

ATHABASCA TAR SANDS STUDY  
THE ENVIRONMENTAL IMPACT OF  
*IN SITU* TECHNOLOGY

A report prepared for  
Intercontinental Engineering of Alberta Ltd.

by  
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and  
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Research Council of Alberta  
January, 1973

## FOREWORD

The Athabasca Oil Sands have been estimated to contain more than 600 billion barrels of heavy oil, and are generally considered to be the largest known reservoir of oil. They outcrop along the Athabasca River valley and its tributaries in northeastern Alberta between latitudes  $56^{\circ}30'$  and  $58^{\circ}$  north, and between the Saskatchewan-Alberta boundary and  $112^{\circ}$  west longitude. The extent of the oil-impregnated sand in the subsurface is incompletely delimited, but it appears to extend over an area of 20,700 square miles bounded by latitudes  $55^{\circ}$  and  $58^{\circ}$  north between the Fourth and Fifth Meridians (Fig. 1). It is thus 204 miles long and 120 miles wide.

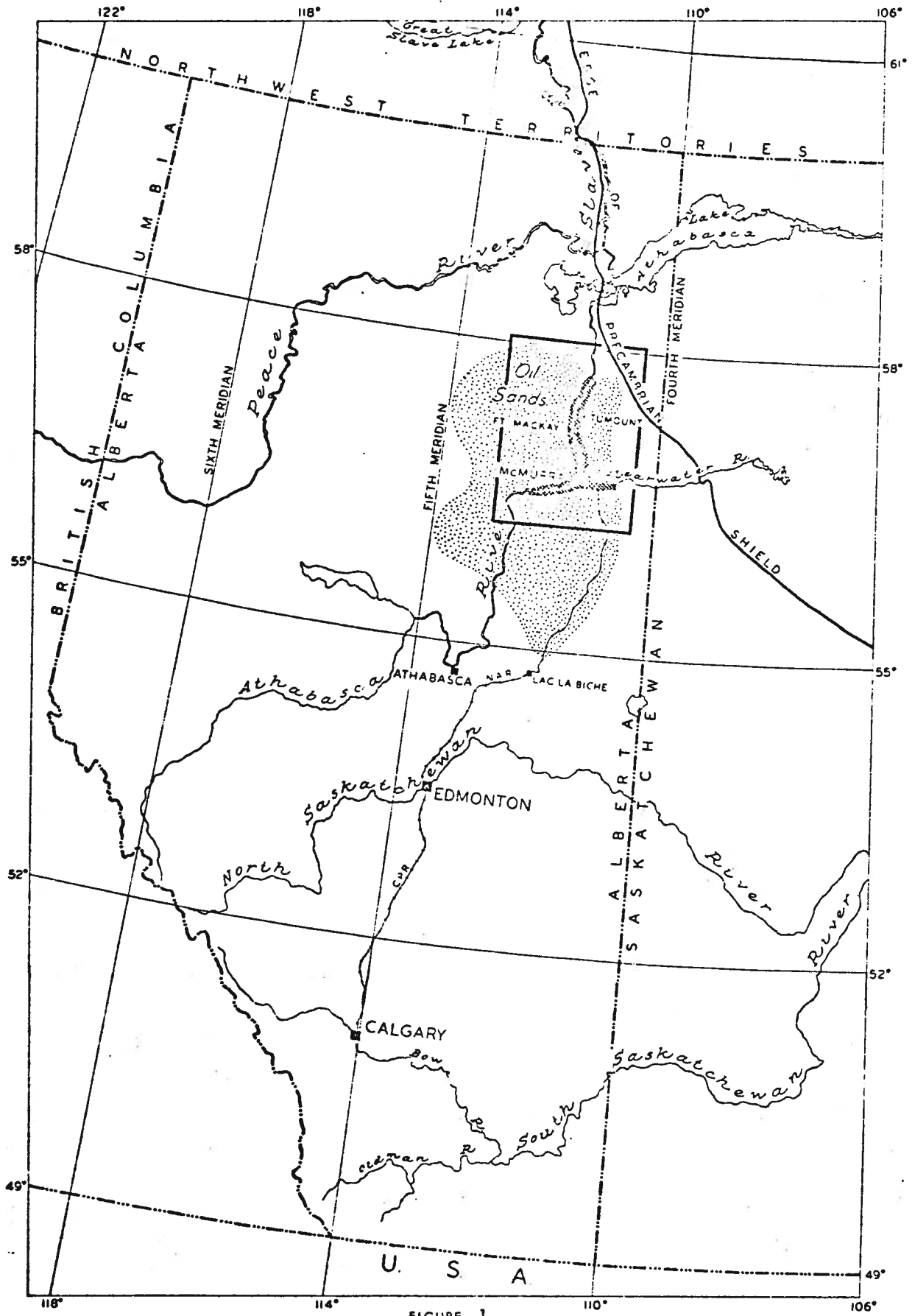


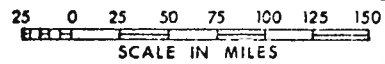
FIGURE 1

SUBSURFACE EXTENT-ATHABASCA OIL SANDS 

OUTCROP 

BITUMINOUS SANDS AREA 

(After Carrigy & Zamora)





RESEARCH COUNCIL OF ALBERTA

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EDMONTON, ALBERTA, CANADA

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OUR REF: MAC/IJM/bb

January 15, 1973

Mr. Harold V. Page  
Project Director  
Athabasca Tar Sands Study  
Intercontinental Engineering of Alberta Ltd.  
11055 - 107 Street  
EDMONTON, Alberta

Dear Mr. Page:

We have the pleasure to transmit herewith our report, "The Environmental Impact of *In situ* Technology," for the Athabasca Tar Sands Study as requested in your letter of August 15, 1972.

Yours sincerely,

*M. A. Carrigy*  
M. A. Carrigy, P. Geol.

*I. J. McLaws*  
I. J. McLaws, P. Geol.  
Geology Division  
Research Council of Alberta

## Intercontinental Engineering of Alberta Ltd.

11055-107 Street Edmonton, Alberta, Canada

August 15, 1972.

Dr. M.A. Carrigy,  
Research Council of Alberta,  
11315 - 87 Avenue,  
Edmonton, Alberta.

Dear Maurice:

Re; Athabasca Tar Sands Study  
In-situ Technology

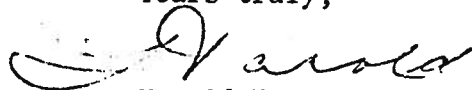
This will confirm our recent discussions in which we indicated a desire to have you provide consulting services on the environmental impacts of the in-situ recovery technology.

This will comprise part of Phase III of our Study and we have allocated \$5,000. of our Study budget to the specific investigation of the in-situ method.

I believe you are already familiar with the terms of reference for our Study as a result of your participation to date. We sincerely appreciate the support and advice which you have provided throughout Phase II of our Study. Your technical contributions were incorporated into our progress report to the Client, a copy of which is being mailed with this letter.

We can discuss this subject in further detail at our meeting scheduled for Tuesday, August 29th.

Yours truly,



Harold V. Page, P.Eng.,  
Project Director.

ATHABASCA TAR SANDS STUDY

HVP:ejb

P.S. Please note that the Client has designated our progress report as strictly confidential and therefore the information provided therein should be used only for the requirements of our Study.

## ACKNOWLEDGMENTS

The writers are indebted to a number of colleagues for assistance in the preparation of this report. J. D. Lindsay, Head of the Soils Division, supplied maps and photographs and offered advice on the terrain, organic soils, and sand dune distribution in the Bituminous Sands Area. C. R. Neill, P. Eng. of the Highways and River Engineering Division, gave us advice with regard to estimations of runoff and supplied aerial photographs of streams in the area. We are also grateful to officers of the Department of Lands and Forests and the Energy Resources Conservation Board who supplied data on request.

We are grateful to all of these people for assistance, but the writers accept full responsibility for the accuracy and manner in which the data is presented in this report.

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## INTRODUCTION

For the purposes of this study, we have examined the demands that will be made on the environment of the Bituminous Sands Area by the production of 1.3 million barrels per day\* of bitumen by *in situ* methods of extraction, *in situ* extraction implying the recovery of bitumen from the pores without disturbing the reservoir rock. This process usually involves the drilling of many injection and production wells into the reservoir in a closely spaced pattern, and the collection and delivery of the bitumen to a field plant for upgrading to a synthetic oil.

Most of the *in situ* methods require the application of differential pressure to the reservoir, and for this reason it is generally conceded that for safe and effective operations with today's technology, the overburden should not be less than 500 feet. The study area is therefore confined to that portion of the Athabasca deposit buried to depths of more than 500 feet in the Bituminous Sands Area. This *in situ* area comprises about 3,700 square miles and is about 64 per cent of the Athabasca deposit within the Bituminous Sands Area. Some 2,000 square miles of the Athabasca deposit, all of it buried deeper than 500 feet, lies outside the Bituminous Sands Area and is not considered in this report. In addition, that portion of the Athabasca deposit covered by 200 to 500 feet of overburden has not been included, although it may conceivably be developed by *in situ* methods at some future time.

Existing patents on *in situ* technology and extensive literature on secondary recovery of petroleum have been reviewed. It is clear that much of this technology cannot be transferred to the Athabasca deposit without considerable modification.

Our predictions, at this time, of the environmental effects of large scale *in situ* production are subject to some significant limitations. Firstly, there is no commercial production from *in situ* operations in the Bituminous Sands Area, and although some experimental work has been carried out by two oil companies with two of the most promising methods, factual data is scarce.

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\* It is assumed that 1.3 million barrels of bitumen will yield 1.0 million barrels of 'synthetic' oil.

Secondly, the area has until very recently been largely inaccessible and little factual data exist on the meteorology, hydrology, soils, vegetation, and wildlife of the area. Current evaluations of the economic values of the renewable resources of the area were not available during the preparation of this report.

Within this context, we have proceeded to examine in a theoretical way those actions which we believe will have a significant effect on the environment in the Bituminous Sands Area should commercial *in situ* production begin.

Shell Canada Limited and Muskeg Oil Company applied to the Energy Resources Conservation Board for permission to go into commercial or semi-commercial production, but both applications were subsequently withdrawn. The Shell Canada Limited submission was based on a steam-injection system for extraction and included data on upgrading the bitumen to a synthetic oil in two stages. The first stage processing was to take place at the production site and the final upgrading in Edmonton. The Muskeg Oil Company submission was concerned only with the production of the raw bitumen by a modified underground combustion method and did not include details of the bitumen upgrading phase; thus, it is considered to be a semicommercial venture. Because of these differences, it is difficult to make meaningful comparisons between the two systems. For example, in the Muskeg Oil Company application, details of the field gases are given because, in the absence of a processing plant, they will have to be flared or vented. In the Shell application, no field gas analyses are given because they enter the primary processing plant along with the steam and bitumen emulsion. Similarly, saline water produced along with the bitumen emulsion in the Muskeg Oil Company method has to be concentrated and disposed of before the bitumen is delivered to a distant processing plant, whereas in the Shell Canada Limited system, the saline water in the emulsion is diluted by process waters and ultimately discharged into the surface drainage system.

From our examination of these two applications for commercial and semi-commercial production by *in situ* methods, we believe the following major environmental impacts can be anticipated.

1. Air quality

a) Steam injection (field and primary upgrading facility)

In the Shell Canada Limited application, 460,000 long tons a year of sulphur dioxide was to be emitted to the atmosphere from a plant producing 100,000 barrels of synthetic oil a day. These emissions will come from the burning of the high sulphur residual fuel (pitch) in the power plant used to generate the steam for injection and the electricity for primary processing.

If this process were to be used for the production of 1 million barrels of synthetic oil, without SO<sub>2</sub> abatement, 4.6 million long tons of sulphur dioxide would be emitted annually from fewer than 10 plants. This amount of sulphur dioxide would be equivalent to 20 per cent of the estimated annual emission of sulphur dioxide from the untreated stack gases of all stationary power plants in the United States in 1970.\* About 80 per cent of the SO<sub>2</sub> emission would be produced by burning fuel to produce steam for injection into wells.

b) COFCAW (field facilities only)

Extrapolation of experimental data provided by Muskeg Oil Company suggests that 0.5 million tons of SO<sub>2</sub> a year would be produced by flaring the gases collected with the bituminous emulsion for each 1.3 million barrels of raw bitumen produced.

2. Land clearing (field facilities only)

To accommodate drilling sites, roads, pipelines, etc., required by *in situ* extraction, large tracts of land have to be occupied for periods of up to 7 years. For example, a well field producing 130,000 barrels of bitumen a day would have about 1,600 operational wells spaced less than 300 feet apart over an area of 5.0 to 6.0 square miles at all times. If the clearing is confined to pipeline rights of way, servicing roads, and well sites, 50 per cent of the vegetation would have to be cleared. Thus, to produce 1.3 million barrels of bitumen, the total area cleared of vegetation at any one time would be between 25 and 30 square miles in fewer than 10 well fields.

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\* *Ad hoc* panel on Control of sulfur oxide from Stationary Combustion  
Sources: National Academy of Engineering, Washington, D.c. 1970.

### 3. Water consumption

#### a) Steam injection (field and primary and secondary upgrading facilities)

A fully integrated steam-injection system capable of producing 100,000 barrels of synthetic oil would require 25,200 gallons of water a minute, which is equivalent to a stream flow of 55.5 cubic feet per second. Thus, 10 plants producing a total of 1.0 million barrels of synthetic oil would require an amount of water equivalent to a flow of 555 cubic feet per second.

#### b) Steam injection (field facilities only)

The water requirement for production of 1.3 million barrels a day of raw bitumen by steam injection is estimated to be about 260 cubic feet per second.

#### c) COFCAW (field facilities only)

Early experimental data indicate that less water is required for bitumen production by underground burning than for steam injection, as most of the formation water produced along with bitumen can be recycled without treatment.

### 4. Groundwater contamination

Although no estimate of the magnitude of the groundwater contamination problem can be given at this time, we can anticipate that, during *in situ* extraction, chemicals will be injected into the reservoir for a variety of reasons, for example, to initiate combustion, stimulate production, seal off permeable layers, and to heat the formation. Normally the concentrations of these chemicals will be low, and most of them will be recovered during production. However, it must be emphasized that *in situ* operations conducted in the Bituminous Sands Area are in the zone of moving groundwater which ultimately discharges into the surface drainage system, and constant monitoring will be needed to prevent contamination of the groundwater supplies which may be needed for domestic or industrial purposes.

### 5. Liquid effluents

#### a) Steam injection (upgrading facilities only)

Little data are available on the temperature or composition of the effluents to be discharged from a steam injection processing plant. Shell

Canada Limited, in their submission, estimated that 10 barrels of oil dispersed in 396,000 barrels of water would be discharged into the Ellis River for each 100,000 barrels of synthetic oil produced.

b) COFCAW (field facilities only)

A large volume of saline water will be produced along with the bitumen. The salts in this water will be concentrated during field processing. Experimental data supplied by Muskeg Oil Company suggest that up to 600,000 barrels a day of salt water will be collected during the production of 1.3 million barrels of raw bitumen.

## CONCLUSIONS AND RECOMMENDATIONS

### With regard to Environmental Protection

If the full oil-producing potential of the Athabasca Oil Sands is to be realized, a viable method or methods of *in situ* extraction must be available. At the present time, no applications are pending to produce commercial quantities of bitumen by *in situ* methods, and we estimate that it will require 8 to 10 years of intensive research and development to evolve a suitable method and to do the field testing necessary to ensure that it will meet acceptable conservation and environmental criteria. Environmental problems associated with the two most advanced *in situ* methods developed to date are discussed in this report in some detail.

Because of the lead time available before commercial *in situ* development begins in the Bituminous Sands Area, there is time, if work is begun immediately, to establish the basic environmental criteria by which to ensure that when commercial development is approved it can proceed with the minimum of disturbance to the environment.

To collect the data necessary to establish these environmental criteria the following actions and time table for their initiation or completion are recommended:

- 1) Effective immediately, require that all holders of leases in the *in situ* area begin collecting ecological baseline data, so that adequate environmental impact statements can be provided to the Department of the Environment when applications for commercial development are made.
- 2) Effective immediately, prohibit withdrawal of water from all lakes and streams in the *in situ* area until a survey has been made of all possible sources and the volumes available. Priorities of water use can then be established.
- 3) Effective immediately, begin drafting regulations requiring the minimum of land clearing around wells, pipelines and other temporary field facilities.

- 4) As soon as possible, establish a network of recording stations in the *in situ* area to measure the following parameters at appropriate intervals for a period of at least 10 years:
  - a) precipitation, b) evaporation, c) air temperature, d) stream flows, e) lake levels, f) water tables, g) water temperatures, h) water quality, i) pressures at several depths in deep observation wells drilled from ground surface to base of the bituminous sands.
- 5) As soon as possible, draft regulations requiring monitoring of all experimental *in situ* test sites for groundwater contamination.
- 6) As soon as possible, draft regulations to ensure that no toxic concentrations chemicals or radioactive materials are injected into the bituminous sands reservoir.
- 7) Before commercial *in situ* development permits are issued, draft regulations to ensure the production zone is flushed and refilled with compatible formation water after production has ceased.
- 8) Before 1975, determine the location of all suitable dam sites on streams crossing the *in situ* area so that water storage sites and catchment areas may be protected.
- 9) Before 1978, make an inventory of all renewable resources such as lumber, fish, wildfowl, fur-bearing animals and big game in the *in situ* area.
- 10) Before 1978, make a survey of the *in situ* area to establish the presence of any unique animals, plants, nesting sites, spawning grounds, ecosystems, etc., with a view to making satisfactory arrangements for their protection.
- 11) Consider early assessment of impact of commercial development on native people and establish lines of communication.
- 12) Before commercial *in situ* development permits are issued, draft regulations to ensure land reclamation objectives will be achieved after production has ceased.



With regard to Government Policy

Because of the early stage of development of *in situ* extraction processes in the Athabasca Bituminous Sands, there is an opportunity for the Alberta Government to maintain control of, and exercise leadership in, the development of the major portion of the Athabasca reserves.\* The first requirement is a new leasing policy for the whole deposit, one feature of which should be that no more than 50 per cent of the deposit\*\* shall be leased at any one time, and that these leases shall be distributed throughout the area in some sort of checkerboard pattern.\*\*\*

In addition to the 50 per cent restriction on leased acreage within the *in situ* area, it is recommended that no more permits or leases be issued in the Bituminous Sands Area where depths of overburden are greater than 200 feet but less than 500 feet. This area or zone, which comprises 838,000 acres, completely surrounds the mining area, and the bituminous sands beneath this area are too deeply buried for open-pit mining and too shallow for *in situ* methods. Keeping this strip clear of leases will prevent jurisdictional disputes that will undoubtedly arise if these two methods of extraction are allowed to share common lease boundaries. It will also simplify administrative procedures if, in the future, different regulations are to apply to the mining and *in situ* leases.

With regard to Research Policy

We believe the problems of *in situ* technology in the Athabasca deposit to be sufficiently different from conventional "secondary recovery" methods used in the petroleum industry to require unique solutions which can only be tested and evaluated in the area of development. Therefore, the Alberta Government should encourage cooperation among lease holders for the testing of new and novel methods of *in situ* extraction by initiating and supervising research and development programs.

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\* It is estimated that 3.7 million acres or 73 per cent of the Athabasca deposit is overlain by more than 500 feet of overburden.

\*\* In the Bituminous Sands Area 39 leases comprising a total of 1.7 million acres are located in the *in situ* area. This represents 53 per cent of the land in the Bituminous Sands Area with more than 500 feet of overburden.

\*\*\* This will allow lease boundaries to be adjusted to ore body dimensions without disturbing neighbouring lease holders and prevent the establishment of monopolies.

**PART I BITUMINOUS SANDS AREA**

- 1.1. Topography and drainage**
- 1.2. Climate**
- 1.3. Surficial deposits**
- 1.4. Soils**
- 1.5. Vegetation**
- 1.6. Fauna**
- 1.7. Bedrock geology**
- 1.8. Groundwater**

## 1.1. Topography and drainage

The Bituminous Sands Area is located in northeastern Alberta on the Interior Plain, adjacent to the Canadian Shield. The main drainage of the area is provided by the Athabasca-Clearwater system, the valleys of which are incised into a broad, gentle, muskeg-covered high plain to depths of 200 to 300 feet (Map 1). The tributary streams originate in three highland areas: the Birch Mountains to the northwest, which rise to about 2700 feet; Stony Mountain to the south, reaching an elevation of 2500 feet; and Muskeg Mountain to the east, with a gradual rise to 1900 feet. To the southwest of the area, between Birch Mountains and Stony Mountain and north of the eastward flowing Athabasca River, is a subdued highland with gentle slopes called the Thickwood Hills. These hills give rise to northward flowing tributaries of the MacKay River, with only a few short streams flowing southward to the Athabasca.

A few shallow lakes are located in the area, the largest and most numerous of which are located on the top of Birch Mountains and form an interconnected chain of lakes which flow into the Ells River. These are called Eaglenest, Gardiner, and Namur Lakes. The only other lakes of any size, Algar and Gregoire Lakes, are located on the high plain to the south, with streams flowing in and out of them. McClelland Lake is located in the lowlands northeast of Bitumount in an area of internal drainage.

## 1.2. Climate

The climate of the Bituminous Sands Area is subarctic and is similar in many respects to that experienced in Edmonton. Fort McMurray, at an elevation of 800 feet, has a mean annual temperature of 29.8 degrees Fahrenheit and on an average remains frost free for approximately 67 days each year. Mean annual precipitation is approximately 18 inches over the region, although there is good reason to believe that there is an orographic effect on precipitation distribution.