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A STUDY OF METALLIC EMISSIONS FROM THE MAIN STACK AT SYNCRUDE'S MILDRED LAKE PLANT

Concord Scientific Corporation
Downsview, Ontario

FOREWORD

The following report describes a study conducted on SCL's main stack. The purpose of the study was to determine the emission rate of selected metallic elements and to estimate their deposition on the surrounding lands.

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A Study of Metallic Emissions from the Main Stack at Syncrude's Mildred Lake Plant
Volume I

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Prepared for

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EXECUTIVE SUMMARY

Concord Scientific Corporation has conducted a study of emissions from the main stack at Syncrude Canada Limited's Mildred Lake plant.

The terms of reference for this study were:

- To carry out a field stack sampling program and associated chemical analyses to determine selected metallic elements and related substances emitted in particulate and vapour form from Syncrude's main plant stack and the emission rates and the size distribution of the particles.
- To model the dispersion of these emissions to estimate the annual concentrations and deposition within 50 to 100 km from the stack, primarily to estimate the loadings on surrounding lands.

The field stack sampling programme was carried out between June 13 and June 19, 1984, during which one preliminary test and three valid compliance tests were completed.

The samples from these tests (130 in total) were analyzed for 26 elements by three independent analytical laboratories: Ontario

Research Foundation, Barringer Magenta Limited and Diagnostic Research Laboratories Limited.

The emission rates of total particulate matter and of individual metals both particle bound and in vapour form were calculated from the stack measurements and chemical analysis. These emissions were modelled using an existing, conventional dispersion model to estimate ground level concentrations and deposition patterns of these substances up to 100 kilometers from the Syncrude stack.

The concentration and deposition patterns were determined as annual averages by direction from the stack, based on input to the model of climatological data from Edmonton and Fort Smith, the nearest upper air stations providing the required data.

This report includes the details of the field sampling and chemical analysis protocols and of the modelling methods used, and presents the results and a disussion of the data.

The salient features of the results are summarized below.

- The measured average emission rate of total particulate matter from Syncrude's main process stack is about 35 ± 7 grams per second (3020 ± 600 kg/day). This result converts to 0.053 grams/kilogram of stack gas and is well below the Alberta standard of 0.2 grams/kilogram of stack gas.

- The uncertainty in the emission data at the 90 % confidence level is ± 14 g s^{-1} (2 standard deviations) calculated from the particulate emissions rate. Additional uncertainty caused by potential bias in the sampling due to increases or decreases in emission rate (i.e. sample representativeness) would increase this by a factor of 1.4. The overall uncertainty therefore would be ± 26 g s^{-1} or the emission rate would vary between 61 and 9 g s^{-1} or 0.092 and 0.014 g/kg of stack gas for a 90 % confidence interval.

- The range of emission rates for individual metallic constituents of the stack gas (including both particulate and vapour-phase forms) ranged from 320 milligrams per second (27.6 kg/day) for iron to 6 micrograms per second (0.0005 kg/day) for beryllium.

- Emissions for lead, cadmium, selenium, arsenic, mercury and beryllium are very low.

- The corresponding ground level concentrations of particulate matter and metals in the area around the stack, as determined by the model calculations, were found to reach a maximum at three to five kilometers from the stack. The maximum ground level concentration (annual average) at this distance is estimated at 0.06 micrograms per cubic meter for total particulate matter. The corresponding range for metals was from 540 picograms per cubic meter for iron to 0.01 picograms per cubic meter for beryllium.

- The model output also included dry deposition fluxes of total particulate matter and metals. The maximum deposition also occurs at a distance of three to five kilometers from the stack. The annual average deposition for total particulate matter (assumed to be 10 μm diameter) at this distance is 3.5 x 10^4 micrograms per square meter per year. Similarly for individual metals, the annual deposition ranges from 314 micrograms per square meter per year for iron to 0.006 micrograms per square meter per year for beryllium.

- These concentrations and deposition estimates are those attributable to the Syncrude stack, since other influences were not evaluated (i.e., other stacks, emission sources or wind blown dust).

- The compass sector into which maximum concentrations and deposition occur is to the southeast of the stack. The next greatest concentration and deposition amounts occur in the sector northwest of the stack.

1. INTRODUCTION

Study Terms of Reference and Scope

Concord Scientific Corporation has undertaken a study on behalf of Syncrude Canada Limited to determine the emission rates and deposition patterns of certain metallic elements emitted from the main process stack at its Mildred Lake upgrading plant.

Some preliminary data on the chemical composition of the stack emissions of particulate matter had been obtained during previous studies, but neither source testing to compliance test standards for particulate and vapour-phase metallic constituents nor mathematical modelling estimates of the deposition field for these emissions had been carried out. The results of the latter activity are essential in assessing the potential environmental impact of Syncrude's emissions.

The following were the study's terms of reference in conducting the investigation:

- To carry out a comprehensive programme of sampling particulate and vapour-phase emissions of specified metallic elements from the main process stack.

- To develop and execute the sampling protocol under the most rigorous compliance testing requirements of the Alberta and Canada Source Testing Codes.

- To determine the particle size distribution of particulate emissions and the particulate and vapour-phase components of specified elements by an optimized sampling method.

- To analyze the collected material according to an optimized protocol for 26 specified elements (primarily metals) in three independent laboratories.

- To apply a conventional atmospheric dispersion model to the emission rates of the individual elements determined in the foregoing steps, using currently available meteorological data, to estimate annual average deposition fluxes and concentrations of these elements in the environs of the plant.

The scope of this study was defined by the number of sets of valid source test samples to be collected under the conditions of compliance testing of normal plant operations - that is, three sets under current Alberta and Canada Source Testing Codes - and the number and type of elements to be determined in each sample.

Stack sampling and chemical analysis were to be carried out by recognized, standard methods. In addition, the sampling programme would be carried out in co-ordination with plant process operations, so that daily information exchange during the field sampling programme would allow immediate assessment respecting sample representativeness.

The three independent analytical laboratories were to follow the analytical and quality assurance protocols specified by Concord Scientific for each element, so that results would be directly comparable and analytical uncertainty would be well documented.

Measurements of meteorological parameters were not to be made during the field programme, since annual deposition patterns were desired, requiring long-term meteorological data. Preliminary estimates of annual average air concentration and deposition patterns only were required; therefore, a conventional, readily available dispersion model was to be used. That is, development of a site-specific, advanced deposition model was not within the scope of this work.

Chapter 2 of this report discusses study procedures and methods for sampling and processing of samples. Details of the MIX model used to calculate concentrations and fluxes are also described in this chapter. Chapter 3 describes the results of the analytical programme and outlines how emission estimates were calculated. The chapter also describes the modelling results for deposition and concentrations of metals around the Mildred Lake Plant. Chapter 4 provides a discussion on uncertainties in the data and compares the estimated concentration and deposition estimates with studies already conducted in the area and with other data available for remote rural and urban areas for some corresponding metallic elements. Data from stack measurements and process information and sample analysis are provided in some detail in Volume II, Appendices I, II, III and IV.

2. STUDY PROCEDURES

2.1 Sampling Methods

Source sampling for determining compliance with emission regulations requires that testing meet the following conditions:

1. sampling must be performed under process conditions representative of normal production rates and processes, excluding process upsets;

2. sampling results must truly represent the emissions from the source;

3. the equipment and methods for sampling must meet the specifications of the Code; and

4. a minimum of three valid tests must be completed after satisfactory completion of a preliminary test.

The sampling of stack particulate matter for metallic elements as well as the vapour-phase components of the more volatile metals was required in this study. In addition, information about the particle size distribution of the emissions was also required. To satisfy these objectives, three separate sampling trains: an isokinetic sampling train for sampling total particulate matter as well as vapour-phase lead and cadmium, an isokinetic sampling train for sampling total particulate matter as well as vapour-phase arsenic, selenium and mercury and a multi-cyclone train to determine the particle size distribution were used. All containers, impingers, connectors and miscellaneous glassware employed in the study were cleaned by a rigorous procedure prior to sampling. Final aliquots of rinse solutions were kept for proofing purposes. Sampling protocols were executed in accordance with the Government of Canada stack sampling code, since this was more stringent than the Alberta Government code applicable. Samples were kept locked in containers at all times after sampling and hand delivered to the analytical laboratories by a Concord employee. Process conditions monitored to assure representativeness of the samples are summarized in Appendix III.

2.2 Field Testing Procedures

2.2.1 Description of Reference Protocols

The reference source testing method for measurement of particulate matter from stationary sources is the Environment Canada Code: EPS 1-AP-74-1. Equipment and apparatus used had specifications equivalent to those required by the Code. Slight changes to the sample recovery procedure were made in view of the specialized sampling requirements. Any modifications to the sampling protocols were within acceptable limits as prescribed by the stack sampling code.

There are no applicable codes for size-selective sampling or for vapour-phase metals, although reference methods exist for collection of mercury vapour from chlor-alkali plants, EPS 3-EC-81-4 (Mercury: Methods for Sampling, Preservation and Analysis), lead from secondary lead smelters, EPS 1-AP-78-31 (Measurement of Emissions of Particulate Matter and Lead from Secondary Lead Smelters) and Arsenic from Gold Roasting Operations (EPS 1-AP-79-1). These methods are cited in Appendix IV. The individual methods used are presented below, including a discussion of variances from published procedures.

2.2.1.1 Determination of Particle Size Distribution

A Flow Sensor particle sizer sampling train was used in-stack to collect particles in a series of five cyclones and a back-up glass fiber filter. Cyclone D_{50} values were 6.0, 2.6, 1.9, 0.7 and 0.4 microns using the isokinetic sampling rate selected. The apparatus is shown in Appendix I, Figure 2. The back up filter was a Gelman type AE glass fiber filter. The Flow Sensor was selected because of the very low wall loss characteristics (Appendix I, Figure 1) and the ability to collect a large amount of particulate matter in each stage without carry over to adjacent stages. A cold box was used in series with the Flow

Sensor train to determine the moisture content of the stack gas as a cross-check on the two other sampling trains.

2.2.1.2 Determination of Particulate Matter (Metals) and Vapour-Phase Arsenic, Selenium and Mercury

The sampling train designated Train A is shown in Appendix I, Figure 3. A Teflon-lined probe was used, followed by a filter holder with a tared Gelman AE filter, followed by seven impingers. The impingers contained the following solutions:

Impinger 1 - 100 mL DI water
2 - blank
3 - 100 mL DI water
4 - 100 mL DI water
5 - 100 mL 2 % w/v $KMnO_4$ in 10 % v/v H_2SO_4
6 - blank
7 - silica gel

The first blank impinger was incorporated to collect liquid carry over from the first impinger as moisture was condensed from the stack gas during the test. After two traverses, the first two impingers were emptied (contents combined) and re-charged to prevent carry over and therefore contamination of the third impinger. Samples from impingers 1, 3 and 4 were kept separate. The silica gel was also recharged after the first two traverses.

2.2.1.3 Determination of Particulate Matter (Metals) and Vapour-Phase Lead and Cadmium

This sampling train designated Train B is shown in Appendix I, Figure 3. The train was essentially identical to Train A except for the use of six impingers and different collection solutions. The impingers contained the following:

Impinger 1 - 100 mL 5 % v/v aqua regia
2 - blank
3 - 100 mL 5 % v/v aqua regia
4 - 100 mL DI water
5 - blank
6 - silica gel

The blank impinger #2 was incorporated to trap the condensation overflow from impinger #1 and thus maintain a discrete sample. At the end of two traverses, impingers 1, 2 and 6 were re-charged.

2.2.2 Description of Sampling Events

Sampling started on June 13 and ended on June 19. The sampling produced a total of five sets of samples, one preliminary test and 4 compliance tests, one of which (#3) was invalidated due to a process upset. A brief description of sampling events is presented below, while a more detailed summary is presented in Appendix III.

Preliminary Test - June 13

Only two traverses on Trains A and B were performed. Considerable moisture was collected, indicating the first two impingers would have to be re-charged after two traverses during the sampling.

The size-selective sampling train was used on two ports, sampling for two hours on each port. Since very little particulate matter was collected from either sample, the sampling period for the testing was extended from four hours, recommended as a minimum in the stack sampling code, to eight hours. Sampling in subsequent tests was therefore conducted for two hours at each of four ports at a point of equivalent stack gas velocity.

Test 2 - June 14

Test 2 was the first compliance test. Pressure tests were conducted on the CO boiler which delayed sampling until 1150 hours. After two traverses were completed, a fire in the extraction plant and a problem with the utility boiler were reported which further delayed the start of sampling for traverses 3 and 4 until ~1930 hours.

Test 3 - June 17

Test 3 was performed after a 2 day delay. The Electrostatic Precipitators (ESP's) were not functioning on June 15, while on June 16, a fire at the feed pump for the fluid coker and a main air blower problem resulted in a reduced bitumen feed rate until 1600 hours. Sampling was not conducted on either of these 2 days.

On June 17, the sampling test ran smoothly, however notification of a load switch with the three utility boilers was not given until late in the sampling interval, and the test was therefore invalidated.

Test 4 - June 18

There were no problems that affected the process or the sampling, except for a brief interruption of sampling due to a report of a problem with the cokers. This was found to be erroneous, however, and a valid test was completed.

Test 5 - June 19

Sampling started at 1225 hours, however the sampling was stopped a short time later due to a power interruption which stopped a feed pump. Sampling was reinitiated at 1415 hours. A valid test was completed.

Tests 2, 4 and 5 together comprised the three compliance tests. Details of process and sampling events for these tests is provided in Volume II, Appendix III. The data demonstrate that the sampling on these three days met the main objective of compliance testing i.e., that tests be conducted during normal operating conditions as defined by the design criteria for process operation and not under "upset" conditions. That the samples obtained were representative of the stack gas under normal conditions was therefore documented and confirmed.

2.3 Sample Distribution and Analysis

Sampling trains were taken apart in the field in a trailer located near the stack. The collected particles from the probes, cyclones and the filters and the impinger solutions were transferred to containers which had been prelabeled and washed by the rigorous procedures required by the appropriate codes. These samples were capped and placed in individual plastic bags to prevent contact between samples during shipment and placed in containers for shipment. During shipment samples were kept locked with the keys held by the field coordinator. Shipping containers were transported from the site to the Concord Scientific (CSC) Environmental Laboratory, by truck to the airport in Fort McMurray and then by airplane to Toronto. The field coordinator travelled in the same vehicles and examined the sample containers at all transfer points and confirmed the integrity of the containers.

At the CSC laboratory the coordinator unlocked the containers and supervised the handling. The samples were first catalogued and then grouped by test number. Tests I and III were archived since I was a preliminary test and III was obtained under upset plant conditions. Samples from tests II, IV and V were processed according to the following protocol:

2.3.1 Sample Preparation

1) Flow Sensor Samples

Particles collected in each cyclone had been transferred to tared plastic containers in the field. They were placed in a desiccator for a 24 hour period, and then containers plus sample were weighed again to obtain the weight of sample collected. Cyclone water rinse samples in glass vessels were dried slowly under mild heat and then scraped into the plastic containers containing the appropriate cyclone catch. The containers were then re-weighed to determine the total cyclone catch.

Filters from the Flow Sensor train were placed in a desiccator for 24 hours and weighed. The particle catch was determined by difference from the initial filter weight obtained on the same analytical balance. One blank filter was carried through the sample handling procedure for each test.

Sample containers were then labelled with a CSC Laboratory number. Because the particle catches were small, in spite of the extended sampling periods, the whole sample was sent for analysis to the Ontario Research Foundation, Metals Laboratory. Results are outlined in Appendix I, Table 9.

2) Train A and Train B Particle Catches

Filters from Train A and Train B and comparably prepared blank filters were placed in a desiccator for a minimum period of 24 hours and weighed. The particle catch was determined by difference from weighings performed prior to transport to the field. The filters were then placed in a plexiglass apparatus machined to divide the filters into 12 equal sections. Sections 1, 5 and 9; 2, 6 and 10; 3, 7 and 11 and 4, 8 and 12 from each filter were grouped and placed in separate petri dishes. This procedure was performed to minimize problems with uneven distribution of particles on the filters, since the filters were held vertically during the stack sampling. The petri dishes were labeled with sequential laboratory numbers and one dish from each sample was sent to each of the three analytical laboratories.* In addition, the fourth set was submitted to one of the laboratories as a separate sample, labeled with a different number. This procedure provided data on precision of analysis. Acetone and water rinses of the probes were used after sampling to recover the particles trapped in the probe. These samples were dried under mild heat in beakers and the contents were transfered to pre-weighed plastic containers. Much less than a gram of particles was collected. These samples were not split, therefore, and were analyzed only by the ORF laboratory. Results are presented in Appendix I, Tables 3 to 8.

* ORF, Ontario Research Foundation
* BML, Barringer Magenta Ltd.
* DRL, Diagnostic Research Laboratories

3) Impinger Samples

Impinger samples from Train A were used to obtain measurements of vapour phase arsenic and selenium in the water impingers and vapour phase mercury in the impinger charged with the $KMnO_4$ solution. Since the $KMnO_4$ impinger followed the water impingers, the water impingers were also analyzed for mercury.The total contents of impingers 1 and 2 were combined and an aliquot was removed and preserved in the field with 1 mL of 2% $K_2Cr_2O_7$ and 1 mL of 50% H_2SO_4 per 100 mL of sample for the mercury analysis. A similar procedure was followed with impingers 3 and 4. In the laboratory, the impinger contents were weighed on a triple beam balance to obtain total volumes to the nearest 0.5 mL and divided into 3 aliquots. The $KMnO_4$ impinger contents were also weighed and divided into 3 aliquots. Train B, aqua regia-filled impingers for collection of vapour phase lead and cadmium, were treated in the same manner, i.e., the contents of impingers 1 and 2 and those of 3 and 4 were combined, weighed and divided into 3 aliquots. One aliquot from each sample was submitted to each laboratory for analysis. Results are outlined in Appendix I, Tables 3 to 8.

4) Blanks, Proofing Solutions and Wash Solutions

Solutions were obtained for confirmation of reagent blank levels and for determining background levels in the sampling train components (i.e., the probes, filter holders, and impingers) prior to each sampling test. These solutions were also analyzed by the same procedures. Solution quantities were between 50 and 100 mL. Because of the low volumes and concentrations expected (and found), these were not divided but sent to either ORF or BML for analysis.

5) QA/QC Samples

Several types of quality assurance and quality control samples were submitted blind to each laboratory. The QA/QC solution samples were prepared prior to submission of the field test samples and sent for analysis as part of the complement of samples to each laboratory. Particulate reference materials certified for metals matching this type of source were unavailable. NBS Standard Reference Material (SRM), number 1648, urban particulate matter, certified for metals was therefore selected as an approriate check sample. These samples were quite different in concentrations of individual elements when compared with the stack samples, but provided checks of recovery efficiency, calibration accuracy and precision. The laboratories each identified these check samples as being unique and quite different in metals composition when compared with the stack samples. Results are presented in Appendix I, Table 10. Not all metals determined have certified values.

The aqua regia digestion used for this study is not a total digestion and recoveries of some elements such as Si, Al, Fe, Ti, Cr and Zn were known to be low for particulate matter matrices. It should be noted that this extraction procedure was selected on the basis of several constraints. Firstly, only glass fibre type filters are rugged enough to withstand the rigors of stack sampling conditions, e.g., temperature. Teflon filters provide advantages in terms of significantly reduced background levels for Si, Na, Ca and trace elements but are not suitable for this application. Secondly, two types of elements were identified to be of interst to this study. Those were the elements such as Si, Al, Fe, Ca, and Mg which form the major metallic components of the stack particulate matter, but data were already available from other studies for these elements. The second group of elements were those for which little or no data were available from past studies. These included Pb, Cd, As, Se, and Hg. Information on particulate and vapour phase concentration of these elements was the primary emphasis of the study. Since these elements were present in very low concentrations in the filter catches, filter background levels could easily have masked trace elements released from particles in a total digestion procedure such as digestion using HF. The efficiency of extraction for airborne particulate matter for the latter metals by the aqua regia method, however, was known to be high (Appendix I, Table 12). This technique was proposed, therefore, as the best approach available to obtain valid data for the latter set of elements while still providing data for comparison with previous results for the former element set. ORF provided additional results for the metals on the NBS-SRM 1648 samples using an HF digestion, which shows enhanced recoveries of some elements.

Solution samples were also submitted which contained known amounts of metals. These were prepared by dissolution of known quantities of metal (analytical grade) using methods prescribed in the APHA's "Standard Methods of Analysis For the Examination of Water and Waste Water", 15th Edition. Further assessment of the overall variability of the data can be obtained from analyses of the filter replicate data, the inter-laboratory comparisons, the duplicate samples and the interday sampling results. A summary of the solution standard data is presented in Appendix I, Table 11.

In addition to these measures, the laboratories carried out internal quality control procedures. These included analysis of internal duplicate samples, reagent blanks, spiked samples and recovery checks.

2.3.2 Sample Analysis Methods

Analytical procedures to be used by each of the laboratories were specified prior to initiation of analysis. The factor most affecting the accuracy and precision of analysis was the digestion of particulate matter samples and filters. For these, an aqua regia digestion was specified to obtain a leachable quantity for the metals in sample particulate matter. Mercury extraction was performed on a separate portion of the filter by a different procedure. An extractive (i.e., aqua regia) rather than total digestion method was selected because of the potential contamination problems from the filter matrix when the filters are processed by a total digestion method as discussed in section 2.3.1, particularly for metals present in trace quantities such as lead, cadmium, arsenic, selenium and mercury. However, for many metals, an aqua regia digestion yields equivalent results to a total fusion of the sample. Data for a comparision of recoveries on the NBS-SRM 1648 by a total digestion method and by the aqua regia method are presented in Appendix I, Table 10.

Sample analysis methods for solids, filters and impingers are outlined in the following sections.

1) Analysis of Filter Samples

Mercury

A weighed portion of each filter was digested with sulfuric, nitric and hydrochloric acids as well as potassium permanganate and potassium persulfate (60°C, 16 hr). The resulting solutions were reduced with hydroxylamine hydrochloride and diluted to volume. An aliquot of each solution was removed and further reduced with stannous chloride immediately prior to analysis by cold vapour atomic absorption spectrophotometry.

"Other Metals"

This includes Al, Ba, Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, Sn, Si, Ti, Be, V, and Zn, which were analyzed by DC plasma emission spectrophotometry (ORF, DRL) or inductively coupled plasma emission spectrophotometry at (BML) and Pb, Cd, and Ag, which were done by flame atomic absorption spectrophotometry.

Weighed portions of filter material were placed into erlenmeyer flasks. Aqua regia was added and the samples were evaporated to a low volume. The aqua regia treatment was repeated two more times before the solutions were diluted with hot deionized water, filtered, and diluted to volume for analysis.

Arsenic and Selenium

Aliquots of the above filtered solutions were removed. Nitric acid (5 mL) and concentrated sulfuric acid (2 mL) were added and the solutions were evaporated to fumes of SO_3. Deionized water (~5 mL) and hydrochloric acid (5 mL) were added and the solutions were heated to boiling. After cooling, the samples were diluted to volume for analysis by hydride generation and atomic absorption spectrophotometry.

Solids Analysis

These procedures were employed for:

A. Cyclone samples where weighable portions were available.
B. Other solid samples such as coke dust, hopper samples and soils.

The procedures used for sample preparation and analysis were identical to those employed for the filter analysis except that these samples were allowed to settle prior to analysis instead of being filtered. In addition, the hopper samples and the coke sample were reanalyzed for all metals except arsenic, selenium and mercury using an alternate preparation procedure outlined below.

Alternate Sample Preparation Procedure

A weighed portion of each sample was initally digested with nitric acid. Perchloric acid was added and the samples were carefully evaporated to fumes of percholoric acid. (Additional nitric acid was added as necessary to prevent an uncontrolled reaction). Water and nitric acid were added to the cooled samples prior to filtering and dilution to volume for analysis. The residual filter paper and particles were ashed in a platinum crucible and the insoluble residue was fused with sodium carbonate. The cooled melt was dissolved in hydrochloric and hydrofluoric acids and diluted to volume for analysis. The results for the original solution and the fused residue were combined.

Impinger Solutions

Mercury, Permanganate Impingers

The entire impinger solution for each sample was initially reduced with a solution of hydroxylamine hydrochloride. The clear solutions were diluted to volume and an aliquot from each was removed and further reduced with stannous chloride immediately prior to analysis by cold vapour atomic absorption spectrophotometry.

NOTE: Three samples containing permanganate were clear, indicating that insufficient permanganate was initially present to overcome the reducing power of the stack gas sample. Additional permanganate was added during sampling but the solutions were still clear at the end of the sampling period. This is a serious shortcoming of the acid permanganate mercury sampling method, since SO_2 present in the stack gas reduces the concentration of permanganate. Acidic hydrogen peroxide has been used to remove SO_2 prior to the acid permanganate (McQuaker and Sandberg, 1982) to maintain the oxidation potential of the acid permanganate solution. These researchers sampled stack gas containing ~15,000 ppm SO_2 at 10-12 LPM for 1-2 hours and demonstrated high collection efficiency for mercury. Little information on the collection efficiency of mercury at low or no permanganate levels exist; however, the authors cited work of Caban and Chapman (1972) who determined that at a permanganate concentration of 0.5% w/v, collection efficiency dropped from 100% to 75% in the first impinger (50 mL of 10% permanganate in H_2SO_4). However, only 2 impingers were used and mercury-spiked air was sampled. Since the absorbing solution was clear, it is evident that the collection efficiency for mercury vapour would be affected. However, the incorporation of a peroxide pre-scrubber in the As, Se, Hg train would have affected the collection efficiency of As and Se. The state-of-the-art for the simultaneous collection of several metallic vapours has not been fully validated at this time.

Water Impingers, Mercury

To the entire solution additional potassium dichromate and nitric acid were added 72 hrs prior to analysis to overcome the reducing power of the solution. An aliquot of the impinger solution was then digested at 90°C for 3 hrs with potassium permanganate, potassium persulphate, nitric and sulphuric acids and then reduced with hydroxylamine hydrochloride. The clear solution was diluted to volume and reduced with stannous chloride just prior to analysis by cold vapour atomic absorption spectrophotometry.

Arsenic and Selenium

Aliquots (25 mL) of these solutions were transferred to erlenmeyer flasks. Nitric acid (5 mL) was added and the samples were heated on a hot plate. After cooling, 2 mL of concentrated sulfuric acid were added and the solutions were evaporated to fumes of SO_3. Deionized water (~5 mL) was added to the cooled samples along with 5.0 mL of hydrochloric acid. The solutions were brought to a gentle boil to ensure complete dissolution of selenium. The cooled solutions were diluted to 25 mL for analysis of arsenic and selenium by hydride generation atomic absorption spectrophotometry using sodium borohydride as a reducing agent.

Lead and Cadmium

Aliquots (25 - 100 mL depending on sample availablity) were transferred to beakers with covers. Aqua regia (8 mL) was added, and the solutions were slowly evaporated to 3 mL on a hot plate. Nitric acid (1 mL) was added and the samples were digested for a few more minutes prior to cooling and diluting to volume for analysis of lead and cadmium by flame atomic absorption spectrophotometry. (D_2 arc background corrected).

Remaining samples (ORF only)

These samples consisted of cyclones from which weighable subsamples were not available, probe wash solutions, proofing rinses etc. Samples were transferred to erlenmeyer flasks and aqua regia was added to the original polystyrene or polyethylene bottles. The bottles were shaken and the acid was transferred to the digestion flask. The resulting solutions were evaporated to 2-3 mL and fresh aqua regia was added. The acid treatment was repeated twice. The solutions were allowed to cool and were transferred to volumetric flasks. Aliquots of the digestate were immediately removed and processed as for aqua regia impingers for mercury, arsenic and selenium analyses. The remaining solution was used for metal analysis by plasma emission and atomic absorption for appropriate metals as indicated.

2.4 Modelling

The Mixed Layer Statistics Dispersion Model (MIX) developed by the Atmospheric Environment Service, Environment Canada (Matthias, 1981) was selected for modelling the dispersion of emissions from the Syncrude stack. The model is briefly described in Section 2.4.1. The rationale for the selection of various model inputs is given in the following section. A brief outline of the available validation information on the model and a summary of the sensitivity of the model to the input parameters are given in section 2.4.3. The model outputs, which are based on unit emission rates, are described in section 2.4.4. The description of the methods used to obtain estimates of elemental concentrations in air and of deposition fluxes based on measured elemental emissions appears in section 2.4.4.

2.4.1 Model Description

To estimate ground level pollutant concentration and deposition fluxes resulting from the emission and dispersion of pollutants from Syncrude's elevated stack, a Mixed Layer Statistical Dispersion Model (MIX) was used. MIX (Matthias, 1981) is a Gaussian point source model which uses statistical or climatological input data and includes depletion of the plume pollutants by dry deposition and first order chemical decay. Wet deposition is not considered by this model.

The MIX model includes various submodels for the following:

- plume rise calculation (using the Briggs formulation)
- diurnal variation of surface heat flux (assumed to be sinusoidal during the day and decreasing at night)
- surface shear stress
- mixing heights (daytime and nighttime)
- turbulence intensity
- atmospheric stability class.

The climatological data for the mixed layer consists of seasonal joint frequency distributions of maximum mixing height and mean wind speed. The mean nocturnal inversion gradient, mean ambient temperature, regional albedo and the wind direction frequency distribution are also included.

The model first calculates, for any specified downwind distance, the distribution (in 50 concentration ranges) of ground level concentrations. For these calculations, it is assumed that the wind direction within each of nine 40° sectors is distributed randomly over a period of a season or a year. It was further assumed that the emission is uniformly distributed in the horizontal within the sector. The mean of these ground level concentrations $\bar{C}_i$, for season i, is then calculated and, using the wind direction frequency, the seasonal mean ground level concentration $\bar{C}_{n_i}$ is calculated for each sector. The seasonal deposition flux $\bar{F}_{n_i}$ in sector n, , is then the product of the seasonal deposition velocity, V_{d_i} and $\bar{C}_{n_i}$. Note here that i represents each season and n represents each wind direction sector.

The annual deposition flux $\bar{F}_{n_T}$, is determined by summing seasonal deposition fluxes, $\bar{F}_{n_i}$.

2.4.2 Model Inputs

The model inputs are comprised of stack parameters, meteorological parameters and data, together with pollutant parameters. These input parameters and the values used in the modelling are given in Table 2.1. The bases for the selection of these values are described below.

a) Physical Stack Parameters

The latitude, stack height and stack top diameter are data supplied by Syncrude. The stack gas exit temperature and velocity are measured values (this study) and are close to the design values (data supplied by Syncrude). During the field sampling program of June 1984,

TABLE 2.1

Model Inputs

	Values
Location (latitude)	57.04° N
Stack height	183.0 m
Stack top diameter	7.9 m
Stack gas exit velocity	21.6 m s^{-1}
Stack gas exit temperature	230.5 C
Roughness length	0.03 m
Location of upper air station	Fort Smith (YSM), Edmonton (YEG)
Metallic element emission rate	1 g s^{-1}
Downwind distance	1, 3, 10, 15, 20, 30, 50, 100 km
Chemical reaction rate	0
Deposition Velocity	
0.1 μm particles	
Winter and spring	0.003 m s^{-1}
Summer and fall	0.013 m s^{-1}
10 μm particles	
Winter and spring	0.014 m s^{-1}
Summer and fall	0.022 m s^{-1}

the values of these parameters ranged from 21.6 - 23.2 m s^{-1} for the exit velocity and 230.5 to 237.1°C for the exit temperature. Historical data for these parameters indicate the selection of these values reflects typical and representative conditions for the stack. These stack parameters are required in the calculation of the plume rise. The impacts of the variation of the stack parameters (exit velocity and exit temperature) on the predicted concentrations are given in section 2.4.3.

b) Meteorological Parameters

The roughness length value used is the recommended value for the terrain in the vicinity of the plant. The terrain is generally muskeg and is equivalent to low grass, steppe (1-4 cm) or fallow fields (2-3 cm). The surface roughness lengths recommended for use in the model are based on data summarized by Simiu and Scanlan (1978). A value of 3 cm (0.03 m) was selected. The influence of roughness length on the model output (concentration at specified downwind distances) is given in section 2.4.4.

The other meteorological input data are climatological information for the first order meteorological station closest to the stack.

The climatological data required by the model are derived from percentage joint frequency distribution (JFD) tables of daily mixed layer, wind speed, wind direction and maximum mixing height. These mixed layer data have been generated for the four year period 1965 to 1969 over a sparse network of radiosonde stations in Canada and northern U.S. (Portelli, 1977). The mixed layer properties do not vary strongly with surface characteristics since they are more strongly linked to geostrophic flow.

The Syncrude stack is nearly equidistant from the two closest radiosonde stations at Fort Smith and Edmonton. The climatological data for these stations are different (See section 2.4.3) hence model outputs describing emissions from the Syncrude stack were obtained using data for both stations.

c) Emission Rate

A unit emission rate (1 g s^{-1}) was selected in order to simplify the analysis. For individual elements, the measured emission rates were used to scale the calculated unit emission rates, thereby providing the appropriate concentration and flux estimates. For example, if the estimated concentration of element X at a distance of 10 km from the stack were 300 pg m^{-3} based on the unit emission rate, then for an actual emission rate of 0.230 g s^{-1} (230,000 μg s^{-1}) for element X, the actual concentration at 10 km would be 300 x 0.23 = 64 pg m^{-3}.

d) Downwind Distance

Downwind distances of 1, 3 , 5, 10, 15, 20, 30, 50 and 100 km were selected for the estimation of concentration and flux.

e) Chemical Reaction Rate

The particulate species measured in the field program are not expected to undergo any chemical reaction that would change their phase, i.e., conversion to vapour or liquid phase. It is also assumed that size changes, particle aggolomeration or disintegration are negligible. The chemical reaction rate was therefore taken to be zero.

In the case of vapour phase species (Pb, Hg, As, Se and Cd), it was also assumed that no phase changes occurred as a result of chemical reaction. The chemical reaction rate for these species was also taken to be zero.

f) Deposition Velocity

The original formulation of the MIX model was modified to allow the seasonal dependency of the deposition velocity to be included. The seasonal variation of V_d arises because of the difference of surface cover in the seasons (snow in winter and spring, tall grass/muskeg in summer and fall).

Deposition velocity is also a function of particle size. A recent literature review (CSC, 1983) of dry deposition velocity data for particulate matter indicated that two particle sizes are adequate to describe V_d for particles. Theoretical studies (Slinn, 1977; Sehmel and Hodgson, 1978) indicate that V_d passes through a minimum at 0.1-1.0 µm, hence significant differences in V_d with particle size occur for ~0.1 µm and ~10 µm particles. The model was therefore run using two sets of values for the deposition velocities that correspond to 0.10 µm and 10 µm diameter particles. The sensitivity of the modelled concentration to variation in V_d is indicated in section 2.4.3. It should be noted however that the flux will be directly proportional to the value of V_d.

It is also assumed that the deposition velocities for the vapour phase species (Pb, Se, Cd, As and Hg) are similar to the deposition velocity for 0.1 µm particles. Measured values for the deposition velocities for gases such as I_2 (.0002 to 0.26 m s^{-1}) and Thorium B (0.0008 to 0.026 m s^{-1}) are in a similar range (Sehmel, 1980) to that used for 0.1 µm particles. The deposition velocities for I_2 and Thorium B are also similar to those for particulate sulphate or ammonium which have mass median diameters close to 1 µm (for example Pierson et al. 1980; Heard and Wiffen 1969).

The formulation of the MIX model does not include wet deposition. The effect of omitting wet deposition on the long-term deposition estimates is not known precisely since the total percentage of time each year that precipitation occurs is small in this region. Long-term statistics indicate precipitation occurs on an average of 30% of days but the duration of the events on these days will result in a much smaller percentage of total time that precipitation occurs. Barrie (1980) found that the latter was about 2 % during the field study period and his paper provides estimates of the total deposition in the Tar Sands area. This point is discussed in sections 3.4 and 4.3.

2.4.3 Model Outputs

The model output provides the following information based on unit (1 g/s) emission rate for each specified downwind distance:

- The frequency distribution of concentrations that occurs in a downwind sector. This distribution of concentrations arises from the statistical variation of climatological conditions.
- The long-term average concentrations in each of the nine 40° sectors. The frequency distribution of wind direction is taken into account.
- The average annual deposition flux of particles in each sector.

Downwind distances of 1, 3, 5, 10, 15, 20, 30, 50 and 100 km were used. At each distance, the model was run using climatological data for Fort Smith and Edmonton and also using deposition velocities appropriate for 0.1 μm and 10 μm diameter particles. The average annual sector concentrations and fluxes at each downwind distance are given in Appendix I, Tables 14 to 21.

The spatial variation of the concentration and the flux are illustrated by means of contour plots. A complete set of contour plots based on unit emission rates is given in Appendix 1, Figures 6 through 13. Typical examples of these plots are presented in Figures 2.1 and 2.2. In these figures, concentric circles are drawn to represent the distance from the stack. The contour lines show concentrations in units of 10^{-4} μg m^{-3} (Figure 2.1) or fluxes in units of μg m^{-2} yr^{-1} (Figure 2.2).

The concentration and flux for individual elements (using the actual elemental rates rather than unit emission rates) are presented in section 3.4.

The MIX model is a Gaussian dispersion model. Gaussian formulations have been tested extensively by the air quality community and are now an accepted tool for air quality assessment purposes and are considered to be accurate within a factor of two. Although the MIX model has not been validated directly against experimented data, it has been compared to existing validated models. An assessment using the MIX model was carried out in 1980 by Environment Canada and the Ontario

Figure 2.1

Concentration Contour Plot for the Dispersion of 0.1 μm Particles Based on 1 g s^{-1} Particulate Emission Rate

Edmonton Climatological Data

Numbers on Contours are in Units of 10^{-4} μg m^{-3}

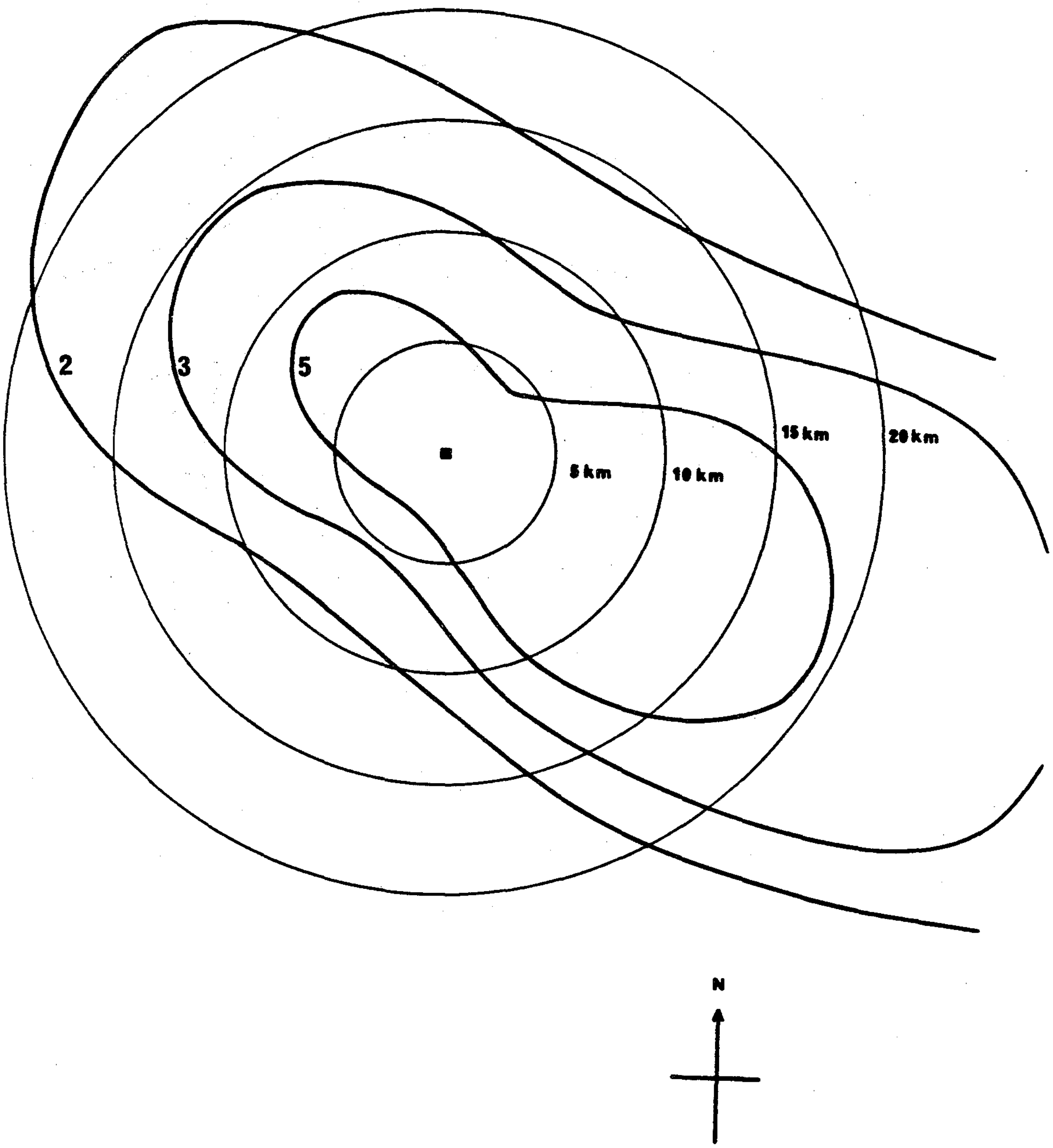
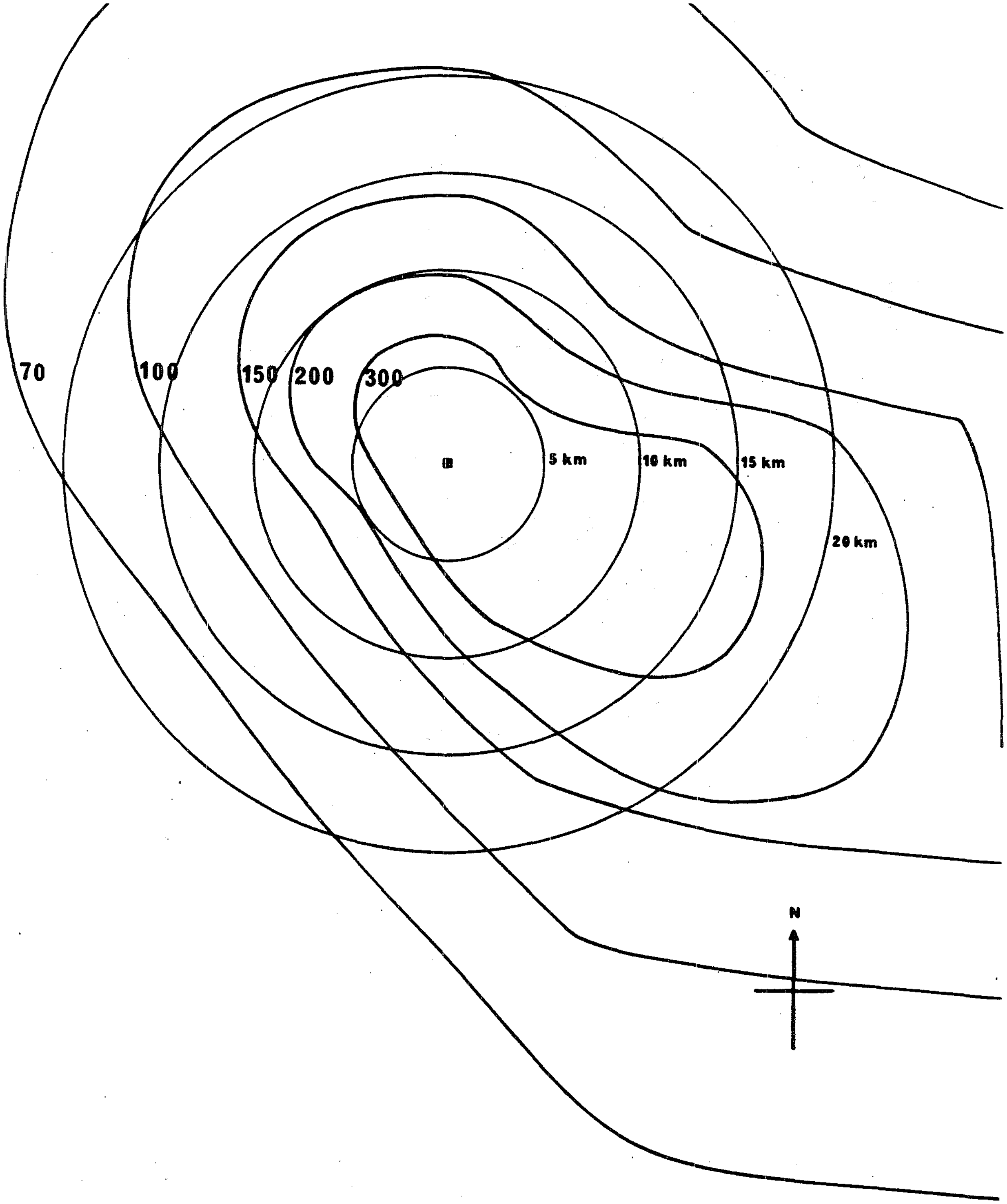


Figure 2.2

Flux Contour Plot for the Deposition of 10 μm Particles Based on 1 g s^{-1} Emission Rate

Edmonton Climatological Data

Numbers on Contours are in Units of μg m^{-2} yr^{-1}



Ministry of the Environment on the air quality impacts of the Atikokan power plant in Ontario, which had become a Canada - U.S. environmental issue. The U.S. EPA reviewed the model methodology, and concurred with its elegant approach. The results of the MIX model were found to be very similar to those produced by EPA's RAM model (a UNAMAP model) which had undergone considerable evaluation. The MIX model results thus were found to be an accepted basis for evaluation of air quality impacts in an international forum.

The sensitivity of the model outputs to selected non-process input parameters, namely, deposition velocity, roughness length and meteorological station (hence climatological data), was also examined. Table 2.2 summarizes the test values used and those selected for modelling this dispersion from the Syncrude stack.

The results of the sensitivity analyses performed using various values for the stack exit temperature, stack gas exit velocity and the roughness length is summarized in Appendix 1, Figure 4. Similarly, the sensitivity of the model output to changes in deposition velocity is illustrated in Appendix I, Figure 5.

The deposition velocity values selected for use as model inputs correspond to 0.10 and 10 μm diameter particles. Field measurements of stack particle size distributions indicate a bimodal distribution with predominance of particles with 0.30 μm and 6.0 μm 50 % cut-

TABLE 2.2

Summary of Test Values Used For Sensitivity Analysis

Parameter	Test values			Values selected
Stack gas exit velocity (m s^{-1})	27.4*	21.6	23.3	21.6
Stack gas exit temperature (°C)	232*	231	237	230
Roughness length (m)		0.006	0.030	0.030
Upper air meteorological station	Fort Smith, Edmonton			Fort Smith and Edmonton
Deposition velocity				
0.10 μm particles				
Winter and spring (m s^{-1})	0.003	0.015	0.0006	0.003
Summer and fall (m s^{-1})	0.013	0.065	0.0026	0.013
10 μm particles				
Winter and spring (m s^{-1})	0.014	0.070	0.0028	0.014
Summer and fall (m s^{-1})	0.022	0.110	0.0044	0.022

* Design values

points. Since the deposition velocities of particles are at a minimum in the 0.1 to 1 μm size range, the deposition velocity for the 0-1 μm particles will be appropriate for modelling the behaviour of the smaller group of particles from the stack (those with ~0.3 μm cut points). Similarly, the deposition of the group of larger particles emitted from the stack can be modelled by using V_d for 10 μm particles.

The roughness length selected was 0.030 m. This value, which is acceptable for the type of terrain in the study area, yields greater concentration and flux estimates than the choice of the other value tested (0.006 m).

The model was run using climatological data for both Edmonton and Fort Smith since a clear choice between these stations is not feasible. The Syncrude stack is equidistant from Edmonton and Fort Smith, so the usual criteria on which a choice can be made are inappropriate. The optimal approach, that of creating a data set for Mildred Lake by interpolation of the climatological data (Matthias, 1984), was not feasible within the scope of this preliminary study. The outputs from both stations were compared and the set leading to greater estimates of local deposition chosen.

2.4.4 Conversion Method to Obtain Predicted Concentration and Flux Data From Stack Sampling

The model outputs are based on unit (1 g/s) stack emissions. Chemical analyses of stack samples provide actual emission rates for each of twenty-six elements. The concentration and flux contours indicated for the unit emission rate are simply multiplied by the actual emission rate for each element to yield concentration and flux contours for each element.

3. RESULTS

3.1 Sampling Program Evaluation

3.1.1 Process Observations and Sample Representativeness

Process parameters were monitored during the test intervals to ensure that all contributing processes were operational and that abnormal or upset conditions did not exist. Prior to each test, the plant process co-ordinator was contacted to provide a status update of all operations. During the tests, process status updates were reported to the sampling crew on a regular basis. Documentation of process conditions consisted of plotting selected process trends for immediate review subsequent to test completion. If the trends indicated that process parameters were within the normal range of operation, the test was acceptable from the point of view of the representativeness criterion.

The process trends examined immediately after test completion included:

(1) Assignable trends produced by 10 minute "slices" of data points.

(2) Assignable trends produced by hourly average data points.

(3) Operators' process logs.

(4) Manually logged electrostatic precipitator rectifier panel readings.

All process data were stored in the plant's DAP computer system. Upon completion of the test program, average values of pertinent process parameters were calculated for the actual test intervals.

The three tests for compliance were conducted on June 14, 18 and 19. The assignable trends and process summary sheets illustrate that the process operation was consistent with normal and stable operating levels of the plant. The summaries of assignable trends are contained in Appendix III.

Process observations as documented by the test crew and process data reports indicate several individual process variations along with pertinent comments. The process fluctuations displayed in the assignable trends are considered to be within the boundaries of typical and representative operation.

Process Review and Comments

As noted from the precipitator logs, Electrostatic Precipitator Rectifier Sections A2 and A4 were out of service on process line

8-1 for the course of the survey. As a result, emissions were marginally higher during the survey compared with emissions when all sections were operational. A log of all electrostatic precipitator hopper temperatures was acquired throughout the survey. With the exception of one hopper (TAG 82TA11) which gave significantly lower temperature readings, all hoppers appeared to be functioning without problems.

June 14, 1984

On June 14th, high temperatures caused rectifier B6 (8-2) to stop functioning at 11:30 and rectifier A6 (8-2) to stop functioning at 12:30. These outages were reported immediately by the process coordinator. B6 was placed back in service within an hour; however, temperature problems disabled the A6 section until 17:30. Readings indicate that only a minimal impact on opacity occurred during this time interval. An elutriator was taken out of service on 8-2 at 13:05 to 16:20 for silo repair. Again minimal influence on optical emissions was recorded. When the elutriator was out of service, problems with the blower were noted; however, stack sampling did not overlap with this period which occurred at 14:30. Sampling for determination of particle sizes was initiated just as this problem came under control.

Two bitumen extraction trains were in service during this test day. Soot blowing was initiated at 14:15 on CO boiler #1 and at 16:38 on both CO boilers. This was part of the standard operating procedure for the boilers. Conditions for this test were considered to be representative of normal operations and the test was, therefore acceptable for assessing emissions.

June 18, 1984

During the day, continual problems were encountered with the sour water stripper system (Plant 16). NH_3 flow to the CO boiler was highly variable until 17:33 when the flow appeared to stabilize, but at a somewhat lower rate than during the June 14 run. Concurrently at 17:33, a 2 - 3% increase in opacity was indicated, although at this time, a slight increase in steam output at boilers 101, 201 and 301 was noted.

Soot blowing was conducted on CO boiler No. 1 from 13:40 to 14:56 and on CO boiler No. 2 from 16:33 to 17:20. This was part of the standard operating procedure for the boilers. Two extractions trains were on line in the plant during the test intervals.

A report of bad data accumulation on the computer monitoring system was received at 14:38, although no irregularities were evident from the assignable trends. Conditions for this test were considered to be representative of normal operations and the test was, therefore acceptable for assessing emissions.

June 19, 1984

On June 19, three bitumen extraction trains were functioning in the plant compared with two trains for June 14 and June 18. Between 12:40 and 12:50, power problems were experienced and the G-6 unit stopped functioning. Sampling was not conducted during this period however.

Computer logged data was off line from 12:39 to 12:54 due to a plant power surge. Computer logging difficulties were also reported between 10:15 to 10:25 and 10:58 to 11:07.

Soot blowing occurred on CO boiler No. 1 between 13:52 and 15:12, and on CO boiler No. 2 between 16:25 and 17:12. This was part of the standard operating procedure for the boilers.

Process conditions for this test were considered to be representative of normal operations and the test was, therefore acceptable for assessing emissions.

Because of the intensive plant monitoring and reporting effort conducted during the study, there can be no doubt regarding representativeness of the sampling during each of the three test days. Detailed documentation of the process parameters is provided in the Appendix III.

3.1.2 Sampling Results

Sampling was carried out using rigorous stack sampling procedures with each of the three stack sampling trains, i.e. the Flow Sensor Train, Train A and Train B on each of three test days. Sampling results are summarized in Appendix I, Tables 1 and 2. It is evident that in spite of the extended sampling hours the particle catches were low indicating efficient operation of the stack gas recovery systems such as the electrostatic precipitators and other systems. With such low loadings, irreproducibility of sampling and analytical results can be considerable. Appendix I, Table 2, for example, shows that for Train A and Train B, the total particle catch was approximately 600 mg for tests II and IV whereas for Test V, the mean catch was only 400 mg, even though an additional extraction train was in service. In each of the three tests, the total mass collected on the Flow Sensor Train was substantially lower than that on the isokinetic sampling trains, for reasons which are set forth below.

The in-stack cyclone sampler was developed by the Southern Research Institute (SRI) to allow in-situ determination of the particle size distribution and to provide sufficient sample size for chemical analysis. It was not developed as an alternative to the EPA Method 5 or absolute filter sampling methods specified by sampling codes, for sampling of stack particulate matter. The manufacturer (Flow Sensor, a division of Andersen Samplers Inc.) has no data comparing the total catch of the cyclone sampler and a total particulate sampler. Some data exist at SRI; however, the data are not collated into a report on the sampler's performance in the field. SRI's experience with the sampler is extensive and several illustrations of the sampler's performance were given by Dr. J. McCain of SRI (personal communication August, 1984). Dr. McCain stressed the following points regarding the sampler's operating characteristics:

- Although in principle, the total particulate catch in the cyclones should be equal to that collected by the EPA Methods or comparable total particulate matter sampling trains for stacks, since both are desiged to sample isokinetically, the cyclone sampler operates at a set flow rate which is related to the size cuts selected for sampling and the stack gas velocity and is therefore susceptible to variations in stack gas velocity.

- Comparisons of the cyclone sampler to an in-stack absolute filter (EPA method 17) has been found to be good; however, the cyclone sampler always gives lower particulate values when compared to the EPA Method 5 train or other extra-stack filter methods as specified for this study. The difference between the two is related to the amount of condensibles in the stack gas and the source characteristics. For example, stack gas temperatures considerably greater than 250°F, the temperature at which "particulate matter" is collected and defined in EPA method 5, (Syncrude's stack was at 450°F), causes condensible compounds to pass through the cyclone sampler which would be collected by an EPA Method 5 or comparable sampling train. The higher the temperature and the amount of condensibles, the greater the discrepancy. Differences of as much as a factor of 10 have been observed in side by side sampling studies.

For purposes of this assessment, therefore, the emission factors calculated will be based on the particle catches of Trains A and B. The particle size analytical data are used to confirm the analytical estimates from the other sampling trains and to provide data relevant to the modelling of concentration and deposition fields of the metallic elements to the environs of the Syncrude plant. The Flow Sensor Train data for the particle size distribution assists in selection of the appropriate deposition velocities for the modelling of deposition and concentration fields.

The particle size distribution on all three test days demonstrated a bimodal distribution with 50 to 70% of the mass in size fractions with a 6 μm cut point while much of the remainder was in the size fraction less than 1 μm. The test II data contained 57% of the mass in cyclone I and 40% on the filter, while in runs 4 and 5 more of the mass was distributed among cyclones 2 to 5. The differences in distribution among the the different tests were within acceptable ranges. Histograms of particle sizes from each test are presented in Appendix II. Differences in process parameters for these tests were not observed.

3.2 Analytical Results

3.2.1 QA/QC Sample Results

Two types of standards were distributed to check accuracy and precision of analysis. National Bureau of Standards Standard Reference Material 1648 (NBS-SRM 1648) for urban particulate matter was submitted in duplicate containers in 1.0 gram quantities to each laboratory. Certified values are provided for Zn, Fe, Cu, Al, V, Ni, Cr, Na, Cd, Pb, As and Se. Additional concentrations (uncertified) are also given for Co, Mn, Mg, Ba, Ti and Ag. Each laboratory provided data for the full range of elements including P, Be, Si, Ca, Mo, Zr, Sn and Hg. The main purpose of this sample was to assess the recovery efficiency of the aqua regia digestion and to assess laboratory reproducibility and comparability. Results are summarized in Appendix I, Table 10. Also provided in this table are data on the total fusion digestion provided by ORF. A summary of recovery efficiencies for this standard is given in Table 3.1.

Important features of these data are described here.

- Cobalt and beryllium recoveries were approximately 50% low for BML, however these elements were present in very low amounts;

TABLE 3.1

Average Recoveries Based on NBS-SRM 1648

Element	BML (%)	DRL (%)	ORF Aqua Regia (%)	Mean Recovery (%)	ORF Total Digestion (%)
Fe	81	98	81	87 ± 10	99
Al	39	39	36	38 ± 2	90
Si*	1	0.1	16	6 ± 9	-
Ca	100	88	91	93 ± 6	-
Na	47	40	73	53 ± 18	75
V	62	66	74	67 ± 6	72
Mg	74	79	77	77 ± 2	95
Ti	14	23	30	22 ± 8	92
Mn	81	104	85	90 ± 12	91
P *	105	95	98	99 ± 5	-
Ni	76	93	62	77 ± 16	65
Zn	96	95	92	94 ± 2	91
Pb	102	98	80	93 ± 12	88
Cr	18	26	28	24 ± 5	69
Cu	94	94	92	93 ± 1	103
Ba	21	35	68	41 ± 24	96
Cd	89	97	103	96 ± 7	93
Mo*	29	52	49	43 ± 12	-
Co	53	111	114	92 ± 34	111
Se	79	130	62	90 ± 35	-
Zr*	3	2	8	4 ± 3	-
Sn*	121	75	127	108 ± 28	-
As	154	113	97	121 ± 29	-
Ag	100	133	112	115 ± 17	-
Hg	-	-	-		-
Be*	47	89	100	79 ± 28	-

* Relative to total digestion performed by ORF, since no certified values are quoted.

- Fe recoveries were low for BML and ORF by approximately 19%;
- Silicon recoveries were uniformly poor however this was expected because of the digestion procedure specified;
- Magnesium recoveries were low by 26 to 21%;
- Al recoveries were low by a factor of 2.5 in the three laboratories;
- V and Ni data also demonstrated low recoveries except for DRL where a Ni recovery factor of 93% was found;
- Cr and Ti values were approximately three to four times lower than certified values;
- BML reported low recoveries on Cd by AA but acceptable results using ICAP emission spectrometry (the latter were the results reported);
- BML also reported high recoveries for As;
- BML and ORF reported low recoveries of Se;

The low recoveries on the Fe, Cu, Al, Cr and Ti were expected because these elements are usually found in non-extractable forms in particulate matter. Recovery is usually 100% efficient only by a fusion extraction method. This method would have been unsuitable for use with the glass fiber filter, however since large amounts of contaminants would have been released from the filter matrix to interfere with quantitation of elements present in low amounts. Some information on filter composition is contained in Appendix IV.

The total digestion method using HF and Na_2CO_3 fusion conducted by ORF, markedly improved recoveries for Si, Fe, Mg, Al, Mo, Cr, Ba, Ti and Zr and had a negligible effect on recoveries of other elements (Appendix I, Table 10).

On the basis of this one sample, it was not justifiable to adjust the data for the recoveries found. The reasons for this are two-fold. Firstly, this standard sample is a composite of urban particulate matter which contains a variety of matrices and particle types ranging from particles from combustion sources to particles from wind-blown dust. These do not accurately reflect the composition of one source such as the Syncrude stack. Secondly, Table 4.4 shows that data for most metallic elements from previous studies of Syncrude emissions, except for Si, are comparable with current data, indicating adjustments were not warranted.

On the whole, data were quite comparable for the three laboratories for the elements reported. Reproducibility among laboratories on extraction and analysis ranged from ± 35% for Se to ± 1% for Cu. Significant biases were evident for Se, with ORF and BML giving lower results; BML gave higher values for As and lower values for Ti, Ba and Cr.

Data for solution standards submitted as impinger solutions are presented in Appendix I, Table 11. All laboratories reported less than the detection limit for all parameters for the blank samples and therefore indicated laboratory processing procedures were free of contamination. A significant positive bias was noted for Se in sample 2 in all laboratories. The fact that all the laboratories reported higher values and that the variability for this parameter was quite high, 1.40 to 0.78 ppm, suggests the possibility of contamination of this sample. For BML, mercury was reported as 20% low and lead values were 10 to 20% low compared with expected values. Nickel data were 10 to 30% low in all the laboratories. Sodium demonstrated the highest degree of variability in the solution standards. Other elements were analyzed with a high degree of accuracy and precision, especially considering the low concentration levels in the standards.

3.2.2 Duplicates and Inter-Lab Comparisons

Duplicate filter samples, particle samples and SRM 1648 were analyzed with good reproducibility in general. Poor precision was observed for elements such as P and Si since filter background values were high and also highly variable. Fe, Cr, and Ti also showed poor within-laboratory precision, but this can generally be attributed to the aqua regia extraction method which does not reproducibly extract these elements from complex particulate matrices. BML also demonstrated a consistent pattern of under-recovery on the Test 5B duplicate sample indicating potential under-recovery of metals during extraction. Insufficient data were available to perform a detailed statistical analysis of precision of analysis within the laboratories, since only a few replicates of each type of analysis were conducted in each laboratory.

Results for each of the laboratories are presented in Appendix I, Tables 3 to 12. A summary of the analytical precision achieved for each element for each sample is given in Table 3.2. These data are derived from analysis of filter samples which were submitted to each of the laboratories and are based on four comparisons for each test. It should be pointed out that the filters were lightly loaded in spite of the extended sampling times. This was indicative of the low emission rates for particulate matter and for vapour phase metallic species. This however, resulted in very small sample sizes and therefore challenged the analytical sensitivity of the methods. Each of laboratories

TABLE 3.2

Filter Analysis
(Between Laboratory Precision [μg])

	Run 2A		Run 2B		Run 4A		Run 4B		Run 5A		Run 5B	
	$\bar{x}$	± SD	$\bar{x}$	± SD	$\bar{x}$	± SD	$\bar{x}$	± SD	$\bar{x}$	± SD	$\bar{x}$	± SD
Fe	4800	± 260	3690	± 1000	1290	± 120	1660	± 270	1070	± 200	1200	± 270
Al	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Si	-	-	-	-	-	-	-	-	-	-	-	-
Ca	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Na	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
V	400	± 27	300	± 85	114	± 17	168	± 46	106	± 19	124	± 28
Mg	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Ti	330	± 16	232	± 80	77	± 10	104	± 24	72	± 13	79	± 18
Mn	128	± 7	99	± 21	33	± 7	47	± 5.8	31	± 6.4	32	± 7.6
P	70	± 10*	95	± 38*	50	± 27*	83	± 21*	BDL	-	BDL	-
Ni	140	± 7.9	87	± 32	24	± 18	66	± 13	39	± 10	63	± 9.3
Zn	BDL	- -	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Pb	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Cr	10	± 5.5	5.8	± 3.2	3.6	± 1.2	BDL	-	BDL	-	BDL	-
Cu	3.2	± 1*	2.5	± 1*	2.5	± 1*	BDL	-	BDL	-	BDL	-
Ba	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Cd	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Mo	22	± 8*	17	± 9.4*	BDL	-	BDL	-	BDL	-	BDL	-
Co	8	± 4.7	4.2	± 1.5	BDL	-	BDL	-	BDL	-	BDL	-
Se	5.6	± 2.3	6.9	± 2.3	7.0	± 2.3	5.8	± 2.4	4.5	± 2.6	3.2	± 2.0
Zr	7.8	± 4	3.2	± 2.6	BDL	-	BDL	-	BDL	-	BDL	-
Sn	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
As	3.1	± 1	3.0	± 1.4	1.5	± .4	1.6	± 0.7	1.5	± .3	1.3	± 0.4
Ag	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Hg	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-
Be	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-	BDL	-

*Some laboratories reported results at or below the blank value. The blank value was therefore used for comparison.

identified very low concentrations on the filters for Co, Zn, Be, Cu, P, Ba, Sn, Cd, Pb, Ag and Hg. High and variable background values were observed on the filters for Si, Al, Ca, Mg and Na. The reproducibility (Table 3.2) for other selected elements ranged from:

- ±6 to ±21 μg for a mean quantity of 62 μg for manganese;
- ±120 to ±1000 μg for a mean quantity of 2285 μg for iron;
- ±17 to ±85 μg for a mean quantity of 202 μg for vanadium;
- ±7.9 to ±32 for a mean quantity of 70 μg for nickel;
- ±10 to ±80 for a mean quantity of 110 μg for titanium;
- ±.3 to ±1 for a mean quantity of 2 μg for arsenic and
- ±2 to ±2.4 for a mean quantity of 5.5 μg for selenium.

Results of impingers were uniformly low and also near the detection limits of the analytical methods; the agreement among the laboratories was quite consistent. Comparison of results for soil samples, coke dust and electrostatic precipitator (ESP) hoppers was also performed. These data are outlined in Appendix I, Table 12. Poor comparisons were particularly evident for Si and Na. For other elements, the precision of analysis was similar to other reported data.

ESP hopper samples are also compared with results of the cyclone catch analyses. The profile of elements for the two types of samples is significantly different. In particular Si, Mn, Cu, Na, Ti and Zr are enriched in the cyclone samples suggesting that these elements are found in higher concentrations on the fine particulate matter, i.e., the material emitted from the stack rather than on the coarser material removed efficiently by the ESP's.

3.2.3 Inter-Sample Comparisons

For most elements, the elemental composition was similar between samples. Most elements were present at very low levels, or near the detection limits of the analytical methods. Particle catches varied from day to day and sample to sample, having a mean value of 530 ± 110 mg when the same type of sampling train is compared, i.e. Trains A and B (Appendix I, Table 1).

One sampling anomaly detected was the consistent enhancement of concentrations of Ni in Train B particle probe catches but not on the corresponding filter. The sampling probe was re-checked for possible cracks or other problems, but nothing was found. Additional washes of the probe Teflon liners with water and aqua regia were analyzed; however, no Ni or contamination from other metals was detected. Proofing solutions obtained prior to the sampling programme indicated very low levels of concentrations of metals in the probes. However, proofing solutions obtained from washes prior to sampling for Tests IV and V showed enhanced Ni levels. Analytical contamination has been ruled out since samples were analyzed in one batch. One possible source of this contamination could result from taking apart of the probes after each test. This could have dislodged metal from the Train B probe fittings, resulting in Ni contamination from stainless steel particles.

Since data for Train B was significantly higher for Ba, Cu, Cr, Cd and Pb, these data only were used to calculate emissions for these elements. The Ni data from the Flow Sensor, Train A and from the ESP hoppers form a consistent set. Data from Train B for Ni is significantly different and inconsistent with other components of this set. As a result, only Train A data was used to calculate emission rates for this parameter.

3.3 Emission Rates

The total emission of particlate matter (35 ± 7 g/s) and emission rates for each parameter were calculated on the basis of the mean values of six measurements obtained for each of three test days. For the data flagged by an asterisk in Table 3.1, the Train B results only were averaged, since these were consistently higher, and therefore provide more conservative (i.e., positively biased) estimates for these metals. Train A data only were used for Ni for reasons outlined above.

The sampling information was obtained from instruments calibrated before and after the execution of the sampling program. Total stack gas emissions estimates were also based on accurate measurements of the stack diameter, velocity and composition.

Emissions for all elements except for Fe, Al, Mg, Ca, Si were very low. In general, the emission rates for other elements e.g., Be, Cr, As, and Hg were less than 1.0 mg/s (0.09 kg/day), except for Se, Cd and Pb which were 1.1, 1.6 and 3.8 mg/s, respectively. The factors contributing to the emission rate and the variability in this rate are the variability in the composition of the raw materials used in the process, variations in the process controls including emission control devices such as the electrostatic precipitators. The estimation of the accurate emission rates includes these sources of variation in addition to the the variation contributed by the measurement process, i.e., the sampling, extraction and analytical protocols. The emission rates determined are quoted in Table 3.3 along with an estimate of precision (Std. Dev.) of these data. An additional source of variation which is more difficult to assess in the context of this study is the representativeness of these emission estimates for process operations when upset conditions exist or other non-routine events occur. The three sets of tests described by these emission data were obtained under compliance test conditions and therefore will not reflect the latter operating conditions. The overall variation (where the variation includes the contributions of the measurement variables) in the estimates for the emission rates ranges from ± 122% (one standard deviation) for Mg to ± 22% (one standard deviation) for Al. The combined effects of low particulate matter emission rates and low concentration of these elements in the particles on concentration and deposition in the environs of the Mildred Lake Plant are discussed in the following section on modelling.

TABLE 3.3

Metal Emission Rates
µg/s

Element	Flow Sensor Run 2	Run 2A	Run 2B	Flow Sensor Run 4	Run 4A	Run 4B	Flow Sensor Run 5	Run 5A	Run 5B	Mean	Std. Dev.	Mean (kg/day)	Std. Dev. (kg/day)
Particle													
Total (g/s)	(18.1)	40.6	33.3	(13.5)	42.5	40.7	(17.5)	24.1	30.9	35.4	7.2	3060	622
Fe	290,000	489,000	580,000	151,000	219,000	260,000	342,000	160,000	197,000	318,000	174,000	27	15
Al	182,000	114,000	150,000	130,000	126,000	105,000	169,000	71,400	111,000	112,900	25,800	9.8	2.2
Si	225,000	95,400	231,000	137,000	74,000	87,400	166,000	55,700	110,000	109,000	62,600	9.4	5.4
Ca	32,100	26,600	279,000	28,400	30,900	95,400	31,400	12,200	79,700	87,300	99,400	7.5	8.6
Na	380,000	29,200	57,300	270,000	121,000	28,900	241,000	30,600	25,900	48,800	37,200	4.2	3.2
V	27,500	44,800	48,400	18,600	25,200	33,000	22,400	18,300	24,200	32,300	12,100	2.8	1.0
Mg	13,800	9,700	48,700	10,500	100,000	11,400	12,700	5,030	9,500	30,700	37,500	2.6	3.2
Ti	39,800	39,500	58,000	23,000	23,400	9,410	26,000	16,300	22,100	28,100	17,700	2.4	1.5
Mn	11,600	15,400	23,200	8,900	7,060	7,660	53,700	4,350	5,240	10,500	7,400	0.90	0.64
P	3,340	6,290	15,100	1,800	3,560	19,600	2,200	1,090	12,800	9,740	7,200	0.84	0.62
Ni**	11,700	15,600	208,000	7,800	7,500	292,000	35,000	4,900	190,000	9,300	5,600	0.8	0.5
Zn	1,640	3,110	14,500	2,600	2,560	2,550	2,000	1,220	1,630	4,260	5,060	0.40	0.40
Pb*	390	390	6,400	<170	390	2,220	690	200	2,590	3,750	2,310	0.32	0.20
Cr*	2,400	840	8,200	2,400	600	1,340	38,200	540	880	3,500	4,100	0.3	0.35
Cu*	2,100	390	2,100	1,000	400	2,080	4,600	270	1,090	1,760	580	0.15	0.05
Ba	1,230	400	1,510	830	870	2,020	1,000	750	3,680	1,540	1,200	0.13	0.10
Cd*	<60	40	1,910	<60	30	1,610	<140	<60	1,020	1,510	450	0.13	0.04
Mo	2,100	910	1,970	2,211	940	940	1,500	610	820	1,030	480	0.09	0.04
Co	1,000	520	1,700	660	400	600	1,300	200	480	650	540	0.06	0.05
Se	180	550	660	140	690	740	100	660	120	570	230	0.05	0.02
Zr	1,150	1,300	790	760	460	310	1,500	200	350	570	410	0.05	0.04
Sn	390	190	460	540	270	270	530	200	340	290	100	0.02	0.009
As	180	240	320	170	190	260	140	170	180	230	58	0.02	0.005
Ag	300	40	<70	<200	40	<40	<200	<40	90	28	35	0.002	0.003
Hg	9	10	7	4	30	30	3	10	8	20	10	0.002	0.001
Be	<60	10	30	<100	<6	<6	<70	<6	<6	6	11	0.0005	0.0009
Vapour													
Se	-	630	-	-	500	-	-	440	-	520	97	0.045	0.008
Pb	-	-	<60	-	-	<60	-	-	<60	<60	0	<0.005	0.000
Cd	-	-	20	-	-	10	-	-	110	50	56	0.004	0.005
Hg	-	20	-	-	10	-	-	20	-	20	6	0.002	0.0005
As	-	20	-	-	<5	-	-	<5	-	6	11	0.0005	0.001
Total													
Pb	-	-	6,460	-	-	2,280	-	-	2,650	3,800	2,310	0.330	0.200
Cd	-	-	1,930	-	-	1,620	-	-	1,130	1,560	400	0.13	0.03
Se	-	1,180	-	-	1,190	-	-	1,100	-	1,160	49	0.10	0.004
As	-	260	-	-	190	-	-	170	-	210	47	0.02	0.004
Hg	-	30	-	-	40	-	-	30	-	40	6	0.003	0.0006

* Run 2B, 4B and 5B values only were used to calculate mean emission rates.
** Run 2A, 4A and 5A values only were used to calculate emission rates

3.4 Modelling Results

All modelling results describing the annual mean concentration and flux estimates based on unit emission rates are tabulated in Appendix I, Tables 14 to 21. The tables contain the concentration or flux values at specified distances downwind of the stack in each of nine sectors. For each climatological station (Edmonton or Fort Smith) there are four tables which tabulate the flux or concentration data for each of two particle sizes (0.1 µm or 10 µm).

The vapour phase species (Pb, Se Cd, As and Hg) may be treated as being similar to 0.1 µm particles since the deposition velocities are expected to be similar (see section 2.4).

These data are illustrated in twelve contour plots. There are four basic types of plots, namely concentration contours and flux contours for each of the two particle sizes. The contour plots extend to ~100 km from the stack. These four types of plots are provided for each of the two stations used as a source of climatological data. In order to illustrate the behaviour of the flux contours close to the stack, additional plots with contours up to ~25 km from the stack were prepared. Consequently a total of twelve plots are provided. Figures 6 to 9 in Appendix I, show the concentration contours while Figures 10 to 13 show the flux contours. In all cases, unit emission rates have been assumed.

The major features of the concentration and flux data are discussed in the following two subsections. These features include:

a) The influence of the selection of the climatological station on the model results.
b) The distance from the stack at which maximum concentrations or fluxes occur.
c) The downwind directions where the greatest impacts occur.
d) The effect of particle size.
e) The most cautious estimates of potential impact of plant emissions.

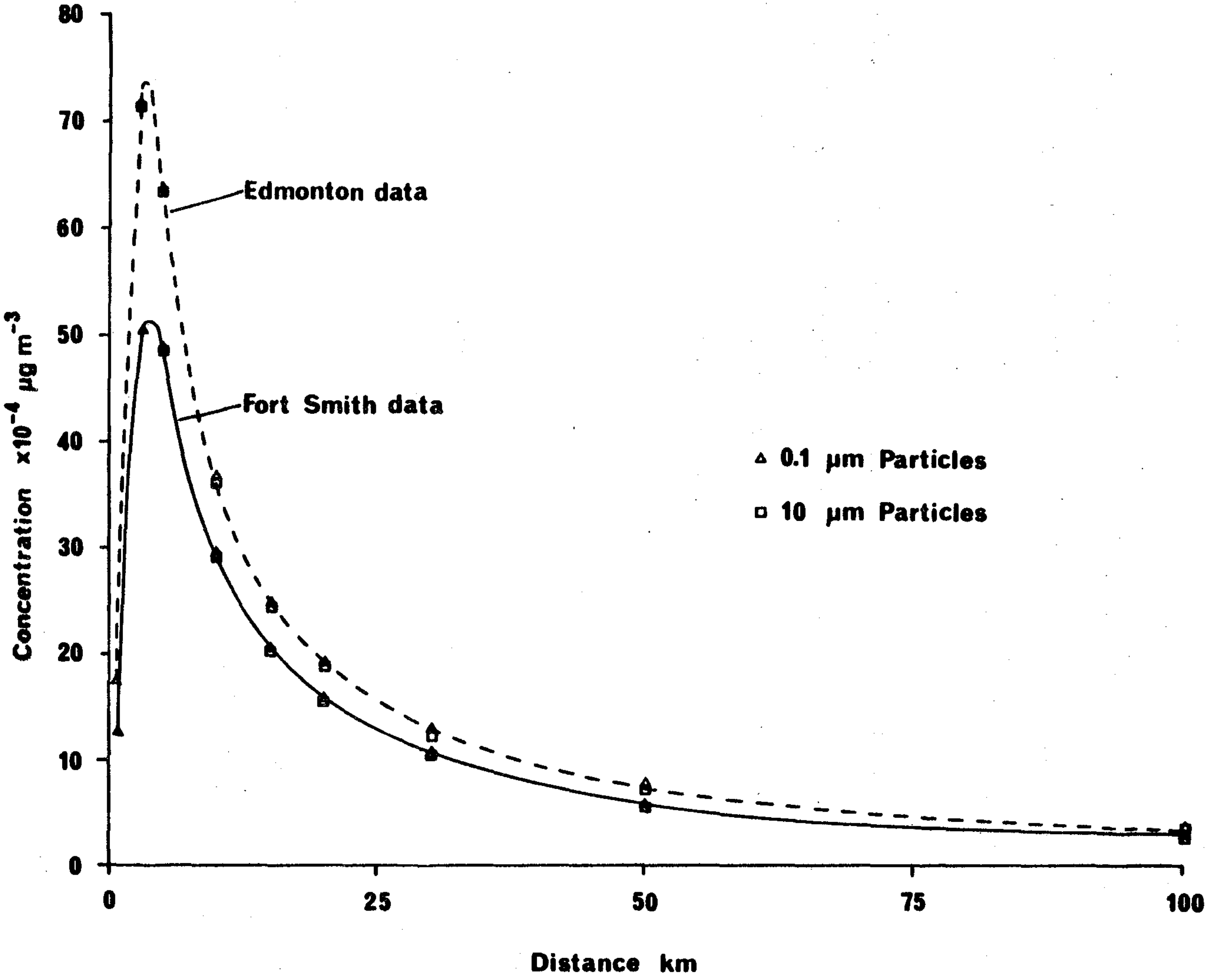
General features of modelling results

The effect of the selection of Fort Smith or Edmonton as the site for which climatological data are used can be determined from examination of the concentrations independent of wind direction sector, and also by examining the sector with the highest concentrations and fluxes.

Figure 3.1 shows the sector-independent concentrations as a function of downwind distance, when climatological data for Edmonton and Fort Smith are used for modelling the dispersion from the Syncrude stack. These sector-independent concentrations correspond to the hypothetical case in which the wind direction is constant, i.e., the

Figure 3.1

Variation of Sector Independent Concentrations for 0.1 μm and 10 μm Particles as a Function of Downwind Distance



wind blows from only one sector all the time. The plot shows that the use of the Edmonton data results in higher concentrations at all distances. In Figure 3.1, the concentrations for the 0.1 and 10 µm particles are similar (but not identical). The spacing of the downwind distances at which the concentrations were calculated did not allow precise determination of the distance at which the maximum concentrations of the two sizes of particles occur.

Figure 3.2 shows modelling results for the sector (105-145°) with the highest concentration and flux for 0.1 µm particles. This sector lies to the southeast of the Syncrude stack. Again the higher values result when the Edmonton data are used.

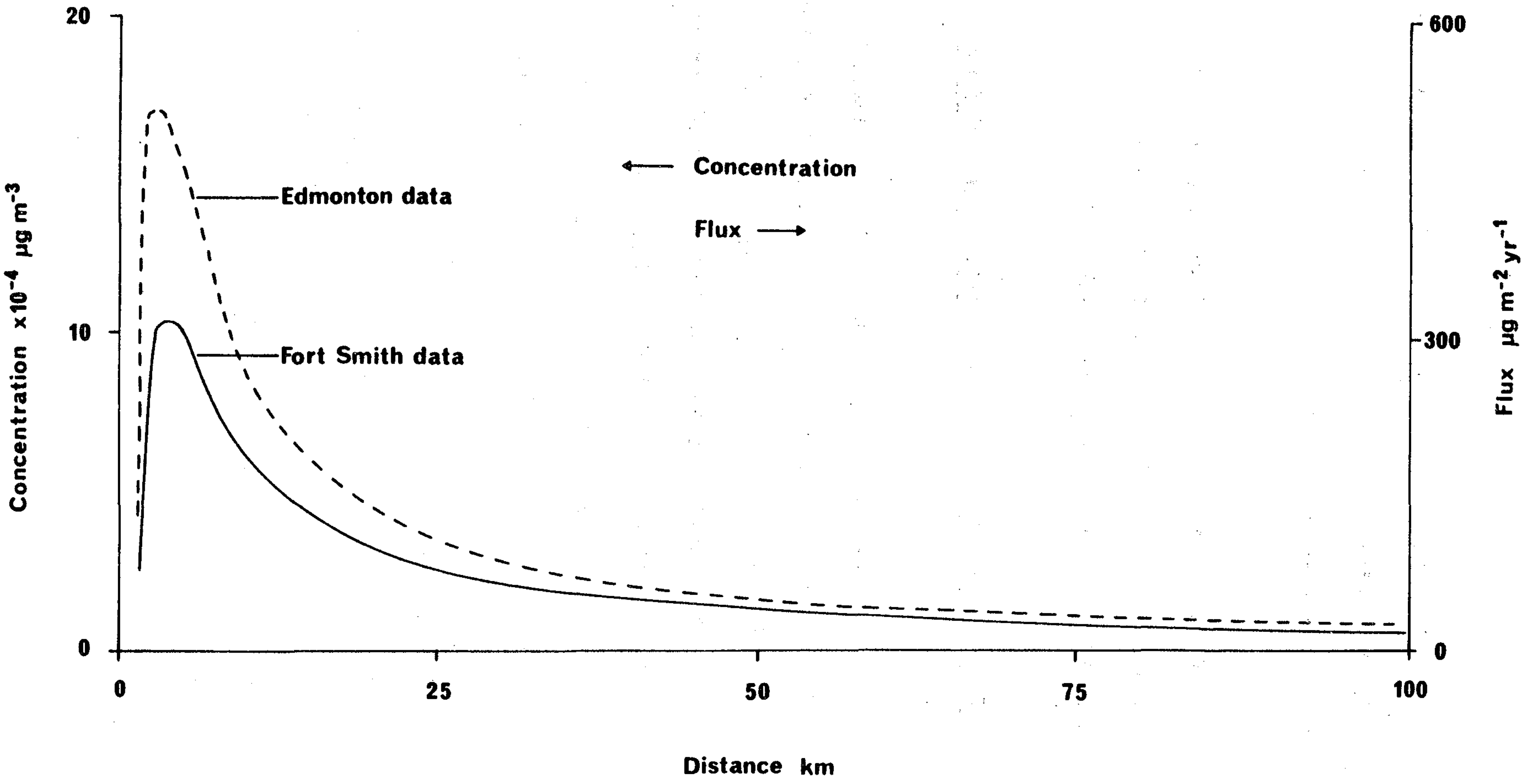
In view of this, the model predictions obtained through use of Edmonton climatological data should be emphasized to avoid underestimating impact, since they will yield the greater estimates of concentrations and fluxes.

Figures 3.1 and 3.2 also show that the highest concentrations occur between 3 and 5 km from the stack.

In general, similar directional dispersion patterns of the dispersion from the Syncrude stack are shown regardless of the climatological data set used (viz., Fort Smith or Edmonton). This pattern shows that:

Figure 3.2

Variation of the Concentrations and Fluxes of 0.1 μm Particles with Distance for the Sector (105-145°) with the Highest Concentrations and Flux



a) The sector lying between 105 and 145° and the adjacent sectors (approximately south east of the Syncrude stack) has the highest concentrations and fluxes.

b) The direction with the second highest concentration and flux levels occurs in the sector between 305-345° and adjacent sectors or approximately northwest of the Syncrude stack.

Effects of particle size on concentration and flux.

The smaller particles, which have the lower deposition velocities, have concentrations that are slightly higher than those for the larger particles in the study area, especially at downwind distances of 5 km or more. At increasingly greater distances, the difference between the modelled concentrations for the 0.10 µm and 10 µm particles increases. This is to be expected since the heavier particles are deposited more rapidly and are depleted from the plume to a greater extent.

In the case of the flux, the 10 µm diameter particles have the higher flux. The difference in the deposition velocities of the 0.1 and 10 µm particles result in a flux for 10 µm particles of about twice the magnitude of the flux for 0.1 µm particles.

3.4.1 Concentrations of Total Particulate Matter and Metals

In the following discussion, the modelling results which reflect the higher estimates of concentration and flux are used to illustrate the total suspended particulate concentration and the concentrations of specific elements. Since the use of data characteristic of 0.10 μm particles yields the higher estimates for the concentration of particulate matter, these data are used. The mean total stack emission rate measured in the field sampling program was 35.4 g s^{-1}. The maximum concentration of total particulate matter (assuming 0.1 μm particles) is about 0.06 μg m^{-3} at a distance of 3-5 km in the sector lying between 105 and 145° (southeast of the plant).

The total emission rates for elements were presented in Table 3.3. The emission rates result in the highest concentrations in the sector 105-145° ranging from 540 pg m^{-3} for iron to 0.010 pg m^{-3} for Be.

The concentration contour plots for each element are illustrated in Figures 3.3 and 3.4 in conjunction with Table 3.4. The concentration contour plots are generically labelled and refer to model results for 0.1 μm particles using climatological data from Edmonton,

Figure 3.3

Generic Concentration Contour Plot for 0.1 μm Particles
Edmonton Climatological Data

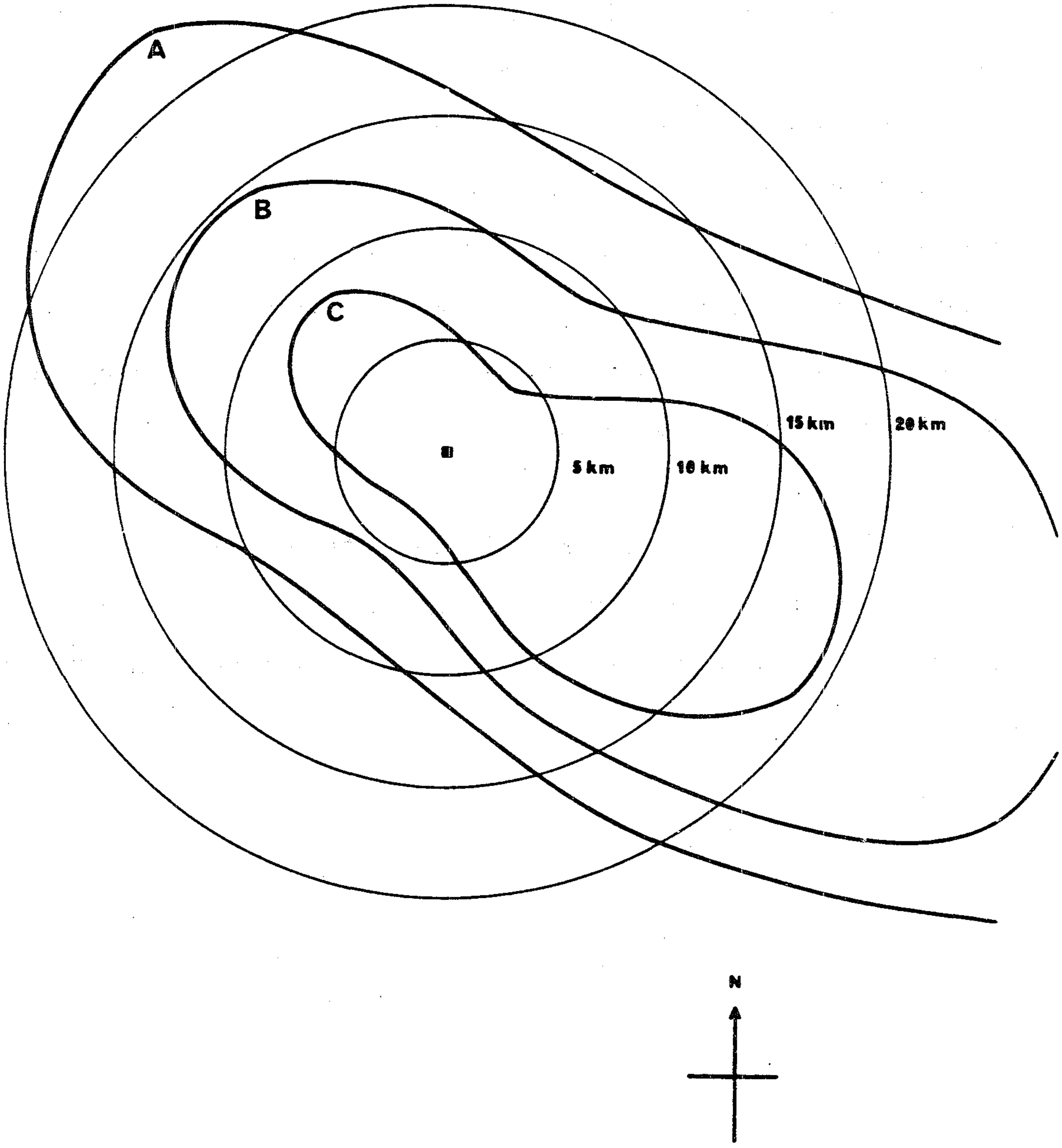


Figure 3.4

Generic Concentration Contour Plot for The Dispersion of 0.1 μm Particles

Fort Smith Climatological Data

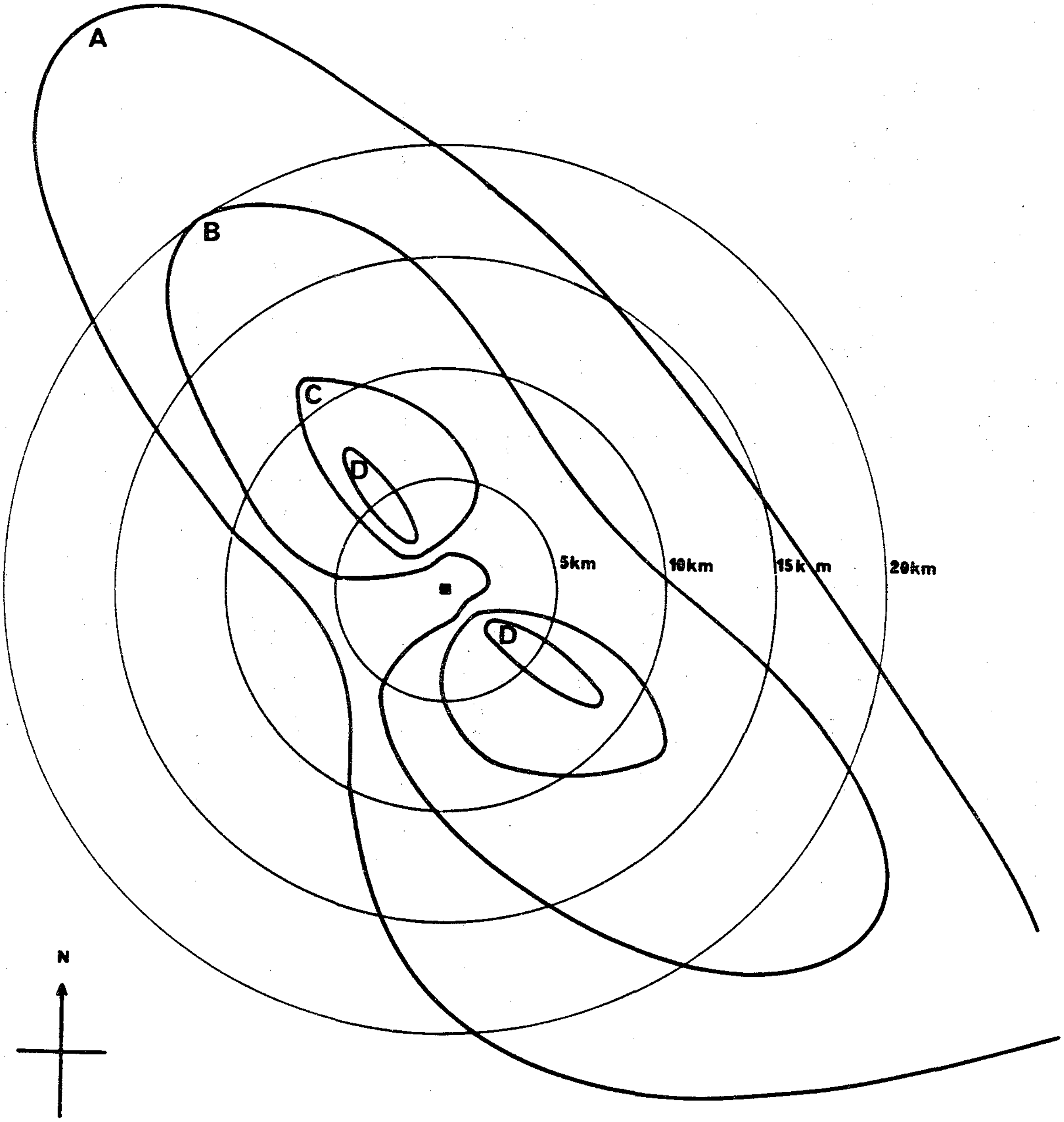


TABLE 3.4

Key to Concentration Contour Plots

Emission Rate $\mu g\ s^{-1}$		Value for Contour Label in pg m^{-3}			
		A	B	C	D
X1*	1‡	200	300	500	700
X2**	35.4‡	7,080	10,620	17,700	24,700
Fe	318,000	63.6	95.4	159	223
Al	112,900	22.6	33.9	56.4	79.0
Si	109,000	21.80	32.7	54.5	76.3
Ca	87,300	17.5	26.2	43.6	61.1
Na	48,800	9.76	14.6	24.4	34.2
V	32,300	6.46	9.69	16.2	22.6
Mg	30,700	6.14	9.21	15.4	21.5
Ti	28,100	5.62	8.43	14.0	19.7
Mn	10,500	2.10	3.15	5.25	7.35
P	9,740	1.95	2.92	4.87	6.82
Ni	9,300	1.86	2.79	4.65	6.51
Zn	4,260	0.85	1.28	2.13	2.98
Pb	3,750	0.75	1.13	1.88	2.63
Cr	3,500	0.70	1.05	1.75	2.45
Cu	1,760	0.35	0.53	0.88	1.23
Ba	1,540	0.31	0.46	0.77	1.08
Cd	1,510	0.30	0.45	0.76	1.06
Mo	1,030	0.21	0.31	0.52	0.72
Co	650	0.13	0.20	0.32	0.46
Se	570	0.11	0.17	0.28	0.40
Zr	570	0.11	0.17	0.28	0.40
Sn	290	0.06	0.09	0.14	0.20
As	230	0.05	0.07	0.12	0.16
Ag	28	0.006	0.01	0.01	0.02
Hg	20	0.004	0.006	0.010	0.014
Be	6	0.001	0.002	0.003	0.0042
Vapour					
Se	520	0.104	0.156	0.260	0.364
Pb	<60	<0.01	<0.02	<0.03	<0.04
Cd	50	0.01	0.02	0.02	0.04
Hg	20	0.004	0.006	0.010	0.014
As	6	0.001	0.0018	0.0030	0.0042
Total					
Pb	3,800	0.76	1.14	1.90	2.66
Cd	1,560	0.31	0.47	0.78	1.09
Se	1,160	0.232	0.348	0.580	0.812
As	210	0.042	0.063	0.105	0.147
Hg	40	0.008	0.012	0.020	0.028

* Unit emission rate

** Total particle emission rate

‡ Units of g s^{-1}

(Figure 3.3) and Fort Smith (Figure 3.4). These figures must be used in conjunction with Table 3.4 which shows the numerical values of concentrations which are applicable to the contours.

Barrie (1980) reported ambient concentrations of several elements in the vicinity of an oil sands plant. The measured concentrations included contributions from anthropogenic (the GCOS main stack), wind blown, and background sources. Sulphur and vanadium were the only elements considered to be primarily anthropogenic in origin. Vanadium concentrations measured some 10 km from the source were 110 ng m^{-3}. After correction for background and windblown dust contributions, the anthropogenic component (80%) contributed about 80 ng m^{-3} of vanadium. The vanadium emission rate was 7.8 g s^{-1}(27 tonne/day particulates with 2.5% vanadium content) and is 240 times greater than that of the Syncrude stack reported in this study (see Table 3.4). The model estimate from the current study for the sector with the highest annual mean vanadium concentration is 0.02 ng m^{-3} based on measured vanadium stack emission rates, corresonding to 0.5 ng m^{-3} based on a unit emission rate for vanadium. For a stack emission rate of 7.8 g s^{-1} of vanadium, the model estimate for the sector with the highest annual mean concentration would therefore be 4.7 ng m^{-3}, some 17 times lower than that measured by Barrie. It should be noted, however, that there are differences in stack parameters and that Barrie's measurements refer to an averaging time of three days (June 19-22, 1977) and took place at periods during which the monitoring site was known to be downwind of the source. An averaging time of one year may be expected to be about four times lower than that for three days (Stern, 1968), so the values reported by Barrie are of the same order of magnitude as those predicted by the model.

3.4.2 Fluxes of Total Particulate Matter and Metals

The most conservative modelling results (i.e., biased toward over-predicting) for fluxes are obtained by considering 10 μm particles. The maximum flux of total particulate matter would therefore be about 3.5×10^4 μg m^{-2} yr^{-1} at 3-5 km from the stack in the sector lying between 105 and 145°.

The fluxes for total particulate matter and for individual elements are summarised in Figures 3.5A to 3.6B and in Tables 3.5 and 3.6. The contour plots for the fluxes refer to 10 μm particles. These plots are also generically labelled with the information in Figures 3.5A and 3.5B referring respectively, to model estimates of the dispersion up to 20 and 100 km from the Syncrude stack derived using Edmonton climatological data. Similarly, Figures 3.6A and 3.6B refer to Fort Smith climatological data. In conjunction with these plots, Tables 3.5 and 3.6 respectively show the numerical values to be attached to the contours for both total particulate matter and for individual metals.

Figure 3.5A

Generic Flux Contour Plot for the Deposition of 10 μm Particles (0-20 km) Edmonton Climatological Data

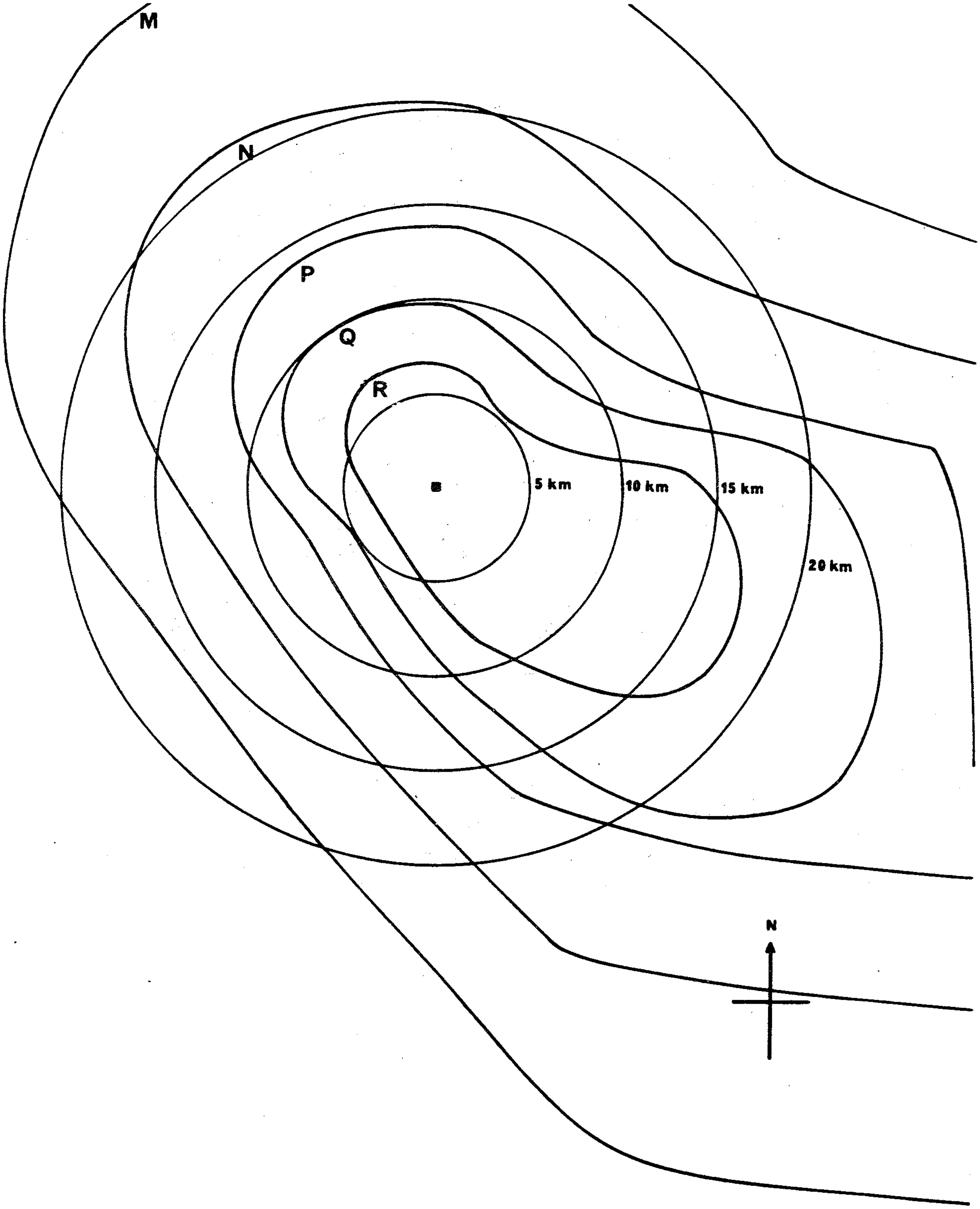


Figure 3.5B

<u>Generic Flux Contour Plot for the Deposition of 10 µm Particles (0-100 km)</u>
<u>Edmonton Climatological Data</u>

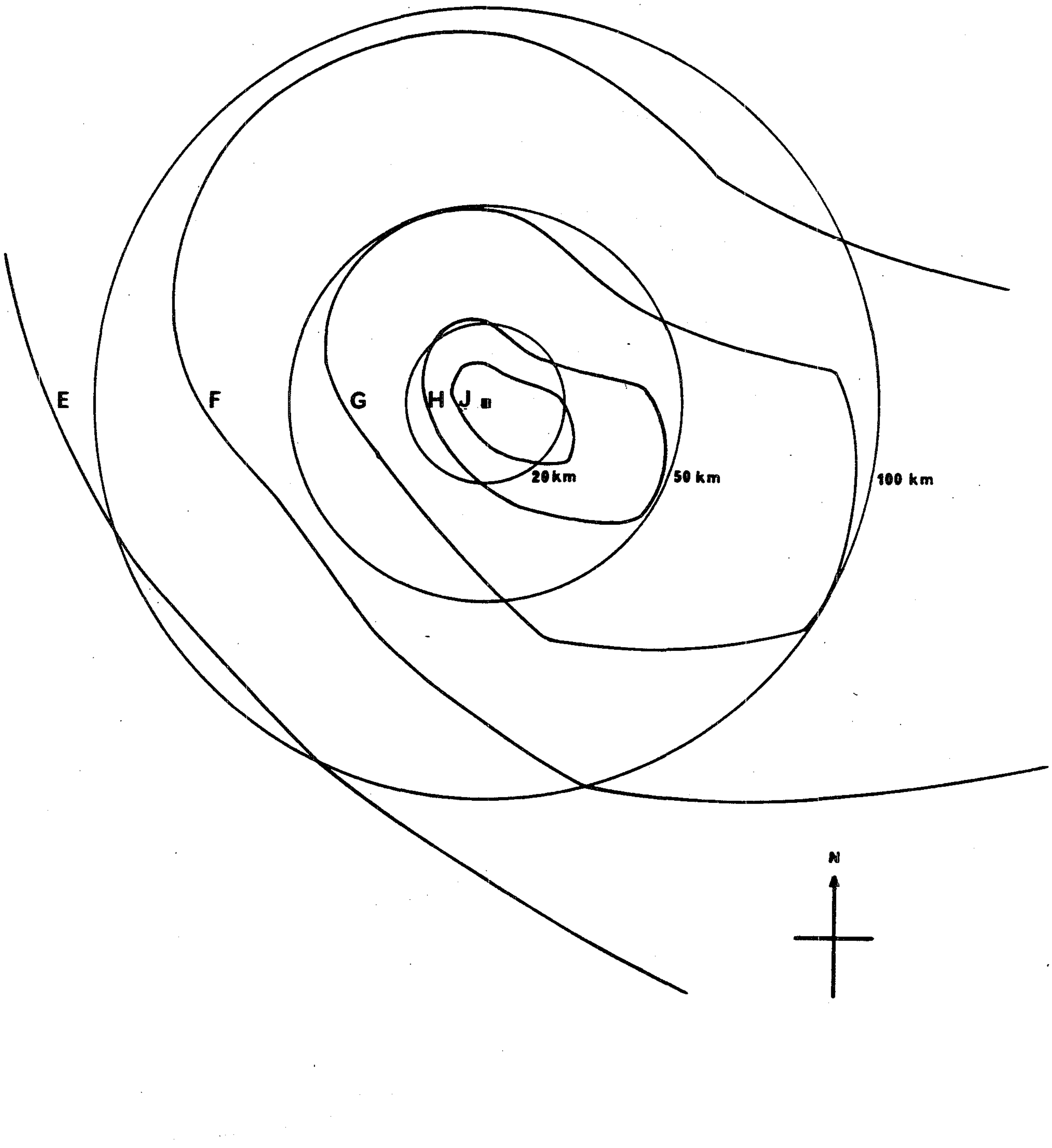


Figure 3.6A

Generic Flux Contour Plot for the Deposition of 10 μm Particles (0-20 km)
Fort Smith Climatological Data

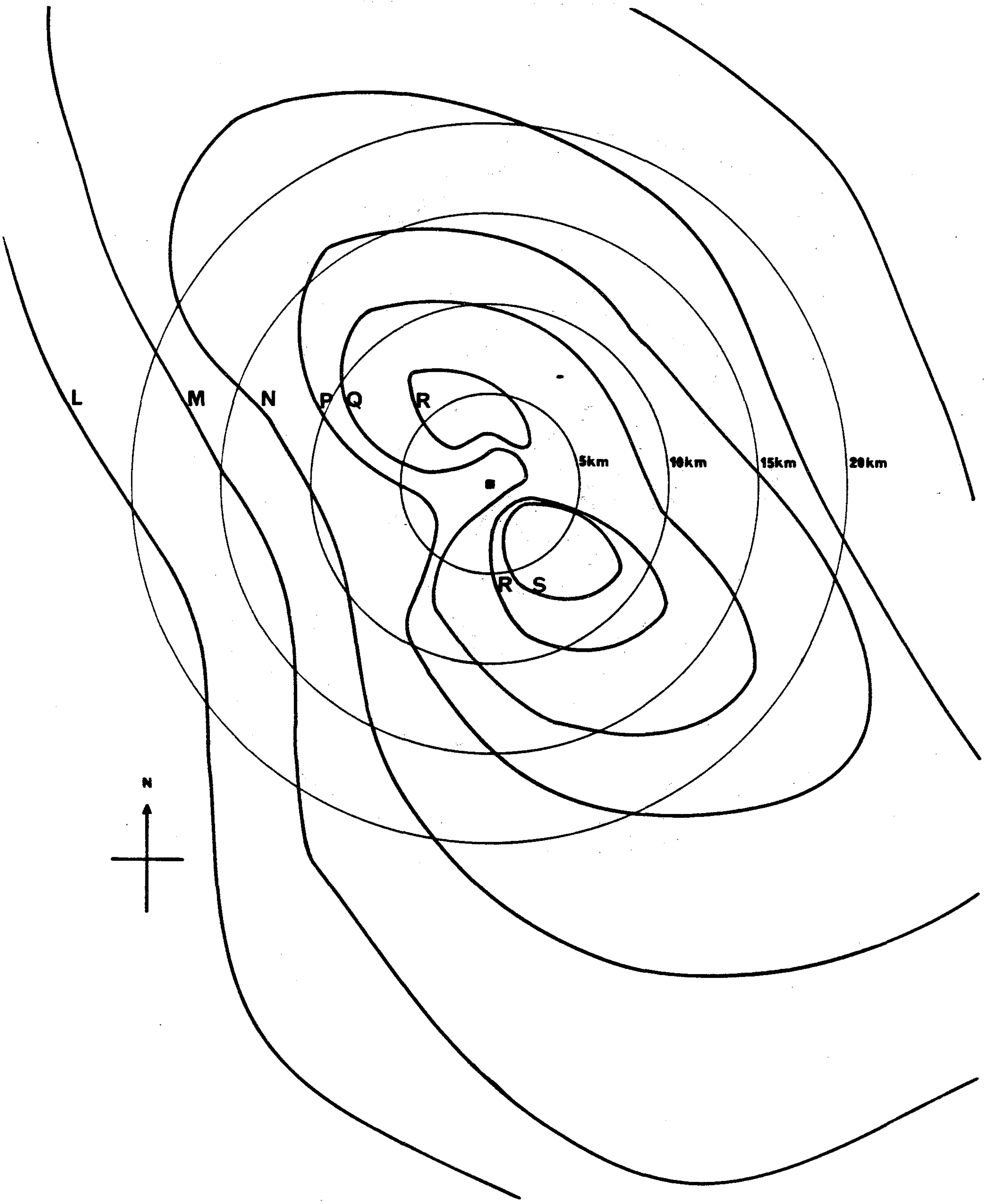


Figure 3.6B

Generic Flux Contour Plot for the Deposition of 10 μm Particles (0-100 km) Fort Smith Climatological Data

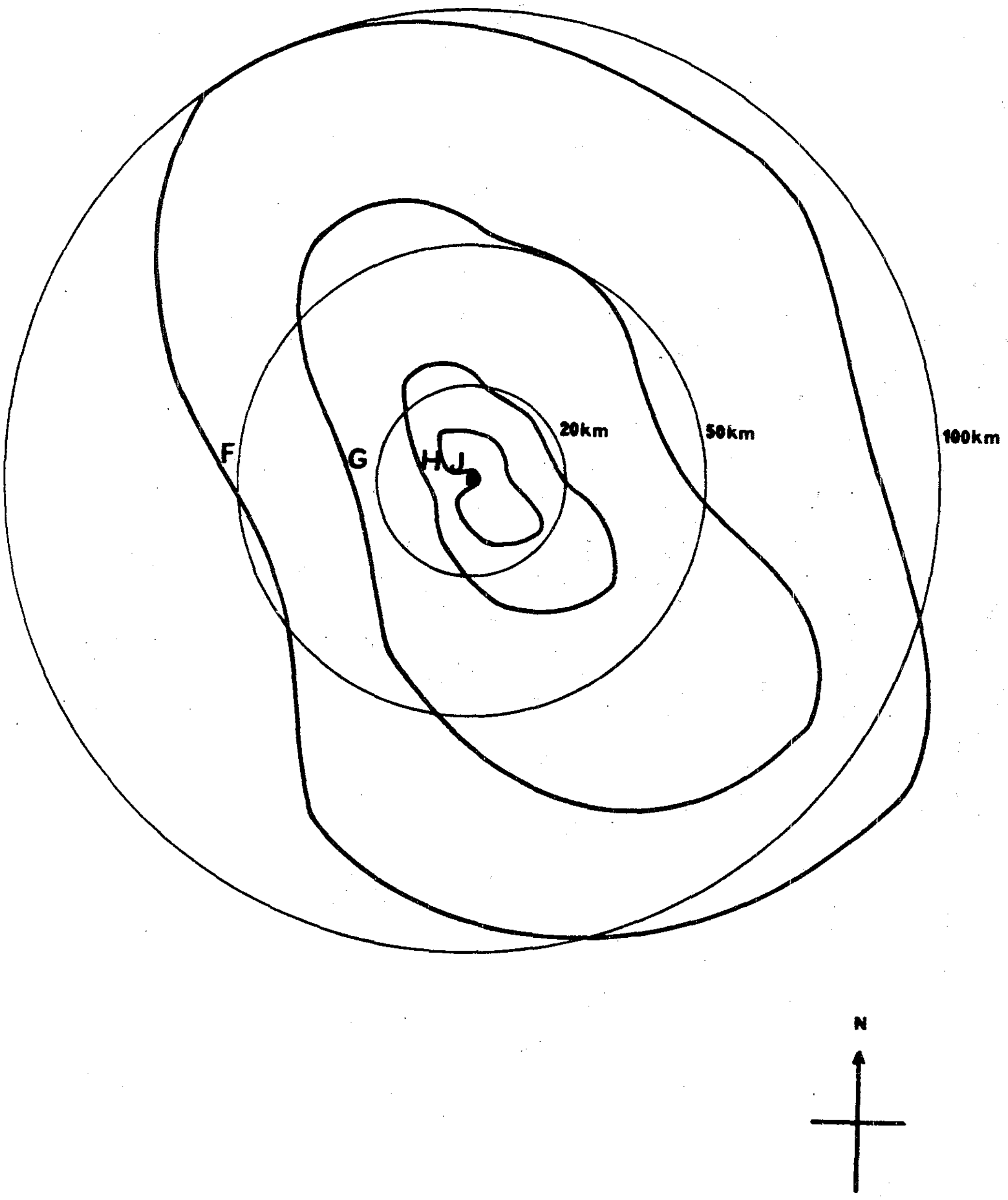


TABLE 3.5

Key to Flux Contour Plots (0-100 km)

Emission Rate µg s^{-1}		Value for Flux Contours Label in ng m^{-2} yr^{-1}				
		E	F	G	H	J
X1*	1‡	10,000	20,000	40,000	100,000	200,000
X2**	35.4‡	354,000	708,000	1,420,000	3,540,000	7,080,000
Fe	318,000	3,180	6,360	12,700	31,800	63,600
Al	112,900	1,130	2,258	4,520	11,300	22,600
Si	109,000	1,090	2,180	4,360	10,900	21,800
Ca	87,300	873	1,750	3,492	8,730	17,500
Na	48,800	488	976	1,952	4,880	9,760
V	32,300	323	646	1,292	3,230	6,460
Mg	30,700	307	614	1,230	3,070	6,140
Ti	28,100	281	562	1,120	2,810	5,620
Mn	10,500	105	210	420	1,050	2,100
P	9,740	97.4	195	390	974	1,950
Ni	9,300	93	186	372	930	1,860
Zn	4,260	42.6	85.2	170	426	852
Pb	3,750	37.5	75.0	150	375	750
Cr	3,500	35.0	70.0	140	350	700
Cu	1,760	17.6	35.2	70.4	176	352
Ba	1,540	15.4	30.8	61.6	154	308
Cd	1,510	15.1	30.2	60.4	151	302
Mo	1,030	10.3	20.6	41.2	103	206
Co	650	6.5	13.0	26.0	65.0	130
Se	570	5.7	11.4	22.8	57.0	114
Zr	570	5.7	11.4	22.8	57.0	114
Sn	290	2.9	5.8	11.6	29.0	58.0
As	230	2.0	4.6	9.2	23.0	46.0
Ag	28	0.28	0.56	1.12	2.8	5.6
Hg	20	0.20	0.40	0.80	2.0	4.0
Be	6	0.06	0.12	0.24	0.6	1.2
Vapour						
Se	520	5.2	10.4	20.8	52.0	104
Pb	<60	<0.6	<0.60	<2.4	<6.0	<12.0
Cd	50	0.50	1.0	2.0	5.0	10
Hg	20	0.20	0.40	0.80	2.0	4.0
As	6	0.06	0.12	0.24	0.60	1.2
Total						
Pb	3,800	38	76	152	380	760
Cd	1,560	15.6	31.2	62.4	156	312
Se	1,160	11.6	23.2	46.4	116	232
As	210	2.1	4.2	8.4	21	42
Hg	40	0.4	0.8	1.6	4.0	8.0

* Unit emission rate
** Total particle emission rate
‡ Units of g s^{-1}

TABLE 3.6

Key to Flux Contour Plots (0-20 km)

Emission Rate $\mu g\ s^{-1}$		Value for Flux Label in ng m^{-2} yr^{-1}						
		L	M	N	P	Q	R	S
X1*	1‡	50,000	70,000	100,000	150,000	200,000	300,000	400,000
X2**	35.4‡	1,770,000	2,480,000	3,540,000	5,310,000	7,080,000	10,620,000	14,160,000
Fe	318,000	15,900	22,260	31,800	47,700	63,600	95,400	127,000
Al	112,900	5,650	7,900	11,300	16,900	22,600	33,900	45,200
Si	109,000	5,450	7,630	10,900	16,340	21,800	32,700	43,600
Ca	87,300	4,370	6,110	8,730	13,100	17,500	26,200	34,900
Na	48,800	2,440	3,420	4,880	7,320	9,760	14,600	19,500
V	32,300	1,620	2,260	3,230	4,850	6,460	9,690	12,900
Mg	30,700	1,540	2,150	3,070	4,610	6,140	9,210	12,300
Ti	28,100	1,410	1,970	2,810	4,220	5,620	8,430	11,200
Mn	10,500	525	735	1,050	1,580	2,100	3,150	4,200
P	9,740	487	682	974	1,460	1,950	2,920	3,900
Ni	9,300	465	651	930	1,400	1,860	2,790	3,720
Zn	4,260	213	298	426	639	852	1,280	1,700
Pb	3,750	188	263	375	562	750	1,130	1,500
Cr	3,500	175	245	350	525	700	1,050	1,400
Cu	1,760	88	123	176	264	352	528	704
Ba	1,540	77.0	108	154	231	308	462	616
Cd	1,510	75.5	106	151	226	302	453	604
Mo	1,030	51.5	72.1	103	154	206	309	412
Co	650	32.5	45.5	65.0	97.5	130	195	260
Se	570	28.5	39.9	57.0	85.5	114	171	228
Zr	570	28.5	39.9	57.0	85.5	114	171	228
Sn	290	14.5	20.3	29.0	43.5	58.0	87.0	116
As	230	11.5	16.1	23.0	34.5	46.0	69.0	92.0
Ag	28	1.4	2.0	2.8	4.2	5.6	8.4	11.2
Hg	20	1.0	1.4	2.0	3.0	4.0	6.0	8.0
Be	6	0.3	0.4	0.6	0.9	1.2	1.8	2.4
Vapour								
Se	520	26.0	36.4	52.0	78.0	104	156	208
Pb	<60	<3.0	<4.2	<6.0	<9.0	<12	<18	<24
Cd	50	2.5	3.5	5.0	7.5	10	15	20
Hg	20	1.0	1.4	2.0	3.0	4.0	6.0	8.0
As	6	0.3	0.4	0.6	0.9	1.2	1.8	2.4
Total								
Pb	3,800	190	266	380	570	760	1,140	1,520
Cd	1,560	78	109	156	234	312	468	624
Se	1,160	58	81	116	174	232	348	464
As	210	10.5	14.7	21.0	31.5	42.0	63.0	84.0
Hg	40	2.0	2.8	4.0	6.0	8.0	12.0	16.0

* Unit emission rate

** Total particle emission rate

‡ Units of g s^{-1}

As indicated previously, the model only considers dry deposition. Previous studies at a tar sands plant (Barrie, 1980; Fanaki et al., 1979) suggest that wet deposition may be important in removing particulates especially in winter. An upper estimate of the total (wet and dry) deposition from the Syncrude stack may be obtained in a scenario in which all the stack emissions are deposited in only two sectors within 25 km from the stack. The sectors to the southeast (105-145°) and northwest (305-345°) receive fluxes in approximately 2.4:1 ratio (see for example, Table 19, Appendix I). If all particulate emissions were deposited in these sectors in this ratio, and within 25 km, the fluxes would be 45 mg m^{-2} yr^{-1} in the southeast sector and 19 mg m^{-2} yr^{-1} in the northwest. This represents the maximum amount of deposition attributable to the Syncrude stack.

4. DISCUSSION

This chapter is intended to place the results of the study in context with respect to the overall confidence that can be placed in the representativeness of the data and with respect to the comparability of results from this study with data from other relevant studies and surveys.

That is, the following sections address the question of whether the sampling and modelling results reported here are reasonable and meaningful in light of what is currently known about air quality impacts of industrial emission , especially in the Tar Sands area.

4.1 Representativeness of Results

The process parameters related to particulate emission from the main stack showed little variability during each of the three days of valid tests (see Appendix III - Process Information). These control parameters varied by at most a few percent during the course of a day and from day to day. The monitoring parameter most directly related to the measurements of stack gas particle loading, the stack opacity reading, showed the most appreciable daily and day-to-day trends and, therefore, may provide the best estimator of the variability, hence representativeness, of the measured loadings.

The relationship between any of the process control parameters and the detailed chemical composition of stack particulate matter cannot be determined with any certainty, because of the complexity of the processes contributing to the main stack gases.

It is suggested that the best benchmark for the current measurements, then, is the continuously measured stack gas opacity. This parameter is sensitive to changes in the stack gas particle loading and has a well-documented historical record against which to assess whether the current measurements are consistent with normal operations.

The relationship between the measured stack gas opacity (by transmissometer) and particle loading is of the form:

$$\text{Loading (g/kg flue gas)} = 0.436 \ln \left[\frac{1}{1 - A}\right] - 0.001$$

where A = opacity as a fraction. The permitted emission is 0.20 g of particulate/kg flue gas (Alberta emission standard) , corresponding to A = 0.37 (37% opacity). This means that the loading varies as the logarithm of the opacity, or approximately linearly up to opacity values of about 30%.

During the current tests, when monitored process variables indicated stable, normal operations, the extreme values for the stack opacity were;

June 14, 1984: 35% (max.) - 13% (min.);
June 18, 1984: 30% (max.) - 12% (min.);
June 19, 1984: 30% (max.) - 15% (min.).

The mean value of the opacity during this study was about 20%, which is close to the historical, therefore expected, value. The variability of the opacity during sampling test periods was not as great as the extreme values cited above, viz.:

Mean (June 14, 18, 19): 19.7%
Std. dev.: 4.4%
Extremes: 27.8% (max.) - 14.1% (min.)

The measured mean particle loadings during the valid tests, therefore, represent averages of excursions that could vary by 40% about the mean. If all sampling had taken place during periods when the higher particulate loadings prevailed as indicated by opacity, then the measured values might have been a factor of about 1.4 higher, at most. This is a reasonable estimate of the possible bias in representativeness of the test loadings compared with process excursions, short of upset.

4.2 Comparisons with Emissions from Similar Plants

A comparison between emissions from Syncrude's main stack and other plants provides a means to put Syncrude's emissions into perspective. However, the uniqueness of the Syncrude facility limits its comparison with a similar plant. Therefore, data from an allied industrial sector, namely, the coal-fired electrical utility sector, has been chosen as representative of emissions from similar plants. Historical Syncrude data will also be used for comparative purposes.

There are eight coal-fired power plants in Alberta, all of which are subject to the particulate emission standard of 0.2 g/kg flue gas. There are no standards to regulate emissions of metals from these plants. Alberta Environment has not conducted particulate emission tests on these plants. Data exist from tests conducted by the plants themselves, however this information is not available to Concord. Since these data are not available and only limited GCOS data are accessible, the following comparison is made of the elemental composition of the main stack particulate matter with the elemental composition of fly ash from other sources.

Table 4.1 lists a comparison between the metal composition of the Syncrude fly ash particles versus various coal-fired fly ashes and limited data from the GCOS power plant. Due to differences in the time

TABLE 4.1

Particulate Metal Composition from Syncrude's Main Stack, and Fly Ashes from Related Plants

		COAL-FIRED FLY ASH (μg/g)					
	Concord value Syncrude Particulate μg/g	Ontario Hydro Post-Precipitation Fly Ash Curtis 1977	Kronberg et al. 1981 Western Canadian Coals (Ash 3-11%)	Boyd 1981 South Saskatchewan Coal	Wangen 1981 U.S. subbituminous (22 % ash)	Evans et al. 1979 U.S. bituminous (12 % ash)	GCOS Shelfentook 1978 Power Plant flyash (n=3)
Fe	9,115 ± 4,990	69,900 (10%)	-	1,865 - 3,940	25,600 ± 2,300	-	46,000 ± 2,000
Al	3,280 ± 740	103,000 (15%)	-	-	139,000 ± 6,400	-	116,000 ± 6,000
Si	3,125 ± 1,790	-	-	-	-	-	-
Ca	2,500 ± 2,850	20,700 (20%)	-	-	17,400 ± 400	-	19,000 ± 5,000
Na	1,400 ± 1,070	3,410 (25%)	-	-	12,700 ± 300	-	-
V	925 ± 360	239 (15%)	10 - 150	130 - 160	94 ± 6	220	25,000 ± 2,000
Mg	880 ± 1,075	4,380 (40%)	-	-	9,900 ± 2,500	-	8,000 ± 800
Ti	800 ± 500	5,850 (15%)	-	2,470 - 4,410	6,000 ± 800	-	17,000 ± 3,000
Mn	300 ± 210	254 (15%)	-	520 - 770	149 ± 4	350	900 ± 60
P	280 ± 210	-	-	-	-	-	-
Ni	270 ± 160	193 (30%)	5 - 450	18 - 32	-	90	10,000 ± 1,000
Zn	120 ± 145	375 (15%)	3 - 400	160 - 240	80	280	-
Pb	108 ± 67	158 (25%)	<2 - 150	22 - 50	-	60	-
Cr	100 ± 120	216 (25%)	0.3 - 15	24 - 40	28.5 ± 2.7	170	-
Cu	50 ± 16	142 (10%)	60 - 180	50 - 70	65 ± 10	130	-
Ba	45 ± 35	1,540 (25%)	200 - 2,000	100 - 650	1,130 ± 40	890	-
Cd	45 ± 15	4.3 (20%)	0 - 0.3	5 - 6.8	-	0.7	-
Mo	30 ± 14	-	3 - 30	15 - 26	-	20	2,300 ± 200
Co	19 ± 16	36 (15%)	3 - 130	18 - 23	9.6 ± 0.7	70	-
Se	16 ± 7	261 (50%)	0.03 - 0.3	0.7 - 1.2	6 ± 1.6	15	-
Zr	16 ± 12	-	60 - 200	-	-	-	-
Sn	8 ± 3	-	<1 - 10	-	-	-	-
As	7 ± 2	233 (30%)	0.5 - 2	70 - 90	15.4 ± 1.5	165	-
Ag	0.8 ± 0.6	7.5 (60%)	0.1 - 0.3	-	-	-	-
Hg	0.6 ± 0.3	0.5 (55%)	1	0.2	-	0.8	-
Be	0.2 ± 0.3	10 (35%)	-	3.9 - 4.2	-	15	-
		(uncertainty)					

frame involved, in sampling and analytical techniques, pollution control equipment and fuel type, it is meant for comparative purposes only. Although the data are limited, it is evident that the particles emitted from Syncrude are not significantly different than typical coal fly ash, but appear dissimilar to the GCOS power plant fly ash.

4.3 Comparison of Concentration and Deposition Estimates with Available Data

In order to put the estimates provided in Section 3.4 in context, several sets of multi-element concentration and deposition data are summarized in the following. These data are:

- annual National Air Pollution Surveillance network (NAPS) data from 1978-81 for total suspended particulate matter (TSP) and lead for selected Canadian cities;
- recent air quality data for metals in U.S. urban and non-urban areas from the National Air Surveillance Network (NASN);

- fine and coarse inhalable particulate and metals data from the NAPS dichotomous sampler network;

- AOSERP study data.

4.3.1 NAPS and NASN Data for Populated Areas

Tables 4.2 and 4.3 summarize some related NAPS concentrations data and Table 4.4, some related NASN concentration data. The estimated contribution (i.e., increment above background) of the Syncrude emissions to downwind ambient concentrations of both total particulate matter and individual metals is about 1000 times lower than corresponding concentrations in populated areas of Canada and the U.S.

4.3.2 AOSERP Data

Table 4.5 illustrates particulate metals concentrations measured 10 km downwind (predominantly) and 80 km upwind of the GCOS plant in 1976 and 1977 (prior to start-up of the Syncrude plant). The upwind concentrations (at Birch Mountain) under the conditions of measurement represent clean, background levels. The estimated increment contributed by the Syncrude emissions is about 10 percent of these background levels. That is, the Syncrude emissions are estimated to increase the background levels by about 10 percent.

TABLE 4.2

Coarse/Fine Partiuclate and Selected Trace Metal Data - 7 Canadian Cities 1980

		Edmonton (10255-104th St.)	Halifax (N.S. Tech. Coll.)	Montreal (Peel & deMaisoneuve)	Ottawa (88 Slater)	Toronto (67 College)	Winnipeg (65 Ellen)	Vancouver (2294 W 10th Ave.)
Mass	$\mu g/m^3$							
	Coarse*	43.8 ± 33.6	17.7 ± 6.4	29.1 ± 18.0	17.4 ± 8.9	21.7 ± 9.7	30.4 ± 15.6	48.8 ± 33.6
	Fine**	24.9 ± 11.6	21.7 ± 8.9	28.6 ± 19.3	20.7 ± 11.6	22.4 ± 11.8	17.2 ± 8.8	24.9 ± 11.6
	Total	73.6 ± 36.1	39.3 ± 13.4	57.5 ± 24.2	38.1 ± 17.4	44.0 ± 17.6	47.6 ± 18.6	46.7 ± 20.7
Metals	ng/m^3							
Arsenic	Coarse	4.3 ± 1.4	6.3 ± 2.0	4.2 ± 1.9	3.1 ± 1.7	3.0 ± 1.5	13.7 ± 37.8	4.5 ± 2.2
	Fine	3.5 ± 1.1	6.1 ± 2.4	5.5 ± 2.3	5.1 ± 3.1	5.8 ± 2.4	5.4 ± 4.0	6.0 ± 2.9
	Total	7.7 ± 1.0	12.4 ± 3.7	9.6 ± 3.9	8.2 ± 3.7	8.8 ± 3.5	19.1 ± 41.5	10.5 ± 3.3
Chromium	Coarse	12.6 ± 8.6	3.9 ± 3.3	9.9 ± 10.2	4.4 ± 2.3	7.3 ± 5.0	6.6 ± 8.0	5.7 ± 4.1
	Fine	11.3 ± 9.6	6.2 ± 4.8	13.6 ± 11.9	5.6 ± 4.0	7.6 ± 4.7	8.3 ± 11.6	18.6 ± 17.4
	Total	23.9 ± 17.0	10.1 ± 5.5	23.5 ± 20.8	9.0 ± 5.1	14.9 ± 8.0	14.9 ± 11.9	24.4 ± 16.4
Lead	Coarse	189 ± 76	66.7 ± 30.1	189 ± 99.1	138 ± 84.9	87.1 ± 71.5	149 ± 87.3	184 ± 95.4
	Fine	556 ± 290	174 ± 81.3	676 ± 235	402 ± 157	290 ± 134	315 ± 172	693 ± 365
	Total	745 ± 356	241 ± 91.8	865 ± 270	538 ± 188	377 ± 145	478 ± 249	877 ± 446

** d <2.5 μm   * 2.5 <d<15μm

Source: Concord Scientific Corporation report 110.27/110.30. Determination of Concentrations of Selected Fine Particulate Air Contaminants in Seven Canadian Cities, for EPS, March 1981. All stations are NAPS stations.

TABLE 4.3

NAPS Air Quality Data for TSP and Lead (1978-1981) for Selected Canadian Cities

	1978		1979		1980		1981	
	TSP[a]	Lead[b]	TSP[a]	Lead[b]	TSP[a]	Lead[b]	TSP[a]	Lead[b]
Edmonton								
127 St. & 133 Ave.	65 (2.0)	0.26 (2.35)	81 (1.9)	NA	82 (1.7)	NA	64 (1.6)	NA
146 St. & 92 Ave.	41 (1.6)	0.21 (2.20)	NA	NA	NA	NA	NA	NA
175 St. & 105 Ave.	59 (2.4)	0.20 (2.41)	73 (2.2)	NA	72 (2.1)	NA	66 (1.8)	NA
Calgary								
Bonny Brk & 18A St. S.E.	96 (1.5)	0.24 (2.54)	139 (1.8)	NA	152 (1.7)	NA	136 (1.7)	NA
39 St. & 29 Ave. N.W.	49 (1.7)	0.11 (3.31)	56 (1.6)	NA	70 (2.0)	NA	65 (1.7)	NA
Red Deer								
4747 50th St.	53 (2.1)	0.21 (2.36)	61 (2.1)	NA	70 (2.2)	NA	61 (1.8)	NA
Vancouver								
250 West 70th Ave*	82 (1.5)	0.75 (2.10)	86 (1.6)	0.72 (2.17)	72 (1.6)	0.56 (2.10)	NA	NA
970 Buyard+	67 (1.5)	0.80 (1.60)	62 (1.6)	0.75 (1.77)	70 (1.5)	0.73 (2.30)	66 (1.6)	0.88 (1.71)
Toronto								
Sherbourn & Wilton*	140 (1.7)	NA	129 (1.7)	0.88 (1.94)	131 (1.6)	0.60 (2.39)	113 (1.7)	0.56 (1.78)
Evans & Arnold+	71 (1.5)	0.99 (2.87)	84 (1.4)	0.75 (1.85)	91 (1.5)	0.87 (1.97)	96 (1.5)	1.1 (1.86)

* generally, higher TSP readings occur at these stations for the respective city

\+ for lead

Alberta stations are representative

a - TSP, $\mu g/m^3$ annual geometric mean (and geometric deviation)

b - lead, $\mu g/m^3$ annual geometric mean (and geometric deviation)

NA - Not available or insufficient data (1979, 1980 & 1981 Alberta lead not reported) National Air Quality Objective for TSP = 60 $\mu g/m^3$ annual geometric mean (acceptable = 70 $\mu g/m^3$)

TABLE 4.4

U.S. Air Quality Data for Metals

pg/m^3 *

	1977		1978		1979	
Urban						
Be	45.1	(70.2)	74.9	(89.5)	53.8	(75.8)
Ba	31.6	(63.1)	26.5	(82.7)	4.8	(68.1)
Cd	2.2	(7.3)	2.4	(8.3)	1.9	(5.1)
Cu	208	(242)	201	(211)	259	(179)
Fe	1,308	(1,191)	1,273	(1,272)	1,018	(1,049)
Pb	889	(759)	765	(688)	584	(560)
Mn	43	(68)	42	(52)	38	(62)
Mo	2.2	(5.6)	2.1	(4.9)	1.5	(6.5)
Ni	10.0	(20.9)	11.0	(23.2)	9.6	(12.8)
V	16.5	(27.4)	19.1	(33.5)	20.8	(35.2)
Zn	161	(260)	164	(303)	26.3	(238)
Non Urban						
Be	38.9	(38.7)	47.4	(37.9)	38.6	(19.9)
Ba	8.9	(9.4)	5.7	(11.8)	11.8	(70.0)
Cd	0.8	(1.6)	0.8	(1.0)	0.8	(5.1)
Cu	193	(219)	266	(290)	142	(290)
Fe	218	(326)	307	(433)	162	(230)
Pb	92.0	(104)	84.3	(110)	84.2	(102)
Mn	22	(13)	21	(5)	21	(3)
Mo	1.1	(1.1)	1.1	(1.3)	0.8	(0.4)
Ni	4.8	(14.3)	3.9	(3.5)	3.2	(1.9)
V	6.9	(8.2)	8.5	(10.4)	7.9	(8.5)
Zn	46.6	(232)	42.4	(110)	13.4	(46.2)

* arithmetic mean (and S.D.)

Urban: n = 4,648 for 1977, 3,614 for 1978, 2,507 for 1979 where n = #of valid 24 hour samples.

Non Urban: n = 709 for 1977, 458 for 1978, 235 for 1979

ICAP analysis

Source: EPA-600/S4-83-053
Air Quality Data for Metals: 1977 Through 1979 from the National Air Surveillance Network, USEPA 1984.

The impact of the Syncrude emissions relative to the concentrations measured downwind of the GCOS plant can be assessed by comparing:

- relative emission source strengths (at the time of measurement);
- relative release (stack) height;
- time-averaging basis.

According to Barrie (1980), the GCOS parameters were 27 tonnes per day total particulate emission at a stack height of 107 m, compared with the Syncrude values of 3 tonnes per day at a height of 183 m. The measurements at Mildred Lake in Table 4.5 are three-day average concentration at sites which were directly impacted by the GCOS plume (samples A and B); whereas, the estimates of the Syncrude plume's impact are annual averages.

A rule of thumb for converting 24-hour average concentrations at a sampling site to annual average values at that site, taking into account wind statistics, is to divide the 24-hour value by about a factor of between 10 and 20. The difference in emission source strength and stack height would lead to a factor of about 150 to 200 times lower concentration contributions at a given ground level point for the

TABLE 4.5

Atmospheric Concentration (ng/m^3) of Various Elements in Suspended Particles at Mildred Lake and Birch Mountain

Element*	June 1977 - Mildred Lake			March 1976 - Birch Mountain		
	Period A(16th-19th)	Period B(19th-22nd)	Period C(22nd-25th)	Period 1(3rd-7th)	Period 2(7th-13th)	Period 3(13th-17th)
Al	1,500	2,300	1,500	41	56	70
As	0.7	0.9	0.4	0.4	1.1	0.4
Ba	-	38	-	-	-	-
Ca	2,200	2,800	2,700	19	41	40
Fe	3,000	2,400	890	-	-	-
Mg	260	870	780	31	23	26
Mn	28	49	38	0.7	0.9	7.0
Na	-	-	-	130	76	67
Ti	110	210	82	-	6.7	7.9
V	80	110	4.2	0.5	4.5	4.7
Zn	-	23	-	-	~6	-

Note: Samples taken at Birch Moutain were true background (no wind-blown dust or anthropogenic component from GCOS).
Samples taken at Mildred Lake, A and B contain a larger proportion of anthropogenic particles since they were directly affected by GCOS emissions.

* INAA analysis

Source: Barrie (1980)

Syncrude stack relative to the 1976/77 GCOS situation. Applying these factors to the AOSERP/GCOS data yields comparable annual average concentrations to the estimates based on the Syncrude emissions provided in this report, namely, concentrations of less than 100 mg m^{-3} total particulate at the point of maximum concentration and less than 1 mg $m^{-3}$for the most concentrated elements.

That is, the current estimates for Syncrude emissions are consistent with previous measurements in the Oil Sands area.

4.3.3 Total Deposition Estimates

The relative importance of dry and wet deposition processes is unclear. Since only a few studies have been performed in this region, the predominant mechanisms for deposition of material from the stack to the environs have not been established. It has been suggested that wet deposition processes may be relatively more efficient near a point source and same indication of this has been reported by Barrie (1980) in the Oil Sands area. Barrie, however, also indicated that precipitation occurred only for 2 % of the time during his field studies. The relative importance of all deposition in the area can therefore be assessed by evaluating a total deposition scenario in a limited area around the Syncrude stack. This will provide an upper limit to the deposition and will therefore be indicative of worst case conditions. According to the total deposition estimate scenario developed in Section 3, a reasonable upper limit estimate of deposition of the Syncrude emissions into the predominant southeast sector (105-145°) within 25 km of the stack, is 45 mg $m^{-2}yr^{-1}$ for total particulate matter and proportionately less for individual elements.

A comparison of data provided by Barrie (1980) in a study conducted in 1977 can also be made using vanadium as an elemental tracer for a tar sands plant and normalizing the data to compensate for the different emission source strengths.

Barrie (1980) reported that 58% (i.e. 28.4 tonnes) of the vanadium released over a 70 day period (49 ± 7 tonnes) was deposited within 25 km of the stack. This corresponds to an average of 75 mg $m^{-2}yr^{-1}$. If all the vanadium particulate emissions from the Syncrude stack were deposited in a 25 km radius from the stack, the vanadium flux would be only 513 μg $m^{-2}yr^{-1}$. The model estimates of the present study indicate that the highest flux of vanadium would be 10 μg $m^{-2}yr^{-1}$ for 0.1 μm particles, or 19 μg $m^{-2}yr^{-1}$ for 10 μm particles. It should be noted that the stack emissions of vanadium that gave rise to the fluxes derived from Barrie's data were ~250 times greater than those measured in this study: in contrast, the vanadium fluxes within 25 km radius from the stack as measured by Barrie are ~150 times greater than those estimated by the model.

Measured deposition rates (Fanaki et al., 1979) for vanadium at fifteen stations in the vicinity of the GCOS stack ranged from 600 to 8100 μg $m^{-2}yr^{-1}$. These values may be compared with the current model estimates for the sector with the highest fluxes in which the values ranged from ~600 μg $m^{-2}yr^{-1}$ at 3-5 km to 30 μg $m^{-3}yr^{-1}$ at 100 km from the stack. Again the lower vanadium emission rates of the Syncrude stack (by a factor of ~250) as well as other differences such as stack height, temperature etc. must be borne in mind.

The above data provide some measure of the relative and absolute amounts of emissions from the Syncrude stack. It should be reiterated that the selection of vanadium as the basis for comparison is due to the fact that this element (as well as sulphur) was shown to be predominantly anthropogenic in origin and clearly associated with tar sands processing plant emissions.

5. CONCLUSIONS

Concord Scientific Corporation has conducted a preliminary study of emissions of particulate and vapour-phase metals from the main stack at Syncrude Canada Limited's Mildred Lake plant.

The field stack sampling programme was carried out between June 13 and June 19, 1984, during which one preliminary test and three valid compliance tests were completed. The samples from these tests (130 in total) were analyzed for 26 elements by three independent analytical laboratories.

The emission rates of total particulate matter and of individual metals both on particles and in vapour form were calculated from the stack measurements and chemical analysis results. These emissions were modelled using an existing, conventional dispersion model to estimate ground level concentrations and deposition patterns of these substances up to 100 kilometers from the Syncrude stack.

The concentration and deposition patterns were determined as annual averages by direction from the stack, based on input to the model of climatological data from Edmonton and Fort Smith, the nearest stations providing the required data. Alternate meteorological scenarios were also examined and discussed.

Important findings of the study are that:

- The measured average emission rate of total particulate matter from Syncrude's main process stack is about 35 ± 7 grams per seconds (3020 ± 600 kg/day). This result converts to 0.053 g/kg of stack gas and is well below the Alberta standard of 0.2 g/kg of stack gas.

- The uncertainty in the emission data at the 90 % confidence level is ± 14 g s^{-1} (2 standard deviations) calculated from the particulate emissions rate. Additional uncertainty caused by potential bias in the sampling due to increases or decreases in emission rate (i.e. sample representativeness) would increase this by a factor of 1.4. The overall uncertainty therefore would be ± 26 g s^{-1} or the emission rate would vary between 61 and 9 g s^{-1} or 0.092 and 0.014 g/kg of stack gas for a 90 % confidence interval.

- Emissions for lead, cadmium, selenium, arsenic, mercury and beryllium are very low.

- The range of emission rates for individual metallic constituents of the stack gas (including both particulate and vapour-phase forms) ranged from 320 milligrams per second

(27.6 kg/day) for iron to 6 micrograms per second (0.0005 kg/day) for beryllium.

- The ground level concentrations of particulate matter and metals in the area around the stack, as determined by the model calculations, were found to reach a maximum at three to five kilometers from the stack. The maximum ground level concentration (annual average) at this distance is estimated at 0.06 micrograms per cubic meter for total particulate matter. The corresponding range for metals was from 540 picograms per cubic meter for iron to 0.01 picograms per cubic meter for beryllium.

- The model outputs found that the maximum dry deposition also occurs at a distance of three to five kilometers from the stack. The annual average dry deposition for total particulate matter (assumed to be 10 μm diameter) at this distance is 35 milligrams per square meter per year. Similarly for individual metals, the annual deposition ranges from 314 micrograms per square meter per year for iron to 5.9 nanograms per square meter per year for beryllium.

- These concentrations and deposition estimates are those attributable to the Syncrude stack since other influences were not evaluated (i.e., other stacks, emission sources or wind blown dust). Chapter 4 describes same comparative data from a variety of sources.

- The compass sector into which maximum concentrations and deposition occurs is to the southeast of the stack.
- The next greatest concentration and deposition amounts occur in the sector northwest of the stack.

Information describing the level of confidence in the estimates and other important data is described in Volume I of this report. Detailed data on all measurements is contained in Volume II of this report.

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A Study of Metallic Emissions from the Main Stack at Syncrude's Mildred Lake Plant
Volume II

CSC 110.J449

Prepared for

Syncrude Canada Ltd.

by

Concord Scientific Corporation
2 Tippett Road
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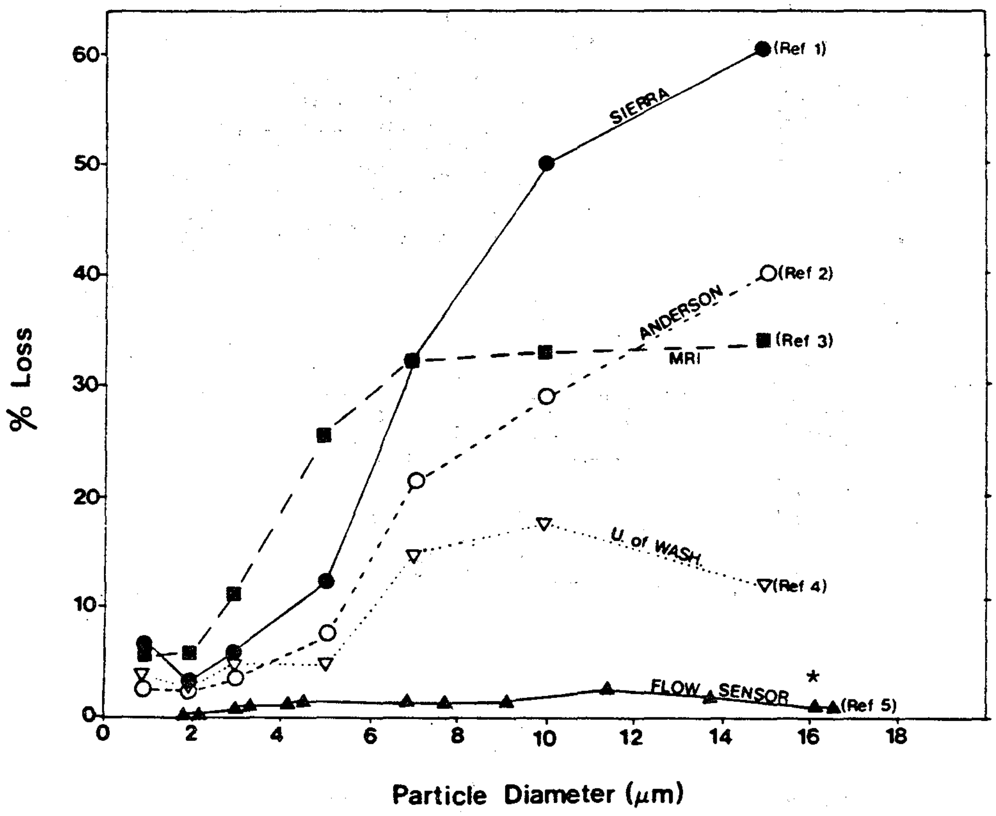
Figure 1

Comparison of Impactor Wall Losses



* Unit that will be used for the study.

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Figure 2

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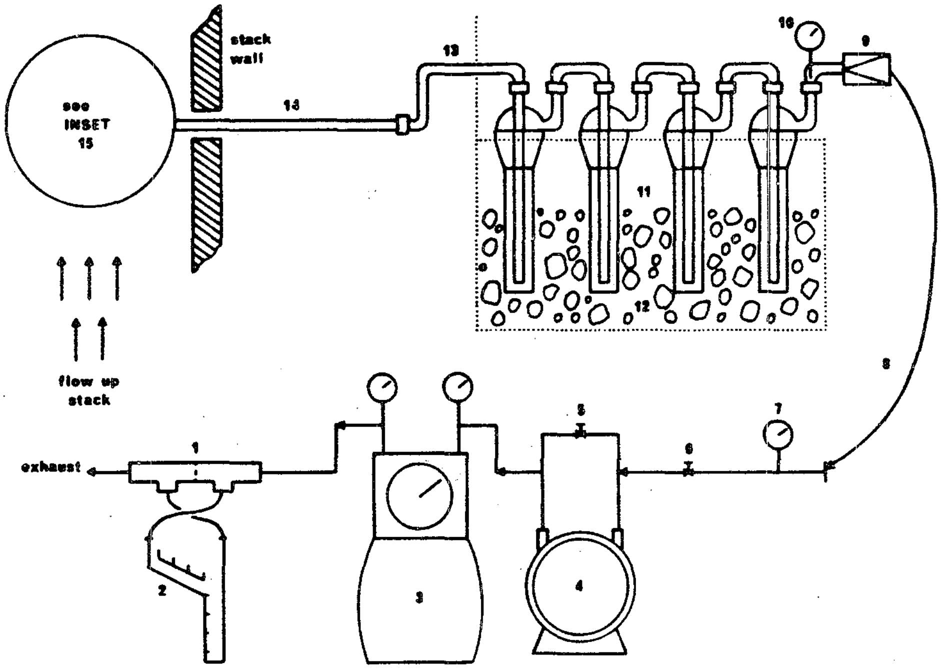
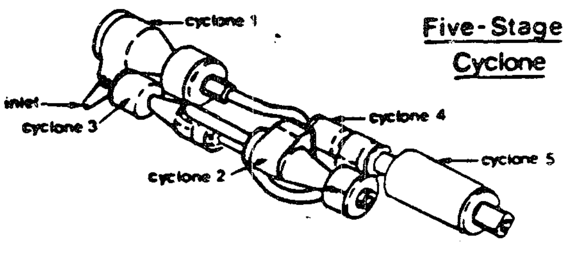


KEY

① ORIFICE
② MANOMETER
③ DRY TEST METER
④ AIR-TIGHT PUMP
⑤ BY-PASS VALVE
⑥ MAIN VALVE
⑦ VACUUM GAUGE
⑧ VACUUM LINE
⑨ CHECK VALVE
⑩ THERMOMETER
⑪ IMPINGERS
⑫ ICE BATH (ie: COLD BOX)
⑬ FLEXIBLE SAMPLE LINE
⑭ PROBE
⑮ SRI 5-STAGE CYCLONE PARTICLE SIZER

INSET

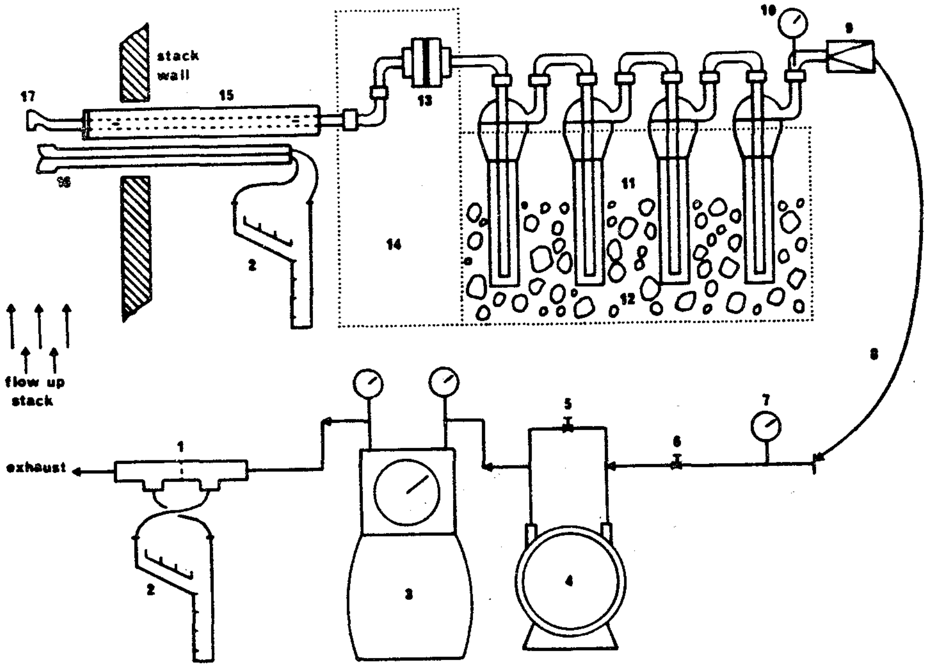
Five-Stage Cyclone



Note: A back-up filter would be used but is not shown on this particular diagram. (refer to item 13, Figure 3)

Figure 3

Particulate and Vapour Metal Sampling Train



KEY

① ORIFICE
② MANOMETER
③ DRY TEST METER
④ AIR-TIGHT PUMP
⑤ BY-PASS VALVE
⑥ MAIN VALVE
⑦ VACUUM GAUGE
⑧ VACUUM LINE
⑨ CHECK VALVE
⑩ THERMOMETER
⑪ IMPINGERS Note: more than 4 will be used.
⑫ ICE BATH (ie: COLD BOX)
⑬ FILTER HOLDER
⑭ OVEN (ie: HOT BOX)
⑮ PROBE (Teflon - lined)
⑯ REVERSE-TYPE PITOT
⑰ NOZZLE

Train A - for As, Se, Hg & total particulate matter

Train B - for Pb, Cd & total particulate matter

Figure 4

Sensitivity Analysis of Flux Due to Variation of Stack Exit Temperature T, Stack Gas Exit Velocity V_s, and Roughness Length z_0

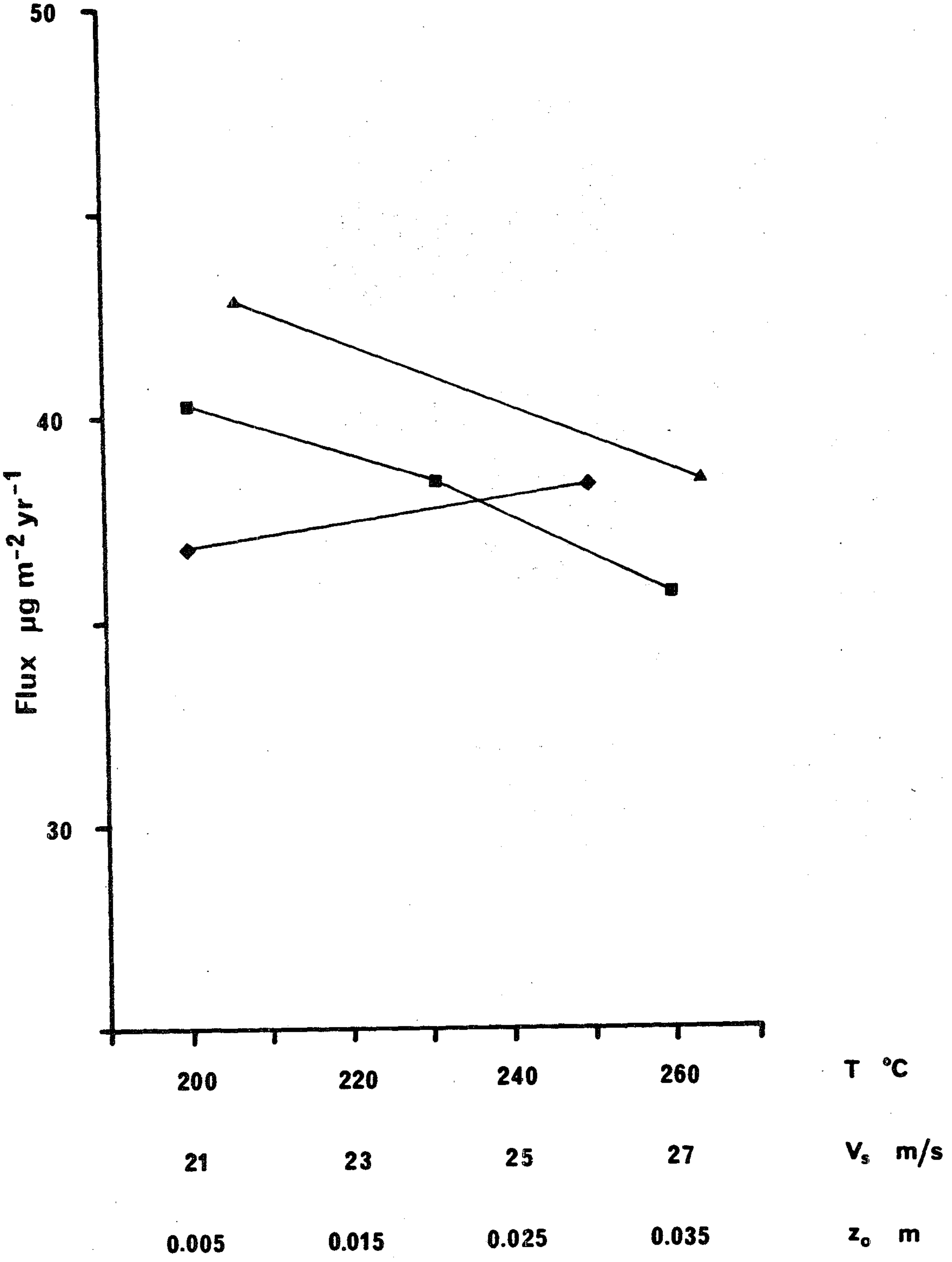


Figure 5

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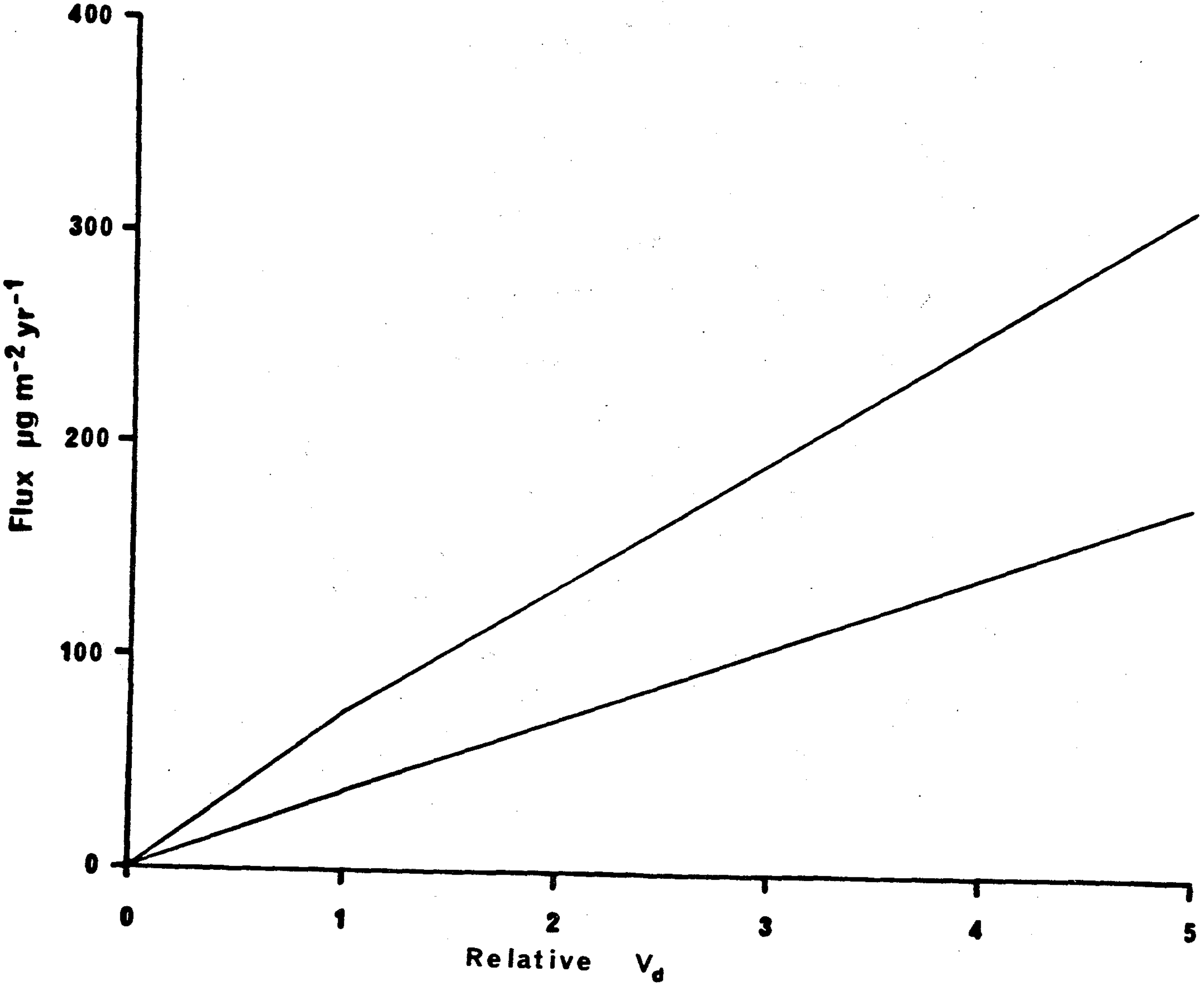


Figure 6

Concentration Contour Plot for the Dispersion of 0.1 μm Particles Based on 1 g s^{-1} Particulate Emission
Edmonton Climatological Data
Numbers on Contours are in Units of 10^{-4} μg m^{-3}

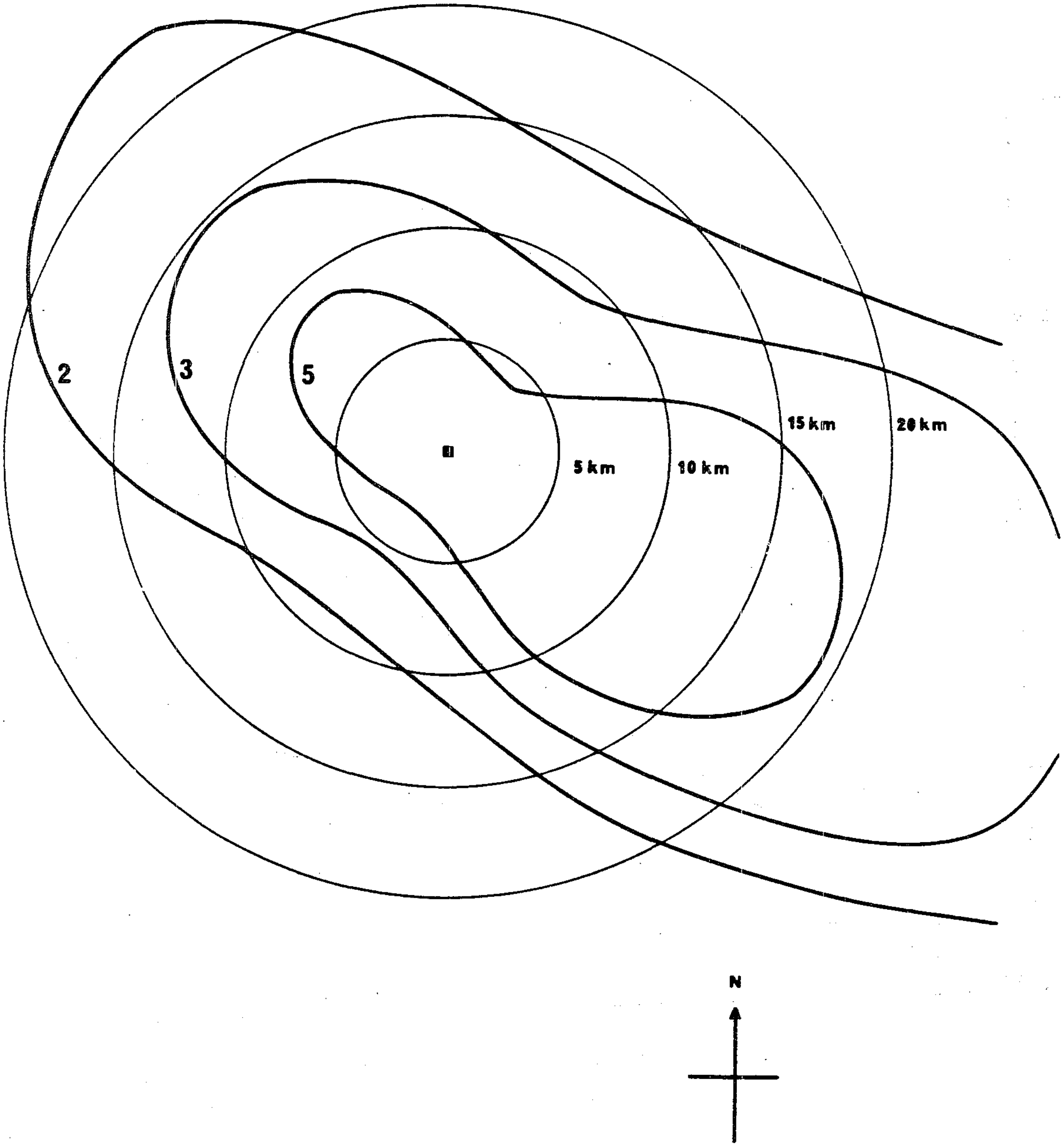


Figure 7

Concentration Contour Plot for the Dispersion of 10 μm Particles Based on 1 g s^{-1} Particulate Emission
Edmonton Climatological Data
Numbers on Contours are in Units of 10^{-4} μg m^{-3}

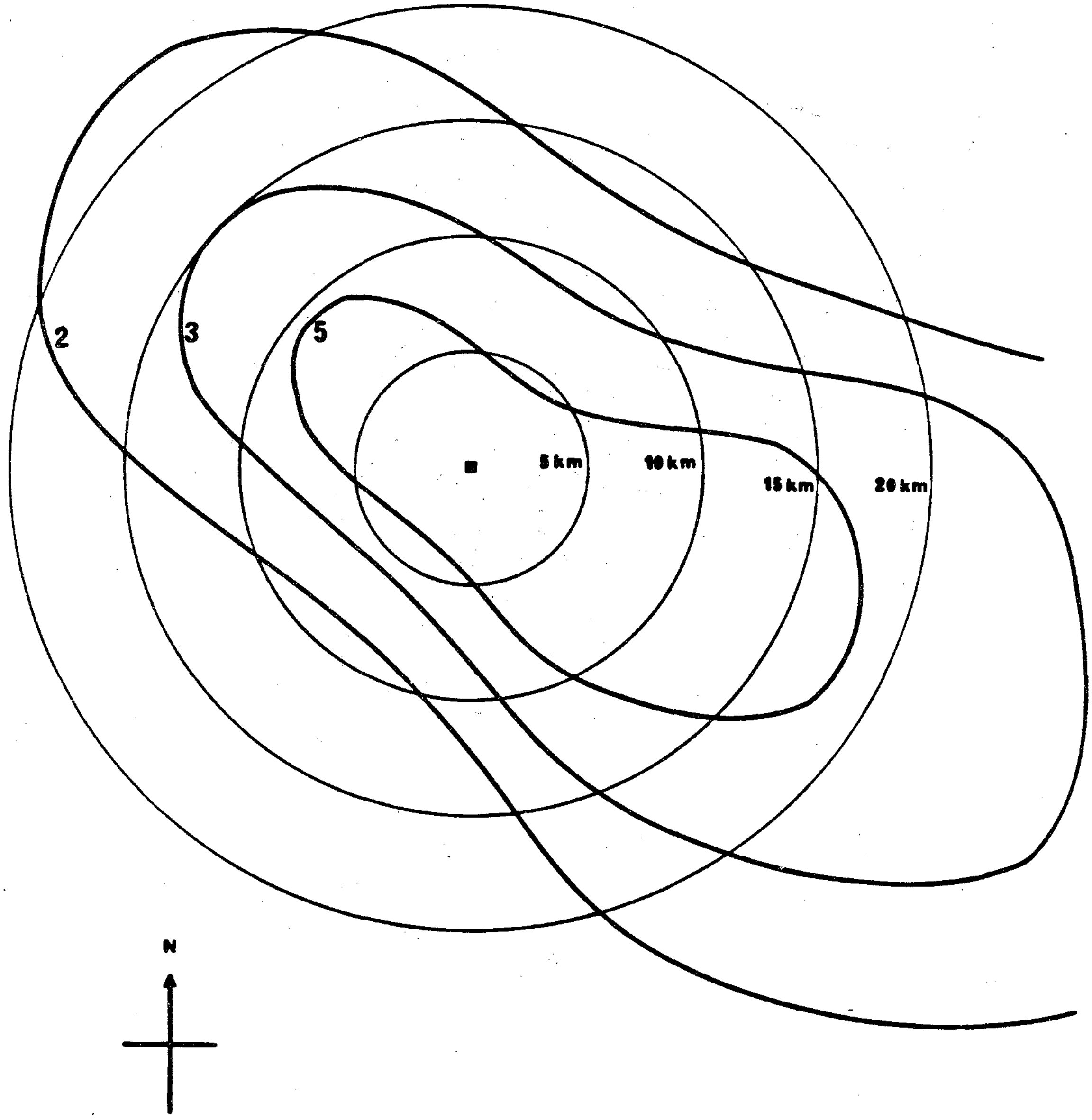


Figure 8

Concentration Contour Plot for the Dispersion of 0.1 μm Particles Based on 1 g s^{-1} Particulate Emission
Fort Smith Climatological Data
Numbers on Contours are in Units of 10^{-4} μg m^{-3}

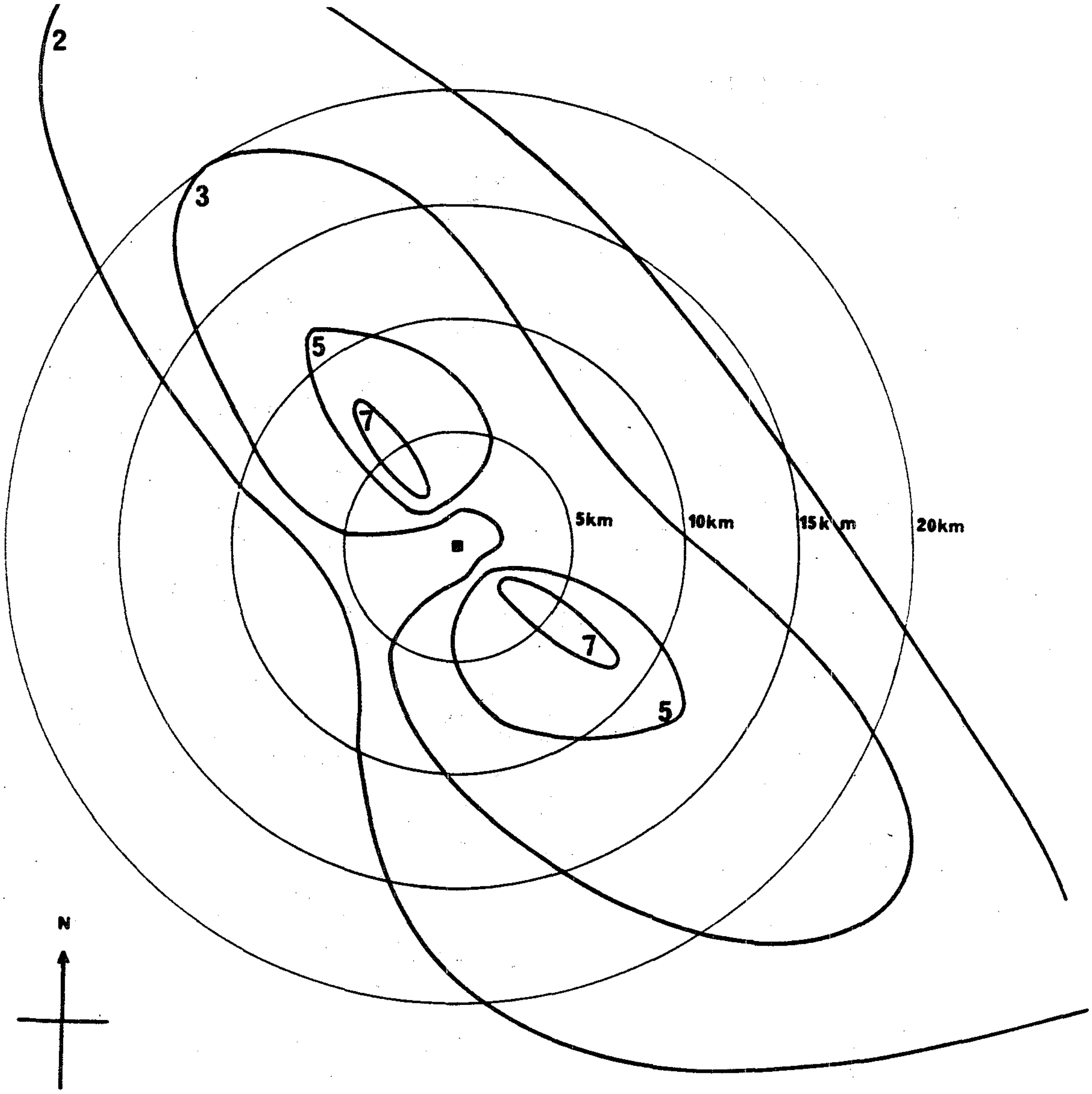


Figure 9

Concentration Contour Plot for the Dispersion of 10 μm Particles Based on 1 g s^{-1} Particulate Emission

Fort Smith Climatological Data

Numbers on Contours are in Units of 10^{-4} μg m^{-3}

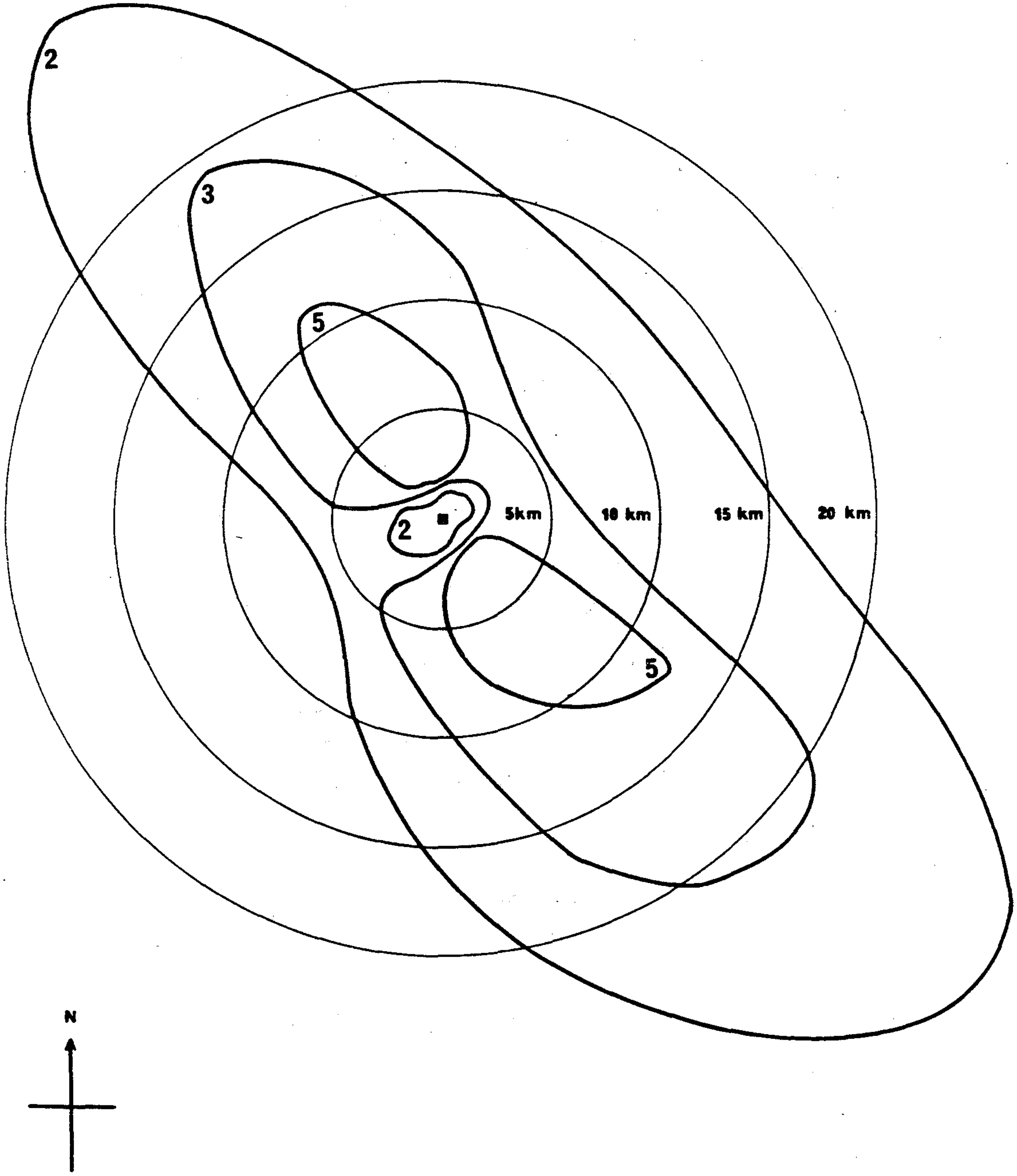


Figure 10A

Flux Contour Plot (0-20 km) for the Deposition of 0.1 μm Particles Based on 1 g s^{-1} Particulate Emission Rate
Edmonton Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

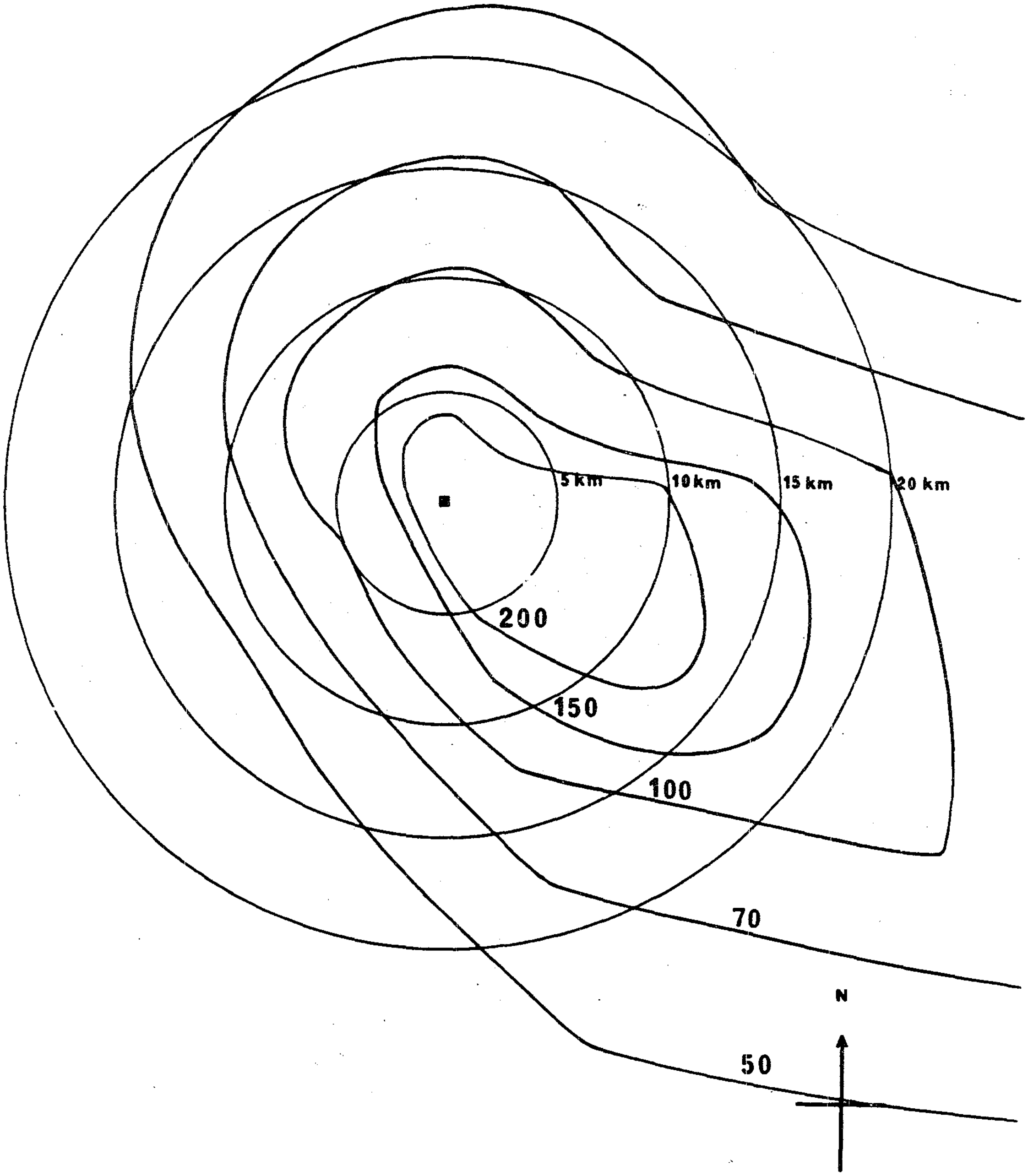


Figure 10B

Flux Contour Plot (0-100 km) for the Deposition of 0.1 μm Particles
Based on 1 g s^{-1} Particulate Emission Rate
Edmonton Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

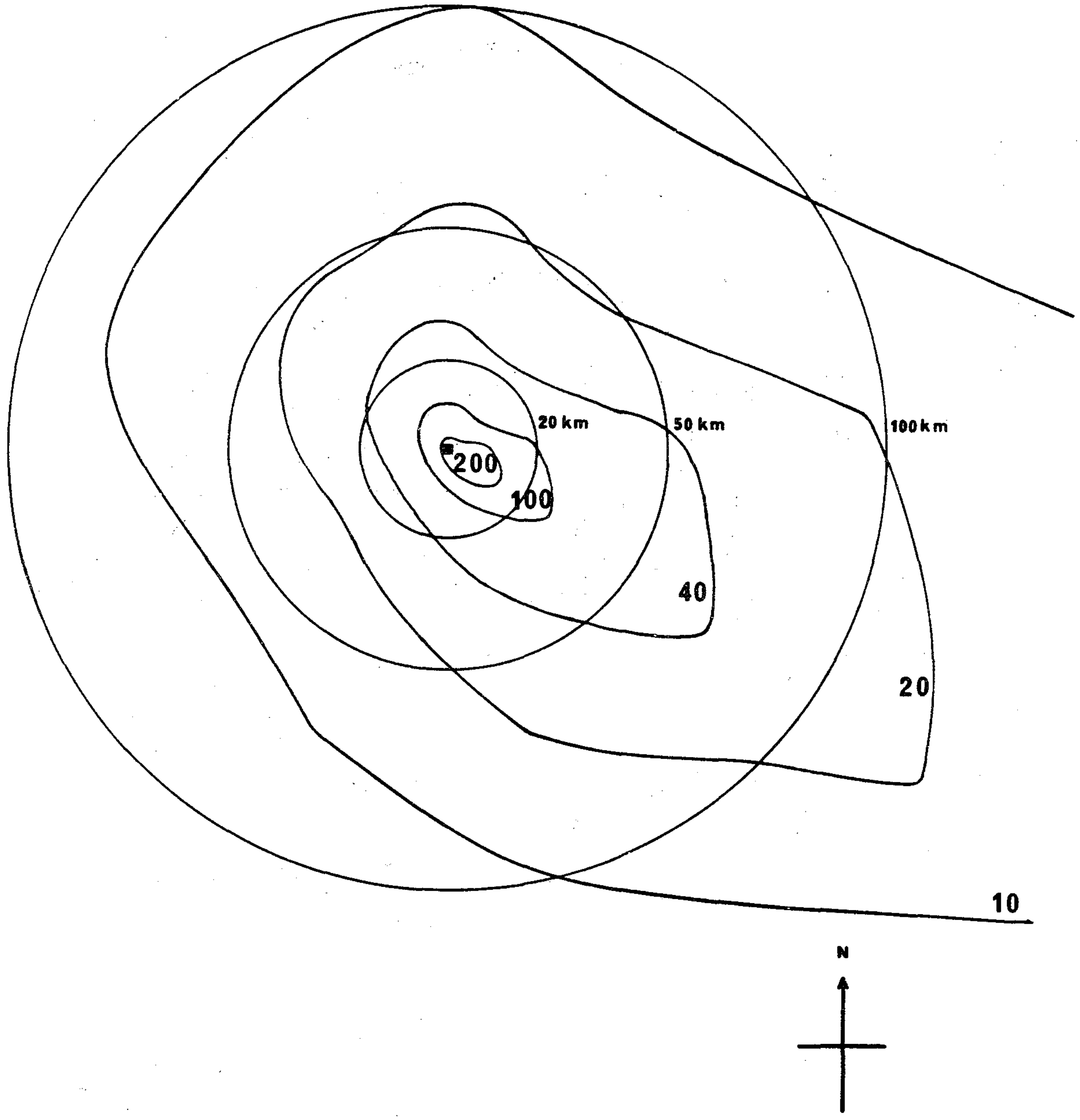


Figure 11A

Flux Contour Plot (0-20 km) for the Deposition of 10 μm Particles Based on 1 g s^{-1} Particulate Emission Rate
Edmonton Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

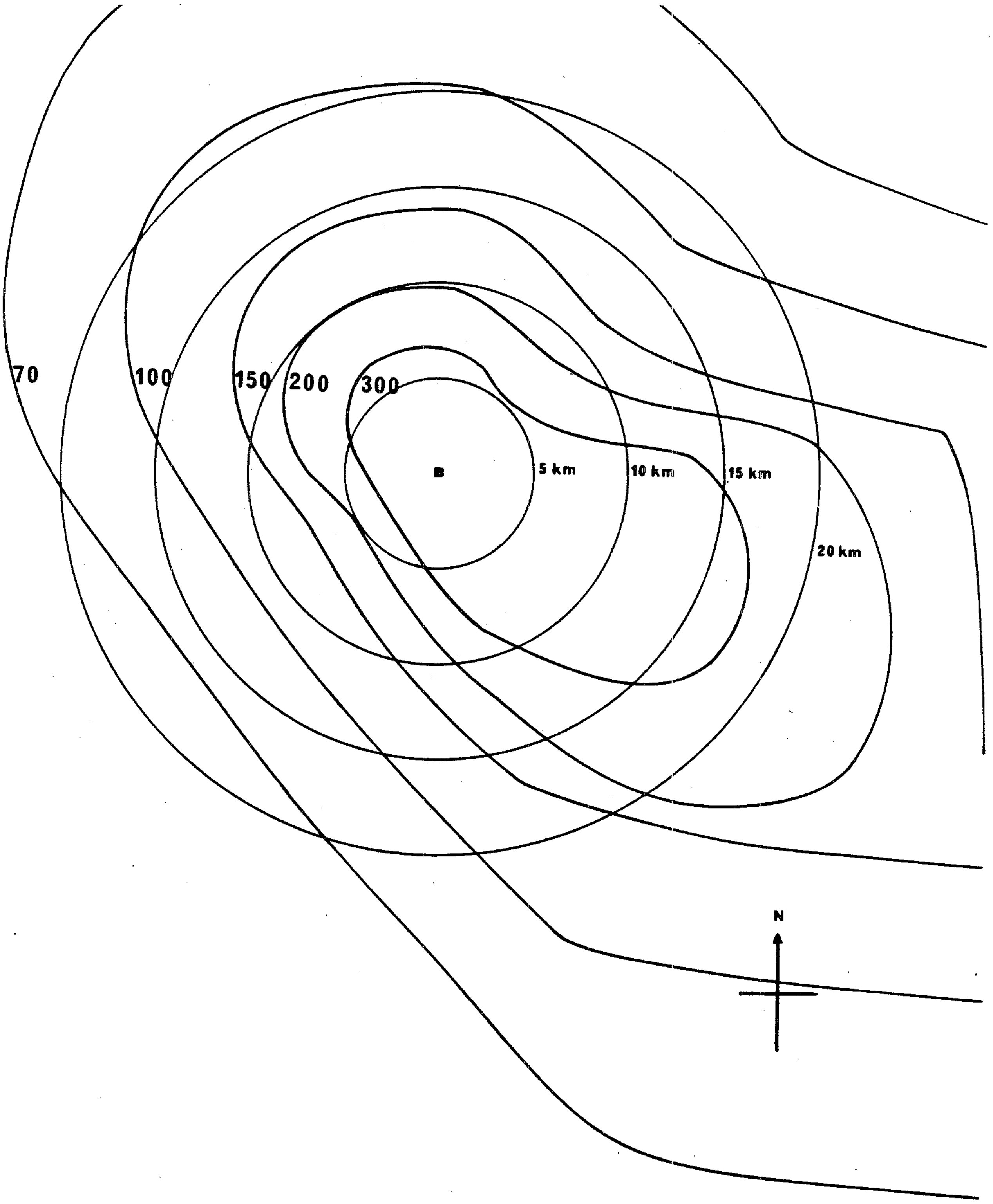


Figure 11B

Flux Contour Plot (0-100 km) for the Deposition of 10 μm Particles Based on 1 g s^{-1} Particulate Emission Rate

Edmonton Climatological Data

Numbers on Contours are in Units of μg m^{-2} yr^{-1}

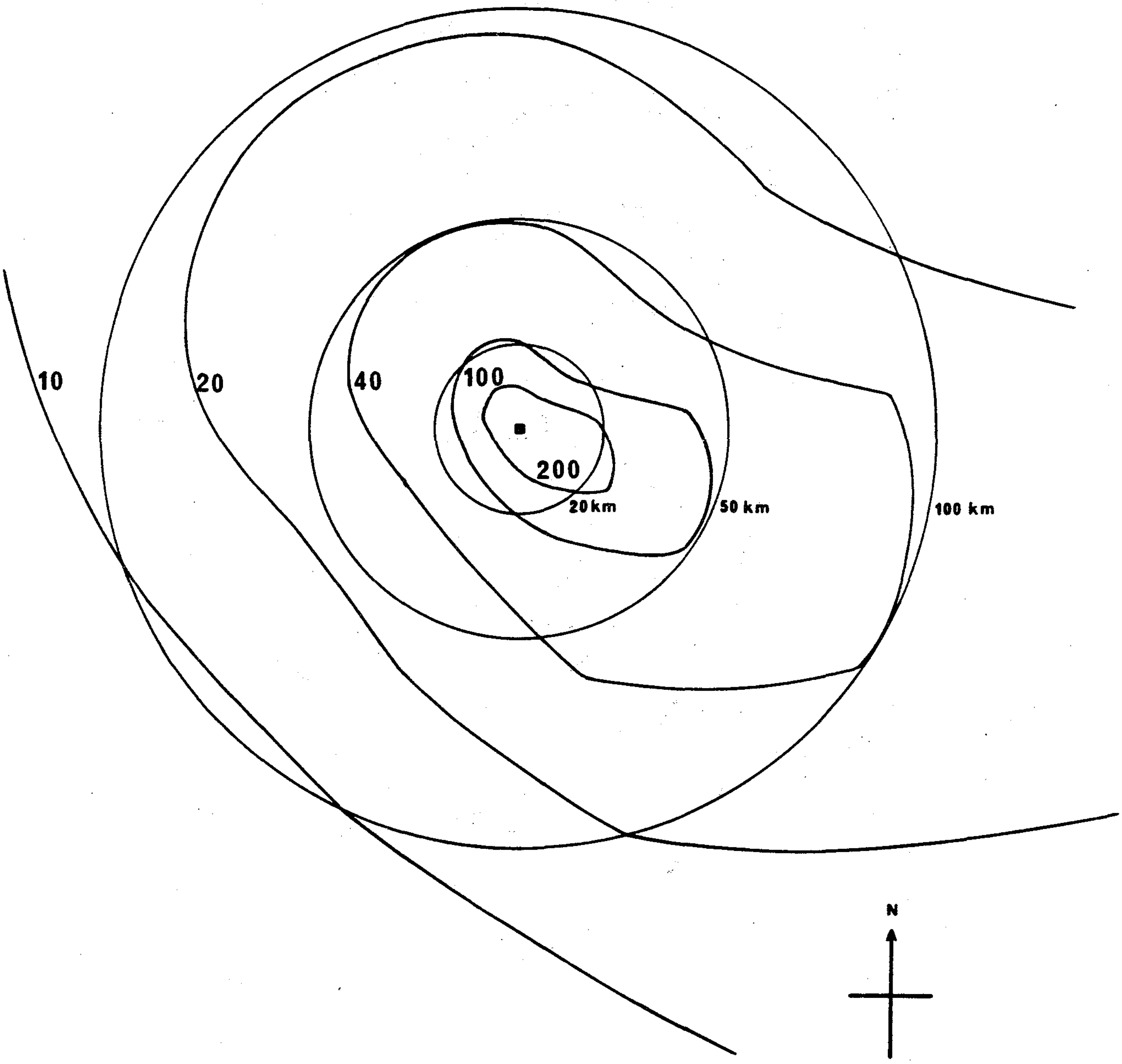


Figure 12A

Flux Contour Plot (0-20 km) for the Deposition of 0.1 μm Particles Based on 1 g s^{-1} Particulate Emission Rate
Fort Smith Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

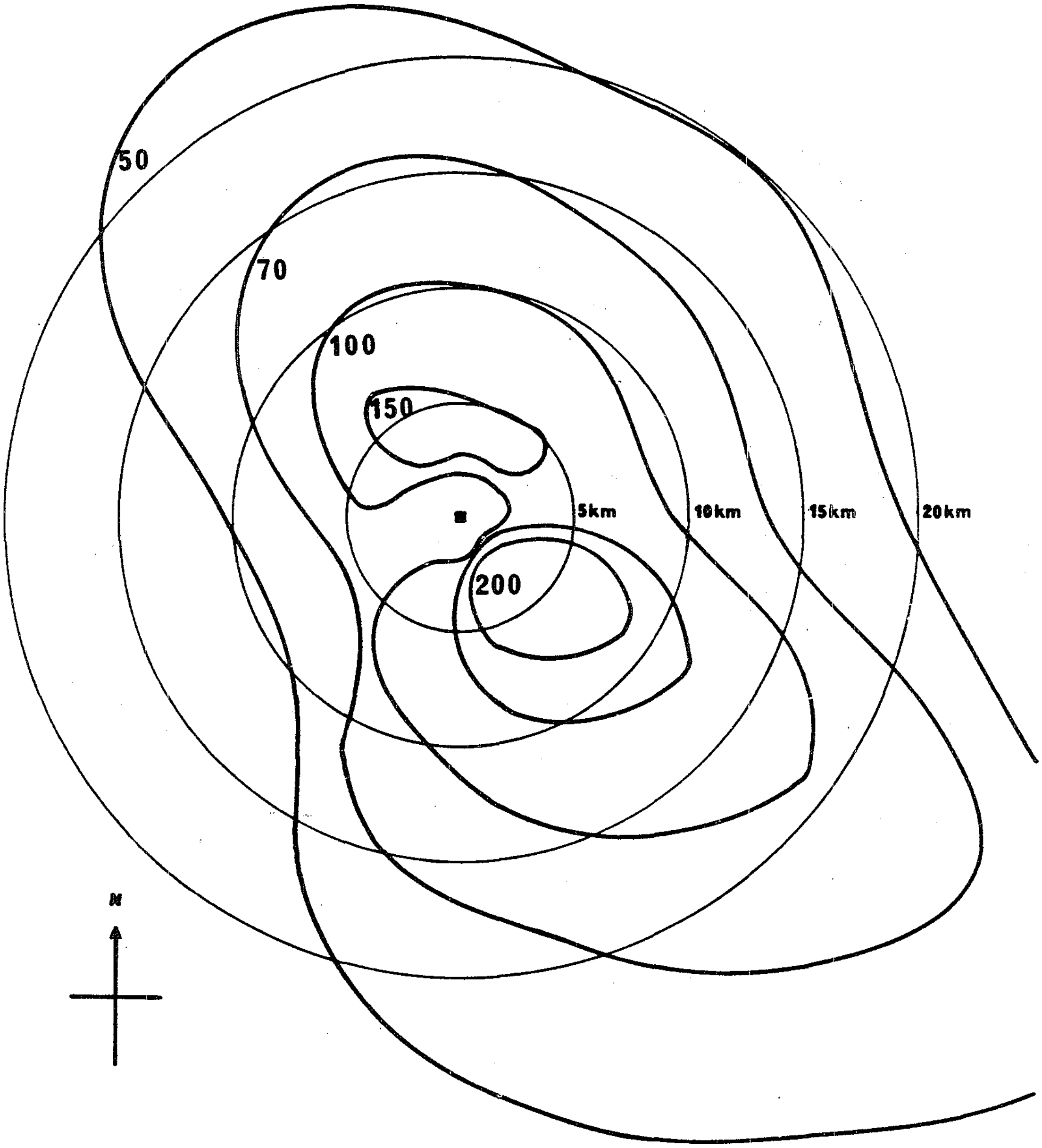


Figure 12B

Flux Contour Plot (0-100 km) for the Deposition of 0.1 μm Particles
Based on 1 g s^{-1} Particulate Emission Rate
Fort Smith Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

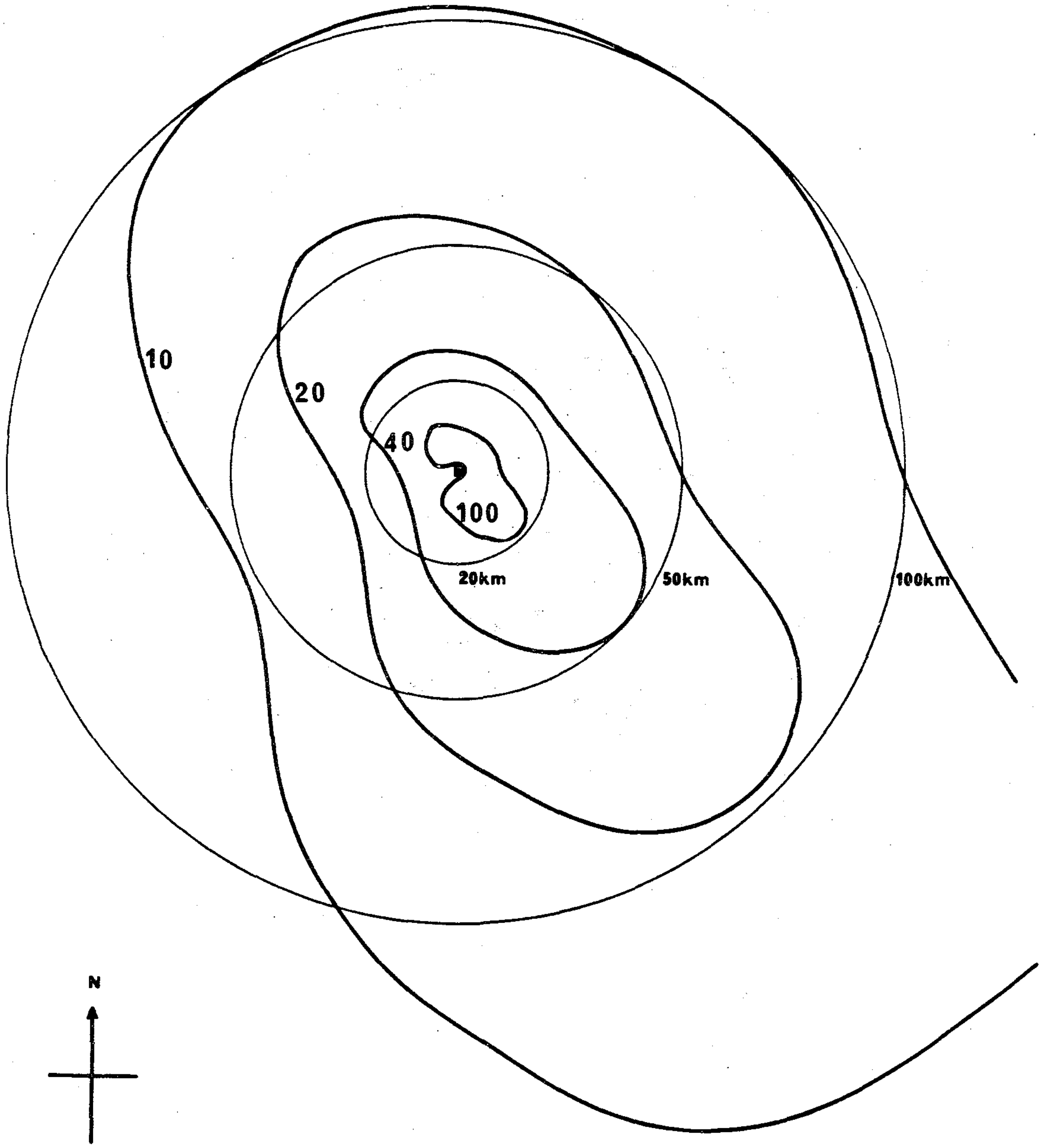


Figure 13A

Flux Contour Plot (0-20 km) for the Deposition of 10 μm Particles Based on 1 g s^{-1} Particulate Emission Rate
Fort Smith Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

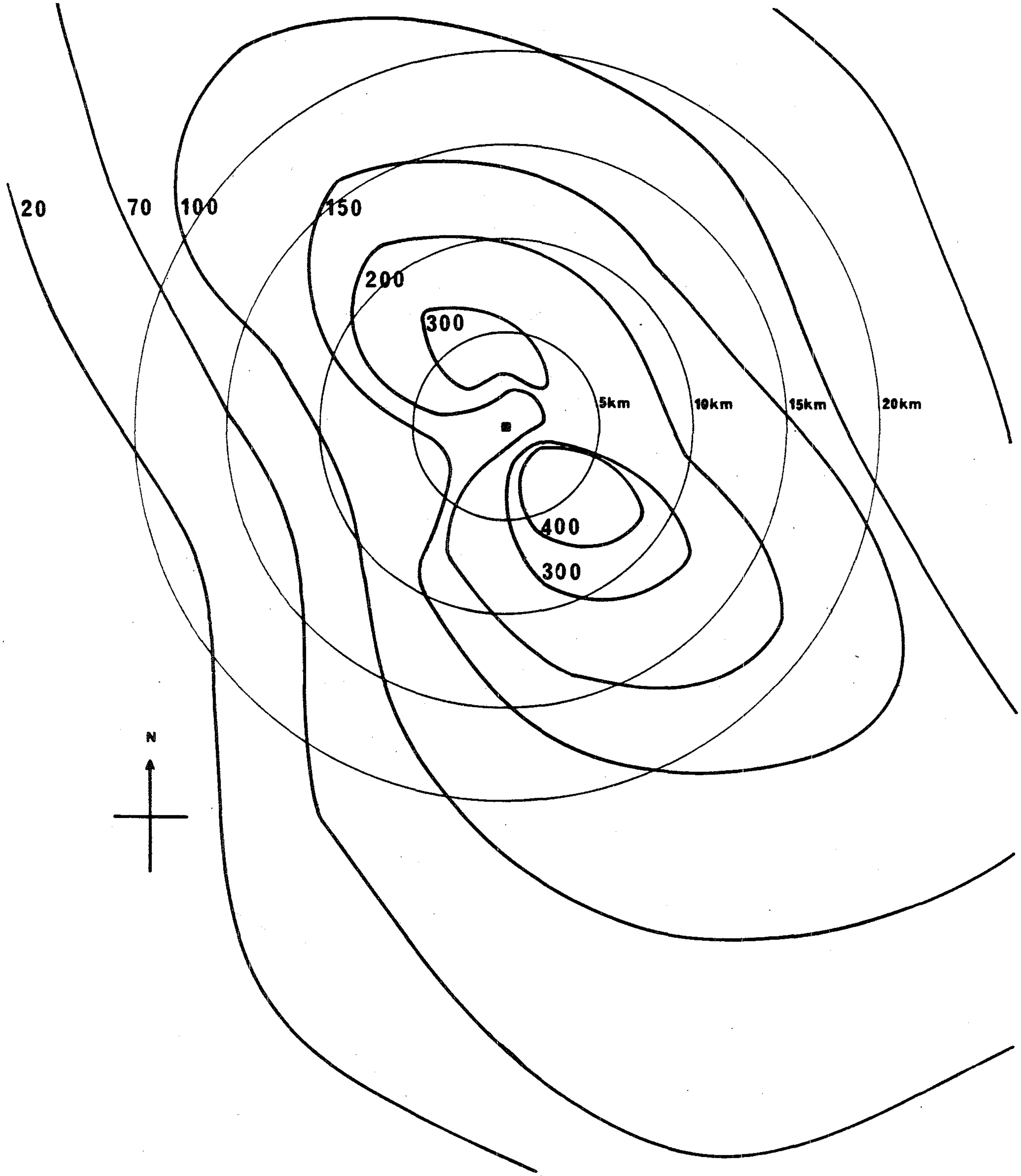


Figure 13B

Flux Contour Plot (0-100 km) for the Deposition of 10 μm Particles Based on 1 g s^{-1} Particulate Emission Rate
Fort Smith Climatological Data
Numbers on Contours are in Units of μg m^{-2} yr^{-1}

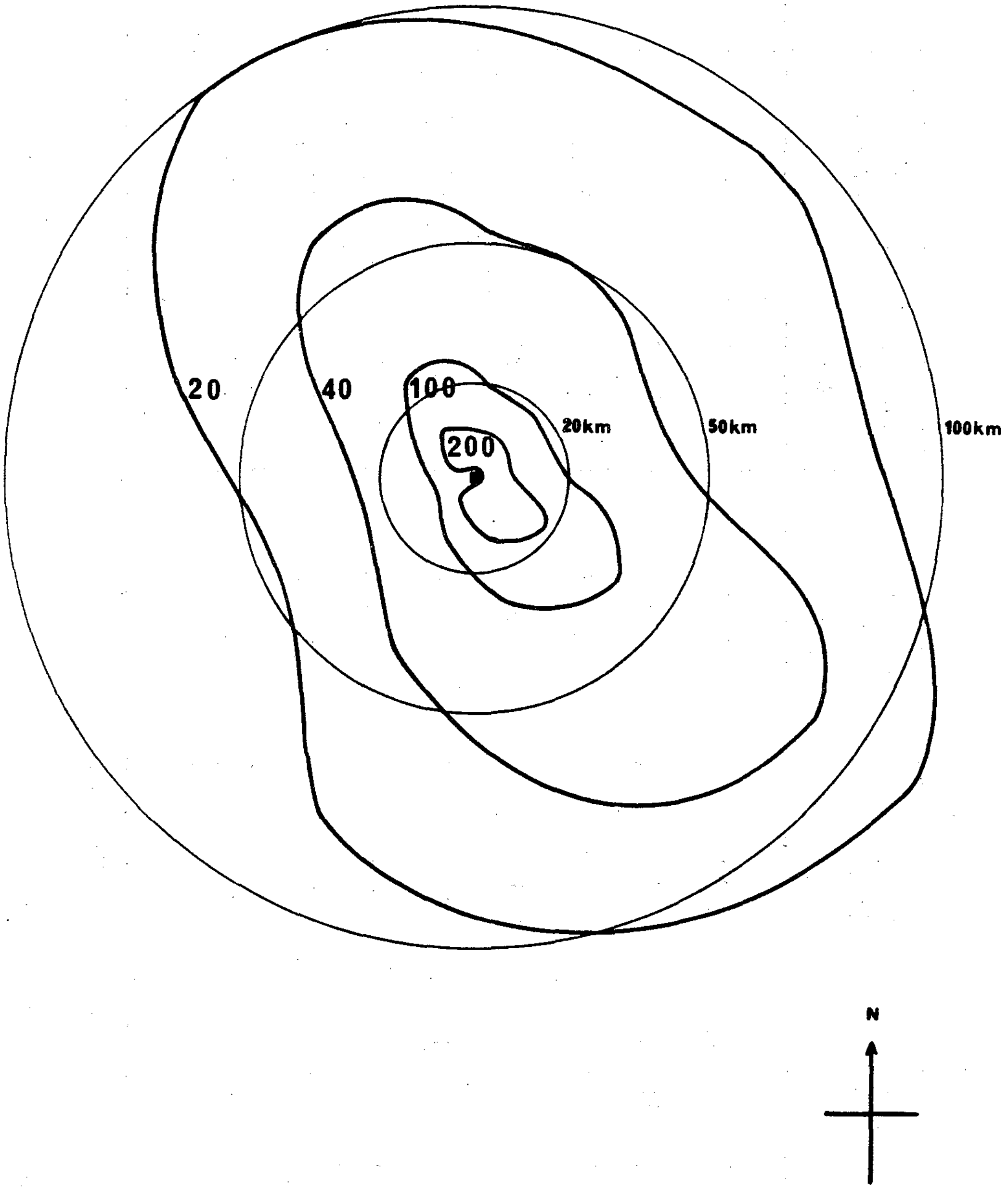


TABLE 1

Particulate Matter Sampling Results

Test	Probe Catch (mg)	Filter Catch (mg)	Total Particle Catch (mg)	Sample Volume Nm^3	Concentration mg/Nm^3*	Total Stack Gas Volume Nm^3/s	Emission Rate g/s
2A	323.6	302.0	625.6	7.87	79.5	510	40.6
2B	265.1	240.9	506.0	7.23	70.0	476	33.3
4A	504.4	127.3	631.7	7.74	81.6	520	42.5
4B	418.4	187.3	605.7	7.47	81.1	502	40.7
5A	175.1	179.6	354.7	7.67	46.2	522	24.1
5B	259.9	194.9	454.8	7.34	62.0	500	30.9
Mean	324.4	205.3	529.7	7.55	70.1	505	35.4**
Standard Deviation	108.9	54.4	111.5	0.25	14.0	17	7.2

*Nm^3 conditions are 25°C and 760 mm Hg

**Corresponds to 3,060 kg/day

TABLE 2

Sampling Information Summary

Test	Sampling Train	No. of Points Sampled	Total Sampling Time (min)	Sampling Volume (m^3)	Probe Catch (mg)	Particle Catch Per Cyclone or Filter (mg)						Total Particle Catch (mg)	Impinger Volumes (ml)		
													1	2	3
Test II June 14/84	Flow Sensor	4	480	9.864	N/A	205.3	6.12	6.80	1.87	2.44	140.6	363.1	N/A	N/A	N/A
	Train A	48	240	7.87	323.6	301.8						625.4	1237	547	238
	Train B	48	240	7.23	265.1	240.8						505.9	1388	309	N/A
Test IV June 18/84	Flow Sensor	4	480	9.864	N/A	144.7	24.37	7.54	4.20	1.14	73.61	255.6	N/A	N/A	N/A
	Train A	48	240	7.74	504.4	127.4						631.8	1333	303	135
	Train B	48	240	7.47	418.4	187.2						605.6	1301	309	N/A
Test V June 19/84	Flow Sensor	4	480	9.853	N/A	178.8	41.73	14.80	7.40	4.57	89.67	336.9	N/A	N/A	N/A
	Train A	48	240	7.67	175.1	179.7						354.8	1252	301	137
	Train B	48	240	7.34	259.9	194.9						454.9	1314	280	

TABLE 3

Analytical Results

Train 2A
Date June 14, 1984
Weight of Probe Wash Sample 323.6 mg
Weight of Filter Sample 301.8 mg
Volume of Impinger 1 & 2; 1237.5 ml.
Volume of Impinger 3 & 4; 547 ml.
Volume of Impinger 5 & 6; 238.5 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	8	BDL	8	5	12/12
Zn	48	BDL	48	BDL	BDL/BDL
P	27	70	97	BDL	BDL/BDL
Be	0.2	BDL	0.2	BDL	BDL/BDL
Si	1470	-	1470	-	- -
Fe	2820	4720	7540	5130	4580/4610
Mn	120	117	237	129	132/132
Ca	410	BDL	410	BDL	BDL/BDL
Mg	150	BDL	150	BDL	BDL/BDL
Cu	6	BDL	6	BDL	5/2
Al	1760	BDL	1760	BDL	BDL/BDL
V	260	430	691	419	373/385
Mo	14	BDL	14	BDL	23/23
Ni	110	131	241	131	141/147
Cr	13	BDL	13	9	15/15
Na	450	BDL	450	BDL	BDL/BDL
Ba	6	BDL	6	BDL	BDL/BDL
Ti	270	339	609	346	310/334
Zr	6	14	20	5	6/6
Sn	3	BDL	3	BDL	BDL/BDL
Cd	0.7	BDL	0.7	BDL	BDL/BDL
Pb	6.0	BDL	6.0	BDL	BDL/BDL
Ag	0.6	BDL	0.6	BDL	BDL/BDL
As	0.79	3.0	3.79	4.7	2.4/2.4
Se	1.12	7.4	8.52	8.0	3.6/3.6
Hg	0.16	BDL	0.16	BDL	BDL/BDL
Impingers					
1 & 2 As		BDL		4.9	BDL
3 & 4 As		0.30		1.6	BDL
Total As		0.30		6.5	BDL
Impingers					
1 & 2 Se		7.2		BDL	2.4
3 & 4 Se		2.5		0.45	BDL
Total Se		9.7		0.45	2.4
Impingers					
1 & 2 Hg		0.17		BDL	0.34
3 & 4 Hg		0.10		BDL	0.03
5 & 6 Hg		0.03		0.06	0.11
Total Hg		0.30		0.06	0.48
Total Particle & Vapour Metals					
As			4.1	11.2	2.4
Se			18.2	8.5	6.0
Hg			.46	0.06	0.48

TABLE 4

Analytical Results

Train 2R
Date June 14, 1984
Weight of Probe Wash Sample 265.1 mg
Weight of Filter Sample 240.8 mg
Volume of Impinger 1 & 2; 1387.9 ml.
Volume of Impinger 3 & 4; 309 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	26	BDL/BDL	26	5	6
Zn	220	BDL/BDL	220	BDL	BDL
P	110	93/148	230	BDL	BDL
Be	0.4	BDL/BDL	0.4	BDL	BDL
Si	3510	-/-	3510	-	-
Fe	5450	3610/3140	8820	5134	2873
Mn	260	99/85	352	129	84
Ca	4240	BDL/BDL	4240	BDL	BDL
Mg	740	BDL/BDL	740	BDL	BDL
Cu	32	BDL/BDL	32	BDL	1
Al	2280	BDL/BDL	2280	BDL	BDL
V	460	290/263	736	419	223
Mo	30	BDL/BDL	30	BDL	17
Ni	3100	71/57	3164	131	90
Cr	125	BDL/BDL	125	9	5
Na	870	BDL/BDL	870	BDL	BDL
Ba	23	BDL/BDL	23	BDL	BDL
Ti	670	230/189	880	346	166
Zr	12	BDL/BDL	12	5	6
Sn	7	BDL/BDL	7	BDL	BDL
Cd	29	BDL/BDL	29	BDL	BDL
Pb	98	BDL/BDL	98	BDL	BDL
Ag	BDL	BDL/BDL	BDL	BDL	BDL
As	1.89	3.0/3.0	4.89	4.7	1.2
Se	1.94	7.4/8.7	10.0	8.0	3.6
Hg	0.10	BDL/BDL	0.10	BDL	BDL
Impingers					
1 & 2 Pb		BDL		BDL	BDL
3 & 5 Pb		BDL		BDL	BDL
Total Pb		BDL		BDL	BDL
Impingers					
1 & 2 Cd		BDL		BDL	BDL
3 & 5 Cd		0.3		BDL	BDL
Total Cd		0.3		BDL	BDL
Total Particle & Vapour Metals					
Pb			98	BDL	BDL
Cd			29	BDL	BDL

TABLE 5

Analytical Results

Train 4A
Date June 18, 1984
Weight of Probe Wash Sample 504.4 mg
Weight of Filter Sample 127.4 mg
Volume of Impinger 1 & 2; 1332 ml.
Volume of Impinger 3 & 4; 303.5 ml.
Volume of Impinger 5 & 6; 135.5 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	6	BDL/BDL	6	BDL	BDL
Zn	38	BDL/BDL	38	BDL	BDL
P	31	44/BDL	53	BDL	BDL
Be	BDL	BDL/BDL	BDL	BDL	BDL
Si	1100	-/-	1100	-	-
Fe	2030	1280/1180	3260	1454	1253
Mn	78	27/27	105	41	36
Ca	460	BDL/BDL	460	BDL	BDL
Mg	1480	BDL/BDL	1480	BDL	BDL
Cu	6	BDL/BDL	6	BDL	1
Al	1870	BDL/BDL	1870	BDL	BDL
V	270	116/91	374	132	115
Mo	14	BDL/BDL	14	BDL	BDL
Ni	97	14/14	111	BDL	45
Cr	9	BDL/BDL	9	5	BDL
Na	1800	BDL/BDL	1800	BDL	BDL
Ba	13	BDL/BDL	13	BDL	BDL
Ti	280	70/67	348	88	82
Zr	7	BDL/BDL	7	BDL	BDL
Sn	4	BDL/BDL	4	BDL	BDL
Cd	0.4	BDL/BDL	0.4	BDL	BDL
Pb	5.0	1.7/BDL	5.8	BDL	BDL
Ag	0.6	BDL/BDL	0.6	BDL	BDL
As	1.21	2.0/1.3	2.86	1.6	1.2
Se	2.04	7.7/8.7	10.2	8.0	3.6
Hg	0.48	BDL/BDL	0.48	BDL	BDL
Impingers					
1 & 2 As		BDL		4.0	BDL
3 & 4 As		BDL		0.56	BDL
Total As		BDL		4.56	BDL
Impingers					
1 & 2 Se		6.3		1.2	1.6
3 & 4 Se		1.1		BDL	0.36
Total Se		7.4		1.2	1.96
Impingers					
1 & 2 Hg		0.16		BDL	1.3
3 & 4 Hg		BDL		BDL	1.3
5 & 6 Hg		BDL		BDL	BDL
Total Hg		0.16		BDL	2.6
Total Particle & Vapour Metals					
As			2.85	6.2	1.2
Se			17.6	9.2	5.56
Hg			.64	BDL	2.6

TABLE 6

Analytical Results

Train 4B
Date June 18, 1984
Weight of Probe Wash Sample 418.4 mg
Weight of Filter Sample 187.2 mg
Volume of Impinger 1 & 2; 1301, ml.
Volume of Impinger 3 & 4; 303.5 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	9	BDL	9	BDL/BDL	BDL
Zn	38	BDL	38	BDL/BDL	BDL
P	180	111	291	BDL/80	BDL
Be	BDL	BDL	BDL	BDL/BDL	BDL
Si	1300	-	1300	-/-	-
Fe	1800	2050	3850	1650/1470	1490
Mn	60	54	114	45/40	48
Ca	1420	BDL	1420	BDL/BDL	BDL
Mg	170	BDL	170	BDL/BDL	BDL
Cu	31	BDL	31	BDL/BDL	1
Al	1560	BDL	1560	BDL/BDL	BDL
V	250	236	490	154/142	139
Mo	14	BDL	14	BDL/BDL	BDL
Ni	4270	80	4350	64/49	69
Cr	20	BDL	20	BDL/BDL	BDL
Na	430	BDL	430	BDL/BDL	BDL
Ba	30	BDL	30	BDL/BDL	BDL
Ti	BDL	140	140	100/84	94
Zr	5	BDL	5	BDL/BDL	BDL
Sn	4	BDL	4	BDL/BDL	BDL
Cd	24	BDL	24	BDL/BDL	BDL
Pb	33	BDL	33	BDL/BDL	BDL
Ag	BDL	BDL	BDL	BDL/BDL	BDL
As	1.06	2.7	3.8	1.4/1.2	1.2
Se	1.86	9.1	11.0	6.1/4.5	3.6
Hg	0.43	BDL	.43	BDL/BDL	BDL
Impingers					
1 & 2 Pb		BDL		BDL	BDL
3 & 5 Pb		BDL		BDL	BDL
Total Pb		BDL		BDL	BDL
Impingers					
1 & 2 Cd		BDL		BDL	BDL
3 & 5 Cd		0.21		BDL	BDL
Total Cd		0.21		BDL	BDL
Total Particle & Vapour Metals					
Pb			33	BDL	BDL
Cd			24.2	BDL	BDL

TABLE 7

Analytical Results

Train 5A
Date June 19, 1984
Weight of Probe Wash Sample 175.1 mg
Weight of Filter Sample 179.7 mg
Volume of Impinger 1 & 2; 1252.ml.
Volume of Impinger 3 & 4; 301 ml.
Volume of Impinger 5 & 6; 137 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	3	BDL	3	BDL	BDL/6
Zn	18	BDL	18	BDL	BDL/BDL
P	16	BDL	16	BDL	BDL/BDL
Be	BDL	BDL	BDL	BDL	BDL/BDL
Si	820	-	820	BDL	-
Fe	1070	1280	2350	812	1070/1130
Mn	36	28	64	23	36/36
Ca	180	BDL	180	BDL	BDL/BDL
Mg	74	BDL	74	BDL	BDL/BDL
Cu	4	BDL	4	BDL	2/1
Al	1050	BDL	1050	BDL	BDL/BDL
V	140	129	269	83	103/109
Mo	9	BDL	9	BDL	BDL/BDL
Ni	44	28	72	BDL	45/45
Cr	8	BDL	8	BDL	BDL/BDL
Na	450	BDL	450	BDL	BDL/BDL
Ba	11	BDL	11	BDL	BDL/BDL
Ti	150	89	239	58	70/70
Zr	3	BDL	3	BDL	BDL/BDL
Sn	3	BDL	3	BDL	BDL/BDL
Cd	BDL	BDL	BDL	BDL	BDL/BDL
Pb	3	BDL	3	BDL	BDL/BDL
Ag	BDL	BDL	BDL	BDL	BDL/BDL
As	0.68	1.8	2.48	1.8	1.2/1.2
Se	1.94	7.8	9.74	5.4	2.4/2.4
Hg	0.19	BDL	.19	BDL	BDL/BDL
Impingers					
1 & 2 As		BDL		3.7	BDL
3 & 5 As		BDL		0.55	BDL
Total As		BDL		4.25	BDL
Impingers					
1 & 2 Se		5.7		BDL	1.5
3 & 5 Se		0.8		BDL	BDL
Total Se		6.5		BDL	1.5
Impingers					
1 & 2 Hg		0.34		BDL	0.38
3 & 4 Hg		BDL		BDL	0.45
5 & 6 Hg		0.002		0.011	0.053
Total Hg		0.34		0.011	0.88
Total Particle & Vapour Metals					
As			2.48	6.0	1.2
Se			16.2	5.4	3.9
Hg			.53	0.11	0.88

TABLE 8

Analytical Results

Train 5B
Date June 19, 1984
Weight of Probe Wash Sample 259.1 mg
Weight of Filter Sample 194.9 mg
Volume of Impinger 1 & 2; 1314.5 ml.
Volume of Impinger 3 & 4; 280 ml.
BDL = Below Blank Level; All data are blank corrected

Parameter	ORF (µg)			BML (µg)	DRL (µg)
Filter	Probe Wash	Filter or Impinger	Total	Filter or Impinger	Filter or Impinger
Co	7	BDL	7	BDL/BDL	6
Zn	24	BDL	24	BDL/BDL	BDL
P	140	48	188	BDL/BDL	BDL
Be	BDL	BDL	BDL	BDL/BDL	BDL
Si	1610	-	1610	-/-	-
Fe	1600	1300	2900	1400/789	1250
Mn	48	29	77	39/22	36
Ca	1170	BDL	1170	BDL/BDL	BDL
Mg	140	BDL	140	BDL/BDL	BDL
Cu	16	BDL	16	BDL BDL	1
Al	1630	BDL	1630	BDL/BDL	BDL
V	220	135	355	148/83	127
Mo	12	BDL	12	BDL/BDL	BDL
Ni	2740	52	2788	67/BDL	69
Cr	13	BDL	13	BDL/BDL	BDL
Na	380	BDL	380	BDL/BDL	BDL
Ba	54	BDL	54	BDL/BDL	BDL
Ti	240	84	324	97/54	82
Zr	5	BDL	5	BDL/BDL	BDL
Sn	5	BDL	5	BDL/BDL	BDL
Cd	15	BDL	15	BDL/BDL	BDL
Pb	38	BDL	38	BDL/BDL	BDL
Ag	1	BDL	1	BDL/BDL	BDL
As	0.90	1.8	2.7	1.2/0.9	1.2
Se	1.69	BDL	1.69	3.8/3.8	4.8
Hg	0.11	BDL	0.11	BDL	BDL
Impingers					
1 & 2 Pb		BDL		BDL	BDL
3 & 5 Pb		BDL		BDL	BDL
Total Pb		BDL		BDL	BDL
Impingers					
1 & 2 Cd		1.2		BDL	BDL
3 & 5 Cd		0.46		BDL	BDL
Total Cd		1.66		BDL	BDL
Total Particle & Vapour Metals					
Pb			38	BDL	BDL
Cd			16.6	BDL	BDL

TABLE 9

Analytical Results Flow Sensor Train (ORF)

(μg)

PARAMETER	Test II, June 14, 1984							Test IV, June 18, 1984							Test V, June 19, 1984						
Sample Volume	9.864 Nm^3							9.864 Nm^3							9.853 Nm^3						
Size Fraction (··)	6.05	2.55	1.89	0.70	0.36	Filter	Total	6.05	2.55	1.89	0.70	0.36	Filter	Total	6.00	2.52	1.86	0.69	0.36	Filter	Total
wt collected (mg)	205.3	6.12	6.80	1.87	2.44	140.6	363	144.7	24.37	7.54	4.20	1.14	73.61	256	178.75	41.73	14.80	7.40	4.57	89.67	336
Co	14.6	<4.3	<1	<1	<1	<3.35	19.9	7.2	<4.9	<1	<1	1	<3.35	12.8	12.5	8.8	<1	<1	1	<3.35	25.0
Zn	18.7	5.2	1	<1	2	<10.8	32.8	23.2	19.5	<1	2	<1	<10.8	50.1	19.7	10.4	1	<1	1	<10.8	38.0
P	39.0	<24.5	<5	<5	<5	<16	66.8	<14.5	<24.4	<5	<5	6	<16	35.6	21.4	<12.5	<5	<5	<5	<16	43.2
Be	.45	<1.2	<0.2	<.3	<0.3	<.97	<1.2	<.72	<1.46	<.3	<.3	0.05	<.97	<1.9	<.72	<.83	0.05	<0.05	0.05	<.97	<1.37
Si	3860	104	340	140	9	<93	4500	1590	560	330	120	5	<93	2650	1640	876	510	120	<5	<93	3200
Fe	4886	239	370	160	15	122	5790	1580	755	300	180	24	83.5	2920	3910	1960	480	100	1	146	6606
Mn	205	6.1	11	6	<1	4.5	233	48	48.7	30	16	<1	28.6	172	804	208	14	3	<1	13.8	1040
Ca	524	<24.5	38	13	<5	<105	642	289	112	35	19	<5	<105	510	350	117	74	13	<1	<105	610
Mg	224	9.8	17	7	<1	<34	275	116	46.3	15	7	<1	<34	202	139	55.9	27	6	<1	<34	245
Cu	22.2	<4.3	5	3	1	8.6	41.9	8.7	<4.9	3	3	<1	<3.1	19.3	30.4	50.5	2	1	<1	4.7	89.1
Al	3100	171	250	100	4	<35	3640	1610	582	210	95	2	<35	2510	1910	818	420	86	<1	<35	3260
V	489	21.4	27	11	<1	<3.1	550	258	68.2	22	10	<1	<3.1	360	286	96	39	8	<1	<3.1	432
Mo	26.7	<12.2	<3	<3	<3	<9.6	42.1	17.4	17.0	<3	<3	<1	<9.6	42.7	<8.9	18.8	<1	<1	<1	<9.6	29.6
Ni	181	12.8	13	10	1	16.4	234	83.9	31.7	13	15	3	3.8	150	340	308	18	6	<1	10.6	683
Cr	28.7	<4.3	3	4	2	7.4	47	13.0	7.3	7	11	4	3.8	46.1	500	216	8	2	<1	10.6	737
Na	595	<220	<50	<50	<50	6820	7600	362	~292	<50	<50	<50	4480	5200	536	292	60	<50	<50	3720	4660
Ba	20.5	<1.22	1.5	0.6	<0.3	<3.18	24.6	9.1	3.2	1.4	0.6	<0.3	<3.18	16.0	10.7	4.2	2.4	0.5	<0.3	<3.2	19.5
Ti	731	33.7	6.5	23	0.8	.78	796	263	110	50	18	0.6	.31	442	268	153	77	15	0.3	.46	513
Zr	19.5	1.8	1	<0.3	<0.3	<.84	23	8.4	4.6	1.0	<0.3	<0.3	<.84	14.7	10.0	17.1	1.5	<0.3	<0.3	1.71	29.8
Sn	<3.1	<4.3	2	2	<1	<3.2	7.8	<2.9	<4.9	2	2	1.0	<3.2	10.5	<3.6	~3.8	2	2	1	<3.2	10.3
Cd	<.82	<1.2	<0.3	<0.3	<0.3	<1.0	<1.2	<.72	<1.2	<0.3	<0.3	<0.3	<1.0	<1.2	<.89	2.5	<0.3	<0.3	<0.3	<1.0	<2.6
Pb	<3.0	<4.3	<1	<1	<1	2.6	7.8	<2.9	<4.9	<1	<1	<1	<3.2	<3.2	<3.6	7.9	1	<1	<1	<3.15	13.3
Ag	2.7	<2.4	<0.5	<0.5	<0.5	<2.6	6.0	<1.4	<2.4	<0.5	<0.5	<0.5	<2.6	<3.9	<1.8	0.83	<0.5	<0.5	<0.5	<2.6	<3.8
As	1.5	.16	0.11	0.05	<0.03	1.65	3.5	0.82	.30	0.08	0.06	<0.03	.62	1.37	1.1	0.79	0.10	0.05	0.03	.65	2.72
Se	2.6	.34	<.05	<.05	<0.05	.47	3.5	2.02	0.73	<0.05	<.05	<.05	.36	2.64	1.5	0.21	0.12	<0.05	<0.05	<.27	2.01
Hg	0.16	.009	<.007	<.007	<0.007	<.010	.18	0.04	0.03	<.007	<.007	<.007	<.0067	0.084	.038	<.012	<.007	<0.01	<.007	<.0065	0.064

TABLE 10

Laboratory Intercomparison - NBS-SRM1648
µg/g

		BML		ORF**		ORF(^{2})		DRL	
Certified Values µg/g		#2747	#2748	#2743	#2744	#2743	#2744	#2745	#2746
Co	18	9	10	21	20	20	20	20	20
*Zn	4,760 + 140	4,360	4,770	4,500	4,220	4,310	4,370	4,480	4,560
P		7,830	7,860	7,700	6,990	7,450	7,500	7,120	7,100
Be		1.06	1.07	2.3	2.2	2.3	2.2	2	2
Si		673	656	17,500Δ	17,100Δ	140,000	107,000	<100	<100
*Fe	39,100 ± 1,000	31,500	31,800	32,700	30,500	38,800	38,500	38,800	38,000
Mn	860	669	722	740	720	780	790	889	900
Ca		58,000	61,600	57,700	50,600	60,200	59,100	52,200	53,400
Mg	8,000	5,710	6,110	6,500	5,890	7,420	7,720	6,380	6,220
*Cu	609 ± 27	570	580	560	560	620	630	572	572
*Al	34,200 ± 1,100	12,900	13,900	12,400Δ	12,100Δ	30,000	31,300	13,400	13,100
*V	140 ± 3	86.7	85.5	104	104	101	102	92	92
Mo		20	<20	35Δ	33Δ	69	69	36	36
*Ni	82 ± 3	60	64	51	50	54	53	78	74
*Cr	403 ± 12	75	74	101Δ	121Δ	260	300	106	104
*Na	4,250 ± 20	2,000	2,000	3,030	3,180	3,380	2,990	1,720	1,720
Ba	737	139	165	408	590	706	711	260	252
Ti	4,000	532	565	1,340Δ	1,070Δ	3,720	3,640	990	848
Zr		5	5	14Δ	13Δ	163	180	4	2
Sn		127	140	150	130	108	113	80	86
*Cd	75 ± 7	52^{+} (66)	53^{+} (67)	81	73	62	77	74	72
*Pb	6,550 ± 80	6,800	6,600	5,180	5,310	5,780	5,810	6,440	6,380
Ag	6	6^{+} (2.4)	6^{+} (2.1)	7.0	6.5	No Result	No Result	8	8
*As	115 ± 10	173	181	110	113	No Result	No Result	130	130
*Se	27 ± 1	21.4	21.4	16.5	17.0	No Result	No Result	34	36
Hg		1.42	1.52	1.3	1.2	No Result	No Result	1.1	0.99

NOTES:
Δ for ORF, HF digestion has used on a separate sample and these elements showed significantly great recovery.
\+ by AA where noted (when performed by 2 methods).
* certified values.
** Total digestion method results

TABLE 11

Laboratory Intercomparison - Solution Standards (ppm)

	STANDARD 1 (Blank Solution)				STANDARD 2				STANDARD 3				STANDARD 4			
Element	Theoretical Value	BML	ORF	DRL	Theoretical Value	BML	ORF	DRL	Theoretical Value	BML	ORF	DRL	Theoretical Value	BML	ORF	DRL
Al		<0.01	<0.01	<0.015	-	<0.01	0.04	<0.015	2.00	2.06	1.80	1.60	0.50	0.51	0.50	0.41
Ba		<0.005	<0.003	<0.006	-	<0.005	<0.003	<0.006	0.50	0.496	0.42	0.40	0.12	0.121	0.11	0.10
Ca		<0.01	<0.05	<0.015	-	0.03	<0.05	<0.015	2.00	2.09	1.70	1.40	0.50	0.49	0.46	0.57
Cr		<0.01	0.01	0.003	-	<0.01	<0.01	<0.003	0.50	0.51	0.40	0.50	0.12	0.12	0.09	0.13
Fe		<0.01	<0.01	<0.006	-	<0.01	0.03	0.006	4.00	4.64	3.56	3.60	1.00	1.11	0.95	0.93
Hg		0.004	<0.00007	<0.0002	0.50	0.40	0.504	0.48	-	<0.0005	<0.00007	0.0028	-	0.0005	<0.00007	<0.0002
Mg		<0.01	<0.01	0.005	-	0.02	<0.01	<0.005	1.50	1.48	1.23	1.10	0.38	0.38	0.33	0.32
Mn		<0.01	<0.01	<0.015	-	<0.01	<0.01	<0.015	0.50	0.53	0.45	0.46	0.12	0.13	0.12	0.12
Na		<1	<0.50	<0.40	1.50	2	1.70	1.60	6.00	23.0	20.0	<0.4	1.50	6	5.70	4.80
Ni		<0.05	<0.01	<0.02	-	<0.05	0.01	<0.02	1.00	0.89	0.69	0.87	0.25	0.22	0.17	0.23
Pb		<0.05	0.03	<0.03	0.50	0.40	0.51	0.49	0.50	0.45	0.49	0.49	0.12	<0.05	0.12	0.13
Se		<0.001	<0.0005	<0.003	0.50	1.40	1.12	0.78	-	<0.001	<0.0005	<0.003	-	<0.001	0.0007	<0.003
Si		<0.05	0.27	0.015	-	<0.05	0.44	0.025	1.00	10.1	0.66	7.50	0.25	.238	0.23	.20
Sn		<0.01	0.01	<0.025	-	<0.01	0.01	<0.025	0.50	<0.01	0.48	0.49	0.12	<0.01	0.14	0.08
V		<0.005	<0.01	0.005	0.50	0.47	0.45	0.47	1.00	1.02	0.85	0.87	0.25	0.222	0.23	0.23
Zn		<0.05	0.01	0.013	-	<0.05	<0.01	<0.013	2.00	2.20	1.75	1.80	0.50	0.51	0.47	0.49

TABLE 12

Sample Composition Comparison

(μg/g)

	Soil Sample - June 12/84 (Vicinity of Trailer)							Coke Dust on Ground - June 12/84						
	ORF		DRL		BML			ORF		DRL		BML		
	#2644	#2645	#2646	#2647	#2648	#2649	$\bar{x}$ ± S.D.	#2650	#2651	#2652	#2653	#2654	#2655	$\bar{x}$ ± S.D.
Co	3.4	3.7	4	2	<5	<5	3.8 ± 1.1	2.4	2.3	2	3	<5	<5	3.3 ± 1.4
Zn	28	27	28	64	57	50	42 ± 17	65	54	63	32	80	68	60 ± 16
P	110	150	110	110	220	150	140 ± 43	38	37	40	40	<50	<50	42 ± 6
Be	0.3	0.4	0.2	0.4	0.1	0.1	0.2 ± 0.1	0.3	0.3	<0.2	<0.2	<0.05	<0.05	0.2 ± 0.1
Si	1,430	1,890	<100	160	233	225	670 ± 780	260	430	130	170	90	92	200 ± 130
Fe	7,660	10,500	11,000	9,270	16,500	10,900	11,100 ± 3,000	8,050	7,090	8,850	9,270	11,500	8,190	8,800 ± 1,500
Mn	140	146	134	97	242	154	150 ± 50	78	85	89	153	93	70	95 ± 30
Ca	14,200	18,900	10,800	11,700	11,200	13,700	13,000 ± 3,000	2,260	2,912	2,490	2,890	1,790	2,290	2,400 ± 420
Mg	3,210	6,190	3,370	4,320	3,650	3,570	4,050 ± 1,100	660	720	678	728	409	540	620 ± 120
Cu	13	13	6	7	10	8	9.6 ± 2.9	10	8	9	8	14	8	9.5 ± 2.3
Al	1,560	1,630	1,790	1,920	2,370	2,130	1,900 ± 300	760	660	720	750	690	770	720 ± 43
V	28	27	32	29	34	30	30 ± 2.6	30	38	46	43	41	45	40 ± 5.9
Mo	9	8	8	8	<20	<20	12 ± 6.1	4	4	6	8	<20	<20	10 ± 7.6
Ni	11	12	17	22	23	19	17 ± 5.0	11	13	22	18	26	21	18 ± 5.7
Cr	8	8	12	16	13	15	12 ± 3.4	9	5	12	12	13	9	10 ± 3.0
Na	410	430	130	140	200	200	250 ± 130	170	190	70	60	100	100	120 ± 53
Ba	22	24	23	22	32	21	24 ± 4.0	6	7	7	7	8	6	6.8 ± 0.8
Ti	87	83	110	108	65	71	87 ± 18	39	41	42	53	31	35	40 ± 7.5
Zr	3	3	3	3	<5	<5	3.7 ± 1.0	2	2	2	2	<5	<5	3 ± 1.5
Sn	5	7	<2	<2	<10	<10	6 ± 3.6	2	2	<2	<2	<10	<10	4.7 ± 4.1
Cd	0.2	0.4	<2	<2	<1	<1	1.1 ± 0.8	0.2	0.3	<2	<2	<1	<1	1.1 ± 0.8
Pb	10	10	20	10	15	10	12 ± 4.2	5	7	10	20	<5	<5	8.7 ± 5.9
Ag	<0.5	<0.5	<1	<1	<0.5	<0.5	<1 ± -	<0.5	<0.5	<1	<1	<0.5	<0.5	0.7 ± 0.2
As	1.8	2.6	1.2	1.2	2.4	1.9	1.8 ± 0.6	1.7	1.5	1.0	1.2	1.5	1.1	1.3 ± 0.3
Se	0.2	0.2	<0.2	0.2	0.3	0.3	0.2 ± 0.05	0.1	0.1	<0.2	<0.2	0.3	0.3	0.2 ± 0.09
Hg	0.03	0.02	0.02	0.02	0.14	<0.02	0.04 ± 0.05	<0.004	0.004	<0.005	0.010	<0.02	<0.02	0.01 ± 0.008

TABLE 12 (Cont'd)

Sample Composition Comparison
(μg/g)

	E.S.P. Hopper A2 B7 - June 17/84				Combined Cyclone Catches (ORF only)			
	ORF #2656	DRL #2657	BML #2658	$\bar{x}$ ± S.D.	Test #2	Test #4	Test #5	$\bar{x}$ ± S.D.
Co	24	32	25	27 ± 4	55	50	74	60 ± 13
Zn	22	29	40	30 ± 9	90	196	113	133 ± 56
P	126	120	110	119 ± 8	184	139	128	150 ± 30
Be	0.7	0.6	<0.05	0.4 ± 0.35	<3	<7	<4	<5 ± 2
Si	460	<100	380	314 ± 189	12,400	10,400	9,500	10,760 ± 1,490
Fe	7,200	9,270	9,880	8,780 ± 1,400	16,000	11,400	19,600	15,700 ± 4,100
Mn	220	290	265	258 ± 35	640	672	3,080	1,460 ± 1,400
Ca	1,290	1,390	1,870	1,510 ± 314	1,770	2,000	1,800	1,860 ± 122
Mg	500	680	756	647 ± 132	760	790	730	758 ± 31
Cu	14	16	13	14.3 ± 1.5	120	76	260	152 ± 99
Al	8,190	11,400	11,100	10,230 ± 1,770	10,000	9,830	9,660	9,840 ± 185
V	1,570	1,840	1,790	1,730 ± 144	1,520	1,410	1,280	1,400 ± 116
Mo	113	115	110	113 ± 2.5	120	170	88	124 ± 40
Ni	400	557	504	487 ± 80	640	590	2,030	1,090 ± 815
Cr	10	21	18	16.3 ± 5.8	130	180	2,190	832 ± 1,170
Na	1,430	1,450	1,300	1,390 ± 81	20,900	20,400	13,800	18,400 ± 3,950
Ba	47	52	60	52.9 ± 6.4	68	63	58	63 ± 5
Ti	360	518	470	451 ± 82	2,190	1,730	1,520	1,820 ± 340
Zr	16	10	20	15 ± 5	63	58	88	70 ± 16
Sn	4.9	<2	<10	~5.6 ± 4	22	41	31	31 ± 10
Cd	0.9	<2	<1	~1.3 ± 0.6	<3.3	<5	<8	<5 ± 2
Pb	18	24	10	17.2 ± 7.0	22	<12	39	<24 ± 13
Ag	<1	<1	<0.5	~0.8 ± 0.3	16	<16	<11	<14 ± 3
As	2.5	2.0	3.3	2.6 ± 0.66	10	5	8	8 ± 2
Se	2.3	5.0	2.6	3.3 ± 1.5	10	10	6	9 ± 2
Hg	<0.01	0.005	<0.02	~0.012 ± 0.008	0.5	0.3	<0.2	0.3 ± 0.2

TABLE 13

Analytical Detection Limits

	Solutions μg/ml			Filters ** μg/filter (total) (Blank values)		
	ORF	BML	DRL	ORFΔ	BML	DRL
Co	0.01	0.02	0.01	11	8	6
Zn	0.01	0.03	0.013	49	80	42
P	0.05	0.30	0.13	60	80	60
Be	0.0005	0.0003	0.003	3	.7	1.2
Si		0.03		460	160	1,010
Fe	0.01	0.005	0.006	80	66	127
Mn	0.01	0.005	0.015	11	2	6
Ca	0.05	0.01	0.015	6,640	4,700	11,200
Mg	0.01	0.005	0.005	2,760	1,990	4,460
Cu	0.01	0.002	0.003	11	6.3	2.6
Al	0.01	0.01	0.015	3,250	2,380	4,900
V	0.01	0.003		11	0.8	5
Mo	0.03	0.10	0.015	33	30	6
Ni	0.01	0.03	0.02	11	19	9
Cr	0.01	0.005	0.003	11	7.7	6
Na	0.50	0.50	0.40	22,400	18,100	28,800
Ba	0.003	0.003	0.006	50	42	80
Ti		0.003	0.003	3	0.8	2.6
Zr	0.003	0.02	0.015	4	8	6
Sn		0.01	0.025	11	50	12
Cd	0.001	0.002	0.01	3	2	12
Pb	0.01	0.01	0.02	11	10	22
Ag	0.005	0.003	0.015	6	0.8	6
As	0.0003	0.001	0.003	.3	0.2	1.2
Se	0.0005	0.001	0.001	1.2	0.2	1.2
Hg	0.00007	0.00004	0.0002	.03	0.06	.06

Δ Based on 2 samples from test 2

* Based on 1st cyclone samples only

** Based on average of 6 blank filter values for each element

TABLE 14

Annual Mean Concentration (x 10^{-4} $\mu g/m^3$) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Edmonton
Particle Size - 0.10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	0.86	3.49	3.05	1.75	1.20	0.92	0.62	0.37	0.17
225° - 265°	0.96	3.87	3.43	1.97	1.35	1.04	0.70	0.41	0.20
265° - 305°	1.79	7.18	6.36	3.65	2.51	1.92	1.29	0.76	0.36
305° - 345°	2.09	8.30	7.44	4.27	2.93	2.24	1.51	0.89	0.42
345° - 25°	1.50	6.03	5.34	3.07	2.11	1.61	1.08	0.64	0.30
25° - 65°	1.30	5.24	4.64	2.67	1.83	1.40	0.94	0.56	0.27
65° - 105°	3.20	1.28	11.40	6.53	4.49	3.43	2.3	1.36	0.65
105° - 145°	4.28	17.00	15.30	8.76	6.02	4.60	3.09	1.82	0.87
145° - 185°	1.86	7.46	6.61	3.80	2.01	1.99	1.34	0.79	0.38
Total*	17.84	71.85	63.57	36.47	24.45	19.15	12.87	7.60	3.62

* Sector independent values

TABLE 15

Annual Mean Concentration (x 10^{-4} $\mu g/m^3$) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Edmonton
Particle Size - 10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	0.86	3.43	3.03	1.71	1.17	0.89	0.59	0.34	0.15
225° - 265°	0.96	3.86	3.41	1.93	1.32	1.00	0.66	0.38	0.17
265° - 305°	1.78	7.15	6.32	3.57	2.44	1.85	1.22	0.70	0.31
305° - 345°	2.09	8.37	7.39	4.18	2.85	2.16	1.43	0.82	0.36
345° - 25°	1.50	6.01	5.30	3.00	2.05	1.55	1.03	0.59	0.26
25° - 65°	1.30	5.22	4.61	2.61	1.78	1.35	0.89	0.51	0.22
65° - 105°	3.19	12.80	11.30	6.39	4.36	3.31	2.19	1.25	0.55
105° - 145°	4.28	17.20	15.20	8.57	5.85	4.44	2.93	1.67	0.73
145° - 185°	1.86	7.44	6.57	3.71	2.54	1.92	1.27	0.73	0.32
Total*	17.73	71.48	63.13	35.67	24.36	18.47	12.21	6.99	3.07

* Sector independent values

TABLE 16

Annual Mean Concentration (x 10^{-4} μg/m^3) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Fort Smith
Particle Size - 0.10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	0.86	3.43	3.34	2.03	1.42	1.09	0.75	0.45	0.22
225° - 265°	0.54	2.14	2.08	1.27	0.88	0.68	0.46	0.28	0.13
265° - 305°	0.86	3.43	3.34	2.03	1.42	1.09	0.75	0.45	0.22
305° - 345°	2.31	9.24	9.01	5.48	3.82	2.99	2.01	1.21	0.58
345° - 25°	1.42	5.66	5.52	3.36	2.34	1.80	1.23	0.74	0.36
25° - 65°	1.06	4.22	4.12	2.51	1.74	1.35	0.92	0.55	0.27
65° - 105°	1.19	4.77	4.65	2.83	1.97	1.52	1.04	0.62	0.30
105° - 145°	2.54	10.10	9.88	6.01	4.18	3.23	2.20	1.32	0.64
145° - 185°	1.67	6.66	6.49	3.95	2.75	2.12	1.45	0.87	0.42
Total*	12.45	49.65	48.43	29.47	20.52	15.87	10.81	6.49	3.12

* Sector independent values

TABLE 17

Annual Mean Concentration (x 10^{-4} $\mu g/m^3$) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Fort Smith
Particle Size - 10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	0.85	3.42	3.32	2.00	1.38	1.05	0.71	0.41	0.18
225° - 265°	0.54	2.13	2.07	1.25	0.86	0.66	0.44	0.25	0.11
265° - 305°	0.86	3.42	3.32	2.00	1.38	1.05	0.71	0.41	0.18
305° - 345°	2.31	9.22	8.94	5.39	3.72	2.84	1.90	1.10	0.48
345° - 25°	1.42	5.65	5.48	3.30	2.28	1.74	1.16	0.67	0.30
25° - 65°	1.06	4.21	4.09	2.46	1.70	1.30	0.87	0.50	0.22
65° - 105°	1.19	4.76	4.61	2.78	1.92	1.47	0.98	0.57	0.25
105° - 145°	2.54	10.10	9.80	5.91	4.08	3.11	2.08	1.21	0.53
145° - 185°	1.67	6.64	6.44	3.88	2.68	2.05	1.37	0.79	0.35
Total*	12.44	49.55	48.07	29.97	20.00	15.27	10.22	5.91	2.50

* Sector independent values

TABLE 18

Annual Deposition Flux (μg m^{-2} yr^{-1}) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Edmonton
Particle Size - 0.10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	33.3	136	114	63.4	43.5	33.1	22.1	12.9	6.01
225° - 265°	28.2	114	96.8	54.5	37.4	28.5	19.0	11.1	5.22
265° - 305°	36.5	145	126	71.5	49.1	37.4	25.0	14.7	6.92
305° - 345°	43.5	175	158	92.5	63.4	48.4	32.4	19.0	8.98
345° - 25°	52.8	214	164	104	71.5	54.4	36.3	21.2	9.90
25° - 65°	44.9	182	157	89.9	61.6	46.9	31.3	18.3	8.52
65° - 105°	96.8	392	340	194	133	101	67.8	39.6	18.5
105° - 145°	123	499	439	254	174	133	88.6	51.8	24.3
145° - 185°	59.3	242	208	118	81.1	61.7	41.2	24.1	11.3

TABLE 19

Annual Deposition Flux ($\mu g\ m^{-2}\ yr^{-1}$) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Edmonton
Particle Size - 10 µm

Sector / Distance (km)	1	3	5	10	15	20	30	50	100
185° - 275°	64.5	264	223	123	84.1	63.6	41.9	23.9	10.4
225° - 265°	38.2	233	201	112	76.7	58.1	38.3	21.8	9.54
265° - 305°	82.7	319	284	161	110	83.2	55.0	31.4	13.8
305° - 345°	97.3	387	353	203	139	105	69.6	39.7	17.4
345° - 25°	101	408	353	198	135	102	67.3	38.3	16.6
25° - 65°	84.1	336	293	165	113	85.3	56.1	31.8	13.8
65° - 105°	193	773	677	382	261	198	130	74.1	32.3
105° - 145°	246	988	877	499	340	258	170	96.8	42.2
145° - 185°	118	482	418	235	161	122	803	45.7	19.9

TABLE 20

Annual Deposition Flux (μg m^{-2} yr^{-1}) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Fort Smith
Particle Size - 0.10 μm

Distance (km) Sector	1	3	5	10	15	20	30	50	100
185° - 275°	32.9	140	131	79.0	55.0	42.1	28.5	17.0	7.97
225° - 265°	18.1	76.4	72.2	43.6	30.3	23.2	15.8	9.39	4.42
265° - 305°	25.8	107	102	61.3	42.7	32.7	22.1	13.2	6.20
305° - 345°	43.9	170	170	104	72.6	55.8	38.0	22.7	10.8
345° - 25°	39.8	161	157	96.0	66.9	31.4	35.0	20.9	9.88
25° - 65°	37.6	157	150	90.4	63.0	48.3	32.7	19.5	9.16
65° - 105°	35.0	141	138	84.7	59.1	45.4	30.9	18.4	8.72
105° - 145°	71.9	297	284	172	120	92.1	62.5	37.3	17.6
145° - 185°	53.0	223	211	127	88.8	68.1	46.2	27.5	13.0

TABLE 21

Annual Deposition Flux (μg m^{-2} yr^{-1}) by Sector at Different Distances

Based on Unit Emission Rates
Climatological Station - Fort Smith
Particle Size - 10 μm

Sector \ Distance (km)	1	3	5	10	15	20	30	50	100
185° - 275°	62.5	262	246	147	102	77.5	51.7	29.8	13.0
225° - 265°	35.6	147	139	83.6	57.8	44.0	29.4	17.0	7.42
265° - 305°	51.1	204	196	117	81.0	61.5	41.0	23.6	10.3
305° - 345°	100	371	375	227	156	119	79.6	45.9	21.0
345° - 25°	80.0	318	311	188	130	99.3	66.5	38.4	16.8
25° - 65°	71.6	294	280	168	116	88.4	59.0	34.0	14.8
65° - 105°	68.9	273	268	153	113	85.9	57.5	33.2	14.5
105° - 145°	148	593	572	344	238	181	121	69.9	30.6
145° - 185°	107	444	422	254	176	134	89.5	51.7	22.7

APPENDIX II

Stack Sampling Results

```
PARTICULATE EMISSION REPORT                         DATE : 14/06/84
CONCORD/SYNCRUDE                                    RUN  : 2A
REF. No. : 1085



 CONCENTRATION @ 12% CO2  112.2 mg/Nm3           0.0491 g/Scf
               @ ACT CO2   79.5 mg/Nm3           0.0347 g/Scf
                           44.2 mg/Am3           0.0193 g/Acf

 EMISSION RATE             40.59 g/s             322.17 lb/hr


 SAMPLING VOLUME            7.87 Nm3             277.72 Scf

 AVERAGE ISOKINETICITY    104.7 %


 FLUE GAS CHARACTERISTICS

 MOISTURE                  18.74 %

 TEMPERATURE               237.1 deg C            458.8 deg F

 FLOW                    1837880 Nm3/hr         1081740 Scfm
                         4064230 m3/hr          2392130 Acfm

 VELOCITY                  23.11 m/s             4549.2 fpm


 GAS ANALYSIS
               O2          3.50 %
               CO22         8.50 %
               CO          0.02 %
               MOL. WT.    29.5 g/g MOLE (DRY)


 *STANDARD CONDITIONS : METRIC   0 deg C. 101.325 kPa
                        IMPERIAL 77 deg F. 29.92 in. Hg
```

```
PARTICULATE EMISSION REPORT                     DATE : 14/06/84
CONCORD/SYNCRUDE                                RUN  : 2B
REF. No. : 1085




 CONCENTRATION @ 12% CO2    98.7 mg/Nm3          0.0432 g/Scf
               @ ACT CO2    69.9 mg/Nm3          0.0306 g/Scf
                            39.1 mg/Am3          0.0171 g/Acf

 EMISSION RATE             33.29 g/s             264.17 lb/hr


 SAMPLING VOLUME            7.23 Nm3             255.37 Scf

 AVERAGE ISOKINETICITY     102.4 %


 FLUE GAS CHARACTERISTICS

 MOISTURE                  19.38 %

 TEMPERATURE               236.8 deg C            458.2 deg F

 FLOW                    1713070 Nm3/hr        1008280 Scfm
                            3796940 m3/hr         2234810 Acfm

 VELOCITY                  21.59 m/s             4250.0 fpm

 GAS ANALYSIS
                 O2         3.50 %
                 CO2        8.50 %
                 CO         0.02 %
                 MOL. WT.   29.5 g/g MOLE (DRY)



 *STANDARD CONDITIONS : METRIC   0 deg C. 101.325 kPa
                        IMPERIAL 77 deg F. 29.92 in. Hg
```

```
PARTICULATE EMISSSSSION REPORT                  DATE : 18/06/84
CONCORD/SYNCRUDE                             RUN  : 4A
REF. No. : 1085




 CONCENTRATION @ 12% CO2  108.9 mg/Nm3          0.0476 g/Scf
              @ ACT CO2    81.7 mg/Nm3          0.0357 g/Scf
                           45.9 mg/Am3          0.0201 g/Acf

 EMISSION RATE            42.52 g/s             337.46 lb/hr


 SAMPLING VOLUME           7.74 Nm3             273.17 Scf

 AVERAGE ISOKINETICITY    101.0 %


 FLUE GAS CHARACTERISTICS

 MOISTURE                 18.64 %

 TEMPERATURE              234.2 deg C            453.6 deg F

 FLOW                   1874320 Nm3/hr         1103190 Scfm
                        4094520 m3/hr          2409960 Acfm

 VELOCITY                 23.28 m/s             4583.1 fpm

 GAS ANALYSIS
              O2           4.00 %
              CO2          9.00 %
              CO           0.02 %
              MOL. WT.     29.6 g/g MOLE (DRY)



 *STANDARD CONDITIONS : METRIC   0 deg C. 101.325 kPa
                       IMPERIAL 77 deg F. 29.92 in. Hg
```

```
PARTICULATE EMISSION REPORT                       DATE : 16/06/84
CONCORD/SYNCRUDE                                  RUN  : 4B
REF. No. : 1085



 CONCENTRATION @ 12% CO2  108.1 mg/Nm3          0.0473 g/Scf
               @ ACT CO2   81.1 mg/Nm3          0.0354 g/Scf
                              47.3 mg/Am3          0.0207 g/Acf

 EMISSION RATE            40.72 g/s             323.17 lb/hr


 SAMPLING VOLUME           7.47 Nm3             263.64 Scf

 AVERAGE ISOKINETICITY    100.2 %


 FLUE GAS CHARACTERISTICS

 MOISTURE                 19.04 %

 TEMPERATURE              233.2 deg C            451.8 deg F

 FLOW                   1807290 Nm3/hr         1063740 Scfm
                        3826230 m3/hr          2252050 Acfm

 VELOCITY                 21.76 m/s             4282.8 fpm


 GAS ANALYSIS
               O2          4.00 %
               CO2         9.00 %
               CO          0.02 %
               MOL. WT.    29.6 g/g MOLE (DRY)



 *STANDARD CONDITIONS : METRIC   0 deg C. 101.325 kPa
                        IMPERIAL 77 deg F. 29.92 in. Hg
```

```
PARTICULATE EMISSION REPORT                          DATE : 19/06/84
CONCORD/SYNCRUDE                                      RUN  : 5A
REF. No. : 1085



 CONCENTRATION @ 12% CO2   61.7 mg/Nm3              0.0270 g/Scf
               @ ACT CO2   46.3 mg/Nm3              0.0202 g/Scf
                           26.2 mg/Am3              0.0115 g/Acf

 EMISSION RATE            24.14 g/s                 191.60 lb/hr


 SAMPLING VOLUME           7.67 Nm3                 270.77 Scf

 AVVERAGE ISOKINETICITY     99.9 %


 FLUE GAS CHARACTERISTICS

 MOISTURE                 18.88 %

 TEMPERATURE              231.9 deg C                449.5 deg F

 FLOW                   1878400 Nm3/hr            1105590 Scfm
                        4082660 m3/hr             2402980 Acfm

 VELOCITY                 23.21 m/s                 4569.8 fpm

 GAS ANALYSIS
               O2          4.00 %
               CO2         9.00 %
               CO          0.02 %
               MOL. WT.    29.6 g/g MOLE (DRY)


 *STANDARD CONDITIONS : METRIC    0 deg C, 101.325 kPa
                        IMPERIAL 77 deg F, 29.92 in. Hg
```

```
PARTICULATE EMISSION REPORT                          DATE : 19/06/84
CONCORD/SYNCRUDE                                     RUN  : 5B
REF. No. : 1085




 CONCENTRATION @ 12% CO2    82.6 mg/Nm3          0.0361 g/Scf
               @ ACT CO2    61.9 mg/Nm3          0.0271 g/Scf
                            35.2 mg/Am3          0.0154 g/Acf

 EMISSION RATE             30.96 g/s             245.73 lb/hr



 SAMPLING VOLUME            7.34 Nm3             259.25 Scf

 AVERAGE ISOKINETICITY      99.0 %



 FLUE GAS CHARACTERISTICS

 MOISTURE                  19.87 %

 TEMPERATURE               230.7 deg C            447.2 deg F

 FLOW                    1799390 Nm3/hr         1059090 Scfm
                         3949360 m3/hr          2324520 Acfm

 VELOCITY                  22.46 m/s             4420.6 fpm


 GAS ANALYSIS
               O2           4.00 %
               CO2          9.00 %
               CO           0.02 %
               MOL. WT.     29.6 g/g MOLE (DRY)




 *STANDARD CONDITIONS : METRIC   0 deg C. 101.325 kPa
                        IMPERIAL 77 deg F. 29.92 in. Hg
```

```
FIVE STAGE SERIES CYCLONE PARTICLE SIZE TEST DATA

--------------------------------------------------------------------------------------------------

CLIENT : SYNCRUDE                      CITY AND PROVINCE : FORT MCMURRAY ALBERTA        DATE : JUNE 14 1984

SAMPLING LOCATION : MAIN STACK         RUN-TEST NUMBER : 14-1(RUN 2)                    TIME OF START : 11:30
--------------------------------------------------------------------------------------------------

 TOTAL SAMPLE VOLUME:                            348.30 DSCF      9.864 NM3

 AVERAGE SAMPLING RATE (STACK CONDITIONS):        1.627 ACFM      0.046 AM3/MIN

 TOTAL IMPINGER CATCH:                           1751.1 ML.

 AVERAGE STACK TEMPERATURE:                       460.5 DEG.F     238.1 DEG.C

 AVERAGE ISOKINETIC:                              102.1 %

STACK GAS ANALYSIS
-----------------

                   WET BASIS          DRY BASIS
 CONSTITUENT       MOLE PERCENT       MOLE PERCENT
 -----------       ------------       -----------

 CO2                  6.85               8.50
 O2                   2.82               3.50
 CO                   0.02               0.02
 N2(BY DIFFERENCE)   70.88              87.98
 H2O                 19.44               0.00
                     ------             ------
 TOTAL               100.00             100.00

 VISCOSITY OF STACK GAS :   245.120 MICROPOISE

 CYCLONE  NET PARTICULATE   PERCENTAGE OF                          CUMULATIVE PERCENTAGE     D50 PARTICLE
 STAGE    WEIGHT            TOTAL PARTICULATE  CUMULATIVE          LESS THAN                 DIAMETER
 NUMBER   (GRAMS)           WEIGHT             PERCENTAGE          STATED D50 DIAMETER       (UM)
 -----------------------------------------------------------       ---------------------------------
 1          0.2053            56.52              100.00                 43.48                  6.05
 2          0.0061             1.69               43.48                 41.79                  2.55
 3          0.0068             1.87               41.79                 39.92                  1.89
 4          0.0019             0.51               39.92                 39.40                  0.70
 5          0.0024             0.67               39.40                 38.73                  0.36
 FILTER     0.1407            38.73               38.73
 -----------------------------------------------------------       ---------------------------------

 TOTAL PARTICULATE WEIGHT :  0.3632 GRAMS

 PARTICULATE CONCENTRATION
 -------------------------

    0.03681 G/NM3      0.01609 GRAINS/DSCF

    0.01641 G/AM3      0.00717 GRAINS/CF
```

```
FIVE STAGE SERIES CYCLONE PARTICLE SIZE TEST DATA
-----------------------------------------------------------------------------------------

CLIENT : SYNCRUDE                CITY AND PROVINCE : FORT MCMURRAY ALBERTA       DATE : JUNE 18 1984

SAMPLING LOCATION : MAIN STACK   RUN-TEST NUMBER : 18-1 (RUN 4)                  TIME OF START : 12:02
-----------------------------------------------------------------------------------------

 TOTAL SAMPLE VOLUME:                           348.31 DSCF      9.864 NM3

 AVERAGE SAMPLING RATE (STACK CONDITIONS):       1.607 ACFM      0.046 AM3/MIN

 TOTAL IMPINGER CATCH:                          1781.4 ML.

 AVERAGE STACK TEMPERATURE:                      454.5 DEG.F     234.7 DEG.C

 AVERAGE ISOKINETIC:                             100.6 %

STACK GAS ANALYSIS
------------------

                     WET BASIS           DRY BASIS
 CONSTITUENT        MOLE PERCENT        MOLE PERCENT
 -----------        ------------        -----------

 CO2                   7.23                 9.00
 O2                    3.21                 4.00
 CO                    0.02                 0.02
 N2(BY DIFFERENCE)    69.84                86.98
 H2O                  19.71                 0.00
                     ------               ------
 TOTAL               100.00               100.00

 VISCOSITY OF STACK GAS :   243.817 MICROPOISE

 CYCLONE  NET PARTICULATE    PERCENTAGE OF                          CUMULATIVE PERCENTAGE      D50 PARTICLE
 STAGE    WEIGHT             TOTAL PARTICULATE  CUMULATIVE          LESS THAN                  DIAMETER
 NUMBER   (GRAMS)            WEIGHT             PERCENTAGE          STATED D50 DIAMETER        (UM)

 ------------------------------------------------------------       ----------------------------------------
 1            0.1447             56.62             100.00                43.38                   6.05
 2            0.0244              9.54              43.38                33.84                   2.55
 3            0.0075              2.95              33.84                30.89                   1.89
 4            0.0042              1.64              30.89                29.25                   0.70
 5            0.0011              0.45              29.25                28.80                   0.36
 FILTER       0.0736             28.80              28.80
 ------------------------------------------------------------       ----------------------------------------

 TOTAL PARTICULATE WEIGHT :  0.2556 GRAMS

 PARTICULATE CONCENTRATION
 -------------------------

    0.02590 G/NM3      0.01132 GRAINS/DSCF

    0.01169 G/AM3      0.00511 GRAINS/CF
```

```
FIVE STAGE SERIES CYCLONE PARTICLE SIZE TEST DATA

-------------------------------------------------------------------------------------------------------

CLIENT : SYNCRUDE                   CITY AND PROVINCE : FORT MCMURRAY ALBERTA          DATE : JUNE 19 1984

SAMPLING LOCATION : MAIN STACK      RUN-TEST NUMBER : 19-1 (RUN 5)                     TIME OF START : 11:22
-------------------------------------------------------------------------------------------------------

 TOTAL SAMPLE VOLUME:                        347.93 DSCF     9.353 NM3

 AVERAGE SAMPLING RATE (STACK CONDITIONS):    1.610 ACFM     0.046 AM3/MIN

 TOTAL IMPINGER CATCH:                       1847.1 ML.

 AVERAGE STACK TEMPERATURE:                   450.0 DEG.F    232.2 DEG.C

 AVERAGE ISOKINETIC:                          100.3 %

STACK GAS ANALYSIS
------------------

                    WET BASIS           DRY BASIS
 CONSTITUENT        MOLE PERCENT        MOLE PERCENT
 -----------        ------------        -----------

 CO2                    7.17                9.00
 O2                     3.19                4.00
 CO                     0.02                0.02
 N2(BY DIFFERENCE)     69.32               86.98
 H2O                   20.31                0.00
                       ------              ------
 TOTAL                 100.00              100.00

 VISCOSITY OF STACK GAS :   242.433 MICROPOISE

 CYCLONE   NET PARTICULATE     PERCENTAGE OF                          CUMULATIVE PERCENTAGE      D50 PARTICLE
 STAGE     WEIGHT              TOTAL PARTICULATE  CUMULATIVE          LESS THAN                  DIAMETER
 NUMBER    (GRAMS)             WEIGHT             PERCENTAGE          STATED D50 DIAMETER        (UM)
 -------------------------------------------------------------        ---------------------------------------
 1           0.1788               47.28             100.00                52.72                    6.00
 2           0.0417               11.04              52.72                41.68                    2.51
 3           0.0148                3.91              41.68                37.76                    1.86
 4           0.0074                1.96              37.76                35.81                    0.69
 5           0.0457               12.09              35.81                23.72                    0.36
 FILTER      0.0897               23.72              23.72
 -------------------------------------------------------------        ---------------------------------------

 TOTAL PARTICULATE WEIGHT :  0.3781 GRAMS

 PARTICULATE CONCENTRATION
 -------------------------

    0.03836 G/NM3      0.01677 GRAINS/DSCF

    0.01727 G/AM3      0.00755 GRAINS/CF
```

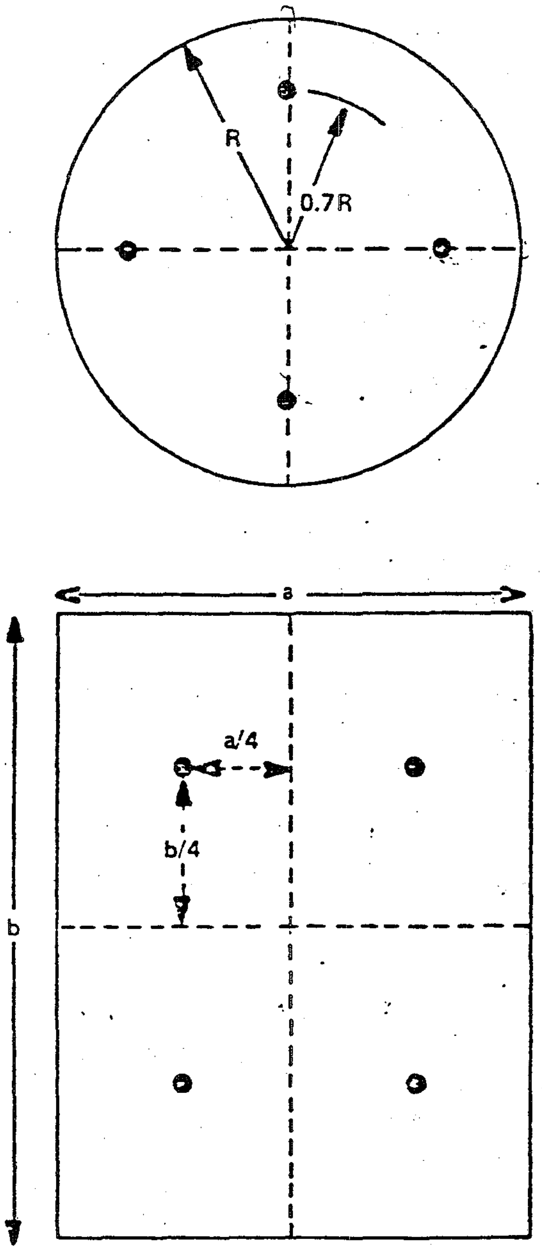
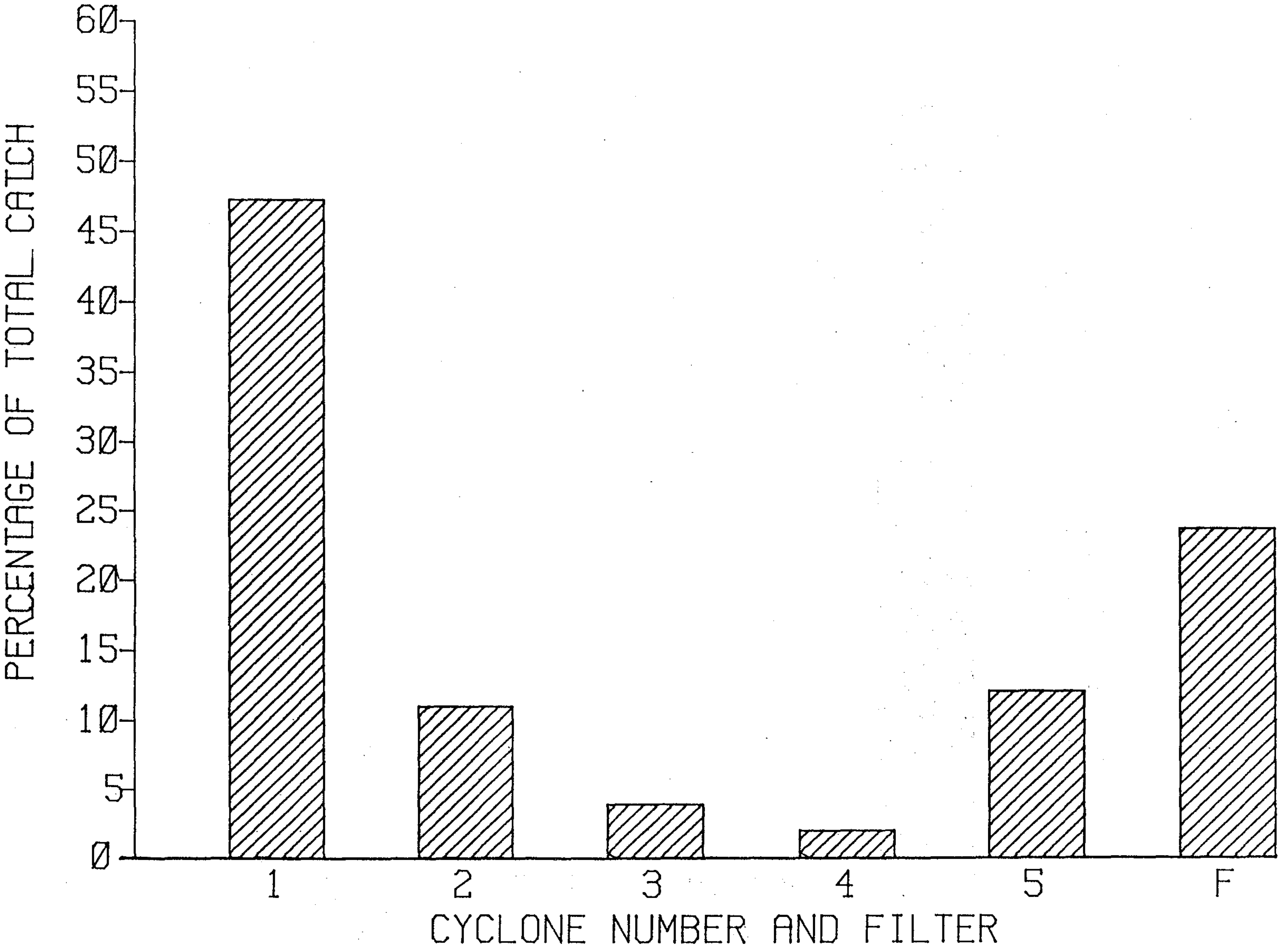
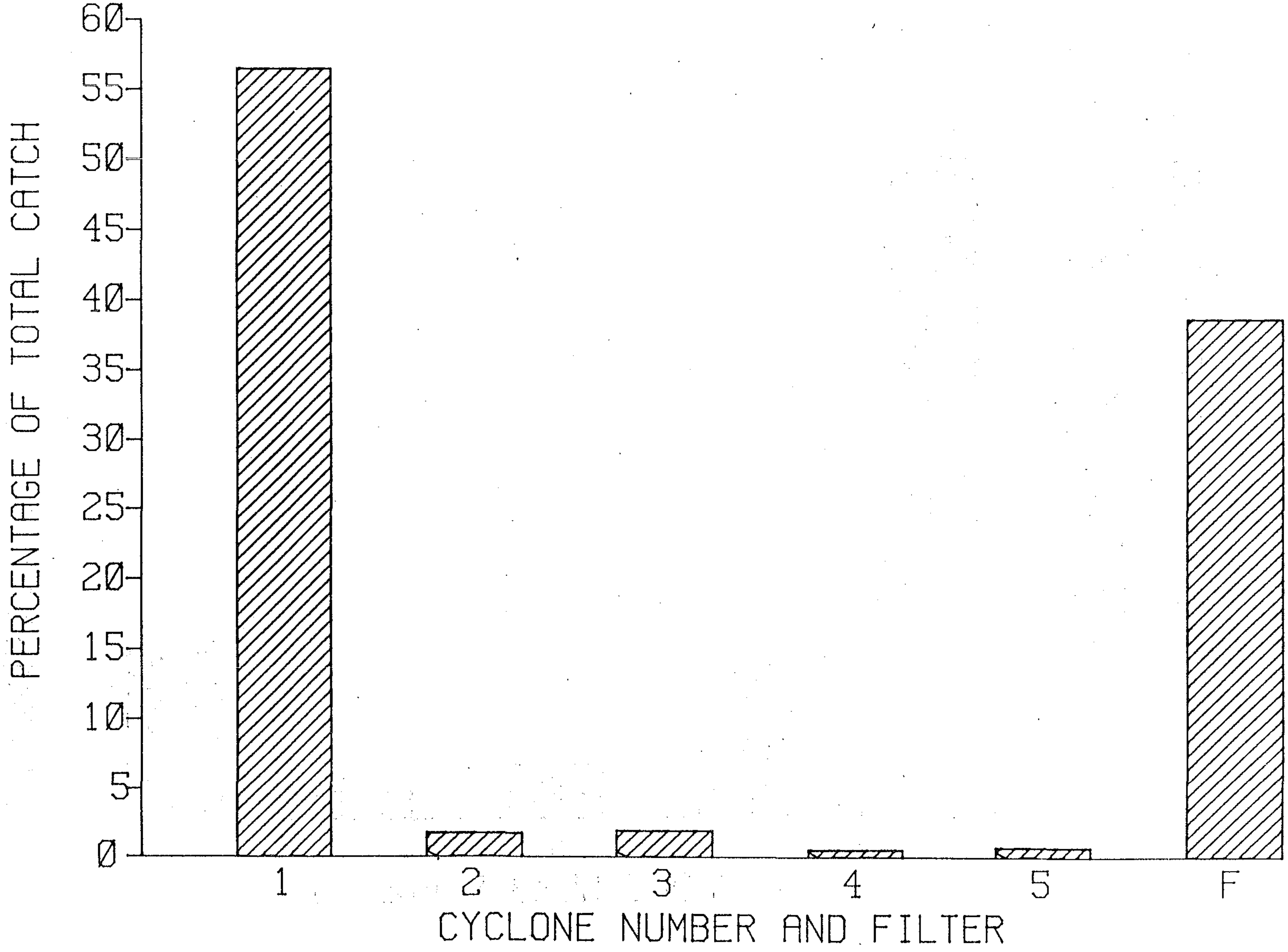


Figure 4. Recommended sampling points for circular and square or rectangular ducts.

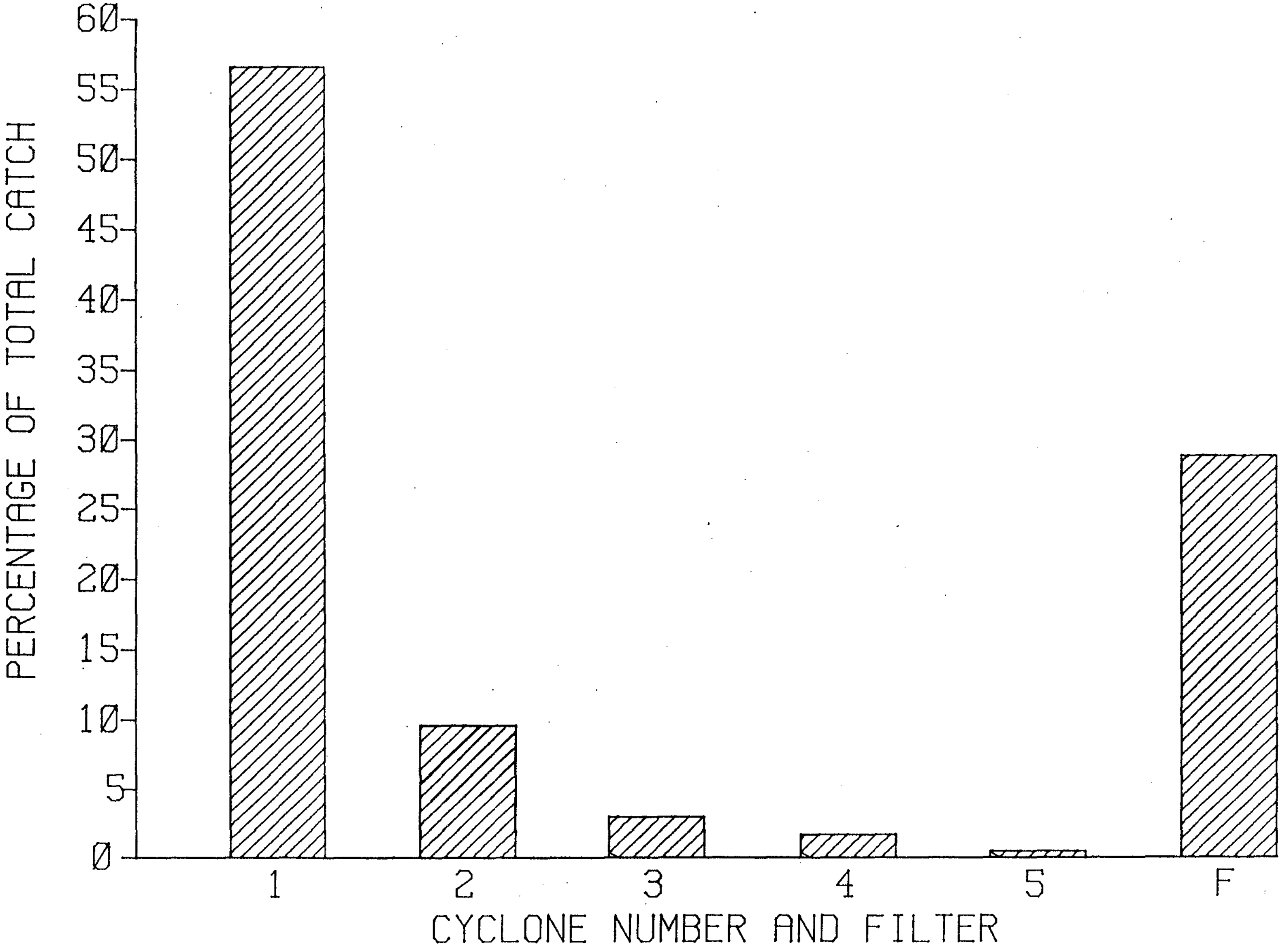


RUN #5 PARTICLE SIZE DISTRIBUTION

RUN #2 PARTICLE SIZE DISTRIBUTION



RUN #4 PARTICLE SIZE DISTRIBUTION



APPENDIX III

Process Documentation and Assignable Trend Summary

Appendix III contain proprietary
process and technical data and
has therefore been withheld.

APPENDIX IV

Miscellaneous Background Documentation

47-20118-84-165

Analysis of Source Samples Provided by Concord Scientific

for

Concord Scientific
2 Tippett Road
Downsview, Ontario
M3H 2V2

Attention: Mr. P. Fellin

A.R. Kean
Associate Research Scientist
Environmental and Chemical
Engineering Division

July 17th, 1984

ONTARIO RESEARCH

SHERIDAN PARK RESEARCH COMMUNITY

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4 NO REPORT ISSUED BY US SHALL BE PUBLISHED IN WHOLE OR IN PART WITHOUT OUR PRIOR WRITTEN CONSENT
5 OUR NAME SHALL NOT BE USED IN ANY WAY IN CONNECTION WITH THE SALE, OFFER OR ADVERTISEMENT OF ANY ARTICLE, PROCESS OR SERVICE.
6 WE RESERVE THE RIGHT NOT TO COMMENCE AND OR CONTINUE ANY WORK UNTIL PAYMENT ARRANGEMENTS SATISFACTORY TO US ARE ESTABLISHED

TABLE I

Mercury Analysis of Permanganate Impingers

Method of Analysis	ORF #	Client Identification	Concentration µg/Bottle
Cold Vapour Atomic Absorption Spectrophotometry	84-1270	02543	0.0084
	84-1271	02544	0.065
	84-1272	02545	0.011
	84-1273	02546	0.054
	84-1274	02547	0.018
	84-1275	02548	0.20
	84-1276	02559	0.033
	84-1277	02609 [1]	0.013
	84-1278	02612 [1]	0.0053
	84-1279	02615 [1]	0.0042

[1] - Solutions were clear - i.e., no $KMnO_4$ excess

no $K_2Cr_2O_7$ preservative

TABLE II
Mercury Analysis of Solution

Method of Analysis	ORF #	Client Indentification	Concentration µg/mL
Cold Vapour Atomic Absorption Spectrophotometry	84-1280	02538	<0.00002
	84-1281	02539	<0.00002
	84-1282	02540	0.00006
	84-1283	02541	0.00035
	84-1284	02542	0.00006
	84-1285	02549	0.00003
	84-1286	02560	0.00005
	84-1287	02618[1]	0.00014
	84-1288	02621[1]	0.00019
	84-1289	02624[1]	0.00013
	84-1290	02627[1]	<0.00004
	84-1291	02630[1]	0.00028
	84-1292	02633[1]	<0.00005

[1] Insufficient $K_2Cr_2O_7$ added to overcome reducing power of solution. 1 mL 10% $K_2Cr_2O_7$, 1 mL HNO_3 added to all bottles in this series. 72 hr. wait prior to sampling.

TABLE III

Arsenic, and Selenium Analysis of Solutions

Method of Analysis	ORF #	Client Identification	Concentration μg/mL	
			As	Se
Hydride Generation Atomic Absorption Spectrophotometry	84-1293	02533	<0.0005	0.001
	84-1294	02534	<0.0005	<0.001
	84-1295	02535	<0.0005	0.0042
	84-1296	02536	<0.0005	<0.001
	84-1297	02537	<0.0005	<0.001
	84-1280	02538[1]	<0.0005	0.0047
	84-1298	02558	<0.0005	0.0011
	84-1299	02586	<0.0005	0.0059
	84-1300	02590	0.0006	0.0049
	84-1301	02593	0.0006	0.0047
	84-1302	02594	<0.0005	0.0048
	84-1303	02598	<0.0005	0.0049
	84-1304	02602	<0.0005	0.0054
	84-1305	02603	<0.0005	0.0040
	84-1306	02606	<0.0005	0.0041

[1] Sample contained dichromate - Solution also analysed for Hg

TABLE IV

Lead, and Cadmium Analysis of Solutions

Method of Analysis	ORF #	Client Identification	Concentration µg/mL	
			Pb	Cd
Flame Atomic Absorption Spectrophotometry	84-1307	02550	<0.01	0.001
	84-1308	02551	<0.01	0.001
	84-1309	02552	<0.01	0.001
	84-1310	02553	<0.01	<0.001
	84-1311	02554	<0.01	0.001
	84-1312	02555	<0.01	0.001
	84-1313	02557	<0.01	0.001
	84-1314	02561	<0.01	<0.001
	84-1315	02564	<0.01	<0.001
	84-1316	02565	<0.01	0.001
	84-1317	02569	<0.01	<0.001
	84-1318	02573	<0.02	0.001
	84-1319	02577	<0.01	0.003
	84-1320	02580	<0.02	0.001
	84-1321	02581	<0.01	0.001
	84-1322	02585	<0.01	0.001

TABLE V

MULTIELEMENT ANALYSIS OF FILTERS AND SOLIDS (WEIGHABLE)

METHOD OF ANALYSIS	CONCENTRATION µg/g									
	ELEMENT	OUR #84-1323 Your #02644	OUR #84-1324 Your #02645	OUR #84-1325 Your #02650	OUR #84-1326 Your #02651	OUR #84-1327 Your #02656(e) [1]	[2]	OUR #84-1328 Your #02659	OUR #84-1329 Your #02660	OUR #84-1330 Your #02664
DCP(a)	Co	3.4	3.7	2.4	2.3	24	35	71	< 700	50
	Zn	28	27	65	54	22	28	91	850	160
	P	110	150	38	37	126	161	190	< 4,000	< 100
	Be	0.3	0.4	0.3	0.3	0.7	0.9	2.2	< 200	< 5
	Si	1,430	1,890	260	430	460	16,500	18,800	17,000	11,000
	Fe	7,660	10,500	8,050	7,090	7,200	10,500	23,800	39,000	10,900
	Mn	140	146	78	85	220	309	1,000	1,000	330
	Ca	14,200	18,900	2,260	2,912	1,280	2,220	2,550	< 4,000	2,000
	Mg	3,210	6,190	660	720	500	850	1,090	1,600	800
	Cu	13	13	9.9	8.4	13.6	22	108	< 700	60
	Al	1,560	1,630	760	660	8,190	13,280	15,100	28,000	11,100
	V	28	27	30	38	1,570	2,610	2,380	3,500	1,780
	Nb	9.2	7.7	3.9	4.0	113	180	130	< 2,000	120
	Ni	11	12	11	13	400	870	880	2,100	580
	Cr	8	8	9	5	9.8	48	140	< 700	90
	Na	410	430	170	190	1,430	1,660	2,900	< 36,000	2,500
	Ba	22	24	6.3	6.9	47	76	100	< 200	63
	Ti	87	83	39	41	360	2,370	3,560	5,500	1,820
	Zr	2.9	3.0	1.8	1.7	16	100	95	300	58
	Sn	5	7	2.1	2.3	4.9	8.7	<15	< 700	<20
FAA(b)	Cd	0.2	0.4	0.2	0.3	0.9	< 5	<4	< 200	<5
	Pb	10	10	5.0	7.0	17.5	<20	<15	< 700	<20
	Ag	<0.5	< 0.5	< 0.5	< 0.5	< 1	-	13	< 400	<10
HGAA(c)	As	1.82	2.62	1.74	1.52	2.5	-	7.3	27	5.7
	Se	0.16	0.16	0.11	0.13	2.3	-	12.8	56	14
CVAA(d)	Hg	0.029	0.024	<0.004	0.004	< 0.01	-	0.77	1.5	0.29

METHOD OF ANALYSIS	CONCENTRATION µg/g								
	ELEMENT	OUR #84-1331 Your #02665	OUR #84-1332 Your #02669	OUR #84-1333 Your #02670	OUR #84-1334 Your #02695	OUR #84-1335 Your #02699	OUR #84-1336 Your #02703	OUR #84-1337 Your #02707	OUR #84-1338 Your #02711
DCP(a)	Co	<200	70	210	<10	<10	<10	<10	<10
	Zn	800	110	250	40	40	50	50	50
	P	<1,000	120	<300	<50	<50	<50	<50	60
	Be	< 60	< 4	< 20	< 3	< 3	< 3	< 3	< 3
	Si	23,000	9,200	21,000	650	890	480	<60	130
	Fe	31,000	21,900	47,100	80	70	70	80	70
	Mn	2,000	4,500	5,000	<10	<10	<10	<10	<10
	Ca	4,600	1,960	2,800	6,680	5,400	5,900	5,900	6,200
	Mg	1,900	780	1,340	2,810	2,300	2,600	2,300	2,450
	Cu	<200	170	1,210	<10	<10	<10	<10	<10
	Al	23,900	10,700	19,600	3,430	2,840	3,320	2,360	2,450
	V	2,800	1,600	2,300	<10	<10	<10	<10	<10
	Nb	700	<60	450	<30	<30	<30	<30	<30
	Ni	1,300	1,900	7,370	<10	<10	<10	<10	<10
	Cr	300	2,800	5,190	<10	<10	<10	<10	<10
	Na	12,000	3,080	7,000	22,000	19,000	21,000	18,900	19,000
	Ba	130	60	100	51	46	46	42	44
	Ti	4,500	1,500	3,660	< 3	3	< 3	<3	3.3
	Zr	190	56	410	5	3	<3	<3	<3
	Sn	<200	<20	<90	<10	<10	<10	<10	<10
FAA(b)	Cd	<50	< 5	60	< 3	< 3	< 3	<3	<3
	Pb	<200	<20	190	<10	<10	<10	<10	10.6
	Ag	<100	<10	<20	< 5	< 5	<5	<5	<5
HGAA(c)	As	12.5	6.2	19	0.4	0.3	0.2	0.3	0.2
	Se	30	8.2	5	1.0	1.3	0.9	1.1	1.0
CVAA(d)	Hg	1.4	0.21	< 0.3	<0.03	<0.03	0.04	<0.02	<0.03

(a) DC plasma emission spectrophotometry
(b) Flame atomic absorption spectrophotometry
(c) Hydride generation atomic absorption spectrophotometry
(d) Cold vapour atomic absorption spectrophotometry
(e) [1] normal digestion
[2] special digestion

TABLE V (Con't)

MULTIELEMENT ANALYSIS OF FILTERS AND SOLIDS (WEIGHABLE)

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION µg/g OUR #84-1339 Your #02715	OUR #84-1340 Your #02719	OUR #84-1341 Your #02722	OUR #84-1342 Your #02723	OUR #84-1343 Your #02727	OUR #84-1344 Your #02731	OUR #84-1345 Your #02735	OUR #64-1346 Your #02734
DCP(a)	Co	<10	<10	<10	<10	<10	<10	<10	<10
	Zn	30	50	40	20	40	50	30	30
	P	<50	110	150	130	80	80	80	<50
	Be	<3	<3	<3	<3	<3	<3	<3	<3
	Si	550	50	400	580	50	370	230	130
	Fe	60	2,690	2,350	1,640	3,370	1,070	1,040	990
	Mn	<10	80	70	50	90	30	30	30
	Ca	5,400	2,900	2,900	1,240	2,200	1,500	1,100	1,300
	Mg	2,330	1,090	1,340	480	890	570	410	480
	Cu	<10	<10	<10	<10	<10	<10	<10	<10
	Al	2,990	2,640	2,730	1,850	3,210	1,390	1,310	1,180
	V	<10	220	200	190	310	100	110	80
	Mo	<30	<30	<30	<30	<30	<30	<30	<30
	Ni	<10	60	50	70	80	20	40	20
	Cr	<10	<10	<10	<10	<10	<10	<10	<10
	Na	20,000	17,000	17,000	15,000	16,300	17,600	15,300	16,800
	Ba	45	33	37	42	39	26	26	22
	Ti	<3	170	140	110	240	57	66	55
	Zr	7	8.2	7.7	8.1	13	<5	<5	<5
	Sn	<10	<10	<10	<10	<10	<10	<10	<10
FAA(b)	Cd	<3	<3	<3	<3	<3	<3	<3	<3
	Pb	<10	<10	<10	<10	<10	10	<10	<10
	Ag	<5	<5	<5	<5	<5	<5	<5	<5
HGAA(c)	As	0.3	2.4	2.4	2.3	2.3	1.8	1.6	1.3
	Se	0.95	6.3	7.2	7.9	6.0	7.0	6.4	7.8
CVAA(d)	Hg	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION µg/g OUR #84-1347 Your #02739	OUR #84-1348 Your #02743 (e) 1	2	OUR #84-1349 Your #02744 (e) 1	2	OUR #84-1350 Your #02761	OUR #84-1351 Your #02762	OUR #84-1352 Your #02763
DCP(a)	Co	<10	21	20	20	20	<10	<10	<10
	Zn	30	4,500	4,310	4,220	4,370	20	30	50
	P	<50	7,700	7,450	6,990	7,500	<50	<50	<50
	Be	<3	2.3	2.3	2.2	2.2	<3	<3	<3
	Si	50	17,500	104,000	17,100	107,000	70	180	330
	Fe	1,040	32,700	38,800	30,500	38,500	30	40	50
	Mn	30	740	780	720	790	<10	<10	<10
	Ca	2,800	57,700	60,200	50,600	59,100	820	1,600	1,300
	Mg	1,100	6,500	7,420	5,890	7,720	360	640	470
	Cu	<10	560	620	560	630	<10	<10	<10
	Al	2,140	12,400	30,000	12,100	31,300	370	600	450
	V	100	104	101	104	102	<10	<10	<10
	Mo	<30	35	69	33	69	<30	70	<30
	Ni	30	51	54	50	53	<10	<10	<10
	Cr	<10	101	260	121	300	<10	<10	<10
	Na	16.500	3,030	3,380	3,140	2,990	13,000	13,000	14,000
	Ba	37	408	706	590	711	15	22	20
	Ti	71	1,340	3,720	1,070	3,640	<3	<3	<3
	Zr	5	14	163	13	180	<3	<3	<5
	Sn	<10	150	108	130	113	<10	<10	<10
FAA(b)	Cd	<3	81	62	73	77	<3	<3	<3
	Pb	<10	5,180	5,780	5,310	5,810	<10	<10	<10
	Ag	<5	7.0	-	6.5	-	<5	<5	<5
HGAA(c)	As	1.6	110	-	113	-	0.33	0.5	0.3
	Se	6.9	16.5	-	17.0	-	1.5	0.8	1.4
CVAA(d)	Hg	<0.02	1.3	-	1.2	-	0.04	<0.02	0.04

TABLE V (Con't)

MULTIELEMENT ANALYSIS OF FILTERS AND SOLIDS (WEIGHABLE)

METHOD OF ANALYSIS	CONCENTRATION µg/g				
	ELEMENT	OUR # 84-1353 Your #2764	OUR # 84-1354 Your # 2765	OUR # 84-1355 Your # 2766	OUR # 84-1356 Your # 2767
DCP(a)	Co	<10	<10	<10	<10
	Zn	40	20	20	30
	P	<50	<50	<50	<50
	Be	<3	<3	<3	<3
	Si	<50	240	<50	<50
	Fe	350	110	300	480
	Mn	20	10	100	50
	Ca	380	330	300	320
	Mg	120	100	110	100
	Cu	37	<10	<10	22
	Al	110	100	120	90
	V	<10	<10	<10	<10
	Mo	<30	<30	<30	<30
	Ni	60	10	20	40
	Cr	30	10	20	40
	Na	20,700	21,000	24,700	21,300
	Ba	<3	<3	6	<3
	Ti	4	<3	3.3	3.6
	Zr	4	4	3	8
	Sn	<10	<10	<10	<10
FAA(b)	Cd	<3	<3	<3	<3
	Pb	<10	15	<10	<10
	Ag	8	<5	<5	<5
HGAA(c)	As	2.9	2.9	2.3	2.3
	Se	2.4	1.0	2.1	1.0
CVAA(d)	Hg	0.06	<0.02	<0.02	<0.02

TABLE VI

MULTIELEMENT ANALYSIS OF SOLUTIONS AND SOLIDS (NON-WEIGHABLE)

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION μg/bottle							
		OUR #84-1357 Your #02522	OUR #84-1358 Your #02523	OUR #84-1359 Your #02524	OUR #84-1360 Your #02525	OUR #84-1361 Your #02526	OUR #84-1362 Your #02527	OUR #84-1363 Your #02528	OUR #84-1364 Your #02529
DCP(a)	Co	11	14	2	3	2	3	2	2
	Zn	6	17	3	5	6	6	4	4
	P	12	25	<5	6	5	6	6	6
	Be	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
	Si	160	530	48	84	52	49	55	43
	Fe	970	2,070	220	450	240	70	2	5
	Mn	260	1,020	310	190	47	21	<1	<1
	Ca	77	230	54	69	10	140	14	16
	Mg	24	80	8	6	1	6	<1	1
	Cu	110	79	39	7	9	1	<1	<1
	Al	200	950	18	51	12	13	3	4
	V	22	120	1	4	<1	<1	<1	<1
	Mo	10	22	<3	<3	<3	<3	<3	<3
	Ni	550	580	50	58	36	41	<1	<1
	Cr	130	240	18	78	34	10	<1	<1
	Na	110	210	<50	<50	<50	<50	<50	<50
	Ba	0.8	5.0	0.10	0.79	<0.3	1.4	<0.3	<0.3
	Ti	33	240	1.5	6.0	1.0	0.6	0.5	0.7
	Zr	8.7	12	0.4	0.8	1.6	<0.3	<0.3	<0.3
	Sn	5	8	<1	1	<1	<1	<1	<1
FAA(b)	Cd	1.1	1.4	<0.3	<0.3	2.2	<0.3	<0.3	<0.3
	Pb	3	5	<1	1	4	1	<1	<1
	Ag	0.9	1.0	1.1	<0.5	<0.5	<0.5	<0.5	<0.5
HGAA(c)	As	0.28	0.49	0.05	0.05	0.05	0.03	<0.03	<0.03
	Se	0.17	0.77	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CVAA(d)	Hg	0.043	0.072	0.016	<0.007	<0.007	<0.007	<0.007	<0.007

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION μg/bottle							
		OUR #84-1365 Your #02530	OUR #84-1366 Your #02531	OUR #84-1367 Your #02532	OUR #84-1368 Your #02556	OUR #84-1369 Your #02636	OUR #84-1370 Your #02661	OUR #84-1371 Your #02662	OUR #84-1372 Your #02663
DCP(a)	Co	2	2	2	2	3	< 1	< 1	< 1
	Zn	7	2	4	8	2	1	< 1	2
	P	17	9	5	5	7	< 5	< 5	< 5
	Be	<0.3	<0.3	<0.3	<0.3	<0.3	< 0.3	< 0.3	< 0.3
	Si	72	50	44	33	10	340	140	9
	Fe	46	11	50	<1	2	370	160	15
	Mn	1	<1	2	<1	<1	11	6	< 1
	Ca	200	21	130	13	23	38	13	< 5
	Mg	8	2	8	<1	<1	17	7	< 1
	Cu	<1	<1	1	13	<1	5	3	1
	Al	14	7	14	1	<1	250	100	4
	V	1	<1	1	<1	<1	27	11	< 1
	Mo	<3	<3	<3	<3	<3	<3	<3	< 3
	Ni	390	1	560	<1	<1	13	10	1
	Cr	4	1	6	<1	<1	3	4	2
	Na	54	50	<50	<50	<50	<50	<50	<50
	Ba	0.5	<0.3	0.7	<0.3	< 0.3	1.5	0.6	< 0.3
	Ti	1.9	1.1	2.2	0.9	< 0.3	65	23	0.8
	Zr	0.5	<0.3	<0.3	<0.3	< 0.3	1	<0.3	< 0.3
	Sn	<1	<1	1	<1	4	2	2	<1
FAA(b)	Cd	2.3	<0.3	2.1	<0.3	<0.3	<0.3	<0.3	< 0.3
	Pb	2	<1	<1	<1	1	<1	<1	< 1
	Ag	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	< 0.5
HGAA(c)	As	<0.03	<0.03	<0.03	<0.03	<0.03	0.11	0.05	< 0.03
	Se	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	< 0.05
CVAA(d)	Hg	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	< 0.007

(a) DC plasma emission spectrophotometry

(b) Flame atomic absorption spectrophotometry

(c) Hydride generation atomic absorption spectrophotometry

(d) Cold vapor atomic absorption spectrophotometry

TABLE VI (Con't)

MULTIELEMENT ANALYSIS OF SOLUTIONS AND SOLIDS (NON-WEIGHABLE)

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION µg/bottle OUR #84-1373 Your #02666	OUR #84-1374 Your #02667	OUR #84-1375 Your #02668	OUR #84-1376 Your #02671	OUR #84-1377 Your #02672	OUR #84-1378 Your #02673	OUR #84-1379 Your #02689	OUR #84-1380 Your #02690
DCP(a)	Co	< 1	<1	1	<1	< 1	1	8	26
	Zn	< 1	2	< 1	1	< 1	1	48	220
	P	< 5	< 5	6	< 5	< 5	< 5	27	110
	Be	< 0.3	< 0.3	0.05	0.05	< 0.05	0.05	0.15	0.4
	Si	330	120	5	510	120	< 5	1,470	3,510
	Fe	300	180	24	480	100	1	2,820	5,450
	Mn	30	16	< 1	14	3	< 1	120	260
	Ca	35	19	< 5	74	13	< 1	410	4,240
	Mg	15	7	< 1	27	6	< 1	150	740
	Cu	3	3	< 1	2	1	< 1	6	32
	Al	210	95	2	420	86	< 1	1,760	2,280
	V	22	10	< 1	39	8	< 1	260	460
	Mo	< 3	<3	< 1	< 1	<1	< 1	14	30
	Ni	13	15	3	18	6	< 1	110	3,100
	Cr	7	11	4	8	2	< 1	13	125
	Na	<50	<50	< 50	60	< 50	< 50	450	870
	Ba	1.4	0.6	< 0.3	2.4	0.5	< 0.3	6.2	23
	Ti	50	18	0.6	77	15	0.3	270	670
	Zr	1.0	< 0.3	< 0.3	1.5	< 0.3	< 0.3	6.2	12
	Sn	2	2	1.0	2	2	1	3	7
FAA(b)	Cd	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.7	29
	Pb	< 1	< 1	< 1	1	< 1	< 1	6	98
	Ag	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5
HGAA(c)	As	0.08	0.06	< 0.03	0.10	0.05	0.03	0.79	1.89
	Se	< 0.05	< 0.05	< 0.05	0.12	< 0.05	< 0.05	1.12	1.94
CVAA(d)	Hg	< 0.007	< 0.007	< 0.007	< 0.007	0.010	< 0.007	0.16	0.10

METHOD OF ANALYSIS	ELEMENT	CONCENTRATION µg/bottle OUR #84-1381 Your #02691	OUR #84-1382 Your #02692	OUR #84-1383 Your #02693	OUR #84-1384 Your #02694	OUR #84-1385 Your #02749	OUR #84-1386 Your #02752	OUR #84-1387 Your #02755	OUR #84-1388 Your #02758
DCP(a)	Co	6	9	3	7	1	< 1	< 1	< 1
	Zn	38	38	18	24	1	< 1	175	47
	P	31	180	16	140	5	< 5	< 5	< 5
	Be	< 0.3	< 0.3	< 0.3	< 0.3	0.05	< 0.05	< 0.05	< 0.05
	Si	1,100	1,300	820	1,610	27	44	650	230
	Fe	2,030	1,800	1,070	1,600	< 1	3	356	95
	Mn	78	60	36	48	< 1	<1	45	12
	Ca	460	1,420	180	1,170	< 5	<5	170	46
	Mg	1,480	170	74	140	< 1	<1	123	33
	Cu	6	31	4	16	< 1	<1	< 1	< 1
	Al	1,870	1,560	1,050	1,630	< 1	4	180	50
	V	270	250	140	220	< 1	45	85	23
	Mo	14	14	9	12	< 3	<3	< 3	< 3
	Ni	97	4,270	44	2,730	< 1	<1	69	17
	Cr	9	20	8	13	1	<1	40	9
	Na	1,800	430	450	380	<50	170	2,000	570
	Ba	13	30	11	54	<0.3	<0.3	42	11
	Ti	280	240	150	240	0.4	0.4	0.4	0.6
	Zr	6.8	4.6	3.0	5.2	<0.3	<0.3	<0.3	< 0.3
	Sn	4	4	3	5	1	1	48	14
FAA(b)	Cd	0.4	24	<0.3	15	<0.3	<0.3	<0.3	< 0.3
	Pb	5	33	3	38	3	51	49	12
	Ag	0.6	< 0.5	<0.5	1.3	<0.5	<0.5	<0.5	< 0.5
HGAA(c)	As	1.21	1.06	0.68	0.90	<0.03	0.03	0.03	< 0.03
	Se	2.04	1.86	1.94	1.69	<0.05	112	<0.05	0.07
CVAA(d)	Hg	0.48	0.43	0.19	0.11	<0.007	50.4	<0.007	< 0.007

W.D. #8330B

REPORT ON THE ANALYSIS OF FILTER MEDIA, SOLIDS AND SOLUTION SAMPLES

(REFERENCE C.S.C. FILE NO. 110.J449)

Prepared for:
Concord Scientific Corporation
2 Tippet Road
Downsview, Ontario
M3H 2V2

Prepared by:
Barringer Magenta Limited
304 Carlingview Drive
Rexdale, Ontario
M9W 5G2

W.O. #84-0398

July, 1984

TABLE 1

Details of Analytical Procedures Employed

Sample Type	Parameter	Sample Volume Taken	Final Digestate Volume	Conversion* Factor	Final Units
Impinger Solutions	Pb, Cd	50 ml	10 ml	0.2	ug/mL
Impinger Solutions	As, Se	10 ml	10 ml	1.0	ug/mL
Impinger Solutions	Hg	25 ml	25 ml	1.0	ug/ml
Acetone Washes	Full Metals	Entire Sample	50 ml	0.53 (#2503) 0.43 (#2520) 0.42 (#2642) 0.31 (#2643)	ug/ml
Filters	Hg	1 Section (1/12)	25 ml	300	ug/filter
Filters	Other Metals	2 Sections (1/6)	25 ml	150	ug/filter
Solids	Hg	0.250 g	25 ml	100	ug/g
Solids	Other Metals	0.250 g	25 ml	100	ug/g
Probe Rinses	Full Metals	N/A	N/A	1	ug/ml

* Factor by which the digestate solution concentration, in ug/ml, must be multiplied to get result in "final units".

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FILE: T4$0398A
DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) IMPINGER SOLUTIONS - PB & CD

WO NO: 84-0398

SAMPLE ID	PB UG/ML	CD UG/ML
SAMPLE #2489	<.01	<.002
SAMPLE #2517	<.01	<.002
SAMPLE #2563	<.01	<.002
SAMPLE #2563	<.01	<.002
SAMPLE #2567	<.01	<.002
SAMPLE #2571	<.01	<.002
SAMPLE #2571	<.01	<.002
SAMPLE #2575	<.01	<.002
SAMPLE #2576	<.01	<.002
SAMPLE #2579	<.01	<.002
SAMPLE #2583	<.01	<.002
SAMPLE #2583	<.01	<.002
SAMPLE #2641	<.01	<.002
BLANK	<.01	<.002
ERA STD.	.10	.120
ERA (CERT.)	.16	.159
NBS #1643A	.03	.008
NBS (CERT.)	.03	.010
REPT. #2563	<.01	<.002

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DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) IMPINGER SOLUTIONS - AS & SE

WO NO: 84-0398

PAGE: 1

SAMPLE ID	AS UG/ML	SE UG/ML
SAMPLE #2484	<.001	<.001
SAMPLE #2500	.001	.001
SAMPLE #2502	<.001	<.001
SAMPLE #2513	.001	<.001
SAMPLE #2514	.002	.001
SAMPLE #2515	<.001	<.001
SAMPLE #2588	.003	<.001
SAMPLE #2588	.004	<.001
SAMPLE #2589	.004	<.001
SAMPLE #2589	.004	<.001
SAMPLE #2592	.003	.001
SAMPLE #2596	.003	<.001
SAMPLE #2596	.003	.001
SAMPLE #2600	.003	<.001
SAMPLE #2600	.003	<.001
SAMPLE #2601	.003	<.001
SAMPLE #2601	.003	<.001
SAMPLE #2605	.002	<.001
SAMPLE #2608	.002	<.001
SAMPLE #2637	<.001	<.001
SAMPLE #2638	.002	.001
SAMPLE #2640	<.001	<.001
BLANK	<.001	.001
REPT. #2601	.004	<.001
EPA STD.	.095	.067
EPA (CERT.)	.071	.077
NBS #1643A	.010	.083
NBS (CERT.)	.011	.076

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FILE: T4$0398C
DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) IMPINGER SOLUTIONS - HG WO NO: 84-0398 PAGE: 1

SAMPLE ID	HG UG/ML
SAMPLE #2505	.00024
SAMPLE #2509	.00024
SAMPLE #2611	.00028
SAMPLE #2614	.00016
SAMPLE #2617	.00016
SAMPLE #2620	<.00004
SAMPLE #2623	<.00004
SAMPLE #2626	<.00004
SAMPLE #2629	<.00004
SAMPLE #2632	<.00004
SAMPLE #2635	<.00004
SAMPLE #2639	.00004
BLANK	<.00004
BLANK + SPK.	.00040
#2611 + SPK.	.00068
#2632 + SPK.	.00044

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FILE: T4$0398D
DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) IMPINGER SOLUTIONS - VOLUMES   WO NO: 84-0398   PAGE: 1

SAMPLE ID	VOLUME ML
SAMPLE #2484	41.5
SAMPLE #2489	101.0
SAMPLE #2500	96.0
SAMPLE #2502	37.0
SAMPLE #2503	95.0
SAMPLE #2505	22.0
SAMPLE #2509	33.5
SAMPLE #2513	48.0
SAMPLE #2514	138.0
SAMPLE #2515	75.0
SAMPLE #2517	95.0
SAMPLE #2520	115.0
SAMPLE #2637	90.0
SAMPLE #2638	116.0
SAMPLE #2639	45.0
SAMPLE #2640	93.0
SAMPLE #2641	100.0
SAMPLE #2642	120.0
SAMPLE #2643	160.0

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FILE: T4$0398E
DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) ACETONE RINSE SOLNS. - FULL METAL SCAN

WO NO: 84-0398

SAMPLE ID	AG UG/ML	AG(AA) UG/ML	AL UG/ML	AS UG/ML	B UG/ML	BA UG/ML	BE UG/ML	CA UG/ML	CD UG/ML	CD(AA) UG/ML	CO UG/ML
SAMPLE #2503	<.003	<.005	<.005	<.001	<.002	<.003	<.0003	.026	<.005	<.005	<.03
SAMPLE #2520	<.003	<.005	<.004	<.001	<.002	<.003	<.0003	.024	<.005	<.005	<.02
SAMPLE #2642	<.003	<.005	.009	<.001	.004	<.003	<.0003	.071	<.005	<.005	<.02
SAMPLE #2643	<.003	<.005	<.003	<.001	<.001	<.003	<.0003	.023	<.005	<.005	<.02
BLANK	<.005	<.005	<.01	<.001	<.004	<.005	<.0005	<.01	<.01	<.005	<.05
REPT. #2503	<.003	<.005	<.005	<.001	<.002	<.003	<.0003	.008	<.005	<.005	<.03

SAMPLE ID	CR UG/ML	CU UG/ML	FE UG/ML	HG UG/ML	K UG/ML	MG UG/ML	MN UG/ML	MO UG/ML	NA UG/ML	NI UG/ML	P UG/ML
SAMPLE #2503	<.005	<.004	.016	.0015	<.5	<.005	<.005	<.1	6.2	<.03	<.3
SAMPLE #2520	<.004	<.003	.017	.0033	<.5	<.005	<.005	<.10	<.5	<.03	<.3
SAMPLE #2642	.007	<.003	.061	.0012	<.5	.014	<.005	<.10	7.1	<.03	<.3
SAMPLE #2643	.004	<.002	.021	.0048	<.5	.004	<.005	<.10	.6	<.03	<.3
BLANK	<.01	.035	<.01	<.0005	<1	<.01	<.01	<.2	<1	<.05	<.5
REPT. #2503	<.005	<.004	<.005	.0008	<.5	<.005	<.005	<.1	6.0	<.03	<.3

SAMPLE ID	PB UG/ML	SE UG/ML	SI UG/ML	SN UG/ML	SR UG/ML	TH UG/ML	TI UG/ML	V UG/ML	ZN UG/ML	ZR UG/ML
SAMPLE #2503	<.03	<.001	.06	<.5	<.0005	<.03	<.003	<.003	<.03	<.03
SAMPLE #2520	<.03	<.001	<.03	<.5	<.0005	<.03	<.003	<.003	<.03	<.02
SAMPLE #2642	<.03	<.001	.04	<.5	<.0005	<.03	<.003	<.003	.03	<.02
SAMPLE #2643	<.03	<.001	<.03	<.5	<.0005	<.03	<.003	<.003	<.03	<.02
BLANK	<.03	<.001	<.05	<.5	<.001	<.05	<.005	<.005	.14	<.05
REPT. #2503	<.03	<.001	<.03	<.5	.0008	<.03	<.003	<.003	<.03	<.03

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FILE: T4$0398F
DATE: 12/07/84
MATRIX: FILTERS

CONCORD SCIENTIFIC (P. FELLIN) FILTER SAMPLES - FULL METAL SCAN

WO NO: 84-0398

PAGE: 1

SAMPLE ID	AG UG/FILT.	AG(AA) UG/FILT.	AL UG/FILT.	AS UG/FILT.	B UG/FILT.	BA UG/FILT.	BE UG/FILT.	CA UG/FILT.	CD UG/FILT.	CD(AA) UG/FILT.	CO UG/FILT.
SAMPLE #2696	<.8	<2	2320	.2	71200	37.7	<.07	4500	<2	<2	<8
SAMPLE #2700	<.8	<2	3030	.2	96100	52.1	<.07	5990	<2	<2	<8
SAMPLE #2704	<.8	<2	2020	<.2	59500	36.6	<.07	3950	<2	<2	<8
SAMPLE #2708	<.8	<2	1160	.2	34300	21.9	<.07	2350	<2	<2	<8
SAMPLE #2712	<.8	<2	2900	.2	88100	52.4	<.07	5840	<2	<2	<8
SAMPLE #2716	<.8	<2	2860	.2	96100	50.7	<.07	5840	<2	<2	<8
SAMPLE #2720	<.8	<2	3960	2.3	47600	49.1	<.08	3040	<2	<2	<8
SAMPLE #2724	<.8	<2	2630	1.6	30900	45.3	<.07	2250	<2	<2	<8
SAMPLE #2726	<.8	<2	1710	1.4	14800	34.7	<.07	1240	<2	<2	<8
SAMPLE #2728	<.8	<2	4240	4.9	8240	54.8	<.07	2200	<2	<2	13
SAMPLE #2732	<.8	<2	1930	1.8	15900	42.6	<.07	1460	<2	<2	<8
SAMPLE #2736	<.8	<2	2090	1.4	9450	49.4	<.07	1660	<2	<2	<8
SAMPLE #2738	<.8	<2	1400	1.1	19100	31.8	<.07	1280	<2	<2	<8
SAMPLE #2740	<.8	<2	1420	2.0	10600	37.1	<.07	1430	<2	<2	<8

SAMPLE ID	CR UG/FILT.	CU UG/FILT.	FE UG/FILT.	HG UG/FILT.	K UG/FILT.	MG UG/FILT.	MN UG/FILT.	MO UG/FILT.	NA UG/FILT.	NI UG/FILT.	P UG/FILT.
SAMPLE #2696	6	5	62	.39	1000	1970	2	<30	16600	17	<80
SAMPLE #2700	8	6	86	1.56	1400	2520	2	<30	21900	8	<80
SAMPLE #2704	8	6	53	.06	900	1690	<2	<30	15700	18	<80
SAMPLE #2708	7	13	53	<.01	500	1040	<2	<30	11200	43	<80
SAMPLE #2712	9	4	79	.41	1400	2370	3	<30	21500	13	<80
SAMPLE #2716	8	4	64	.95	1400	2350	2	<30	21600	16	<80
SAMPLE #2720	11	13	2910	1.04	1000	1370	79	<30	20400	89	<80
SAMPLE #2724	11	3	1720	.18	800	943	47	<30	22100	83	<80
SAMPLE #2726	9	2	1540	.34	500	436	42	<30	17800	68	90
SAMPLE #2728	17	4	5200	.16	1200	904	131	<30	21700	150	<80
SAMPLE #2732	13	2	1520	.84	700	538	43	<30	23800	56	<80
SAMPLE #2736	10	3	1470	.20	800	594	41	<30	21900	86	<80
SAMPLE #2738	6	4	855	.39	300	485	24	<30	15400	42	<80
SAMPLE #2740	7	2	878	.21	600	502	25	<30	13800	43	<80

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FILE: T4$0398F
DATE: 12/07/84
MATRIX: FILTERS

CONCORD SCIENTIFIC (P. FELLIN) FILTER SAMPLES - FULL METAL SCAN

WO NO: 84-0398

SAMPLE ID	PB UG/FILT.	SE UG/FILT.	SI UG/FILT.	SN UG/FILT.	SR UG/FILT.	TH UG/FILT.	TI UG/FILT.	V UG/FILT.	ZN UG/FILT.	ZR UG/FILT.
SAMPLE #2696	<10	.2	167	<50	4.3	<8	<.8	<.8	47	<8
SAMPLE #2700	<10	.4	170	<50	5.4	<8	<.8	<.8	55	<8
SAMPLE #2704	<10	.2	160	<50	3.4	<8	<.8	<.8	89	<8
SAMPLE #2708	<10	.2	105	<50	2.2	<8	<.8	<.8	106	<8
SAMPLE #2712	<10	<.2	197	<50	5.0	<8	1.1	<.8	93	<8
SAMPLE #2716	<10	.2	188	<50	5.1	<8	<.8	<.8	81	<8
SAMPLE #2720	<10	9.7	1210	<50	17.4	<8	198	232	72	11
SAMPLE #2724	<10	6.3	543	<50	13.9	<8	101	155	78	<8
SAMPLE #2726	<10	4.7	268	<50	11.9	<8	85.0	143	55	<8
SAMPLE #2728	<10	8.2	437	<50	25.5	8	347	420	91	13
SAMPLE #2732	30	8.2	330	<50	11.6	<8	88.8	133	77	<8
SAMPLE #2736	<10	4.0	346	<50	13.2	10	97.7	149	75	<8
SAMPLE #2738	<10	4.0	310	<50	8.7	<8	55.2	83.9	52	<8
SAMPLE #2740	<10	5.6	224	<50	8.3	<8	59.4	83.8	58	<8

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FILE: T4$0398G
DATE: 12/07/84
MATRIX: AQ-REG

CONCORD SCIENTIFIC (P. FELLIN) SOLID SAMPLES - FULL METAL SCAN

WO NO: 84-0398

PAGE: 1

SAMPLE ID	AG PPM	AG(AA) PPM	AL PPM	AS PPM	B PPM	BA PPM	BE PPM	CA PPM	CD PPM	CD(AA) PPM	CO PPM
SAMPLE #2648	<.5	<1	2370	2.4	3020	32.1	.12	11200	<1	<1	<5
SAMPLE #2649	<.5	<1	2130	1.9	2030	21.3	.06	13700	<1	<1	<5
SAMPLE #2654	<.5	<1	691	1.5	2030	8.4	<.05	1790	<1	<1	<5
SAMPLE #2655	<.5	<1	766	1.1	2240	6.5	<.05	2290	<1	<1	<5
SAMPLE #2658	<.5	<1	11100	3.3	2630	59.7	<.05	1870	<1	<1	25
SAMPLE #2747	2.4	6	12900	173	7000	139	1.06	58000	66	52	9
SAMPLE #2748	2.1	6	13400	181	7500	165	1.07	61600	67	53	10
BLANK	<.8	<1	32	<.2	2770	<.8	<.07	37	<2	<1	<8
REPT. #2648	<.5	<1	2010	1.5	1940	21.8	.05	8570	<1	<1	<5
SY-2	<.5	<1	4000	18.1	5710	30.1	10.9	35600	<1	<1	30
SY-2	<.5	<1	4980	18.1	5810	38.4	12.3	38900	<1	<1	28
SY-2 (CERT.)	--	--	64100	18.0	85.0	460	23.0	57000	--	--	11
NBS #1645	--	--	--	--	--	--	--	--	--	--	--
NBS (CERT.)	--	--	--	--	--	--	--	--	--	--	--
MESS-1	--	--	--	--	--	--	--	--	--	--	--
MESS (CERT.)	--	--	--	--	--	--	--	--	--	--	--

FILE: T4$0398G
DATE: 12/07/84
MATRIX: AQ-REG

CONCORD SCIENTIFIC (P. FELLIN) SOLID SAMPLES - FULL METAL SCAN

WO NO: 84-0398

SAMPLE ID	CR PPM	CU PPM	FE PPM	HG PPM	K PPM	MG PPM	MN PPM	MO PPM	NA PPM	NI PPM	P PPM
SAMPLE #2648	13	10.1	16500	.14	300	3650	242	<20	200	23	220
SAMPLE #2649	15	7.9	10900	<.02	300	3570	154	<20	200	19	150
SAMPLE #2654	13	13.5	11500	<.02	100	409	93	<20	100	26	<50
SAMPLE #2655	9	7.5	8190	<.02	200	541	70	<20	100	21	<50
SAMPLE #2658	18	13.3	9880	<.02	1300	756	265	110	1300	504	110
SAMPLE #2747	75	570	31500	1.42	4200	5710	669	20	2000	60	7830
SAMPLE #2748	74	580	31800	1.52	4300	6110	722	<20	2000	64	7860
BLANK	7	<1.2	25	<.02	<200	6	<2	<30	200	<8	<80
REPT. #2648	42	28.4	7180	.06	200	2750	89	<20	300	14	180
SY-2	7	5.8	23700	--	2000	9800	1320	30	3200	12	1800
SY-2	7	5.3	26300	--	2700	10600	1480	<20	3800	9	1810
SY-2 (CERT.)	12	5.0	43900	--	37200	16300	2480	<20	32200	10	1880
NBS #1645	--	--	--	.96	--	--	--	--	--	--	--
NBS (CERT.)	--	--	--	1.10	--	--	--	--	--	--	--
MESS-1	--	--	--	.19	--	--	--	--	--	--	--
MESS (CERT.)	--	--	--	.17	--	--	--	--	--	--	--

BARRINGER MAGENTA

304 CARLINGVIEW DRIVE
REXDALE, ONTARIO
M9W 5G2
(416) 675-3870

3750 - 19TH STREET
SUITE 105
CALGARY, ALBERTA
T2E 6V2
(403) 276-9701

FILE: T4$0398G
DATE: 12/07/84
MATRIX: AQ-REG

CONCORD SCIENTIFIC (P. FELLIN) SOLID SAMPLES - FULL METAL SCAN

WO NO: 84-0398

SAMPLE ID	PB PPM	SE PPM	SI PPM	SN PPM	SR PPM	TH PPM	TI PPM	V PPM	ZN PPM	ZR PPM
SAMPLE #2648	15	.3	233	<10	16.7	<5	65.2	34.2	57	<5
SAMPLE #2649	10	.3	225	<10	14.4	<5	71.3	29.5	50	<5
SAMPLE #2654	<5	.3	90	<10	4.9	<5	31.3	40.7	80	<5
SAMPLE #2655	<5	.3	92	<10	5.6	<5	35.3	45.1	68	<5
SAMPLE #2658	10	2.6	382	<10	81.5	<5	474	1790	40	20
SAMPLE #2747	6800	21.4	673	127	143	<5	532	86.7	4360	5
SAMPLE #2748	6600	21.4	656	140	148	<5	565	85.5	4770	5
BLANK	<5	<.2	49	<10	<.1	<8	<.8	<.8	29	<8
REPT. #2648	15	.3	176	<10	68.5	<5	77.0	28.8	682	<5
SY-2	85	<.2	731	<10	41.5	408	750	34.5	172	153
SY-2	85	<.2	337	<10	45.1	405	782	35.5	176	177
SY-2 (CERT.)	80	--	281000	4	275	380	839	52.0	250	280
NBS #1645	--	--	--	--	--	--	--	--	--	--
NBS (CERT.)	--	--	--	--	--	--	--	--	--	--
MESS-1	--	--	--	--	--	--	--	--	--	--
MESS (CERT.)	--	--	--	--	--	--	--	--	--	--

BARRINGER MAGENTA

304 CARLINGVIEW DRIVE
REXDALE, ONTARIO
M9W 5G2
(416) 675-3870

3750 - 19TH STREET
SUITE 105
CALGARY, ALBERTA
T2E 6V2
(403) 276-9701

FILE: T4$0398H
DATE: 12/07/84
MATRIX: SOLNS.

CONCORD SCIENTIFIC (P. FELLIN) PROBE RINSE SOLNS. - FULL METAL SCAN

WO NO: 84-0398

SAMPLE ID	AG UG/ML	AG(AA) UG/ML	AL UG/ML	AS UG/ML	B UG/ML	BA UG/ML	BE UG/ML	CA UG/ML	CD UG/ML	CD(AA) UG/ML	CO UG/ML
SAMPLE #2751	<.005	<.01	<.01	<.001	<.004	<.005	<.0005	<.01	<.01	<.01	<.05
SAMPLE #2754	<.005	<.01	<.01	<.001	<.004	<.005	<.0005	.03	<.01	<.01	<.05
SAMPLE #2757	<.005	<.01	2.06	<.001	.005	.496	<.0005	2.09	<.01	<.01	<.05
SAMPLE #2760	<.005	<.01	.51	<.001	<.004	.121	<.0005	.49	<.01	<.01	<.05
BLANK	<.005	<.01	<.01	<.001	<.004	<.005	<.0005	.01	<.01	<.01	<.05
ERA STD	<.005	<.01	.52	.095	.326	.159	.168	.12	.16	.12	.17
ERA (CERT.)	--	--	.51	.071	.214	.120	.175	--	.16	.16	.19

SAMPLE ID	CR UG/ML	CU UG/ML	FE UG/ML	HG UG/ML	K UG/ML	MG UG/ML	MN UG/ML	MO UG/ML	NA UG/ML	NI UG/ML	P UG/ML
SAMPLE #2751	<.01	<.008	<.01	.0040	<1	<.01	<.01	<.2	<1	<.05	<.5
SAMPLE #2754	<.01	<.008	<.01	.400	<1	.02	<.01	<.2	2	<.05	<.5
SAMPLE #2757	.51	<.008	4.64	<.0005	4	1.48	.53	<.2	23	.89	<.5
SAMPLE #2760	.12	<.008	1.11	.0005	<1	.38	.13	<.2	6	.22	<.5
BLANK	<.01	<.008	<.01	<.0005	<1	.03	<.01	<.2	<1	<.05	<.5
ERA STD	.14	.362	.30	2.09	<1	.03	.23	.2	<1	.23	<.5
ERA (CERT.)	.15	.352	.26	2.20	--	--	.24	.3	--	.26	--

SAMPLE ID	PB UG/ML	SE UG/ML	SI UG/ML	SN UG/ML	SR UG/ML	TH UG/ML	TI UG/ML	V UG/ML	ZN UG/ML	ZR UG/ML
SAMPLE #2751	<.05	<.001	<.05	<.01	<.001	<.05	<.005	<.005	<.05	<.05
SAMPLE #2754	.40	1.40	<.05	<.01	<.001	<.05	<.005	.470	<.05	<.05
SAMPLE #2757	.45	<.001	10.1	.01	.001	<.05	<.005	1.02	2.20	<.05
SAMPLE #2760	<.05	<.001	2.38	<.01	<.001	<.05	<.005	.222	.51	<.05
BLANK	<.05	<.001	<.05	<.01	<.001	<.05	<.005	<.005	<.05	<.05
ERA STD	.10	.067	.10	.19	<.001	<.05	.254	.353	.25	<.05
ERA (CERT.)	.16	.077	--	.22	--	--	.269	.356	.16	--

BARRINGER MAGENTA

304 CARLINGVIEW DRIVE
REXDALE, ONTARIO
M9W 5G2
(416) 675-3870

3750 - 19TH STREET
SUITE 105
CALGARY, ALBERTA
T2E 6V2
(403) 276-9701

FILE: T4-0461
DATE: 25/07/84
MATRIX: AQ

CONCORD SCIENTIFIC (P.FELLIN)

[illegible] PO: 84-0461

PAGE: 1

SAMPLE ID	AG MG/L	AL MG/L	B MG/L	BA MG/L	BE MG/L	CA MG/L	CD MG/L	CO MG/L	CR MG/L
#1 H2O	<.005	<.01	<.004	<.005	<.0005	.47	<.01	<.05	<.01
#2 H2O	<.005	<.01	<.004	<.005	<.0005	.36	<.01	<.05	<.01
H2O BLK	<.005	<.01	<.004	<.005	<.0005	<.01	<.01	<.05	<.01
#1 AQ-REG	<.005	<.01	.221	<.005	<.0005	.25	<.01	<.05	<.01
#2 AQ-REG	<.005	.02	.218	<.005	<.0005	.14	<.01	<.05	<.01
AQ-REG BLK	<.005	.01	.213	<.005	<.0005	.05	<.01	<.05	<.01

SAMPLE ID	CU MG/L	FE MG/L	K MG/L	MG MG/L	MN MG/L	MO MG/L	NA MG/L	NI MG/L	P MG/L
#1 H2O	<.008	<.01	<1	.08	<.01	<.2	<1	<.05	<.5
#2 H2O	<.008	<.01	<1	.05	<.01	<.2	<1	<.05	<.5
H2O BLK	<.008	<.01	<1	<.01	<.01	<.2	<1	<.05	<.5
#1 AQ-REG	<.008	.11	<1	.02	<.01	<.2	<1	<.05	<.5
#2 AQ-REG	.023	.15	<1	<.01	<.01	<.2	<1	<.05	<.5
AQ-REG BLK	<.008	.01	<1	<.01	<.01	<.2	<1	<.05	<.5

SAMPLE ID	PB MG/L	SI MG/L	SR MG/L	TH MG/L	TI MG/L	V MG/L	ZN MG/L	ZR MG/L
#1 H2O	<.05	.08	.004	<.05	<.005	<.005	<.05	<.05
#2 H2O	<.05	.11	.001	<.05	<.005	<.005	<.05	<.05
H2O BLK	<.05	<.05	<.001	<.05	<.005	<.005	<.05	<.05
#1 AQ-REG	<.05	<.05	.003	<.05	.010	<.005	<.05	<.05
#2 AQ-REG	<.05	1.47	<.001	<.05	.021	<.005	<.05	<.05
AQ-REG BLK	<.05	1.44	<.001	<.05	<.005	<.005	<.05	<.05

DIAGNOSTIC RESEARCH LABORATORIES
1885 LESLIE STREET, DON MILLS, ONTARIO, CANADA M3B 3J4
TELEPHONE (416) 445-5809 TELEX 06-986947

CERTIFICATE OF ANALYSIS

TO: Concord Scientific Corporation
2 Tippett Road
Downsview, Ontario
M3H 2V2

Attn: P. Fellin

DATE SUBMITTED: June 26, 1984 REPORT #: 254

RE YOUR REF. #: REF. FILE #: 248

SAMPLES SUBMITTED TO US FOR ANALYSIS SHOW RESULTS AS FOLLOW:

(see attached report)

DIAGNOSTIC RESEARCH LABORATORIES

Roy G. Smith

CERTIFIED BY:
ROY G. SMITH

DATE: July 13, 1984

```
DIAGNOSTIC RESEARCH LABORATORIES 18-JUL-84  REPORT 254 REF. FILE 248 PAGE    1

SAMPLE                       CD NG/ML  PB NG/ML
-------------------------------------------------
02562                          <10       <20
02566                          <10       <20
02568                          <10       <20
02570                          <10       <20
02572                          <10       <20
02574                          <10       <20
02578                          <10       <20
02582                          <10       <20
02584                          <10       <20
02750                          <30       <30
02753                          <30       490
02756                          <30       490
02759                          <30       130
```

```
SAMPLE                      CD UG/G   PB UG/G
--------------------------------------------
02646                        <2         20
02647                        <2         10
02652                        <2         10
02653                        <2         20
02657                        <2         24
02745                        74       6440
02746                        72       6380
```

```
DIAGNOSTIC RESEARCH LABORATORIES 18-JUL-84  REPORT 254 REF. FILE 248 PAGE   3

     SAMPLE                    CD UG/TF  PB UG/TF
     ----------------------------------------------
     02697                       <12        24
     02701                       <12        24
     02705                       <12        24
     02709                       <12        12
     02713                       <12        24
     02717                       <12        24
     02721                       <12        24
     02725                       <12        12
     02729                       <12        24
     02730                       <12        24
     02733                       <12        12
     02737                       <12        12
     02741                       <12        24
     02742                       <12        12
```

SAMPLE	AS NG/ML	SE NG/ML	NA NG/ML	SN NG/ML	HG NG/ML
02587	<1.0	2.5	--	--	--
02591	<1.0	<1.0	--	--	--
02595	<1.0	1.5	--	--	--
02596	<1.0	1.5	--	--	--
02597	<1.0	1.0	--	--	--
02598	<1.0	1.5	--	--	--
02599	<1.0	1.5	--	--	--
02604	<1.0	1.5	--	--	--
02607	<1.0	1.0	--	--	--
02610	--	--	--	--	0.51
02613	--	--	--	--	0.41
02616	--	--	--	--	0.46
02619	--	--	--	--	0.27
02622	--	--	--	--	0.07
02625	--	--	--	--	1.00
02628	--	--	--	--	1.73
02631	--	--	--	--	0.31
02634	--	--	--	--	1.52
02750	<3.0	<3.0	<400	<25	<0.20
02753	<3.0	780.	1600	<25	480.
02756	<3.0	<3.0	<400	490	2.30
02759	<3.0	<3.0	4800	80	<0.20

```
SAMPLE                  AS UG/G   SE UG/G  NA UG/G  SN UG/G  HG NG/G
--------------------------------------------------------------------
02646                       1.2     <0.2     1300       <2     25.0
02647                       1.2      0.2     1400       <2     25.0
02652                       1.0     <0.2      700       <2    <5.00
02653                       1.2     <0.2      600       <2     10.0
02657                       2.0      5.0     1450       <2      5.00
02745                      130.     34.0     1720       80   1100.
02746                      130.     36.0     1720       86    990.
```

SAMPLE	AS UG/TF	SE UG/TF	NA UG/TF	SN UG/TF	HG NG/TF
02697	<1.2	<1.2	27600	<12	<60.00
02701	<1.2	<1.2	28200	<12	<60.00
02705	<1.2	<1.2	33000	<12	<60.00
02709	<1.2	<1.2	24600	<12	<60.00
02713	<1.2	<1.2	31800	<12	<60.00
02717	<1.2	<1.2	27600	<12	<60.00
02721	2.4	4.8	24600	<12	<60.00
02725	2.4	4.8	21600	<12	<60.00
02729	3.6	4.8	24600	<12	<60.00
02730	3.6	4.8	22200	<12	<60.00
02733	2.4	4.8	21600	<12	<60.00
02737	2.4	6.0	22200	<12	<60.00
02741	2.4	3.6	25800	<12	<60.00
02742	2.4	3.6	23400	<12	<60.00

```
SAMPLE                   BE NG/ML  V NG/ML   MO NG/ML CR NG/ML MN NG/ML
-----------------------------------------------------------------------
02750                      5.0       5.0      <15       3.0      <15
02753                     <3.0     470.       <15      <3.0      <15
02756                     <3.0     870.       <15     500.       460
02759                     <3.0     230.       <15     130.       120
```

```
DIAGNOSTIC RESEARCH LABORATORIES 18-JUL-84  REPORT 254 REF. FILE 248 PAGE    8

   SAMPLE                  FE NG/ML  CO NG/ML NI NG/ML CU NG/ML ZN NG/ML
   ---------------------------------------------------------------------
   02750                       <6       <10      <20     <3.0       13
   02753                        6       <10      <20     <3.0      <13
   02756                     3600       <10      870     <3.0     1800
   02759                      930       <10      230     <3.0      490
```

SAMPLE	ZR NG/ML	AG NG/ML	BA NG/ML	AL NG/ML	CA NG/ML
02750	<15	<15	<6.0	<15	<15
02753	<15	<15	<6.0	<15	<15
02756	<15	<15	400.	1600	1400
02759	<15	<15	100.	410	570

```
SAMPLE                      MG NG/ML   P NG/ML   SI NG/ML TI NG/ML
----------------------------------------------------------------
02750                            5      <130        15        <3
02753                           <5      <130        25        <3
02756                         1100      <130      7500         5
02759                          320      <130      2000         3
```

```
SAMPLE                    BE UG/G   V UG/G   MO UG/G  CR UG/G  MN UG/G
----------------------------------------------------------------------
02646                       0.2      32.0        8     12.0      134
02647                       0.4      29.0        8     16.0       97
02652                       0.2      46.0        6     12.0       89
02653                      <0.2      43.0        8     12.0      153
02657                       0.6    1840.       115     21.0      290
02745                       2.0      92.0       36    106.       886
02746                       2.0      92.0       36    104.       900
```

```
SAMPLE                      FE UG/G   CO UG/G  NI UG/G  CU UG/G  ZN UG/G
-----------------------------------------------------------------------
02646                         11000         4       17      6.4       26
02647                          9270         2       22      7.4       64
02652                          6850         2       22      8.6       63
02653                          9270         3       18      8.4       32
02657                          9270        32      557     16.0       29
02745                         38800        20       78     572.     4480
02746                         38000        20       74     572.     4560
```

SAMPLE	ZR UG/G	AG UG/G	BA UG/G	AL UG/G	CA UG/G
02646	3	<1	23.0	1790	10600
02647	3	<1	22.0	1920	11700
02652	2	<1	7.0	715	2490
02653	2	<1	7.4	753	2890
02657	10	<1	52.0	11400	1390
02745	4	8	260.	13400	52200
02746	2	8	252.	13100	53400

SAMPLE	MG UG/G	P UG/G	SI UG/G	TI UG/G
02646	3370	110	<100	110
02647	4320	100	160	108
02652	678	40	130	42
02653	728	40	170	53
02657	684	120	<100	518
02745	6380	7120	<100	990
02746	6220	7100	<100	848

SAMPLE	BE UG/TF	V UG/TF	MO UG/TF	CR UG/TF	MN UG/TF
02697	<1.2	7.2	<6	6.0	6
02701	<1.2	4.8	6	7.2	6
02705	<1.2	3.6	12	6.0	6
02709	<1.2	4.8	<6	4.8	6
02713	<1.2	6.0	6	4.8	6
02717	<1.2	3.6	<6	6.0	6
02721	<1.2	228.	24	10.8	90
02725	<1.2	144.	12	7.2	54
02729	<1.2	378.	30	20.4	138
02730	<1.2	390.	30	20.4	138
02733	<1.2	120.	12	4.8	42
02737	<1.2	132.	12	6.0	42
02741	<1.2	108.	12	7.2	42
02742	<1.2	114.	12	8.4	42

SAMPLE	FE UG/TF	CO UG/TF	NI UG/TF	CU UG/TF	ZN UG/TF
02697	162	<6	<9	2.4	42
02701	126	<6	<9	2.4	42
02705	126	<6	9	2.4	48
02709	102	6	9	2.4	36
02713	132	<6	<9	2.4	42
02717	114	6	9	3.6	54
02721	3000	12	99	3.6	60
02725	1620	6	78	3.6	36
02729	4710	18	150	7.2	48
02730	4740	18	156	4.8	48
02733	1380	6	54	3.6	30
02737	1380	12	78	3.6	36
02741	1200	6	54	4.8	42
02742	1260	12	54	3.6	42

SAMPLE	ZR UG/TF	AG UG/TF	BA UG/TF	AL UG/TF	CA UG/TF
02697	<6	<6	78.0	4790	10600
02701	<6	<6	78.0	4790	10600
02705	<6	<6	90.0	5620	13000
02709	<6	<6	66.0	4120	9400
02713	<6	<6	84.0	5720	12500
02717	<6	<6	78.0	4630	10800
02721	12	<6	72.0	3760	5270
02725	6	<6	50.0	2390	3150
02729	12	<6	72.0	4540	4550
02730	12	<6	60.0	4130	3470
02733	<6	<6	42.0	2000	2350
02737	6	<6	60.0	2410	3160
02741	6	<6	72.0	3280	5660
02742	<6	<6	66.0	2970	4880

```
SAMPLE                         MG UG/TF  P UG/TF  SI UG/TF TI UG/TF
------------------------------------------------------------------
02697                           4250      <60      1070       24
02701                           4330      <60      1100       24
02705                           5100      <60      1010       24
02709                           3760      <60       750       24
02713                           4970      <60      1210       36
02717                           4300      <60       930       24
02721                           2090       60       820      192
02725                           1300      <60      1710      120
02729                           1840       60      1520      336
02730                           1400      <60      1340      360
02733                            940      <60      1450      108
02737                           1250       60      1160      108
02741                           2270      <60      1450       96
02742                           1960      <60      1100       96
```

Type A
Glass Fiber Filters

FEATURES

▪ High tensile strength. ▪ Excellent handling characteristics. ▪ Good wetting properties. ▪ Minimum of 99.9% retention for particles of .3 μm as determined by DOP tests. ▪ Binder free.

This is the original glass fiber filter pioneered by Gelman Instrument Company over 15 years ago. It continues to be widely used for high volume sampling. Since zinc is one of the raw materials incorporated in the glass fibers, Type A Filters have a variable zinc content. Another component of the filter, sulfuric acid, is used as a dispersion medium, making the sheets unsuitable for measurement of sulfates.

Type A Glass Fiber Filters are less likely to develop static charge or tear than other glass fiber media types. They are used extensively in applications where zinc and iron content is not important, or where sulfate content is not being determined.

Size	37 mm	47 mm	102 mm	8"x10"
Product No.	61715	61694	61696	61701
Filters/Pkg.	500	100	100	100

TYPE A GLASS FIBER FILTER SPECIFICATION REPORT

The following physical/chemical properties represent typical, average values obtained in accordance with accepted test methods. They are subject to normal manufacturing variations and are supplied as a technical service. *The analysis has been made in accordance with EPA procedures (micrograms/8" x 10" sheet).*

ELEMENTS:

Antimony	.30	Manganese	.200
Arsenic	.30	Mercury	.100
Beryllium	.1	Molybdenum	.10
Bismuth	.10	Nickel	.10
Cadmium	.5	Selenium	.5000
Chromium	.10	Tin	.10
Cobalt	.10	Titanium	.170
Copper	.2	Vanadium	.10
Iron	.2300	Zinc	.5000 to 25,000
Lead	.20		

OTHER PHYSICALS:

BSO	.522	Flow Resistance (Max.) @ 320 cm/min.	.80 mm
*pH	.8.5	Flow Rate (air) lpm/cm² @ 70 cm Hg	.50
DOP @320/cm/min (ASTM Method 2986	.99.9%	Max. Use Temp.	.400°C
Tensile Strength (Fed. Spec. UUP31B)	.750 gr	Static Properties	Low
Weight, 8"x10" sheet	.4.0±.3 gr.	Ability to Fold	Excellent

WATER EXTRACTABLE IONS:

Sulfate	.100	Chloride	.1500
Nitrate	.50	Fluoride	.15
Ammonia	.20		

*pH—Gelman Procedure:
A. 500 ml distilled water.
B. Add 15 drops saturated KCl solution
C. Shred one 8"x10" sheet and soak in prepared water for one hour.
D. Run pH at ambient temperature.

Type A/E
Glass Fiber Filters

FEATURES

▪ Low trace metals. ▪ Medium Handling characteristics. ▪ Available in all sizes. ▪ Minimum of 99.9% retention for particles of .3 μm as determined by DOP tests. ▪ Binder free.

Type A/E Glass Fiber Filters are composed of low acid soluble glass fiber. They contain low levels of both zinc and iron. The filters do react with atmospheric sulfur dioxide; and therefore, when high levels of sulfur are expected, corrections for this reaction should be accounted for.

Type A/E Glass Fiber Filters are binder free and ideal for gravimetric analysis of air pollutants. This pure, organic free filter is the basis for procedures widely used in determining municipal and industrial air polluting substances.

Size	25 mm	37 mm	47 mm	102 mm	8"x10"
Product No.	61630	61652	61631	61633	61638
Filters/Pkg.	500	500	100	100	100

TYPE A/E GLASS FIBER FILTER SPECIFICATION REPORT

The following physical/chemical properties represent typical, average values obtained in accordance with accepted test methods. They are subject to normal manufacturing variations and are supplied as a technical service. *The analysis has been made in accordance with EPA procedures (micrograms/8" x 10" sheet).*

ELEMENTS:

Antimony	.20	Manganese	.2
Arsenic	.20	Mercury	.80
Beryllium	.1	Molybdenum	.10
Bismuth	.10	Nickel	.10
Cadmium	.2	Selenium	.200
Chromium	.10	Tin	.10
Cobalt	.10	Titanium	.10
Copper	.2	Vanadium	.10
Iron	.100-1800	Zinc	.90
Lead	.10		

OTHER PHYSICALS:

BSO	.522	Flow Resistance (Max.) @ 320 cm/min.	.80 mm
*pH	.9.0	Flow Rate (air) lpm/cm² @ 70 cm Hg	.60
DOP @320/cm/min ASTM Methods 2986)	.99.9%	Max. Use Temp.	.400°C
Tensile Strength (Fed. Spec. UUP31B)	.600 gr.	Static Properties	.Medium
Weight 8"x10"sheet	.4.0±.3 gr.	Ability to Fold	Good

WATER EXTRACTABLE IONS:

Sulfate	.600	Chloride	.1500
Nitrate	.115	Fluoride	.87
Ammonia	.13		

*pH—Gelman Procedure:
A. 500 ml distilled water.
B. Add 15 drops saturated KCl solution.
C. Shread one 8"x10" sheet and soak in prepared water for one hour.
D. Run pH at ambient temperature.

U. S. Department of Commerce
Malcolm Baldrige
Secretary

National Bureau of Standards
Ernest Ambler Director

National Bureau of Standards
Certificate of Analysis
Standard Reference Material 1648
Urban Particulate Matter

This Standard Reference Material (SRM) is intended for use in the calibration of apparatus and evaluation of methods used in the analysis of atmospheric particulate matter and materials with a similar matrix.

Certified Values of Constituent Elements: The certified values for the constituent elements are shown in Table 1. The analytical techniques used in the certification are shown in Table 3. The certified values are based on measurements of 6 to 30 samples by each of the analytical techniques indicated. Noncertified values are given for information only in Table 2.

Notice and Warnings to Users: This material is a naturally occuring urban dust to be used for analytical purposes only. It may contain a number of chemicals of unknown toxicities, therefore, the utmost caution and care must be exercised in its use.

Expiration of Certification: This certification is invalid after 5 years from date of purchase. Should it be shown to be invalid prior to that time, users will be notified by NBS.

Stability: This material should be kept in its original bottle and stored at temperatures between 10-30 °C. It should not be exposed to intense source of radiation, including ultraviolet lamps or sunlight. Ideally, the bottle should be kept in a desiccator at the recommended temperature.

Use: A minimum of 100 mg of the dried material (See Drying Instructions) should be used for any analytical determination to be related to the certified values of this certificate.

Source and Preparation of Material: This SRM was prepared from urban particulate matter collected in the St. Louis, Missouri, area in a baghouse specially designed for this purpose. The material was removed from the filter bags and combined in a single lot. This product was screened through a fine-mesh sieve to remove extraneous materials and thoroughly blended in a V-blender. The material was then bottled and sequentially numbered. The material was collected over a period in excess of 12 months and, therefore, is a time-integrated sample. While not represented to be typical of the area in which it was collected, its use should typify the analytical problems of atmospheric samples obtained from industrialized urban areas.

Homogeneity Assessment: Randomly selected bottles were used for the analytical measurements. Each analyst examined at least 6 bottles, some of them measuring replicates from each bottle. No correlation was found between measured values and the bottling sequence. Also, the results of measurements of samples from different bottles were not significantly different than the measurements of replicate samples from single bottles. Accordingly, all bottles of this SRM have been assigned the same certified values of constituent elements.

Instructions for Drying: This material should be dried at 105 °C for 8 hours before use. Because the certified concentrations are reported on a "dry-weight" basis, the concentrations determined on undried samples should be adjusted for the moisture content of the samples.

The overall direction and coordination of the technical measurements leading to certification were performed under the chairmanship of J.K. Taylor.

The technical and support aspects involved in the preparation, current and previous certification, and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by T.E. Gills and W.P. Reed.

Washington, D.C. 20234
May 11, 1982
(Revision of Certificate
dated 11-16-78)

George A. Uriano, Chief
Office of Standard Reference Materials

(over)

Table 1. Certified Values of Constituent Elements

Major Constituents

Element	Content[a] Wt. Percent
Aluminum[b]	3.42 ± 0.11
Iron	3.91 ± 0.10
Potassium[b]	1.05 ± 0.01

Minor Constituents

Element	Content[a] Wt. Percent
Lead	0.655 ± 0.008
Sodium[b]	0.425 ± 0.002
Zinc	0.476 ± 0.014

Trace Constituents

Element	Content[a] µg/g	Element	Content[a] µg/g
Arsenic	115 ± 10	Nickel	82 ± 3
Cadmium	75 ± 7	Selenium[b]	27 ± 1
Chromium	403 ± 12	Uranium	5.5 ± 0.1
Copper	609 ± 27	Vanadium[b]	140 ± 3

[a] The uncertainties shown for the elements except those noted by superscripts include errors associated with both measurement and material variability. They represent the 95 percent tolerance limits for individual subsamples, i.e., 95 percent of the subsamples from a single unit of this SRM would be expected to have a composition within the indicated range of values 95 percent of the time.

[b] These elements were recently certified as a part of the NBS update certification program. The values for the indicated constituent are the "best value" based on all measurement methods used and the associated uncertainty is expressed as the standard error considering variability within and between analytical methods.

Table 2. Noncertified Values for Constituent Elements

Note: The following values are not certified because they are not based on the results of either a reference method or two or more independent methods. These values are included for information only.

Major Constituents

Element	Content Wt. Percent
Sulfur	(5.0)
Magnesium	(0.8)

Minor Constituents

Element	Content Wt. Percent
Chlorine	(0.45)
Titanium	(0.40)

Trace Constituents

Element	Content µg/g	Element	Content µg/g
Antimony	(45)	Lanthanum	(42)
Barium	(737)	Rubidium	(52)
Bromine	(500)	Manganese	(860)
Cerium	(55)	Samarium	(4.4)
Cesium	(3)	Scandium	(7)
Cobalt	(18)	Silver	(6)
Europium	(0.8)	Thorium	(7.4)
Hafnium	(4.4)	Tungsten	(4.8)
Indium	(1.0)		
Iodine	(20)		

Supplemental Information

The values listed below are based on measurements made in a single laboratory and are given for information only. While no reason exists to suspect systematic bias in these numbers, no attempt was made to evaluate such bias attributable to either the method or the laboratory. The method used for each set of measurements is also listed. The uncertainties indicated are two times the standard deviation of the means.

Constituent	Content Wt. Percent
Nitrogen (NO_3)	(1.07 ± 0.06)
Nitrogen (NH_4)	(2.01 ± 0.08)
Sulfate	(15.42 ± 0.14)
SiO_2	(26.8 ± 0.38)
Freon Soluble	(1.19 ± 0.47)

Methods Used:

Nitrate - Extraction with water and measurement by ASTM Method D992

Ammonia - NaOH addition followed by steam distillation and titration

Sulfate - Extraction with water and measurement by ASTM D516

SiO_2 - Solution and measurement by ASTM Method E350

Freon Soluble - Extraction with Freon 113, using the Method described in "Standard Methods in Examination of Water and Waste Water," 14th Edition, p. 518, American Public Health Association, Washington, D.C.

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14. L. P. Powell
15. T. C. Rains
16. T. A. Rush

Table 3 Methods and Analysis

Method/ Element	A	B	C	D	E	F	G	H	I
Ag			●						
Al			●					●	
As			●		●				
Ba			●						
Br			●						
Cd	●	●	●	●					
Ce			●						
Cl							●		
Co			●						
Cr		●	●						
Cs			●						
Cu	●	●			●				
Eu			●						
Fe	●	●	●		●				
Hf			●						
I			●			●			
In			●						
K	●		●						
La			●						
Mg			●						
Mn	●		●						●
Na	●		●						●
Ni	●	●		●					
Pb	●	●		●					
Rb			●						
S							●		
Sb			●						
Sc			●						
Se	●		●						●
Sm			●						
Th			●						
Ti			●						
U		●							
V	●		●						
W			●						
Zn	●	●	●	●					

Analytical Methods

A. Atomic Absorption Spectrometry
B. Isotope Dilution Mass Spectrometry
C. Neutron Activation Analysis
D. Polarography
E. Spectrophotometry
F. Photon Activation Analysis
G. Ion Chromatography
H. D.C. Plasma Atomic Emission Spectrometry
I. Flame Emission Spectrometry

EVALUATION OF WALL LOSSES
IN FLOW SENSOR
SOURCE TEST IMPACTOR

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EXECUTIVE SUMMARY

Inadvertent loss of particulate matter on the walls of an inertial impactor is a factor which influences the quality of data acquired in field applications of such a device. The Flow Sensor impactor was designed to reduce wall losses through the use of a high degree of flow venting on each impaction stage and the avoidance of small sharply turning passages between stages.

To quantify the losses of the Flow Sensor system, a set of laboratory experiments was conducted in which the impactor was used to sample monodisperse oleic acid aerosols over the size range of 1.9 to 16.5 um. A fluorescent analytical tracer, which was added to the oleic acid, was washed from the impactor walls and the relative mass compared with the total mass sampled by the system. Peak wall losses were 3.5 percent over the range of sizes employed in the experiments.

INTRODUCTION

With the advent of the means to reliably generate monodisperse aerosols from materials for which there are sensitive analytical measurement techniques, it has become possible to characterize the design limitations of particle fractionation systems. One of these limitations, the wall losses, can have a significant impact on the value of the field data. For example, an inertial impactor was used in the National Air Sampling Network (NASN) for acquisition of size distribution data on aerosols in the ambient atmosphere. Test results subsequent to its useage showed that wall losses were 50 percent for 4 μm diameter particles and 95 percent for 10 μm particles (1). An original version of the dichotomous sampler, the cascade centripeter (2) had wall losses of 40 percent at the cutpoint sizes; however, in later designs these losses were reduced to approximately 6 percent (3). Particle size data from devices which have high wall losses must be subject to question.

An evaluation of wall losses for several commercially available source test impactors was performed by Cushing et al (4) who operated the units in the horizontal position and sampled solid ammonium fluorescein aerosols. For true wall losses it would appear to be preferable to use liquid aerosols whereby those particles which strike a wall will adhere to that surface.

For the experiments performed herein, an oil droplet aerosol formed from oleic acid tagged with sodium fluorescein, was employed. The impactor was operated in the horizontal position with a straight inlet nozzle of the same diameter as the acceleration jet of the internal pre-impactor, 1.07 cm.

Flow rate through the system was 14.2 L/min (0.5 cfm) for all tests. Wall losses were determined by eluting the fluorescent tag from all components of the system, the metal parts and the after-filters.

METHODOLOGY

Aerosol was generated with a vibrating jet atomizer (5) from a solution of ethanol and oleic acid with the tag of sodium fluorescein. Freshly formed mist was passed by a 10 mCi Kr-85 radioactive source to neutralize electrical charge. Upon evaporation of the ethanol there results a uniformly sized aerosol of oleic acid droplets containing 10 percent (m/v) of sodium fluorescein.

The aerosols were sized sized by first collecting samples on glass slides that were made oil-phobic by treatment with 3M Co. Chemical FC-721. A Cassella impactor was used for collection of these samples. The size of the droplets on a treated slide was measured with the aid of a calibrated Filar eyepiece in a light microscope. Due to the interfacial and surface tension, the droplets assume the shape of a plano-convex lens on the slide. Calculation of equivalent spherical droplet diameter from the size of the droplet observed under the microscope can be made through use of the "flattening coefficient" of Olan-Figueroa (6). Aerodynamic size was then calculated from the equivalent spherical diameter assuming that the particle density was that of pure oleic acid, 0.895 g/mL.

Prior to a test, in an analysis laboratory all components of the impactor were washed in a detergent solution, rinsed with distilled water and dried with filtered air. The unit was assembled using stainless steel impaction substrates for the collection stages and a glass fiber after-filter. The impactor was encased in a shroud of polyethylene film, brought into the test laboratory, and mounted external to a 15 cm diameter aerosol test duct. During operation, aerosol from the generator was passed through the test duct where a sample was diverted to the impactor while the excess aerosol was passed through an absolute filter and the air discharged back into the laboratory. The impactor was operated at the set flow rate of 14.2 L/min for sufficient time to collect adequate fluorescein for analysis.

The sampler was then removed to the analysis laboratory where it was disassembled and the components immersed in ethanol (EtOH) to extract the fluorescein. The metal impactor components were totally submerged in EtOH and mildly agitated for a period of at least one minute whereas the after-filter was soaked in EtOH for at least an hour, also with periodic mild agitation. Subsequently, the solutions from both the components with which wall losses are associated (jet plates, housing, etc.) and those associated with normal collection (impaction substrates, pre-impactor and after filter) were diluted with measured amounts of water and 4 ml aliquots were removed for analysis. One drop of 1 N NaOH was added to each aliquot to stabilize fluorescence. Concentration of fluorescein was determined with a Turner Model 111 Fluorometer. Wall losses, WL, are defined as material deposited on any internal surface other than the pre-impactor and collection substrates compared with the total material sampled:

$$WL = \frac{M_{wl}}{M_{cs} + M_{wl}} \qquad (1)$$

where M_{wl} = mass of particulate matter on extraneous surfaces

M_{cs} = mass of particulate matter on collection surfaces

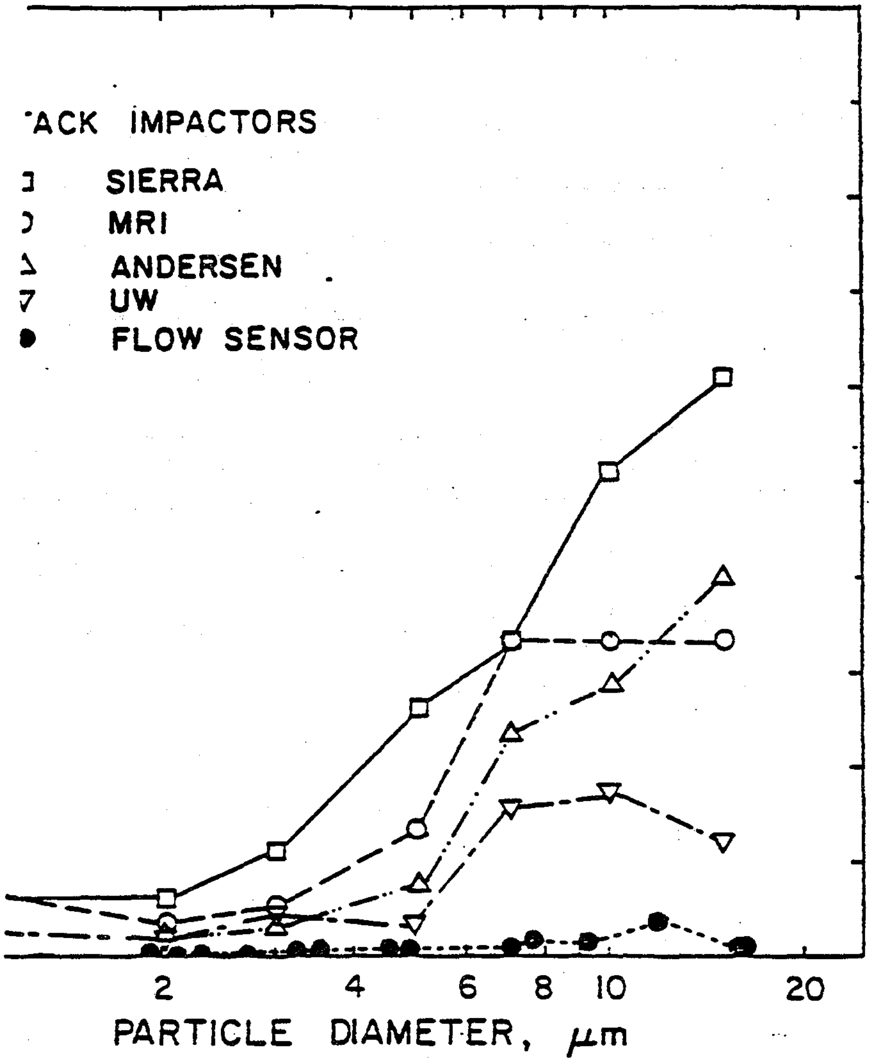
RESULTS

A total of 14 wall loss tests were conducted encompassing the range of particle sizes from 1.9 to 16.5 µm aerodynamic diameter. Resulting data are shown in Figure 1 wherein the total wall losses are given as a function of aerodynamic size. It may be noted that the peak losses are 3.6 percent and that these are associated with a size of 11.7 µm. Wall losses were less than 1 percent for all sizes less than 7.5 µm.

Shown for comparative purposes in Figure 1 are the wall loss data of Cushing et al (4) for other source test impactors.

DISCUSSION OF RESULTS

All inertial impactors exhibit some wall losses. Rao and Whitby (7) used oleic acid aerosols from a vibrating jet atomizer to characterize the wall losses of a Lundgren impactor and an Andersen 1-cfm ambient sampler. They noted the Lundgren impactor had losses of 5 percent for 7 µm particles and 15 percent for 16 µm particles. For the Andersen impactor, their data show wall losses of 10 and 52 percent for sizes of 7 and 15 µm, respectively. On the other hand, using methodology similar to that of Rao and Whitby, the present study shows the Flow Sensor stack impactor to have



GURE 1. Wall Losses of Source Test Cascade Impactors. Flow Sensor Data from Present Study, Other Data from Cushing et al (4).

losses of less than one percent at both 7 and 16 μm.

Data from the study of Cushing et al (4) cannot be directly compared with the present data because of their use of dry ammonium fluorescein aerosols. There is a potential that dry particle wall loss data could be either lower or higher than liquid particle data. Dry particles which strike a wall, rebound, and are eventually deposited on a collection surface tend to cause lower apparent wall loss values. Particles which rebound from a collection surface and are deposited on a wall will increase the apparent losses. In the work of Cushing et al, greased collection substrates were used with the MRI, and UW impactors and glass fiber collection substrates were used with the Sierra and Andersen impactors. Both of those substrates, but particularly the grease coatings, tend to reduce particle rebound from the collection surfaces. In spite of the limitations on comparisons dictated by the differences in methodologies, it may be noted from Figure 1, the wall losses for the Flow Sensor impactor are considerably lower than those of other impactors.

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Conditions of Use

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