# ALBERTA OIL SANDS
# ENVIRONMENTAL RESEARCH PROGRAM
# 1975-1980:
# SUMMARY REPORT

by

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## PREFACE

This report is not intended to be a definitive review of published literature concerning environmental changes which might occur in northern ecosystems as a result of massive industrial development. Rather, it is intended to summarize a large number of surveys and some research of a distinctly applied nature and to describe the manner in which the Alberta Oil Sands Environmental Research Program (AOSERP) was carried out.

The level of impact reported to date is described in a manner which allows environmental managers in government and industry to decide what additional research may be required to support future environmental management decisions. It was not possible with available data and within the terms of reference for this report to predict the consequences of future massive development of the Athabasca Oil Sands; to do so would be speculative.

The position is taken a priori in organizing this report that the AOSERP systems approach to environmental research points the way to description of air, land, water, and human systems in terms (conceptually at least) of dynamic models, which may be useful in directing future research and in assessing long-term environmental effects of development of the Athabasca Oil Sands. Such an approach lends itself to computer simulation modelling which may be used to develop alternative predictive impact scenarios and research options, without prior committal of large research budgets.

The systems approach used by AOSERP is only the first step toward any in-depth assessment of ecosystems and social impacts--an administrative convenience for organizing a complex series of investigations. In order to assess with any degree of exactitude what the long-term impacts of oil sands development might be, extensive research will be required to develop a predictive capabiity which does not now exist. Some of the obvious gaps in research knowledge are discussed and recommendations advanced which might aid in correcting these deficiencies.

## SUMMARY

This report provides background information which describes the initiation and conduct of AOSERP from 1975 to 1980. The program amassed a very large amount of baseline information over its five-year life, at a cost of about $17.4 million. The assessment is made that baseline information on the Athabasca Oil Sands region is now complete enough that additional general surveys will not be required in future. Rather, recommendations are advanced for specific applied research projects. Systems research results are described below in relation to possible effects on ecosystems and people.

AIR SYSTEM

For the Air System, atmospheric research has culminated in the construction of an air quality model for the region. This first-order frequency distribution model has the unique characteristic that permits biological and social weighting of calculated ground level concentration values for pollutants according to meteorological parameters included in a time series data file. Further development and use of the air quality model will provide a powerful tool for prediction of air quality, as well as the basis for air quality control decisions. In this regard, the Air System program is further advanced than Land, Water, and Human systems, and comes closest to meeting its major objectives. A serious deficiency still occurs in the Air System with respect to knowledge of deposition of atmospheric pollutants, although some preliminary estimates are available for winter months. This lack of information will prejudice the capacity of terrestrial ecologists to assess the effects of air pollution on terrestrial ecosystems.

LAND SYSTEM

Land System research has proceeded to the point where an adequate data base has been established for soils and surficial

geology, vegetation, and wildlife. A large part of the area is not highly productive for ungulate species such as moose or caribou, whose numbers apparently are stable or declining. Wherever public access is increased, or further withdrawals of terrestrial habitat made, ungulate populations will be reduced. Of particular significance will be completion of a bridge across the Athabasca River near Fort MacKay, which will provide easy access to fish and wildlife on the east side of the Athabasca River. Lacking more precise information, the judgement is offered that the moose population of the Muskeg River basin will decline and that the numbers of pike, walleye, and grayling available to anglers likewise will be reduced as a consequence of increased angling pressure.

Research concerning impacts of air pollution on soils and vegetation has not as yet demonstrated that damage has occurred from atmospheric pollutants. Biomonitoring carried out to date shows no physiological response of jack pine and other sensitive woody-stemmed plants to atmospheric pollutants. Experimental evidence indicates that ground level concentrations of $SO_2$ would have to be considerably higher than at present to result in a significant response. Nevertheless, changes have occurred in sulphur content of vegetation, and species frequency occurrence of lichens shows indication of change. Changes in soil chemistry have not been demonstrated in relation to deposition of atmospheric pollutants.

No accurate prediction can be made at this time of the long-term effects of low-level air pollution on vegetation, particularly when quantitative information is lacking on deposition of air pollutants. For this reason, it seems self-evident that permanent biomonitoring networks must be established, using appropriate organisms and methodology to provide an early warning system of assessing air pollution impacts over extended time periods.

## WATER SYSTEM

Baseline information on hydrology, hydrogeology, water quality, and aquatic biota of the Athabasca Oil Sands region is essentially complete. Studies of water chemistry and aquatic biota in the Athabasca River fail to reveal significant impacts downstream of Fort McMurray and the two presently operating oil sands plants, either from materials emanating from the industrial operations or from domestic sewage and municipal drainage from Fort McMurray. Lake acidification potential in the region appears to be low at present development levels. The Athabasca River has been shown to be extremely important for fish, and projections as to water withdrawal by the year 2000 indicate that these might exceed 40% of the mean daily low flow of the Athabasca River at Fort McMurray. A combination of low flow and increased sewage and other effluents could result in deterioration of conditions in late winter when fish are known to be migrating upstream in the Athabasca River under ice cover.

Streams tributary to the Athabasca River have been shown to constitute an important part of the Athabasca system, both for spawning and rearing of fish. Production in tributary streams is highest in upstream reaches, both for primary and secondary production. A number of areas through which tributary streams run have relatively high erosion potential. Sediment from disturbed erodable areas could have a deleterious effect on aquatic organisms in tributary streams, and the amount of sediment entering tributary streams will increase with increased human activity in the region.

## HUMAN SYSTEM

Human System research has described conditions in the Athabasa Oil Sands region both in historical and in contemporary terms. Data have been accumulated on demographic and socio-economic changes which have occurred as a consequence of oil sands development. There has been a startling transformation of the region during the period from 1960 to 1980, with Fort McMurray increasing its population by about 10 times. Fort McMurray now dominates the region as an urban centre of about 30 000 people, and was accorded city status on 1 September 1980.

Research data have been used to construct a conceptual framework for social research which can be related to the still rapidly changing conditions resulting from oil sands development. Development of appropriate indicators of social change has allowed an in-depth, quantitative assessment of the adjustment of people in Fort McMurray to social conditions in this urban area. No psychological disorientation has been recorded for residents of Fort McMurray, who generally have a positive and optimistic view of their jobs and social environment, both at present and for the future. In-depth descriptions have been provided for the several stages of development of resource communities.

Human System research has been directed to the needs of users and has attempted to identify policy-relevant socio-economic parameters. A compendium of social statistics has been compiled and interpreted in a manner which may permit the use of computer simulation models in a quantitative fashion to assist in predicting the direction and magnitude of social change which may take place as development of the Athabasca Oil Sands proceeds.

FUTURE RESEARCH

Recommendations for future environmental research have been made on the assumption that continued massive development of the Athabasca Oil Sands will take place. The proposition is advanced that the present level of spending on environmental research by industry and government should be maintained as an investment in the maintenance of acceptable environmental quality for the region.

In the Air System, future research should involve the continuing refinement of the regional air quality model presently under development, as well as investigation of medium- and long-range transport of atmospheric pollutants. High priority should be given to integration of atmospheric research with research in Land, Water, and Human systems.

In the Land System, research should be directed toward biomonitoring, as well as continuing physical and chemical monitoring in the region. Two basic approaches have been suggested for terrestrial biomionitoring research: primary productivity studies aimed at detecting any shift in total ecosystem productivity; and research in soil/litter phenomena, including nutrient retention and recyclng and possibly the role of microarthropods in litter turnover.

For the Water System, it is suggested that biomonitoring research in aquatic ecosystems should follow the same pattern as that recommended for terrestrial ecosystems. Based on the acquired knowledge of primary (autotrophic) and secondary (heterotrophic) production in stream systems, aquatic biomonitoring research should concentrate on developing a methodology through which the most sensitive areas of production can be monitored in a quantitative fashion. These consist of the upper reaches of the major tributaries to the Athabasca River System.

Statements concerning lack of evidence for significant direct effects of air or water pollution on terrestrial and aquatic ecosystems shoud not be construed as a conclusion that such effects are not present, or that they will not be present in future. It is clear that the potential exists for establishment of several additional surface mines and in situ operations, which will contribute in an additive fashion to pollution and disturbance in the region.

Future research in the Human System should be directed, intitially at least, toward the construction of a model to describe the process of community dynamics in the Athabasca Oil

Sands region. Such a model should be derived with the objective of applying it to the study of public policy decisions in relation to continued oil sand development, and should be based on existing knowledge of the region and modified on the basis of the results of future social research as the need arises.

The criteria which form the bases for public policy decisions in the Athabasca Oil Sands region require serious analysis, using the research results available from AOSERP studies. To accomplish this objective, a comprehensive and integrated overview is required of socio-economic research in the region, and comparison of results with existing theory and practice of social analysis of the development of resource communities.

It was not found possible to achieve objectives outlined in the Introduction. Effects of oil sands development were assessed, but not in an integrated fashion. Rather, in examining research results, few interdisciplinary connections were apparent. This is considered a major deficiency of AOSERP research results.

## TABLE OF CONTENTS

## TABLE OF CONTENTS (CONCLUDED)

## LIST OF TABLES

## LIST OF FIGURES

## ACKNOWLEDGEMENTS

All those investigators who produced the research described in this report are acknowledged as contributors; other research is cited, but does not constitute a part of this summary.

A large number of persons gave generously of their time in discussing the general direction this report should take, and I have used their ideas freely.

Appreciation is expressed to Suncor Inc. (formerly Great Canadian Oil Sands Ltd.) for access to the company library, and to Syncrude Canada Ltd. for supplying a large number of research monographs.

Sincere thanks are expressed to all the staff in the former AOSERP office for assistance, but particularly to A. Avramenko, S. Grant, W. Hume, B. Kasinska, A. Mann, B. Munson, and M. Rehn. H.S. Sandhu and D.S. Davison always took time when approached to provide technical advice which is appreciated. P. Hetherington typed the manuscript.

In the field, D. Hadler was always available to make visits to corporate leases and research sites much easier than without his help. R. Findlay arranged a tour of the Amoco Canada Ltd. in situ pilot operation near Gregoire Lake and D. Dabbs provided a helicopter and ground tour of the Alsands project site.

To all individuals and organizations from whom I received assistance, I express my gratitude.

Following completion of the first draft of this report, it was forwarded to 21 referees for criticism. Comments of referees have resulted in reorganization of the report and incorporation of a number of suggestions for improvement of text. Aside from correction in errors of fact, I am grateful for suggested new approaches to discussion of an obviously complex subject; I have freely used these ideas. To all referees (who remain unknown to me) I express my thanks; it is my belief that incorportion of their comments has materially improved the final draft of this report.

# 1. INTRODUCTION

## 1.1 PURPOSE AND OBJECTIVES OF REPORT

This report consists of a review and evaluation of environmental research carried out in the Athabasca Oil Sands region of northern Alberta, Canada. Generally, the review is restricted to investigations within the original study area boundaries prescribed for the Alberta Oil Sands Environmental Research Program (designated by the acronym AOSERP) and to the activities generated by that program. However, in order to assess adequately the research effort mounted by AOSERP, as well as to evaluate the need for future environmental research in the Athabasca Oil Sands region, it was found necessary also to examine a number of environmental research reports produced by oil sands corporations. The major corporate generators of environmental research in the Athabasca Oil Sands region are Syncrude Canada Ltd. and Suncor Inc. (formerly Great Canadian Oil Sands), and more recently Alsands Project Group. The latter company recently has filed an environmental impact assessment of its proposal to build an oil sands plant.(1)

Although a number of alternatives exist or are being developed for extraction of bitumen in the Athabasca Oil Sands region, the assumption is made that existing technology will prevail for the immediate future (five years). Consequently, the research carried out to date and the predictions which may be derived from it are examined in this report in relation only to open pit mining and hot water separation of bitumen (Suncor, Syncrude, and Alsands) or to so-called in situ technology (Amoco Canada Limited) where deep deposits are subjected to thermal treatment and liquid bitumen is forced to the surface. Each of the two extraction methods poses a different set of environmental problems. In the case of in situ operations in the Athabasca Oil Sands region, little has been published on possible environmental effects. With a dearth of environmental research knowledge in this area of oil sands extraction technology, recourse has been taken to examination of a proposed large in situ operation near Cold Lake, Alberta. The Cold Lake project has been described in documents published by Esso Resources Canada[2] and in the transcripts of public hearings[3] and will be used to provide a preliminary estimate for research needs on the effects of in situ operations in the Athabasca Oil Sands region.

Four objectives were established for this report:

1. To assemble and analyze all research reports resulting from AOSERP;
2. To provide a review of the research reports produced by AOSERP;
3. To assess the completedness or otherwise of the research results from AOSERP; and
4. To develop recommendations concerning the need for future environmental research in the Athabasca Oil Sands region.

## 1.2 METHODOLOGY AND REPORT ORGANIZATION

The AOSERP Project covered a period of five years, with a cost of $17,323,673.[4] Consequently, in preparing this document, it has been found necessary to review approximately 200 environmental research reports, including 58 reports produced by oil sands corporations and relating to the Athabasca Oil Sands region. This material covered a very wide range of investigations, far too diffuse for any one person to assess as to technical content. It should be emphasized, therefore, that the author in many cases has used exclusively the assessment of referees to determine the technical completeness and scientific validity of research reports. Interpretation of the usefulness of research results is, however, the responsibility of the author.

Integration of research results to provide an assessment of environmental impact (EIA) was not carried out in the same manner as would be done under the guidelines established by the Alberta Department of Environment.[5] It should be mentioned at the outset that the scope and detail of the Alberta Environmental Research Program permits much more intense analysis than is generaly possible in an EIA. Consequently, its research results provide data which may be used both by government and by industry to rationalize the future long-term consequences of oil sands development with increased precision and confidence.

The conclusions, which relate to Objectives 4 and 5 above, are based largely on the identification of remaining knowledge gaps of significance in the Athabasca Oil Sands region. These conclusions, however, have been influenced also by obtaining an appreciation of the information needs both of government and industry, as these needs relate to environmental management decisions in the area affected by development. Scientific reports form the factual basis for gaining an appreciation of environmental effects of oil sands development. Conclusions as to completeness of research information and the need for future research must be considered judgemental.

Not all AOSERP or industry reports are cited in this analysis. Nor is any attempt made to recapitulate the results described in research reports themselves, which are contained in separate AOSERP publications. Additionally, a relatively complete description of the total program is contained in an interim report compiled in 1978 and published in April 1979.(4) Additional references cited herein refer mainly to research under way, but with results not available when the interim report on AOSERP was published. For a detailed listing of references to environmental and socio-economic studies in the Athabasca Oil Sands region, the reader is referred to a bibliography published elsewhere.(6)

## 1.3 STUDY AREA

### 1.3.1 Athabasca Deposits

The AOSERP study area is shown in Figure 1, with an approximation of the Athabasca Oil Sands deposits indicated as a stippled overlay. Three major oil sands deposits occur in

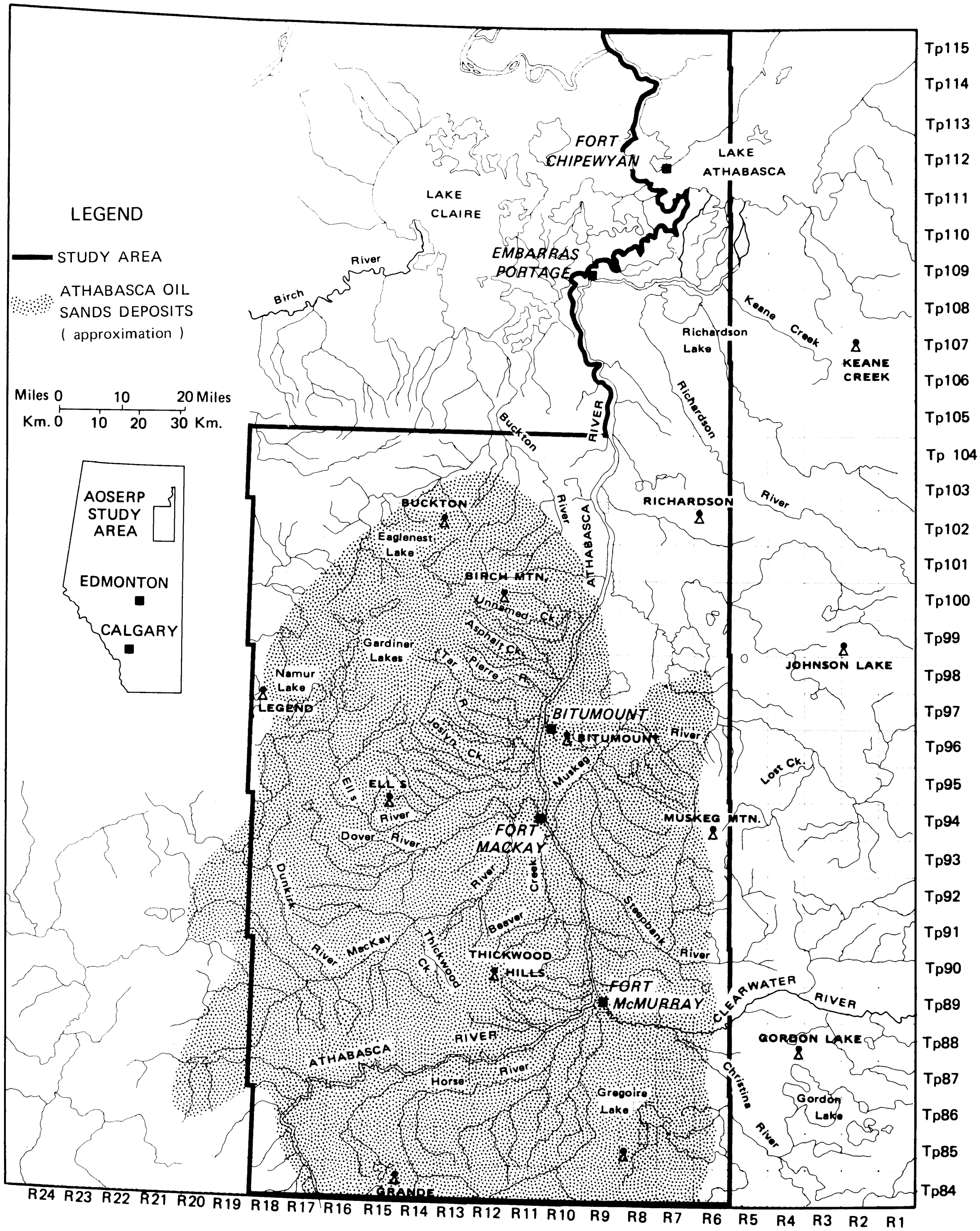
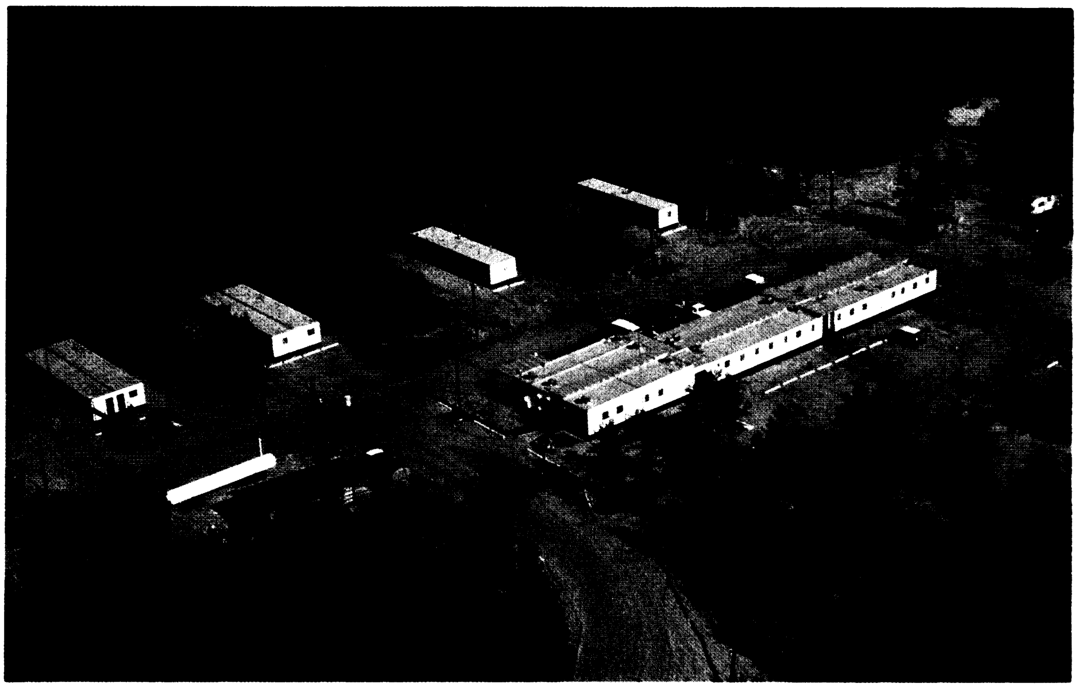



Figure 1. AOSERP study area.



The Mildred Lake Research Facility; accommodations and well-equipped laboratories provided for researchers in the Alberta Oil Sands Environmental Research Program. (Photo — G. Hunter, AOSERP)

One of many small streams flowing through the Athabasca Oil Sands area. (P. Lulman, Syncrude)

The oil sands region contains a diversity of ecosystems. A large area of shifting sand dunes represents one of the more interesting and fragile of these. (AOSERP file)

Alberta, with the Athabasca deposit being the largest. Various estimates of bitumen reserves have been published, but there appears to be agreement that the Athabasca deposit contains not less than 600 x $10^9$ barrels of bitumen.[7] Many papers have been produced on various aspects of oil sands deposits and extraction technology in Alberta. For more detailed descriptions, the reader is referred to the K.A. Clark Volume[8] and Guide to the Athabasca Oil Sands Area[9], both published by the Research Council of Alberta.

The first suggestion for hot water extraction of bitumen from the Athabasca Oil Sands was made nearly 100 years ago; subsequently, such a process was developed and patented by Dr. K.A. Clark of the Research Council of Alberta and first placed in commercial operation by Great Canadian Oil Sands Limited (now Suncor). The so called Clark hot water extraction process results in significant environmental problems. These problems in turn have been the focus for considerable environmental research, both by industry and government. It is to be expected that additional plants will be built using hot water extraction process[8], or other technology as it becomes available.

Much of the Athabasca deposit lies buried so deeply that bituminous ore cannot be recovered from open pit mines.[9] Rather, in situ thermal treatment likely will be employed to recover bitumen from these deep deposits. Environmental problems resulting from the use of in situ technology will require a substantially different focus on environmental research. The possibility for several in situ operations in the Athabasca Oil Sands region appears strong[10], although no in situ operation has yet proceeded to full-scale commercial development. Consequently, the environmental effects of in situ operations are considered to be potentially significant to a degree that will require considerable future emphasis. A simplified geological cross-section of the Athabasca Oil Sands is shown in Figure 2,

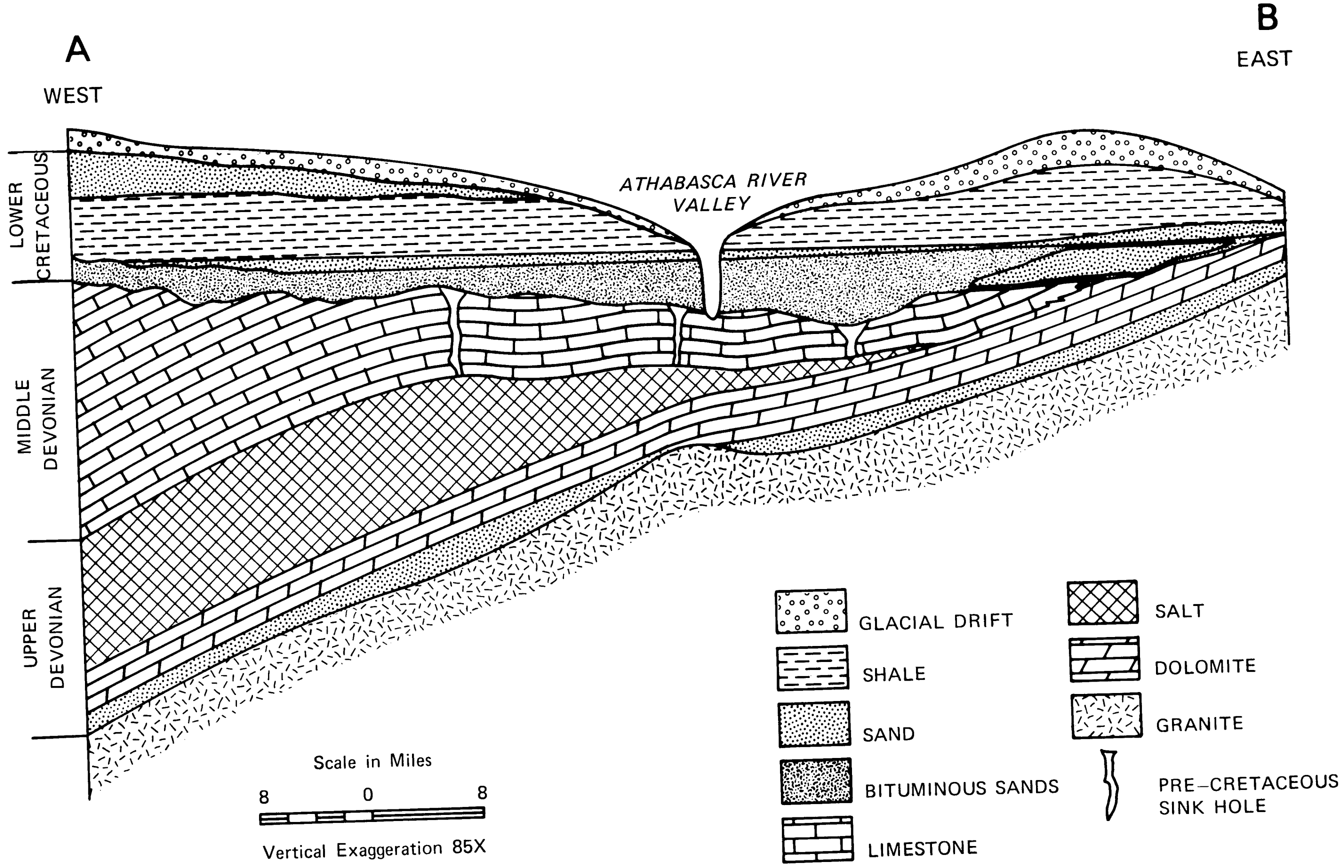



Figure 2. Simplified geological cross-section of the Athabasca Oil Sands about 50 km north of Fort McMurray, Alberta.

outlining the general location of bituminous ore in relation to other materials.

Although the physical extent of the Athabasca Oil Sands deposit is reasonably well known, little precision can be attached at present to an estimate of the area which can be mined economically, since this will change with the price of oil and cost of recovery of bitumen. Nevertheless, it is possible to construct scenarios which give a reasonable idea of the results of varying rates of development in the region. These in turn may provide insight into the range of impacts likely to result from oil sands development, as well as into the environmental research which may be necessary in the future.

### 1.3.2 Physiography and Climate

The physical characteristics and location of the AOSERP study area have sharply influenced the kind of research carried out during the past five years. It is apparent from an examination of Figure 1 that the lower Athabasca River, terminating in the Peace-Athabasca Delta, together with its tributaries, is a dominant feature of the AOSERP region. Consequently, water-related research has been extensive, dealing with both surface and groundwater hydrology, water quality and aquatic habitats, as well as invertebrates, fish, autotrophic (algal), and heterotrophic (microbial) populations.

The Athabasca River is joined by its largest tributary, the Clearwater River, at Fort McMurray. At the junction of the Athabasca and Clearwater, the Athabasca River valley is sharply incised into the surficial glacial drift and underlying Cretaceous sediments. North of Fort McMurray, the Mackay, Dover, and Ells rivers comprise the major tributaries draining from the west, while the Steepbank, Muskeg, and Firebag rivers constitute the most important tributaries draining from the east. Each of the tributary drainages provides an important contribution to total aquatic habitat of the Athabasca system in its lower 300 km, both for fish[11] and for furbearers.[12]

Topographic relief may be important in modifying wind flow, and cold air may drain into the Athabasca River valley, contributing to localized meteorological variability. Such variability in temperature and wind direction could have important effects on the distribution of air pollutants and occurrence of fog during some months of the year. Climate of the area has been described as cold temperate, with relatively long periods of cold, dry weather during winter and relatively long periods of sunny, warm weather during summer.[13] The general circulation pattern of the area is from west to east. However, low pressure systems embedded in this flow may bring warm air from the south in advance of their travel, and draw down colder air of Arctic origin in their wakes. In winter, these migratory low pressure systems are of sufficient strength to displace ridges of Arctic air which may become entrenched over the western prairies for several weeks at a time. As a consequence of movement of air masses and pressure systems, cold and warm periods frequently alternate throughout the year. Change in temperature in the region often is accompanied by precipitation events.

Annual precipitation is relatively low, with a pronouced summer maximum, largely from convective storms, and persistent snow cover in winter. Such meteorological conditions are relevant to investigation of deposition of atmospheric pollutants. In addition, mean wind speeds, as well as frequency and persistence of calms, may be more relevant to an assessment of existing and future air quality than extremes in temperature.

Because of latitude of the region (56°N - 59°N), with the associated very large differences in solar radiation between summer and winter, there may be a swing of 80°C in ambient temperature, from plus 30°C in summer to minus 50°C in winter. Temperature inversions of more than 3°C between ground level and 500 m are not uncommon in winter over the Athabasca River valley.

A general representation of the topography of the region is shown in Figure 3. The narrow, deeply incised Athabasca River valley at the junction of the Athabasca and Clearwater rivers at Fort McMurray progressively widens to the north into a broad shallow lowland river plain, eventually to merge with the Peace-Athabasca Delta, at the western end of Lake Athabasca. The shape and orientation of the Athabasca River to the surrounding highlands and high plains, together with meteorological variations discussed above, may complicate the research required to assess air quality in the region.(14)

## 1.4 CONDITIONS PRIOR TO DEVELOPMENT

The physical character of the AOSERP study area probably has for the most part remained unchanged for many decades. Activities associated with oil sands development, such as construction of roads and movement of aircraft, boats, and land vehicles, are so obvious that an impression may be gained that rapid and significant changes are occurring over widespread areas of the region. The natural surface of the land has been totally disrupted on actual oil sand plant construction sites, in mining sites, and in large tailings ponds, but these constitute less than 1% of the study area. Perhaps the largest changes in the natural landscape have resulted from roads and seismic lines, or perhaps the nature of vegetation as a result of more sophisticated fire detection and suppression during the past two decades.

The foregoing comments should not be construed as suggesting that relatively small changes are not important, because such alterations may have far-reaching impacts. However, most of the baseline research described in the the AOSERP Interim Report has been carried out in a natural environment that appears so far not to have suffered any general debilitation from oil sand activities. Data gathered from such an environment are therefore extremely valuable as benchmark information against which future developmental impacts can be measured.

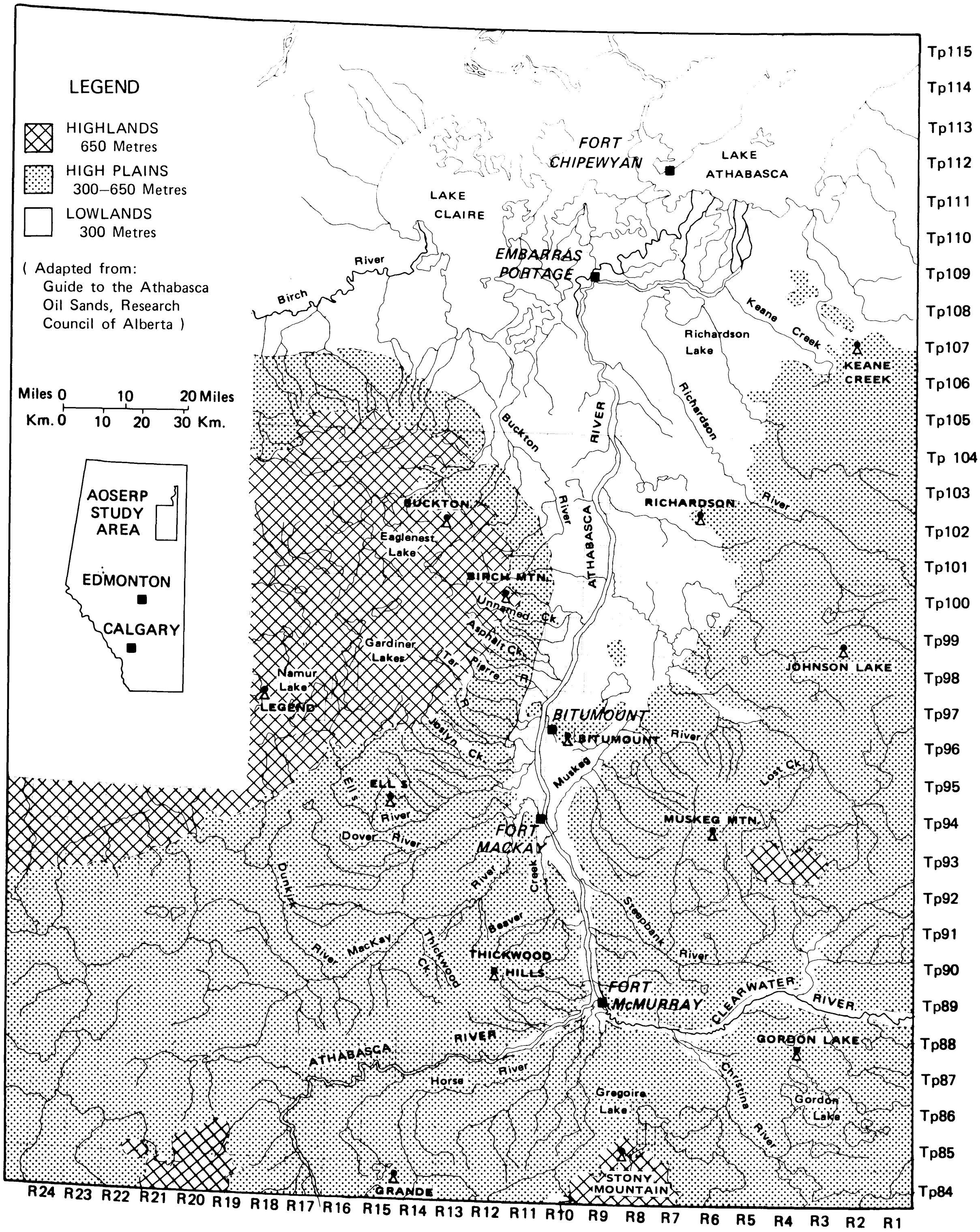



Figure 3. Gross topography of the lower Athabasca River drainage area.

## 1.5 STAGES OF DEVELOPMENT

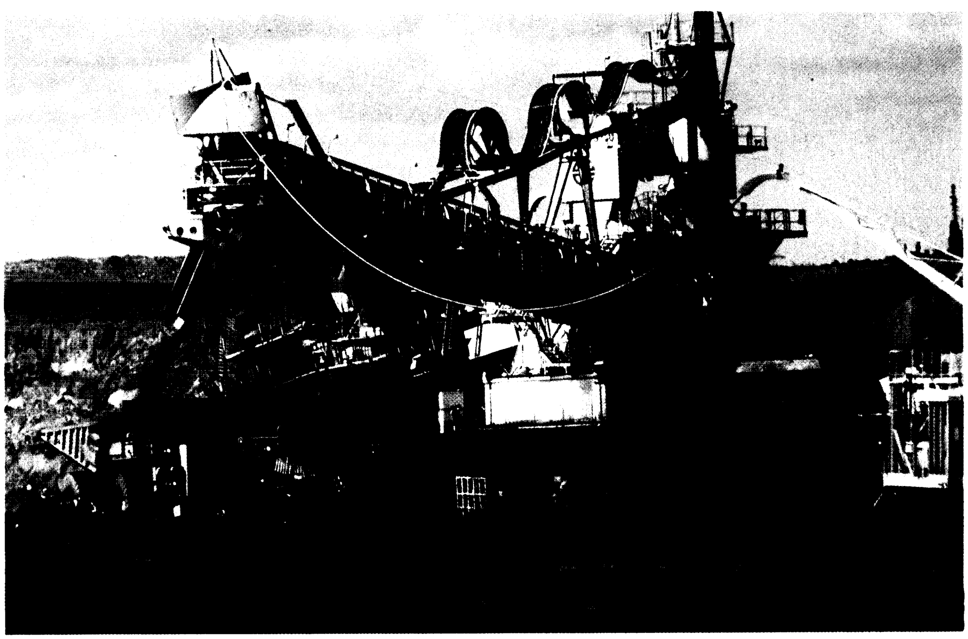
In order to effectively assess the research effort mounted by AOSERP, it is necessary to provide an overview of general impacts related to oil sands development. Development of the Athabasca Oil Sands has been described as a series of mega projects.(15) Public submissions to the Alberta Energy Resources Conservation Board (ERCB) have indicated investments for individual projects in the order of $5 billion in terms of 1978 dollars, and employing a labour force of 7000 to 8000 persons during initial construction. Consequently, the impacts of such large developments require a considerable amount of research information in order to assess the importance of both biophysical and socio-economic effects.

A sequence of events has been described for the various stages of development of oil sands projects. When a corporation or consortium of companies makes the decision to develop an oil sands extraction plant, a public disclosure is made, followed by preparation of an environmental impact assessment, public hearings by the ERCB, approval by the ERCB and the Cabinet of the Government of Alberta, and finally construction of the plant. Each of these stages of development of an oil sands plant results in a socio-economic or biophysical impact.(15)

Approval of the first oil sands plant (Great Canadian Oil Sands, now Suncor) was followed almost immediately by increased construction activity in Fort McMurray, with a concurrent change in the labour force.(16) The importation of new technology to the region provided new employment opportunities, new residents, high incomes, and demands for goods, services, and land in excess of supply. These primary impacts resulted in local inflation of the economy and shortages in land, housing, and labour.(17)

Concurrent with early development of the first oil sands plant was rapid upgrading of transportation. The first highway was completed to Fort McMurray in 1967 and air service schedules

Suncor, Inc. (formerly Great Canadian Oil Sands). This company was the first to operate in the oil sands region, beginning in 1969 and reaching a capacity of 58 500 barrels per day in 1980.
(D. Hadler, AOSERP)



Bucket wheel mining system used at Suncor; these huge machines have a materials handling capacity of 8000 tons per hour.
(H.P. Sims, Research Management)

(P. Ziemkiewicz, Energy and Natural Resources)

(B. Pearson)

Syncrude Canada Ltd. uses a combination dragline and bucket wheel system of mining in the oil sands region. These large draglines have a bucket capacity of 80 cubic yards.

were increased to meet the demand for air travel between Fort McMurray and Edmonton and Calgary. Highway access was extended to the Suncor and Syncrude operations by construction of a bridge across the Athabasca River and a modern highway as far north as the Syncrude site. The secondary road link to Fort MacKay was brought up to all-weather standards, providing reliable access to Fort McMurray in all seasons of the year, and the road to Anzac was paved. These transportation improvements provided the rapidly growing population of the region with mobility throughout the Athabasca River valley, as well as providing the small settlements of Fort MacKay and Anzac improved access to Fort McMurray and other parts of Alberta. In addition, improved access was provided for persons other than local residents to visit the oil sands region. Private boat travel on the Athabasca and Clearwater rivers increased sharply as did both the consumptive and non-consumptive uses of fish and wildlife resources and recreation.[18]

## 1.6 PRESENT CONDITIONS

While most of the natural landscape may not have suffered large-scale perturbation, there have been very large and very rapid socio-economic changes in the region. As a consequence, Fort McMurray has increased its population by more than 10 times (from less than 2500 in 1960 to about 27 000 in 1978). The outlying communities of Fort MacKay, about 60 km to the north, and Anzac, about 40 km south of Fort McMurray, have been impacted, but population in these communities has declined as employable residents shifted their abodes closer to Suncor and Syncrude. Fort Chipewyan, about 240 km north of Fort McMurray, has more than doubled its population (from about 700 in 1960 to over 1500 in 1980), but this growth does not appear to be connected directly with oil sands development. The total population of the Athabasca Oil Sands region, with about 95% of the population resident in

Fort McMurray, has grown from less than 3000 in 1960 to about 30 000 in 1980.[19]

The only base industrial activity in the Athabasca Oil Sands region of significant economic importance is oil sands extraction. Agriculture in the region is insignificant, and both forestry and commercial fishing appear to have declined in importance since 1960. Trapping occurs on 345 registered traplines in the area, and is of undoubted importance to a number of individuals[20] although low in economic value to the region as a whole.

Manufacturing in the region is located entirely in Fort McMurray and employs about 50 people. The service industry has grown rapidly as the population has increased, but employment in this sector has lagged. This is probably due to competition with the construction industry which at times has accounted for up to 35% of the construction labour force in Fort McMurray, not including the actual labour force of up to 7000 persons employed directly on plant sites. Retail outlets have increased dramatically to accommodate the population growth associated with oil sands development. Income in the region is generally high, reflecting the significant investment of capital in oil sands plants and associated activities.

The Athabasca Oil Sands region has changed dramatically, both in demographic and in economic character over the past 20 years, so that the presently operating oil sands plants and the urban centre of Fort McMurray now dominate the area. The social and biophysical changes in the region are discussed in Section 3. Assessment of possible long-term impacts of oil sands development on natural ecosystems and on the people of the region are provided in Section 4.

# 2. THE MANDATE FOR AOSERP

## 2.1 DEVELOPMENT OF THE PROGRAM

The Alberta Oil Sands Environmental Research Program initially was conceived as a response to the perceived needs by government officials for an extensive, long-term research effort into possible effects of development of the Athabasca Oil Sands. Internal reports by scientists in Alberta Environment (Research Secretariat) and Environment Canada (Environmental Management Service) late in 1973 resulted in 1974 in negotiations between the Government of Alberta and the Government of Canada on the need for a joint research effort in the oil sands region. In February 1975, the two governments signed the Canada-Alberta Agreement for the AOSERP. This Agreement as originally signed, together with an amended agreement signed in 1977, is reproduced in Appendices 8.1 and 8.2.

### 2.1.1 Canada-Alberta Agreement for AOSERP

Several aspects of the Canada-Alberta Agreement for AOSERP are important to the original development of the Program. The Agreement in its preamble stated that "....large-scale industrial development will have immense economic, social and environmental effects...." and that "....the results of an intensive study of the area will be useful in predicting the effects of any proposed development...." The Agreement also restricted the research program to investigations of "....environmental aspects of renewable resources involved in the development of oil sands...." in the legally described AOSERP study area. As a consequence of the stated intent of the initial AOSERP agreement between Alberta and the Federal Government, the Program was restricted to investigation of renewable resources only, eliminating the possibility of research into any aspects of oil sands technology. In addition, the Program was restricted to a study area with legally defined boundaries.

The administration arrangements in the initial Canada-Alberta Agreement for AOSERP provided that Alberta and Canada supply funds for AOSERP within their individual budget estimates. The Alberta portion of the AOSERP budget (not less than $2 million annually) was provided by Alberta Environment. The Federal portion of the budget (not more than $2 million annually) was provided under authority of the Federal Treasury Board as a fiscal pool for AOSERP. Federal funds were allocated within Environment Canada to Fisheries and Marine Service (now Fisheries and Oceans), Atmospheric Environment Service, and Environmental Management Service. The latter agency was assigned the responsibility for release of AOSERP Federal funds as required. The Program was administered by a Program Director and staff under the general direction of a Steering Committee of two persons reporting to the respective Ministers of Environment for Canada and Alberta, and was chaired by Alberta.

Under the original Canada-Alberta Agreement for AOSERP, project priorities and budgets were drawn up by Technical Research Committees (TRC's) dealing with hydrology, hydrogeology, terrestrial fauna, aquatic fauna, meteorology, vegetation, land use, and human environment. Late in 1974, a consultant was retained to interview senior staff in appropriate government agencies, and to assemble groupings of research projects for the committees. The chairmen of the TRC's were constituted as an Advisory Committee on Program Coordination, chaired by the Program Director. By April 1975, funds had been allocated to the Program and some projects were under way.(21) The Technical Research Committees are listed in Table 1.

### 2.1.2 Objectives of AOSERP

Aside from the protocols setting forth the Canada-Alberta Agreement for AOSERP, specific objectives were also stated. These objectives were concerned largely with accumulating the information necessary to an understanding of the

Table 1. AOSERP Technical Research Committees.

| Sector Responsibility | Agency Chairmanship |
|---|---|
| Meteorology and air quality | Atmospheric Environment Service, Fisheries and Environment Canada |
| Terrestrial fauna | Fish and Wildlife Division,[a] Alberta Recreation, Parks and Wildlife |
| Aquatic fauna[b] | Fisheries and Marine Service,[c] Fisheries and Environment Canada |
| Hydrology and water quality | Technical Services Division, Alberta Department of Environment |
| Regional hydrogeology[d] | Alberta Research Council |
| Human environment | Northern Development Branch, Alberta Department of Economic Development |
| Terrestrial vegetation | Alberta Forest Service, Alberta Department of Energy and Natural Resources |
| Land Use[e] | Environmental Co-ordination Services, Alberta Department of Environment |

[a] Now with Alberta Department of Engery and Natural Resources.

[b] Included all aquatic biota.

[c] Now with Canada Department of Fisheries and Oceans.

[d] Financed separately by Alberta Department of Energy and Natural Resources.

[e] Not implemented.

characteristics of the biophysical environment (baseline states), on which could be based research to elucidate the processes and assimilative capacity of air, land, and water.[22] No mention was made initially in the Agreement of the effects of oil sands development on people; objectives relating to the Human System were not formalized until publication of the AOSERP Policy and Direction document in October 1977.[23]

Objective 6 in Schedule "A" of the Agreement directed that the Program was to "... use existing agencies... where possible and to use other sources when necessary." Consequently, during the early part of the Program, both Federal and Provincial line agencies assumed responsibility for most of the work. Direction was further provided to establish priorities and co-ordinate projects in an interdisciplinary fashion to ensure co-operation among both Federal and Provincial agencies, industry, universities, and other institutions. No administrative mechanism was set forth to achieve these aims. Disbursement of AOSERP funds as to source and recipients is shown for the period 1975 to 1980 in Table 2.

A final and important objective directed the Program to "... compile, assess and disseminate research reports..." This objective required Program managers within AOSERP clearly to spell out in research contracts with universities, individuals, and private contractors or in research agreements with government agencies that research reports were to be completed for publication on termination of the contract or agreement. No AOSERP research could be held confidential under the policy set forth in the Canada-Alberta Agreement. Program activities for the first two years of the Program are described in its Annual Reports for 1975 to 1976 and 1976 to 1977.[21, 22]

## 2.2 ORGANIZATION OF AOSERP

Although specific objectives were laid out in the Canada-Alberta Agreement, as discussed above, these were

Table 2. Sources and disbursements of AOSERP funds, 1975 to 1980.

| Source | 1975-1976 | | 1976-1977 | | 1977-1978 | | 1978-1979 | | 1979-1980 | | Grand Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Amount | % | Amount | % | Amount | % | Amount | % | Amount | % | Amount | % |
| Alberta | 2,213,651 | 65 | 1,254,347 | 63 | 2,177,013 | 62 | 2,127,780 | 54 | 2,893,526 | 100 | 11,666,317 | 67 |
| Canada | 1,164,979 | 35 | 1,327,929 | 37 | 1,344,448 | 38 | 1,815,000 | 46 | —[a] | | 5,657,356 | 33 |
| Totals | 3,383,630 | 100 | 3,582,276 | 100 | 3,521,461 | 100 | 3,942,780 | 100 | 2,893,526 | 100 | 17,323,673 | 100 |
| Recipients | | | | | | | | | | | | |
| Government | 2,740,329 | 81 | 2,312,644 | 65 | 2,187,200 | 62 | 1,896,095 | 48 | 1,523,926 | 53 | 10,660,194 | 63 |
| University | 302,707 | 9 | 788,017 | 22 | 498,160 | 14 | 187,000 | 5 | 218,000 | 8 | 1,993,884 | 11 |
| Consultant | 304,594 | 10 | 481,615 | 13 | 836,101 | 24 | 1,859,685 | 47 | 1,151,600 | 39 | 4,669,595 | 27 |

[a] Government of Canada withdrew from AOSERP at the end of fiscal year 1978-1979.

sufficiently lacking in precision and detail that they were open to somewhat differing interpretation by each TRC. Under the terms of the initial Canada-Alberta Agreement, it was specified that each TRC have at least one Federal and one Provincial member, as well as a member of the Oil Sands Environmental Study Group (OSESG) comprised of representatives appointed by oil sands corporations. Because OSESG did not contribute financially to the operation of AOSERP, all TRC's were chaired either by a Federal or a Provincial representative. Each TRC was given full authority to plan and initiate research projects, with the consequence that control of operations and research policies and scientific direction became extremely difficult under the committee system.

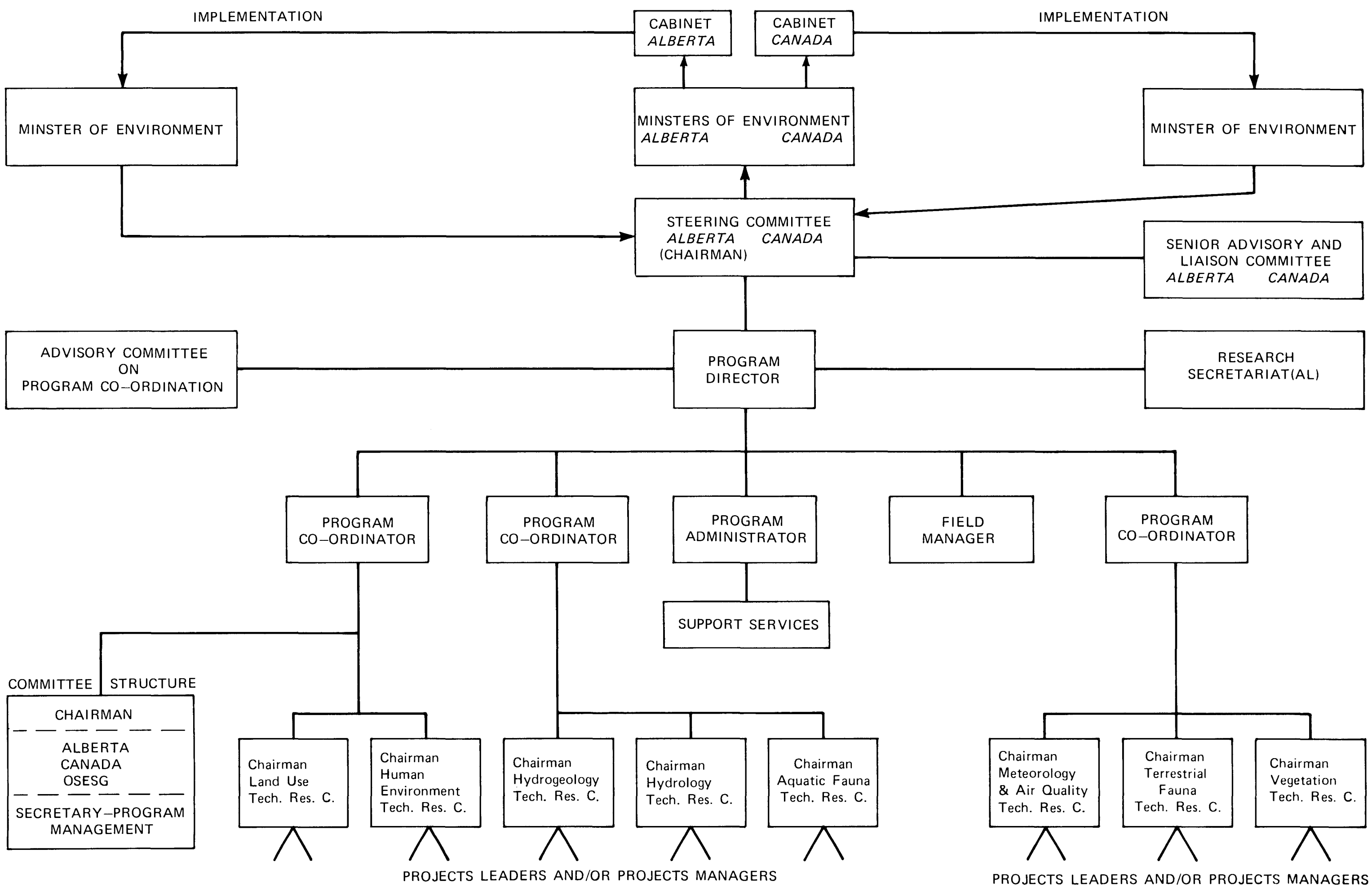
It should be emphasized that members of the TRC's were primarily responsible for identifying the research needs and setting the early priorities for AOSERP, as well as identifying and involving a large number of available experts to plan and execute field research projects. It is doubtful that the Program could have been implemented with such dispatch without the considerable efforts of TRC members. However, it became apparent by the end of the second year of the Program that, under a diffuse committee system with over 50 members, government policy for the Program could not be implemented, controlled, or changed, as the need might arise. Consequently, the decision was made to delete the committee structure from the Canada-Alberta Agreement. The Agreement was amended in September 1977 to accommodate these changes. The initial and reorganized structure for AOSERP is shown in Figures 4 and 5, respectively.

### 2.2.1 Policy and Direction

Concurrent with reorganization of AOSERP was the need to publish a more comprehensive definition of program objectives, related to the perceived needs of user agencies of government and industry in the oil sands region. At the same time, it was recognized that the policy should be consistent with the existing

LEASERS

## ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM



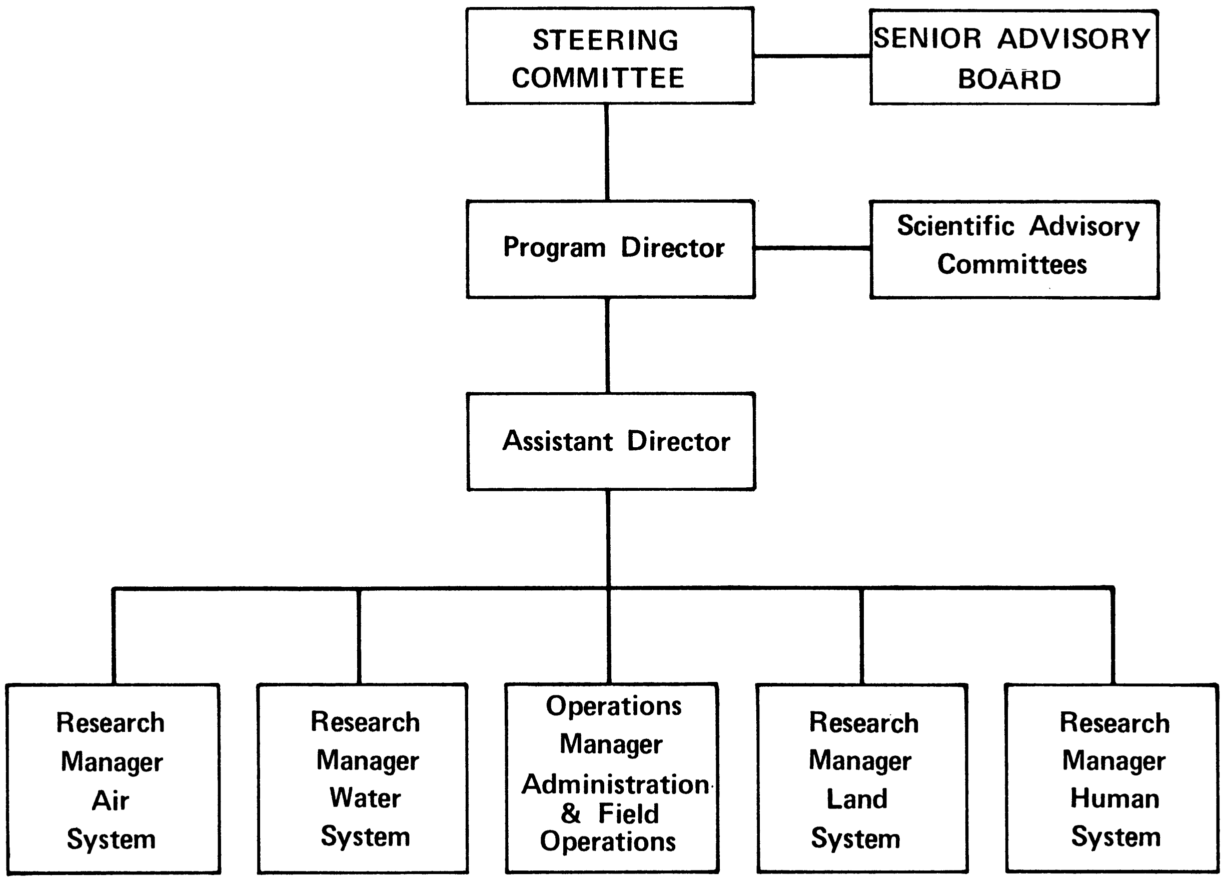



Figure 5. Organization of AOSERP under the Canada-Alberta Agreement as amended, 1977.

research policy of Alberta Environment, which was responsible for administering the Program. A policy and direction document was produced and circulated for comment to more than 100 managers in government, industry, and research institutions. The AOSERP Policy and Direction was approved by the sponsoring governments and published in November 1977.[23]

The early activities in AOSERP were committed to extensive surveys of surficial geology and soils, vegetation, wildlife, fish, and hydrology. In addition, a network of stations was set up to provide data on meteorology and air quality in the region on a continuous basis. Similar networks of stations were established to accumulate data on water quality and hydrology on a regular sampling schedule. A review was carried out early in 1977 of ongoing AOSERP activities, in order to determine priorities for investigations in years three through five of the Program. As a result of this review, a comprehensive survey of soils was considered high priority for completion by year five,[24] particularly to provide data for habitat mapping of the area. Intensive studies of wildlife[25,26,27,28] were assigned low priority and brought to conclusion. Operation and maintenance of the air quality and meteorology network, as well as of the water quality and hydrology networks, was considered high priority for continuance, at least to the end of year five of the Program, in order to establish reliable data bases. The very widespread fish sampling program was redirected to provide delineation of stream habitat, in a fashion similar to that employed in British Columbia.[29] An internal planning document[30] was produced specifically to provide direction and impetus for social research, which in the first two years of the Program lagged seriously behind biophysical research in terms of funding.

### 2.2.2 Systems Approach to Research

It was mentioned earlier that consolidation of AOSERP involved the establishment in 1977 of four systems (Air, Land, Water, Human) under which all research activities were redirected. The Air System remained relatively unchanged because it appeared in large part to be meeting AOSERP objectives. The former sectors of hydrology, water quality, hydrogeology, and aquatic fauna were combined under the Water System and given new orientation. Activities formerly directed under the aegis of committees dealing with land use (including soils and surficial geology), vegetation, and terrestrial animals (principally birds and moose, wolf, and caribou) were placed under the Land System. Human System research was reoriented toward the proposition that social impacts ultimately could be analyzed with the use (conceptually at least) of a community process model related to rapid social changes caused by "mega project" development.(30)

It is important to emphasize at this point that the organization of AOSERP was aimed primarily at the need to provide reliable scientific information, generated by highly qualified researchers, which would be of use to managers responsible for implementation of government policy. Industry priorities initially were not included as criteria because industry to that point had not made a fiscal contribution to AOSERP. Nevertheless, industry representatives had been members of Technical Research Committees from the beginning of the Program. As well, both Suncor and Syncrude had spent large sums of money on environmental research. The results of AOSERP investigations obviously could provide usable information to oil sands corporations, particularly in assessment of the possible impacts of new oil sands plants.

The systems approach by AOSERP did not in itself result in a significant number of new and better research projects. Rather, as an administrative organization, it resulted in a reduction of research approaches from eight Technical Research Committees to four systems, each headed by a research manager and receiving direction from a single source. The result was that the program became more responsive to government policy and more capable of responding to identified research needs and deficiencies. It should also be emphasized that the systems approach to research used by the Program provides no direction as to the policy which should be pursued for environmental management in the oil sands region. Such policy recommendations may emanate from examination of research results, but were not included in the objectives set by the Canada-Alberta Agreement or the terms of reference for this report.

## 2.3 QUALITY ASSURANCE

Quality of research reports has been of concern to funding agencies for a considerable period of time. Where analytical procedures are employed (e.g., chemical analyses of environmental contaminants), it is routine to provide duplicate samples for analyses to more than one laboratory, to ensure that methodology has not compromised the results. Such practices were also routinely followed in air and water quality analyses carried out for AOSERP. Analytic results, therefore, are considered comparable to those reported from most other environmental programs.

Quality assurance goes much beyond analytical procedures. Credibility of a research program of any kind can only be achieved through review and publication of research reports. As well, applied research must be carried out under a research design which meets problem-oriented criteria established in advance of project initiation. The following section deals with two methods employed by AOSERP to aid in quality assurance.

### 2.3.1 Scientific Advisory Committees and Referees

The relatively short-term nature of most AOSERP research projects resulted after the first two years of operation in a rapid flow of interim or final research reports. In addition, reorientation of the Program at the end of the second year required evaluation of early research results and review of scientific direction for the total AOSERP effort. The decision was taken to appoint scientific advisory committees comprised of persons largely outside the Program, and known for their capabilities and experience in particular disciplines. Scientific advisory committees were appointed for each of the Air, Land, Water, and Human systems in 1977.

Each scientific adisory committee met at the request of the research manager for that system, primarily to review general directions of that portion of the program with which it was concerned, and reported its discussions and recommendations to the Program Director. These committees provided highly qualified sounding boards for reflection of conceptual research design, as well as ideas for specific research projects. As such, their contribution to the Program was very large. Terms of Reference for scientific advisory committees are contained in Appendix 8.4.

One of the specific objectives set forth in the Canada-Alberta Agreement for AOSERP was to "....disseminate research reports...." For such reports to be useful required that they be scientifically accurate and that they meet the research objectives laid out for the project. To achieve this aim, qualified referees were retained under contract to review research reports. Turnaround time from receipt of a research report by AOSERP to return of referees' comments to the author was generally less than 30 days. Referees' comments were sent to authors verbatim as photocopies, less the identity of the referee. For most reports, a minimum of two referees was employed. Referees most often were scientists from universities in Alberta, elsewhere in Canada, or the United States, although scientists from industry, government, and private consulting firms also were used as referees from time to time. Staff of AOSERP generally did not referee research reports after 1977.

### 2.3.2 Quality Assurance Boards

Although scientific advisory committees and referees proved invaluable in providing scientific direction for the Program and peer review of research results, large individual research projects which would run for three to five years were judged to require special attention. Accordingly, the concept of a Quality Assurance Board (QAB) was developed, in which scientists with highly specialized qualifications and extensive experience in the project discipline were asked to provide advice. The QAB was intended to review the project proposal before the project commenced, and to advise on applicability of the expected results. The research contractor retained to carry out the project was required to defend both the pre-project research proposal and resulting research reports before the QAB, in a seminar setting, open also to potential users. The first application of a QAB in direct analysis of a specific research project (in January 1980) appeared to have been highly successful from the varied points of view of AOSERP Program Management, potential users, and the research contractor. It appears that the use of QAB's can achieve at least the following: (1) assurance of a high quality research design; (2) usefulness to potential users; and (3) highly qualified advice to the research contractor. If the three results outlined above are all achieved, it would appear that little likelihood exists for a major research contract not to achieve its stated objectives.

## 2.4 AOSERP-INDUSTRY RELATIONSHIPS

All AOSERP research was oriented to the possible effects of Athabasca Oil Sands development. Consequently, oil sands corporations have a strong interest in research sponsored by AOSERP. From its inception, when industry was represented on all Technical Research Committees, AOSERP maintained a close liaison with both Suncor and Syncrude. As a consequence, research areas of mutual interest to AOSERP and industry, but not initially included, were identified by the mid-point of the Program in 1977. Potential research projects generally were seen in two contexts: (1) those specific to company leases; and (2) those with application to the region as a whole.

### 2.4.1 AOSERP-Industry Model for Joint Research

In order to delineate more precisely the major research interest of AOSERP and oil sands corporations, as well as to identifiy areas where joint sponsorship of research might prove advantageous, a model for AOSERP-industry joint research was drafted in 1978 within AOSERP and approved by Suncor, Syncrude, and other active oil sand companies. The model provided that either AOSERP or a corporation could initiate a research project and invite co-sponsorship from the other. This model has been used as a basis for increasing frequency of joint sponsorship of research by government and oil sands corporations, and is contained in Appendix 8.3. The model is considered to be mutually educative for environmental research managers, both in industry and in government, and tends to promote better technical liaison, as well as to aid in increasing awareness of research needs of industry and government by the respective research managers in each.

## 3. RESEARCH RESULTS

Review of research results in this section provides a general summary of AOSERP investigations in relation to the four systems mentioned previously. It should be pointed out that the four systems largely were used for administrative convenience to define and consolidate program objectives more clearly, rather than for the construction of a scientific design for integrating AOSERP research on an interdisciplinary basis. Moreover, it will be seen that few interdisciplinary connections exist between systems, or even between research projects within the same system. Thus, the division of AOSERP into the four systems resulted in the development of an operational framework strongly compartmentalized and strongly directed toward the assessment of the direct effects of oil sands development on the natural ecosystem and the human population of the region. To achieve this result required a departure from continuing detailed surveys and documentation of baseline information.

Reorganization of AOSERP resulted in re-definition of general program research objectives, followed by redefinition of core specific research objectives for the Air, Land, Water, and Human systems. The general research program was designed to meet three-year and five-year objectives. Review of research results in this section is restricted to three-year objectives outlined below. Discussion relating to five-year and longer-term objectives is contained in Section 6.

Year-Three Objectives

1. To review existing data with respect to the total area likely to be affected by oil sands development.
2. To identify gaps in the data base and establish projects that will eliminate these deficiencies.
3. To establish monitoring networks in order to obtain baseline data on variables in the environmental systems and review the monitoring requirements annually.

4. To identify environmental and social problems that can be expected to result from present and proposed oil sands development.
5. To promote the establishment of an integrated data storage and retrieval system encompassing all information pertinent to the program and ensure that all data generated through the program are placed in the data system.
6. To establish a conceptual framework by which current knowledge will aid in the design, conduct or redirection of research projects.
7. To present a program report during year three (1978) that describes current understanding of the baseline states and processes of the environmental systems in the AOSERP study area.

## 3.1 AIR SYSTEM

Air System investigations were initially conceived and designed on the premise that any possible effects of airborne pollutants would be widely dispersed and that they would be closely related to climatological and meteorological characteristics of the region. Furthermore, because of the knowledge already available with regard to the Suncor plume, it was assumed that ground level concentrations of $SO_2$ would be relatively low. Consequently, attention was directed as a first priority to acquiring baseline meteorological and air quality data on a regional basis.

Although AOSERP Air System objectives were not published until 1977, they were in large part derived from the program established in 1975, and became fully operational in 1976. Air System objectives (from AOSERP Interim Report to 1978)[4:17] are listed below:

1. To establish data acquisition systems to effectively describe existing physical conditions and processes including: climatology, air quality, precipitation

chemistry, lower atmospheric soundings, and inventory of emissions from all sources;

2. To describe major meteorological and air quality characteristics of the oil sands region based on historical and current data;

3. To apply physical models to processes of air pollutant dispersion, transport, and deposition;

4. To develop systems for predicting levels of air pollution resulting from oil sands processing and the extent of dispersion and impingement on land and water; and

5. To provide advice and scientific support to other research sectors in areas relating to meteorology and air quality.

In order to satisfy the data acquisition needs of the Program, networks were established to gather baseline information on meteorology and air quality.

### 3.1.1 Data Acquisition Networks

The meteorological data acquisition network consisted of nine solar-charged, battery-operated stations which were programmed to telemeter hourly wind, temperature, and precipitation data to a central facility at Mildred Lake. The network is shown in Figure 6. As part of the basic meteorological data acquisition program, a 152-m instrumented tower, and precipitation and snow survey have been operational since 1976. The data are archived on hard copy and paper and magnetic tapes and are available through the Research Management Division of Alberta Environment.

The air quality data acquisition network consisted of three stations (Birch Mountain, Bitumount, and Fort McMurray) and was established to provide data on ambient air quality over a relatively large area. At Fort McMurray, $SO_2$, $O_2$, and particulates were routinely measured. At Bitumount and Fort McMurray, levels were recorded of $H_2S$, CO, $NO_x$, particulates, Pb, Cu, Mg, Cr, Cd, Hg, Zn, Be, V, Ni, Mo, and Co. The network provides an indication of requirements for constructing an air quality

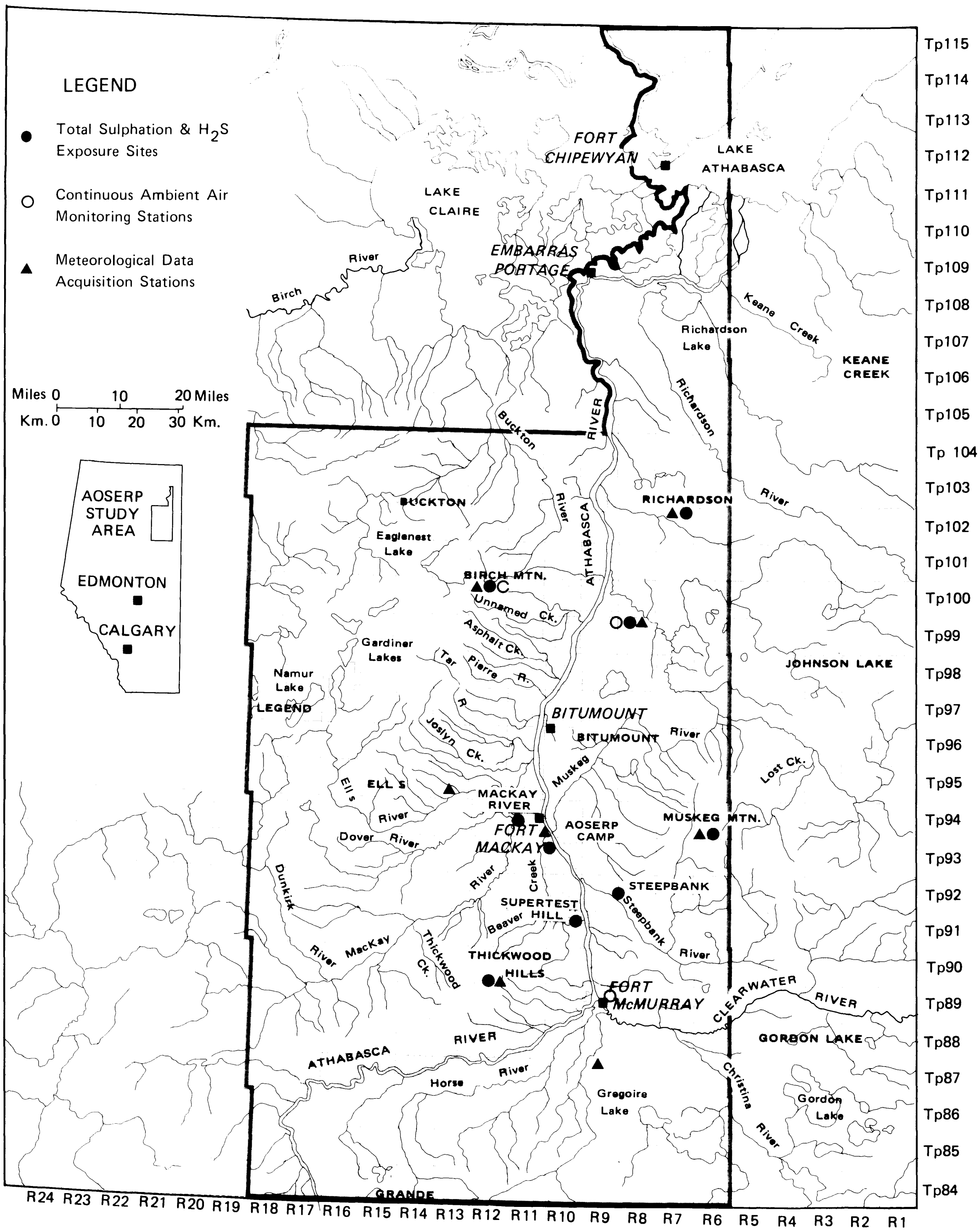


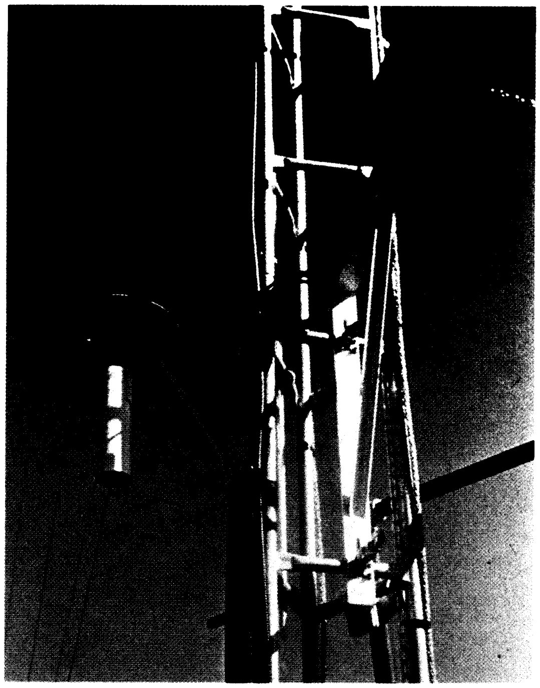

Figure 6. AOSERP air quality monitoring and meteorological data acquisition networks.

climatology for the area, as well as supplementing industry networks operated at Syncrude and Suncor at closer proximity to the two major emission sources.[31]

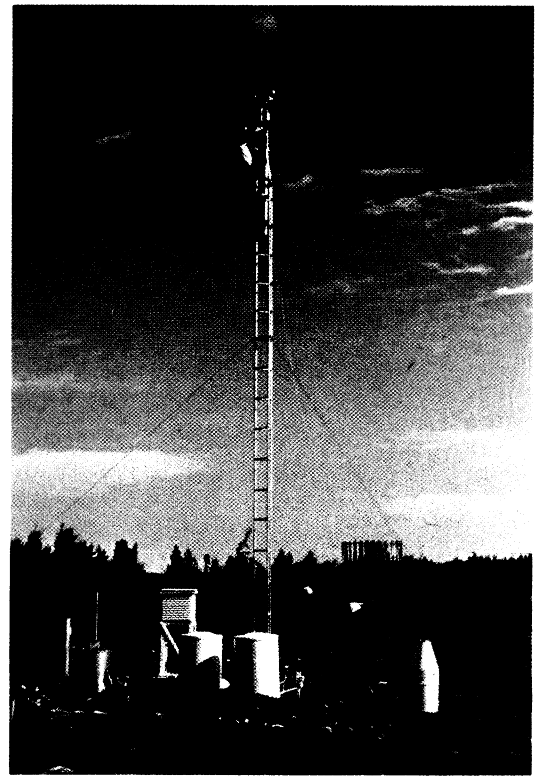
Aside from the network described above, a total of 13 continuous monitors recorded levels of $SO_2$ and $H_2S$ and over 100 total sulphate exposure sites were operated through the combined effort of AOSERP and industry. Suncor has carried out extensive air quality sampling since it began operations. The operation of air quality monitors and total sulphate exposure sites on a shared basis was considered to provide much wider coverage at less cost than if air quality sampling were to be done on an individual basis. An inventory of man-made and natural emissions was assembled and placed in a computer retrieval system to facilitate ease of access.

Construction of the 152-m instrumented tower in the Athabasca River valley was intended to provide data on air movements in the vicinity of Suncor, from which could be determined the dispersion of the plumes from the main stack at this plant. These data were considered essential in determining the frequency of concentrations of airborne pollutants in relation to local meteorology, as well as in providing information on the possible effects of terrain in modifying air flows near ground level.

The meteorological data acquisition and precipitation chemistry networks (Figure 6) and 152-m tower have been operational for four years. The hourly data accumlated on wind, temperature, and precipitation provide an extensive data base for climatology of the region. Usefulness of the data may be limited in relation to the construction of dispersion models, and requires evaluation for use in terrestrial ecosystem models and biomonitoring. A very large meteorological data base now exists, but regional meteorological data in large part remain unanalyzed. Data from the tall tower are of limited usefulness, except for site-specific investigations near the Suncor plant. Minisonde data are considered more useful and acoustic sounder data may be



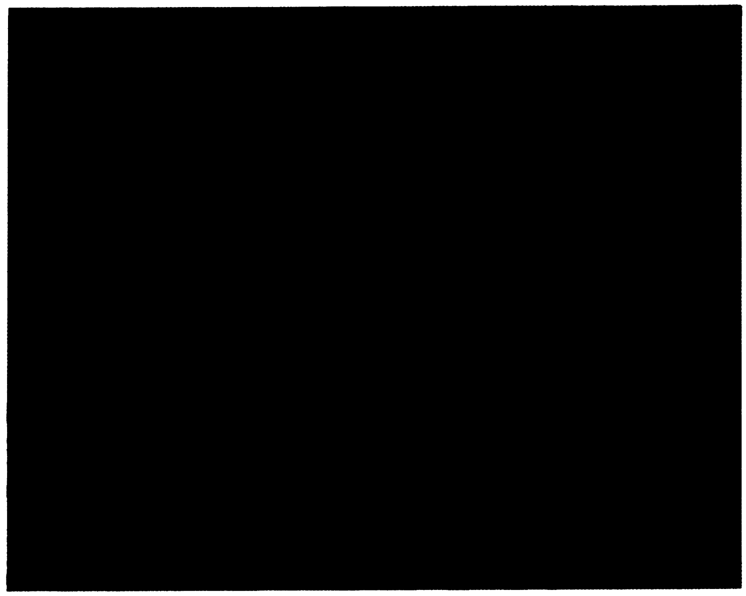
Humidity sensor and temperature monitor. (A. Mann, AOSERP)



Instrument towers carry various sensors located at critical heights. (A. Mann, AOSERP)

Snow gauge. (H. Johnston, AOSERP)

An intensive network of air quality monitoring stations was operated during the first five years of the Program. Key stations are still maintained by government and industry.



Minisonde balloon and theodolite used for upper air monitoring. (M. Falk, AOSERP)

Sampling snow for $SO_2$ deposition. (A. Mann, AOSERP) the most useful in relation to requirements of logistics and manpower.

The air quality network has collected ground level concentration data for a number of airborne constituents for three years.[31] The air quality climatology for the area is now described in detail. The data provide very useful supplementary information which can be related to industry networks which are relatively close to the emission sources. A combined meteorological data acquisition and air quality system was installed in the vicinity of the Amoco Canada Ltd. in situ pilot plant near Stony Mountain (Gregoire Lake), about 50 km south of Fort McMurray, in co-operation with Amoco Canada Ltd. The system consists of four meteorological towers and a highly sophisticated integrated air quality instrument package in a trailer on the Amoco site. The meteorological towers provide data for analysis of flow characteristics in the vicinity of Stony Mountain, where terrain exerts a significant effect on atmospheric flow at lower levels. Because of technical problems, the air quality instrument package to date has produced little usable data. When fully operable, the system is expected to provide a means of assessing emissions from the Amoco Canada Ltd. in situ operation and integrating the data with respect to several air quality and atmospheric parameters simultaneously. A study was carried out[32] to identify all possible sources of toxic emissions from oil sands plants. Special emphasis was placed on the emissions likely to come from in situ operations, as well as those to be expected from the technology presently employed by Suncor and Syncrude and from conventional mining and extraction processes in future. Included in the study were recommendations for both water and air sampling for toxic substances over extended time periods to accumulate a reliable and stable data base.

Both the air quality network and the meteorological data acquisition system largely have met their stated objectives of acquiring sufficient data that a preliminary assessment can be made of the climatology of air movements and distribution of isopleths of selected atmospheric pollutants. The data obtained to date are highly useful in planning future air system research. As an adjunct to research on meteorology and air quality, an air system directory has also been compiled.[33] The directory provides a comprehensive listing of all air quality and meteorology data, including location of and description of sensors, extent of data records, and location of archived data. The data are available on request to researchers in government, industry, research institutions, and private sector consultants.

### 3.1.2 Meteorology

Feasibility of the use of weather radar was investigated as an aspect of applying advanced technology to acquisition of meteorological data.[34] The use of weather radar, in conjunction with conventional methods of acquiring meteorological data, was judged economically, technically, and scientifically feasible, but was considered of relatively low priority to implement, to staff, and to reduce the data in relation to identified needs of users of hydrological and air quality information. Very high resolution radiometry imagery (VHRR) from the multi-spectral scanner (MSS) of LANDSAT was assessed for monitoring weather conditions in the AOSERP study area.[35] While LANDSAT imagery could resolve surface features, its 9 to 18-day return period frequency made it unsuitable for studying such features as occurrence of fog, plume trajectories, etc. NOAA satellites give twice daily coverage but provide inadequate resolution of features essential to assess effects of industrial development. No combination of NOAA and LANDSAT imagery was considered adequate to provide weather data of use to AOSERP.

Conclusions of the report mentioned above may be unduly pessimistic as to frequency of coverage. Some satellites now give more than twice daily coverage and provide very high resolution data (visual and thermal). Thus, the application of rapidly improving remote sensing technology should be examined frequently (A.S. Mann, Atmospheric Environment Service, personal communication) as to its suitability in providing high quality meteorological information on a regional basis. Such information might prove valuable in gaining a better appreciation of problems associated with storm cells and acid precipitation.

A number of research projects were initiated to elucidate atmospheric processes which might affect plume dispersion from the Suncor and Syncrude plants, and which could be related to ambient air quality in the area. Three field studies were carried out to provide preliminary information on plume behaviour of the Suncor plume in relation to the meteorology of the area as well as the rate of $SO_2$ oxidation in the plume. For the majority of observations, both in March 1976 and February 1977, inversion conditions prevailed. It was found that, with a cross-valley flow, winds near ground were decoupled from winds aloft, with lower level flow aligning with the Athabasca River valley walls.(35,36,37) Thus, assessment of plume behaviour at tower altitudes was made more difficult because of terrain effects on wind flow. Oxidation rates of $SO_2$ were found to be lower than expected from theoretical estimates under conditions of the field studies. These studies provided atmospheric scientists with the opportunity to assess the appropriateness of methodology and equipment, as well as the usefulness of data gathered from the tall tower located in the river valley.

Knowledge of plume dispersion characteristics is critical to any assessment of the impacts of air pollutants. A project was developed in 1976 to carry out intensive plume surveys as an integral part of short-duration field studies, from which climatology could be related to plume dispersion and turbulence measurements.(38) The five cases used for analysis of plume geometry, mass flux calculations, and turbulence characteristics provided comparisons between observed plume structure and profiles predicted from the Gaussian model. Lateral and vertical plume spread were derived from each case. Significant differences occurred between observed values of the lateral dispersion coefficient and Pasquill-Gifford values, with the former being several times larger, which the authors speculated might be due to the presence of multiple sources. Values for the vertical plume dispersion coefficient were similiar to Pasquill-Gifford values, but decreased more slowly downwind. It was the conclusion of the study that a promising approach had been developed for determining the relationship between turbulence and plume dispersion for the Athabasca Oil Sands extraction plants.

Together with the knowledge of plume dispersion characteristics, long-term and long-range predictions of the effects of air pollutants require knowledge of climatological effects. A study was carried out to determine the climatology of low level air trajectories (movement of air parcels).[39] Most frequently, air masses move into the Athabasca Oil Sands region from the west and out of the region to the east, at the surface to 1500 m above the surface of the ground. These air masses may entrain emissions and are important to transport of atmospheric pollutants, particularly in summer months. Also of interest is a significant secondary component of air mass movement from the south and southeast at the surface level during spring months.

### 3.1.3 Air Quality

In order to identify the effects of air pollutants on air quality, the physical and chemical characteristics of the atmospheric constituents must be known. An extensive literature review was carried out to identify chemical transformation processes in plumes from oil sands plants which could be of importance in assessing long-term environmental effects.[40] Four major aspects of atmospheric chemistry were discussed: clean air chemistry, oxidant chemistry, $SO_2$ chemistry, and aerosol chemistry. It was concluded that high ozone concentrations and formation of Pan-type oxidants probably would take place, especially during summer when concentrations of both man-made and naturally occurring reactive hydrocarbons could be sufficient to fuel oxidant chemistry. Homogeneous gas phase reactions via interactions of $SO_2$ with oxidative processes were suggested as the prime transformation route of $SO_2$ to sulphate during summer, with aqueous phase reactions being important at all times. Studies relating to climatic and geographic conditions in northern Alberta also are specifically discussed. A parallel study of pollutant transformation processes was carried out to examine experimentally in the Suncor plume the summertime rates of oxidation of $SO_2$ to sulphuric acid and sulphates in order to determine the in situ $SO_2$ plume dispersion characteristics of $SO_2$ and particulates. Oxidation rates of $SO_2$ were found to be low (typically less than 0.5%) in early morning; later in the day, these rates rose to 1 to 3%, with a downwind ozone "bulge" occurring in several afternoon samples. Results suggest that photo-chemical processes play an important role in oxidation of $SO_2$.[41]

The initial long-range objectives of atmospheric research in the Athabasca Oil Sands region included evaluation and development of an air quality model to fit the needs of regulatory agencies in assessing air quality of the region. Inputs to such a model are in large part based on knowledge of climatology and meteorology of the region as well as characteristics of terrain and industrial pollutants discussed earlier. As a preliminary to extensive model development, experiments were performed with the Climatological Dispersion Model (CDM) to calculate annual averaged values of $SO_2$ concentrations at ground level.[42]

The major meteorological input to the model is the long-term joint speed and direction frequency distribution of winds in the vicinity of pollution sources. CDM calculations were reasonably well correlated with observational data; the model is therefore considered useful for computing seasonal or annnual-average ground level concentrations (glc) of $SO_2$, but is not intended for evaluation of short-term glc. The maximum annual-average concentration of $SO_2$ was found to be below the Federal Maximum Desirable Level, National Air Quality Objective. The model calculations predicted that, with both Suncor and Syncrude in full operation, the annual-average glc of $SO_2$ would not be significantly higher than that observed with only the Suncor plant operating. Because of lack of data from the Mildred Lake meterological station, Fort McMurray data were used and correlated with Mildred Lake data. These data suggest significant terrain effects which are of importance in the development of any useful air quality models for the region. To this date, no project has been developed to determine terrain effects or to incorporate these in an operating air quality model.

The climate of the area and climatology of atmospheric flows, along with the field studies, all of which were discussed earlier, provide the basis for assessing dispersion, transport, and impingement of pollutants near emission sources, as well as regionally and at long range.

Dispersion measurements of the Suncor plume resulting from the 1976 and 1977 field studies provided enough data that further field work on plume dispersion characteristics was not recommended. Instead, a comprehensive analysis of sigma data was undertaken in order to derive a procedure which could be used to predict plume sigma values.(43) This latter study suggested the need for more sigma data. The analysis of AOSERP plume sigma data was also intended to provide a user needs evaluation when used in conjunction with two users' surveys carried out concurrent with the plume sigma data analyses(44,45) and air quality modelling.

### 3.1.4 Air Quality Modelling

A relatively large effort was devoted to investigation of atmospheric models and their application to air quality management in the oil sands region. A literature review was carried out of both Gaussian and more complex Eulerian models,(46) which resulted in recommendations that a flexible model be used to allow input of local chemistry and dispersion characteristics and inclusion of complex terrain effects, following which there would be a staged implementation of model use from the simple Gaussian (CRSTER, CDM) to more complex (LIRAQ' ADPIC). A study was carried out to calculate the annual glc of $SO_2$, using Suncor data as an input to the CDM, and allowed some comparison with measured annual average values. Both the values predicted from the model and the measured values for the glc of $SO_2$ were below the generally acceptable upper limit, indicating no cause for concern. However, the study concluded that it would be desirable to rerun the model with Syncrude data to achieve greater precision to predict the glc of $SO_2$ with two emission sources. The study recommended also that the monitoring network density be increased for model validation and that real wind and dispersion data be used, rather than parameters fixed in the model.

An in-depth study was carried out to implement and assess the CRSTER model(47) by testing the state of the art EPA model with the use of Suncor data. Results compared reasonably well with the CDM determinations mentioned above. The study resulted in recommendations that monitoring be increased to allow comparison of model predictions and that a flare stack plume rise algorithm be developed. The study also suggested that more recent EPA models be examined for inclusion of multi-source data, field tests for worst case episodes, and increased quality control of data. A parallel study provided detailed examination of the Livermore Laboratory models (LIRAQ and ADPIC) for possible use in the oil sands region.(48) The study examined algorithms, data requirements, application, and logistics of implementation. The study concluded that the ADPIC model might be useful for episodal studies, but that severe computational difficulties could be expected, reprogramming might be required, and implementation of this model for the Athabasca Oil Sands region should not be attempted before careful program analysis was carried out. The

LIRAQ model was judged to be inapplicable to problems in the oil sands region. A problem analysis was carried out of plume dispersion in a convective boundary layer.(49) This study provided a theoretical discussion of plumes in a boundary layer, effects of a convection in summer, and applications to looping plumes in the oil sands region. It recommended field investigations to obtain model-directed data, measurement of incoming radiation, climatology of mixing depths and wind profiles, and a visual plume observation program.

A preliminary ice fog model dealing with physical processes in ice fog formation was developed, using observational data obtained in the oil sands region.(50) This study resulted in a recommendation for the development of a sophisticated fog model which could incorporate topography and assess pollutant-fog interations. Because of the relatively infrequent occurrence of fog (potentially 10 to 13 days/year), a low priority was assigned to continuing development of ice fog models. A study was carried out to investigate the chemical fate of pollutant gases from oil sands plants and to develop a comprehensive computer algorithm which could be used to derive plume chemistry in mathematical terms.(51) This chemical model was designed to incorporate the chemistry of sulphur dioxide, oxides of nitrogen, ozone, and hydrocarbons and to validate the chemistry of these compounds experimentally. The model has been tested, but requires data from plume chemistry studies to obtain reaction rates.

A highly significant objective of AOSERP was to supply advice and scientific information on meteorology and air quality to government agencies and industry which could be used as a basis for environmental management decisions. Involved in that objective were the needs of users in a variety of government agencies and industry as well as researchers in several disciplines. Consequently, as mentioned earlier(45), user requirements were analyzed in relation to airshed management strategies. This analysis provided an overview of the application of air quality simulation models to air quality management. Included in the analysis is a summary of the types of models in use, how they are applied, and an analysis of model criteria. The report defines the strategies employed in air quality management and concludes that only one of the four main strategies has need of air quality models on which to base management decisions.

A study of user needs[44] was carried out to determine the application of computer simulation models to airshed management, in order to provide direction for the formulation, development, and application of an air quality model to air quality management in the Athabasca Oil Sands region. The model deemed most appropriate to users' needs included three basic components: glc file, meteorological time series file, and the frequency distribution model itself. The procedure used for selection of an appropriate model relied on three main parameters: application, implementation, and importance. Application parameters reflected the degree to which the model type accurately simulated physical processes which determine wind flow and dispersion of atmospheric pollutants. Implementation parameters concerned requirements for input data, computers and personnel. Importance parameters evaluated which physical processes were important for particular user needs. Major user needs were identified as: maintenance of air quality standards; long-term dry deposition patterns; and generation of frequency distributions of canopy-top pollutant concentrations as functions of biologically important parameters, such as surface moisture, temperature, season, time of day, etc. Several types of air quality models were identified as meeting user needs, and the rationale for selection of a specific model was discussed in detail. Five suggested stages of implementation for air quality model program are stated below:

1. The implementation of a Gaussian frequency distribution model of a modified CRSTER form to include site-

specific dispersion parameters and biological stratification parameters;

2. The site-tuning of a Gaussian standard model with a consideration of convective effects for tall stacks;
3. The determination of a modified potential flow terrain model with site-specific dispersion co-efficients;
4. The determination of spatial distribution and importance of terrain effects in the AOSERP region; and
5. The generation of a representative wind data base for the frequency distribution model.

As indicated earlier, AOSERP Air System research had a two-part final objective: to provide meteorological and air quality data to a variety of users and to develop an airshed management program for the Athabasca Oil Sand region. Large amounts of data are available for use by researchers, government agencies, and environmental managers in industry, which in large part satisfies the first part of the final Air System objective of AOSERP. A multi-year program for development and refinement of a series of air quality models has been initiated, with the first phase consisting of the first of the five stages outlined above.[52] It should be emphasized that the frequency distribution model developed in this Air System research project differed significantly from the traditional climatological dispersion model (CDM), with the major difference being the inclusion in the AOSERP model of biologically or sociologically important weighting factors. Available data were analyzed to provide inputs for weighting parameters and dispersion specifications, and it was determined that extensive refinement and extension of the data base will be required before appropriate wind speeds can be generated for the model. As well, a need was identified to parameterize wind direction fluctuation for plume sigma estimates by means of boundary layer classifications specified by available parameters.

It has been stated earlier that the air quality model developed by AOSERP is intended as a working air quality model, rather than as a research model. As a result, the first working version of the model strongly reflects airshed management requirements and specified user needs. As background to a workshop for model users[53], a discussion of model capabilities and an outline of its components was developed. This material, produced by D.S. Davison, is quoted below.

> <u>OVERVIEW OF MODEL CAPABILITIES</u>
> The model is a frequency distribution model which is designed using a time-series approach. Basically the model provides an integrated picture of ground level concentrations (glc) of a given pollutant over a specified time period. As in other frequency distribution models, the average glc values and their frequency distribution for various concentration levels are calculated. However, the model has additional characteristics which should make it a more powerful management tool for typical users. Three of the major improvements are outlined below.
>
> The frequency distribution of ground level concentrations can be very efficiently modified to allow for the sensitivity of the particular receptor. For instance, a biologist could limit his concern for times in which active photosynthesis is taking place. The land-use planner might wish to be especially concerned with glc values during daytime recreational hours. The model can permit limitation of the data set being considered to specific seasons or times of day. In a more general way, the model will permit a weighting of the calculated glc values according to any of the meteorologial parameters included in a time series data file. For instance, the weighting of the glc values could be made a function of temperature. The weighted glc values then become a measure of both the concentration value and the susceptibility measure which was emphasized by all the biologists interviewed for the user survey.
>
> The model can also generate a time series of concentrations at any given receptor location based upon the historical time series of meteorological data. A frequency distribution of the time between occurrences of glc values above a given critical value can also be generated. This type of analysis can then be used to

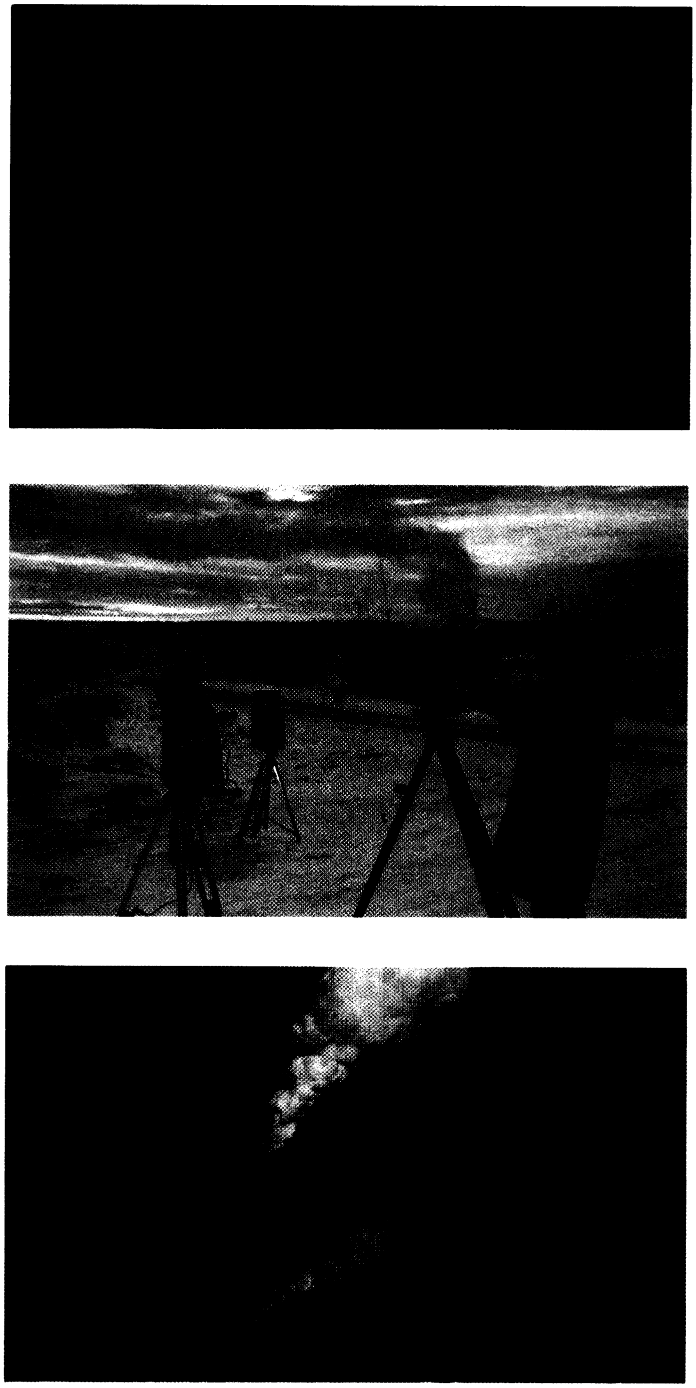
estimate the likely time period between high concentration episodes. That information was identified as being very useful for biologists studying the effect of a recovery concept after an exposure and for land-use planners in assessing a nuisance to deteriorated air quality. Because the model can be used to simulate various possible developmental scenarios, the time between episodes can be used to assess the likelihood of exceedance of various air quality objectives using historical return periods and future emissions.

A third major feature of the model is the flexibility in the source specification. The model is designed to precalculate and store on file the amount of dilution for each source at each receptor point in a grid. As long as no new sources are desired and glc values are desired only for regions inside the grid, then users need only run one portion of the model to vary source strengths, and weighting of glc values and to utilize most other model analysis options. The significance of this modular feature is that it is much simpler and far more efficient (i.e., less expensive) to run a wide range of simulation studies. Thus, the glc values due to a single source or group of sources can be assessed by varying the source rates (which can be set to zero to ignore a particular source). This feature permits some estimates of the incremental effects of additional sources; so that many aspects of different developmental scenarios can be assessed easily without the need to regenerate the main ground-level concentration file. The source strengths can be similarly varied to study different contaminant species (e.g., $SO_2$, $NO_x$, etc.).

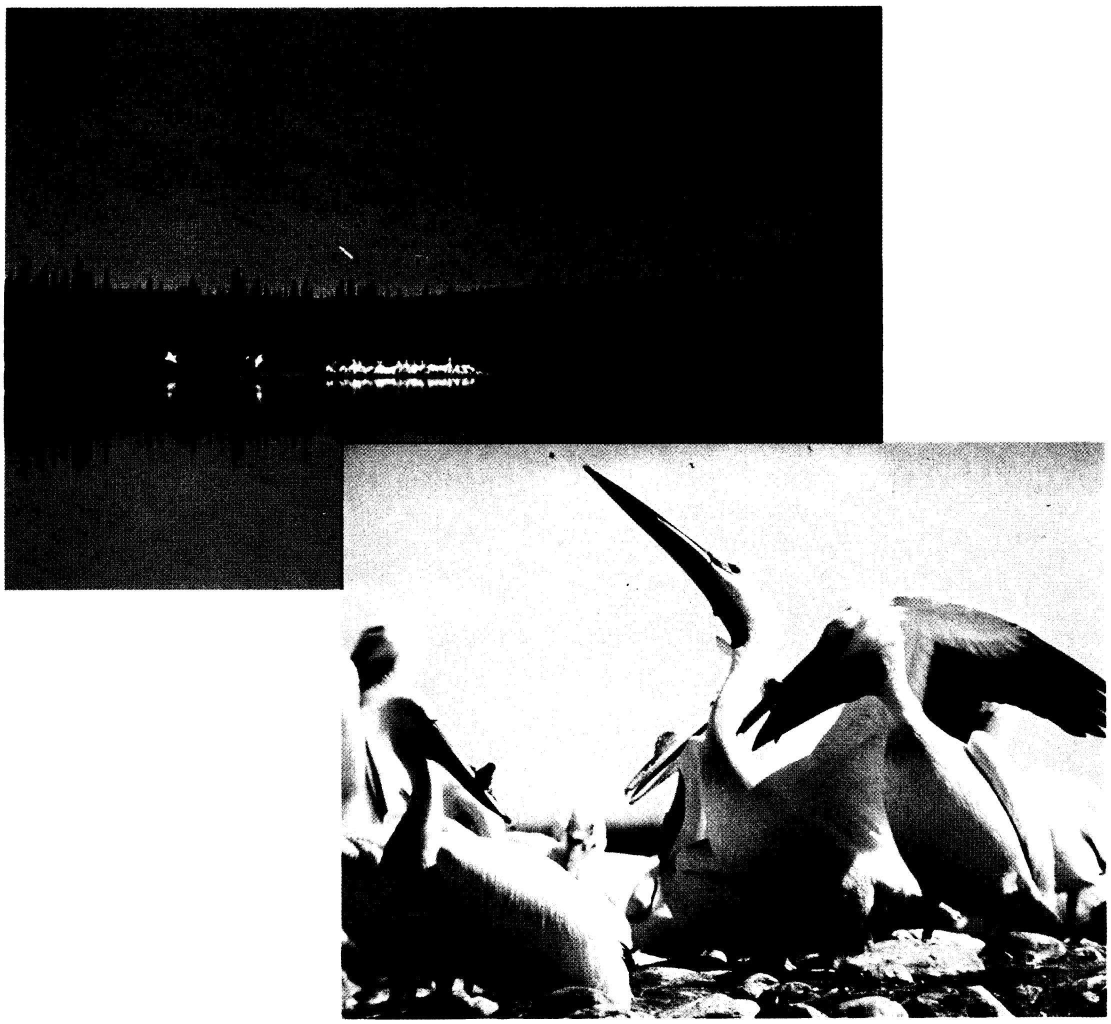
## OUTLINE OF MODEL COMPONENTS

The model has three basic components. The typical user would access the frequency distribution model, itself, called FRQDTN. This program calculates frequency distributions and performs other statistical analyses based upon input parameters including the susceptibility weighting descriptors. The program FRQDTN utilizes two pre-generated files which are the remaining two major components of the model system.

The first major file assessed by FRQDTN is the time series of the meteorological data. The meteorological data presently include wind speed and direction, temperature, relative humidity, mixing height cloud cover, precipitation and snow depth. The time series file is the final output from a series of analysis



Plumes (W. Hume, AOSERP) and plume photography (M. Falk, AOSERP). Study of emission plumes aids in developing transport and deposition models for aerial pollutants.



Foraging White Pelicans *(Pelecanus erythrorhynshos).* (R. Beaver, CWS) programs for the various parameters. The final program which synthesizes the data sets and performs some additional analyses is called TIMSER. The typical user would not need to run TIMSER since the time series file would normally be available.

The second major file is the ground level concentration file generated by the program GLCGEN. The ground level concentrations are pre-calculated for all possible dispersion classes, for specified sources and receptors. This pre-calculation avoids the necessity of separately computing the ground level concentrations at each time series entry. Although there is an approximation involved in the discretization of the parameters controlling dispersion into dispersion classes, the precalculation reduces the model run-time by about an order of magnitude. All the major dispersion formulations are within GLCGEN; so that a typical user who chooses to use the existing formulations need not run GLCGEN.

A unique feature of the development of the airshed air quality model discussed above was the appointment of a Quality Assurance Board (QAB) to review the progress of model development and to offer criticism and advice at pre-determined stages of the research project. As a result of the interactions of the QAB with the researchers who developed the model, significant shifts in emphasis occurred. The final report on development of the model also incorporates QAB comments and critical review of the product.

## 3.2 Land System

The geographic location of the Athabasca Oil Sands region, plus its topography and climate, determines its major environmental characteristics. AOSERP studies were directed toward the determination of regional baseline conditions with respect to vegetation, soils, surficial geology, and wildlife. In addition, field studies were commenced to determine possible impacts of air pollution on vegetation and soils, as well as laboratory studies to determine threshold levels and symptomology of injury to vegetation by $SO_2$. The land system objectives designed to meet those goals are listed below:[4:31]

1. To review and assess the available information pertaining to terrestrial ecosystems of the AOSERP study area;

2. To undertake studies which may be used to establish the baseline states for physical, chemical, and biological constituents of the terrestial ecosystems of the study area which could be altered by oil sands development;

3. To identify substances which may be introduced into the metabolic pathways of the terrestrial ecosystems of the study area and their effects on these metabolic pathways;

4. To assess and report on all physical, chemical, and biological disruptions of the terrestrial ecosystems in the study area resulting from oil sands development;

5. To undertake studies directed toward restoration of biological productivity to terrestrial ecosystems disrupted, damaged, or destroyed in the course of oil sands development; and

6. To derive a conceptual and/or mathematical model which can be used to predict the effects on the terrestrial ecosystem and its capacity to assimilate those effects without permanent or long-lasting debilitation.

### 3.2.1 Fauna

During the first two years of the program, heavy emphasis in Land System research was placed on constructing a general inventory of bird and mammal species of the region. Species selected for initial study were those considered to have potential for a negative response to oil sands development. These included waterfowl, migratory and resident birds of the forest ecosystem, rare, sensitive, and endangered species (e.g., white pelicans and peregrine falcons), and moose, caribou, and wolves.

In order to provide an estimate of the number of moose in the region, a project was designed for estimating moose densities with reliable statistical confidence intervals. A model was developed which was considered appropriate to quadrant or transect surveys, and which provided statistically reliable estimates of visibility bias and absolute density as well as realistic estimates of population variance.[54] To serve the general objective of minimizing damage to and preserving habitat for moose as one of the most important ungulate species in the region, the relationship was studied between moose and the habitats and forages available to them. Radio telemetry was employed to track moose to delineate seasonal use and preference and avoidance of habitats and forages. Observations indicated that upland habitats were seasonally most heavily utilized and preferred (greatest impact of oil sands development would result from destruction of upland habitat). The study included data on the ranked importance of major plant associations and the ranked importance of forage species consumed by moose.[55] Moose are widely distributed in the oil sands region in a variety of habitats. The dynamics of moose in the region were extensively investigated between 1976 and 1978[56] and revealed that the pupulation is stable or declining. Comparison with a population of moose at Rochester, Alberta[57] revealed lower fecundity, and mortality of adults chiefly as a result of hunting and wolf predation. Along with data gathered earlier, likely critical habitats were identified. A conclusion of this research was that increased exploitation of moose (by hunting) would produce a major population decline. A population estimate of 4595 moose for the entire AOSERP study area (0.18/km$^2$) was obtained for the winter of 1977 to 1978.

Dynamics of woodland caribou were studied over the same period as for the moose.[58] The total population of the AOSERP study area was estimated at 433 animals for the winter of 1977 to 1978. Calculated rate of population growth indicated a stable or slowly declining population and recruitment of calves appeared to be low. Cause of mortality was not determined, but duration of snow cover appeared one likely cause. Hunting and wolf predation were judged to be minor factors in total mortality.

Because of the location of caribou herds, these animals are not likely to be affected directly by oil sands development. Sustained increased mortality from hunting would likely extirpate caribou from the Athabasca Oil Sands region. The study concluded that woodland caribou in the Athabasca Oil Sands region in future could be exposed to significantly increased human disturbance. No conclusions were presented as to the likely consequences of increased disturbance on caribou numbers or distribution.

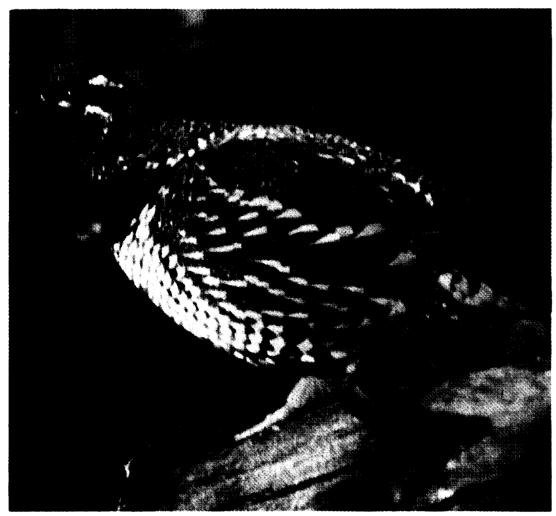
The wolf is of widespread, but low density, occurrence in the Athabasca Oil Sands region.[59] Population studies on wolves carried out from 1975 to 1978 revealed a total wolf population of about 140 animals. The population appeared to have increased significantly during the course of the investigation (from 1975 through 1977). Trapping and early death of pups were judged to be the chief mortality factors. Geographic distribution of wolves and kill location was associated with density of moose. Some members of wolf packs became associated with garbage dumps; these animals were in poorer condition than wolves dependent entirely on natural prey. As with caribou, this study concluded that wolves in future would be subjected to significantly increased human disturbance as a consequence of continued development of the Athabasca Oil Sands.

A species of relative abundance and importance in the AOSERP study area is the black bear. Support was provided to a study at Cold Lake, Alberta to provide information on responses of black bears to habitat alterations, bear-human interactions, and refuse disposal, all of which have caused concern in other areas.[60] Results of the study indicate that bear-human interactions can be minimized with adequate refuse disposal methods.

A review of AOSERP faunal studies indicated a deficiency in baseline information with respect to insects, which comprise the major component of animal biomass in terrestrial ecosystems. Surveys were carried out to describe the insect fauna of the

Wolf *(Canis lupis).* (L. Carbyn, CWS)

Predators and game and furbearing animals are important inhabitants of the oil sands regions. Studies of population dynamics and habitat preference aid in assessing the impact of oil sands mining on this valuable natural resource.



Spruce Grouse *(Canachites canadensis).* (K. Lumbis, CWS)

Bull Moose *(Alces alces)* with radio-tracking device. (T. Fuller, University of Wisconsin)

Revegetation plots on Suncor tailings dyke.
(J. Selner, Energy and Natural Resources)

Aerial photograph of a vegetated portion of the Suncor dyke. (H.P. Sims, Research Management)

Small mammal damage to seedlings is one problem encountered in reclamation schemes.
(H. Johnston, AOSERP)

Reclamation of tailings pond containment dykes is a major concern. A self-maintaining and erosion-controlling cover must be established.

region[61] and insectivorous animals dependent on insect fauna.[62] Insects not only comprise the largest component of total animal biomass but are important as food for insectivores, may be important to people as biting insects, or may do damage to vegetation, depending on the taxa involved. An insect survey of the Suncor dike showed that insects were abundant in dike vegetation. Insect attacks were tolerable for deciduous trees but more severe on conifers. Insect damage was not the chief limiting factor in mortality of trees on the Suncor dike.[63]

Next to insects, small mammals (rodents) constitute the most abundant animals in the Athabasca Oil Sands region. In order to develop baseline data on small mammals and to identify their relationship to other components of the forest ecosystem, the ecology of five major species in the region was investigated.[64] Distribution, habitat, and food preferences were reviewed for the red-backed vole, meadow vole, deer mouse, red squirrel, and snowshoe hare. All five species were abundant, widely distributed, and important prey species for furbearers and raptors. Each species has potential as a pest in afforestation. The red-backed vole and deer mouse appear to erupt into large populations every three to four years. The red squirrel and meadow vole fluctuate widely in numbers, related to a variety of causes, while the snowshoe hare reaches peak numbers every 8 to 10 years.

Because of problems associated with survival of trees on afforestation sites, the potential for damage to trees by small mammals was reviewed.[65] Natural distribution and densities of small mammals was investigated as well as demographic trends, habitat requirements and utilization, feeding habits, and damage to plants. Small mammal damage was light on natural sites; vegetation species susceptibility was highly variable. Numbers of small mammals were only weakly associated with damage to plants. For snowshoe hares, rate of browsing was inversely correlated with amount of available browse. The study concluded that control of damage by small mammals on reclaimed areas was best achieved through the provision of supplementary food, manipulation of habitat (reduced cover), and the use of chemical repellants.[66]

During planting trials of vegetation on the Suncor dike, it became apparent that rodents (and possibly insects) could cause significant damage or mortality to planted tree seedlings. A project was initiated to monitor rodent damage to tree seedlings. An estimate was made of rodent populations on the Suncor dike and poison bait feeding stations were established as a means of controlling rodent numbers. Results of attempts to control rodents and damage to seedlings were inconclusive.[67]

The availability of furbearers to native people of the area is of economic importance. An analysis of fur production for the five-year period 1970 to 1975 indicated that about $165,000 in fur was produced from 131 registered traplines in the area, and that several times the amount reported could actually have been produced in the region.[68] The four major species of semi-aquatic mammalian furbearers in the Athabasca Oil Sands region are muskrat, beaver, mink, and otter (in order of importance). A study mentioned earlier on the ecology of semi-aquatic furbearers of the areas produced an annotated bibliography concerning life history, physiology, mortality factors, environmental quality, and management of the four species.[28] This study provides an excellent reference base for any future study of the four species of furbearers mentioned above, particularly in relation to effects of oil sands development on fur production and operation of traplines.

One of the large groups of warm-blooded animals in the oil sands region comprises birds. These were inventoried in two major categories: terrestrial birds and waterfowl. The study on terrestrial birds[69] provides an annotated checklist of 220 species and includes notes on the status of each species with respect to residence, breeding, and migration status. Habitats were identified for each species of bird and the potential impacts of oil sands development were related to habitat requirements and usage. It may be concluded that some species will be eliminated from actual oil sands plant sites, but the total direct impact on terrestrial birds in the oil sands region will be relatively small because of the small percentage of total area affected. The surveys on terrestrial birds provide extensive baseline data of considerable value to any future work on this group.

Species distribution and habitat preferences were determined for staging or breeding of waterfowl in the oil sands region.[70] Less than 1000 breeding pairs were counted, but fall staging surveys indicated numbers between 11 000 and 24 000 ducks. Evidence was not presented in this report for widespread effects of oil sands development on waterfowl with the exception that tailings ponds pose a threat at all times to migrating waterfowl because of oil on the surface of these waterbodies. Suggestions were made to render tailings ponds as unattractive as possible to waterfowl and, failing success, to use appropriate methods to deter waterfowl from use of tailings ponds.

Included in studies of birds was an inventory of selected species of rare, endangered, or senstive status, carried out over a three-year period from 1975 to 1977.[71] Three major groups of birds were surveyed: raptors, colonial birds, and selected sensitive species, except for peregrine falcons and white pelicans, which are reported elsewhere.[72,73] The study concluded that increased levels of human activity associated with further oil sands development pose a potential threat to rare, sensitive, or endangered species of birds.

### 3.2.2 Soils

Prior to initiation of AOSERP, detailed information was not available on the soils of the Athabasca Oil Sands region. It was decided to inventory and map the extent and locations of soils throughout the region in order to provide baseline information for prediction of the effects of oil sands development on terrestrial ecosystems. Soil mapping was also intended to provide baseline information to all disciplines involved with research in the Athabasca Oil Sands region. All areas to be covered were field checked and sampled and preliminary maps prepared. In the Birch Mountains, Dunkirk Plain, and Kazon Upland, permafrost was encountered in most organic soils. It was suggested that a reclassification to sub-Artic, rather than Boreal might be used by other researchers. Further work on ecological land classification might result in classification changes for some areas to sub-Arctic or high-, mid-, or low-Boreal regions. Land districts were divided according to relief, geology, and geomorphology, while soils were described in terms of particle size, pH, wetness, and soil temperature.[70]

Soils of the area were identified and mapped according to the system developed by Lacate.[75] Aerial photography used in the soils inventory was 1974 black and white Panchromatic at a scale of 1:50 000. Field maps were reduced from 1:50 000 to 1:250 000 for publication and are held in the files of the Research Council of Alberta. Dominant upland soils of the region were identified as Gray Luvisols and Eutric Brunisols supporting vegetative covers of white spruce, trembling aspen, and jack pine. Soils developed on materials of recent glacial deposition were identified as Regosols and Gleysols. Soils in lowland, poorly drained sites are mainly organic and consist of bog and peat fens which occupy a large portion of the region. Vegetation on bog soils is largely black spruce and a variety of deciduous shrubs.[76]

Availability of materials suitable for rebuilding soils during reclamation of disturbed areas is of extreme importance. Many exploitable oil sands deposits are overlain with muskeg, which must be de-watered and stripped before surface mining can commence.[1] The surface overburden materials often consist of peat which can be stored for later use. The effect of the drying and freeze-thaw cycle on peat may affect its usefulness in reclamation, since peat may be stored for several years before being used as a soil amendment. Peat was characterized as to chemical, physical, and microbiological properties and the changes likely to occur in these after prolonged storage were assessed.[77] This study was terminated by accidental destruction of peat piles before any useful information was obtained. Drying affected most physical properties of peat, as well as microbial activity, as measured by enzyme activity and and $CO_2$ production. When inorganic constituents were mixed with peat, microbial activity increased. Undisturbed peat showed little microbial activity. Peat is considered to be the best available material for reconstructing soils on tailings pond dikes and reclaimed mine pits.

There is potentially very wide application of information relating to characteristics of soil materials to be reclaimed after oil sands development. Such information is of direct interest to government agencies and industry alike. A research project was initiated to provide detailed characterization of soils at a number of sites.[78] Eleven field sites were instrumented to monitor ground temperature, soil moisture tensions, moisture content, and position of water tables. There were eight sites on sand, one on glacial till, and two on the Suncor dike. Soil sulphur content and mechanisms and rates of $SO_2$ uptake by soils were measured to determine the effects of current ground level concentrations of $SO_2$ on soil pH, available sulphur, and soil biological activity.

### 3.2.3 Vegetation

A vegetation inventory of the oil sands region was begun in 1976, with air photo coverage of major plant associations from both true colour and false-colour infrared photographs at a scale of 1:15 000.[79] A vegetation classification system had been developed earlier, both from air photography and field studies.[80] The preliminary vegetation classification was to form the basis for the design of a full-scale vegetation inventory and habitat mapping program for the whole AOSERP study area at a scale of 1:50 000. The preliminary vegetation classification divided the plant associations into two major types: upland communities and wetland communities. These major associations each were further divided into more distinct associations of species. The vegetation classification developed by AOSERP has been widely used as a basis for most other terrestrial surveys in the Athabasca Oil Sands region.

Animals are distributed in and depend on various vegetation assoications or habitats.[81] As a means of providing comprehensive baseline information on forest plant ecology and habitats, an extensive review of the literature pertaining to the vegetation of the Athabasca Oil Sands region was carried out.[82] This study examined in detail the ecological factors associated with mature canopy and understory vegetation in terms of soil and moisture requirements, reproduction, establishment, growth, successional roles, and sensitivity to pollutants. The study also examined the nature, causes, incidence, and extent of fire and its ecological consequences, including its influence on soil heat balance, soil pH, and nutrient availability. The general dynamics of vegetation were summarized for muskeg and related wetlands, river and lake shores, uplands and lowlands, and the understory associations. Five general approaches to studying and classifying vegetation were dicsussed: physiognomic classification; ordination (continuum) view of vegetation; floristic classification; physiognomy and dominance; and biophysical land classification. For each approach, a general description was provided of characteristics of the system, data requirements, advantages and disadvantages, and application. The study provides a variety of approaches for use by researchers interested in the plant ecology of the region.

As a companion research project to determine ecological factors important in the Athabasca Oil Sands region mentioned above, a project was carried out to prepare ecological habitat maps of the region.[83] This study involved the development of a "habitat" classification system for combined mapping of vegetation and surficial geology, ground surveys ("truthing"), and preparation of maps at a scale of 1:50 000. A second, more detailed study was carried out on the vegetation and related surficial geology of the Muskeg River basin.[84] This study provided much larger scale coverage of surficial features and plant associations, as well as more detailed examination of the understory. Examination of the results in a workshop determined that the broader coverage and classification used in ecological habitat mapping were adequate, and the expense involved in mapping the region at a larger scale was not justified.

The extraction process technology presently used in oil sands plants results in production of very large volumes of tailings sludge, as well as very large tonnages of spent sand. Consequently, it is of concern to know how to reclaim tailings pond dikes and waste piles of sand with permanent vegetative cover. A project was initiated to assess the long-term performance of vegetation of steeply sloping sands and to provide information from which predictions could be made as to the maintenance of various kinds of vegetation on tailings sand.[85] The research was carried out in a natural jack pine forest on a natural sand dune with deep slopes. Such conditions are typical of many areas in the Athabasca Oil Sands region. In two years of field investigations, extensive data were accumulated on micrometeorology, soil physics, plant physiology, heat pulse, tree geometry and optical properties, role of lichens, mycorrhizae, energy, water balance, and radiation. These data were integrated into a mathematical model of the jack pine forest under the conditions and in the locality of the experimental field investigations. The data obtained were related to conditions to be expected on mined sands and tailings pond dikes resulting from oil sand extraction operations. The authors suggested that a process-oriented approach, using a totally integrated model, provided reasonable predictions for vegetation management on steep dikes and waste sands. The authors stressed that this research was preliminary to a more comprehensive approach and that further investigation would be required to refine the data and predictive capability of the study.

A second approach to revegetation of mined sands was initiated to evaluate the suitability of native and introduced species of trees and shrubs. A project was developed to identify factors important to survival of seedlings, to test ecotypes from invading species on disturbed soils elsewhere, and to develop recommendations for suitable genotypes which could be propagated.(86) The project resulted in the extensive collection of seeds of native trees and shrubs, but conclusions could not be drawn from the information collected in this study. A third project was initiated to identify and collect propagules from herbaceous and shrubby species on areas of disturbed soil where natural revegetation had taken place; to test such materials for survival and establishment on tailings sand and amended tailings sands and spoil materials; and to develop techniques for propagation of genotypes to test and their use in large-scale reclamation projects.(87) No firm conclusions were reached from the results of this project.

### 3.2.4 Air Pollution Impacts

A large number of studies have been carried out on the ecological impact of air pollutants during the past decade.(88,89) In order to establish baseline conditions of vegetation response to air pollution in the Athabasca Oil Sands region, a comprehensive research program was designed. This program was intended to determine response of vegetation to existing ground level concentrations of $SO_2$, and to determine experimentally the symptomology and threshold levels for injury, as well as ecological bench marking for detection of effects and physiology and mechanisms of injury to vegetation. A similar study on the long-term and transitory effects of physiological response of jack pine to $SO_2$ had been carried out earlier in the vicinity of Whitecourt, Alberta, with some assistance from AOSERP and is report elsewhere.[90]

In order to determine symptomology of $SO_2$ injury (visible and microscopically observable effects), six boreal forest plant species were fumigated in an environmental growth chamber with 0.34 ppm $SO_2$ for up to 40 days.[91] All species showed a gradual decline in $CO_2$ gas exchange which was correlated with symptom development characteristic of $SO_2$ injury. Paper birch was the most sensitive to $SO_2$ injury, followed by green alder, jack pine, Labrador tea, and white and black spruce. Visual threshold level of $SO_2$ injury was defined as the "time and concentration where visual foliar damage was first detected." Physiological threshold level of $SO_2$ injury was defined as the "time and concentration which reduces net $CO_2$ assimilation by ten percent."

Although detectable effects of $SO_2$ injury to vegetation may not be lethal, it is probable that vegetation suffers significant injury by the time symptoms are visible. Biochemical studies carried out under the same concentrations as those outlined above resulted in alteration of metabolism of chlorophyll and other pigments by inhibiting lipid synthesis and various enzyme systems.[92] Plants fumigated with $SO_2$ exhibited biochemical responses deleterious to normal growth, but showed considerable recovery when returned to an $SO_2$-free environment. These results are in agreement with the study in the vicinity of Whitecourt, Alberta, cited above.[90] An attempt was made experimentally under field conditions to detect pre-visual $SO_2$ injury to jack pine and white spruce from the impingement area in the immediate vicinity of the Suncor plant[93] and which was termed "ecological benchmarking." No appreciable effects could be detected in the field on biochemical and physiological functions which responded to $SO_2$ under laboratory conditions. Further experimentation was suggested with species known to be most sensitive to fumigation by $SO_2$.

In a number of studies carried out on the impact of air pollution, particular attention has been paid to the impact on lichens, but almost all the reported studies have been "post-mortem" in the sense that they have dealt with severely damaged areas. It should be emphasized that the study discussed above on ecological benchmarking and biomonitoring in the Athabasca Oil Sands region was carried out where obvious damage to the forest ecosystem had not been documented. The study should therefore be of value in providing baseline information on vegetation and soils in areas of low to zero impingement, as well as in the maximum impingement area of the Suncor plume. No apparent impact of air pollution on soils or vegetation has been detected to date, but these sensitive monitoring techniques are intended to provide "early warning" of possible long-term impacts of low concentration air pollution in the oil sands region.

The studies discussed herein outline a preliminary approach to investigation of the effects of atmospheric pollutants on vegetation. These studies were carried out over five years and concluded in 1980. Continuing experimental fumigation of living plants with concentrations of $SO_2$ at 0.34 ppm confirmed the symptomology and threshold levels for pollutant injury to vegetation, and the high sensitivity of deciduous trees and shrubs as compared to conifers was also confirmed. A quantitative measure of reduction in metabolic rate is now available of the species tested with $SO_2$ and it has been determined that S uptake is extremely variable. As a result of studies of the physiology and mechanisms of uptake of $SO_2$ by vegetation, there is in 1980 no detectable metabolic response of vegetation to present $SO_2$ levels in the oil sands region. Although no changes have been detected to date in metabolic response of vegetation to $SO_2$ impingement from the

The land-water interface provides a diversity of complex habitats necessary for the maintenance of many aquatic and terrestrial animals. The oil sands region is rich in such riparian habitats.

A pothole-bog-upland mosaic.

Shoreline vegetation transition is complex along a quiet section of the Steepbank River... (P. Thompson, AOSERP)

However, the Steepbank also cuts through terrain of more pronounced relief, creating more abrupt land-water transition zones. Such river margins are fragile and of considerable importance, especially to aquatic life forms.

Vegetation mosaic along the MacKay River
(T. Chamberlin, B.C. Ministry of Environment)

Beaver dam south of Fort MacKay.
(E. Hennan, CWS)

Meandering river courses create many kilometres of riparian habitat relative to actual horizontal distance covered. Such rivers often change course in flood, creating new habitats while altering or destroying others.
(T. Chamberlin)

Suncor stack, the doubling of total $SO_2$ emissions when Syncrude became operational suggests that caution is required in interpretation of results over the relatively short five-year time span of the study of $SO_2$ effects. Consequently, biomonitoring plots were established to determine possible gradients in S deposition and uptake by plants. For vascular plants, with variable distances of stands from emission sources, no evidence could be adduced from community structure and species composition that there was any environmental change at these sites asociated with the Suncor plume, for the relatively short term during which they were studied. Similarly, lichen community analysis did not provide data which could indicate a trend to change in species composition with distance from the emission source. However, within the zone of direct impingement, there were changes in species composition of some lichens, but these could not be correlated to effects of the Suncor plume alone.

Soil chemical analysis revealed an extremely variable pattern, which prevented correlations being established between soil chemistry and soil type or soil chemistry and distance from the pollution source. In soil samples, total S content was very low, and significant corelation betwen soil S and emissions from the Suncor stack could not be established. Sulphur content in tree species appeared to show a trend with distance from the emission source but was not statistically significant. These data will provide a baseline measure of S in vegetation which can be used in future studies of S deposition. Chemical analyses of some selected understory plant species showed a substantial increase in S content with decrease in distance from the Suncor plant, but these data must be viewed with caution since the measured S levels may be a reflection of site characteristics, such as stand density, with consequent increased opportunity for direct deposition on lower vegetation. Experiments are currently in progress to provide additional data for better interpretation of results, particularly in relation to the possibility of synergistic effects of sulphur dioxide and nitrogen oxides (S. Malhotra, Canadian Forestry Service, personal communication).

## 3.3 WATER SYSTEM

The Athabasca Oil Sands region is dominated by two major river systems (Athabasca and Clearwater) which join at Fort McMurray. The mainstems of these two systems and their tributaries drain a variety of ecologically different basins, which contribute to variability in physical, chemical, and biological characteristics of surface waters. Because of the very large area drained, plus the fact that the Athabasca River terminates in the Peace-Athabasca Delta, AOSERP water system research was wide ranging, both in geographic scope and technical character. Objectives set out to elucidate the important aspects of the aquatic ecosystems in the Athabasca Oil Sands region are outlined below:[4:40]

1. To review and assess the available information pertaining to aqueous systems of the AOSERP study area;

2. To undertake studies which may be used to establish the baseline states for physical, chemical, and biological constituents of aqueous systems of the study area which could be altered by oil sands development:

3. To identify substances which may be introduced into the metabolic pathways of aqueous systems of the study area and their effets on metabolic pathways;

4. To assess and report on all physical, chemical, and biological disruptions of aqueous systems in the study area resulting from oil sands development;

5. To derive a conceptual and/or mathematical model which can be used to predict the effects on aqueous systems and their capacity to assimilate those effects without permanent or long-lasting debilitation; and

6. To undertake studies directed toward restoration of biophysical productivity to aqueous systems

disrupted, damaged, or destroyed in the course of oil sands development.

Aquatic resources of the Athabasca Oil Sands region have four major uses. The mainstem Athabasca is still a major transportation route between Fort McMurray and Lake Athabasca and the Slave River system to the north of Fort Chipewyan. As a transportation route, the Athabasca system is unlikely to be affected by oil sands development, and no research was carried out on this aspect of the system. A second major use of the Athabasca system is for private boat travel, both for native people travelling in the region and for recreation, and hunting and fishing. A third use of the system is supply of water for domestic use and for dilution of sewage effluent from the communities in the region. The fourth major use is for industrial supply of water for operation of oil sands plants. In total, therefore, the Athabasca River system warrants serious attention with respect to the impingement on its resources by oil sands development.

### 3.3.1 Hydrology

In order to determine flow regimes and water quality parameters, networks were established to record information on flows and suspended sediments.[94 to 99] Network sampling locations are shown in Figure 7. A major emphasis in Water System research was to characterize the physical aspects of the mainstem Athabasca. Considerable data were available for hydrologic aspects of the Athabasca and Clearwater rivers, and an additional intensive regional hydrologic network was established on a number of tributaries. These data are contained in Water Survey of Canada compilations[94 to 97] with a synthesis and analysis providing an assessment of hydrometric data requirements for the future.[100] Included in these studies are data on suspended sediments[98,99], which indicate a large sediment load for the mainstem Athabasca during the ice-free period. The conclusion

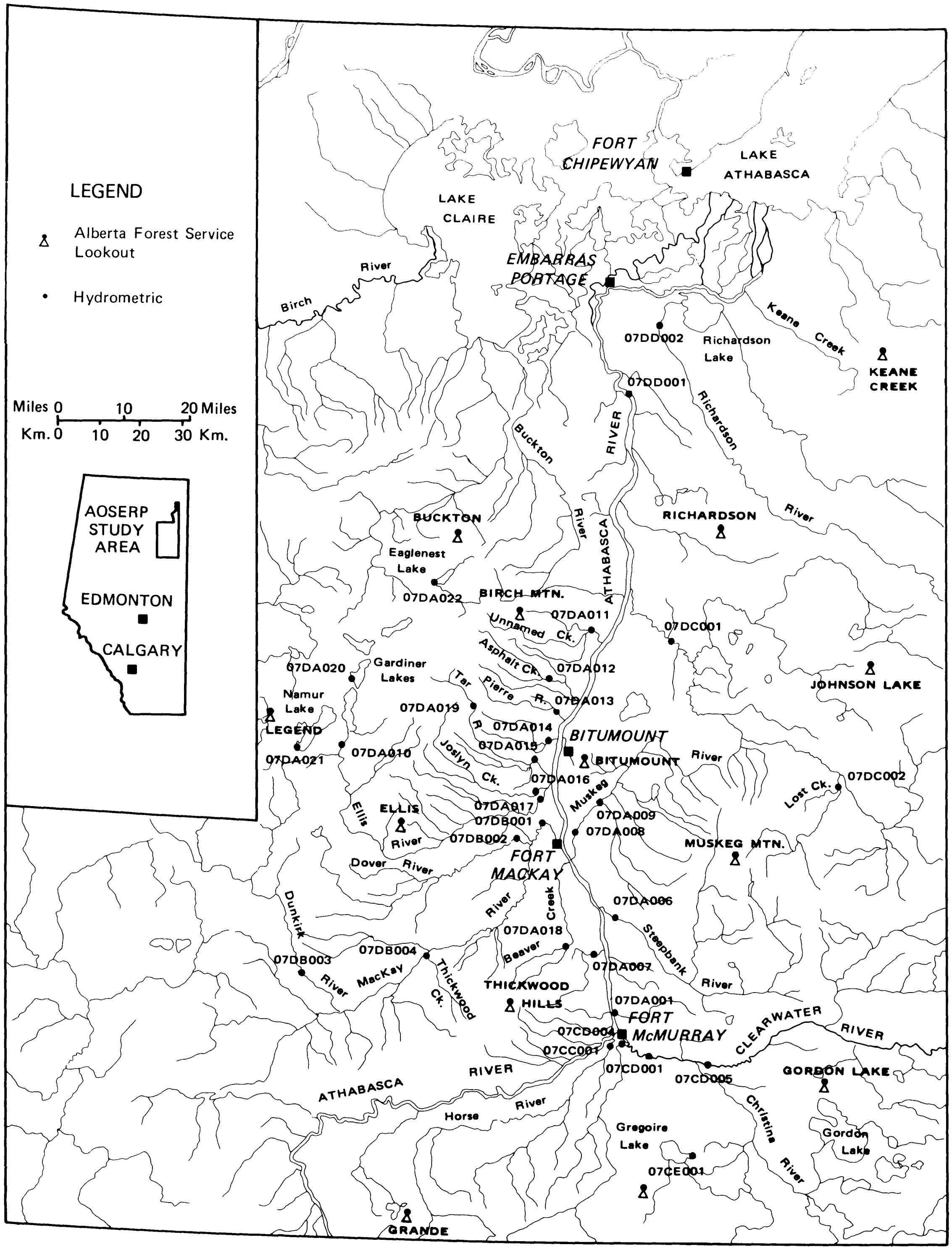



Figure 7. AOSERP water quality sampling and water gauging stations.

may be drawn that the mainstem Athabasca River is unlikely to be significantly impacted by siltation from oil sands development.

Work is in progress to determine the rates of mixing and deposition of silt in the Peace-Athabasca Delta of Athabasca River water. Data are not yet available to make quantitative estimates of effects on the Peace-Athabasca Delta of increased water withdrawals from the Athabasca River.

An investigation of the hydrogeology of the Muskeg River basin provided detailed information on the importance of muskeg drainage areas to stream flow generation.[101] Other than for a brief period in winter and during snowmelt, the drainage from adjacent muskeg is a major contributor to stream flow along with groundwater inflow. This work was carried out on Hartley Creek and essentially the same patterns were observed for Muskeg, Firebag, and Steepbank rivers, as well as Thickwood Creek. The study concluded that stream flow in all basins will be influenced by the drainage and/or disturbance of muskeg, and that, where disturbance of muskeg is extensive, there will be marked variation in water chemistry as a consequence.

A regional hydrogeological study was completed under the aegis of the Research Council of Alberta. While technically not part of AOSERP, the study was included under an AOSERP Committee, and provided baseline data for deep groundwater movements in geological formations associated with or in close proximity to the Athabasca River valley.[102]

A comprehensive review was made of the effects of sedimentation on aquatic biota[103], and simulation modelling of oil sands development provided rough estimates of total water use over the next 30 years.[104] These studies provided evidence that, unlike the mainstem Athabasca, siltation of streams tributary to the Athabasca will be a distinct possibility because of the high erosion potential for some areas within the region. Results of simulation modelling also suggested that water use (assuming a medium rate development scenario) may be of a magnitude to cause serious concern in relation to low winter flows in the Athabasca Rver by the year 2000.

### 3.3.2 Water Quality

Natural inputs of both organic and inorganic constituents occur in all aquatic systems. Baseline information on water quality parameters provides background information useful in prediction of man-induced environmental impacts from industrial developments and urban centres. AOSERP water quality investigations were oriented toward the assessment of existing information, identification of introduced substances resulting from oil sands development, and the analysis of likely disruptions of aquatic ecosystems.

The concentrations and distribution of natural organic constituents in the Athabasca River, both upstream and downstream of oil sands development, are of importance in determining possible loading from sources associated with development. A study was carried out to assemble chemical data upstream of Fort McMurray to establish the background levels against which comparisons could be made of the concentrations of the same constituents sampled from downstream points. Emphasis was placed on naturally occurring classes of organic compounds known to be constituents of wastewaters from oil sands processing. Water soluble constitutents, tannins and lignins, asphaltenes, and polar constituents were identified as the major organic components occurring naturally in Athabasca River water. Water contained an average of 9 mg/L of organic carbon, principally as dissolved organic carbon (DOC).[105] Water soluble organics averaged 6.9 mg/L; tannins and lignins 0.24 mg/L; and extractable carbon fractions--20% asphaltenes, 33% polar constituents, and 10% hydrocarbons. Sediment samples contained an average of 11 000 to 20 000 mg/kg of total organic carbon, 6% of which was extractable. Of this extractable portion, asphaltenes comprised 39%, polar compounds 17%, and hydrocarbons 16%. The study concluded that "organic constituents in this segment of Athabasca River are mainly water soluble, naturally occurring compounds, with minimal uptake by bacteria, and provide a steady natural input to the river system."

A comparative study was made of Athabasca River water and waste waters from Suncor and Syncrude operations to determine the contribution of these operations to organics in the Athabasca River.[106] Total organic carbon in the Athabasca River above the Suncor plant averaged 13 mg/L, not greatly different from that above Fort McMurray (9 mg/L). Under ice conditions in the Athabasca River, the chemical composition of hydrocarbons 10 km downstream of Suncor was very similar to that in the upgrading plant effluent, diluted 70 fold. It was concluded from this study and from the study of the Athabasca River above Fort McMurray that the main source of light hydrocarbons in the river is the Suncor upgrading plant; oxygenated compounds could be either from natural sources or the dike drainage filter system. Mine depressurization waters from the Syncrude lease also contribute organic constituents to the Athabasca River.

A study of lake acidification potential in the oil sands region revealed that the susceptibility of lakes to acidification was low, and that lakes in the region were well buffered. It was determined that surface waters would not become acidic, even if exposed to levels of acid rain as severe as those experienced in eastern North America and Europe.[107]

Heavy metals in surface waters may pose human health problems if concentrations reach unacceptable levels. Investigation of natural humic substances and metallic elements in surface waters in the oil sands region did not provide evidence of any connection with industrial operations, but did reveal that humics increased the solubility of metals, which sometimes reached significant concentrations. Concentrations of both humics and metallic elements were correlated with increased flows.[108] Dispersion pathways of heavy metals in the Athabasca River were determined from dredged sediments and sediment cores along the

Athabasca River between Fort McMurray and the confluence of Riviere des Rochers and Slave River. No unusual metal concentrations were detected, and total concentrations were low, when compared to data from other areas. Vanadium and nickel concentrations were correlated with each other and with organic carbon. Higher concentrations occurred lower in the system, with the highest being recorded from Lake Athabasca sediments.[(109)]

As indicated above, hydrometric and water quality networks were established as early activities of AOSERP. In addition, an intensive water quality study was initiated in the Muskeg River basin. The major objective of this study was to obtain enough water chemistry and hydrometric data to enable calculation of water chemistry budgets, and to provide a model on which water quality parameters could be based, both for the Muskeg River drainage basin and other drainage basins of the area.[(110)]

Organic compounds are important in assessment of water quality. A study was carried out to determine the impact of the Suncor plant on organic constituents in the Athabasca River. Differences in amounts of organic carbon between samples from bottom sediments upstream and downstream of the plant were recorded. Chemical composition of hydrocarbons in river water 10 km below the plant was the same as that in the upgrading plant effluent. The samples indicated that the origin of these groups of organic compounds is unclear, and may have been from natural sources, mine depressurization water, or dike drainage filters. (The latter is now collected and pumped back to the tailings pond.) No evidence was presented to indicate seepage of pond material through the dike into the Athabasca River. Results of the study outlined above should be treated with caution because of the extremely small number of samples and the high degree of variability in natural constituents in Athabasca River water.[(111)] In addition no statistical or error analyses were presented.

A first-order priority for the program was to investigate the possibility of toxic effects of water-borne effluents.

A study was carried out on aquatic environmental toxicity to establish a broad toxicological screening system[112] to determine the identification of appropriate organisms and their responses to toxic agents at various life stages. This study evaluated toxicity to fish of mine depressurization water and some of its major constituents. It was determined that a 20 to 30% dilution of mine depressurization water from the Syncrude lease resulted in a 10-day $LC_{50}$ for trout. Various organisms tested showed highly variable responses to mine depressurization water which changed in chemical characteristics and toxicity after storage. This study substantiated work carried out earlier.[113] A study of acute and chronic toxicity of vanadium to fish indicated that vanadium was only moderately toxic and should not be the cause of urgent concern.[114]

Another priority of the program was to investigate acidification of surface waters, resulting from airborne emissions of acidifying agents such as sulphur diodixe ($SO_2$) and nitrogen oxides ($NO_x$). Funds were provided by AOSERP to assist experimental lake acidification in the vicinity of Kenora, Ontario. Results of these studies have been reported elsewhere.[115]

It is a difficult task to establish with precision the water quality baseline states in the Athabasca Oil Sands region because of the high degree of variability in water chemistry mentioned earlier. In addition, water quality demands are different for domestic use as compared to industry, while industrial water quality requirements themselves are highly variable.[10] An intensive study was carried out of the water quality characteristics of the Muskeg River system which provides some measure of variability which might be expected in the larger tributary streams of the Athabasca system.[116] Such intensive studies are valuable in providing baseline information against which changes in water chemistry may be compared as development in the basin takes place. For the Muskeg River basin, such parameters as specific conductance and concentrations of major ions, such as

$Ca^{++}$, $Mg^{++}$, and $HCO_3^-$, as well as $Na^+$ and $Cl^-$, were relatively stable throughout the year. Factors influencing variability in the chemical constituents were increased surface and groundwater flows. Both this study of water quality and a study of hydrogeology of the Muskeg basin[141] provided evidence that water storage in and movement from muskeg areas have a major influence on seasonal patterns and concentrations of $Ca^{++}$ and $Mg^{++}$, as well as NA:Cl ratios. The distance water travelled through the Muskeg basin allowed assessment of basic water quality information in sub-basins to be deduced by monitoring focal points. Good statistical relationships were found between specific conductance and discharge and the concentrations of major ions, and from these it was found possible to calculate baseline annual chemical throughput for the system. Changes in dissolved oxygen concentrations were related to biological production, as well as turbulence, turbidity, and temperature during the ice-free period and to biochemical decomposition of organic material under ice-cover. Observed natural levels of As, Hg, Ni, Zn, Fe, and Mn were higher than for Alberta Surface Water Quality Objectives. For the Athabasca Oil Sands region as a whole, a regular sampling program was placed in operation in 1976.[117] This project was designed to provide regional baseline water quality data, with particular reference to variation in water quality parameters over time at the junction of important stream basins with the Athabasca River. These data were intended to be used in future research to construct water quality models and confirm their general accuracy by comparison of observed and predicted water quality parameters. Firm relationships were established between stage discharge and concentration of major dissolved ionic species for most of the streams sampled. The relationships for each stream were attributed to the physiography and geology of the drainage basin, which affected discharge and water chemistry, respectively, and ranged from highly variable hard waters in the MacKay and Hangingstone rivers to relatively stable soft waters in the Firebag and Richardson rivers. Turbidity varied from consistently clear (Firebag) to consistently turbid (Hangingstone). Most streams had brief periods of high turbidity during peak runoff in spring. Many smaller tributaries showed long durations of high concentrations of dissolved organic compounds, likely caused by input from muskegs which they drained or passed through. Throughout the region, maximum total dissolved organic carbon levels varied from 10 to 45 ppm. Occurrence of higher levels typically corresponded to inputs from adjacent areas during spring and autumn. Maximum total phosphorus ranged from 0.1 to 0.5 ppm.

### 3.3.3 Microbiological and Invertebrate Production

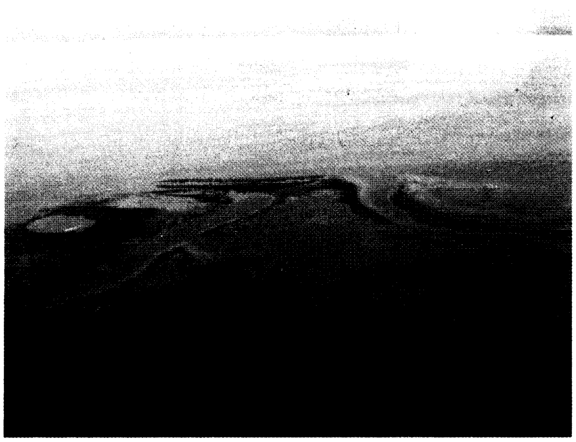
The ultimate routing of inputs of organic carbon and chemical nutrients to aquatic stream ecosystems is determined by the capacity of heterotrophic organisms to incorporate these constituents into living biomass. Fixation of organic carbon occurs as a result of two processes: carbon fixation by plant life within stream systems and fixation of organic carbon outside streams by green plants and subsequent transfer of plant material directly to the stream in the form of plant debris or leaching of plant material into surface waters.

A preliminary study was carried out to determine the chemical and microbial characteristics of the Athabasca River as background to development of a biological/chemical model which could be used to predict the impacts of oil sands development.[118] An essential component of such a model is quantification of the capacity of the river to assimilate or metabolize organic compounds introduced to the river as a consequence of oil sands development. This project produced a definitive literature review of assimilative capacity of river systems through microbial degradation of organic compounds and on the methods of determining nutrient uptake by microbial populations. Some preliminary data were generated on the rate of uptake of radio-labelled glutamic acid by microbial populations in order to assess the effects of organic compounds from natural and industrial sources on the rate of heterotrophic assimilation in the Athabasca River. Total planktonic heterotrophic potential was similar at various river sites and showed no increase or decrease below the current mining area. Detailed descriptions of methodologies were included in the report, which concluded that oil sands mining wastes entering the river at present have no significant stimulatory or toxic effect on the uptake of glutamic acid by planktonic bacterial populations of the Athabasca River.

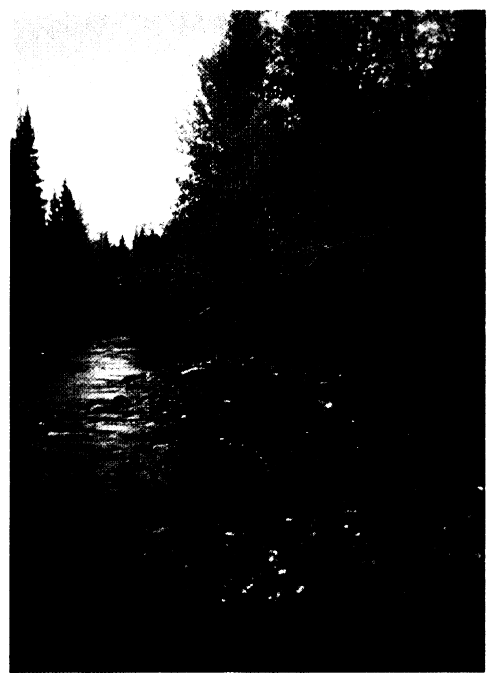
A study was carried out on the biochemical ecology of the Athabasca River to evaluate the possible relationship between microbial populations and the effects of industrial activities and Fort McMurray sewage effluent discharge.[116] No significant differences were found in microbial population numbers above Fort McMurray and below the Suncor oil sands plant. Twenty-fold fluctuations were observed in numbers of bacteria, with the lowest occurring in August and in the winter and the highest in May and the autumn. Microbial numbers were not associated with numbers of silt particles. It should be pointed out that the lack of significant differences in density of microbial populations in the Athabasca River above and below the Fort McMurray sewage outfall may be due to the very large dilution of sewage with river water or sampling error, both of which could have contributed to the variability of samples.

A study of comparative primary productivity was carried out on five streams tributary to the Athabasca River.[120] These were: Muskeg, Steepbank, Hangingstone, Ells, and MacKay rivers, all relatively extensive and potentially important to the total Athabasca system. Algae in flowing water may be important in the total energy flow by producing organic carbon for other components of the aquatic ecosystem, or by providing habitats for other organisms. This study of primary productivity was restricted to investigation of algae (blue-green, green, diatoms,

The Athabasca River flows through the oil sands region to the Athabasca Delta, a complex aquatic ecosystem rich in many natural resources. (H. Johnston, AOSERP)

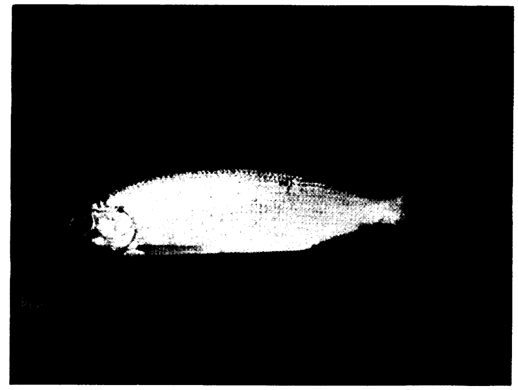


Athabasca Delta (H. Johnston)



A pristine stream, part of the huge Athabasca watershed. (K. Lumbis, CWS)

Fish fence on the Muskeg River.
(R. Wallace, Freshwater Institute)



Goldeye from the Athabasca River.
(B. Bond, Freshwater Institute)

Monitoring of water quality and aquatic fauna was carried out as part of the AOSERP aquatics research sub-program.

Water quality monitoring is continued year-round.
(H. Johnston, AOSERP)

and red) and did not include macrophytes, which appear to be of minor importance in these streams. Results indicate that seasonal fluctuations in algal numbers and productivity are to be expected. No nutrient or physical factor was identified as a single controlling mechanism in fluctuations of algal population size, but current velocity, which is related directly to stream discharge rate, appeared to be the most important factor. An estimate of the contribution of epilithic (attached) algae to the organic matter of the five streams varied more than 10-fold, with mean productivity between 0.63 and 2.18 $g \cdot m^{-2} \cdot y^{-1}$.

Aquatic fauna investigations were initiated on the mainstem Athabasca River[121] and intensive studies were begun on the Muskeg River drainage basin.[122,123] The major tributary of Muskeg River, Hartley Creek, was selected for intensive study because of the probable development in the basin by Shell Resources Canada (now Alsands Project Group). Studies in the Muskeg River basin were concerned with assessment of comparative autotrophic and heterotrophic production in this stream system. Some preliminary experiments were carried out to assess the effects of synthetic crude oil and ponded tailings on invertebrates in situ. In general, synthetic crude oil increased productivity of selected substrates, while tailings sludge sharply reduced the numbers of macroinvertebrates.[121] Mechanisms involved in the effects of these materials on invertebrates were not reported.

To complement the information obtained on primary productivity, a study was designed to utilize the data gathered during intensive studies on the Muskeg basin cited above in order to assess secondary, or heterotrophic productivity.[124] This study did not include the microbial utilization of organic carbon which is the basic first step in heterotrophic production in streams but, rather, concentrated on the invertebrate (insect) fauna, in terms of production, trophic interactions, habitats, and limiting factors. A major objective of this study was to define, from available literature, the problems inherent in quantifying heterotrophic production in streams and to design an appropriate research plan for an investigation of comparative invertebrate resources and production in selected streams tributary to the Athabasca River. The study identified physical and chemical factors which directly or indirectly affect now or could affect stream productivity in the region. Included in this study was a non-quantitative benthic survey of the Ells, MacKay, Hangingstone, and Steepbank rivers (using a trophic, rather than taxonomic approach) which indicated that, in general, the upper reaches of these streams are significantly more productive than lower reaches. Allochthonous organic materials interactive with algae and bacteria are the main sources of energy driving the production systems of these streams.[126] The data gathered in the preliminary study also indicate that upstream energy is exported downstream and that a shift occurs away from detritivores and herbivores in upper reaches toward omnivores and carnivores in downstream river reaches. The relationships between components of stream production and possible trophic linkages were presented in a conceptual schematic model together with identified requirements and investigative design for quantifying productivity estimates for streams tributary to the Athabasca River in the oil sands region.

Based on development of the system used to estimate production outlined above, a second study was carried out to provide preliminary quantification of the level of secondary production in the Muskeg River.[126] The study determined that secondary production in the Muskeg River was highest upstream by a factor of two times that of a central site and four times that of a downstream site. Production values were compared with those from other rivers but were considered relative assessments of production rather than true estimates because of lack of data from highly productive periods in spring and autumn. This study confirmed that production was based on detrital and algal feeding in upstream reaches, shifting to carnivores and omnivores in downstream reaches, as shown by the preliminary studies. Production values of 301.2, 144.1, and 78.8 $g \cdot m^{-2} \cdot y^{-1}$ were given for upper, middle, and lower reaches, respectively, of the Muskeg River. These values indicate that the Muskeg River is highly productive in relation to levels of production generally reported for other streams, and that upstream reaches are very important to heterotrophic production. From the study cited earlier, autotrophic (algal) production appears to be about 1% of heterotrophic production in the Muskeg River.

### 3.3.4 Fish

Studies of fish fauna and habitat in the Athabasca River system consitute a large portion of the AOSERP research effort. Intensive studies of several of the larger tributary streams (Muskeg, Steepbank, and MacKay rivers)[127,128,129] provide baseline fisheries data on the larger tributaries in the Athabasca system which have a potential for alteration by oil sands development. These rivers all have substantial fish populations in them or may be important spawning or rearing areas for the species moving out of the mainstem Athabasca during spawning migrations.[130] The fish populations of the Athabasca River downstream of Fort McMurray were surveyed in depth because the lower Athabasca River, between Fort McMurray and the Peace-Athabasca Delta, was considered to have a significant potential for impact resulting from oil sands development. Twenty-seven species of fish were identified from the Athabasca River, which appears to be a very important migratory route for a number of species moving upstream from the lower river and possibly the Peace-Athabasca Delta and Lake Athabasca. Because some species are migrating under ice, late winter conditions may be critical to their successful ascent to the Athabasca River. The entire lower Athabasca River constitutes an important feeding area for immature goldeye. Over 9000 fish were sampled, and the tag returns indicated that walleye, goldeye, lake whitefish, and longnose and white suckers found in the lower Athabasca River belong to populations which over-winter in Lake Athabasca and the Peace-Athabasca Delta.

An investigation was carried out on the lower Athabasca River at Richardson Lake to study the walleye population in that area.(131) It had been shown earlier(132) that walleye habitat in the shallow marshlands of the Peace-Athabasca Delta was susceptible to changes in water levels, and that information on this species would be useful in assessing water use in the oil sands development area. The initial study on walleye, plus a subsequent investigation(133), indicated that the shallow marshlands comprising the Richardson Lake complex were important areas of walleye habitat.

Considerable attention was paid to sampling and tagging of fish in the Athabasca River in an attempt to delineate migration timing and routes.(134) As well, experimental work was carried out on the development of radio tags for fish to provide more precise information on fish movements.(135) This latter study did not progress to the stage that it made a significant contribution to knowledge of life histories of the various species or their behaviour in the Athabasca River. Studies of fish fauna in the Muskeg River revealed that this stream is an important spawning (and possible rearing) area.(136)

From the surveys described above, it was known that substantial numbers of adult lake whitefish occurred in the mainstream Athabasca River in autumn, and that these fish were in spawning condition. A study was therefore carried out to determine the actual and potential spawning areas for this population.(137) Lake whitefish were found to spawn during October in the Athabasca River from Fort McMurray upstream to Cascade Rapids. Major concentrations of spawning whitefish were observed immediately below Mountain Rapids, 24 km upstream of Fort McMurray. Post-spawning tag recoveries indicate that these fish comprise one or more populations from the west end of Lake Athabasca. No lake whitefish were observed to spawn in Clearwater River. From the studies of the fish fauna in the mainstream Athabasca River and its tributaries, the system (over at least 300 km), can be said to be of great significance in production of fish, as well as supplying spawning and rearing habitat for a number of species resident in the Peace-Athabasca Delta and Lake Athabasca.

The physical characteristics of an aquatic ecosystem, together with the chemical characteristics of its water, to a large extent determine the amount of biological material which can be produced within it. Animals and plants occur within ecological systems in habitats to which they have become adapted for reproduction, growth, feeding (fish and other animals), uptake of nutrient (bacteria and plants), or other aspects of their continued existence. One of the critical aspects of the maintenance of fish populations is suitable habitat at all important stages of the life history of the species in question. In order to delineate the habitats of fish in the Athabasca system, a study was initiated to provide background information on stream habitat classification.(28) This study, referred to previously, was designed to identify the appropriate parameters which could be used to characterize aquatic habitats in the Athabasca Oil Sands region. Ten parameters were selected for each of lake and stream habitats, and the study reviewed the possible use of remote sensing data for interpretation and assessment of aquatic habitats as well as the levels of data processing and computerized mapping techniques. The study suggested that aquatic habitats be characterized and mapped using essentially the same system as that employed by the Resource Analysis Branch of the British Columbia Ministry of Environment. The study provides a convenient, simple, and relatively rapid means of classifying aquatic habitats which might be disturbed or altered as a consequence of oil sands development.

A second study of aquatic habitats was carried out to describe some of the sites where fish collections were made during the course of previous studies.[138] A survey was made of sites at the confluences of streams with the Athabasca and Clearwater rivers, as well as downstream of points of land and islands. In all, 25 sites were surveyed and habitat parameters (current velocity and direction, depth, Secchi disc visibility, substrate composition, and temperature) were recorded. These descriptions and measurements provide some data relating to the importance of stream mouths to various species of fish.

Because of the suspected or known importance of tributary watersheds to fish in the Athabasca River system, the major streams in the Firebag, Muskeg, Steepbank, MacKay, and Ells watersheds were characterized and all data considered important were included in a biophysical inventory.[139] Methodology was the same as that for the study outlined above. The physical characteristics of nine streams in the five watersheds were summarized and compared. Hydrometric and water quality data, as well as information on autotrophic and heterotrophic production, were included in the data summaries. The characteristics of streams were related to occurrence and distribution of fish, together with the factors which tend to promote or limit fish production. From 16 to 24 species of fish were found in the five watersheds surveyed. Forage fish were the most abundant species in every stream and the most widespread and important sport fish, in order of decreasing abundance, were Arctic grayling, northern pike, and walleye. A good correlation was found between the physical characteristics of streams and the distribution and abundance of fish. This study provided a partial catalogue of fish habitats and species abundance in the Athabasca Oil Sands region, and may be useful to managers of aquatic resources as a convenient means of assessing the potential for fish production and importance of the various reaches in satisfying the needs of recreational fishing. As well, a data base is available for judging the importance of river reaches in major tributaries as spawning and rearing areas and the potential for stream perturbation as a consequence of oil sands development.

It is to be expected that continued development of the Athabasca Oil Sands will result in environmental alterations of aquatic systems. From research discussed herein, there is little doubt that the Athabasca River system is of great importance to fish populations in Lake Athabasca and that the Athabasca River and tributaries are in themselves important fish producers. A variety of influences may be exerted on the Athabasca River, emanating from domestic sewage and industrial effluents, saline groundwater from mining operations, deposition of stack emissions, and water withdrawals for consumptive use. Regulation of industry prevents discharge of most waste waters directly to the Athabasca River, but it will not be possible to prevent some intrusion of foreign substances on a probably increasing scale. Assessment of environmental effects of water pollution generally is based on analytical methods to check aquatic systems for occurrence of various toxic substances at concentrations not greater than those prescribed by law.

An alternative to analytical assessment is to monitor aquatic systems with living organisms, chosen for their known sensitivity and physiological response to waterborne pollutants. In order to assess the applicability of aquatic biomonitoring to the Athabasca River system, a review of aquatic biomonitoring was carried out.(140) The major objectives of the review were to examine aquatic biomonitoring methodology with special attention to diversity indices; identify the kinds of environmental effects likely to result from oil sands development; and summarize the type of data likely to be obtained from the application of different biomonitoring methodologies. The report outlines the general principles and methods reported in the current literature, and emphasizes those most likely to be directly applicable to the Athabasca Oil Sands region. The basic assumption is made that changes in the aquatic environment will be reflected by detectable changes in living organisms in the ecosystem. The report concluded with the specific recommendations that an aquatic biomonitoring program be instituted in the Athabasca Oil Sands region as soon as possible. Although the review of aquatic biomonitoring is a preliminary assessment, it provides the basis for considering what may be necessary for continuing assessment of the impacts on aquatic ecosystems of further oil sands development.

## 3.4 HUMAN SYSTEM

Research in the Human System was directed toward the gathering of baseline information concerning social processes associated with resource development. Of particular interest to government agencies was the need to identify and analyze the impacts of oil sands development on Fort McMurray and adjacent communities. Early in the human environment research program, the decision was made to identify and quantify social indicators of the response of people in the region to oil sands development, and to measure both the identifiable positive and negative effects. A second major thrust was to gather relevant baseline information, both of a biophysical as well as of a social nature, and to attempt to integrate these data in a manner which would elucidate the significant social changes resulting from oil sands development.

Research needs identified by government agencies and industry in the oil sands region had provided initial direction for social research.[22] A set of research objectives was evolved which essentially paralleled those of the Air, Land, and Water systems, and are listed below:[4:66]

1. To review and assess the available information pertaining to the Human System of the AOSERP study area;

2. To undertake studies which may be used to establish the baseline states for social conditions of the

study area which could be altered by oil sands development;

3. To identify and explain various direct and indirect impacts of the development on people of the region, including the relationships between changes in socio-economic conditions and social and personal adjustment;

4. To critically assess the relationship between people and the changing urban and natural environments of the region, including use of various resources by the population and effects of changes in the environment upon people;

5. To derive a conceptual model which can be used to forecast the effects of oil sands development on the human systems and their capacity to absorb these effects without permanent or long lasting debilitation; and

6. To undertake studies which will identify alternative measures to rectify or prevent any negative effects of the development activities on people of the region.

The objectives stated above were aimed at generating information which could be used by oil sands corporations and governments alike to maximize the benefits of oil sands development and to minimize or ameliorate identifiable or likely disbenefits. An obvious consequence of oil sands development was foreseen as a wide-ranging series of changes to the physical and social environment of the region. Few usable social data were available for the region, at least in an organized form, with the exception of the Peace-Athabasca Delta and Fort Chipewyan, about 200 km north of Fort McMurray. The Peace-Athabasca Delta and Fort Chipewyan had been the subject of an intensive earlier study.[132] The initial AOSERP studies provided a description of what was taking place as a result of oil sands development, plus analyses of the impacts on the communities of the region. The Human System research effort consolidated the baseline information obtained by exploratory studies and directed the total research effort toward analyses which were relevant to public and private sector policy intervention, if such actions were required.

Five major components were included in the general strategy for Human System research: (1) exploratory studies; (2) conceptual framework; (3) field studies; (4) compendium of social statistics; and (5) integration of research results.

### 3.4.1 Exploratory Studies

As an initial approach, a research project was initiated to design and develop a baseline data system as a repository for both social and biophysical data. It was determined that a baseline data system could be developed but its usefulness, at least to social scientists, would be limited by unevenness of available social data and lack of common boundaries used by agencies which originally had collected the data.[141]

The Human System research program at the outset identified the need for direction in gathering the kinds of information which could be applied to analyses and forecasts of the impacts of oil sands development on the people of the region (impacts on "quality of life"). A study was commenced to assess the feasibility of a social indicators research model.[142] This study produced a review of the literature on social indicators, an analysis of relevant operational frameworks previously reported in the literature, and a preliminary assessment of data relevant to the oil sands region. The report concluded that social indicators could be useful "... in making policy decisions more explicit, informed, and provide for more rational choice among priorities within the prevailing value system." As well, the report suggested that "... social indicators appear to have more policy relevance and implications than other groupings of social statistics." Paradigms of goal areas were provided, with considerable emphasis on quality of life. One example from the existing literature included nine main indicators as follows: income, education, employment, health, housing, physical environment, recreation, public order and legal justice, and transportation. Each of the main indicators has sub-categories. The report suggested careful development of a framework for a social indicators research model relevant to identified social issues in the oil sands region, but this suggestion was not pursued by AOSERP on the assumption that data incomparability and difficulties in applicability of methodology did not warrant further support for constructing a social indicators model.

In order to provide a context for research on human response to rapidly changing conditions in the oil sands communities, a research project was initiated to identify the issues involved in the relationship between rapid resource development and family and individual adjustment to changing social conditions. The report attempted to gain some preliminary insight into what might be happening to people in the region, why it was happening, whether it was harmful or beneficial, and whether any policy decisions would be necessary to mitigate harmful effects or enhance beneficial effects of oil sands development. The study of family and personal adjustment provides a well-documented review of human well-being in resource communities in general and the oil sands region in particular. The study concluded that many research reports have described social responses to conditions in resource communities, but virtually none exists which has explained, by means of systematic scientific research, why these responses occur. The study reviewed both published and unpublished material considered pertinent to social impacts associated with new resource communities. A tentative theoretical model and research design was proposed for study of social and personal adjustment in the oil sands region[143], as a result of this study.

An explanatory study of social deviance in the oil sands region was carried out as a means of assessing the impacts of development on this facet of human behaviour. The research design included the review and assessment of the literature on social deviance as a preliminary to identification and integration of variables specific to understanding the significance of deviance in the oil sands region.(144) The research was also intended to identify pertinent qualitative and statistical data on deviance in the oil sands region and to suggest future research. The project relied on data from three sources: published literature, existing regional information on deviance, and data from interviews with field staff of appropriate government agencies. For the purpose of the study, social deviance was defined as alcohol and drug abuse, crime, and delinquency. Demographic variables considered important in analysis of deviance as defined included: age, sex, marital status, income, ethnicity, and education. With few exceptions, however, it was found that relevant information was not available which would allow examination of the variables selected. This study determined that the rate of alcohol consumption was significantly above the Alberta average, and that excessive use of alcohol appeared to be an accepted social norm. Alcohol abuse was related to accidents, to crime, and to delinquency. The report stated that a tendency existed for juveniles to use alcohol as a primary recreational and socializing activity. The report on deviance concluded that most of the money available to counteract deviance was spent on treatment, rather than on preventive programs such as public education, research, and social planning.

Referees of the report on the study of social deviance in the oil sands region pointed out a number of deficiencies in the methodology and use in interpretation of raw data and published literature on this subject, as well as the narrow definition of deviance itself. Although this study may be deficient in statistical treatment, it points out significant concerns of field staff of agencies which deal with deviance. The study also concentrates on possible mitigation measures by suggesting that a more comprehensive view be taken of the social structure and norms of the community, as well as suggesting stronger emphasis on identifying causes of deviance, rather than treating problems after they have developed.

A number of social problems have come to be identified with rapidly expanding resource communities, but often little hard data are available which can be used to measure their magnitude. In addition, there appears to be no widely accepted research design for integrated studies of social problems in resource communities. A study was initiated by AOSERP with the objectives of identifying significant social problems which might be peculiar to the Athabasca Oil Sands Region and designing a system of social preventive and rehabilitation mesures for identified social problems. This research dealt with types of problems which need to be identified; the social, economic, environmental, and cultural variables which might contribute to social problems; and preventive and rehabilitation measures which might be instituted. Relevant issues, methodology, and data collection techniques were reviewed. An annotated bibliography of literature dealing with social problems in resource towns is included.(145) The report provides extensive reference material for future use in research on similar problems. While the report covered many of the theoretical aspects of social problems which may occur in resource towns, it did not develop a complete design for the 10-year research program which was recommended as its major conclusion. Major components of the total human environment were identified as: (1) the biophysical environment; and (2) society and culture and definitions of each and their interactions, were suggested in relation to analyses over time (10 years) of qualitative changes which might be used better to interpret statistical social data. A parallel study of social problems specifically oriented to the communities of Fort McMurray, Anzac, and Fort MacKay provided descriptive insights into social problems in the Athabasca Oil Sands region as perceived by interviewed residents who provided the basis for the conclusions reached by the study.(146) Referees criticized the study on a number of grounds, including the very small sample (43) of persons interviewed, as well as lack of scientific rigour in data interpretation. Nevertheless, the research results provide descriptive insight useful to the design and implementation of more carefully analyzed social research projects.

As a means of recording the historical development of the Athabasca Oil Sands region over the past 100 years, a research project was carried out to analyze and document migration to and from the region, economic factors which have influenced development, society and government, and oral history.(147) The research report (in two volumes) is extensively and carefully documented, and includes descriptive commentaries on geographic setting, prehistory, historic native peoples, and recent history. The authors suggested that, during the last 200 years, the Athabasca Oil Sands region has been characterized by periods of high economic activity, interspersed with long periods of relatively slow growth. Dominant forces included the fur trade, missionaries, and transportation. The area also has been influenced by strong social and economic forces originating largely outside the region.

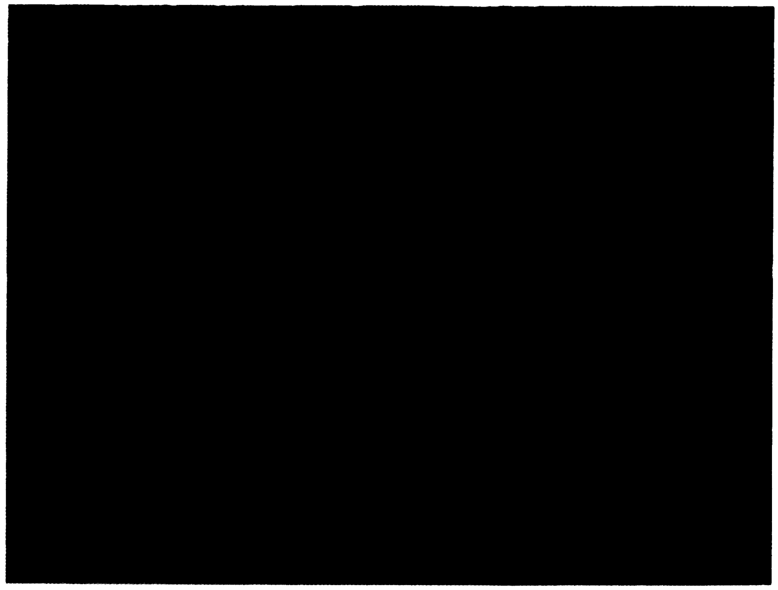
The authors concluded that the interaction of indigenous people with those moving into the region, in association with outside economic interests, deserves further research, especially in relation to education and health, which were once the assumed responsibilities of church organizations, but which now are controlled by Federal, Provincial, and municipal institutions.

The most recent outside influence on the economy of the region (and the people residing in it) has been development of the oil sands, beginning approximately in 1960. An overview of local economic conditions in the oil sands region since 1961 provided a general assessment of the economic impacts resulting from oil sands development.(150) The research was intended to provide some definition of relationships and interfaces between economic growth and changes in social and personal conditions. In

Settlement of Fort MacKay. (R. Seidner, AOSERP)

Settlement of Bitumount. (H. Johnston, AOSERP)

Small northern settlements, such as Fort MacKay and Bitumount shown here, must adjust to the social, economic, and environmental changes brought about by the development of the rich oil sands deposits.



Trapper's cabin near the Clearwater River.
(M. Fox, University of Calgary)

Skins stretched out on frames to dry. (AOSERP file)

Many people of the oil sands region depend upon natural resources such as fur and fisheries, for their livelihoods. AOSERP studies will help to assess and mitigate the effects of oil sands development on these resources.

addition, the research was intended to suggest techniques for forecasting future impacts of oil sands development on the economy of the region. The report concluded that extensive economic opportunities were created by oil sands development, but these were confined almost exclusively to Fort McMurray, with no evidence for substantial economic benefits for Anzac, Fort MacKay, or Fort Chipewyan.

The importance of local resources to native residents of the oil sands region was not documented in the study cited above. A separate study cited earlier on both consumptive and non-consumptive use of fish and wildlife resources also provided little data on the present use and importance of fish and wildlife to native people.(18) The importance of these resources to the people in the Peace-Athabasca Delta has been reported elsewhere.(164, 165)

### 3.4.2 Conceptual Framework

A research project was initiated to satisfy the strategy requirement of the Human System for a conceptual framework for investigations in the oil sands region. This project was intended to identify information needs most pertinent to the requirement of government agencies and oil sands corporations in relation to formulation of social policy.(151) The study was designed to establish criteria for collection of relevant data pertaining to economic, demographic, and social characteristics of the region as a means of identifying changes resulting from oil sands development. These data in turn formed the basis for assessing possible benefits or disadvantages and the need or otherwise of policy actions by government or industry. The conceptual framework study carried out a survey of government agencies and oil sands corporations, which resulted in the identification of 11 indicator areas of importance to policy planning in the region. The indicators identified are: population, employment and labour force, housing, education, health, counselling and welfare services, culture and recreation, protection services, criminal justice, municipal administration and physical services, and regional infrastructure. Each indicator has a number of relevant variables which can be used in statistical analyses.

### 3.4.3 Field Studies

Field studies were carried out primarily in relation to anticipated data requirements resulting from the conceptual framework research, although some were implemented separately and do not correspond directly to the indicator areas identified. Field studies were divided into five sectors: historical, economic, social impacts, labour, and people and their environment.

Historical research consisted of two elements--oral history and history of socio-economic development.[147] The oral history research perhaps has its chief value in providing a sense of the relationship between man and the natural environment, as well as a basis for understanding the perceptions of long-term residents of the relationship of citizens and their government in a region undergoing very extensive and very rapid socio-economic change. The study dealing with the history of socio-economic developments of the region from the late 1880's to the mid-1960's provides some measure of the magnitude of developments over an 80-year period which has resulted in some social stress for older residents and established institutions of government, as well as the former economic and commercial base of Fort McMurray. While these projects do not provide a means of assessing future impacts of oil sands development, they have value in establishing a reasonable view of baseline social and economic conditions prior to construction of the first oil sands plant. As historical records, they stand on their own merits.

Labour-related field studies focussed on the employment patterns of native people[152], the integration of native workers into the labour force, and impacts of construction camps. In the study of native employment patterns, seven general areas were cited as major barriers to employment. These were: economic, education and training, political, social and cultural, health, recruitment techniques, and on-the-job barriers. In addition, analysis of interviews with natives suggested that, within the native community, status, tribe, age, and kin might also exert important influences on native employment patterns. The assumption was proven invalid that native people prefer outdoor, part-time seasonal jobs; the majority of those interviewed wanted full-time employment. Increased training in the region has not reduced native unemployment, possibly because of the very low education level of natives generally (the majority have less than 10 years of formal schooling and virtually no formal training beyond school). The results of this study, taken in conjunction with the literature review for the subject, confirmed the results of earlier studies, which indicate a very serious problem with respect to native employment.

The report on native employment patterns in the Athabasca Oil Sands region provided some insight into the difficulties of reducing native unemployment, and suggested that unemployment rates among natives have not been significantly affected by native employment training programs. The report also suggested that changes in the attitudes of natives to increase employability would have to be accompanied by changes in attitudes of employers. The report revealed that no comprehensive examination had been carried out with respect to employment opportunities for native people, or their life styles, community involvement, or family commitment. What statistical data are available appear to be incomplete or unreliable.

A number of recommendations were advanced for future research. Of prime importance was the need to identify job opportunities and assess available supply of natives with the necessary skills to fill these jobs. A need was identified for research into the aspirations of native persons and evaluation of existing training programs. Research was suggested into the effects on natives of relocation to jobs in different areas, economic implications of increased employment of natives, effects of shiftwork and union or company regulations, and the effects on predominantly native communities of native employment programs by industry. The findings of the report and its recommendations for additional research have implications for policies relating to the problems of native employment in the region. Although some referees questioned the lack of a statistical approach, this study should prove useful to the evaluation of native employment patterns in future.

An allied study was carried out to determine how natives were integrated into the labour force in the Athabasca Oil Sands region.[(153)] The employment history of the majority of natives interviewed was unstable. Over 80% of the sample had averaged less than one year of employment during the three years preceding the interview; 17% had held no job during the same period; and 65% had held between two and eight jobs. Sixteen recommendations were made for increasing employment of natives; most of these related to perceptions of those interviewed. As with the study on native employment patterns, referees suggested that the methodology of sampling may have reduced the reliability of conclusions which might be drawn from the study of native integration into the labour force. Nevertheless, the study discussed above and the study of native employment patterns warrant serious examination, since they both reveal serious problems of native unemployment, without tangible evidence of significant progress to alleviate the situation.

Several scenarios have been reviewed for progressive development of the Athabasca Oil Sands. A study of oil sands plant construction shows that each new plant requires a construction force of several thousand transient workers. Construction of the Suncor plant required 2300 workers, while the Syncrude plant required a force of 7000 housed in camps. The Suncor construction camp was in operation during the years 1964 to 1967, while the Syncrude camps operated from May 1975 to May 1978. The Alsands plant will house about 8000 non-permanent workers probably for five years. The study focussed on the impacts of construction camps on nearby communities and on the occupants of the camps themselves.[154] It was determined from available literature that crude camp conditions and lack of social amenities which formerly prevailed in construction camps no longer are the case. Thus, the recreational diversions formerly sought by camp residents, which often caused problems in nearby communities, were reduced in the case of the Syncrude camp by provision of recreational amenities and a tavern. Modern camps bring to an area a mixture of skilled and unskilled labour, improved conditions for leisure time, and added business opportunities and subsequent employment for local people. Overloading can occur on local health, social, transportation, and other services, particularly on housing. Business activities peak and wane as labour forces increase and decrease. It can be assumed that the size of local communities bears a strong relationship to the impacts of construction camps. The main conclusions of the study were the need for high quality camp facilities including food and recreational opportunities, good pay with opportunities for overtime, good security, and regular opportunities for breaks from camp life.

Assuming that an economy of scale will apply to the construction of future oil sands plants, it seems reasonable to expect that for each plant about 7000 workers will be required at the peak construction level, and that these largely will be housed in camps. Thus, for each new plant, there will be economic and social impacts on existing communities. These impacts may decrease in intensity as the total population increases, but, from the information presented in the study discussed above, will not be negligible. The conclusions and recommendations of the study should form a valuable basis for minimizing any negative impacts of construction camps, and maximizing the positive impacts.

A series of studies was initiated to provide information on people and their environment. These included an exploratory study of environmental perceptions[155], and a study of recreation, culture, and leisure service delivery.[156] The study of environmental perceptions theorized that the relationships between man and environment and between perception and behavior are dynamic and transactional. No clear relationships were demonstrated for the role of demographic, personal, and situational factors in relation to environmental perceptions. No relationship was established between environmental perceptions and oil sands development. It is possible that the methodology employed in the study of environmental perceptions may have contributed to difficulties in linking socio-cultural variables to perceptions by people of the environment in the oil sands region. It was not made clear in the report how human perceptions of the environment in the region might be used by planners and resource managers in relation to the impacts of oil sands development on people.

For the study of recreation, culture, and leisure service delivery, the years of 1972, 1976, and 1979 were used to provide inventories. The 1972 inventory showed an emphasis on recreational, as opposed to cultural, facilities. The 1976 inventory showed only a slight increase in recreational facilities and a dearth of opportunities in performing and creative arts, crafts, and hobbies, as well as a serious lack of informal, unstructured drop-in facilities. Facilities for tennis and curling could not meet the demand. The number of developed playgrounds and parks was inadequate in 1976. The 1979 inventory showed both an expansion of previously existing facilities and an increase in the range of recreational activities. The report concludes that facilities and open space development responded in a manner unrelated to real demand. At least three factors were identified as important to the development of adequate recreational and cultural amenities for Fort McMurray: (1) the town has a relatively compact lower commercial district with satellite suburbs without direct linkage to each other; (2) it has a long winter season; and

(3) recreational preferences in Fort McMurray differed significantly from those in Edmonton, which indicates that further investigation is required before standards are finalized for Fort McMurray.

Human System research is designed to develop an understanding of the relationships between people and their natural and man-made environments. One aspect involves the consequences of oil sands development on human health. A study was developed to identify conditions relevant to human health, the medical parameters which should be measured, and to review existing medical health sources in Alberta to obtain a preliminary assessment of pertinent medical indicators of possible changes in human health of people residing in the oil sands region.[157] The study was designed to identify possible relationships between selected health indicators and environmental conditions associated with oil sands development. To date, results of the study are not yet available.

The foregoing discussion of a variety of field studies indicates an obvious and significant change in the demographic and economic character of the region during the past 20 years. Through a survey of the adult population in Fort McMurray, an assessment was provided of the major impacts on the social fabric of Fort McMurray from reactions of the people to a still changing and rapidly growing urban environment.[149] The population of Fort McMurray is more than 10 times larger today than it was before the first oil sands plant was constructed, having grown from 2600 in 1960 to more than 27 000 in 1980. Personal interviews with 430 residents formed the basis for the study of human adjustment in Fort McMurray, based on the assumption that significant alterations have occurred in the former social environment, and that these can be analyzed by quantification of data obtained by the use of selected social indicators. The indicators used were as follows: demographic composition and differential population stability; perceivied quality of housing and services; labour force activity; incomes and standard of living; social participation and (family) social support; and individual subjective reactions of survey respondents to their life in Fort McMurray.

Survey results provide the first comprehensive statistically based assessment of social adjustment in Fort McMurray. The survey clearly shows that Fort McMurray is a relatively young community with a high proportion of young children, with the proportion of married adults at 77% being close to the Canadian average of 75%. About one-half the adult population comprises those with less than two years' residence. The proportion of those remaining in Fort McMurray after living through construction of an oil sands plant has grown from 12 to 22%, which may indicate a growing demographic stability in the community. Further research is required to provide reliable quantitative analyses of several aspects of population turnover which is still relatively high.

Before the development of Suncor, single family dwellings comprised 90% of housing in Fort McMurray. By 1979, this had shifted to apartments (28%), multiple dwellings (23%), and mobile homes (20%). Employer subsidies for housing were received by 46% of survey respondents. Although the preponderance of housing in Fort McMurray is relatively new (less than 10 years old), respodents were generally critical of their surroundings with respect to landscaping, play space for children, privacy, and noise. Differences in perceived housing quality apparently were related to perception of the total environment. It was determined that respondents perceived the level of services to be similar to those found in other urban settings, with the use of hospital, emergency, and public health services showing a relatively high frequency. Recreational activities not dependent on community facilities seemed to be preferred, perhaps reflecting a relatively strong orientation of Fort McMurray residents to outdoor recreation. About 40% of respondents expressed dissatisfaction with opportunities to find good entertainment. As with housing, individual respondents varied widely in their perceptions of the quality of services available to them.

Annual incomes in Fort McMurray were found to be considerably higher than the average for Canada, Alberta, and Edmonton, totalling about $24,500 per household, and relatively high material standards of living reflect the household income levels. Men in Fort McMurray make more money than women; those under 44 years of age make more than those over 44; oil company employees receive higher incomes and more fringe benefits than public sector employees. Fort McMurray workers differ little from other Canadian workers in their attitudes toward their jobs.

Fort McMurray residents are not socially isolated or withdrawn, and their social integration and participation shows little evidence of negative impact of rapid urban growth of their city. Social integration appears to be positively correlated with length of residence. Family life seems to be little different than that found elsewhere in Canada. About 84% of respondents expressed satisfaction with their family life, but almost 70% expressed concern about community programs and activities for teenagers. No evidence was found to suggest that the psychological orientation of Fort McMurray residents has been negatively affected by their association with the socio-economic patterns of oil sands development. In general, Fort McMurray residents are very satisfied with and optimistic about their future. Problems identified by respodents to the survey questionnaire seemed to be about the same as those found elsewhere in Alberta and Canada.

One of the difficulties encountered in any kind of research project is the availability and reliability of data. Often the kinds of data available plus the methodology used to gather them have prejudiced the opportunity for social scientists to quantify research studies. This problem occurred frequently in the Athabasca Oil Sands region, with data being gathered by different agencies over differing time periods and often without the same spatial boundaries. A research project was developed to derive the fundamental basis for and compile a compendium of social statistics which could comprise the ongoing data repository for those corporations and agencies involved in policy decisions requiring a high degree of statistical certainty, such as the provision of services and facilities. The prime objective of this project was to provide the necessary quantitative component of information required to line the conceptual framework for identification of policy-relevant parameters of socio-economic impacts of oil sands development with the study of social adjustment, as a prelude to integrating the total AOSERP Human System research effort.[158]

The compendium referred to above used as criteria the indicator areas and variables identified by the conceptual framework research to assemble data to illustrate demographic and socio-economic trends in Fort McMurray and the Athabasca Oil Sands region. These data were analyzed in relation to their policy relevance and to identify appropriate strategies for monitoring changes associated with future oil sands development. The study also assessed available data as to what they might reveal about the nature of socio-economic impacts resulting from oil sands development. The findings are integrated with existing social theory on the dynamics of resource communities. The model for analysis used the following approach to the stages of resource community development: (1) baseline; (2) exploration; (3) construction; (4) operation; and (5) maturity and/or decline.

The study recommended:

1. Development by the Alberta Government of a permanent mechanism to monitor communities impacted or created by resource development;

2. Inclusion in collection of demographic and socio-economic data a method to collect information in population mobility and turnover in resource communities; and

3. Development of social services and facilities at earlier stages of resource community development.

New development at Fort McMurray. (AOSERP file)

Construction of new hospital for Fort McMurray — completed in 1979. (F. Edwards, AOSERP)

Fort McMurray experienced a population growth of from 2600 in 1960 to 27 000 in 1980.

The compendium of social statistics contains a large amount of comprehensive and systematically presented statistical information on demographic and socio-economic conditions in the Athabasca Oil Sands region between 1961 and 1979. It makes available, in a usable form, considerable statistical information for social planning which may be required as oil sands development proceeds. These data may also prove useful in the construction of computer simulation models which might provide some direction for integration of research with Air, Land, and Water systems.

# 4. DISCUSSION

Review of AOSERP research results is intended to provide a general summary, indicating the initial direction for AOSERP, and an overview of research projects in each of the four systems. The assessment of likely or observed impacts, which may be determined from AOSERP research reports, may be divided into biophysical effects (ecosystems impacts), effects on people, and effects of people on the environment. Examination of the data bases for each of the four systems has resulted in identification of gaps in research knowledge which would prejudice the opportunity to construct quantitative models which might be used in predictions of long-term impacts of oil sands development.

Descriptions were provided in Section 3 of specific investigations in the Air, Land, Water, and Human systems. These systems were used by AOSERP to compartmentalize research activities largely to define the scope of the program more precisely and for fiscal and administrative control. Examination of the results of research projects indicate little integration between systems, or even between research projects within systems. The use of the word system should not be viewed, therefore, as being suggestive of atmospheric systems or terrestrial or aquatic ecosystems. Neither was research in social science constructed to provide an integrated investigation of the social structure of the human population in the oil sands region. Rather, the Air, Land, Water, and Human systems concentrated their efforts on activities which accumulated baseline information in areas of investigation deemed essential as background for applied research of problems identified during development of the program.

It should be mentioned also that the discussion of research results concerning environmental impacts which follows is restricted by the short time frame (less than five years) over which the investigations were carried out. Consequently, where no evidence was obtained for a measureable impact, this should not be construed as implying that no problem could exist. Ample evidence is available from elsewhere[88,89] that ecological impacts may be extremely subtle, and that they may not be easily detectable in their early stages. This discussion therefore is related to the present state of the environment in the oil sands region. Where it is judged that data gaps exist in baseline information, these are identified and specific recommendations are offered in the concluding section for research which might be useful in providing assessment of future effects of oil sands development.

## 4.1 AIR SYSTEM

Air quality and meteorological networks have gathered large amounts of data. The air quality determinations described in Section 3 indicated that present concentrations of air pollutants are within the allowable limits set by regulations. Direct effects of air pollution on local communities appear to be minimal and not a cause for immediate concern. Meteorological data describe the conditions of air movement, temperature, and precipitation levels at the interface between ground level and tree top height above ground. These data are generally descriptive of meteorological conditions in the region, but may be limited in their application to dispersion of air pollutants because they comprise average values, rather than measurements of magnitude and frequence of fluctuations of wind speed and direction. Application of meteorological data to impacts of air pollution at ground level also may be of questionable value to ecological investigations, because they may not be representative of ground level micrometeorological conditions.

Very little information has been obtained on the possible effects of terrain on air movements near the ground. Consequently, it may be difficult to assess future dispersion and impacts of emissions from new oil sands plants. Likewise, little information is as yet available on acid precipitation in or downwind of the oil sands region, and adequate measurements of both wet and dry deposition of sulphur dioxide do not exist. Finally, measurements of sulphur in snow, which could be used for at least a preliminary assessment of winter deposition of sulphur dioxide, have been carried out only on a casual basis.

In view of the lack of information in the several areas of atmospheric sciences discussed above, significant deficiencies are judged to exist in AOSERP Air System research. These deficiencies will be corrected only by further specific investigations.

## 4.2 LAND SYSTEM

The AOSERP Land System research effort consisted of investigations described previously on fauna, soils, vegetation, and the impact of atmospheric pollutants on vegetation. These investigations did not demonstrate impacts, either in a quantitative or qualitative manner. Some of the changes associated with development were noted earlier, but the impacts of these changes on the terrestrial ecosystem have not been documented. Rather, the investigations carried out to date generally have described the undisturbed terrestrial ecosystem or its components as they exist at present (baseline states) and have not dealt with the response of ecosystem components to environmental stress which might result from oil sands development.

The largest and most obvious impact of development is the direct removal of large areas of the natural environment for construction of transportation routes or facilities, together with the construction or expansion of the urban area of Fort McMurray, and industrial areas associated with development. These areas must be considered as permanently lost to the maintenance of vegetative cover and associated animal life. No estimate has been made of the total withdrawal of wildlands in the Athabasca Oil Sands, but this could easily be done from aerial photographs.

Commercial exploitation of oil sands deposits is constrained by economy of scale and engineering necessities. Thus, any operation will require a mining site of minimum size, a plant site, and an area for waste disposal and retention. The impact of a commercial mining lease would affect a total of approximately 100 $km^2$ and, as with the impacts of transportation and urban development, wildland withdrawal must be considered as permanent, at least for the life of the oil sands plant.

It was not within the terms of reference of this report to consider the problem of reclamation, the responsibility for which was removed from the AOSERP mandate early in 1979 and assigned to the Reclamation Research Technical Advisory Committee formed to co-ordinate reclamation research in the province. Nevertheless, it should be stated that both the Government of Alberta and oil sands corporations have devoted a considerable effort to reclamation research in the oil sands region, and that the knowledge base required to restore permanent vegetation to disturbed areas is increasing rapidly. Notwithstanding this research effort, however, a major deficiency still exists with respect to reclamation of the very large tailings ponds associated with the hot water extraction process. It might be argued that tailings ponds have a low impact on the environment, but they will be permanently non-productive until a means is found to restore them to some acceptable level of biological productivity. It should be mentioned also that oil-covered, open tailings ponds are a threat to migratory birds, particularly during spring and autumn when migration rates of waterfowl are maximized. As far as the author is aware, no published research is available to suggest that tailings ponds associated with oil sands plants can be reclaimed with existing technology.

The development of an in situ operation results in substantially different impacts than those of a conventional surface mine, although the eventual upgrading and refining operations are essentially similar. The proposed Esso Resources Canada operation at Cold Lake is used as a general model to assess the probable impact of in situ extraction in the Athabasca Oil Sands region.[2] There is no development of a surface mine with an in situ oil sands plant. Rather, the surface impact results from construction of roads and wells used to inject air, steam, or water, depending on the technology and the recovery wells from which heavy oil or bitumen is withdrawn. The impact of such construction (which may involve several thousand wells and many thousands of metres of roads) is more or less continuous over the life of the operation. No serious research has been produced which might be used to assess the impact of in situ operations in the Athabasca Oil Sands region. The environmental impact assessment produced by Esso Resources is not in sufficient detail to warrant direct application in the Fort McMurray area, but does provide a base on which such research could be planned.

A continuing concern of both Government and industry must be the potential long-term impact of air pollution on the terrestrial ecosystems of the region. Suncor and Syncrude together are licensed to emit a total of about 640 tonnes of $SO_2$ per day. This amount may be less on occasion, or may for short periods be more, if there is a plant upset which may alter the plant operating regime. The proposed new Alsands plant is designed to produce less than 150 tonnes per day of $SO_2$, which probably also will apply to other oil sands plants which may be constructed in the future.(160) Assuming that each new plant could emit 150 tonnes per day of $SO_2$ (which may be a high estimate), a further 10 plants would more than double the $SO_2$ emissions for the region. Results of research discussed earlier do not provide evidence for damage to soils or vegetation, but there have been shifts in species composition of lichens in areas of plume impingement and increased sulphur content in vegetation with decreased distance from the emission source. At present, it cannot be stated precisely what the long-term prospects may be for effects of air pollution in the region, particularly since investigations have been carried out over a relatively short time span.

Recently, concern has been expressed over the consequences of increased emissions from the Alberta oil sands region.[161,162] A significant deficiency exists with respect to meteorological data (turbulence measurements) which can be applied to precise quantification of dispersion of atmospheric pollutants downwind of emission sources. As well, deposition of $SO_2$ has not been measured with sufficient accuracy or frequency to provide reliable information, and almost no data are available on acid precipitation which might result from increased emissions in the oil sands region. Each of the deficiencies noted above prejudice the opportunity for accurate assessment of ecological impacts of oil sands development.

## 4.3 WATER SYSTEM

As with terrestrial impacts of oil sands development, aquatic impacts may result from a number of causes. Three main categories of impacts on water have been discussed: direct impacts resulting from land disturbance; direct impacts from aqueous pollutants; and indirect impacts from airborne pollutants.

Construction of transportation routes, development of urban areas, and land clearing for oil sands plants all could contribute to direct impacts on surface waters. Almost no reference is made to these possible impacts in AOSERP reports. Impacts of transportation routes are often immediate, but no data appear to have been generated by AOSERP to indicate whether aquatic ecosystems have been affected by road construction or other activities associated with transportation. Of major concern is the possible effect of siltation on streams. In this regard, only the Athabasca River has been reported on in detail with respect to sediment loads and, because of its nature, it is judged to be relatively immune to degradation from siltation. The survey which was carried out on the effects of sediment on aquatic biota indicates that the erosion potential is high in a number of areas in the Athabasca Oil Sands region.[103] This research paper points out the need for caution during new construction in regard to the erodable areas identified, and possible deleterious effects on important tributaries of the Athabasca River.

Because of the relatively low level of air pollution in the region, and the conclusion presented earlier that no evidence to date has been found for damage to vegetation or soils, the assumption is made that no direct or indirect damage from air pollution has occurred to aquatic ecosystems. This assumption is based on the evidence gathered on water quality (chemical) parameters, (both in the intensive studies of the Muskeg River basin and the regional water chemistry investigations) that, to a large degree, water chemistry in the region reflects the characteristics of the drainage basins and their soils and surficial geology.

The Athabasca River investigations have adduced information on sediments, heavy metals, organics, bacteria, invertebrates, and fish. The Alberta Government policy of total containment of liquid tailings appears to provide the necessary safeguards to prevent pollution of the river with toxic substances associated with the hot water extraction process, although organics from small waste water outfalls and mine depressurization water were detected at low concentrations in downstream areas. The levels of microbial populations above and below Fort McMurray were not found to differ substantially, and evidence was not found for significant impacts of development on the Athabasca River. Probably the size of the Athabasca has prevented detection of significant impacts, because of the very large dilution factor for any effluents entering the river.

It has been shown that tributaries of the Athabasca River system constitute important components of the total system. Because of the relatively small size of many of these streams, they are much more vulnerable than the mainstem Athabasca to both physical perturbations and chemical pollution. Other than the accidental introduction of toxic agents, these tributaries are not likely to be chemically polluted as a result of oil sands development. In some cases, however, they are susceptible to siltation because of the highly erodable nature of their banks, and great care will have to be exercised so that road or industrial construction activities do not cause damage to these streams as a result of siltation.

Lakes in the Athabasca Oil Sands region have received little attention. However, the general study of lake acidification potential referred to earlier indicates that the acidification potential is low, and that additional air pollution loads several times greater than present would be required to cause an acidification problem. Work in progress to analyze rain samples in a number of localities in the region should provide better data on the acidification potential of surface standing waters (W. D. Hume, Atmospheric Environment Service, personal communication).

## 4.4 HUMAN SYSTEM

In attempting to document baseline states of the human environment, AOSERP Human System research followed essentially similar objectives as those used by the Air, Land, and Water systems. However, it should be pointed out that data accumulated for much of the Water and Land systems dealt with largely unimpacted areas of the natural environment and even downwind (for air pollution) or downstream (for water pollution) significant impacts on land or water could not be demonstrated. Human System research dealt largely with demographic and social patterns which have been established as a direct result of oil sands development. Further, it was clearly established(151,158) that data which had been gathered prior to or during development of Suncor and Syncrude in many cases could not be used by Human System researchers because of problems associated with boundaries used and methodology of data gathering.

As a result of differing applicability of data, as compared to the natural environment, Human System research in large part documents the end result of changes which already have taken place in the social and demographic character of the human environment in the oil sands region. Because of population growth in the past 20 years, data were accumulated by AOSERP on people, housing, transportation, service facilities, industry, and infrastructures which simply did not exist in 1960. Because the oil sands communities (and particularly Fort McMurray) may still be adjusting to an extremely rapid period of growth, predictions as to the future characteristics of the human environment may be made more difficult. However, the social research carried out since 1975 provides documentation of socio-economic change which has occurred and which now can be used to judge not only the kinds and rates of change, but also the response of people to those kinds of changes.

Demographic and economic impacts have been shown to have radically altered the human environment in the oil sands region. The major change demographically has been a 10-fold increase in population since 1960 and a significant lowering of the age structure. Associated with these changes has been a documented shift in household income levels which are now well above the Canadian and Alberta average. The region is now dominated by Fort McMurray (accorded city status on 1 September 1980) which has a population of about 27 000 people.

However, as mentioned previously in Section 3.4, AOSERP research indicates that there is little difference in patterns of employment and integration of natives into the work force in the oil sands region than that documented for other areas of Canada and Alberta. It would appear, therefore, that whatever steps may have been taken for raising the employment rate of natives and fully integrating them into the labour force have been in large part unsuccessful. The future of the communities mentioned above is by no means clear, and will depend on a number of factors not researched and not easily predictable at the present time. Among these is the impact on the smaller communities of withdrawal of better educated and more employable residents, which may tend to further depress the viability of these centres. In addition, little has been accomplished by AOSERP to evaluate the present status, or future possibility of the education of natives in relation to increasing the benefits they might derive from oil sands development. To date, the community of Fort Chipewyan, which has about 75% of the native population of the region, appears to have been impacted only to a slight degree, but little direct attention was paid by AOSERP to investigation of the impact of oil sands development on Fort Chipewyan.

The assessment of social impacts of oil sands development and cultural responses to those impacts has centred on Fort McMurray. Early concern has been expressed about the quality of life in Fort McMurray, and the Human System research program was intended to provide some understanding of the dynamics of community organization in this rapidly changing urban environment. Research designs for social impact assessment produced a number of indicators which might be used as aids to quantify not only the economic and demographic changes but also to assess the cultural responses to a changing environment through analysis of the perceptions of the residents of Fort McMurray. These research efforts were aimed generally at providing information for future public policy decisions.

In developing the Human System research of AOSERP, it appears that the total effort was heavily oriented toward impact research, rather than development of theory or methodology. Because of the very short-term nature of the individual projects, little in-depth evaluation was possible for the long-term application of the results. The Human System research program was derived primarily from needs identified by government and industry, and the terms of reference for individual research contracts were specified by AOSERP. Thus, the reliance on research direction provided by AOSERP, government agencies, and industry, plus the short-term nature of the investigations, may have prejudiced integration of research projects and development of a balance between accumulation of information and a holistic approach to social research in the oil sands region.

The conceptual framework study discussed earlier attempted to define areas of social research to be followed in response to needs identified by government agencies and industry in relation to social services and human resources. The study was designed to produce information compatible with and useful to management jurisdictions. It is the judgement of the author that the conceptual framework study would have been of considerably greater value in providing a basis for research direction had it been carried out at the beginning of AOSERP, rather than at the end.

Currently, the use of computer simulation models is becoming more frequent, both in ecological and social research.[161] This technique is useful to the degree that assumptions upon which models are constructed can be strengthened by the insertion of real data, to aid in the specification of variables, the relation between variables, and the rationale for choosing indicator areas. The compendium of social statistics discussed in Section 3.4 provided an organized data assembly which should prove useful in any application of computer simulation modelling to social research in the oil sands region.

In addition to social impact research, AOSERP produced information on the use of resources by the people of the region. The use of fish and wildlife resources and parks and recreation areas, as well as the use of the Athabasca River as a receiver of domestic sewage, initially may impose greater stress on these resources than the direct impacts by industry as a result of air and water pollution discussed earlier.

Estimates have been made of the consumptive use by people of the fish and wildlife of the Athabasca Oil Sands region. These estimates allow quantification of present use, the extent of which is largely a consequence of increased human population size and greatly improved access, both of which in turn are a direct consequence of oil sands development. Production estimates for fish are not available, so that only crude approximations could be made from the literature as to the likely maximum desirable levels of exploitation of fish stocks (primarily by sport fishermen) in the Athabasca River system. Grayling, pike, and walleye are the principal available sport fish species, and these are likely to decline in the face of heavily increased harvest by anglers. No change is likely to occur in Lake Athabasca fish populations, other than the possibility of changes in spawning areas for those populations which migrate into the Athabasca River and spawn, and whose progeny are reared in Lake Athabasca rather than in the Athabasca River.

It is unlikely that bird populations will be affected by increased hunting pressure; evidence is strong that bird populations fluctuate in response to factors other than hunting mortality. Providing that bird habitats are not impaired by air pollution, game birds (resident and migratory) likely will show no detectable response to the effects of oil sands development.

Studies of moose and caribou have provided evidence that these ungulates constitute stable or slowly declining populations. At present, natural and hunting mortality generally balance recruitment. Increased access to the Muskeg River basin will likely impose additional hunting mortality on the moose of that area which could result in rapid depletion of the population. A secondary impact on wolves would likely reduce their numbers also in the Muskeg River basin, because moose constitute the single most important diet item for wolves. Caribou are less accessible to hunters than are moose, but increased population pressure would likely result also in increased hunting pressure on caribou.

In general, the likely consequence of oil sands development would be early reduction of fish and wildlife populations most accessible to hunters and fishermen followed by similar reductions of less accessible populations as the human population continues to increase in the Athabasca River valley. Possible reduction in fish and wildlife also should be assessed in relation to its impact on Treaty Indian and Métis use of these resources.

Recreation areas and non-urban parks are in limited supply in the Athabasca Oil Sands region. Increasing population pressure will result in very heavy use of Gregoire Lake Provincial Park and areas such as Poplar Creek below Highway 62. Areas such as Namur and Gardner lakes have high potential for recreation, but access is restricted to air travel. The lakes in the Richardson Tower area also have high potential for recreational use, but the only access road would require considerable upgrading to make this area accessible to residents of the region. If Fort McMurray and the New Town near the proposed Alsands plant grow as expected, recreation areas and park facilities will be inadequate to supply the demand.

As discussed earlier, evidence has not been produced to show that the Athabasca River below Fort McMurray has been significantly impacted by industrial effluents or sewage. Nevertheless, projections of population at a medium rate of development to the year 2000 indicate a population of about 180 000 for the region and a water withdrawal rate of about 25% of the winter mean daily flow in the Athabasca River. With a high rate of development, the population of the region is projected to be about 260 000 with a water withdrawal rate of about 43% of the mean daily winter flow in the Athabasca River.[104] These projections are not to be taken as what will happen. However, the computer simulations from which they were derived are consistent with what is already known about population growth in the Athabasca Oil Sands region. In view of the projections described above and what is known of the migratory movements of fish under ice in the Athabasca River, the potential reduction in water quality from sewage effluents cannot be ignored. To the present, AOSERP has generated virtually no winter data on conditions in the Athabasca River. Such data are essential to an understanding of future impacts on the Athabasca River.

As a result of projections of population growth and the expected impact of this population on resource use in the region, a clear need is indicated for integration of social research with that in the natural sciences. Direct impacts on resources by air and water pollution from oil sands development are relatively easy to assess. The measurement of these impacts, however, will have little precise meaning unless it is linked with assessment of the impact by people on those same resources.

## 5. RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendations for future environmental research in the Athabasca Oil Sands region are made with regard to the minimum level of investigations considered necessary to provide high quality information on which environmental management decisions can be made. All the recommendations therefore are directed toward potential use by government and industry. Notwithstanding the requirements for research which can be applied directly to user needs, it should be recognized also that research is an investment in the maintenance of acceptable environmental quality. Consequently, as long as massive developments continue in the Athabasca Oil Sands region, with as yet unknown long-term environmental impacts, research into the effects of development should be considered as an essential component of the development process.

The question of financing environmental research is foremost in the minds of both government and industry. In the case of the Athabasca Oil Sands, it is difficult to arrive at a precise estimate as to total environmental research funding, but it appears that a figure of $30 million since 1960 would be a reasonable approximation. Over the same period, it would seem that about $3 billion has been invested in oil sands development. The environmental research investment therefore appears to be about 1% of the investment total.

Almost all the funds invested in the environmental research by industry have been directed toward the solution of specific problems , or, in the case of AOSERP, to gathering massive amounts of baseline data. Experience elsewhere, particularly in central and eastern North America and Europe, sharply outlines the need for a different approach. In the industrial areas of central Canada and central and eastern United States, very serious environmental effects have resulted from air pollution. A similar situation now prevails over large areas in Scandanavia.[(88)] The research which has documented severe damage in these two areas has almost been done "postmortem", that is, after severe environmental degradation has occurred. For the Athabasca Oil Sands region, no evidence as yet has been found for damage to either terrestrial or aquatic ecosystems other than those areas withdrawn for construction or municipal development. From experimental data or existing scientific literature, it is not possible to make accurate predictions as to the likely response of ecosystems to long-term low grade air or water pollution.

Specific recommendations outlined below are made with the assumption that the kinds of investigations suggested for the future should result in the construction of predictive models for air, land, water, and human systems. Government and industry together should commit a long-term environmental research program, which should be developed jointly and made known widely to researchers in universities, private consulting firms, and government research institutions. If development of a research policy is pursued as suggested, the widest possible comment should be sought from experienced scientists active in the environmental research field before a research program is commenced.

No standards exist, either in government or industry, for what might be considered as an adequate expenditure on environmental research. Criteria for future research should involve clear identification of an actual or potential problem to which the research is to be addressed. Proposed research should be based on adequate theoretical grounds, and should be of practical importance.

Specific recommendations for future environmental research in the Athabasca Oil Sands region are outlined below:

## 5.1 GENERAL RECOMMENDATIONS

1. Investigations in future should be directed toward processes involved in ecosystem and social system response to specific environmental perturbations, rather than to the accumulation of data from additional sources.

2. A review should be carried out of all information accumulated by AOSERP, and a data catalogue should be published at the earliest possible date, listing the kind of information available, the form in which it is stored, and the programs available for its retrieval.
3. A complete list of all AOSERP reports should be published without delay, whether the AOSERP reports have themselves been published or not.
4. Because of the lack of integration of research within or between air, land, water, and human systems, it is recommended that future research be planned on an integrated inter-systems basis.
5. In order to achieve the objective of integrating research as suggested in (4) above, it is recommended that computer simulation modelling be used as an aid in planning long-term research in the oil sands region.

## 5.2 AIR SYSTEM RESEARCH

1. It is recommended that the air quality model described in Section 3.1 be further refined and developed, and that all available AOSERP air quality and meteorological information be examined as to its suitability for inclusion in the model.
2. It is recommended that high priority be given to research on transport of atmospheric pollutants downwind from emission sources, both in Alberta and in Saskatchewan.
3. Because of the implications for ecological monitoring of the impacts of air pollution, it is recommended that high priority be given to accurate and frequent measurement of the distribution and amounts of

atmospheric pollutants deposited in the oil sands region.

4. It is recommended that the potential amounts and kinds of emissions from in situ operations be assessed in relation to their potential impacts on forest ecosystems.
5. It is recommended that a program be established to monitor sulphur in snow, and that samples be taken on the same plots as those used for terrestrial ecosystem biomonitoring.

## 5.3 LAND SYSTEM RESEARCH

1. It is recommended that the effects of air pollution on terrestrial ecosystems be assessed by the establishment of a biomonitoring program, integrated with the deposition measurement program listed in Section 5.2 (3) above.
2. It is recommended that any biomonitoring program include both industry and government as sponsors with primary responsibility for direct ecosystem response measurements to be assigned to industry, and responsibility for research and development of biomontoring methodology assigned to government.
3. It is recommended that permanent sample plots be established with replicate "ecological analogs" as suggested by Legge et al.[161], with planned sampling of biomonitors over a 50-year period.
4. It is recommended that simultaneous measurements be made of sulphur deposition and soil pH in permanent sample plots, over a 50-year period.
5. It is recommended that organisms chosen as biomonitors be selected to provide information on the deposition of long-term, low concentrations of

atmospheric pollutants which appear typical in the region at the present time.

6. It is recommended that measurements be made of annual basal area increment in jack pine to provide information on primary productivity in the forest ecosystem, as carried out by Legge et al.[162]
7. It is recommended that measurements be made of nutrient retention and carbon efflux of soils in the permanent sample plots in order to provide data on the response of soil and soil organisms to deposition of atmospheric pollutants.
8. It is recommended that field and laboratory experiments be carried out to determine the possible synergistic effects of sulphur dioxide and nitrogen oxides on vegetation and soils.
9. Because of the potential for effects on a very large surface area for each in situ operation, it is recommended that possible benefits and disbenefits for terrestrial mammals and birds be assessed in relation to all potential in situ plants.
10. It is recommended that a preliminary total land use plan be developed for the areas of the oil sands region which will be affected by development over the next 50 years.

## 5.4 WATER SYSTEM RESEARCH

1. Because of the possibility of significant increases of water withdrawals from the Athabasca River, it is recommended that investigation be commenced immediately of conditions in the Athabasca River during the period of ice cover.
2. It is recommended that biomonitoring commence immediately on the streams tributary to the Athabasca

River, and that periphytic algae and benthic macroinvertebrates be considered as the most likely candidate groups of biomonitors.

3. It is recommended that investigations commence immediately to identify and accurately quantify all present water uses, and to project water use in the region for the next 50 years, in 10-year increments.
4. Because of lack of current information, it is recommended that particular attention be paid to the potential effects of in situ operations on surface and groundwater supplies in the oil sands region.
5. It is recommended that monitoring of the Athabasca River system include construction of a physical/chemical biological model to quantify river processes and assimilative capacity, including uptake of man-made, as well as natural organic constituents entering the system.

## 5.5 HUMAN SYSTEM RESEARCH

1. It is recommended that government and industry, in cooperation with native organizations, identify methods which might be used to provide better involvement of natives in the labour force of the oil sands region.
2. It is recommended that research be carried out on the present suitability of education programs for natives, in respect of their potential for employment in permanent occupations in the oil sands region.
3. It is recommended that the AOSERP compendium of social statistics be used by government and industry as the data base for assessment of future policy decisions which might affect the residents of the communities in the oil sands region.

4. It is recommended that deficiencies in service delivery previously identified be researched in relation to integration of planning and future projections by Federal, Provincial, and municipal jurisdictions and industry, and particularly in relation to population growth projections for the region.
5. It is recommended that the first phase of the study on human health be brought to conclusion, and expanded if necessary, to provide an accurate assessment of human health in the region as a whole.
6. It is recommended that an integrated overview of Human System research be prepared, which can identify existing knowledge gaps and which may be used to direct future research, particularly in the area of public policy.

## 6. CONCLUSION

In preceding sections, results of AOSERP studies have been described, deficiencies noted, and recommendations made for future research on the effects of oil sands development. Some concluding statements appear to be warranted, dealing not with specific aspects of the program, but rather with the conduct of environmental research generally.

The lack of interdisciplinary connections between and within AOSERP Air, Land, Water, and Human systems became obvious during review of the individual research projects. Examination of the results of the SNSF Project in Norway indicates progress toward integrated investigations, as does the examination of acidification of the Canadian aquatic environment (H. H. Harvey, Department of Zoology, University of Toronto, personal communication). The lack of integration of scientific investigations may constitute a severe impediment to basic understanding of inter-related processses involved in the effects of air pollution on aquatic and terrestrial ecosystems. Of particular importance is the need to understand the dynamics of the complex physical, chemical, and biological components of terrestrial ecosystems which receive most of the atmospheric constituents (both natural and man-made) which are deposited on the surface of the earth. No method of integrating research from several disciplines will solve all problems. However, funding sources can and should establish the policy that integrated investigations will be accorded a higher priority than non-integrated investigations.

A second major deficiency of AOSERP was its lack of an adequate organizational framework in which to identify and assign priorities for research projects. The funding for AOSERP was in two government jurisdictions--Alberta Department of Environment and Fisheries and Environment Canada. Further complicating the administration of the program was the initial assignment of responsibility for project identification to eight committees, each of which was concerned with several research disciplines.

It was inevitable, therefore, that a multiplicity of research priorities should be created and reorganization of the program at the end of the second year did little to change the basic program direction, or to integrate its many components.

The deficiencies involved with lack of interdisciplinary connections and lack of clear research direction for AOSERP may have prejudiced the capacity for the program to detect effects of emissions and effluents on terrestrial and aquatic ecosystems, respectively. In addition, little information was adduced from social research to indicate what direct effects on people may have occurred during the past 20 years of development. Rather, detailed catalogues have been prepared, both in natural and human environments, of what exists at present. Neither impacts nor predictions for the future are possible from the results of AOSERP investigations. As suggested above, this is a common pattern for environmental investigations.

Research scientists and resource managers alike are reluctant to predict the future impacts of oil sands development, and the five-year, multi-million dollar effect of AOSERP also has been unable to do so. As Lewis et al.[164] have pointed out, four types of predictive methodology may be employed:

1. Qualitative techniques--in the absence of adequate quantitative data over time;
2. Retrospective analyses of data and trend extrapolation;
3. Development of process models; and
4. Empirical methods, coupled with predictive models.

Qualitative techniques do not lend themselves to prediction and, in the case of retrospective analysis, most scientific data gathered in the oil sands region are not of sufficiently long-term nature to be useful for extrapolation. The only viable alternatives for prediction of long-term impacts of oil sands development appear therefore at present to reside in development of process models and predictive scenarios through the early use of computer simulations.

During the past decade, the use of computer simulation modelling for gaining a better understanding of ecological systems has increased rapidly. Application of this aspect of applied systems analysis has been used to aid in environmental impact assessment.[161] Simulation modelling is intended to provide a vehicle for organization of information; to identify connections for data transfers between systems; to evaluate data gaps; and to explore routes for technology transfer from research organizations to regulatory agencies.

Construction of simulation models for the Athabasca Oil Sands region may be used to provide projections of population growth and jobs; patterns of social and economic development; water use and water quality; air pollution; and the development of scenarios for differing rates of development in the region. In general, the predictive capabilities of a simulation model provide a means for specialists and managers to assess the consequences of management decisions, and to insure that research objectives related to management goals and constraints are stated explicitly and completely.

The choice of a multi-system approach to environmental research has a major drawback in that it tends to compartmentalize thinking in relation to impacts, and to isolate researchers and research managers from disciplines other than their own. Construction of a simulation model tends to break down barriers between systems by the initial requirements of problem definition. Simulation models may be useful to achieve agreement between disciplines as to appropriate simulation time periods, the spatial extent and scale of resolution of the model, and the level of detail to be included. As a consequence of this action, data needs can be identified early in the process as requirements for inter-system connections and communication are established between systems. As a means of providing a relatively rapid and complete problem analysis, the simulation model appears to be highly useful. To achieve a high level of integration between systems requires that the model be run with real data and real time in the presence of researchers and resource managers from all systems. Initially, the chief impediment to credibility of a simulation model is the use of simulations which may not use real data, and which may not initially produce realistic predictions. Wherever feasible, real data should be incorporated into model components, particularly for managers who deal daily in real situations.

It is not intended to suggest that computer simulation modelling will provide solutions to all research deficiencies. Used appropriately, however, it is an inexpensive but powerful tool for planning long-term, integrated research programs.

A final question concerns the usefulness of AOSERP as a basis for effective environmental protection in the Athabasca Oil Sands region. The five-year objectives for the Program are listed below, as published in 1977.

1. To determine the nature and magnitude of changes in the environmental systems which can be expected to result from present and proposed oil sands development;

2. To identify the nature of interactions between and among the various components of the environment and those of proposed development and reclamation activities;

3. To determine, predict, and experimentally verify cumulative effects and resiliency of environmental systems that may be affected by oil sands development activities; and

4. To present a Program report during year five (1980) on the baseline conditions, processes, and resiliency of environmental systems as well as a measure of capability concerning individual and cumulative effects of oil sands development.

None of the objectives listed above has been entirely satisfied. Apparently because of low levels of air and water pollution, changes in ecosystems either have not occurred or are still below detectable levels. Notwithstanding deficiencies in meeting objectives (which obviously were very ambitious), AOSERP has produced an extensive data base which has resulted in a reasonable understanding of existing environmental conditions, both in the natural and in the human environment of the region. With a moderate expenditure of funds in the future by industry and government in developing integrated research programs, it should be possible to build an adequate capability for prediction of the long-term effects of oil sands development. On the present evidence, the environmental state of the Athabasca Oil Sands region appears to be reasonably secure, with respect to terrestrial and aquatic ecosystems. For the majority of people residing in the region, expectations are positive, with the exception of natives, whose status in general has not improved as a result of oil sands development. Future environmental quality in the region will be contingent in large part on the adequacy of monitoring programs, both for natural ecosystems and for human environments.

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# 8. APPENDICES

## 8.1 CANADA-ALBERTA AGREEMENT FOR ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM, 1975

THIS AGREEMENT made on the 26 day of February, 1975.

BETWEEN:

THE GOVERNMENT OF CANADA represented herein by the Minister of the Environment (hereinafter called "Canada")

OF THE FIRST PART

AND:

THE GOVERNMENT OF ALBERTA represented herein by the Minister of the Environment (hereinafter called "Alberta")

OF THE SECOND PART

WHEREAS Canada and Alberta have agreed to identify, undertake or encourage and assist research into environmental aspects of the renewable resources involved in the development of oil sands in the area in Alberta described in Schedule "C" hereto, and wish by this agreement to provide a general framework for the co-ordinated planning, funding and implementation of such research; and

WHEREAS initial development is now occurring with expansion imminent and decisions on several industrial proposals now are pending; and

WHEREAS the large scale industrial development of the area will have immense economic, social and environmental effects; and

WHEREAS Canada and Alberta recognize the necessity of improving the scientific understanding of the effects of the oil sands development on the human and natural environment of the oil sands area; and

WHEREAS the results of an intensive study of the area will be useful in predicting the effects of any proposed development, as a basis for considering future proposals; and

WHEREAS the results of the study program will be utilized by Alberta in the approval process for future developments and in the environmental design of any project which might be implemented; and

WHEREAS Canada and Alberta are agreed on the objectives, general strategy and procedures which would govern the identification and selection of such research and the methods of encouragement and assistance; and

WHEREAS His Excellency, The Governor General-in-Council by Order-in-Council P.C. 1975 - 15/360 dated February 25, 1975 has authorized the Minister of the Environment for Canada to execute this agreement on behalf of Canada; and

WHEREAS His Honour, The Lieutenant Governor-in-Council by Order-in-Council P.C. 176/75 dated January 28, 1975 has authorized the Minister of the Environment for Alberta to execute this agreement on behalf of Alberta;

NOW THEREFORE THIS AGREEMENT WITNESSETH that in consideration of the premises, covenants and agreements herein contained, the parties covenant and agree with each other as follows:

## I. DEFINITIONS

In this agreement

(a) *"the Advisory Committee on Program Co-ordination"* means the Committee described in IV (4);

(b) *"Alberta Oil Sands Technology and Research Authority (AOSTRA)"* means the organization established by the Alberta Government to fund technology studies associated with petroleum extraction;

(c) *"area"* means that part of the Province of Alberta described in Schedule "C" to this Agreement;

(d) *"environmental research"* means a fundamental investigation of a potential or actual man-induced change in environmental systems, which could result in identifiable benefits or adverse effects to society;

(e) *"Federal Minister"* means the Minister of the Environment of Canada;

(f) *"fiscal year"* means the period commencing on April 1st of any year and terminating on March 31st of the immediately following year;

(g) *"industry"* means an individual company or the aggregate or any number thereof of industrial companies who seek to develop the oil sands;

(h) *"Ministers"* means the Federal Minister and the Provincial Minister;

(i) *"non-renewable resources"* means minerals, mineral fuels, and similar resources;

(j) *"oil sands"* means sands and other rock materials which contain crude bitumen and includes all other mineral substances in association therewith;

(k) *"oil sands deposit"* means a natural reservoir containing or appearing to contain an accumulation of oil sands;

(l) *"Oil Sands Environmental Study Group"* means the organization which represents the industry in matters pertaining to the Program;

(m) *"Program"* means the research activities resulting from this agreement;

(n) *"Provincial Minister"* means the Minister of the Environment of Alberta;

(o) *"renewable resources"* means biological resources and resources such as terrain, tion, laboratory space, logistics, vehicles and accommodation,

(d) shall be responsible for scheduling project work to ensure the results thereof are available to the parties hereto as soon as practicable,

(e) shall, subject to the direction and approval of the Steering Committee, be responsible for the preparation of news releases and reports for technical and public information,

(f) may, on behalf of a technical research committee, recommend to the Steering Committee that the respective parties hereto, as the case may be, enter into contracts or other arrangements required to meet the objectives of the Program,

(g) shall co-ordinate the activities of the technical research committees.

(4) In addition to the Program Director, the Advisory Committee on Program Co-ordination shall consist of the Chairmen of the technical research committees, the Chairman of Oil Sands Environmental Study Group and one person appointed by the Provincial Minister to represent all the universities in Alberta. The Advisory Committee on Program Co-ordination shall:

(a) provide advice to the Program Director respecting the Program as it or he may deem fit,

(b) recommend any necessary adjustments to budgetary proposals,

(c) meet at the request of the Steering Committee or the Program Director.

(5) Subject to the approval of the Steering Committee, the Program shall be planned and developed by technical research committees oriented to particular problems or disciplines. A technical research committee shall be composed of technical experts appointed by the Steering Committee. The Chairman of each technical research committee shall be as shown on the chart attached as Schedule "D" hereto or, if additional technical research committees are established, as the Steering Committee may determine. Subject also to the approval of the Steering Committee and consistent with the objectives and goals of the Program, each technical research committee will define its own objectives and goals.

(6) The parties hereto shall have regard to any existing programs of Alberta or Canada concerning oil sands environmental research for which the Departments of the Environment of Alberta and Canada are individually or jointly responsible, and agree to co-ordinate these programs as closely as possible with the implementation of the Program.

(7) Subject to paragraph V (8), Alberta shall be the contact with industry and Alberta universities in matters pertaining to this agreement and which have been recommended by the Steering Committee.

(8) Any provision of this agreement may be amended by mutual agreement.

## V. FINANCING

(1) The total cost of the Program is estimated to approximate $40,000,000 expended over a period of 10 years. For the purpose of this agreement, but subject to paragraphs (2) and (3) of this Article, the term of this agreement shall be five years from April 1, 1975, unless this agreement is extended or terminated pursuant to Article VI hereof.

(2) Subject to the terms and conditions of this agreement and to funds being appropriated by Parliament, the sum for which Canada shall be liable hereunder shall approximate $2,000,000 annually for five years from the date hereof and thereafter shall approximate $2,000,000 annually for a further period not exceeding five years where the term of the program is extended pursuant to Article VI hereof.

(3) Subject to the terms and conditions of this agreement and to funds being appropriated by the Legislative Assembly of Alberta, the sum for which Alberta shall be liable hereunder shall approximate $2,000,000 or more annually for five years from the date hereof and thereafter shall approximate $2,000,000 or more annually for a further period not exceeding five years where the term of the program is extended pursuant to Article VI hereof.

(4) Prior to the beginning of each fiscal year the projects to be undertaken for that fiscal year shall be recommended by the Steering Committee for the approval of the Ministers. Alberta will fund and manage the projects for which it is responsible. Canada will fund and manage the projects for which it is responsible. The Steering Committee may recommend a joint project between the parties hereto, the cost of which shall be borne equally by the parties or as otherwise mutually agreed and shall be under the direction and control of one of the parties, in which case the party having that direction and control shall be responsible for all claims and demands

water, and climate that support biological systems;

(p) *"research project"* or *"project"* means a project that is entirely or primarily devoted to conducting research on renewable resources in the area in relation to any matter pertaining to this agreement;

(q) *"Steering Committee"* means the committee established pursuant to paragraph IV (2);

(r) *"technical research committee"* means a committee established by the Steering Committee to identify environmental research requirements and administer the research projects.

## II. PURPOSE

(1) The purpose of this agreement is to establish the "Alberta Oil Sands Environmental Research Program" by which name the Program shall be known.

(2) The purpose of the proposed Program is to provide timely information about factors that will aid the parties in establishing guidelines for socially acceptable limits of damage to present and potential uses of biotic and abiotic resources.

(3) In support of this purpose, Canada and Alberta agree that this agreement is confined to research only and does not involve the management of renewable resources.

(4) The objectives of the Program are attached as Schedule "A" hereto. These objectives may be added to or amended from time to time upon agreement of both parties.

## III. TERMS OF REFERENCE

The Terms of Reference relating to the Program are contained in Schedule "B" hereto.

## IV. ADMINISTRATIVE ARRANGEMENTS

(1) The Ministers shall approve the terms of specific research in the fields of hydrology, hydrogeology, terrestrial fauna, land matters, vegetation, human environment, aquatic fauna, meteorology and others to which they may mutually agree.

(2) There shall be established a Steering Committee, which, under the direction of the Ministers, shall be responsible for the composition, co-ordination and conduct of the Program and shall consist of one member appointed by Alberta who shall have the functions normally performed by a chairman, and one member appointed by Canada. The Steering Committee shall:

(a) meet as its members may determine but in any event shall meet at least once every fiscal year during the currency of this agreement,

(b) recommend to the Ministers for approval any news releases respecting any matter concerning or relating to this agreement or the Program,

(c) annually, and at such other times as it or the Ministers may consider appropriate, report to the Ministers upon the projects carried out under the Program and the progress accomplished in respect thereto,

(d) invite interested departments of Alberta and Canada to send a representative to a Steering Committee meeting at least once each year at which the Committee shall present information upon the current and future research projects of the Program,

(e) appoint the Advisory Committee on Program Co-ordination,

(f) recommend to the Ministers those technical reports prepared for publication,

(g) assume such other duties and administrative responsibilities as the Ministers may from time to time agree and prescribe,

(h) approve the matters mentioned in paragraph (5) of this Article.

Each Steering Committee member shall appoint an alternate to represent him at meetings which he cannot attend and shall in writing notify the other member the name of the person so appointed. In the event that the Steering Committee is unable to agree upon any matter, the same shall be submitted to the Ministers for resolution.

(3) Alberta shall in consultation with Canada appoint a Program Director and such supporting staff as may be required from time to time to meet the objectives of the Program. The Program Director:

(a) subject to the approval of the Steering Committee, shall establish such other technical research committees as he may consider necessary to assist specific portions of the Program,

(b) may convene and shall chair meetings of the Advisory Committee on Program Co-ordination,

(c) shall arrange for the provision of field services common to all field research projects involved in the Program including, without limitaarising in respect of that project; if any goods are purchased therefor, on the completion or other termination of that project they may be sold or otherwise disposed of by mutual agreement, and any proceeds thereof divided pro rata between the parties.

(5) Salaries, travelling expenses and related costs of employees of the parties engaged in the Program and related committee duties shall not be paid from funds approved under this Agreement except for salaries, travelling expenses and related costs of staff specifically assigned to or engaged in studies carried out on behalf of the Steering Committee by department or agencies of the parties.

(6) The salaries, travelling expenses and other costs incurred by Steering Committee Members, their alternates and other government officials appointed to represent those party to the Agreement on committees established or approved by the Steering Committee shall be paid for by their respective government.

(7) Where goods or services in respect of the Program (including, without limitation, equipment, office space or facilities specifically required for the Program) are provided by a party hereto or its agencies and are used or utilized by the other party or its agencies, any cost charged in respect thereto by the party or agency so providing shall be the actual cost to that last-mentioned party.

(8) As between the parties hereto, Alberta alone shall bear the responsibility for negotiating contributions to the Program by industry, to a level and upon such conditions deemed appropriate by the Ministers.

(9) Each party hereto shall, for audit purposes, keep appropriate records of expenditures made hereunder and, if requested by the other party, shall make available to the other party those records.

## VI. DURATION AND TERMINATION

For the purposes of this agreement, the term of the Program shall be five years, which said term may be renewed for a further period of up to five years. Either party may, however, at the end of any fiscal year during the currency hereof, terminate this agreement by giving to the other party by registered mail at least one clear year's notice thereof, it being agreed that no such notice may be given which would result in such termination prior to March 31, 1977.

## VII. SCIENTIFIC INFORMATION PUBLICATION

The parties hereto acknowledge hereby that they are committed to the principle that scientific work performed as part of the Program may be published in appropriate journals and/or technical reports. Save as aforesaid, all information obtained in the Program shall be considered to be in the public domain.

## VIII. NOTICES

Any notice to be given hereunder shall be addressed to the Provincial Minister or the Federal Minister, as the case may be, and shall be deemed to have been given upon the day it is received.

## IX. GENERAL

No Member of Parliament shall hold or be admitted to any share or part of any contract, agreement or commission arising out of this agreement.

IN WITNESS WHEREOF the Honourable Jeanne Sauvé, Minister of the Environment of Canada, has hereunto set her hand on behalf of Canada, and the Honourable William J. Yurko, Minister of the Environment of Alberta, has hereunto set his hand on behalf of Alberta.

In the Presence of:

Signed on behalf of Canada ______________________

(signed) Jeanne Sauvé

Feb. 26, 1975

In the Presence of:

Signed on behalf of Alberta ______________________

(signed) W.J. Yurko

Feb. 25, 1975

This agreement is hereby approved and ratified as a binding Intergovernmental Agreement of the Government of Alberta as evidenced by the signature of the Minister of Federal and Intergovernmental Affairs.

______________________

(signed) Don R. Getty
Minister of Federal and Intergovernmental Affairs for Alberta

## SCHEDULE "A"

### GENERAL OBJECTIVE

To undertake environmental research relative to the renewable resources on the designated area which will make information available to the parties hereto to ensure an acceptable quality of the environment during and after operations for the recovery, transport, and processing of oil sands products. This research will be directed to the solution of practical social and technical environmental problems resulting from oil sands development.

### SPECIFIC OBJECTIVES

1. To identify the baseline states, processes, and absorptive capacity of the biotic and abiotic resources that may be affected by oil sands development activities;
2. To identify the nature of interactions between the various components of the biotic and abiotic environment and the various components of proposed development activities;
3. To predict, in part from information obtained by meeting objectives (1) and (2), the individual and cumulative effects of anticipated developments on the biotic and abiotic environment;
4. To develop the methods necessary to protect the biotic and abiotic environment and finally return the biotic environment to a productive state;
5. To advise regulatory and management agencies and the industry of new scientific and technological information pertinent to their jurisdictions, to minimize adverse environmental effects and maximize beneficial environmental effects;
6. To use existing agencies within the administrations of the parties hereto where possible and to use other sources when necessary. Taking inventories will not be considered as part of the objectives under this Program, except where necessary to provide research information;
7. To establish priorities in areas of research, and assign these priorities in the light of an Alberta development strategy for the oil sands;
8. To co-ordinate the projects within the Program so as to provide an interdisciplinary study of environmental problems;
9. To promote an environmental research program which will ensure co-operation among the governments of Alberta and Canada, industry, universities and other institutions;
10. To compile, assess, and disseminate research reports resulting from this Program.

## SCHEDULE "B"

### TERMS OF REFERENCE

The Program will be broad and comprehensive, except insofar as industry has the sole responsibility for detailed work on leased portions of the area and associated sites for installations or works, but it will not apply to any research and inventories concerning non-renewable resources in the area.

When research information is obtained under this program it shall be available to both parties.

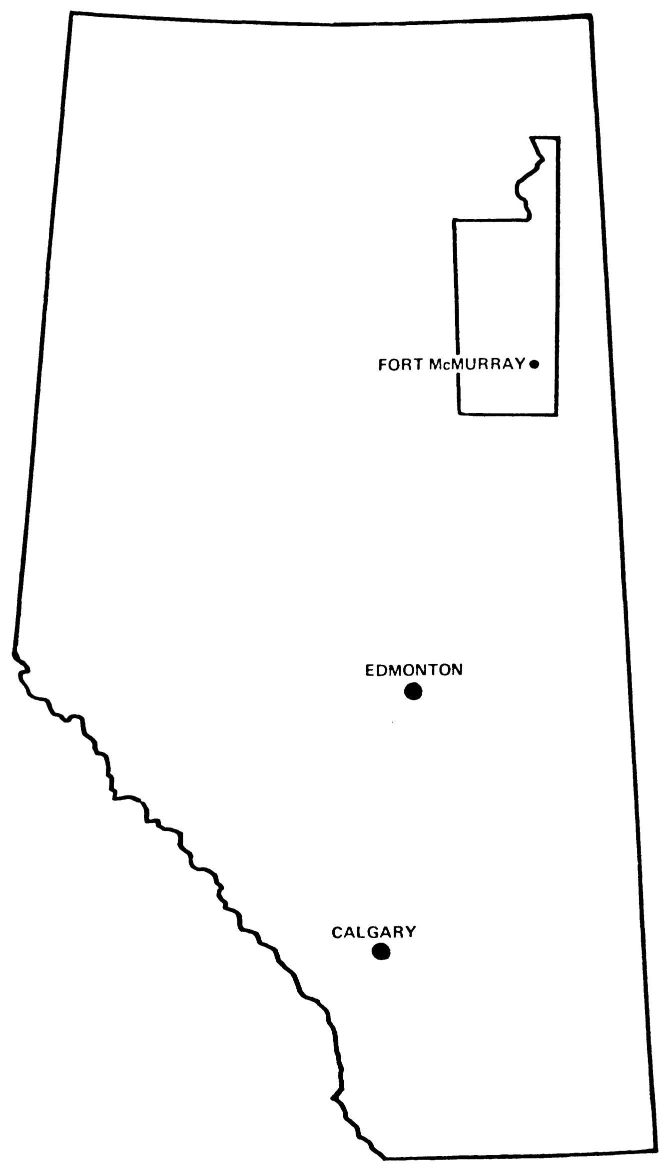
Where Canada conducts research pursuant to these presents and incidentally obtains data respecting non-renewable resources, Canada shall provide Alberta with all such information and shall not use these data nor disclose them to anyone except with the written consent of the Provincial Minister.

For the purpose of this agreement, the chart attached as Schedule "D" hereto shall identify the committee structure and the environmental research subject matter of the Program, as contemplated by the Ministers at the date hereof.

## SCHEDULE "C"

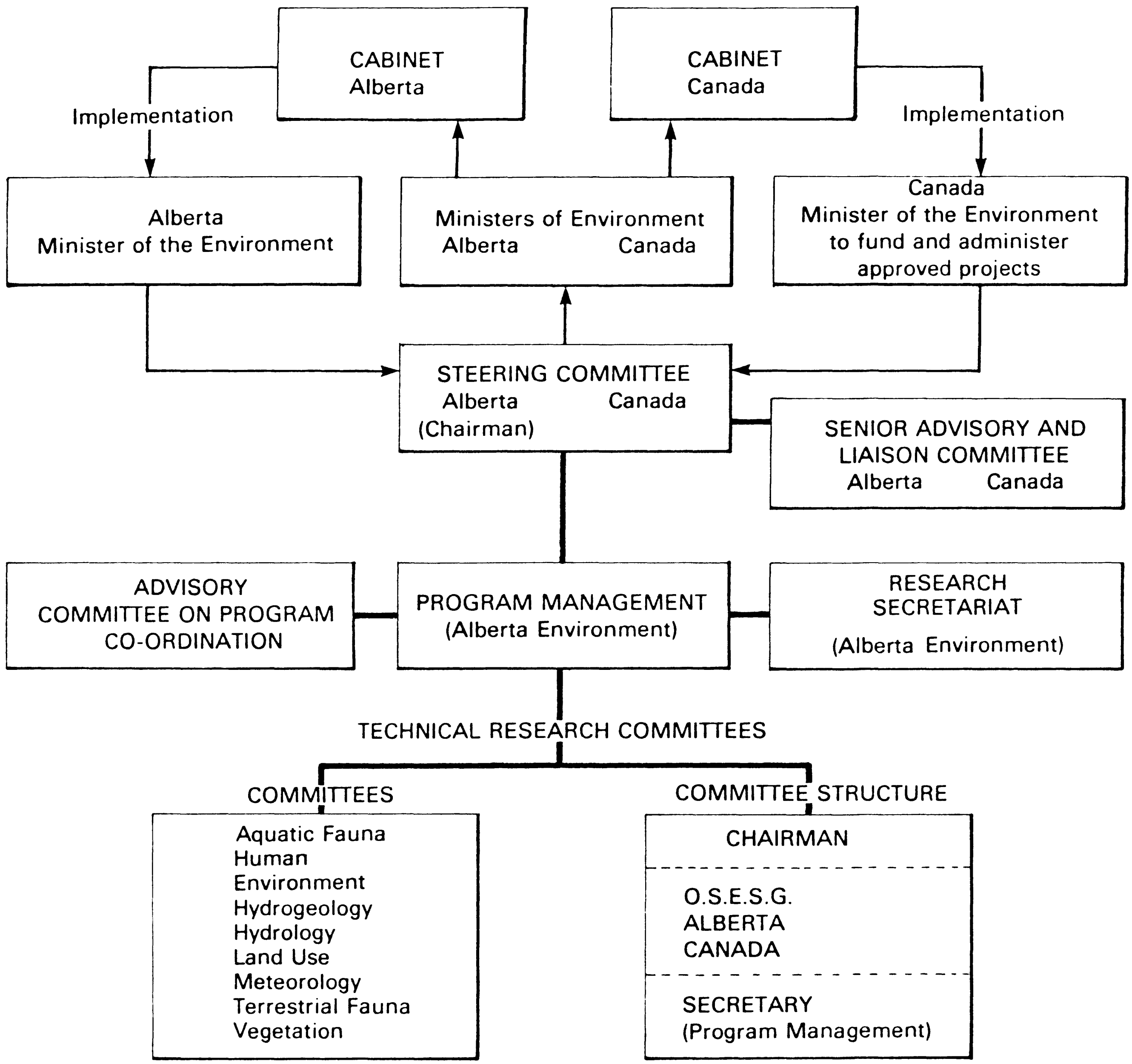
The area under consideration will be the lands comprised within

> Townships 84 to 104, in Ranges 6 to 18 West of the Fourth Meridian, and Townships 105 to 115, in Ranges 6 to 9, excluding Wood Buffalo National Park in the Province of Alberta.



# SCHEDULE "D"

## ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM




### TECHNICAL RESEARCH COMMITTEE CHAIRMAN

The Chairman of each technical research committee listed hereunder shall be chosen from a department or agency of Alberta or Canada which has primary jurisdictional responsibility in the committee's area of interest.

| Technical Research Committee | Department or Agency | Division |
| --- | --- | --- |
| Aquatic Fauna | Environment Canada | Fisheries and Marine Service |
| Hydrogeology | Alberta Research Council | Groundwater |
| Hydrology | Alberta Environment | Technical Services |
| Human Environment | Alberta Northern Development | |
| Land Use | Alberta Environment | Environmental Co-ordination Services |
| Meteorology | Environment Canada | Atmospheric Environment Service |
| Terrestrial Fauna | Alberta Lands and Forests (now Alberta Energy and Natural Resources) | Fish and Wildlife |
| Vegetation | Alberta Lands and Forests (now Alberta Energy and Natural Resources) | Alberta Forest Service |

## 8.2 CANADA-ALBERTA AGREEMENT FOR ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM, AMENDED 1977

THIS AGREEMENT made on the 26th day of September, 1977.

BETWEEN:

THE GOVERNMENT OF CANADA represented herein by the Minister of the Environment (hereinafter called "Canada")

OF THE FIRST PART

AND:

THE GOVERNMENT OF ALBERTA represented herein by the Minister of the Environment (hereinafter called "Alberta")

OF THE SECOND PART

WHEREAS Canada and Alberta have agreed to identify, undertake or encourage and assist research into environmental aspects of the renewable resources involved in the development of oil sands in the area in Alberta described in Schedule "C" hereto, and wish by this agreement to provide for the coordinated planning, funding and implementation of such research; and

WHEREAS initial development is now occurring with expansion imminent and decisions on several industrial proposals now are pending; and

WHEREAS the large scale industrial development of the area will have immense economic, social and environmental effects; and

WHEREAS Canada and Alberta recognize the necessity of improving the scientific understanding of the effects of the oil sands development on the human and natural environment of the oil sands area; and

WHEREAS the results of an intensive study of the area will be useful in predicting the effects of any proposed development, as a basis for considering future proposals; and

WHEREAS the results of the study program will be utilized by Alberta in the approval process for future developments and in the environmental design of any project which might be implemented; and

WHEREAS Canada and Alberta are agreed on the objectives, general strategy and procedures which would govern the identification and selection of such research and the methods of encouragement and assistance; and

WHEREAS His Honour, The Lieutenant Governor-in-Council by Order-in-Council No. 887/77 dated 31st August, 1977, has authorized the Minister of the Environment for Alberta to execute this agreement on behalf of Alberta;

NOW THEREFORE THIS AGREEMENT WITNESSETH that in consideration of the premises, covenants and agreements herein contained, the parties covenant and agree with each other as follows:

## I. DEFINITIONS

In this agreement

(a) "area" means that part of the Province of Alberta described in Schedule "C" to this Agreement;
(b) "environmental research" means a fundamental investigation of a potential or actual man-induced change in environmental systems, which could result in identifiable benefits or adverse effects to society;
(c) "Federal Minister" means the Minister of the Environment of Canada;
(d) "fiscal year" means the period commencing on April 1st of any year and terminating on March 31st of the immediately following year;
(e) "industry" means an individual company or an aggregate or any number thereof of industrial companies who seek to develop the oil sands;
(f) "Ministers" means the Federal Minister and the Provincial Minister;
(g) "non-renewable resources" means minerals, mineral fuels; and similar resources;
(h) "oil sands" means sands and other rock materials which contain crude bitumen and includes all other mineral substances in association therewith;
(i) "oil sands deposit" means a natural reservoir containing or appearing to contain an accumulation of oil sands;
(j) "Program" means the research activities resulting from this agreement;
(k) "Provincial Minister" means the Minister of the Environment of Alberta;
(l) "renewable resources" means biological resources and resources such as terrain, water, and climate that support biological systems;
(m) "research project" or "project" means a project that is entirely or primarily devoted to conducting research on renewable resources in the area in relation to any matter pertaining to the environment;
(n) "Steering Committee" means the committee established pursuant to paragraph IV (2);
(o) "Senior Advisory Board" means the board established pursuant to paragraph IV (3).

## II PURPOSE

(1) The purpose of this agreement is to continue the "Alberta Oil Sands Environmental Research Program".

(2) The purpose of the Program is to provide timely information about factors that will aid the parties in establishing guidelines for socially acceptable limits of damage to present and potential uses of biotic and abiotic resources.

(3) In support of this purpose, Canada and Alberta agree that this agreement is confined to research only and does not involve the management of renewable resources.

(4) The objectives of the Program are attached as Schedule "A" hereto. These objectives may be added to or amended from time to time upon agreement of both parties.

## III. TERMS OF REFERENCE

The Terms of Reference relating to the Program are contained in Schedule "B" hereto.

## IV. ADMINISTRATIVE ARRANGEMENTS

(1) The Ministers shall approve the terms of specific research in the fields of hydrology, hydrogeology, terrestrial fauna, land matters, vegetation, human environment, aquatic fauna, meteorology, and others to which they may mutually agree.

(2) There shall be established a Steering Committee, which, under the direction of the Ministers, shall be responsible for the composition, coordination and conduct of the Program and shall consist of one member appointed by Alberta who shall have the functions normally performed by a chairman, and one member appointed by Canada. The Steering Committee shall:

(a) meet as its members may determine but in any event shall meet at least once every fiscal year during the currency of this agreement,
(b) recommend to the Ministers for approval any news releases respecting any matter concerning or relating to this agreement or the Program,
(c) annually, and at such other times as it or the Ministers may consider appropriate, reports to the Ministers upon the projects carried out under the Program and the progress accomplished in respect thereto,
(d) arrange a meeting of the Senior Advisory Board at least once each fiscal year or as often as is required in order that policy guidance may be provided for on behalf of interested Government departments of Alberta and Canada,
(e) recommend to the Ministers those technical reports prepared for publication,
(f) assume such other duties and administrative responsibilities as the Ministers may from time to time agree and prescribe.

Each Steering Committee member shall appoint an alternate to represent him at meetings which he cannot attend and shall in writing notify the other member the name of the person so appointed. In the event that the Steering Committee is unable to agree upon any matter, the same shall be submitted to the Ministers for resolution.

(3) The Ministers shall appoint a Senior Advisory Board, as recommended by the Steering Committee. The Chairman of the Steering Committee or a member so designated by him in writing shall be the Chairman of the Senior Advisory Board. Senior Advisory Board representation shall be from the Government departments listed in Schedule "D".

The Senior Advisory Board shall:
(a) assist the Steering Committee in evaluating the relevance and timeliness of existing and proposed research efforts relative to the needs of the departments listed in Schedule "D",
(b) provide the Steering Committee with advice on the purpose, objectives and priorities of the research program,
(c) identify areas of interrelationship with research programs other than those provided for in this agreement.

(4) Alberta shall in consultation with Canada appoint a Program Director and such other supporting staff as may be required from time to time to meet the objectives of the Program. The Program Director:

(a) subject ot the approval of the Steering Committee, may establish technical advisory committees or groups as he may consider necessary to assist specific portions of the Program,
(b) shall be responsible to the Steering Committee for the development and implementation of the research projects aimed at meeting the objectives of the Program,
(c) shall arrange for the provision of field services common to all field research projects involved in the Program including, without limitation, laboratory

space, logistics, vehicles and accommodation,

(d) shall be responsible for scheduling project work to ensure the results thereof are available to the parties hereto as soon as practicable,

(e) shall, subject to the direction and approval of the Steering Committee, be responsible for the preparation of news releases and reports for technical and public information,

(f) may recommend to the Steering Committee that the respective parties hereto, as the case may be, enter into contracts or other arrangements required to meet the objectives of the Program,

(5) The parties hereto shall have regard to any existing programs of Alberta or Canada concerning oil sands environmental research for which the Departments of the Environment of Alberta and Canada are individually or jointly responsible, and agree to coordinate these programs as closely as possible with the implementation of the Program.

(6) Subject to paragraph V (8), Alberta shall be the contact with industry and Alberta universities in matters pertaining to this agreement and which have been recommended by the Steering Committee.

(7) Any provision of this agreement may be amended by mutual agreement.

## V. FINANCING

(1) The total cost of the Program is estimated to approximate $40,000,000 expended over a period of ten years. For the purpose of this agreement, but subject to paragraphs (2) and (3) of this Article, the terms of this agreement shall be five years from April 1, 1975, unless this agreement is extended or terminated pursuant to Article VI hereof.

(2) Subject to the terms and conditions of this agreement and to funds being appropriated by Parliament, the sum for which Canada shall be liable hereunder shall approximate $2,000,000 annually for five years from the date hereof and thereafter shall approximate $2,000,000 annually for a further period not exceeding five years where the term of the program is extended pursuant to Article VI hereof.

(3) Subject to the terms and conditions of this agreement and to funds being appropriated by the Legislative Assembly of Alberta, the sum for which Alberta shall be liable hereunder shall approximate $2,000,000 or more annually for five years from the date hereof and thereafter shall approximate $2,000,000 or more annually for a further period not exceeding five years where the term of the program is extended pursuant to Article VI hereof.

(4) Prior to the beginning of each fiscal year, the projects to be undertaken by Alberta, Canada, or jointly, for that fiscal year shall be recommended by the Steering Committee for the approval of the Ministers. The Steering Committee may recommend a joint project between the parties hereto, the cost of which shall be borne equally by the parties or as otherwise mutually agreed. Alberta will provide the initial funding for all research projects on the basis of monthly progress claims reviewed and approved by the Program Director on behalf of the Steering Committee. Alberta will submit claims and will be reimbursed on a quarterly basis by Canada for those projects undertaken by Federal agencies and for the Canada share of jointly funded projects up to a limit of $2,000,000 in any one fiscal year. If any capital goods are purchased for a joint project, on the completion or otherwise termination of that project they may be sold or otherwise disposed of by mutual agreement, and any proceeds thereof divided pro rata between the parties.

(5) Salaries, travelling expenses and related costs of employees of the parties engaged in the Program and related committee duties shall not be paid from funds approved under this agreement except for salaries, travelling expenses and related costs of staff specifically assigned to or engaged in studies carried out on behalf of the Steering Committee by department or agencies of the parties.

(6) The salaries, travelling expenses and other costs incurred by Steering Committee members, their alternates and other government officials appointed to represent those party to the agreement on committees established or approved by the Steering Committee shall be paid for by their respective government.

(7) Where goods or services in respect of the Program (including, without limitation, equipment, office space or facilities specifically required for the Program) are provided by a party hereto or its agencies and are used or utilized by the other party or its agencies, any cost charged in respect thereto by the party or agency so providing shall be the actual cost to that last-mentioned party.

(8) As between the parties hereto, Alberta alone shall bear the responsibility for negotiating contributions to the Program by industry, to a level and upon such conditions deemed appropriate by the Ministers.

(9) Each party hereto shall, for audit purposes, keep appropriate records of expenditures made hereunder and, if requested by the other party, shall make available to the other party those records.

## VI DURATION AND TERMINATION

For the purposes of this agreement, the term of the Program shall be five years, which said term may be renewed for a further period of up to five years. Either party may, however, at the end of any fiscal year during the currency hereof, terminate this agreement by giving to the other party by registered mail at least one clear year's notice thereof, it being agreed that no such notice may be given which would result in such termination prior to March 31, 1979.

## VII. SCIENTIFIC INFORMATION PUBLICATION

The parties hereto acknowledge hereby that they are committed to the principle that scientific work performed as part of the Program may be published in appropriate journals and/or technical reports. Save as aforesaid, all information obtained in the Program shall be considered to be in the public domain.

## VIII. NOTICES

Any notice to be given hereunder shall be addressed to the Provincial Minister or the Federal Minister, as the case may be, and shall be deemed to have been given upon the day it is received.

## IX. GENERAL

No Member of Parliament shall hold or be admitted to any share or part of any contract, agreement or commission arising out of this agreement.

IN WITNESS WHEREOF the Honourable Romeo LeBlanc, Minister of the Environment, has hereunto set his hand on behalf of Canada, and the Honourable David J. Russell, Minister of the Environment of Alberta, has hereunto set his hand on behalf of Alberta.

In the Presence of:

____________________________

Signed on behalf of
Canada

____________________________
Date

In the Presence of:

____________________________

Signed on behalf of
Alberta

____________________________
Date

This agreement is hereby approved and ratified as a binding Intergovernmental Agreement of the Government of Alberta as evidence by the signature of the Minister of Federal and Intergovernmental Affairs.

____________________________
Minister of Federal and Intergovernmental
Affairs for Alberta

## SCHEDULE "A"

### GENERAL OBJECTIVE

To undertake environmental research relative to the renewable resources on the designated area which will make information available to the parties hereto to ensure an acceptable quality of the environment during and after operations for the recovery, transport, and processing of oil sands products. This research will be directed to the solution of practical social and technical environmental problems resulting from oil sands development.

### SPECIFIC OBJECTIVES

1. To identify the baseline states, processes, and absorptive capacity of the biotic and abiotic resources that may be affected by oil sands development activities;
2. To identify the nature of interactions between the various components of the biotic and abiotic environment and the various components of proposed development activities;
3. To predict, in part from information obtained by meeting objectives (1) and (2), the individual and cumulative effects of anticipated developments on the biotic and abiotic environment;
4. To develop the methods necessary to protect the biotic and abiotic environment and finally return the biotic environment to a productive state;
5. To advise regulatory and management agencies and the industry of new scientific and technological information pertinent to their jurisdictions, to minimize adverse environmental effects and maximize beneficial environmental effects;
6. To use existing agencies within the administration of the parties hereto where possible and to use other sources when necessary. Taking inventories will not be considered as part of the objectives under this Program, except where necessary to provide research information;
7. To establish priorities in areas of research, and assign these priorities in the light of an Alberta development strategy for the oil sands;
8. To coordinate the projects within the Program so as to provide an interdisciplinary study of environmental problems;
9. To promote an environmental research program which will ensure cooperation among the governments of Alberta and Canada, industry, universities and other institutions.
10. To compile, assess, and disseminate research reports resulting from this Program.

## SCHEDULE "B"

### TERMS OF REFERENCE

The Program will be broad and comprehensive, except insofar as industry has the sole responsibility for detailed work on leased portions of the area and associated sites for installations or works, but it will not apply to any research and inventories concerning non-renewable resources in the area.

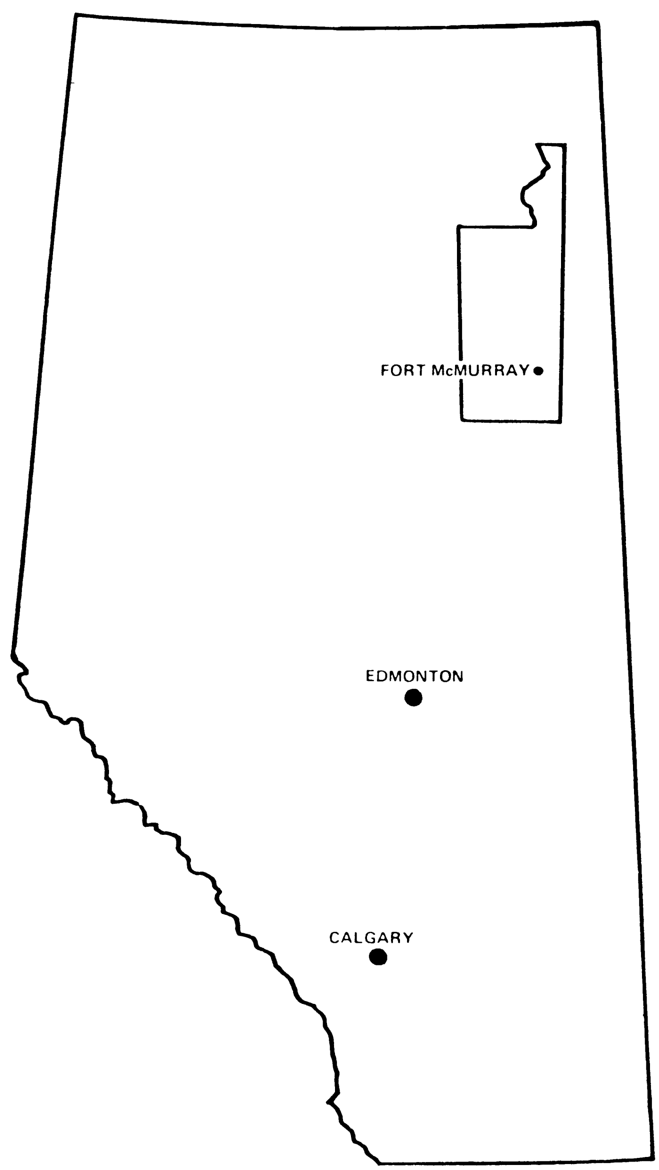
When research information is obtained under this program it shall be available to both parties.

Where Canada conducts research pursuant to those presents and incidentally obtains data respecting non-renewable resources, Canada shall provide Alberta with all such information and shall not use these data nor disclose them to anyone except with the written consent of the Provincial Minister.

## SCHEDULE "C"

The area under consideration will be the lands comprised within

> Townships 84 to 104, in Ranges 6 to 18 West of the Fourth Meridian, and Townships 105 to 115, in Ranges 6 to 9, excluding Wood Buffalo National Park in the Province of Alberta.



## 8.3 AOSERP-INDUSTRY CO-OPERATIVE MODEL

### A SUGGESTED MODEL FOR ENVIRONMENTAL RESEARCH FUNDED JOINTLY BY AOSERP AND OIL SANDS INDUSTRY

18 May 1975

This report develops a model for joint industry-AOSERP environmental research investigations. The model has been generalized to include any aspect of joint sponsorship of environmental research by a company and the Alberta Oil Sands Environmental Research Program.

Background

In general, it is suggested that there is no need to consider joint sponsorship or funding where only a single interest (corporate of AOSERP) can be identified. In many cases, there will be minimal need for access to active company leases by AOSERP researchers, since much of the environmental research on such leases will be site-specific and clearly a company responsibility. However, reclamation research, studies on hydrogeology, toxicology, and others, may be more conveniently carried out on an active lease than elsewhere. In addition, there may be research projects involving air pollution and social impacts that obviously cross lease boundaries and which may be of interest jointly to leaseholders and to AOSERP.

It would appear convenient to develop an umbrella agreement acceptable both to AOSERP and to leaseholders under which terms may be negotiated for individual research projects where the joint interests of AOSERP and of the individual leaseholder can be satisfied most easily.

AOSERP Interests

Relationship of research to AOSERP objectives - The objectives of the AOSER Program are approved by the governments of Canada and

Alberta, under the amended Federal-Provincial agreement which received final signatures on 26 September 1977. Research sponsored by AOSERP must meet the objectives of the Program, under one of the Air, Land, Water, or Human Systems, as laid out in the policy document approved on 20 October 1977.

Research funded and carried out jointly with companies clearly must be of wide enough application that it is distinctly advantageous for the AOSER Program to be involved, or that lack of involvement would be a distinct disadvantage to the conduct of the Program.

## Corporate Interests

Corporate interests involve the need for the leaseholder to develop plans for reclamation, as well as for research on environmental effects of air and water pollutants. Because these efforts ultimately involve evaluation by regulatory agencies, it would seem appropriate to develop research investigations jointly with Government.

Because of the nature of operations on active leases, operating companies will need to exert control over physical access by and activities of researchers. Companies therefore require direct involvement in contracts operating on their leases. Security and safety rules can only be enforced by the company itself.

## Application and Availability of Research

All research funded by AOSERP must be made public under the Federal-Provincial Agreement which provides the operating policy for the Program. For the purposes of this model, no environmental research data obtained under a joint AOSERP-industry project can be considered in any respect to be proprietary or confidential. All such research results will be published.

Jointly funded projects are intended to be of mutual advantage to AOSERP and the co-operating company, and all projects will be of a nature related to effects of oil sands development.

## The Model

The model suggested for AOSERP involvement in research with a company envisages joint sponsorship and funding. It would appear to be in the best interests of the company to contract directly with consultants, whether they be from a private firm, university, government research institutions or other.

In order to provide a legal basis for AOSERP involvement in funding, it is suggested that for each specific jointly funded project, AOSERP and the company negotiate terms which are mutually acceptable, and which provide a firm contractual obligation for both parties. The company would have control over physical access to leases by researchers, and would administer the projects.

Reports by consultants would be delivered simultaneously to the company and to Program Management for AOSERP. The contract between AOSERP and the company would specify the form of approvals required for acceptance of research reports. AOSERP would bear the cost of publication for 150 copies of reports as a contractual obligation to the company involved, at a scientific level acceptable to competent referees. Published reports would clearly indicate the joint sponsorship of the research work.

Research projects may be proposed for joint funding either by a company to AOSERP or by AOSERP to a company.

## Policy Framework

1. No research project will be funded jointly if any part of it is based on data which are in any respect considered confidential by the company.
2. No research project on an active company lease will be sponsored and/or funded by AOSERP if there is not joint sponsorship and/or funding by the leaseholder.

3. AOSERP Research Managers will keep appropriate company contact informed as to development of research plans in the Air, Land, Water and Human Systems, in order that leaseholders will have ample opportunity to identify areas of research of mutual interest, and which might be proposed by company management as suitable for joint sponsorship. Companies will do the same.
4. Research reports will deal only with scientific analyses and concusions drawn thereform. No statements concerning the results of research will be released until Program Management and the company involved have accepted the research report and released it through the Steering Committee and senior company management. In the case of disagreement concerning release of a research report, either AOSERP or the company may release the report within 60 days of completion of the research report.
5. A general agreement will be confirmed by exchange and joint signing of a memorandum of intent between a senior official of the company and the Chairman of the Steering Committee; individual projects will be carried out under contracts with specific and detailed terms of reference appropriate to the general agreement.
6. Transmission of proposals for joint AOSERP-company research to a company form AOSERP or vice versa will be by exchange of letters between the Chairman of the Steering Committee for AOSERP and a senior official designated by the company.
7. A working committee will be established for management of joint projects, with equal membership from AOSERP and the company.

Summary

The suggested model and policy framework for co-opertive research on active company leases sponsored and funded jointly by AOSERP and leaseholders is intended to prevent duplication of research effort and to provide better understanding of research needs and requirements for problem oriented research, both for oil sands companies and the AOSER Program.

It is anticipated that a significant proportion of Land System research on company leases of mutual interest to companies and AOSERP will be oriented to reclamation, and convenient to carry out as joint projects with operating companies. Research in Air and Water Systems generally will be of wide scope with some obvious involvements on leases which would be of high interest both for companies and for AOSERP. Human System research could take place on company leases, and joint AOSERP-company sponsorship of research in the Human System is likely to occur both on and off leases.

## 8.4 TERMS OF REFERENCE FOR SCIENTIFIC ADVISORY COMMITTEES

### INTRODUCTION

Under the Federal-Provincial Agreement, as amended September 26, 1977, for the Alberta Oil Sands Environmental Research Program (AOSERP), provision is made for appointment of committees to act in an advisory capacity to Program Management. This document outlines the terms of reference for Scientific Advisory Committees. These Committees are to serve the primary purpose of providing scientific advice on present and proposed environmental research in relation to oil sands development within the context of the Federal-Provincial Agreement and the environmental priorities of the two governments.

The basic organization of AOSERP (Figure 1) places all research into one of four systems: Air, Human, Land and Water. Research in each system is under the direction of a Research Manager. An Operations Manager is responsible for the provisions of all necessary Program support services. The four Research Managers, the Operations Manager, the Program Director, and the Assistant Director constitute Program Management.

In keeping with the systems approach to research management, it has been recommended to and accepted by the Steering Committee that four Scientific Advisory Committes be appointed to assist in providing scientific direction to the Program. The concept has been supported by the Senior Advisory Board.

The terms of reference laid out herein are intended to provide clear definition of the roles of Scientific Advisory Committees in relation to Program Management. It is hoped that scientists appointed to the Committees will be able to make a significant scientific contribution to the conduct of the Program.

## ESTABLISHMENT OF COMMITTEES

The Federal-Provincial Agreement for AOSERP states:

> "The Program Director.... subject to the approval of the Steering Committee, may establish Technical Advisory Committees or groups as he may consider necessary to assist in specific portion of the Program".

The Committees will be formally known by the following names:

| | |
|---|---|
| Air System Scientific Advisory Committee | (ASSAC) |
| Human System Scientific Advisory Committee | (HSSAC) |
| Land System Scientific Advisory Committee | (LSSAC) |
| Water System Scientific Advisory Committee | (WSSAC) |

## MEMBERSHIP

Membership on each Committee will consist of seven (7) persons and will be drawn from nominations sought as widely as possible by Program Management from government research establishments, Alberta universities and the private sector. Principal qualifications for membership will be scientific training and active involvement in environmental research or research management in a discipline appropriate to the system in question.

Members of each Committee will elect a Chairman for a one-year term to preside at meetings as well as a Vice-Chairman to act in the Chairman's absence. Committee appointments will be for one year, but it is hoped that only about one third of the members will change each twelve months, in order to provide a reasonable degree of continuity.

Since Committee members may be drawn from research institutions or corporations engaged to undertake research for AOSERP, no member of a Scientific Advisory Committee may have an actual involvement in a research project funded by AOSERP. Where a conflict of interest situation is apparent, the member in question will be asked to refrain from Committee deliberations.

Committee members other than Government employees will be reimbursed for out-of-pocket expenses and paid a gratuity of $100.00 for attendance at Committee meetings and workshops: The Federal-Provincial Agreement for AOSERP, Section V(6) provides that:

> "The salaries, travelling expenses and other costs ....incurred by Government officials appointed to represent those party to the Agreement on Committees.... shall be paid for by their respective Government".

In the case of occasional field trips by Committees to the AOSERP study area, charter air services, field transportation, food and lodging at the AOSERP Mildred Lake Research Facility, may be provided as a Program service.

Committees will be expected to function in the generally acceptable manner of working from an agenda, with adequate notice given to allow for study of pertinent material. Agendas and minutes will be kept on record in the Program Management Office, Edmonton, and copies will be made available on request to Committee members.

ROLES OF SCIENTIFIC ADVISORY COMMITTEES

In order that Committees achieve maximum effectiveness, responsibilities have been defined in relation to Program objectives, as follows:

1. To identify existing or potential environmental and social problems associated with oil sands development;
2. To identify gaps in research knowledge associated with environmental and social problems resulting from oil sands development;
3. To advise Program Management in setting priorities for environmental research; and

4. To evaluate the results of environmental research funded by AOSER Program.

In order that Scientific Advisory Committees function efficiently, Program Management will be represented by the respective Research Manager, who will act as Executive Secretary to each Committee. It is expected that four meetings per year will be required for each Committee, in order to review research plans in light of suggested priorities and to evaluate research results that have been reported. Between meetings of the Scientific Advisory Commttees, Research Managers will keep Committee members informed as to progress of research through progress reports and will be responsible for calling meetings and perparing agendas in cooperation with the Committee Chairman.

Committee members may also serve on selection committees to review research proposals and act as referees of reports prior to publication, but such activities will be on a voluntary basis. Selection committees are appointed by the Program Director and chaired by the Research Manager.

Recommendations of selection committees concerning acceptance or otherwise of research proposals will be made through the Research Manager to the Program Director. Members of Scientific Advisory Committees will be asked to remain aloof from the actual conduct of research projects; the management of which is solely the responsibility of the Research Manager. The policy of Government is to advertise for contractors to carry out research. After a decision has been reached to award a contract, it is Program Management policy that no dialogue will occur between Program Management staff and unsuccessful proponents of research proposals. It is expected that members of selection committees will also respect this policy.

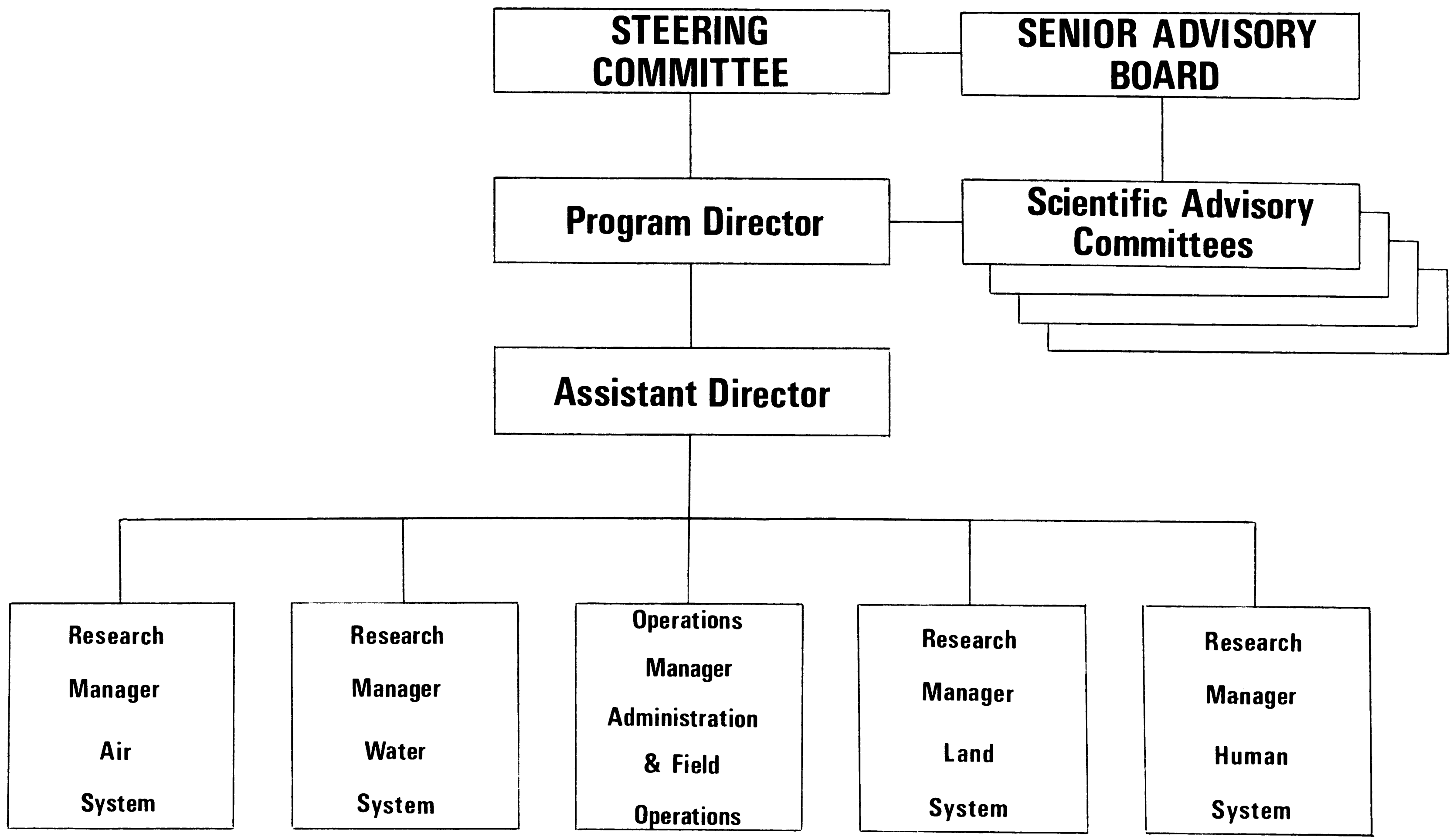



Figure 1. Organization chart.

## 8.5 GLOSSARY

Acronyms

| | |
|---|---|
| ADPIC | - Atmospheric Dispersion of Particle in Cell |
| LIRAQ | - Livermore Air Quality Model |
| CRSTER | - Gaussian model designed to compute ground level ambient air concentrations of SO |
| CDM | - Climatic Dispersion Model |
| LANDSAT | - An orbiting satelite which provides photographic images of the earth's surface |
| NOAA | - National Oceanographic and Aeronautics Administration (U.S.) |
| VHRR | - Very High Resolution Radiometry |
| MSS | - Multi-Spectral Scanner |

Symbols

| | |
|---|---|
| Cu | - copper |
| Ni | - nickel |
| Pb | - lead |
| Sb | - antimony |
| V | - vanadium |
| SO | - sulpher dioxide |
| H S | - hydrogen sulphide |
| $NO_x$ | - nitrogen oxides |

Terms

| | |
|---|---|
| algorithm | - notation of numbers |
| allochthonous | - originating without; used in reference to organic carbon fixation by bacteria (heterotrophic production) |
| autochthonous | - originating within; used in reference to inorganic carbon fixation by plants (autotrophic production) |
| benthic | - found on the bottom (of streams and lakes) |
| biomass | - the amount of living material in a system |
| biomonitoring | - the use of living organisms to assess response of ecosystems to environmental stress |
| carnivore | - feeds on animal matter |
| detritus | - organic debris |
| fauna | - refers to animals |
| flora | - refers to plants |
| glc | - ground level concentration |
| herbivore | - plant-eating |
| insectivore | - insect-eating |
| isopleth | - a line joining equal concentrations of atmospheric constituents |
| invertebrate | - animals without backbones; (generally refers to aquatic insects in this report) |
| macrophyte | - relatively large plants (as contrasted to microscopic); in this report, refers to rooted aquatic plants |
| microbial | - refers to microscopic organisms in soil or water (e.g., bacteria) |

| | |
|---|---|
| omnivore | - feeds on a variety of plant and animal material |
| plankton | - free-floating microscopic organisms |
| sigma | - standard deviation; a statistical measure of variation |
| ungulate | - hoofed animal (e.g., moose, caribou) |

## 8.6 MAN-DAYS OCCUPANCY AT MILDRED LAKE RESEARCH FACILITY

Table 3. Number of man-days occupancy at the AOSERP field research facility, Mildred Lake.

| Year | Man-days Occupancy |
| --- | --- |
| 1975-1976 | Not Operational |
| 1976-1977 | 5603 |
| 1977-1978 | 5773 |
| 1978-1979 | 3595 |
| 1979-1980 | 3024 |