ALBERTA OIL SANDS
CLIMATOLOGICAL AND METEOROLOGICAL
RESEARCH

prepared by

THE CONSERVATION AND UTILIZATION COMMITTEE

OIL SANDS CLIMATOLOGICAL AND HYDROLOGICAL RESEARCH TASK FORCE

approved and published

under the authority of

THE HONOURABLE W.J. YURKO, P. ENG.

MINISTER OF THE ENVIRONMENT

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Alberta

ENVIRONMENT

Environmental Coordination Services

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Dr. E.E. Ballantyne, Chairman
Natural Resources Coordinating Council

Sir:

Re: Alberta Oil Sands Climatological and Meteorological Research

On behalf of the Conservation and Utilization Committee, I have the pleasure of submitting the Alberta Oil Sands Climatological and Meteorological Research Task Force report.

For many years the Conservation and Utilization Committee has functioned as the major inter-departmental resources committee of Alberta. Formerly advisory to the Minister of Agriculture, the Committee now makes its recommendations and report therein to the Natural Resources Coordinating Council and the Minister of the Environment. In the past the Conservation and Utilization Committee has itself authorized reports, appointed task forces, or recommended retention of consultants under its direction.

This report was prepared by a Task Force operating on behalf of the Conservation and Utilization Committee at the request of the Honourable W.J. Yurko, Minister of the Environment for Alberta. Due to the urgent need for environmental research on the Alberta Oil Sands, it is planned to outline such requirements in a series of task force reports on selected environmental research issues such as this one on climatology and meteorology and others on hydrology and hydrogeology, land surface reclamation, etc. these reports are intended to provide a focus for discussion.

Respectfully submitted,

H.W. Thiessen, Chairman
Conservation and Utilization Committee

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Office of
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The Honourable W.J. Yurko, P. Eng.
Minister of the Environment
Government of Alberta

Sir:

Re: Alberta Oil Sands Climatological and Meteorological Research

The undersigned has the honour to transmit herewith the Alberta Oil Sands Climatological and Meteorological Research report prepared by the Conservation and Utilization Committee Oil Sands Climatological and Meteorological Research Task Force.

This report is one of a series of reports prepared by the Conservation and Utilization Committee on the environmental research needs of the Alberta Oil Sands. Since the reports are intended primarily to provide a focus for discussion, comments are invited on oil sands environmental research coordination and implementation, from industry, the academic community, private consultants and government research agencies. Comments should be directed to the Chairman, Research Secretariat, Alberta Department of Environment, Milner Building, Edmonton, Alberta.

Respectfully submitted,

E.E. Ballantyne, D.V.M., P. Ag., F.R.S.H.
Chairman, Natural Resources Coordinating Council

ACKNOWLEDGEMENTS

The contributions of the members of the Conservation and Utilization Committee Oil Sands Climatological and Meteorological Research Task Force are hereby acknowledged:

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Mr. F.E. Burbidge	- Atmospheric Environment Service
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1.0 SUMMARY

1.1 The Problems

The five atmospheric environmental problems most likely to be caused by extensive development of the Alberta Oil Sands are identified and listed below in order of priority based on the magnitude of the hazard they represent:

1. Ambient ground level concentrations of SO_2 near to source
2. Pollution sinks and acid precipitation on a regional scale
3. Water and ice fog
4. Odour
5. Inadvertent weather and climate modification.

1.2 The Solutions

The research required, and the meteorological observations necessary, to solve the above problems on the various scales of atmospheric phenomena are summarized in concise form in table 1.

Table 1. Summary of the Main Research Required and the Meteorological Observations Necessary to Solve the Major Identified Atmospheric Environmental Problems that will be caused by Extensive Development of the Alberta Oil Sands

SCALE OF PHENOMENA	RESEARCH REQUIRED	OBSERVATIONS NECESSARY	APPLICATION
MICRO-SCALE Local scale up to distances of approximately 5 miles	- diffusion from single point sources - evaporation from tallings ponds - fog formation	- five valley floor stations continuously measuring temperature (wet and dry bulb), wind (speed and direction (amount and intensity) - 300-ft meteorological tower and fixed mini-sonde station - collection of fog samples	- details of individual plant design - stack heights, location of tailings ponds etc. - ambient SO_2 concentrations - odour problems
MESO-SCALE Regional scale up to distances of 100 miles	- three dimensional modelling of structure and flow in valley - drift, persistence and chemical reactions of fog - additive and/or synergistic effects of multiple sources	- station (equipped as above) near top of Birch Mountain - limited duration intensive field studies using mobile mini-sonde, aircraft and remote sensing techniques - in-plume measurements of SO_2 and oxidation products downwind of source	- regional planning-location of plants in relation to each other, location of townsites, etc. - inadvertent weather modification
SYNOPTIC SCALE Large scale up to distances of 2,000 miles	- long range transport of pollutants - chemical reactions in clear atmosphere and in precipitation formation - pollution sinks - forecasting pollution potential ("episode climatology")	- solar radiation and evaporation at two stations - upper air station near Fort McMurray - network of precipitation sampling stations within 200 miles of Fort McMurray. Accurate precipitation amounts and intensity at some stations	- disposition of pollutants acidification of soils and water in surrounding region - meteorological control, frequency and forecasting of periods of high pollution potential - inadvertent weather and climate modification

2.0 INTRODUCTION

One oil extraction plant (GCOS) has been in operation for several years, the go-ahead has just been given for a second plant (Syncrude), a third (Shell) has an application pending, and the current energy crises may well accelerate the rate at which additional plants go into production during the next decade. This poses the problem of how to develop the oil sands on an exonomic basis while ensuring a minimum of undesirable effects on the total environment of the oil sands area and the surrounding region.

This report will concern itself only with the atmospheric environment and where necessary with the interface between the atmosphere and the earth's surface in terms of absorption or deposition of pollution. Although "containment at source" is the most effective way of protecting the atmospheric environment, current technology does not allow achievement of this goal either today or probably for some considerable time in the future. To be realistic we must therefore accept the fact that some pollution will enter the atmosphere. The basic question to be answered is: "How much can reasonably be allowed?"

The emissions from the present plant under normal operating conditions are approximately 350 long tons of SO_2 per day. Under upset conditions the plant is allowed to emit at the rate of up to 930 long tons of SO_2 per day for short periods. Values for the proposed Syncrude plant will be only slightly less. Thus, while the present plant is emitting at a rate of less than one-tenth that of the Sudbury area, the combined effect of several plants in a small confined area of the Athabasca Valley could produce within ten years total emissions approaching those of the Sudbury area, or even exceeding them in the case of upset. It is therefore essential that the environmental degradation that has occurred in the Sudbury area not be allowed to occur in the Alberta Oil Sands. To do this, the maximum possible use will have to be made of meteorological knowledge for the location, design and operation of the extraction plants, in order that the effects of air pollution in the area are minimized.

3.0 ANTICIPATED PROBLEMS

The following five problems have been identified concerning the atmospheric environment of the Oil Sands area. They are listed in approximate descending order of priority based on the magnitude of the hazard presented.

3.1 Ambient ground level concentration near to source

Since each of the stacks in the area will be emitting SO_2 at the rate of a few hundred long tons per day (assuming that there will be no near-term breakthrough in stack SO_2 removal technology), the problem is similar to that of the larger sulphur extraction gas plants in Alberta. The "engineering approach" to stack height design is well established, but account must be taken of the restrictive topography in the leased oil sands section of the Athabasca Valley and also the severe climatic conditions in winter. Both of these factors combine to increase substantially the chances of higher pollution potential than occurs in more southerly latitudes where most design experience has been gained.

Another problem could be created by the additive effects of several large sources of SO_2 lined up as they will be, only a few miles apart, along the valley and in the direction of the predominating light winds.

3.2 Transport and deposition of pollutants on the regional scale

Whilst appropriate location and design of the stacks can minimize the local effects, and ensure that the ground level concentrations of the pollutants do not exceed the ambient air quality standards, the eventual disposition of these pollutants will present problems on the regional scale.

The main pollutant will be SO_2 gas, and it is removed from the atmosphere in several ways:

(i) direct absorption by soil and vegetation,

(ii) conversion to sulphate particulates followed by dry deposition on the surface,

(iii) scavenging by precipitation in either the gaseous or particulate phase.

The distance the SO_2 will travel before arriving at the earth's surface in one form or another depends critically on the meteorological conditions, which also affect the rate of the various chemical transformations. There will be a gradual increase in the acidity of the soil and surface water systems within a large region surrounding the Oil Sands. Whether this will critically affect the ecosystems, and if so at what point in time, is difficult to estimate. Experience from other studies (e.g., Sudbury, Scandinavia) suggests that such effects will take many years to become apparent and can occur up to distances of several hundred kilometers from the SO_2 source. Very careful surveillance will thus be required to detect these changes.

3.3 Fog produced by combustion processes and tailings ponds

The topographic (river valley) and climatologic (high frequency of light winds) characteristics of the area are conducive to a high frequency of natural fog. The addition of large amounts of water vapour to the atmosphere through combustion processes and especially from the tailings ponds will increase the frequency of water and ice fogs in the region. The main effects are expected to be interference with transportation and possible shut-down of excavation operations (the latter has already occurred occasionally at the present plant) due to poor visibility. However, if the levels of SO_2 and other pollutants in the area are high then the fogs will be "dirty." Water fog and SO_2 combine to produce droplets composed of dilute solutions of sulphuric acid. These could present a severe health hazard (as in the great London Smog of 1952) and cause damage to property and vegetation in the area.

3.4 Odour produced by H_2S and other byproducts such as mercaptans etc.

The emissions of odour-producing substances will in general occur near ground level and not through the main stack, and under normal operating conditions are not expected to present any problems except possibly within the plant boundaries. If they do occur they will be more of a nuisance and aesthetic problem than any serious environmental hazard.

3.5 Inadvertent climate or weather modification

There is now increasing evidence that man's activities (land clearing, artificial lakes, urban areas and large sources of specific pollutants) can affect weather and climate on the local and regional scale. Effects on a global scale may also exist but are difficult to detect.

The production of man-made fogs can be considered either as pollution by water or as inadvertent weather modification on a local scale. However, the large-scale development of the Oil Sands area will cause:

(i) changes in the characteristics of the earth's surface over hundreds of square miles (by removal of the tar, disturbing the surface, etc.)

(ii) the addition of large quantities of moisture, which in addition to increasing the frequency of fogs, may cause more clouds and rain or snow;

(iii) the addition of pollutants (especially sulphur compounds with their affinity for water) which may affect the natural precipitation mechanisms within clouds.

Whether any of these effects will be large enough to be significant, or even detectable, is not known.

4.0 RESEARCH REQUIREMENTS

In order to solve the meteorological problems outlined in the preceding section a large research effort will be required over the next decade. Since the same type of observations and research will be relevant to more than one problem, it is suggested that the problems be tackled on the basis of several scales of atmospheric phenomena as follows.

Scale	Representative Distances	Representative Times
Micro-scale	up to few miles	up to few hours
Meso-scale	5 - 100 miles	up to 1 day
Synoptic scale	100 - 2000 miles	a few days

4.1 Micro-scale research

This will involve the small-scale motions and turbulence in the atmosphere relevant to the diffusion from single point sources (i.e., stack emissions) and evaporation from water surfaces (e.g., tailings ponds). Studies will be required to test the applicability of prediction formulas developed for use in more southerly latitudes and how they can be modified, or even new ones developed if necessary, to take into account the local climate and topography.

Studies will be required on the evaporation from the tailings ponds to determine whether their shape, depth or location can be designed to minimize the effects. Coating the water with evaporation inhibiters or alternative means of handling the water will need to be investigated.

4.2 Meso-scale research

This will require three-dimensional modelling of the air flow through the whole Oil Sands region. Two approaches can be used here: firstly, by utilizing a scaled topographical model of the region in a wind tunnel, and secondly, by means of computer-simulated numerical models. With such models the additive and/or synergistic effects of several large point sources in the valley, the drift of fog, etc. can be assessed, the output being used to determine the most desirable plant locations and for general regional planning (location of transportation corridors, recreation areas, town sites, etc.).

4.3 Synoptic-scale research

This will require a detailed study of the synoptic scale weather patterns in the area (motions of highs and lows, frequency of stagnating highs, etc.). These studies will provide data for the computation of air parcel trajectories once they have left the Oil Sands area, and the general weather conditions under which the long-range transport and transformation of pollutants will take place.

4.4 Atmospheric chemistry

In order to answer the questions posed in the section on fog production problems (p.4), research on all aspects of the sulphur budget in the atmosphere will be required. These include the following:

(i) the mechanism and rate at which SO_2 is oxidized and converted into sulphate particles;

(ii) the rate at which sulphate particles are deposited on the ground or at which SO_2 gas is absorbed by the soil, vegetation and water surfaces;

(iii) the mechanism and rate at which SO_2 and sulphate particles are removed from the atmosphere by precipitation scavenging or absorbed by fog.

(iv) the relation between each of the above and the ambient meteorological conditions, especially temperature and humidity, and hence the daily and seasonal variation of the chemical/meteorological interactions.

A more detailed knowledge of these above factors will allow rational standards to be set for the combined total emissions of SO_2 from the Oil Sands area.

5.0 METEOROLOGICAL DATA REQUIRED

The presently available meteorological and climatological data in the Alberta Oil Sands and surrounding region are completely inadequate for the listed research needs. The only continuous long-term hourly records are from the Fort McMurray Airport first-order synoptic weather station. However, this location is far from being representative of the conditions in the north-south section of the Athabasca Valley where the extraction plants will be located.

The nearest upper-air data are available from Fort Smith (approximately 250 miles north of Fort McMurray) and Stony Plain-Edmonton (approximately 300 miles southwest). While these may be sufficient to produce useful information on the synoptic scale, they are too far away to provide the required data for micro- and meso-scale studies in the Oil Sands area.

Quite clearly then, a substantial effort will have to be devoted to the acquisition of meteorological and climatological data in the area. It is recommended that two approaches be used:

(i) a basic network of permanent stations be set up to provide continuous long-term data;

(ii) case-studies with intensive field surveys, conducted using special equipment (aircraft, remote sensing, etc.), for limited periods during various seasons of the year over several years.

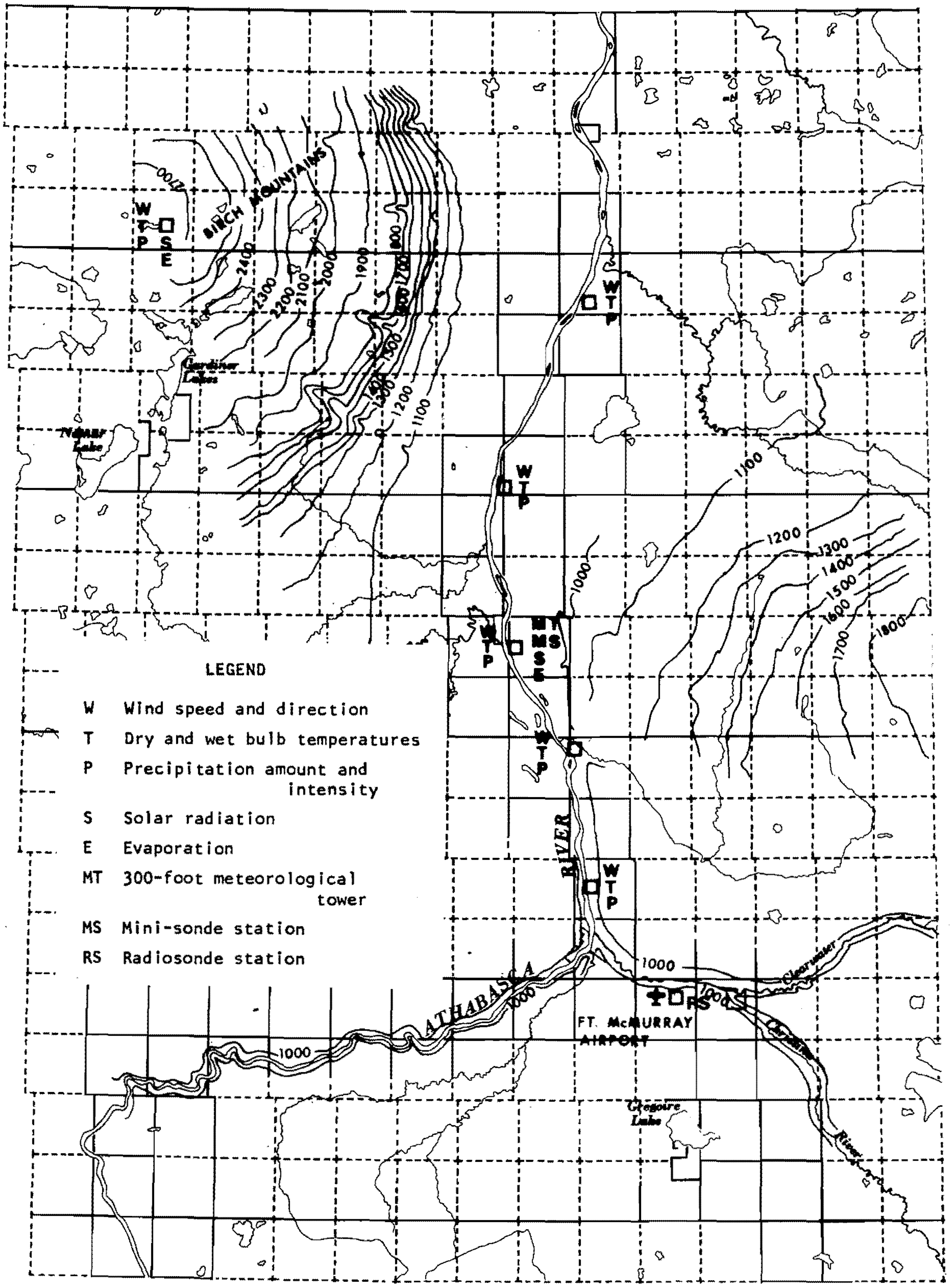

Figure 1. Suggested approximate locations for meteorological stations in the immediate vicinity of the Tar Sands.

5.1 Basic observations

It is not proposed to give here the exact locations for such a basic observing network (such sites depend on many factors such as topography, accessibility, power requirements, personnel, etc.) but the broad specifications of the type and general location (Fig. 1) of the stations that need to be set up is indicated below. The final site selections will have to be made after a very careful survey of the area to consider all the above factors and also the locations of present and future anticipated sources.

Micro-scale

The main requirement here is to obtain accurate measurements of the vertical temperature gradients, and hence the stability, in the lowest few thousand feet of the atmosphere, along with a detailed description of the horizontal wind flow through the valley. These are the most difficult measurements to obtain in sufficient detail for the research requirements. The minimum suggested network is as follows.

(i) Five surface observing stations, approximately 15 miles apart, to be set up along the valley bottom which will continuously record the following parameters:

dry-bulb temperature
wet-bulb temperature
wind speed
wind direction
precipitation.

Starting with the Ft. McMurray Airport as the base, stations could be located approximately:

north of Ft. McMurray townsite near Poplar Island
near present GCOS plant
near Fort MacKay

near Bitumount

north of Bitumount

(ii) One 300-foot high meteorological tower to be located in the Tar Sands area and equipped to measure and continously record temperature, wind speed and wind direction, and turbulence at several levels. At the same location minisondes* should be released on a regular basis. (probably three or four times daily) -- supplemented by additional ascents during high pollution potential -- in order to measure temperature and winds to a height of 5,000 feet. It is recommended that mountain-side stations not be used for this purpose since it is unlikely that their measurements would be representative of conditions in the free atmosphere over the center of the valley.

Meso-Scale

The main ingredient here is to obtain data on a broader scale than just in the river valley. The number of fixed stations required to do this satisfactorily is very large. Thus the best approach to modelling the meteorology of the region will be through case-studies (see section on case-study field surveys below), but it is recommended that one station (with the same instrumentation as the valley stations) be set up at the top of Birch Mountain in order to study the climatological differences between the valley floor and the surrounding high country.

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* The mini-sonde is a lightweight version of the radio-sonde developed by the Atmospheric Environment Service and is designed to be carried aloft by small 18" balloons. Winds are obtained by means of double-theodolite or radar tracking. A call for tenders to manufacture this device commercially has recently gone out from the Department of Supply and Services, and a ready supply should then be available by mid-1974.

Synoptic scale

Present surface data on the synoptic scale are probably adeuate, although it would be desirable to take supplemental observations such as solar insolation and evaporation at some of the synoptic stations surrounding the Oil Sands area (see section on other meteorological measurements, p. 13).

In order to study the long-range transport of pollutants, and for studies of forecasting stagnation periods for eventual meteorological control, there is a need for a full upper-air station in the Oil Sands area. The exact location is not too critical.

5.2 Case-study field surveys

The main goal is to use mobile ground-based equipment and aircraft to supplement the fixed network and obtain much more detailed observations for short periods (up to two weeks at a time) during different seasons. In order to obtain a sufficiently large sample of data for modelling of the meteorology of the Athabasca Valley these studies will be required over a period of several years. This will require the careful integration of the latest remote-sensing and immersion-sensing techniques into well-coordinated studies. All of the following observational techniques should be considered:

(i) mobile mini-sonde unit(s);

(ii) ground-based and airborne photography of pollution plume rise and motion, areal extent and drift of ice-fog, etc.;

(iii) helicopter (or slow-speed aircraft) immersion-sensing of temperature and pollution distributions in the area;

(iv) remote sensing of temperature structure using acoustic radar (SODAR) and pollutants using LIDAR and the correlation spectrometer.

5.3 Atmospheric chemistry

It is assumed that Alberta Environment will be monitoring ground level SO_2 concentrations at a sufficient number of stations in the Oil Sands area. In order to carry out the research outlined in the section on atmospheric chemistry (p. 7) the following will be necessary.

(i) Obtaining of in-plume concentrations of SO_2, and oxidation products as far downwind from the source as detectible. These will be most useful if done in conjunction with the case studies outlined in the section on case-study field surveys (p. 11).

(ii) Setting up of an extensive precipitation sampling network within a 200-mile radius of Fort McMurray. In remote areas it may be necessary to use automatic samplers and collect samples on a monthly basis. However, it will be much more useful to have precipitation samples on a daily or "storm event" basis. Wherever possible samplers should therefore be installed at manned locations where operators can be responsible for collecting the samples on the required time basis. The main emphasis will be on analysis for sulphate and other constituents relevant to the acid rain problem. Stations may be required even farther afield if indicated by preliminary studies.

(iii) Collection and analysis of chemical composition of ice fog particles and water fog droplets is necessary, especially in conjunction with case studies.

(iv) In conjunction with other groups, arrangements for measurements that allow estimates of the uptake of SO_2 and/or sulphates by soils, vegetation and open water surfaces.

5.4 Other meteorological measurements

In order to support the work on the hydrology of the Oil Sands area, the Hydrology Task Force has indicated some specific data requirements for the surface mining areas and the drainage basins where stream diversions are anticipated. The immediate needs could be met by the following observations.

(i) Precipitation -- total amounts and intensity should be measured at all of the meteorological stations listed under the section on micro-scale (p. 10) and meso-scale (p. 11), and, as required, at selected stations listed under the section on atmospheric chemistry (p. 12).

(ii) Solar radiation, evaporation and evapotranspiration should be measured at one valley floor station and at one high-country station. Suggested locations are Fort MacKay and Birch Mountain

6.0 PRIORITIES FOR IMPLEMENTATION OF METEOROLOGICAL OBSERVATIONS

Although implementation of the research requirements is beyond the terms of reference of the Task Force, it is pointed out that the meteorological observations are required before most of the recommended research can begin. This section thus contains general recommendations and priorities for establishing the necessary meteorological stations and precipitation sampling network.

In view of the large amount of instrumentation required (involving several different agencies), it is strongly recommended that a co-ordinating office be set up specifically for this purpose in Fort McMurray. The office would initially have the responsibility (either in-house or by contract, or a combination of both) for the following:

(i) site selection co-ordinating with other existing or proposed industry, hydrology, or forestry monitoring sites, in order to avoid unnecessary duplication;

(ii) installation and maintenance of the meteorological instrumentation and samplers;

(iii) intercomparison calibration of instrumentation used by all groups;

(iv) quality control of records and data reduction;

(v) chemical analysis of fog and precipitation samples;

(vi) publication, on a rapid turn-around basis, of raw data and data summaries in tabulated form or on computer cards or tapes in format required by the research scientists, and other users.

At a later stage this same office may take over responsibility for providing special weather and pollution potential forecasts if real-time meteorological control becomes part of the pollution control strategy. Serious consideration should therefore be given to telemetering all meteorological data from the additional special stations into this office so that experience in understanding and forecasting the local weather conditions in the Oil Sands area can be accumulated prior to the requirement for its real-time use.

6.1 Priorities for installation

Installation of the large amount of instrumentation recommended in the section on basic observations (p. 8) will take considerable time, and will involve considerable capital expenditures. Installation may thus have to be spread over a period of two or three years. In order to provide the maximum amount of new information most rapidly, as well as background measurements before further development in the area, the following installation schedule is recommended:

(i) a detailed survey of all existing stations (belonging to the Atmospheric Environment Service, the Alberta Forest Service and the oil industry) to be carried out to determine whether in their present status, or with supplemental instrumentation, they are suitable from the point of view of location and operating personnel;

(ii) installation of the site in the center of the leased area (probably near Fort MacKay) with all equipment including meteorological tower and mini-sonde.

(iii) installation of first precipitation samplers on a wide spacing over a large region to get background data of sulphur concentrations before additional sources affect the area:

(iv) installation of the remaining valley floor stations;

(v) installation of Birch Mountain station;

(vi) installation of remaining precipitation sampling stations (this could be a continuous on-going process);

(vii) installation of full upper-air station.

6.2 Staffing requirements

In order to carry out the installation, on-going maintenance and the data reduction program outlined above the following minimum staff will be required:

1 meteorologist	- preferably with a background in instrumentation and air pollution
2 instrument technicians	- with a good knowledge of meteorological instruments
1 chemical technician	- with training in sampling and water analysis procedures.