stations in the Detroit area over a period of 12 months. The Ontario criterion and the U.S. secondary standard for the mean annual concentration of sulphur dioxide are both 0.02 ppm (parts per million) of air. This standard was exceeded in all of Windsor and a large part of Detroit. Nearly 5 square miles of Detroit and 4 square miles in Windsor had a mean annual sulphur dioxide concentration which exceeded 0.04 ppm. Over a

square mile of the business section of Windsor had a concentration exceeding 0.05 ppm. Within the boundaries of the cities of Detroit and Windsor maximum 1-hour values ranged from 0.25, the Ontario criterion, to 0.84 ppm of air.

Sulphation measurements, a static method of determining the presence of sulphur dioxide in the atmosphere, are an index of effects of sulphur dioxide on materials such as fabrics, metals, paints, and masonry. The Ontario criterion is 0.4 mg of SO_3/100 cm_2-day (milligrams of sulphur trioxide per 100 square centimeters per day). Only 17 of the 41 stations in the Detroit River area had a sulphation rate less than 1.0 mg of SO_3/100 cm^2-day. The only station that met the Ontario criterion was 15 miles west of Grosse Ile. The collected data confirmed excessive concentrations of sulphur dioxide in the large area affected by industrial activity.

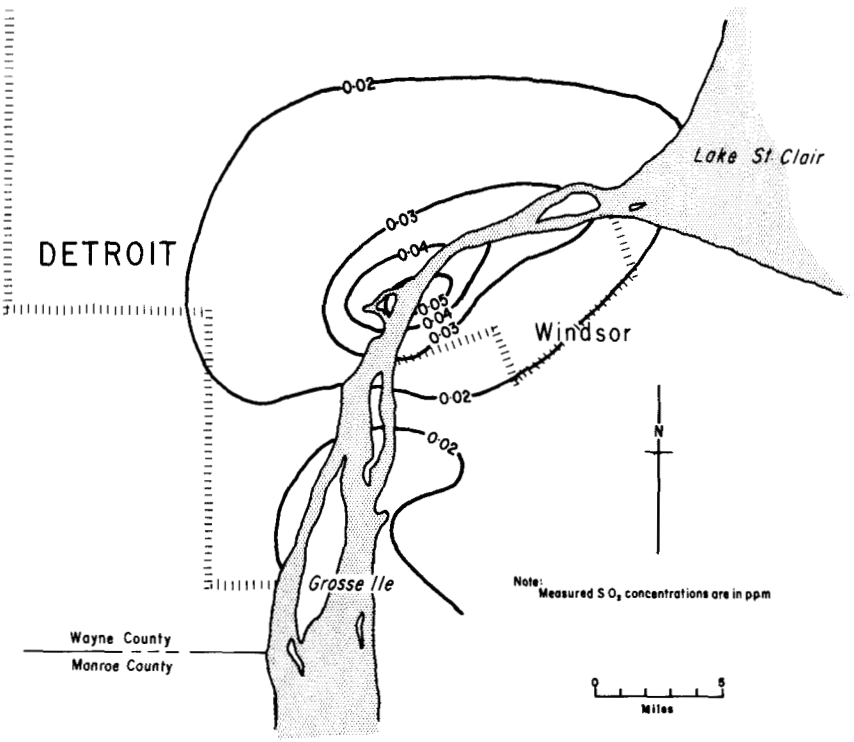

FIGURE 4 MEASURED SO_2 CONCENTRATIONS IN DETROIT RIVER AREA

SOURCES OF EMISSIONS

The sources of emissions in the Detroit River area are shown on Figure 5. Any individual site that emitted 100 tons or more of any single pollutant per year was considered significant and designated as a point source. There are 118 such point sources in the United States and 25 in Canada. Activities emitting less than 100 tons of a pollutant per year were grouped on an area basis according to intensity.

The emissions of particulates and sulphur oxides (SO_x) from various types of sources in each country are summarized in Table 2.

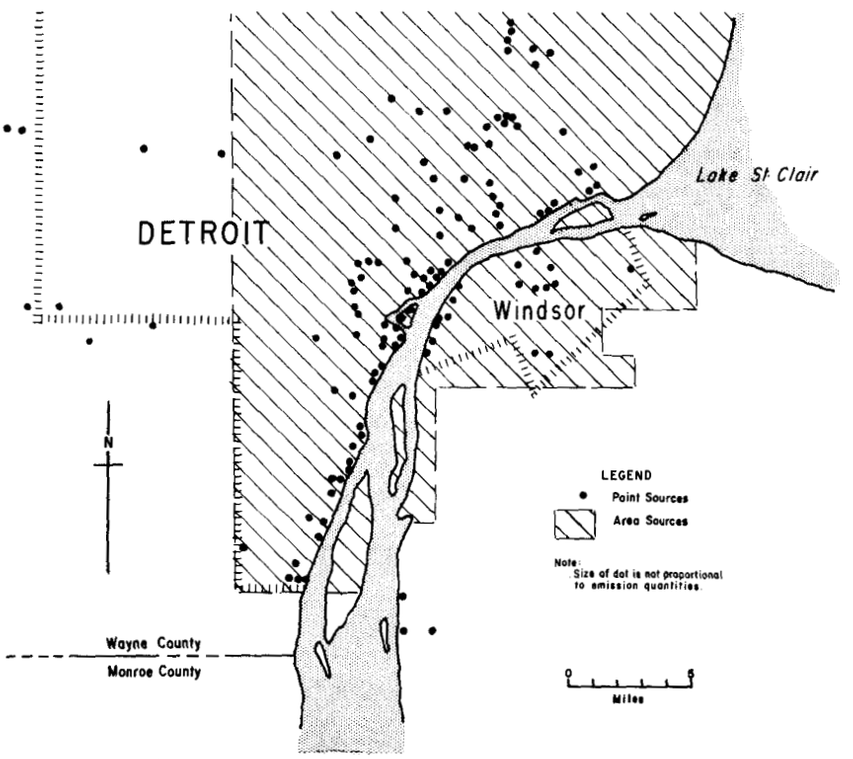

FIGURE 5 SOURCES OF EMISSION IN DETROIT RIVER AREA

Of the 258,000 tons of particulates emitted in the total area, 90 percent were from sources in the United States. Similarly, of the 550,000 tons of sulphur oxides emitted in the area, 94 percent were from sources in the United States. Wayne County, Michigan, was re-

TABLE 2. AIR POLLUTION EMISSIONS IN DETROIT RIVER AREA FOR 1967

[Thousands of tons per year]

Source	Particulates		SO_x	
	U.S.	Canada	U.S.	Canada
Industry:				
Fuel combustion	41.4	12.6	113.9	10.5
Process losses	59.0	8.8	20.7	. . . . .
Power utilities	56.2	0.7	305.1	15.8
Nonindustrial heating	30.4	0.5	62.4	2.6
Refuse combustion	26.6	0.3	1.4	. . . . .
Vehicles	14.2	1.0	7.7	0.6
Ships	2.7	2.5	5.1	4.5
Aircraft and trains	1.0	0.3	0.3	0.1
Total each country	231.5	26.7	516.6	34.1
Total both countries	258.2		550.7	

sponsible for 76 percent of the total of particulate emissions and 86 percent of the total emissions of sulphur oxides.

With regard to particulate emissions from sources in the United States, industrial fuel combustion and process losses accounted for 39 percent of the total for both countries, power utilities 22 percent, incinerators and open burning of refuse 10 percent, fuel combustion in commercial and Government buildings 6 percent, in residences 3 percent, and in heating plants 2 percent. In contrast, the Canadian emissions from the same six types of sources accounted for only 9 percent of the total for the Detroit River area. It should be noted that particulate emissions from ships plying the Detroit River accounted for only 2 percent of the total or a third of the amount emitted by vehicles.

The seven Detroit Edison powerplants in Wayne County discharged 53,000 tons of particulates into the atmosphere in 1967. The largest single source of particulates was Great Lakes Steel located on Zug Island. Their process losses to the atmosphere in 1967 amounted to 27,289 tons of particulates. The other principal offenders were Chrysler Corporation (13,917 tons) and the Ford Motor Company (11,323 tons). On the Canadian side of the River the principal offenders were the Windsor operations of the Ford Motor Company (6,952 tons) and Allied Chemical (4,400 tons).

With regard to emissions of sulphur oxides from U.S. sources, power utilities accounted for 55 percent of the total emissions in the Detroit River area, industrial fuel combustion and process losses 24 percent, fuel combustion in commercial and Government buildings 7 percent, in residences 3 percent, and in heating plants 2 percent. In contrast, the Canadian emissions from the same five types of sources accounted for 5 percent of the total for the Detroit River area. The emissions of sulphur oxides from ships plying the Detroit River were only 2 percent of the total.

The seven Detroit Edison powerplants discharged 300,000 tons of sulphur oxides into the atmosphere in 1967. The other principal offenders in the United States were the Ford Motor Company (15,795 tons), General Motors Corporation (9,437 tons), and Chrysler Corporation (7,835 tons). On the Canadian side the principal offenders were a steam-electric powerplant (15,840 tons), Allied Chemical (3,428 tons), and the Windsor operations of the Ford Motor Company (1,964 tons).

REDUCTION IN EMISSIONS

The Board in its report anticipated a noticeable reduction in the emissions of particulates from point sources. Since 1968 abatement measures have been undertaken for specific sources in both Detroit and Windsor to reduce emissions of particulates.

The regulatory agencies have monitored the concentrations of particulates, sulphur dioxide, hydrocarbons, nitrogen oxides, oxidants, and carbon monoxide since completion of the Board's field studies. Based on continuous data obtained from three stations established by the Board, the average annual particulate concentration in Windsor for 1971 has remained the same as the 1968 concentration. However, the sulphur dioxide concentration in Windsor declined about 20 percent.

In Wayne County particulates were measured at seven locations compatible to those stations used by the Board in 1968. Sulphur dioxide concentrations were measured at three compatible locations. Based on an average of the values obtained at these sites, the average annual particulate concentration in Detroit during 1971 was 12 percent lower than the 1968 value. The sulphur dioxide concentrations declined about 15 percent. This reduction has taken place in spite of increased industrial activity.

TRANSBOUNDARY MOVEMENT

The location of the sources of emissions coupled with the westerly winds, data collected at receptor sites on the banks of the Detroit River,

and visual observations provide unequivocal evidence that air contaminants originating in the industrial complex of Detroit do move across the International Boundary into the Windsor area.

Pollution roses, graphic displays of a combination of pollution measurements with coincident meteorological data, show that there is appreciable transboundary flow of pollutants from the heavily industrialized Zug Island—Ecorse area to Windsor as well as to that portion of Detroit in the vicinity of Belle Isle. This was confirmed by detailed case studies. Aerial sampling of particulate and sulphur dioxide concentrations made along the Boundary verified that the winds transported sizable quantities of air contaminants from the United States into Canada.

Mathematical dispersion models were used to estimate the quantity of air contaminants transported across the Boundary. The dispersion models took account of the location of the sources and their average rate of emissions, the frequency distribution of meteorological conditions, atmospheric mixing depth and the location of receptor sites. Cognizance was taken of local sources and the background level of contaminants. There was high correlation and excellent agreement between the spatial distribution of observed and estimated concentrations of particulates and sulphur dioxide. There was also good agreement between the sulphation rates based on dispersion model estimates and observed values. Thus, considerable confidence can be placed in use of the Board's dispersion models to determine the impact of emissions of one country on the air quality of the other country.

The estimated contribution of U.S. sources to the average annual concentration of particulates in the Windsor area and the contribution of particulates from Canadian sources to the Detroit area are shown on Figure 6.

The average annual transboundary flow of particulates from U.S. sources exceeded both the Ontario criterion and the U.S. secondary standards (60 $\mu g/m^3$) over an area of 33 square miles in Windsor. In fact, the transboundary flow from U.S. sources to 3½ square miles of Windsor was double the Ontario criterion.

In contrast, the maximum transboundary flow of particulates from Canadian sources to the Detroit area was a fraction of U.S. standards.

A comparison of Figure 3, the measured particulate concentration, and Figure 6, the particulate concentration due to transboundary movement, indicates that if it were not for the transboundary movement, the concentration of particulates in the air in Windsor would be well within the Ontario criterion.

The estimated contribution of U.S. sources to the average annual concentration of sulphur dioxide in the Windsor area and the contri-

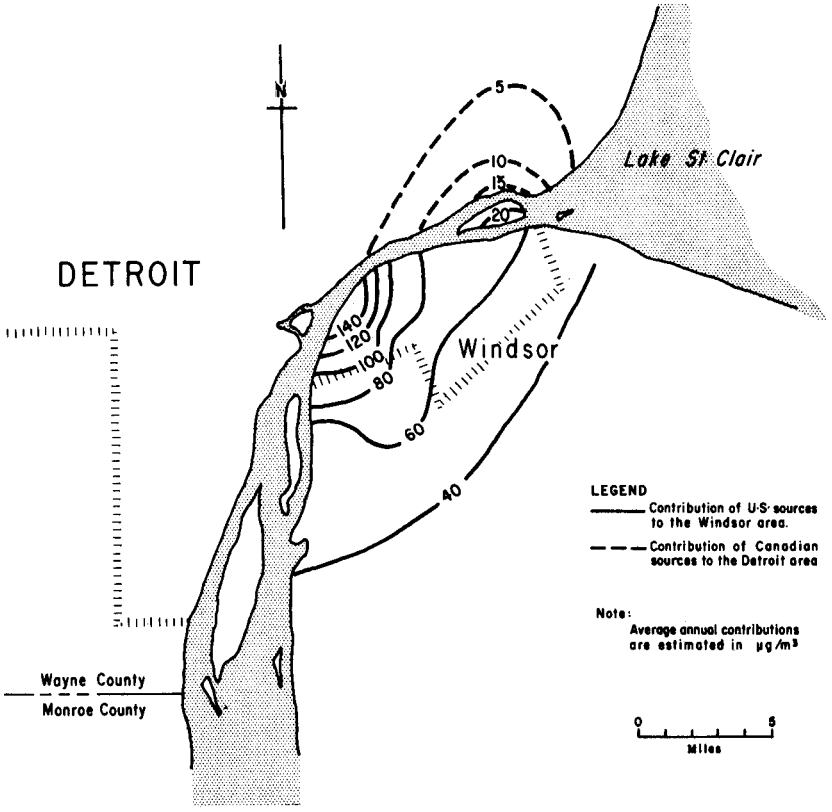

FIGURE 6 TRANSBOUNDARY FLOW OF PARTICULATES IN DETROIT RIVER AREA

bution of sulphur dioxide from Canadian sources to the Detroit area are shown on Figure 7.

The average annual transboundary flow of sulphur dioxide from U.S. sources exceeded both the Ontario criterion and the U.S. secondary standards (0.02 ppm of air) over 18 square miles in Windsor. Furthermore, the transboundary flow from U.S. sources to an area of 2 square miles in the business section of Windsor was double the Ontario criterion.

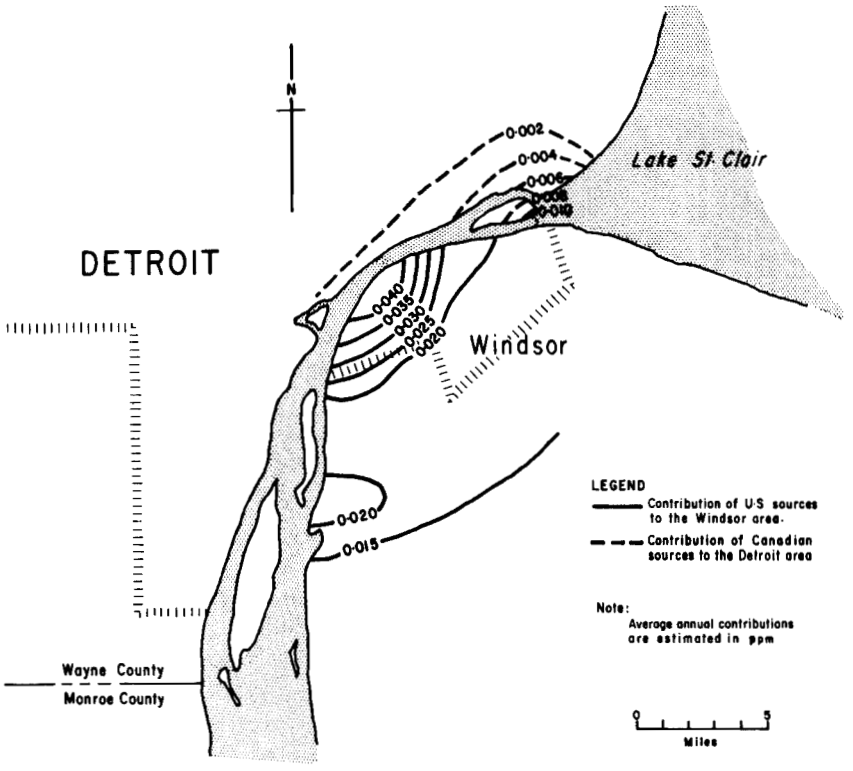

FIGURE 7 TRANSBOUNDARY FLOW OF SO_2 IN DETROIT RIVER AREA

In contrast, the transboundary flow of sulphur dioxide from Canadian sources to the Detroit area was a fifth of the U.S. secondary standards and limited to an area of 5 square miles north of Belle Isle.

A comparison of Figure 4 and Figure 7 reveals that if it were not for the transboundary movement the concentration of sulphur dioxide in the air in Windsor would be lower than the Ontario criterion.

Chapter VIII

AIR POLLUTION IN THE ST. CLAIR RIVER AREA

Lambton County is on the Ontario side of the St. Clair River. It has a population of 115,000 of which 62,000 live in Sarnia. The County's population is expected to grow to 175,000 by the year 2000. Most of the County's work force is employed by the chemical industries and oil refineries located near the shore of the River.

Port Huron is opposite Sarnia on the Michigan side of the St. Clair River. (See verso of title page.) St. Clair County extends along the entire length of the River. The urban area of Metropolitan Detroit is expected to extend into the County. This would increase the County's population from 110,000 to 250,000 by the year 2000. The manufacture of primary metal products and chemicals as well as paper, rubber, and plastic products form the largest segment of the County's economy.

TOPOGRAPHY

The St. Clair River flows from Lake Huron to Lake St. Clair, a distance of 35 miles, in a narrow shallow valley. The adjacent flat plain gently rises 50 feet in 15 miles to the east and 10 miles to the west. The nearest hills, 50 miles to the west, are less than 1,000 feet above the river banks. The surrounding topography has no effect on the movements of air contaminants.

METEOROLOGY

The climate of the St. Clair River area is modified by the Great Lakes. Although the area is in a zone of prevailing westerly winds, the predominant direction of the winds is parallel to the St. Clair River and to the Boundary. This phenomenon is caused by storm systems moving eastward during the spring and summer months being accompanied by northward and southward displacements. Also during the spring and summer, winds blow from Lake Huron during the daytime and from the land to the Lake during the night. Figure 8 is a

graphical comparison of the wind direction frequencies which occurred during the investigation.

The average annual windspeed at Sarnia is 8 miles per hour. The wind is calm 2 percent of the time.

Collected data indicate that on an annual basis ground-based inversions occur on 100 to 180 days a year. The Commission is concerned not only with the frequencies and the time of day of inversions but also with their duration. The concentration of contaminants in the air increases in proportion to the duration of the inversion. During the 12-month investigation period, 272 temperature inversions occurred at Sarnia. Of this number 244 lasted for at least 3 hours, 140 for 12 hours, 3 persisted for 24 hours, and 1 lasted over 36 hours but less than 48 hours.

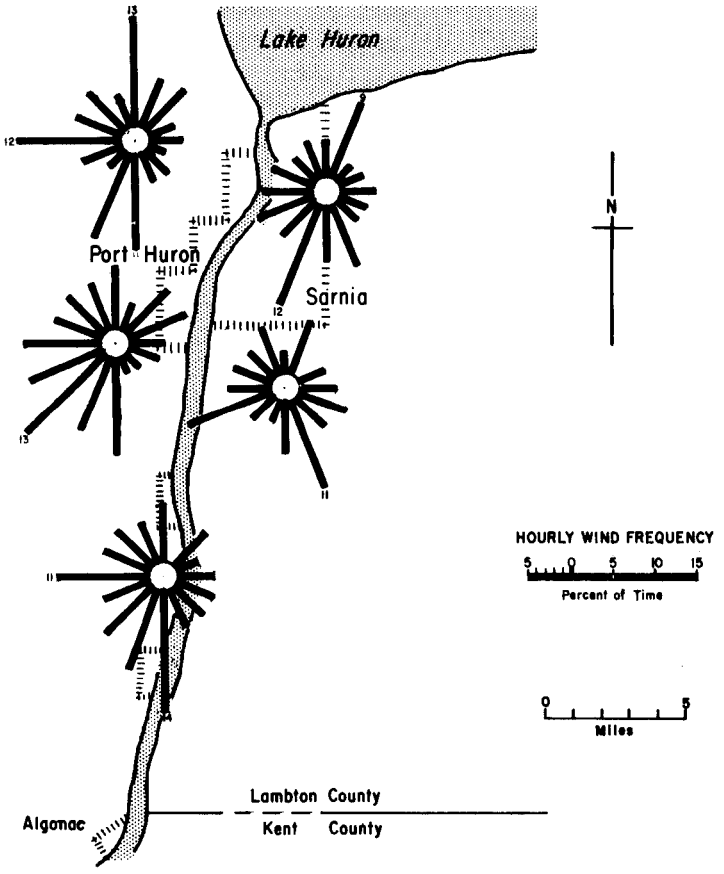

FIGURE 8 DIRECTION AND FREQUENCY OF WINDS IN ST. CLAIR RIVER AREA DECEMBER 1967 - NOVEMBER 1968

AIR QUALITY

The standards described in Chapter VI are compared with actual observations to assess the air quality in the St. Clair River area. The average annual concentrations of particulates and sulphur dioxide measured during the investigation are shown on Figures 9 and 10. During an inversion the concentration of contaminants is much higher than the average annual values.

Suspended particulates were measured at 11 sampling stations in Canada and 11 in the United States. The Ontario criterion and the U.S. secondary standard for mean annual suspended particulate (60 $\mu g/m^3$) was exceeded at the 2 stations in Port Huron; 1 in Marysville, Michigan; 1 in St. Clair, Michigan; and the 9 stations in Ontario extending from Courtright to Lake Huron.

In the Sarnia area approximately 50 square miles had a mean annual concentration greater than 75 $\mu g/m^3$ and 12 square miles greater than 100. Half of the 365 observations made at 4 stations in Sarnia exceeded the Ontario criterion for a 24-hour period (90 $\mu g/m^3$). The maximum observed values ranged from 224 to 300 $\mu g/m^3$.

In the Port Huron area approximately 20 square miles had a mean annual concentration greater than 75 $\mu g/m^3$ and three-quarters of a square mile greater than 100. Of the 397 observations made at 2 stations in Port Huron 15 percent exceeded the U.S. secondary standard (150 $\mu g/m^3$); 30 percent exceeded the corresponding Ontario criterion (90 $\mu g/m^3$). The maximum observed values were 298 and 305 $\mu g/m^3$.

Fluoride concentrations were measured at two sites, one at Marysville and the other at St. Clair. The Ontario criterion is an average of 1.0 ppb for a 24-hour period. Of the 475 observations 1 percent of the samples exceeded 1.9 ppb. The maximum values obtained at each site were 2.2 and 1.3 ppb respectively.

Dustfall samples were collected at 29 locations. The Ontario criterion is 20 tons/mi^2-mo with an annual average of 13 tons/mi^2. This criterion was exceeded over an area of 38 square miles in Sarnia and vicinity, 8 square miles in Port Huron, and 35 square miles in the area around and southeast of St. Clair on both sides of the River. Of the 270 observations only 9 had values equal to or greater than 40 tons/mi^2-mo. These values were obtained at 8 locations where the annual mean was double the Ontario criterion.

Sulphur dioxide concentrations are shown on Figure 10. They are the arithmetic mean of 45,849 samples taken at 8 stations on the Ontario side of the St. Clair River and 6,131 samples taken at 3 stations on the Michigan side over a period of 12 months. The arithmetic mean at all stations exceeded the Ontario criterion and the U.S. secondary standard, a mean annual concentration of 0.02 ppm of air. About 2 square miles in Port Huron, 6½ square miles in Sarnia and

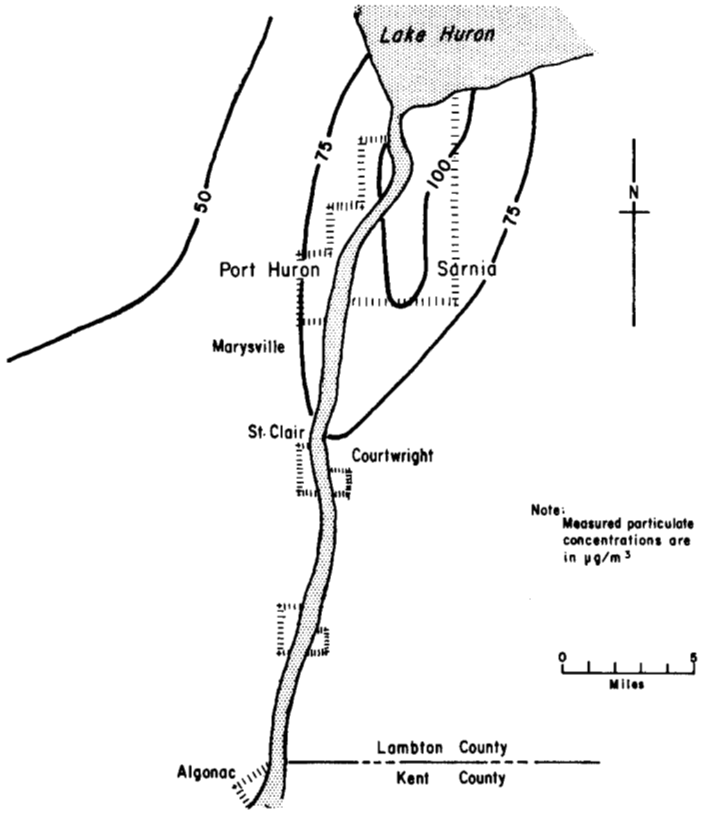

FIGURE 9 MEASURED PARTICULATE CONCENTRATIONS IN ST. CLAIR RIVER AREA

4½ square miles of Ontario southeast of St. Clair, Michigan, exceeded 0.03 ppm. The maximum hourly observations varied from 0.32 to 0.57 ppm in Port Huron, 0.34 to 0.71 ppm in Sarnia, and 0.26 and 0.52 ppm in Ontario east of St. Clair. The Ontario criterion for 1 hour is 0.25 ppm.

Sulphation measurements confirm the presence of sulphur dioxide in the atmosphere. The Ontario criterion is 0.4 mg of SO_3/100 cm^2-day. This criterion was equalled or exceeded at all 32 measurement sites. Seven sites in Sarnia, 4 in Port Huron, and 2 near St. Clair had average values equalling or exceeding 1.0 mg of SO_3/100 cm^2-day.

During February of 1969 an intensive survey was made of sulphation rates. Sulphation sensors were installed at 121 locations parallel to and up to 10 miles from the St. Clair River. The centres of high-sulphation rates, 1.2 to 3.0, were south of Sarnia and east of Sombra, Ontario.

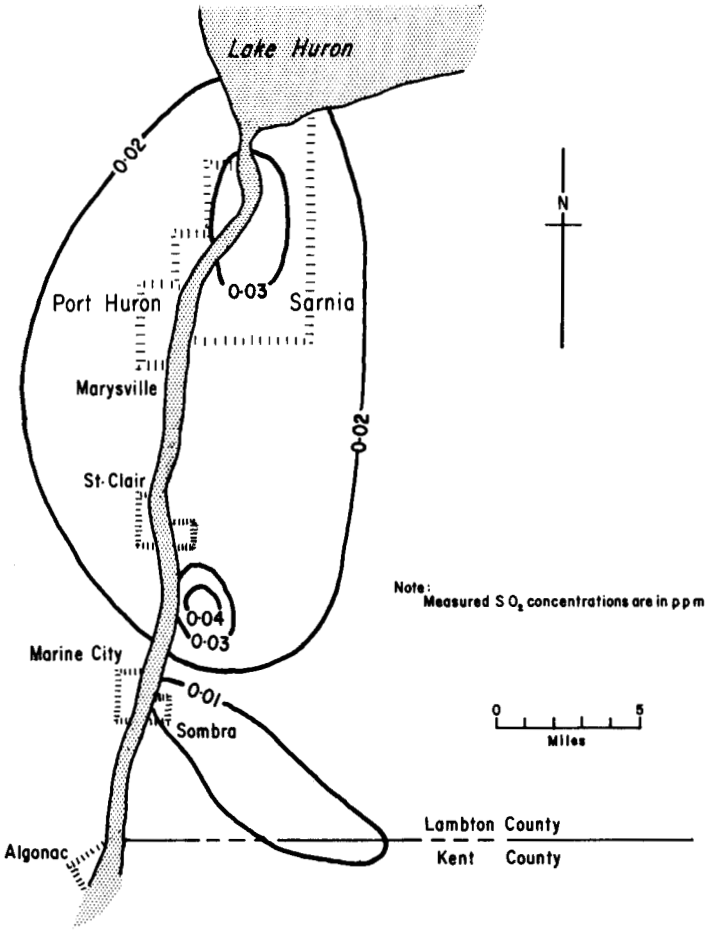

FIGURE 10 MEASURED SO_2 CONCENTRATIONS IN ST. CLAIR RIVER AREA

Odours have been a source of complaint from residents along the banks of the St. Clair River from Lake Huron to Marine City. Between August and December of 1968, 27 patrols were made in the Port Huron-Marysville sector in the early morning or late afternoon, periods of low rates of dispersion, to determine the frequencies of odours. Scentometers were used to measure the intensity of odour. Increasing intensity of odours as determined by the scentometer were recorded on a scale of 1 to 4. Any odour that could be barely detected without using the scentometer but did not measure strength 1 or more on the scentometer was classed as strength 0. The wind direction was determined by a portable anemometer at the point where odours were measured. Odours were detected on 18 of the 27 patrols. Fifteen of the detections had a strength 0, two a strength of 1, and one had a strength of 2.

In addition, for a 7-week period four residents in Port Huron maintained records of their assessment of odours. Slightly objectionable odours were recorded every day at one location. At another location odours were reported on 18 days. In the latter case all except two were classified as severe.

Similarly, an odour survey was conducted in the Marine City sector. Odours were detected on 13 of the 33 patrols. Eleven had a strength of 0, one had a strength of 1, and one had a strength of 2. Five residents of Marine City maintained records of their assessment of odours. Odours were reported by one or more of these observers on 21 of the 48 days. There was only 1 day on which all five observers reported the occurrence of odours.

Hydrogen sulphide concentrations greater than 2 ppb are considered by some to have a perceptible odour. Nearly 15,000 2-hour samples were obtained at four sites in Sarnia and 5,700 samples at two sites in Port Huron. About 10 percent had a hydrogen sulphide concentration greater than 1.0 ppb. In Sarnia the maximum 2-hour concentration was 100 ppb, the highest daily average concentration was 9.0 ppb. In Port Huron the maximum 2-hour concentration was 17.9 ppb, the highest daily average was 4.6 ppb.

SOURCES OF EMISSIONS

The point and area sources of emissions are shown on Figure 11. There are 12 point sources in the United States and 24 in Canada. The emissions of particulates and sulphur oxides from the various types of sources in each country are summarized in Table 3.

TABLE 3. AIR POLLUTION EMISSIONS IN ST. CLAIR RIVER AREA FOR 1967

[Thousands of tons per year]

Source	Particulates		SO_x	
	U.S.	Canada	U.S.	Canada
Industry:				
Fuel combustion	1.5	22.2	3.5	80.4
Process losses	1.6	3.2		17.3
Power utilities	19.0		266.0	
Nonindustrial heating	0.7	0.2	1.1	0.8
Refuse combustion	0.6	0.4		
Vehicles	0.3	0.3	0.2	0.2
Ships	0.5	0.3	2.1	0.9
Aircraft and trains				
Total each country	24.2	26.6	272.9	99.6
Total both countries	50.8		372.5	

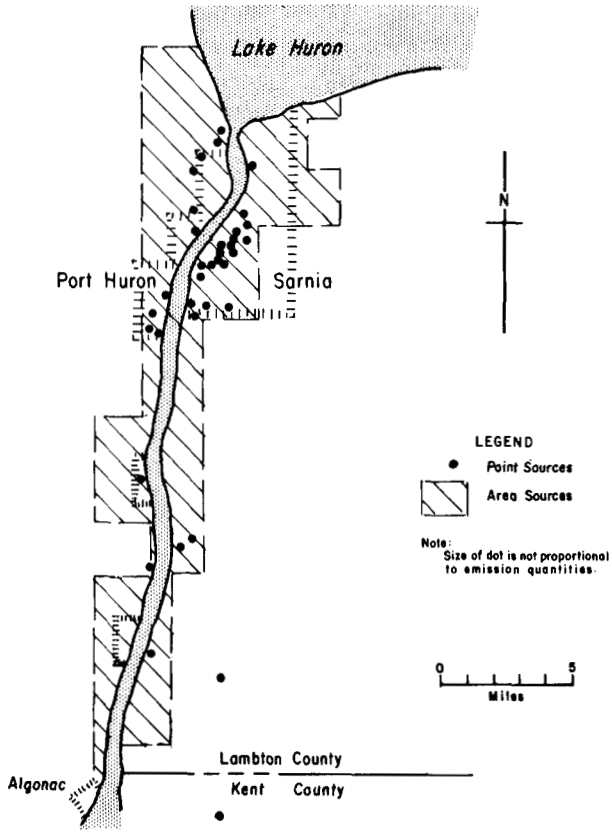

FIGURE II SOURCES OF EMISSION IN ST. CLAIR RIVER AREA

Of the 51,000 tons of particulates emitted in 1967, 52 percent were from sources in Canada and 48 percent from sources in the United States. Of the 373,000 tons of sulphur oxides emitted in the area 27 percent were from sources in Canada and 73 percent from sources in the United States.

With regard to particulate emissions from sources in Canada, industrial fuel combustion accounted for 44 percent of the total for both countries, and industrial process losses 6 percent. Although there are now new installations on both shorelines there were at the time of the emission survey no power utilities along the Canadian shoreline. Of the particulate emissions in the United States, power utilities accounted for 37 percent of the total for both countries, and industrial process losses 3 percent. Particulate emissions from ships plying the River accounted for less than 2 percent of the total.

The Detroit Edison powerplants at Marysville and St. Clair, Michigan, discharged 18,500 tons of particulates into the atmosphere

in 1967; American Cement Corporation 1,420 tons. On the Canadian side of the River the principal offenders were Polymer Corporation (18,280 tons), Imperial Oil (2,046 tons), and Dow Chemical (1,864 tons).

With regard to the emissions of sulphur oxides from U.S. sources, power utilities accounted for 71 percent of the total emissions for the St. Clair River area and industrial fuel combustion about 1 percent. Process losses of sulphur oxides were insignificant. In contrast, the Canadian industrial fuel combustion and process losses accounted for 26 percent of the total for the St. Clair River area. The emissions of sulphur oxides from ships plying the St. Clair River were less than 1 percent of the total.

The Detroit Edison powerplant at St. Clair discharged 230,200 tons of sulphur oxides into the atmosphere in 1967; the plant at Marysville 35,200 tons. The other principal offender in the United States, Diamond Crystal Salt Company, discharged 1,402 tons. The principal Canadian offenders were Polymer Corporation (25,451 tons), Imperial Oil (22,352 tons), Shell Oil (17,106 tons), and Dow Chemical (14,574 tons).

The halogen or gasoline odours in Port Huron are circumstantially associated with the group of petroleum refineries south of Sarnia. The detected paint odour was associated with manufacturing south of Marysville. The malodour experienced at Marine City was attributed to releases of trimethylamine from the Chinook Chemical Company south of Sombra, Ontario.

REDUCTION IN EMISSIONS

As anticipated in the Board's report, abatement and fuel conversion programs have been undertaken. In the Sarnia area emissions of particulates, hydrocarbons, and odorous gases from point sources have been reduced. The beneficial effect of the abatement measures to reduce particulates and sulphur dioxide has been nullified by expansion of the industries and the power utilities. Data collected by regulatory agencies since the completion of the Board's field studies indicate that to the end of 1971 there has not been any significant improvement in the air quality in the St. Clair River area.

TRANSBOUNDARY MOVEMENT

The pollution roses constructed by the Board emphasize that there is not only significant transboundary movement of contaminants originating in each country, but also provide evidence of the contribution of pollutants from local sources. This was confirmed by detailed case studies. Aerial sampling made along the Boundary verified the transboundary movement of pollutants.

Depending upon the wind direction (see Figure 8), pollutants are transported from Canada into the United States as well as in the reverse direction. Emissions from sources south of Sarnia not only contribute to air pollution in Sarnia but also to air pollution in Port Huron across the River. Similarly, sources in St. Clair contribute to air pollution in both Michigan and Ontario. In addition, particulates emitted in the Detroit area reach the St. Clair River area.

Mathematical dispersion models were used to estimate the quantity of air contaminants transported across the Boundary. There was high correlation and excellent agreement between the observed and estimated concentrations. Thus, considerable confidence can be placed on the information in Figures 12 and 13 which show the impact of particulates and sulphur dioxide emitted by one country on the air quality in the other country.

The average annual transboundary flow of particulates from Canadian sources to about a square mile of Port Huron was 30 $\mu g/m^3$. This is half of the Ontario criterion and the U.S. secondary standard. The transboundary flow from Canadian sources to 8½ square miles of Port Huron was a third of the U.S. secondary standard. Outside of this section of Port Huron the transboundary flow of particulates from Canadian sources to the United States was rather insignificant.

In contrast, the transboundary flow of particulates from U.S. sources to 12½ square miles of Sarnia was, on an average annual basis, more than 30 $\mu g/m^3$. The transboundary flow of particulates from U.S. sources to about 107 square miles on the Ontario side of the St. Clair River was a third of the Ontario criterion.

Over 17 square miles of the Canadian area opposite and south of St. Clair, Michigan, received from U.S. sources a sulphur dioxide concentration in excess of the Ontario criterion (0.02 ppm of air). Outside of that area approximately 140 square miles on the Canadian side of the River received from U.S. sources a concentration of sulphur dioxide equal to about half of the Ontario criterion.

In contrast, over 2 square miles of Port Huron received from Canadian sources, on an annual average basis, a sulphur dioxide concentration approaching the U.S. secondary standard (0.02 ppm of air); about 10 square miles received approximately half of the allowable concentration. Elsewhere the transboundary flow of sulphur dioxide from Canadian sources was less than half of the U.S. secondary standard.

The malodours experienced in Port Huron and Marine City, Michigan, are due to transboundary movement from oil refineries and chemical industries in Ontario.

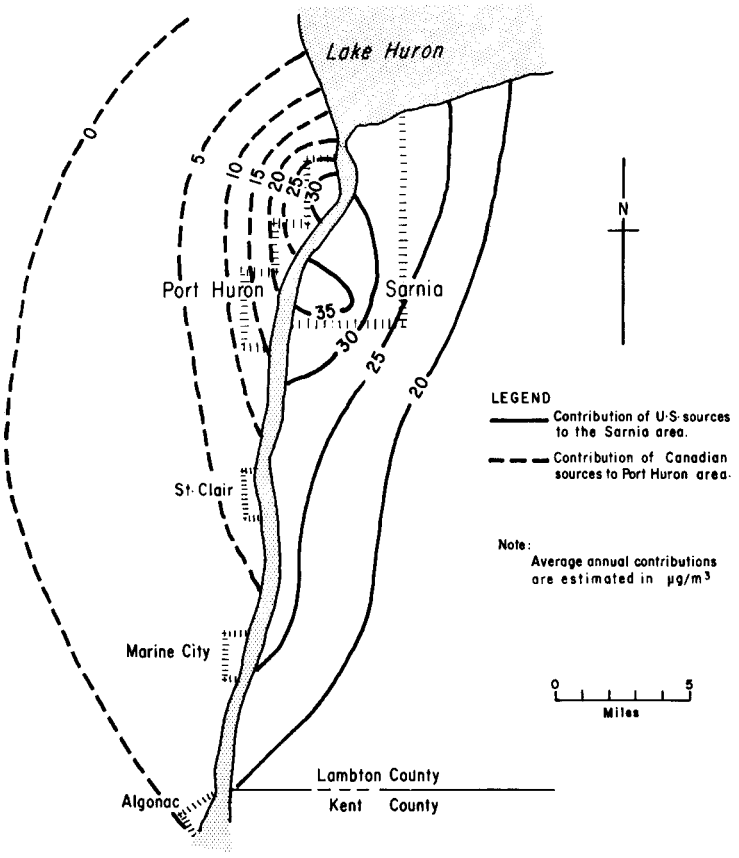

FIGURE 12 TRANSBOUNDARY FLOW OF PARTICULATES IN ST. CLAIR RIVER AREA

A comparison of the total particulate and sulphur dioxide concentrations with the concentrations resulting from transboundary pollution indicates that the ambient air quality on the U.S. side of the River would meet the U.S. secondary standards if it were not for the transboundary movement of contaminants. Similarly, with the exception of 10 square miles in Sarnia, the ambient air quality on the Canadian side of the River would meet the Ontario criteria if it were not for transboundary pollution.

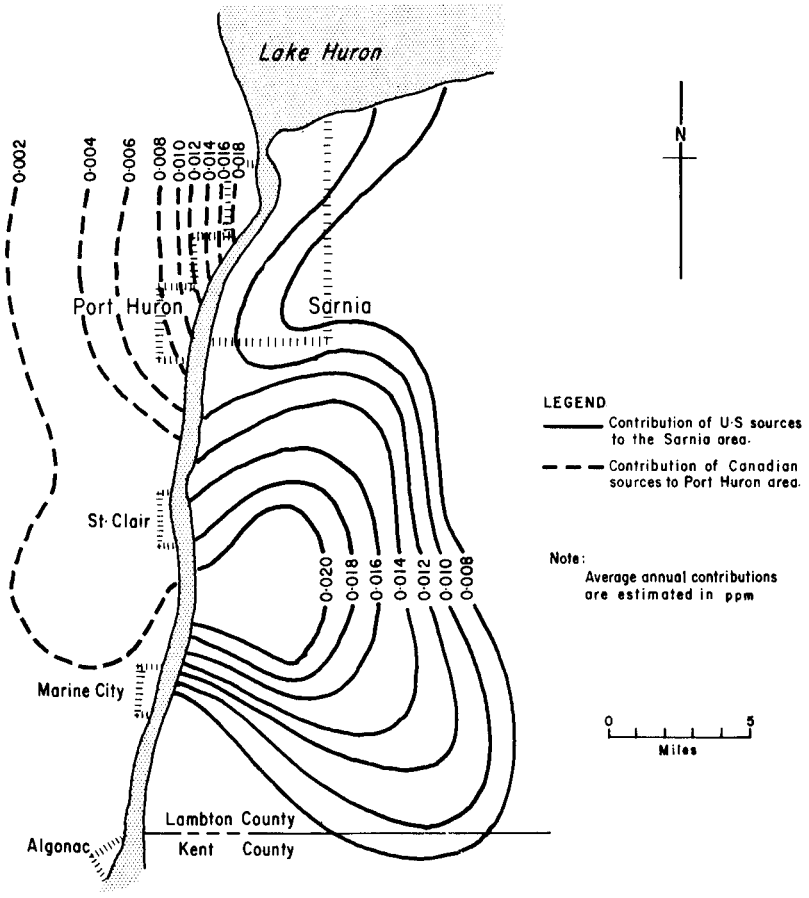

FIGURE 13 TRANSBOUNDARY FLOW OF SO_2 IN ST·CLAIR RIVER AREA

Chapter IX

REMEDIAL MEASURES

Air pollution in the Detroit River and the St. Clair River areas will become more critical unless there is vigorous and concerted implementation of imperative remedial measures. These remedial measures include agreements upon consistent air quality objectives, reducing the emissions of transboundary contaminants, a unified air management contingency plan to prevent air pollution episodes during inversions, an integrated network for measuring air quality, the monitoring of abatement measures, and accelerated research programs.

AIR QUALITY OBJECTIVES

Air quality criteria reflect the current scientific knowledge of the adverse effects of various concentrations and combinations of contaminants on man and his environment. *Air quality standards* are the maximum allowable pollutant exposures determined by a political jurisdiction. They are used by enforcement agencies in designing their emission standards. *Air quality objectives* are the goals of ambient air quality to be attained. The air quality criteria, standards, and objectives all take cognizance of the physical and chemical characteristics of contaminants; methods and accuracy of measurements; exposure parameters; the effects on human health and comfort; the effects on vegetation; objectionable surface deposition; and the soiling, corrosion, and deterioration of materials.

Air contaminants move without restriction across state and international boundaries. Pollutants emitted to the atmosphere in one jurisdiction not only impair the air quality within its own boundaries but also degrade the ambient air quality in the neighbouring jurisdiction. Because the winds are not confined to fixed directions, air contaminants are freely transported across the International Boundary in either direction.

The pervasiveness of air contaminants emphasizes the urgent need to be concerned with not only the effects of emissions to the atmosphere in each country but also the international and global consequences.

Air contaminants emitted in one country should not create conditions that are detrimental to the public health and welfare of citizens or to property in another country. Thus, for those regions adjacent to an international boundary it is imperative that both countries have consistent air quality standards. Such standards form the basis for a concerted implementation of integrated pollution control programs.

The *Transboundary Air Quality Objectives for the Detroit River and St. Clair River Areas*, hereinafter referred to as the Objectives, have been developed to protect public health, safety, general welfare, and property of the citizens on both sides of the International Boundary. The Objectives are intended to be the minimum basis for the formulation of air quality and emission standards on both sides of the Boundary and for the implementation of meaningful programs to reduce the emissions of contaminants to an absolute minimum. The Objectives are set out in detail in Chapter XI.

The *General Objectives* are the three "freedoms" or goals of an effective air management program. They apply to the air flowing in either direction across the International Boundary.

The *Specific Objectives* apply to the ambient air quality in each jurisdiction. The average concentrations for each particular duration include not only the contaminants transported by the winds across the Boundary but also the emissions of that jurisdiction. Thus, the prerequisite for the solution of the air pollution problems of these areas is close and active cooperation by both countries. The ambient air quality should be satisfactory when the concentrations are less than those set out in the Objectives.

The Objectives are not immutable. The Specific Objectives, the numbers associated with them, and the duration of exposures are limited to sulphur dioxide, suspended particulates, and offensive odours, the parameters on which there is sufficient evidence. The reason for not including the other known pollutants was explained in Chapter V. Average annual concentrations are not intended for the day-to-day enforcement activities but rather for their statistical value in projecting the trends of further degradation or, more importantly, assessing the effectiveness of corrective action.

Additional or modified Specific Objectives will be warranted when the subtle actions, interactions, and movement of these and other contaminants become more fully understood; when their effects on man and his environment become better known; and when new and more efficient techniques are developed to remove them at their sources.

REDUCING EMISSIONS

The Air Quality Objectives can only be attained if the emissions of sulphur oxides, particulate matter, and odours are controlled at

the individual sources. The feasibility of removing particulate emissions with an efficiency of 99 percent or higher by weight is now well established. While techniques to desulphurize fuels and flue gases are being studied in pilot plants and in some full scale operations, there are a significant number of powerplants in the United States installing or using desulphurization machinery.

The International Joint Commission in its inquiry into the air quality of the Detroit River and St. Clair River areas was concerned with the need for each jurisdiction to reduce its emissions of air contaminants that flow across the Boundary. It is evident that a firm commitment is required to assure both countries that each jurisdiction will take the necessary steps to accelerate its own programs so as to achieve the ambient Air Quality Objectives set out in this report. Some of the possible methods of reducing or eliminating the emission of transboundary contaminants are indicated below.

Particulate emissions in the Detroit River area during 1967 from industrial processes amounted to 67,800 tons, from industrial fuel combustion 64,000 tons, and from power utilities 56,200 tons. Similarly, in the St. Clair River area emissions from industrial processes amounted to 4,800 tons, from industrial fuel combustion 23,700 tons, and from power utilities 19,000 tons. The degree to which particulate emissions were controlled at various industrial installations and powerplants varied from zero to 98 percent. Since 1967 the progress in the reduction of particulate emissions has been good at a number of individual sources, lagging in some, and imperceptible in others.

Higher efficiencies in the removal of particulates derived from fuel combustion in steam-electric powerplants and industrial, commercial, and governmental installations can be achieved by increasing the surface area of electrostatic precipitators in the stack, placement of precipitators ahead of the air preheaters, and using multiple cyclone collectors on smaller units. Industrial process emissions can be reduced by various types of scrubbers and filters, electrostatic precipitators, adequate hooding, and improved material handling techniques.

Several methods are being developed to remove sulphur dioxide from flue gases including limestone injection, catalytic oxidation, and alkalized alumina sorption. The emissions from petroleum refineries can be reduced by the installation of sulphur dioxide recovery equipment.

Odours can be reduced by improved process controls, floating roofs on storage tanks, improved handling facilities, and oil-water separators. Prohibiting the flaring of materials containing hydrogen sulphide also reduces odours.

Switching to low-sulphur fuels can reduce the sulphur dioxide and particulate emissions from installations burning large quantities of

fossil fuels. Possible fuel substitutes include coal containing less than 1 percent sulphur, low-sulphur oil, and natural gas. Such fuels are more costly and are in extremely short supply. Nevertheless, some major cities have adopted regulations prohibiting the burning of any fuel in excess of a specified sulphur content. In view of the ever-increasing energy requirements and the limited resources of low-sulphur fuels, it is evident that all environmentally acceptable alternatives to meet future energy requirements must be developed without delay.

PROBABLE COSTS

Clean air like clean water is a precious resource. Both have been exploited as a receptor for the wastes generated by man's activities. The costs associated with restoring these resources to a quality that enhances rather than degrades man's environment are costs that cannot be avoided. Postponement will only increase the inevitable cost to society.

The cost of reducing the emissions of transboundary air contaminants cannot, unfortunately, be compared with the benefits, because reliable statistical data to measure the value of better health and all its advantages, to estimate the damage to property, vegetation, furnishings and fabrics, and to evaluate the detrimental effects on the environment are not available.

Furthermore, as the Board pointed out, because of the extreme short supply of all low-sulphur fuels for powerplants, it is not possible to predict with any degree of accuracy the cost and availability of low-sulphur fuels.

Nevertheless, the Board attempted to give a rough indication of the probable annual cost of controlling particulate and sulphur dioxide emissions. The Board assumed that an acceptable air quality for both areas could be achieved through a 50-percent reduction in particulate emissions from area sources including the banning of open burning and an 80-percent reduction of sulphur dioxide emissions from point sources. On this basis the Board found that the estimated annual least cost was in the order of $65 million based on 1969 prices, using flue gas scrubbing technology. The Commission considers that, in view of the uncertainties that exist with respect to scrubbing technology and associated costs, a realistic basis for total cost estimates does not exist at this time.

The Board also estimated the annual cost of achieving the same acceptable air quality for both areas on the basis of fuel substitution at one powerplant and fuel switching at the remaining powerplants in lieu of flue gas scrubbing. (Fuel substitution refers to changing to a

better grade of the same fuel such as 1 percent sulphur coal in place of 3 percent sulphur coal or distillate oil with 0.25 percent sulphur in place of residual oil with 0.75 percent sulphur. Fuel switching consists of changing to a better type of fuel containing less contaminants such as a good grade of oil or natural gas with proper combustion in place of high sulphur coal.) On this basis the least total annual cost would be in the order of $147 million using 1969 fuel costs of 50 cents per million Btu's for natural gas. In view of the general increase in costs since 1969, including a pronounced increase in fuel costs, the Commission notes that the probable annual costs now would be substantially greater than $147 million.

AIR POLLUTION EPISODES

The Detroit River and St. Clair River areas are subject to periods of poor dispersion conditions, some lasting 4 days or more. If emissions are not reduced during these periods of stagnation the resulting excessive concentration of contaminants will accentuate the adverse effects on health. Until recently, protective measures were not taken at the time of an air pollution episode because the associated increases in morbidity and mortality were not appreciated. Inasmuch as man cannot prevent an inversion he must have safety provisions that will prevent an inversion from becoming an air pollution episode.

The Commission considers that it is imperative to develop a unified air management contingency plan as soon as practical. Episode contingency plans exist in both countries. The Province of Ontario in 1970 promulgated regulations which implemented the operation of a plan to cope with potential air pollution episodes. Similarly, a plan prepared by the United States Environmental Protection Agency for the prevention of air pollution emergency episodes was promulgated in October 1971. The effectiveness of these two independent contingency plans in the Detroit River and St. Clair River areas depends upon their joint and coordinated implementation.

An air management contingency plan requires expert meteorological forecasting, continuous air quality surveillance, and authority for progressive reduction or curtailment of emissions from the major sources. When the concentrations of contaminants reach a predetermined critical level and the adverse meteorological conditions are expected to continue, it will be necessary to curtail emissions as quickly as possible. Time will be of the essence. If the air quality continues to deteriorate there must be further abatement of emissions from the remaining point sources not essential to public health or safety. This may limit the operation of the offending sources or may require fuel switching.

The joint implementation of a contingency plan requires integration of air monitoring networks, prompt exchange of all data, concurrence on critical ambient air concentrations, prior agreement on the reduction required by specific sources for various critical concentrations. Since an inversion or episode will likely affect the area on both sides of the International Boundary there must be progressive abatement in both countries. In many instances it would be futile to curtail emissions in one country without similar action in the other country. This requires constant communication between the regulatory agencies in both countries and cooperative implementation of a prearranged plan to prevent air pollution episodes.

SURVEILLANCE AND MONITORING

Surveillance of the ambient air quality in the Detroit River and the St. Clair River areas is necessary to predict trends in air quality, to assess the effectiveness of the reduction of emissions at specific sources, and to determine the need for further control measures. Continuous surveillance is required to detect the development of air pollution episodes. The regulatory agencies on both sides of the two Rivers now have their own programs for measuring the concentrations of air contaminants at selected locations. Nevertheless, it is imperative for both countries to coordinate these programs and to exchange the collected information.

The integration of air quality measurement programs will require the establishment of a permanent international network of observation stations to ensure complete coverage and to eliminate unnecessary duplication of effort and expenses. Many of the existing stations could be incorporated into such a network. In order to ensure that the data collected will be compatible and acceptable by authorities in both countries, uniform procedures and methods of measurement must be employed. It follows that the data and information obtained in each jurisdiction must be made available freely and expeditiously to the other jurisdictions concerned, so that each may assess the combined results and take appropriate action.

There is an immediate need to devise an agreed procedure applicable on both sides of the Boundary whereby emissions will be reduced or curtailed during prolonged inversions. The prevention of air pollution episodes will require coordination of day-to-day efforts on an area basis, irrespective of the Boundary. Such a contingency plan would provide a warning system and a firm assurance that the regulatory agencies would react quickly at the onset of episode conditions.

Monitoring of compliance with an agreement regarding the enforcement of air quality standards and the implementation of programs to reduce the total quality of contaminants emitted to the atmos-

phere is essential to the attainment of the transboundary Air Quality Objectives set out in Chapter XI of this report. Monitoring will involve a periodic review of remedial measures undertaken pursuant to an agreement and carrying out emission surveys. Satisfactory air quality can only be achieved if there is constant cooperation between the affected jurisdictions and a commitment to implement the necessary pollution abatement programs in both countries.

In view of the unique role assigned to the International Joint Commission under the recent Great Lakes Water Quality Agreement, the Commission believes it would be logical and desirable for the two Governments to confer upon it the authority, responsibility and the means for coordinating surveillance, integrating an air management contingency plan, and monitoring of compliance with the relevant international agreements relating to air pollution in the Detroit River and St. Clair River areas.

The Commission would keep the two Governments informed of the results of its activities by regular and special reports. It would make recommendations regarding Air Quality Objectives and standards, abatement programs, environmental impact of emissions in the area, research, regulations, legislation, agreements, enforcement and the like as it might consider appropriate. It would also make recommendations to the State of Michigan and the Province of Ontario for action in specific cases. It would conduct supplemental investigations and public hearings as may be required. The Commission should also have authority to publish its findings and reports on its own initiative.

To assist it in carrying out these functions, the Commission would establish an international board composed of highly qualified persons drawn from the regulatory agencies and the two national governments. This would provide the Commission with not only technical excellence but also appropriate contact with the state, provincial, and national sectors of government whose support would be essential to the success of the board's activities. The Commission would also maintain close contact with the board and its operations and with citizen's advisory groups which the Commission believes would be helpful in maintaining surveillance and obtaining compliance with the Objectives.

Under the general aegis of the Commission the board would have responsibility to initiate the actions necessary to avert air pollution episodes, coordinate surveillance, monitor programs of the agencies, arrange for such verification as may be necessary, analyze the results, and report to the Commission with recommendations for further action. The board would also be the Commission's principal source of technical and scientific advice on matters affecting air quality in the Detroit River and the St. Clair River areas. To this end the Commission would authorize the board to establish committees to deal with specific problems.

RESEARCH

Although existing control technology can remedy many of the known air pollution problems, solutions to many other problems cannot be prescribed at this time because the knowledge and understanding of the physical and chemical phenomena involved is in a large measure fragmentary. The adverse effects of contaminants on health, property, and the total environment, including global effects, are not fully understood or appreciated. Federal, provincial, and state governments should stimulate and support research and development undertakings leading to more effective air management policies in the future.

Among the problems that need the most urgent attention are the continued development of methods and equipment that will: desulphurize fuels, including coal containing significant amounts of pyritic sulphur; remove sulphur dioxide from flue gases; decrease the particulate emissions from industrial processes and powerplants; and minimize or eliminate the emission of offensive odours. Additional research is required to determine the overall effects of tall stacks on the environment and to develop new combustion processes.

Since air quality criteria and standards are derived from the known effects of air pollutants, further research is required to ascertain the effects of exposures to heterogeneous mixtures of contaminants at low concentrations on human health and welfare. Scientific research and economic evaluation to determine more accurately the effects of pollutants on vegetation, materials, and the ecology are also necessary.

The current knowledge of air contaminants is restricted because the ability to detect and measure substances in the air and at the source is limited. Thus, there is a need to develop simplified and less costly instruments as well as instruments that can measure stack emissions remotely. Analytical methods and instruments for determining the concentrations of contaminants should be standardized.

Further research and systematic investigations are necessary to enhance the current understanding of the flow, dispersion, degradation, and atmospheric reactions of contaminants. Such knowledge is urgently needed on a local and regional basis, as well as on a global basis. This could involve a refinement of mathematical models, extensive air quality networks, and even satellite measurements.

Chapter X

CONCLUSIONS

The Governments of Canada and the United States requested the International Joint Commission to inquire into and report on four questions.

In response to question,

1. *Is the air over and in the vicinity of Port Huron-Sarnia and Detroit-Windsor being polluted on either side of the International Boundary by quantities of air contaminants that are detrimental to the public health, safety, or general welfare of citizens or property on the other side of the International Boundary?*

The Commission finds that the air in the vicinity of Port Huron-Sarnia and Detroit-Windsor is polluted by quantities of particulates and sulphur dioxide which are detrimental to the public health, safety, and general welfare of citizens and to the property on the other side of the International Boundary and are in excess of the existing air quality regulations of the State of Michigan and the Province of Ontario.

With regard to the Detroit River area the Commission finds that particulates and sulphur dioxide flowing from U.S. sources to most of the Windsor area are, on an annual basis, in concentrations which exceed the Ontario criteria; and in the western part of the city double the limit set out in the Ontario criteria. On the other hand, the contribution of contaminants from Canadian sources to the Detroit area is, on an annual basis, only a fraction of the U.S. secondary standards and is confined to a small area near Belle Isle. The high level of air pollution in the remainder of Metropolitan Detroit is due to emissions originating within that jurisdiction.

With regard to the St. Clair River area the Commission finds that the transboundary flow of particulates from Canadian sources to over a square mile of Port Huron is, on an annual basis, about half of the U.S. secondary standard; and the flow of sulphur dioxide from Canadian sources to over 2 square miles of

Port Huron, on an annual basis, approaches the U.S. secondary standard. In addition, the malodours experienced in Port Huron and Marine City, Michigan, are due to transboundary movement. The contribution of particulates from U.S. sources to over 12 square miles of Sarnia is, on an annual basis, half of the Ontario criterion; and the contribution of sulphur dioxide from U.S. sources to over 17 square miles of Canadian area opposite and south of St. Clair, Michigan, on an annual basis, exceeds the Ontario criterion. With the exception of 10 square miles of Sarnia the ambient air quality on both sides of the St. Clair River would meet the U.S. secondary standards and the Ontario criteria if it were not for the transboundary flow of contaminants. The high level of air pollution in Sarnia is, to a large measure, attributable to emissions originating in that jurisdiction.

In response to question,

2. *If the foregoing question or any part thereof is answered in the affirmative, what sources are contributing to this pollution and to what extent?*

With regard to the Detroit River area the Commission finds that of the 258,200 tons of particulates emitted in 1967, 231,500 tons originated in the United States and 26,700 tons in Canada; and of the 550,700 tons of sulphur oxides emitted in 1967, 516,600 tons originated in the United States and 34,100 tons in Canada. The principal sources are the steam-electric powerplants and metallurgical industries in Wayne County, Michigan.

With regard to the St. Clair River area the Commission finds that of the 50,800 tons of particulates emitted in 1967, 26,600 originated in Canada and 24,200 originated in the United States; and of the 372,500 tons of sulphur oxides emitted in 1967, 272,900 tons originated in the United States and 99,600 tons originated in Canada. The principal sources are the steam-electric powerplants in Michigan and the oil refineries and chemical industries near Sarnia. The principal offensive odours originated at a chemical plant near Sombra and at petroleum refineries near Sarnia.

In response to question,

3. *If the Commission should find that any sources on either side of the Boundary in the vicinity of Port Huron-Sarnia and Detroit-Windsor contribute to air pollution on the other side of the Boundary to an extent detrimental to the public health, safety, or general welfare of citizens or property, what preventive or remedial measures would be most practical from economic, sanitary, and other points of view?*

With due regard for economic and social considerations the Commission finds that it is most desirable and practicable to assign priorities in the implementation of preventive and remedial measures according to the severity of the effects of specific con-

taminants and the technological feasibility of controlling their emissions.

Based on both of these criteria the remedial measure that will provide the most significant and immediate improvement in air quality is particulate removal from large point sources.

Because of the damage to property and the adverse impact on health of sulphur dioxide when combined with particulate matter, the control of sulphur dioxide emissions is also extremely important. Practicable methods for reducing the sulphur content of coal are not in wide use, due to limitations on sources of supply of treatable coal. Flue gas scrubbing for sulphur dioxide control is in use but still being perfected. An alternative method for reducing sulphur dioxide emissions is switching to low-sulphur fuels. Low-sulphur fuels are in extremely short supply and are becoming increasingly expensive. However, the use of such fuels or resorting to other sources of energy in the future will be necessary unless technology produces other solutions.

Finally, the control of odours from any source and the control of particulate emissions from the numerous minor sources, such as small industries, commercial and public buildings and dwellings, is required and is feasible of accomplishment.

In response to the request that

4. The Commission should give an indication of the probable total cost of implementing the measures recommended,

The Commission considers that, as a rough indication, if fuel switching and fuel substitution were used as a means of controlling the emissions of particulates and sulphur dioxide to achieve an acceptable air quality in both the Detroit River and St. Clair River areas the probable annual cost would be in the order of $150 million based on 1969 prices.

In addition to the above responses, the International Joint Commission further concludes that:

5. There is urgent need for binational contingency plans to reduce emissions of contaminants during adverse atmospheric conditions.

6. There is need for the establishment of a permanent international network of air quality measurement stations, uniform methods of measurement, procedures to facilitate the rapid exchange of data, and acceptance of data collected in one country as a basis for prompt action in the other country.

7. There is need for both countries to have consistent air quality standards in the Detroit River and St. Clair River areas.

8. Inasmuch as the ambient air quality in these areas depends not only on the emissions from one country but also on the emissions from the other country, satisfactory air quality can only be attained if the emissions of particulate matter, sulphur oxides, and odours are controlled at the individual sources in both countries.

9. The International Joint Commission should be assigned the tasks of coordinating continuous surveillance of air quality, monitoring the implementation of preventive and remedial measures, coordinating the rapid exchange of information on air quality, and publishing reports on the effectiveness of programs designed to reduce the emissions of air contaminants and trends in air quality.

10. There is an urgent need to develop environmentally acceptable alternatives for producing energy that will meet current and future requirements.

11. There is an urgent need to develop economically acceptable methods and equipment to desulphurize fuels and flue gases and to decrease the overall emission of particulate matter, sulphur oxides, and odours from powerplants and industrial sources.

12. There is a need for accelerated research to determine the effects of the heterogeneous mixture of air pollutants at low concentrations on health and welfare, on all materials, vegetation, animals, and the total environment.

13. There is need for further research on the chemical and physical phenomena involved in the formation, control, movement, transformation, ultimate accumulation, and dispersion patterns of all air pollutants, not only with respect to the Detroit River and St. Clair River areas, but also with respect to the regional and global impact.

Chapter XI

TRANSBOUNDARY AIR QUALITY OBJECTIVES

GENERAL OBJECTIVES

The air flowing in either direction across the International Boundary in the Detroit River and St. Clair River areas should be:

1. Free from contaminants which have harmful effects on human health.
2. Free from objectionable odours, haze, dirt, and other contaminants which interfere with the normal amenities of living or cause adverse aesthetic effects.
3. Free from contaminants which have deleterious effects on property, materials, and vegetation.

SPECIFIC OBJECTIVES

The ambient air quality for each jurisdiction in the Detroit River and St. Clair River areas shall be considered satisfactory if the measured:

1. *Sulphur dioxide* concentration for
   a. 1 hour is less than 0.25 ppm of air; and for
   b. 24 hours is less than 0.10 ppm of air.
2. *Total suspended particulate* concentration as determined by high-volume samplers and at 1 atmosphere and 70° F. for
   a. 24 hours is less than 120 $\mu g/m^3$; and for
   b. 1 year the annual geometric mean is less than 60 $\mu g/m^3$.
3. *Offensive odours* are absent.

ADDITIONAL SPECIFIC OBJECTIVES

Additional Specific Objectives will be established when warranted for transboundary air contaminants. These may include but will not be restricted to nitrogen oxides, hydrocarbons, and oxidants.

Chapter XII

RECOMMENDATIONS

In response to the Reference dated September 23, 1966, from the Governments of Canada and the United States the International Joint Commission recommends, as a basis for activities with each country to achieve a satisfactory ambient air quality in the Detroit River and St. Clair River areas, that:

1. The Air Quality Objectives as set forth in Chapter XI of this Report be adopted by the Governments of Canada, the United States, the State of Michigan and the Province of Ontario and be incorporated into their standards and regulations for the said two areas.
2. The Governments of Canada and the United States with appropriate participation by the Province of Ontario, the State of Michigan and Wayne County enter into an agreement on schedules for the implementation, at the earliest practicable date, of preventive and remedial measures to achieve the said Air Quality Objectives and on uniform methods for assessing air quality.
3. The Governments of Canada and the United States with appropriate participation by the Province of Ontario, the State of Michigan and Wayne County enter into agreement for coordinated contingency procedures so that regulatory agencies in both countries will quickly and effectively respond to adverse atmospheric conditions by reducing emissions of air contaminants into the atmosphere.
4. The Governments of Canada and the United States specifically confer upon this Commission the authority, responsibility and means for coordination of surveillance, monitoring the implementation of programs, reporting and making recommendations to Governments as outlined in Chapter IX of this Report, and such other duties related to the air quality in the vicinity of the Detroit River and St. Clair River areas as may be

required; the Commission to be authorized to establish an international board and citizen advisory groups to assist it in carrying out these duties.

5. The two Governments, in concert with provincial and state agencies and with industry, stimulate and expand their research programs to reduce the emissions of air contaminants, including specifically desulphurization of fuels and flue gases; to ascertain with more certainty the effects of air contaminants on health, property, vegetation and aesthetics; and to enhance the current knowledge of the physical and chemical phenomena involved in the formation, control, movement, transformation, ultimate accumulation and dispersion patterns of all air pollutants.

Signed this 18th day of July, 1972, as the International Joint Commission's report to the Governments of Canada and the United States on the transboundary air pollution in the Detroit River and the St. Clair River areas.

Christian A. Herter, Jr.

Louis J. Robichaud

Eugene W. Weber

Charles R. Ross

Bernard Beaupré

Keith A. Henry

APPENDIX

TEXT OF REFERENCE TO THE INTERNATIONAL JOINT COMMISSION

On September 23, 1966, the Secretary of State for External Affairs, for the Government of Canada, and the Secretary of State, for the Government of the United States, sent the following Reference to the International Joint Commission through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

As a result of expanding industrial and other activities along the international boundary of the United States and Canada, the Governments of both countries have been increasingly aware of the problem of air pollution affecting citizens and property interests on either side of the boundary. In particular, Governments have received representations that citizens and property in the vicinities of Detroit-Windsor and Port Huron-Sarnia are being subjected to detrimental quantities of air pollutants crossing the boundary.

The problem of air pollution in the vicinity of the cities of Windsor and Detroit was the subject of a Joint Reference to the Commission dated January 12, 1949. The Commission was requested to report whether the air over, or in the vicinity of, Detroit and Windsor was being polluted by smoke, soot, fly ash or other impurities in quantities detrimental to the public health, safety or general welfare of citizens or property on either side of the boundary. In the event of an affirmative answer, the Commission was asked to indicate the extent to which vessels plying the waters of the Detroit River were contributing to this pollution and what other major factors were responsible and to what extent.

The Commission, in its final report to Governments of May 1960, replied in the affirmative to the first question and listed various industrial, domestic and transportation activities on land as being largely responsible. In accordance with the terms of the said Reference, however, the Commission did *not formulate any recommendations with regard to these major factors*, its recommendations being limited to vessels plying the Detroit River.

In view of the seriousness of the problem of air pollution in the vicinity of Port Huron-Sarnia and Detroit-Windsor, both Governments have agreed to refer this matter to the International Joint Commission, pursuant to Article IX of the Boundary Waters Treaty of 1909. The Commission is therefore requested to inquire into and report to the two Governments upon the following questions:

(1) Is the air over and in the vicinity of Port Huron-Sarnia and Detroit-Windsor being polluted on either side of the international boundary by quantities of air contaminants that are detrimental to the public health, safety or general welfare of citizens or property on the other side of the international boundary?

(2) If the foregoing question or any part thereof is answered in the affirmative, what sources are contributing to this pollution and to what extent?

(3) (a) If the Commission should find that any sources on either side of the boundary in the vicinity of Port Huron-Sarnia and Detroit-Windsor contribute to air pollution on the other side of the boundary to an extent detrimental to the public health, safety or general welfare of citizens or property, what preventive or remedial measures would be most practical from economic, sanitary and other points of view?

(b) The Commission should give an indication of the probable total cost of implementing the measures recommended.

In the light of the findings contained in the Commission's report of May 1960, the Commission, in conducting its investigations under this Reference is requested to give initial attention to the Detroit-Windsor area and, to submit its report and recommendations on this problem to the two governments as soon as possible.

The Commission is also requested to take note of air pollution problems in boundary areas other than those referred to in Question 1 which may come to its attention from any source. If at any time the Commission considers it appropriate to do so, the Commission is invited to draw such problems to the attention of both Governments.

For the purpose of assisting the Commission in making the investigations and recommendations provided for in this Reference, the two Governments, upon request, will make available to the Commission the services of engineers and other specially qualified personnel of their respective Governments, and such information and technical data as may have been acquired by such Governments or as may be acquired by them during the course of investigation.

MEMBERSHIP OF THE BOARD AND ITS COMMITTEES

The International Joint Commission appointed the St. Clair-Detroit Air Pollution Board on November 30, 1966. When the Board submitted their report to the Commission in January 1971, membership of the Board consisted of the following:

Canadian Section

W. B. Drowley, Director of the Ontario Air Management Branch, *Chairman.*

P. M. Bird, Director of Environmental Health, Canadian Department of National Health and Welfare.

United States Section

J. C. Oppenheimer, Assistant Commissioner of the Air Pollution Control Office, Environmental Protection Agency, *Chairman.*

B. D. Bloomfield, Assistant Chief of Occupational Health, Michigan Department of Public Health, (since deceased).

FORMER BOARD CHAIRMEN

Dr. T. H. Patterson, Chief of Occupational Health Division, Canadian Department of National Health and Welfare.

A. C. Stern, Assistant Chief of the Division of Air Pollution, United States Public Health Service.

Subsequent to the submission of the Board's report to the International Joint Commission the following members were appointed:

Dr. S. O. Winthrop, Acting Director General of the Air Pollution Control Directorate, Canadian Department of the Environment, vice P. M. Bird.

Lee Jaeger, Chief of the Air Pollution Control Section, Michigan Department of Public Health, vice B. D. Bloomfield.

As authorized by the Commission, the Board established a number of Committees. When the Board submitted its report to the Commission the Committees consisted of the following members:

WORKING COMMITTEE

D. D. Tyler, Project Director of the St. Clair-Detroit River Study, United States National Air Pollution Control Administration, *Chairman.*

L. Shenfeld, Chief of the Air Quality and Meteorology Section, Ontario Air Management Branch.

COMMITTEE ON TRANSBOUNDARY FLOW OF AIR POLLUTION

E. W. Hewson, Oregon State University, *Chairman.*
R. E. Munn, Canadian Department of Transport.
G. T. Csanady, University of Waterloo.
J. B. Harrington, Michigan State University.

COMMITTEE ON SOURCES AND THEIR CONTROL

E. R. Balden, Chrysler Corporation, *Chairman.*
R. M. Dillon, University of Western Ontario.
A. C. Elliott, Steel Company of Canada.
R. L. Broad, Rochester and Pittsburgh Company of Canada.
J. Hunter, Wyandotte Chemical Company.
S. Ozker, Detroit Edison Company.

COMMITTEE ON EFFECTS OF AIR POLLUTION

A. J. de Villiers, Canadian Department of National Health and Welfare, *Chairman.*
J. Isbister, Michigan Department of Public Health.
A. J. Vorwald, Wayne State University.
D. Irish, Dow Chemical Company.
D. O. Anderson, University of British Columbia.
R. B. Sutherland, Ontario Department of Health.
S. Linzon, Ontario Department of Energy and Resources Management.

PARTICIPATING AGENCIES

During the Board's investigation valuable and cooperative assistance was provided by the following agencies:

In Canada

Environmental Health Directorate of the Department of National Health and Welfare
Air Management Branch of the Ontario Department of Energy and Resources Management

In the United States

National Air Pollution Control Administration of the Department of Health, Education, and Welfare
Division of Occupational Health of the Michigan Department of Public Health
Air Pollution Control Division of the Wayne County Department of Health

In addition, municipalities in both Ontario and Michigan cooperated in the Board's study.

PERSONS PRESENTING BRIEFS OR TESTIMONY AT THE INTERNATIONAL JOINT COMMISSION PUBLIC HEARINGS

Where witnesses testified at more than one of the initial or final hearings only one appearance is recorded hereunder.

June 20, 1967 at Port Huron, Michigan

The Hon. Charles R. Chandler, Mayor of Port Huron
Alderman David Boushy, Sarnia
Alleman J. Westrick, City Manager of Marine City
Robert E. Neligan, National Center for Air Pollution Control, U.S. Department of Health, Education, and Welfare
J. A. Kelly, Michigan Air Pollution Control Commission
Dr. Robert E. Rowe, St. Clair County Health Department
Kipton Kaplan, Director of the Bureau of Public Information and Complaints, Port Huron
Mrs. Dorothea Sills, Clerk, Township of East China
Alfred E. Isch, Supervisor, Township of East China
L. M. Tod, President of Lambton Industrial Society, Sarnia
E. R. Morton, Chairman of St. Clair River Research Committee of Lambton Industrial Society, Sarnia
Fred Geddes for Oil, Chemical and Atomic Workers International Union, Local 9–14, Sarnia
James Charrington for Oil, Chemical and Atomic Workers International Union, Local 9–14, Sarnia
Mrs. Norma E. Richards, Port Huron
Mrs. Lawrence Avison, St. Clair
Mrs. Leo G. Rider, Port Huron
The Reverend James Shannon, Marine City

June 21, 1967 at Windsor, Ontario

The Hon. John F. McEwan, Mayor of River Rouge
Alderman W. C. Riggs, Windsor
Patrick Maguire, City of Windsor
Morton Sterling, Wayne County Health Department
D. K. A. Gillies, Hydro-Electric Power Commission of Ontario
Dr. John Howie, Director and Medical Officer of Health, Metro Windsor-Essex County Health Unit
F. E. Tucker for National Steel Corporation, Detroit
John A. McGrath for Fuels Research Council Inc., Washington
Dr. Orlan J. Arnold for Ajem Laboratories, Livonia, Michigan
Dr. George L. Waldbott, Detroit

March 10, 1971 at Sarnia, Ontario

Senator Alvin J. DeGrow, Michigan State Senate (Statement presented by Mrs. Peter Mallery)
Representative David M. Serotkin, House of Representatives, State of Michigan (Statement presented by Mrs. Peter Mallery)
Representative William Jowett, House of Representatives, State of Michigan (Statement presented by Mrs. Peter Mallery)
His Worship Paul Blundy, Mayor of Sarnia
The Hon. O. M. Hanton, Mayor of Port Huron
H. C. Kingstone, Counsel for Canada

D. F. Burns, Counsel for the United States
W. B. Drowley, Ontario Department of Energy and Resources Management
Bernard D. Bloomfield, Michigan Department of Health
William A. Cramer, R.S., St. Clair County Health Department
H. R. Holland, Imperial Oil Ltd., Sarnia
L. M. Tod, Dow Chemical of Canada Ltd., Sarnia
Wayne L. Wingert, Detroit Edison Company
Walter H. Davis for Ontario Tuberculosis and Respiratory Disease Association, Toronto
Edward B. Thompson for Ontario Tuberculosis and Respiratory Disease Association, Toronto
Sol P. Baltimore for Detroit Tuberculosis and Health Society
Mrs. Peter Mallery for Pollution Probe, St. Clair County
Lorne A. Robb, Chairman for Lambton Industrial Society, Sarnia
William S. Bunn of St. Clair County Independent Press, Marine City (Statement presented by Mrs. Peter Mallery)
Donald C. Robbers, Port Huron

March 11, 1971 at Detroit, Michigan

His Worship Frank Wansbrough, Mayor of Windsor
The Hon. John F. McEwan, Mayor of River Rouge
J. C. Oppenheimer, United States Environmental Protection Agency
Morton Sterling, Wayne County Department of Health
Henry Shanfield, Windsor Utilities Commission
R. A. Wiesner, Ford Motor Company, Dearborn
James R. Michie for Pollution Probe, Windsor
Miss Sarah Miller for Pollution Probe, Windsor
Mark Conlin for Students Against Pollution, Windsor
Edward Baillargeon for Windsor District Labour Council
Raymond Clark for Pollution Probe, Patterson Collegiate Institute, Windsor
Mrs. Esther K. Shapiro for Consumer Alliance of Michigan (Statement presented by S. P. Baltimore)
Charles L. Youngs for United Automobile Workers Region I Retired Workers Council, Detroit
James T. Riley for Wayne State University Biological Society
Mrs. Wm. C. Chapman for American Association of University Women, Michigan State Division
Dr. James Swan of University of Michigan School of Natural Resources, Ann Arbor
Dr. David Camp of the University of Detroit, College of Engineering
J. A. McCorquodale of the University of Windsor, Department of Engineering
Dr. R. H. Kummler of Wayne State University (Statement presented by S. P. Baltimore)
Dr. Paul Tomboulian of Oakland University (Statement presented by S. P. Baltimore)
Professor James Martin of St. Clair College, Windsor
George L. Waldbott, M.D., Warren, Michigan
Ronald G. Seale, Windsor
R. C. Quittenton, P. Eng., Windsor
Gerald Romsa, Windsor
Mrs. Mary Ann Shanahan, Windsor
Jerome Shanahan, Windsor
Garry McGonigal, Windsor
Mrs. Shirley Wigle, Windsor
Anthony P. Scarpelli, Sarnia
Bill Barrett, Windsor
Miss Nancy E. Elliott, R.N., Windsor
A. R. McGorman, Windsor

GLOSSARY OF TERMS AND ABBREVIATIONS

Aerometric sampling	—measurement of variables in the atmosphere including wind and constituents
Ambient air	—air in any given location; generally applies to the air outside the confines of a building
Arithmetic mean	—average of a set of numbers or the sum of the numbers divided by the number of numbers
Fossil fuels	—deposits of decomposed organisms in sedimentary strata; collectively refers to coal, oil and natural gas
Fuel substitution	—changing to a better grade of the same fuel, i.e. 1% sulphur coal in place of 3% sulphur coal
Fuel switching	—changing to a different type of fuel, i.e. oil or natural gas in place of coal
Geometric mean	—the n^{th} root of a product of n terms
Microgram (μg)	—one millionth of a gram
Micrometer (μm)	—one millionth of a meter
Milligram (mg)	—a thousandth of a gram
Btu	—British thermal unit; a Btu is defined as the quantity of heat required to raise the temperature of a one-pound mass of water at 60° F. and standard pressure through 1° F.
COH	—coefficient of haze; a COH unit is defined as that quantity of light scattering solids on the filter which produces an optical density equivalent to 0.01 when measured by light transmission
mg SO_3/100 cm^2-day	—milligrams of sulphur trioxide per 100 square centimeters per day
ppb	—parts per billion
ppm	—parts per million
SO_2	—sulphur dioxide

SO_x	—sulphur oxides, i.e. sulphur dioxide and sulphur trioxide
tons/mi^2-mo	—tons (2,000 pounds) per square mile per 30-day period
$\mu g/m^3$	—micrograms per cubic meter

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