ENVIRONMENTAL IMPACT ASSESSMENT OF A SOUR GAS PROCESSING DEVELOPMENT IN THE BRAZEAU REGION OF ALBERTA

Prepared by:
Gordon L. Brown

Presented to:
The Natural Resource Institute
University of Manitoba

In Partial Fulfillment of the Requirements for the
Degree of Master of Natural Resource Management

February, 1977

ENVIRONMENTAL IMPACT ASSESSMENT

OF A SOUR GAS PROCESSING DEVELOPMENT

IN THE BRAZEAU REGION OF ALBERTA

by

GORDON L. BROWN

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCE MANAGEMENT

This report deals with a sour gas processing plant that was being considered by Western Decalta Petroleum Limited, as of July 1976. To facilitate the completion of the detailed environmental impact assessment to be used for my practicum at the Natural Resource Institute, terms of reference were established based on the project as proposed at that time. However, the report does not necessarily reflect the final development proposal of Western Decalta Petroleum Limited. They may, in fact, choose a different plant location, capacity, and configuration.

February, 1977

Gordon L. Brown

A B S T R A C T

Potentially significant environmental effects were identified and evaluated pertaining to the construction and operation of a sour gas processing facility being considered for development within the Lower Brazeau region of Alberta. The study examined adverse and beneficial impacts associated with the physical, biological, social and economic environments.

The Lower Brazeau region is a relatively natural forested area within the lower foothills of the Boreal Forest. Major existing land uses include gas processing and hydro-electric power generation. There are no occupied residences within 20 miles of the proposed development site.

The plant under consideration would process approximately 15.5 million standard cubic feet per day (MMSCFD) of raw gas containing 1.5 percent H_2S, with a production of 14.0 MMSCFD sales gas, 8.4 long tons per day sulphur, and 195 barrels per day condensate. Raw gas would be collected from three wells through four miles of gathering system. The project would result in the direct disturbance of approximately 40 acres of land, consisting of gathering system rights-of-way (17 acres) and plant site (23 acres).

The study revealed that the major adverse effects would be:

(a) Direct loss of approximately 40 acres of vegetation, related wildlife habitat, and potential timberland as well as the exposure of soils highly susceptible to erosion.

(b) Production and release of low concentrations of SO_2 to the atmosphere.

(c) Increased noise levels and general activity in the vicinity of the project site leading to a reduction in land capability as ungulate range adjacent to the site.

(d) Land development opportunity costs, including reductions in recreation capability and fur-harvest potential.

The primary positive impacts that would be associated with the development include:

(a) Approximately 292 man-years of direct employment opportunities for Alberta residents over the 20 year life of the project.

(b) Natural gas and condensate royalties paid to the government of Alberta would approximate 1.7 million dollars per year for each of the 20 years of the project.

Mitigating measures to ameliorate adverse effects are recommended.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

ACKNOWLEDGEMENTS

I should like to express my sincere thanks to those persons who assisted me in the preparation of this report.

I am especially grateful to Mr. J. Lukacs, President, Western Research & Development Ltd. for the financial support and encouragement which enabled me to successfully complete the project.

Special acknowledgement is made to Mr. Jack Harper and Dr. J.P. Higgins of Western Decalta Petroleum Ltd. for permission to use this report for a practicum at the Natural Resource Institute; and to their staff members, Mr. Greg Hay and Mr. Ken Basaraba who assisted in gathering and supplying important data related to the study.

I am particularly grateful to the members of my practicum committee for their help and encouragement: Mr. E.M. Berlie, Mr. D.G. Colley and Dr. D.M. Leahey of Western Research & Development Ltd., and Mr. David Young of the Lombard North Group Ltd.

I would like to acknowledge with special thanks the technical assistance, interest, and support rendered by Messrs. Chris Harvey and Mervyn Davies, Mrs. Linda Sa'ad and Ms. Debbie Vekeman of Western Research & Development Ltd., and Miss Pamela E. McIntosh.

Finally, I appreciate the assistance from the following people who supplied important information related to the study: Mr. R.H. Brown, Petrofina Canada; Mr. Ed Brushet, Energy Resources Conservation Board, Environmental Protection Section; Mr. C. Mjolsness, Spray Lakes Saw Mills; Mr. Frank Nuspel, Alberta Forest Service; and Mr. Guy Boucher, Calgary Power Ltd.

INTRODUCTION

Western Decalta Petroleum Limited, Calgary, Alberta, is proposing to build a sour gas gathering system and gas processing/sulphur recovery plant about 35 miles southwest of Drayton Valley, Alberta. The development would facilitate the production and sale of 14.0 million standard cubic feet per day (MMSCFD) of natural gas from three gas wells in the Brazeau Shunda East Gas Field.

The location of the proposed development is shown in Figure 1.

Under Chapter 34 of the Alberta Land Surface Conservation and Reclamation Act (1973), the Minister of the Environment may, before approving the development proposed by Western Decalta Petroleum Limited, request that a report containing an assessment of the environmental impact be submitted. This report was accordingly prepared for Western Decalta Petroleum Limited, who anticipate such a request, and who wish to avoid delay to the greatest extent possible.

The objective of this environmental impact assessment report is to provide Western Decalta Petroleum Limited with comprehensive information concerning any potential environmental effects associated with the proposed development. The scope and format of this study is consistent with the Alberta Environmental Impact Assessment System Interim Guidelines (1975).

The report is organized in the following manner: Chapter 1 summarizes the report and contains recommendations intended to reduce or ameliorate the extent of anticipated adverse environmental effects associated with the proposed development. Chapter 2 contains a description of the proposed development, Chapter 3 describes the existing physical, biological and cultural environments that may be affected and Chapter 4 contains a comprehensive discussion of the anticipated environmental impacts that would be associated with the development.

Figure I LOCATION OF PROPOSED WESTERN DECALTA PETROLEUM LTD. GAS PROCESSING DEVELOPMENT.

The following terms or abbreviations used throughout the report are defined as they may not be familiar to all readers.

Natural gas: a naturally occurring complex mixture of hydrocarbon and nonhydrocarbon constituents which is obtained from a natural underground reservoir. It exists as a vapour at room temperature and atmospheric pressure.

Raw (feed) gas: untreated natural gas

Sales gas: gas that has the quality to be used as a domestic fuel. It meets the specifications set by a pipeline transmission company and/or a distributing company.

Sweet gas: gas in which the hydrogen sulphide content is less than 1 grain per 100 cubic feet.

Sour gas: gas in which the hydrogen sulphide content is greater than 1 grain per 100 cubic feet.

Acid gas: concentrated H_2S and CO_2 gas stream off a desulphurization unit which becomes the feed to the sulphur recovery plant.

Wet gas: gas that contains more than 0.1 U.S. gallons per thousand cubic feet of condensate.

Condensate: hydrocarbon liquid fraction obtained from a gas stream containing essentially pentanes and heavier hydrocarbons.

Lean gas: gas which contains less than 0.7 U.S. gallons per thousand cubic feet of propane and heavier hydrocarbons.

Rich gas: gas which contains more than 0.7 U.S. gallons per thousand cubic feet of propane and heavier hydrocarbons.

Gathering system: the system of pipelines transmitting gas from the wellheads to the processing plant.

MMSCFD: million standard cubic feet per day

bpd: barrels per day

LTD: long tons per day

Igpm: Imperial gallons per minute

ppm: parts per million

Lsd: legal subdivision, the smallest unit in the land survey system, approximately 40 acres.

1.0 SUMMARY AND RECOMMENDATIONS

1.1 The project and the existing environment

Western Decalta Petroleum Limited is proposing to build a sour gas gathering system and gas processing/sulphur recovery plant in the eastern portion of the Brazeau Gas Field, approximately 35 miles southwest of Drayton Valley, Alberta. The proposed plant would occupy an area of approximately 23 acres in the southeast quarter of Section 33, Township 45, Range 12, West of the Fifth Meridian. Raw gas would be collected from three wells located as follows:

(a) Lsd 6, Section 3, Township 46, Range 12, West Fifth Meridian;
(b) Lsd 11, Section 27, Township 45, Range 12, West Fifth Meridian;
(c) Lsd 15, Section 35, Township 45, Range 12, West Fifth Meridian.

The total length of the gathering system would be about four miles (6.4 km) and it would occupy a total right-of-way area of approximately 17 acres.

Normal operating throughput for the system would be approximately 15.5 MMSCFD of raw gas containing 1.5 percent hydrogen sulphide, with a production of 14.0 MMSCFD sweet gas, 8.4 LTD sulphur and 195 bpd condensate. Sales gas would be pipelined by Alberta Gas Trunk Line to the main gas transmission line 10 miles (16 km) west of the plant site. As sulphur marketing would be uneconomical, sulphur would be stored in block form on the site. Condensate would be stored in a 5000 barrel storage tank on the site and trucked out on a routine basis.

Processing plant units would consist of an inlet separator, a conventional diethanolamine (DEA) sweetening plant and a two stage Claus sulphur recovery plant. Tail gas would be incinerated and discharged through a 200 foot (61 meter) stack designed to maintain sulphur dioxide concentrations at treetop-level below the 0.2 ppm half-hourly average required by

Alberta Environment. In the event of a gas processing plant or sulphur plant shutdown, the raw feed gas or sulphur plant acid gas would be flared from a 160 foot (49 meter) stack. Should the raw gas be flared, treetop-level sulphur dioxide concentrations would be maintained below 0.2 ppm at all times. In order to maintain treetop-level sulphur dioxide concentrations below the 0.2 ppm half-hourly average when acid gas is flared, either the flaring time would be limited to ten minutes, or, as an alternative, the acid gas would be supplemented by 1.5 MMSCFD fuel gas.

Water requirements would be approximately five Igpm which would be obtained from a well drilled on the plant site. All process plant liquid effluents would be stored in a storage tank on site and would be periodically disposed of in a waste water injection well. No liquid wastes would be discharged to the surface or ground water system at any time.

Topography in the vicinity of the proposed development is gently rolling. Elevations vary from 3150 feet above sea level in the valley of the Brazeau River to 4000 feet above sea level approximately 13 miles (21 km) west of the plant site. The elevation at the proposed plant site is 3250 feet above sea level.

The area is underlain by Paskapoo formation bedrock. Surficial deposits include glacial till, lake and river clays and sand and gravel. Major soil types of the region are of the gray wooded variety and the organic variety.

Climate of the area is continental, having short warm summers and long cold winters; the warmest month is July with an average temperature of 15.5°C, and the coldest is January with an average temperature of -13°C. Winds are predominantly from the northwest with a mean annual speed of about 9 km/hr. Annual precipitation is about 500 mm, with approximately 100 mm falling in June.

Heavy forests of lodgepole pine, black spruce, tamarack, and trembling aspen, provide good habitat for a variety of birds and mammals. Land uses in the region include hydro-electric power generation, natural gas processing, occasional timber removal, and fur trapping. Only occasional human recreational activities are supported in the area, in the form of big game hunting and sport fishing. There are no occupied residences within 20 miles (32 km) of the proposed gas processing plant.

1.2 Potentially significant environmental effects

A summary of the anticipated potentially significant environmental effects that would result from the construction and operation of the proposed gas processing plant and gathering system is given in Figure 1.1. It is intended to indicate possible areas of concern that may exist between the development and various components of the existing environment. Although Figure 1.1 summarizes potential impacts as having either adverse or beneficial effects, it should not be considered as a comprehensive end product since it is useful only to identify possible general effects.

Adverse effects are categorized into three levels; minor, moderate, and major. Minor effects are intended to represent potentially minimal or relatively insignificant effects. Moderate effects are potentially significant although the degree of impact may be short term or would not be considered serious if mitigating measures were employed. Major effects are potentially significant effects that generally would be unavoidable even though mitigating measures would lessen the degree of impact to a certain extent.

For example in Figure 1.1, the potential adverse effect upon soils situated along the pipeline route and on the plant site during construction is considered to be major. This is due to the high potential for soil erosion resulting from the clearing of protective vegetation cover, and the distrubance of top soil for grading and pipeline burial. Mitigating

Potentially Significant Areas of Impact			Potentially Significant Effects During Construction 1*	Construction 2**	Operation 1*	Operation 2**
PHYSICAL ENVIRONMENT	LAND	SOILS	●	●	◒	◒
		LAND FORMS	◒	◒	–	–
	WATER QUALITY	SURFACE WATER	O	O	–	–
		GROUND WATER	O	O	–	–
	WATER FLOW REGIME	SURFACE WATER	◒	◒	O	O
		GROUND WATER	O	O	–	–
	ATMOSPHERE	AIR QUALITY	O	O	O	–
		NOISE	●	●	O	–
		ODOUR	O	O	O	–
BIOLOGICAL ENVIRONMENT	VEGETATION	TREES	●	●	O	O
		SHRUBS	●	●	O	+
	WILDLIFE	BIRDS	O	O	O	O/+
		SMALL MAMMALS	O	O	O	O/+
		LARGE MAMMALS	◒	◒	◒	O/+
CULTURAL ENVIRONMENT	LAND USE	RECREATION	O	O	O	O/+
		HYDRO POWER	–	–	–	–
		TIMBER PRODUCTION	O	O	O	O
		FUR TRAPPING	–	–	O	O
	SOCIAL ECONOMIC	SCENIC VIEWS	◒	◒	O	O
		EMPLOYMENT	+	+	+	+
		POPULATION	–	–	–	–

POTENTIAL EFFECT SYMBOLS

O	MINOR ADVERSE EFFECT
◒	MODERATE ADVERSE EFFECT
●	MAJOR ADVERSE EFFECT
+	BENEFICIAL EFFECT
–	NO EFFECT
/	MIXED EFFECT

Figure 1.1 SUMMARY OF POTENTIALLY SIGNIFICANT ENVIRONMENTAL EFFECTS RESULTING FROM CONSTRUCTION AND OPERATION OF GAS PROCESSING PLANT AND GATHERING SYSTEM.

* 1 — LAND INFLUENCED BY THE PROPOSED PLANT

** 2 — LAND INFLUENCED BY THE PROPOSED GAS GATHERING SYSTEM.

measures would lessen the degree of impact to a certain extent, however, soil erosion during construction could be significant. During operation, after revegetation has taken place along the pipeline rights-of-way, the potential adverse effects upon soils is considered to be moderate.

It is stressed that Figure 1.1 simply serves to outline potential areas of concern. For more detailed discussion of specific environmental effects and possible interactions the reader should refer to Chapter 5.

1.3 Unavoidable adverse effects

Major unavoidable adverse effects that are anticipated to be associated with the construction and operation of the Western Decalta Petroleum Limited gathering system and gas processing plant are:

(a) Adverse effects associated with clearing and grading operations, including:

- loss of approximately 40 acres of potential timberland;
- major disturbance to approximately 23 acres of landform due to grading operations on the plant site;
- removal of all vegetation and related wildlife habitat within the proposed development area of approximately 40 acres;
- exposure of approximately 40 acres of soils during construction of the plant and gathering system which would be highly susceptible to erosion due to the loss of protective forest cover.

(b) Sulphur dioxide would be released to the atmosphere although treetop-level concentrations would be maintained within the Alberta Environment half-hourly average sulphur dioxide concentration of 0.2 ppm at all times.

(c) Noise levels and general activity in the vicinity of the plant site and gathering system would increase during the construction period.

(d) Land capability as ungulate range along the northern shore of the Brazeau River south of the proposed development may be permanently reduced due to the general noise and activity associated with gas plant operation.

(e) Plant and well access roads would be upgraded allowing better access for big game hunters, which would result in increased hunting pressure.

(f) The fur harvest capability of the land in the immediate vicinity of the proposed development would be reduced.

(g) An aesthetic impact on the forest setting would be associated with the erection of permanent plant structures. The only structures that would be visible at any distance would be the 200 foot (61 meter) incinerator stack and the 160 foot (49 meter) flare stack.

1.4 Positive effects

A number of positive effects would be associated with the proposed development; the most significant of which are:

(a) Construction and operation would provide direct employment opportunities for Alberta residents. Approximately 292 man years of employment would be made available over the 20 year life of the project.

(b) Natural gas and condensate royalties paid to the province of Alberta would be in the order of 1.7 million dollars for each year of production.

(c) Thick forest presently unsuitable as ungulate grazing land would be cleared along the pipeline corridors resulting in a new food source of colonizing vegetation types preferred by ungulates. A favourable edge effect would develop around the plant site and along the pipeline corridors creating new habitat for birds and small mammals.

(d) Slightly improved access (an additional four miles) would be made available to big game hunters and fishermen.

1.5 Recommendations

A well planned and organized program that would minimize the potential adverse effects on the environment is an essential element of the design, construction, and operation of any industrial development. Modern pollution control technology, conservation practices and other mitigating measures would serve to ameliorate the possible negative impact on the local atmosphere, soil, and water regimes and also to associated vegetation, wildlife and human components.

The following mitigating measures are recommended to ensure that the potential adverse environmental effects resulting from the proposed Western Decalta Petroleum Limited gas processing operations may be minimized.

(a) During construction, activity should be restricted to within the plant site boundaries and pipeline rights-of-way. Disturbance of natural vegetation, water bodies, denning sites and other wildlife habitat should be avoided if possible.

(b) An archaeological or historic site field investigation should precede or coincide with clearing and construction for those areas where land would be disturbed.

(c) Areas of severe topographic relief should be avoided in the selection of the final pipeline routes. Gathering system corridors should parallel, to the extent practical, the existing well access roads.

(d) The perimeter of the plant site should be revegetated to reduce rain water runoff and soil erosion outside the process area.

(e) Revegetation should be conducted along the pipeline rights-of-way immediately after construction to minimize soil erosion along the corridors and to provide future wildlife grazing and refuge areas.

(f) Equipment specifications and location should be planned to minimize noise during plant operation.

(g) Strict control of food waste disposal should be employed to protect wildlife and to prevent conflicts with black bears.

(h) With the exception of the upper portion of the flare and incinerator stacks, low visibility colours should be used on all structures to reduce visual impact to recreationists.

(i) All merchantable timber should be removed for sawlog purposes prior to land clearing operations.

(j) All process waste fluids should be disposed of in a deep injection well. All process area water runoff should be directed to an impermeable holding pond and tested for water quality before being released to the surface water system.

(k) If Calgary Power Ltd. should raise the level of the Brazeau Reservoir to 3200 feet above sea level from the present 3170 feet above sea level, the 6-3-46-12 wellhead should be elevated to 4 feet above the maximum water level. A pad should be built around the wellhead for access purposes and the access road should be upgraded accordingly.

2.0 THE PROJECT

Western Decalta Petroleum Ltd. is proposing to construct a sour gas gathering system and gas processing plant about 35 miles southwest of Drayton Valley, Alberta to collect and process sour natural gas from three gas wells located within the Brazeau East Gas Field. The proposed locations of the gathering system and processing plant in relation to the gas wells are shown in Figure 2.1.

This chapter of the report outlines the major characteristics of the proposed development and the associated potential sources of environmental impact. The majority of the process and design details and characteristics have been supplied by Western Decalta Petroleum Ltd.

2.1 Natural gas characteristics

The combined raw gas composition is given in Table 2.1. The major components of the gas are hydrocarbons (totalling 93.85 Mol %), nitrogen, (0.15 Mol %), carbon dioxide (4.50 Mol %), and hydrogen sulphide (1.50 Mol %). The raw rich sour gas is saturated with water vapour at formation temperature and pressure.

Before the gas can be sold for domestic or commercial use it must meet certain market and transport specifications. The acid gas components (hydrogen sulphide and carbon dioxide), water vapour, the majority of butane, and all of the pentanes and heavier hydrocarbons must be removed.

The sales gas would be delivered to the Alberta Gas Trunk Line Ltd. (AGTL). The required sales gas specification is given in Table 2.2.

The gathering system and processing plant are specified and designed primarily on the basis of the raw gas characteristics. Local environmental features are a major consideration in the design of certain equipment. For example, the prevailing meteorological conditions and the local topography are important in the determination of the incinerator and

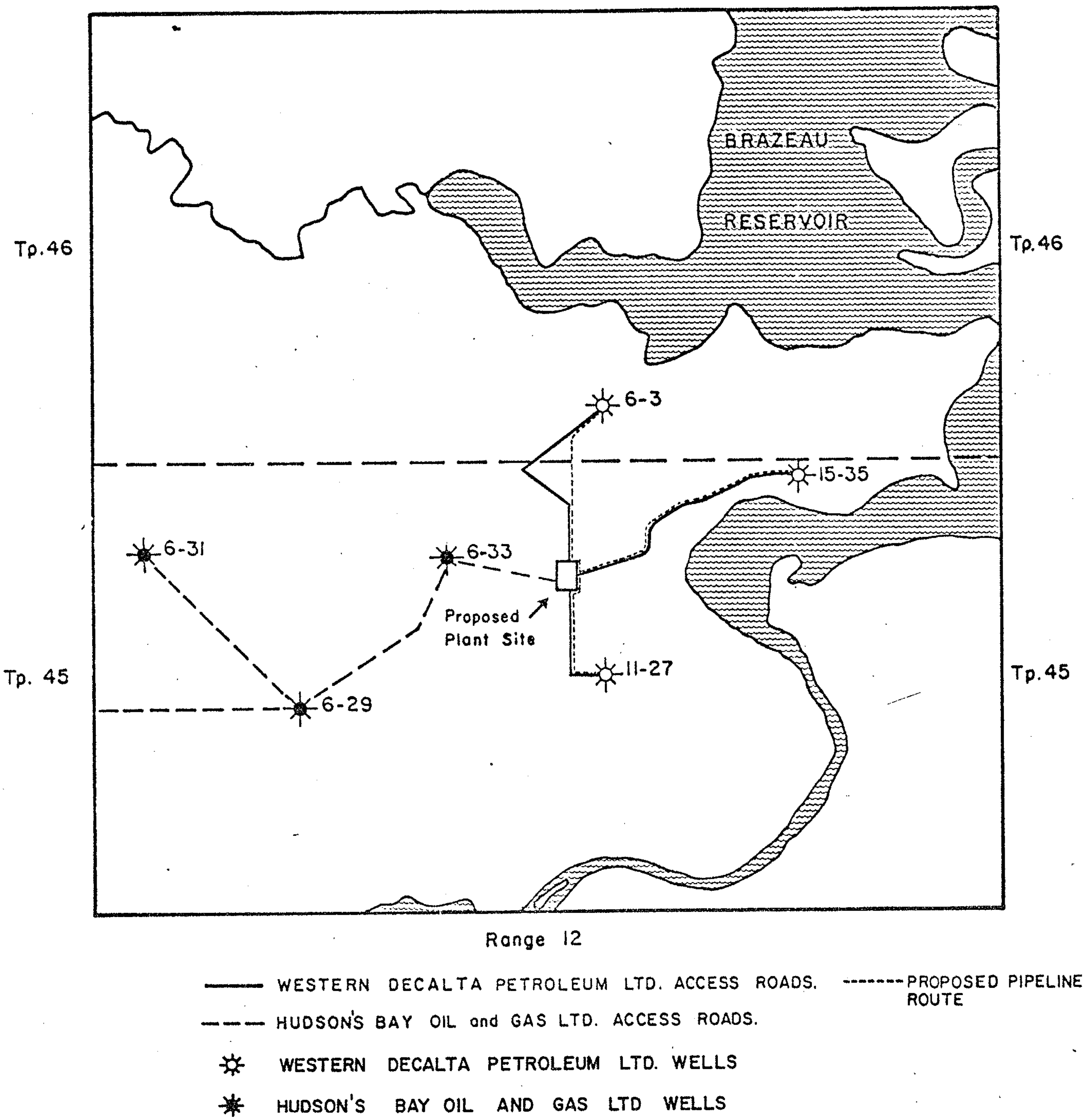


FIGURE 2.1 LOCATION OF WELLS, WELL ACCESS ROADS, PROPOSED PLANT SITE, AND PROPOSED PIPELINES.

Table 2.1

PLANT FEED GAS COMPOSITION
(ON A WATER FREE BASIS)

Component		Mole %
N_2		0.15
CO_2		4.50
H_2S		1.50
C_1 (methane)		87.28
C_2 (ethane)		3.72
C_3 (propane)		0.96
iC_4 (iso-butane)		0.27
nC_4 (normal butane)		0.31
iC_5 (iso-pentane)		0.15
nC_5 (normal pentane)		0.12
C_6 (hexane)		0.16
C_7+ (heptanes plus)		0.88
	Total	100.00

Table 2.2

SALES GAS SPECIFICATION

Characteristic	Specification
Gross heating value	975 BTU per SCF (minimum)
Hydrocarbon dew point	15°F (maximum)
Water content	4 lb per MMSCF (maximum)
H_2S content	0.25 grains per 100 SCF (maximum)
Mercaptans	0.2 grains per 100 SCF (maximum)
Total sulphur	1.0 grain per 100 SCF (maximum)
CO_2 Mol %	2.0 (maximum)

Source: Berlie (1971)

flare stack heights. The design must incorporate features that would enable the sales gas specifications to be met while maintaining all atmospheric and aqueous emissions below the limits established by the Alberta Department of the Environment. The maximum permissible concentrations of air and water emissions are discussed in Sections 4.1 and 4.2.

2.2 Gathering system

The raw gas would be collected from three wells and transported to the processing plant by means of small diameter (three-inch) two-phase flow pipelines. The wells are located as follows:

(a) Lsd. 6, Section 3, Township 46, Range 12, West Fifth Meridian.

(b) Lsd. 11, Section 27, Township 45, Range 12, West Fifth Meridian.

(c) Lsd. 15, Section 35, Township 45, Range 12, West Fifth Meridian.

As shown in Figure 2.1, the majority of the gathering system would be constructed adjacent to the existing well access roads in which case an additional 33-foot right-of-way would be employed. Otherwise, a 50-foot right-of-way would be required.

All line heating or dehydration equipment to prevent hydrate formation in the gathering system would be located at the wellheads. The heaters would be fired by fuel gas supplied by the processing plant through a small (approximately one-inch) diameter fuel line.

2.3 Gas processing and sulphur recovery plant

The proposed plant site would occupy approximately 23 acres, on an elevated piece of land between the three wells, in the southeast quarter of Section 33, Township 45, Range 12, West of the Fifth Meridian.

2.3.1 Capacity and production

The plant would have a design inlet capacity of 19.41 million standard cubic feet per day (MMSCFD) of raw gas, although the normal operating inlet rate would be 15.53 MMSCFD raw gas. The design rate is 125% of normal operating capacity. At the design rate, 17.50 MMSCFD sales gas, 243 barrels per day (bpd) of condensate and 10.50 long tons per day (LTD) of elemental sulphur would be produced. At the normal operating rate of 14.00 MMSCFD sales gas, 195 bpd of condensate and 8.40 LTD of elemental sulphur would be produced.

The design rates are used in this report as they represent the maximun throughput, and therefore the maximum emission rates.

2.3.2 Gas processing and sulphur recovery facilities

A simplified diagram of the major process units is given in Figure 2.2. A non-comprehensive discussion of the major facilities and the basic process is given below.

2.3.2.1 Inlet separator

The combined raw gas from the three wells would enter the inlet separator where sour formation water and condensate would be separated from the gas. Sour water would be fed to the sour water stripper (not shown) and condensate would be fed to the stabilizer tower.

2.3.2.2 Amine contactor

The raw gas would then enter a diethanolamine (DEA) sweetening plant where hydrogen sulphide and carbon dioxide would be absorbed by contact with DEA solution (22.5%) in a high pressure tower. The sweetened gas would then flow to the chilling unit and the rich DEA solution would be fed to the amine regenerator.

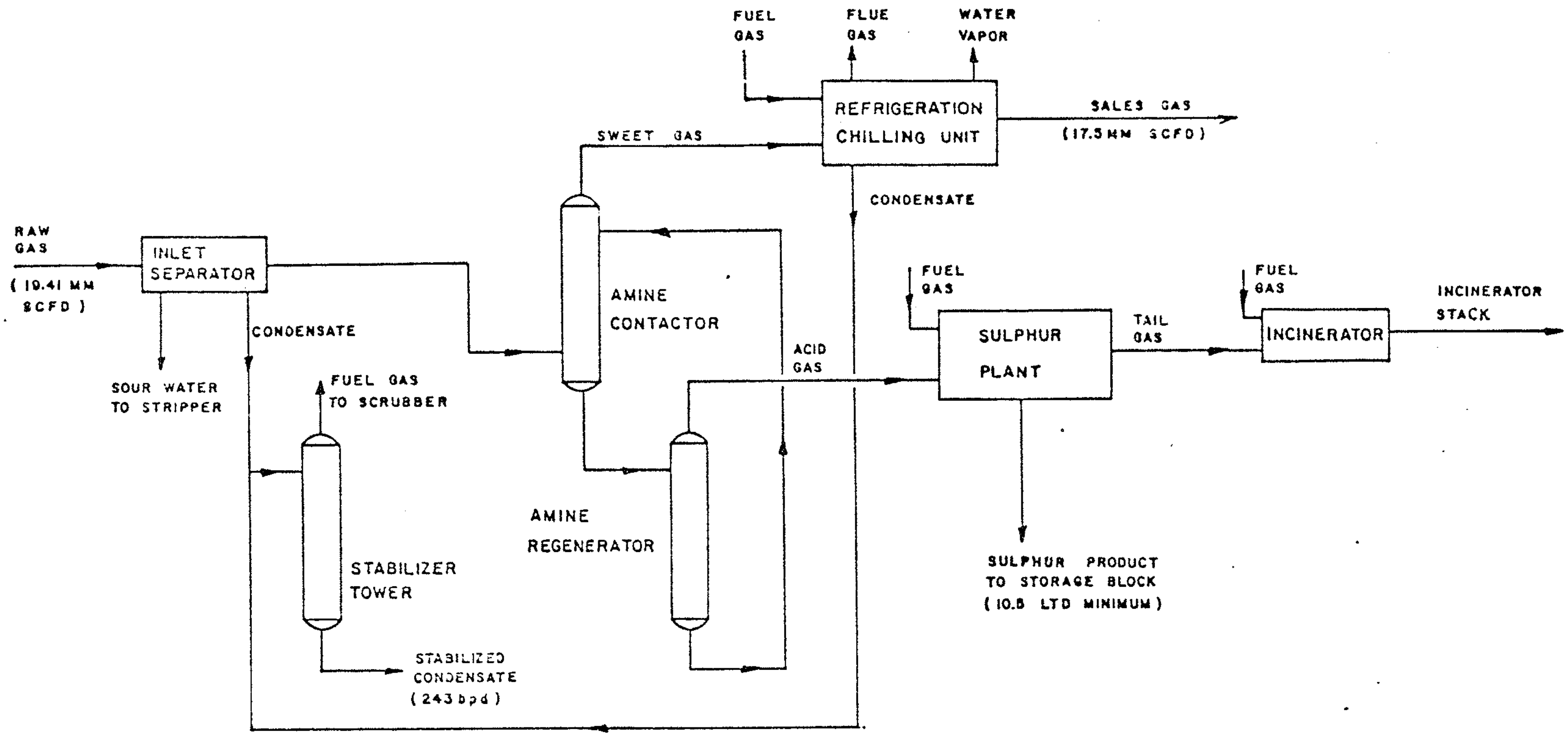


FIGURE 2.2 PROPOSED PROCESS SCHEMATIC FLOWSHEET

2.3.2.3 Amine regenerator

The rich DEA solution would be stripped in the amine regenerator, and the resulting lean DEA solution would be recycled to the amine contactor. Acid gas, composed of hydrogen sulphide, carbon dioxide and water vapour, would be directed to the sulphur plant.

2.3.2.4 Sulphur plant and incinerator

At design rate approximately 1.2 MMSCFD acid gas would enter a two stage Claus sulphur recovery plant designed to operate with a 95% recovery efficiency. At this rate 10.5 LTD of elemental sulphur would be produced and stored in block form on the site, as marketing would not be economical. Tail gas from the sulphur plant would be incinerated with fuel gas and the combustion products would be emitted through the incinerator stack. The proposed incinerator stack height is 61 meters (200 feet).

2.3.2.5 Chilling unit

Sweetened gas from the amine contactor would enter the chilling unit where it would be cooled by heat exchange and propane refrigeration. Glycol would be injected into the chilled gas which would subsequently enter a separation vessel (not shown). Glycol-water solution and unstabilized condensate would be removed, leaving 17.5 MMSCFD sales gas for delivery to AGTL at the boundary of the plant site. The glycol solution would be regenerated by means of a fuel gas fired reboiler and recycled, and condensate would be fed to the stabilizer tower.

2.3.2.6 Stabilizer tower

At the design rate a total of 294 bpd of unstabilized condensate from the inlet separator and the chilling unit would enter the low pressure stabilizer tower producing 243 bpd of stabilized condensate and 80,000 SCFD of fuel gas. Stabilized condensate would be retained in a 5,000 gallon storage tank to be trucked out periodically. Fuel gas would be used for normal process operations.

2.3.2.7 Sour water stripper

Sour formation water from the inlet separator would be stripped with sales gas to remove the majority of the hydrogen sulphide. The formation water would then be stored in a closed holding tank and trucked out periodically to be injected into a disposal well.

2.4 Atmospheric emission sources

There would be three sources of atmospheric emissions: the sulphur plant incinerator stack, the flare stack, and the fuel gas fired heaters.

The mass balance at design rate for the raw gas, the sweet gas from the amine contactor, the acid gas, and the sales gas are given in Table 2.3.

2.4.1 Sulphur plant incinerator stack

At the design rate, 1.2 MMSCFD of acid gas would be fed to the sulphur plant which would convert 95% of the hydrogen sulphide content to elemental sulphur. The remaining sulphur equivalent would be:

Flow rate (raw gas) = 2132.44 moles/hr

Flow rate (H_2S) = 31.86 moles/hr

Acid gas not converted = 31.86 moles/hr x 5/100 = 1.593 moles/hr

$$= \frac{1.593 \text{ moles/hr} \times 32 \text{ lb/mole} \times 24 \text{ hours/day}}{2240 \text{ lb/long ton}}$$

= 0.55 LTD sulphur equivalent

The unconverted sulphur would be incinerated with fuel gas and emitted through the incinerator stack. On combustion, hydrogen sulphide forms sulphur dioxide on a mole for mole basis. Thus the corresponding sulphur dioxide emission rate would be:

$$\frac{1.593 \text{ moles/hr } (H_2S) \times 386 \text{ SCF/mole}}{3600 \text{ seconds/hr}} = 0.17 \text{ SCF/second of } SO_2$$

Table 2.3

MASS BALANCE AT DESIGN RATE

Component	Raw gas	Sweet gas*	Acid gas	Sales gas
N_2	3.20	3.06	0.13	3.06
CO_2	45.59	0.00	93.80	0.00
H_2S	31.86	0.00	30.75	0.00
C_1	1861.68	1847.80	2.53	1817.41
C_2	79.33	77.30	0.30	72.74
C_3	20.47	19.29	0.10	16.00
iC_4	5.76	5.21	0.01	3.61
nC_4	6.61	5.80	0.00	3.59
iC_5	3.20	2.55	0.00	1.21
nC_5	2.56	1.92	0.00	0.79
C_6	3.41	1.95	0.00	0.49
C_7+	18.77	3.79	0.00	1.29
Totals				
Moles/hr	2132.44	1968.83	127.63	1920.20
MMSCFD	19.41	18.24	1.19	17.47

* from amine contactor

2.4.2 Flare stack

If the gas processing plant should experience a shutdown the raw gas would be directed to the flare stack where it would be ignited by the flare pilot burners. The proposed flare stack height is 49 meters (160 feet).

In the event of a sulphur plant shutdown the acid gas would be flared. At the design rate, the raw gas flare rate would be 19.41 MMSCFD and the acid gas flare rate 1.2 MMSCFD. In each case 31.86 moles per hour of hydrogen sulphide would be released. The corresponding sulphur dioxide emission rate would be:

$$\frac{31.86 \text{ moles/hr } (H_2S) \times 386 \text{ SCF/mole}}{3600 \text{ seconds/hour}} = 3.42 \text{ SCF/second of } SO_2$$

2.4.3 Fuel gas fired heaters

Fuel gas would be used on a continuous basis in the sulphur plant reaction furnace, the sulphur plant incinerator, the glycol regeneration heaters, and in the flare stack pilot burners. The fuel gas would be obtained from normal plant operations including amine flashing and condensate stabilization.

The fuel gas emissions would in all cases contain only low concentrations of carbon monoxide and oxides of nitrogen. The combustion products from fuel gas burnt in the sulphur plant would be emitted from the incinerator stack. The flare pilot burner emissions would be emitted through the flare stack. The other heaters would emit their combustion products through small individual stacks, approximately 10 meters (32 feet) in height.

2.5 Aqueous effluents

There would be a number of sources of aqueous effluents resulting from the normal operation. These are listed in Table 2.4 together with the flow rate of each, the contaminants present, the treatments that would be employed, and the disposal methods.

Table 2.4

POTENTIAL SOURCES AND TREATMENT OF AQUEOUS EFFLUENTS

Source	Flowrate (g.p.m.)	Contaminant	Treatment	Disposal
Inlet separator	2.0	H_2S formation water and hydrocarbons	Sour water stripper	Storage tank and disposal well
Condensate stabilizer feed drum	0.5	H_2S, hydrocarbons	Sour water stripper	Storage tank and disposal well
Sulphur plant inlet knockout drum	0.5	H_2S, DEA, hydrocarbons	Recycled to amine surge tank	-
Floor washings	1.0	Oil and grease, DEA treatment chemicals	none	Disposal well
Sanitary waste	1.0	Sewage	Septic tank	Field

The sour water from the inlet separator and stabilizer feed drum would be treated to reduce the hydrogen sulphide content, then retained in a sealed storage tank prior to disposal.

The process area and storage area at the plant site would occupy approximately 160,000 square feet. Surface rainwater runoff would be collected in ditches and directed to a 250,000 Imperial gallon capacity holding pond. The runoff water would be retained in this pond and would be tested before release to the surface drainage to ensure that the wastewater limits contained within the Alberta Clean Water Act were not being exceeded.

2.6 Sources of noise, dust, and odour

The primary disturbance resulting from excessive noise levels, dust and odours would be associated with the construction of the plant and facilities. Disturbance would be caused by the operations of heavy earth moving equipment, fabrication noise, and construction vehicle traffic.

The potential sources of noise, dust, and odour during normal plant operations are as follows.

2.6.1 Noise

The most significant sources of noise associated with plant operations would be (a) exhaust and mechanical noise from the reciprocating compressors, (b) fan noise resulting from the operation of air blowers at the inlets to the sulphur plant and tail gas incinerator, and (c) fan noise associated with the aerial coolers.

The noise levels associated with the operation of all equipment would comply with existing Energy Resources Conservation Board guidelines which state the noise levels may not exceed 65 dB(A) by day as measured at the closest residence, and 50 dB(A) by night. Where possible noise levels would comply with Alberta Department of Labour requirements for workplace noise levels. If not possible workers would be required to wear noise protection in areas where the noise levels exceeded 85 dBA, or limit their exposure (Alberta Board of Health Regulation 30/71).

2.6.2 Dust

Due to market conditions, liquid sulphur production will be poured on a sulphur block for long term storage in solid form.

When the sulphur is shipped in the future, it would be melted and recovered from the storage block in a way that would substantially eliminate the dust problem.

2.6.3 Odour

The most significant sources of odour associated with the process would be the hydrogen sulphide and sulphur dioxide from the sulphur plant operation, liquid sulphur pouring on the sulphur block, and incinerator stack emissions.

The only major chemicals used in the process, diethanolamine and glycol, are well contained and give off little objectionable odour. Condensate is another possible source of odour, although careful handling techniques within the process would effectively contain this potential source of odour.

2.7 Servicing requirements

The estimated maximum electrical power requirements of approximately 100 kw would be supplied by Calgary Power Ltd. The closest transmission line, originating at the Calgary Power Brazeau power station (located in the south half of Township 46, Range 11) runs south along the eastern side of the Brazeau Reservoir, then swings west and terminates at the

Tennaco gas plant (Section 10, Township 44, Range 12). The Western Decalta transmission line would likely run north from the Tennaco plant along the west side of the Brazeau Reservoir, then east to the plant.

The estimated water requirement of 5 Igpm would be obtained from a well drilled on the plant site. Approximately half of this water would be used for process plant requirements and half for floor washing and sanitary purposes.

2.8 Construction schedule

The estimated construction time for the gathering system and processing plant is eight months. Subject to the necessary approvals construction would begin in the spring of 1977 with plant completion and start up about a year later.

3. EXISTING ENVIRONMENTAL CHARACTERISTICS

This chapter summarizes the major features of the physical and biological environment, land use, land resource capabilities, and the social and economic environments that would be affected by the development. In Chapter 4 the anticipated interactions between the proposed development and the existing environmental characteristics will be described.

The study area, as shown in Figure 3.1, refers specifically to the southern half of Township 46, Range 12, west of the Fifth Meridian, and the northern half of Township 45, Range 12, west of the Fifth Meridian.

3.1 Physical environment

The physical environment refers to the existing topographical features, geological features, water resources, soils and climate. The various characteristics of the physical environment that are described do not necessarily refer to areas that would be directly affected. However, certain characteristics are included which are significant in the determination of potentially significant interactions. For example, the topographical features surrounding the proposed development that are included are important in calculating the maximum sulphur dioxide concentrations that would occur at various distances from the gas processing plant. Climatic features are also important in determining sulphur dioxide concentrations.

3.1.1 Topographical features

The study area is situated within the Western Alberta High Plains (Toharsky, 1971) and is characterized by rolling to hilly topography. Relief varies from less than 3150 feet above sea level (ASL) in the Brazeau River valley to over 3400 feet ASL at the western boundary of the study area. With the exception of the Brazeau River valley, relief is relatively gentle in the eastern half of the study area, with elevations averaging about 3200 feet ASL. A number of ranges of hills surround the area on all sides, with maximum elevations ranging from 3250 to greater than 3700 feet ASL.

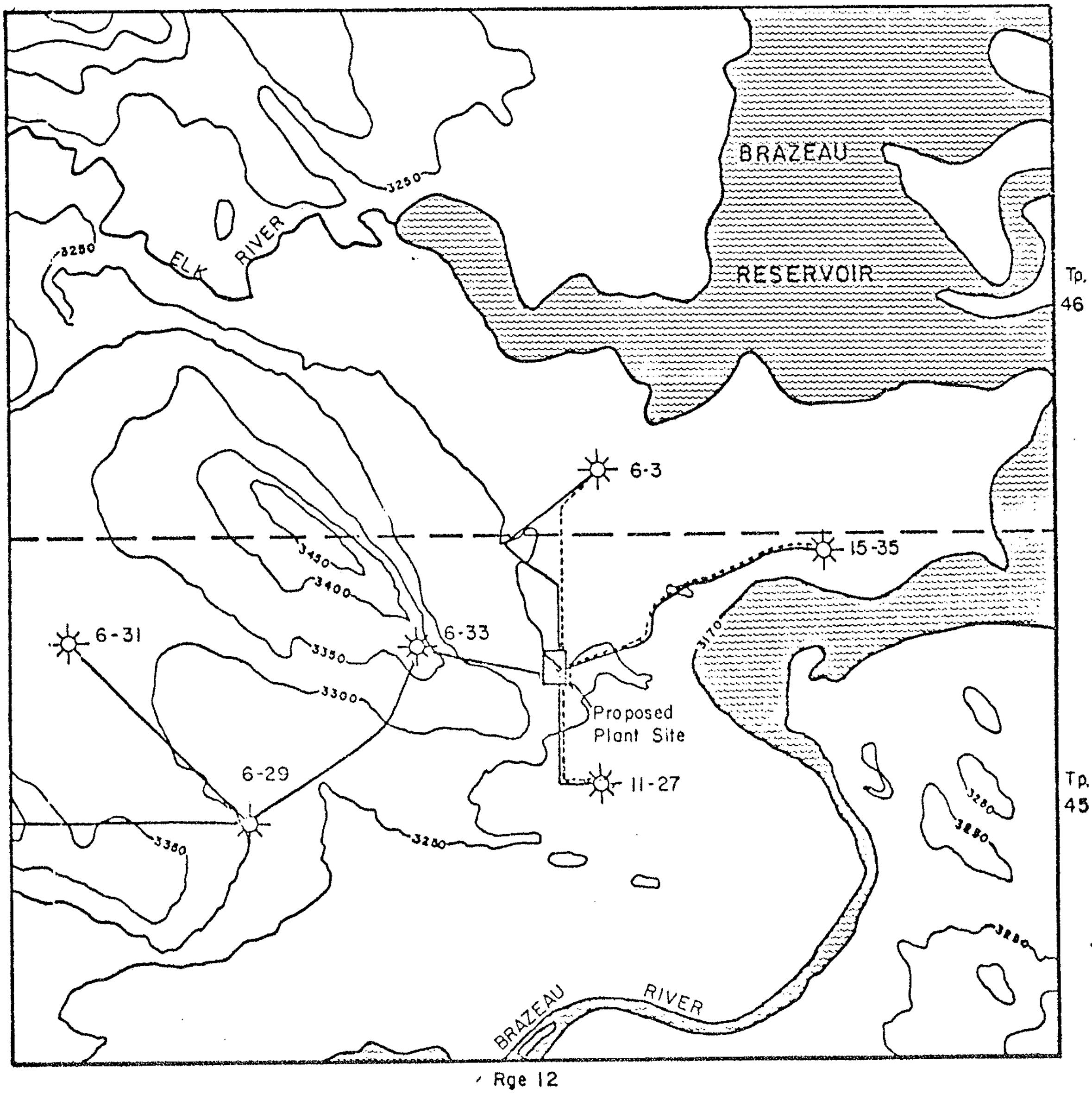


FIGURE 3.1 GENERAL OUTLINE OF STUDY AREA

Outside the study area the topography rises steadily in elevation to the west and southwest, reaching elevations in the foothills belt in excess of 5000 feet at the western boundary of the Lower Brazeau drainage district.

The average elevation east of the study area drops to about 2700 feet at the junction of the Brazeau and North Saskatchewan rivers. The mean slope of the Lower Brazeau drainage district is about 7.5 percent.

3.1.2 Geological characteristics

The primary geological characteristics are described in terms of bedrock formations and surficial deposits.

3.1.2.1 Bedrock formations

Only one bedrock formation is exposed in this portion of the Western Alberta High Plains. This is the continental, Upper Cretaceous-Tertiary Paskapoo formation, which is correlative to the upper part of the Brazeau formation of the foothills. The Paskapoo is underlain by the Upper Cretaceous Edmonton group and the Belly River formation which are correlative to the lower part of the Brazeau formation (Toharsky, 1971).

The Paskapoo consists of non-marine sandstones and shales, with a few thin coal seams. In a survey conducted north of the study area, the formation varies in thickness from a maximum of about 500 feet in the valley of the North Saskatchewan River in Township 49, Range 7 to a maximum of about 2000 feet in the upland areas in Townships 48, 49, Range 10 (Farvolden, 1961).

The foothills belt in the western portion of the Lower Brazeau drainage district is underlain by the Upper Cretaceous Brazeau formation, a non-marine shale sandstone sequence.

3.1.2.2 Surficial deposits

Between the time of deposition of the Paskapoo formation and the beginning of glaciation there was a long period of erosion, which formed rounded hills and southeast trending ridges with intervening broad valleys. Alluvial deposits were laid down in all the ancient channels.

During the Pleistocene the study area and surrounding region was subjected to the activity of glaciers which originated in two separate areas. The first of these, called the Continental or Eastern glacier, moved in a southwesterly direction from the Canadian Shield area. The Cordilleran or Western glacier originated in the mountains of British Columbia and spread eastward.

Rivers flowing down from the Cordilleran glacier deposited coarser materials as eastward trending eskers and carried finer detritus further east. Drainage was hampered in the vicinity of the study area where the Cordilleran glacier met the Continental glacier and formed extensive networks of lakes. As the glaciers melted and receded, the area was covered with glacial drift, including till, lake clays, and sand and gravel deposits. Extensive sand and gravel deposits are present along the floodplain of the Brazeau River. Alluvial deposits of sand and clay were formed as silt-carrying rivers ran into lakes, and today muskegs are common. Some U-shaped sand dunes (aeolian formations) are present in the area where wind has shifted the fine sands of dry lake basins.

The erosion potential of most of the till deposits is low because of the coarseness of the material and because of calcium carbonate cementation. Alluvial fans and outwash deposits have high infiltration capacities and are not easily eroded. Fine tills and residual soils over shale bedrock, however, are highly erodable (FRAS, 1973).

3.1.3 Soils

Soils characteristic of the study area and surrounding region fall into two main orders. These are (1) soils of the Luvisolic order, which are composed of the gray wooded group, and (2) soils of the Organic order, which are composed of the Mesisol group.

Luvisolic soils are well to imperfectly drained soils that have developed under forest or forest-grassland transition zones in moderate to cool climates. These slightly acid soils are moderately to highly leached with light coloured, ashy surface horizons. They are low in fertility since the leaching process has carried much of the soluble mineral nutrients, especially sulphur and phosphorous, from the upper horizons to subsoil horizons. Lime is encountered 30 to 40 inches below the surface. In the native forested state the leaf mat decomposed and leached out quite rapidly with the result that the surface horizon is low in organic matter and nitrogen (Alberta Soil Survey, No. 19).

The fine textured subsoil associated with gray wooded soils has a low permeability and therefore takes water slowly and drainage is poor. Consequently on sloping land severe erosion may result if the stabilizing vegetation is removed.

Gray wooded soils of the area will respond to good agricultural practices as they are located in a favourable rainfall area. Their agricultural capability can be upgraded by the addition of organic matter and the application of mineral fertilizers. It is essential to include legumes in the crop rotation to add nitrogen and organic fibre. Wheat grown on these soils is usually low in protein content and hence of poor quality. However, good malting barley and legumes for hay and seed may be grown successfully (Alberta Soil Survey, No. 19).

Organic soils are poorly drained and are characterized by an accumulation of peat or moss and 30 percent or more organic matter. These soils are restricted to muskeg areas and are normally quite erodable because they are low in calcium carbonate. The muskeg, however, is generally found on flat ground where there is little waterflow, so that the hazard of erosion is not great (FRAS, 1973). These soils are normally located on level to depressional landscapes where surface waters accumulate. In their natural state they are of little agricultural value. If drained, they are generally suitable only for pasture and woodland. However, since they are excellent reservoirs for surface water that help control spring flooding and provide for a steady stream discharge throughout the summer, the larger areas of these soils should never be drained (Alberta Soil Survey No. 28).

Frozen conditions persist longer in the spring in organic soils. In addition they are subject to earlier fall frosts than the better drained mineral soils. Drained organic soils are subject to serious ground fire, and uncontrolled burning can result in complete loss of the organic layer, uneveness of land surface, aggravation of drainage problems, and exposure of poorly structured mineral soils (Alberta Soil Survey No. 28).

3.1.4 Water resources

Water resources that may be affected include standing and flowing surface water systems and the ground water system.

3.1.4.1 Surface water system

The study area is within the Lower Brazeau drainage district, which drains an area of 2190 square miles above the Big Bend Power Plant (Water Survey of Canada). Surrounding the Lower Brazeau drainage district are the Nordegg-Baptiste drainage to the south, the Blackstone to the southwest, the North Saskatchewan to the east, and the Pembina drainage to the north. These drainage districts are shown in Figure 3.2. With the exception of the Pembina River, which flows into the Athabasca River and ultimately into the Arctic Ocean, all these drainage systems are part of the Nelson River drainage system and discharge into the Hudson Bay.

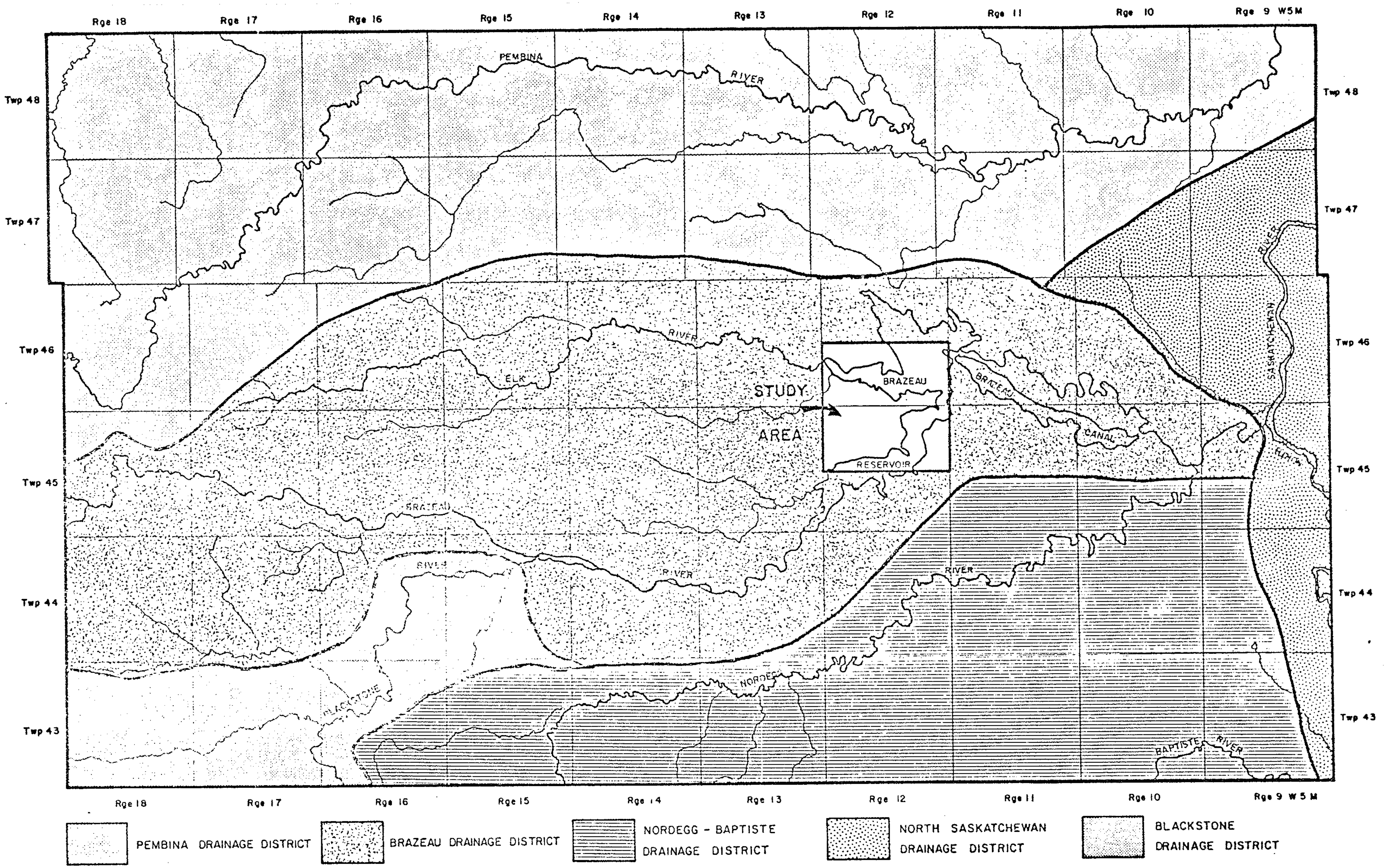


FIGURE 3.2 MAJOR DRAINAGE DISTRICTS IN THE VICINITY OF THE STUDY AREA

The main watercourses within the study area are the Brazeau River and the Elk River. The Brazeau River, which is a tributary of the North Saskatchewan River, flows in a northerly direction through the eastern portion of the study area. The Elk River flows eastward into the Brazeau River in the northern portion of the study area.

Under an agreement between the province of Alberta and Calgary Power Ltd., the Brazeau Dam and Big Bend Power Plant were constructed at the Big Bend site on the Brazeau River between 1961 and 1969. The resulting reservoir now covers a large part of the northern half and southeast quarter of the study area. The dam regulates the flow of the North Saskatchewan River and the power plant produces up to 350,000 kw of hydro-electric power. The maximum level of the reservoir is 3,170 feet ASL since the construction of a spillway at the main dam in 1970 and the low water level is 3102 feet ASL. The ultimate high water level is proposed to be 3,200 feet ASL.

The reservoir has an area of 10,600 acres and contains up to 425,000 acre feet of water (FRAS, 1973). Flow data and water quality data have been monitored for the Brazeau River by Calgary Power Ltd. and Environment Canada (Water Quality Branch, Water Survey of Canada). Monthly maximum, minimum and mean discharges for the Brazeau River below Big Bend plant during the years 1964 to 1974, and below Cardinal River for the years 1971 to 1975 are given in Table 3.1. Brazeau River water quality data monitored by Environment Canada is given in Appendix A.

3.1.4.2 Groundwater system

Groundwater occurence and yield data were estimated for the study area and surrounding region by the Alberta Research Council (1971, 1972). Since limited well data was available in the immediate vicinity of the study area, probable yields were based on estimates from qualitative information such as aquifer lithology and flow regime, and typical yields from surrounding wells with similar features.

Table 3.1

MONTHLY MAXIMUM, MINIMUM, AND MEAN DAILY DISCHARGES IN CUBIC FEET PER SECOND FOR THE BRAZEAU RIVER BELOW BIG BEND PLANT 1965 to 1974 AND FOR THE BRAZEAU RIVER BELOW CARDINAL RIVER 1971-1975

	J	F	M	A	M	J	J	A	S	O	N	D
Maximum	5830	6120	4500	4940	7370	18,100	20,300	16,200	7010	6430	4390	8270
Day-year	05-71	12-73	13-73	13-73	08-73	27-72	05-66	06-66	10-68	2-72	08-73	4-70
Minimum	411	331	382	5	5	32	8	5	5	15	34	160
Day-Year	08-74	20-23	08-74	31-66	1-66	30-08	11-68	18-65	13-65	29-67	16-74	15-74
Mean 1965-1974	1617	1642	1822.3	1135	2172	4181	4256	2516	1033	1210	1573	1621

BRAZEAU RIVER BELOW CARDINAL RIVER 1971-1975

	J	F	M	A	M	J	J	A	S	O	N	D
Maximum	-	-	-	-	5070	12,400	4510	3220	1570	1290	-	-
Day-year	-	-	-	-	31-72	25-72	08-72	10-72	1-74	1-72	-	-
Minimum	-	-	-	-	500	1000	1470	1080	649	385	-	-
Day-year	-	-	-	-	1-75	9-75	24-75	14-75	30-75	31-75	-	-
Mean 1971-1975	-	-	-	-	1753	4728	3254	2242	1149	921	-	-

Source: Environment Canada, Water Surveys of Canada

The Research Council's estimated 20-year safe yield (the constant rate at which a well could be continuously pumped so that at the end of 20 years the water level will be drawn down to the top of the producing aquifer) was 25 to 100 Imperial gallons per minute (Igpm) in the study area. These yields are typical of most of the region underlain by the Paskapoo Formation, where water would normally be taken from a single sandstone aquifer at depths of less than 300 feet below the surface.

Where sandstones are more abundant in thick, more porous layers, the expected yields are 100 to 500 Igpm. These higher yields are estimated for a large area south of Chip Lake, which is about 50 miles north of the study area, and also east in the vicinity of the North Saskatchewan River. Yields west and south of the study area are estimated at 5 to 25 Igpm for some parts of the Paskapoo Formation that contain an abundance of shale, and where aquifers exist as thin sandstone layers or fractured shale.

The groundwater in the region generally contains less than 1000 ppm of total dissolved solids. In the Paskapoo formation the water is generally hard (calcium and magnesium cations dominant) in upland areas and soft (sodium and potassium cations dominant) in topographically lower areas. In upland areas the hard water initially encountered gives way to soft water in lower aquifers.

3.1.5 Climatic features*

Long-term meteorological records have been kept at Rocky Mountain House, which is located approximately 65 kilometers southeast of Brazeau Dam.

3.1.5.1 Surface winds

Observations of wind velocity are made at Rocky Mountain House, where the wind instrument is situated 16 meters above ground level. The surrounding country is rolling plateau and the mountains are situated 50 kilometers to the west. The data considered here are based on the 10-year period 1957 to 1966 inclusive.

---

*Section 3.15 was compiled by Mrs. L. Sa'ad, Western Research & Development Ltd.

Figure 3.3 is a wind rose showing the mean annual wind speed as a function of wind direction and the wind direction frequency. Predominant winds (33 percent) are from the northwest quarter. Winds from the southeast quarter occur nearly as frequently (30 percent of the time). The mean annual wind speed at Rocky Mountain House is 9.1 kilometers per hour. The average annual wind speed at 60 meters (the recommended incinerator stack height) is expected to be 10.6 kilometers per hour, based on neutral atmospheric conditions (Haltiner and Martin, 1957).

A histogram presenting the mean annual wind speed frequency of occurrence is shown in Figure 3.4. These data show that the most probable wind speed is between 6 and 11 kilometres per hour (44.9 percent of the time).

3.1.5.2 Temperature

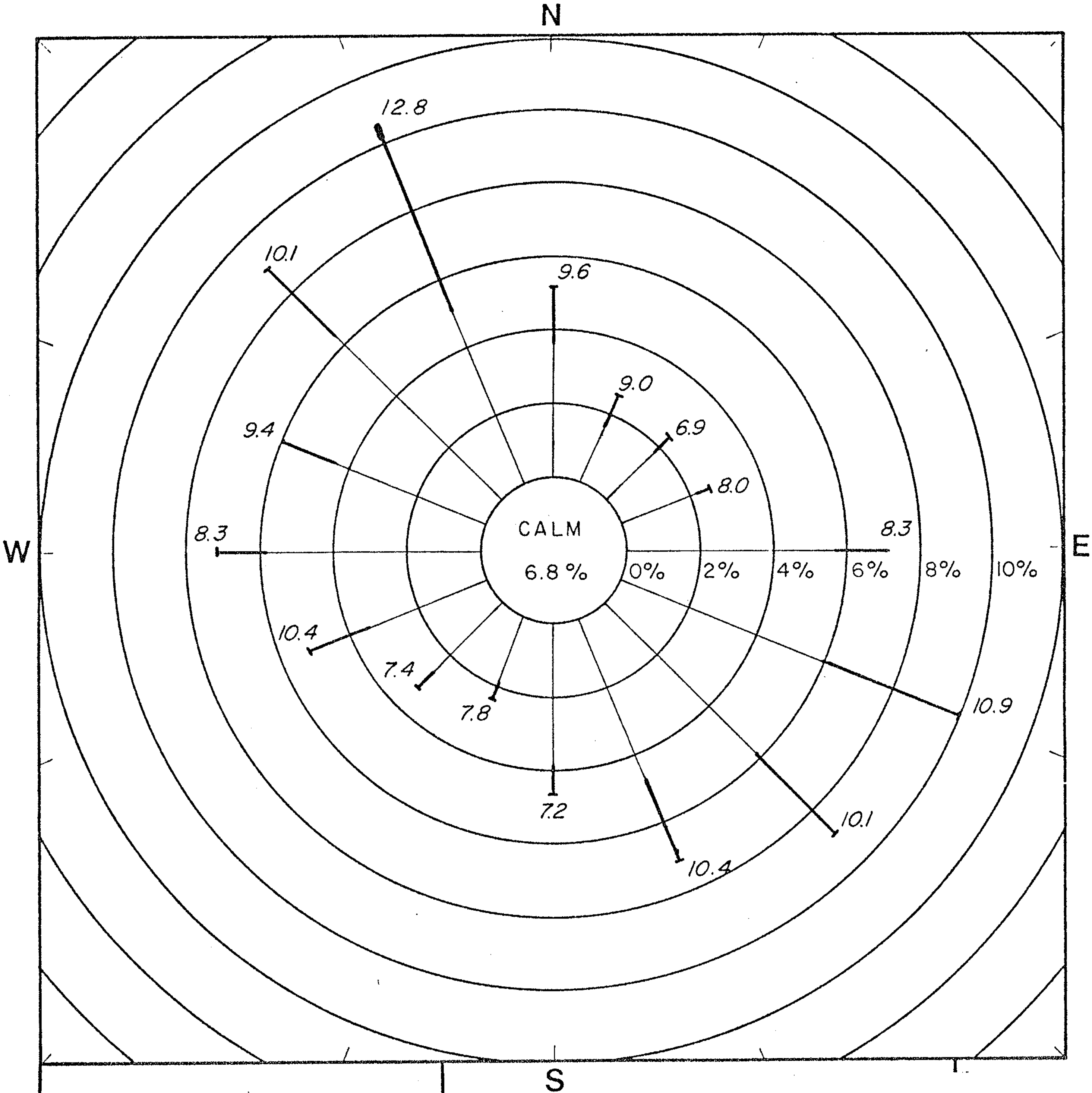
The annual mean daily temperature data based on observations made at Rocky Mountain House are presented in Figure 3.5. The mean daily temperature is 2.5°C.

The summers are short and warm, the warmest month being July with an average temperature of 15.5°C. The winters are long and cold and the average temperature for the coldest month (January) is -13.0°C. The mean annual temperature range is 28.5°C.

For the Edson area, (about 97 kilometers northwest of the study area) the frost-free period is approximately 75 days (Alberta Soil Survey No. 28). The last spring frost usually occurs between June 1 and June 15, and the first fall frost after August 15.

Growing degree-days are defined by the Atmospheric Environment Service as:

$$\sum(Ta - 5.5) \text{ Celsius}$$



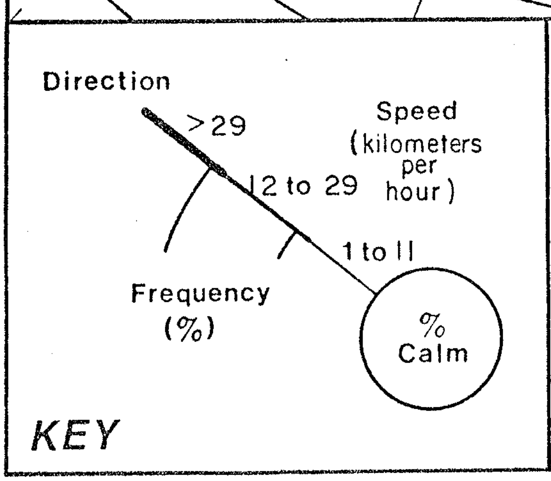


Figure 3.3 MEAN ANNUAL WIND SPEED and DIRECTION FREQUENCY CHART BASED ON 10 YEARS OF DATA GATHERED AT ROCKY MOUNTAIN HOUSE FROM 1957 to 1966. THE MEAN ANNUAL WIND SPEEDS ARE SHOWN IN *ITALICS*.

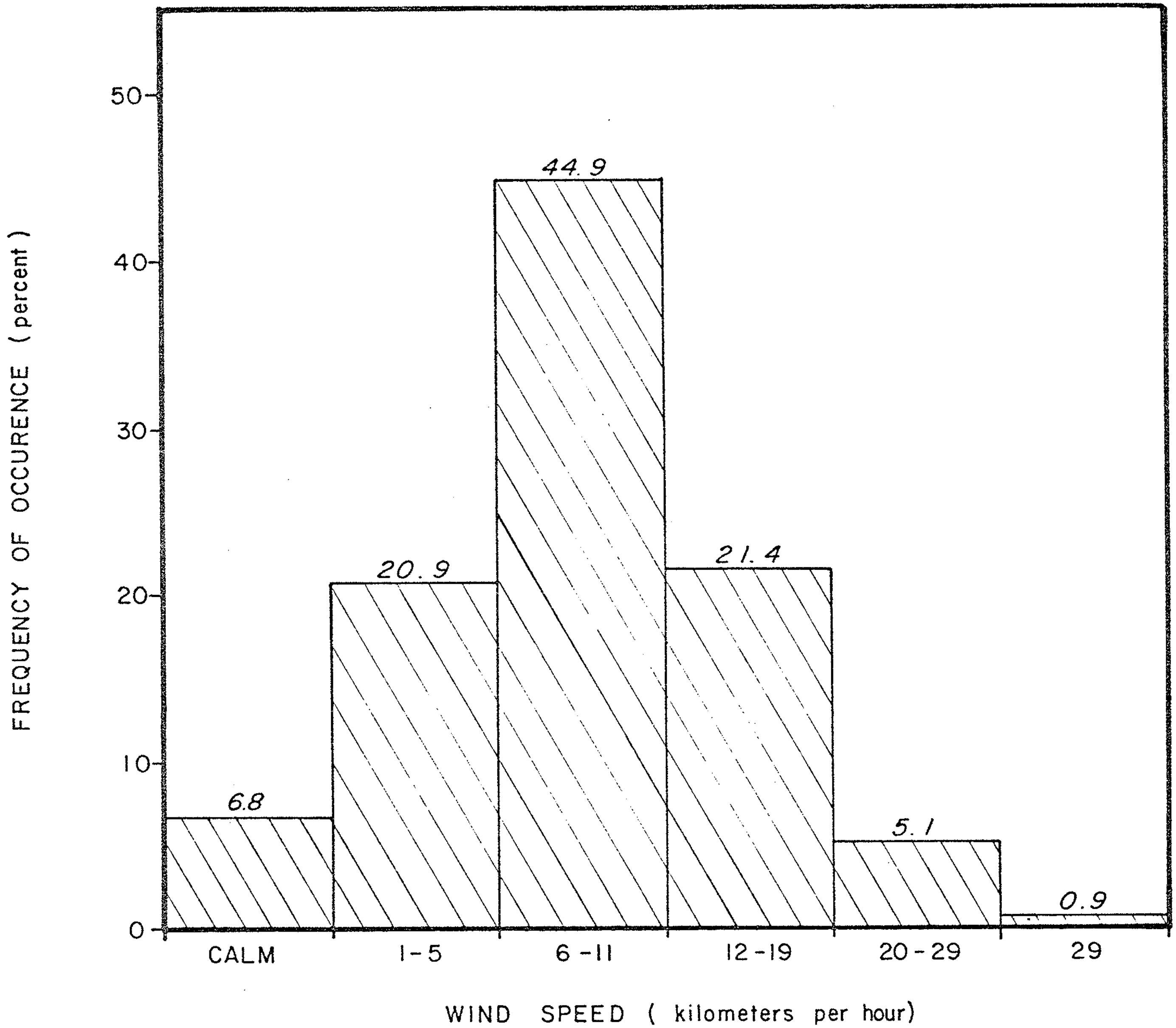


Figure 3·4 THE FREQUENCY OF OCCURENCE OF VARIOUS WIND SPEEDS BASED ON 10 YEARS OF DATA GATHERED AT ROCKY MOUNTAIN HOUSE (1957 to 1966). THE FREQUENCIES ARE SHOWN IN *ITALICS*

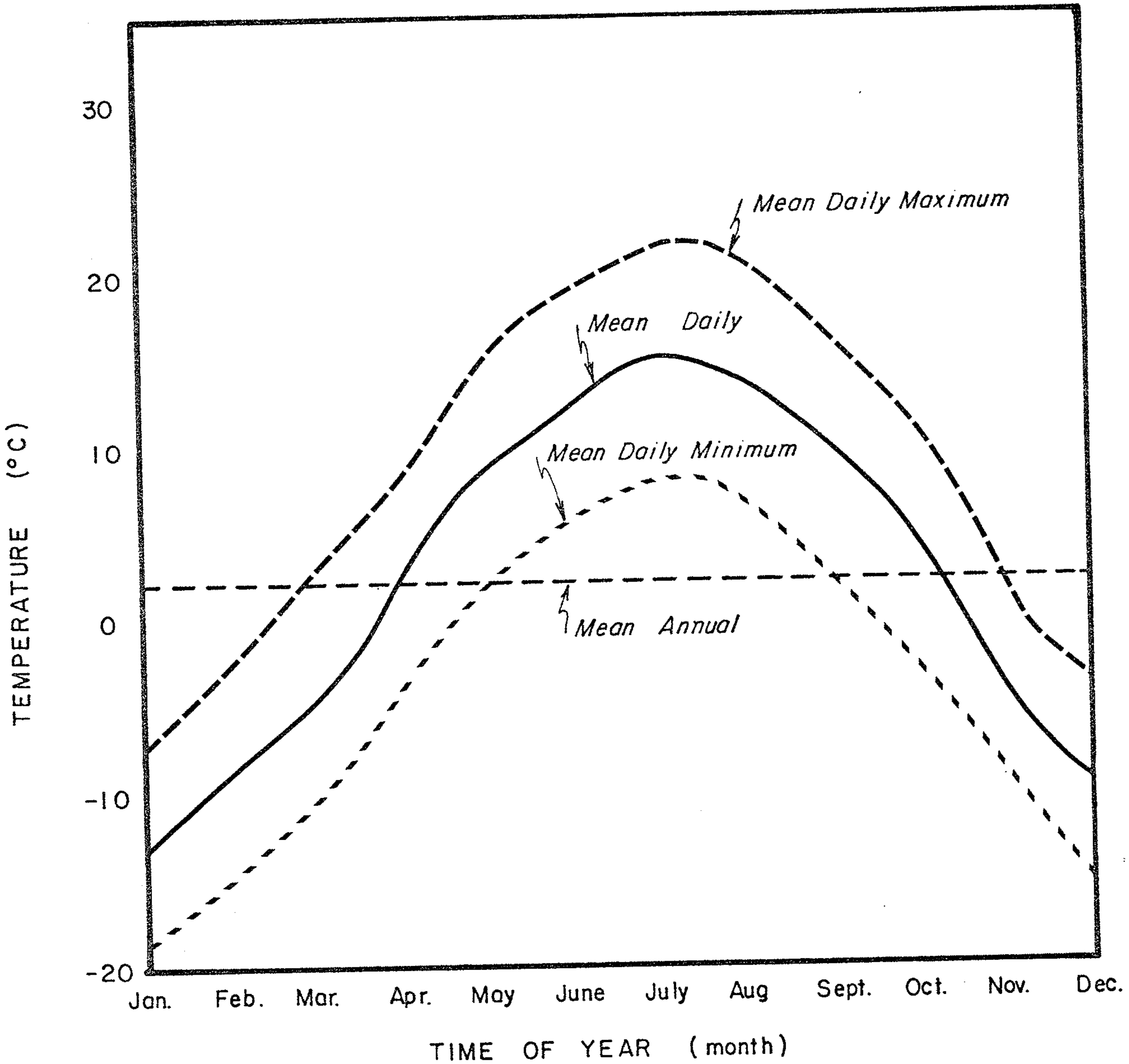


FIGURE 3.5 MEAN DAILY TEMPERATURE DATA AS A FUNCTION OF TIME OF YEAR BASED ON DATA GATHERED AT ROCKY MOUNTAIN HOUSE FROM 1941 – 1970.

where: Ta = mean air temperature for the day
$\sum$ = indicates that successive daily values are summed.

The concept assumes that growth begins (or becomes significant) as air temperature rises to a threshold value of 5.5°C. It is then assumed that subsequent growth is related to the accumulation of degree-days above the threshold. Hence accumulated temperatures, expressed in growing degree-days, are a crude indicator of net radiative energy income during the growing season (Hare and Thomas, 1974). The area around Rocky Mountain House can expect approximately 1100 Celsius growing degree-days. The average for the Calgary region is approximately 1400 degree-days.

3.1.5.3 Precipitation

The mean annual total precipitation as recorded at Rocky Mountain House is 543.0 millimetres, most of which falls during the growing season (May to September inclusive). These five months account for 68 percent of the annual total precipitation. Figure 3.6 is a line graph showing the mean total precipitation as a function of the time of year. The most precipitation occurs during June and the least in November.

Mean total precipitation peaks in June (Figure 3.6), although much of the summer precipitation is associated with thunderstorm activity which peaks in July (Figure 3.7). However the fact that thunderstorm activity peaks one month after the peak total precipitation suggests that much of the June precipitation is associated with synoptic disturbances rather than with localized thunderstorms. The most intense rainfall (millimeters per day of measurable rain) can be expected during May, June and July. Consequently this period would be critical with respect to soil erosion and reclamation of land disturbed during construction.

3.1.5.4 Solar radiation and cloud cover

The meteorological station closest to the proposed plant site for which there are records of hours of bright sunshine and hours of cloudiness,

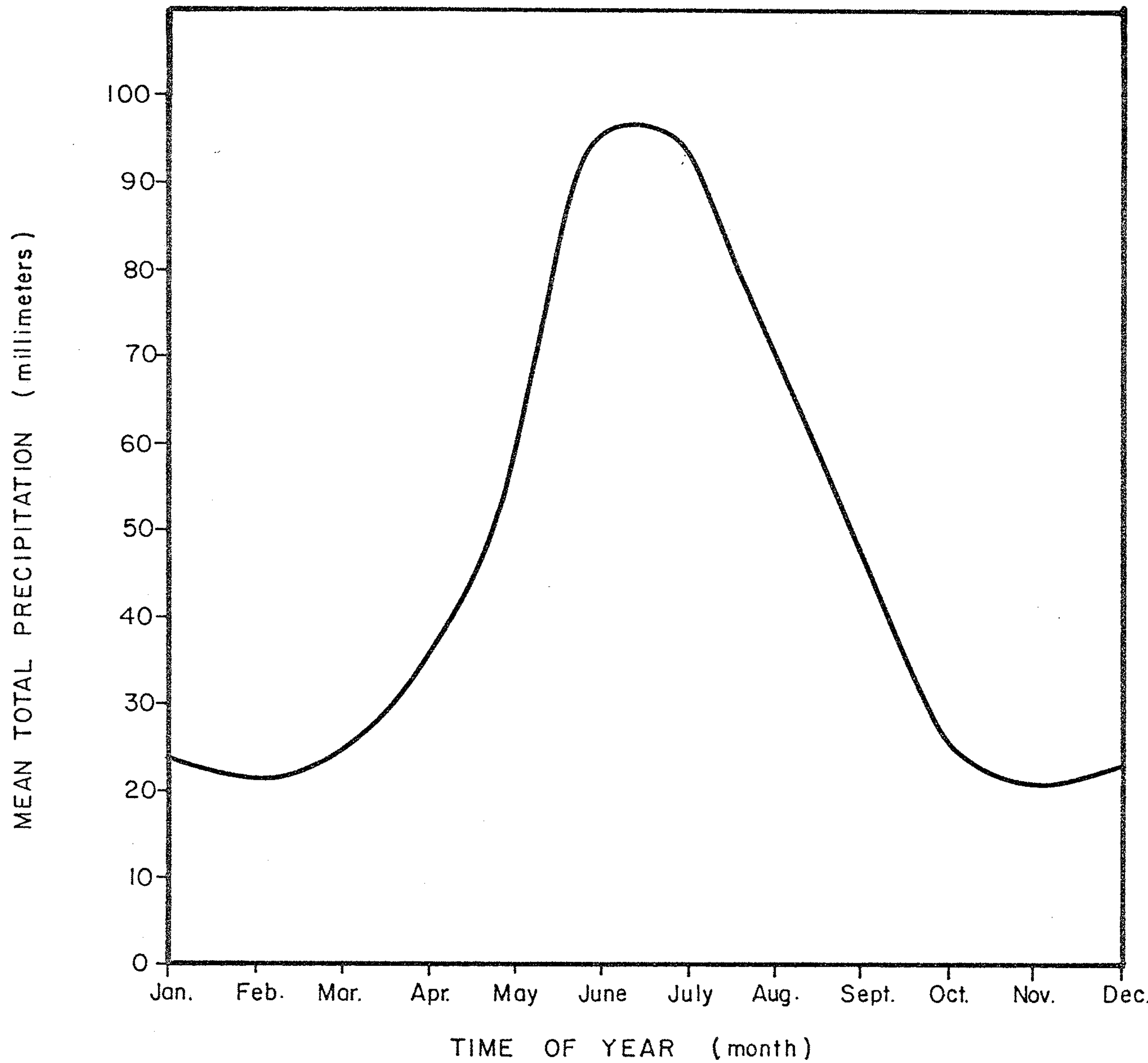


Figure 3.6 MEAN TOTAL PRECIPITATION AS A FUNCTION OF TIME OF YEAR BASED ON DATA GATHERED AT ROCKY MOUNTAIN HOUSE FROM 1941 - 1970

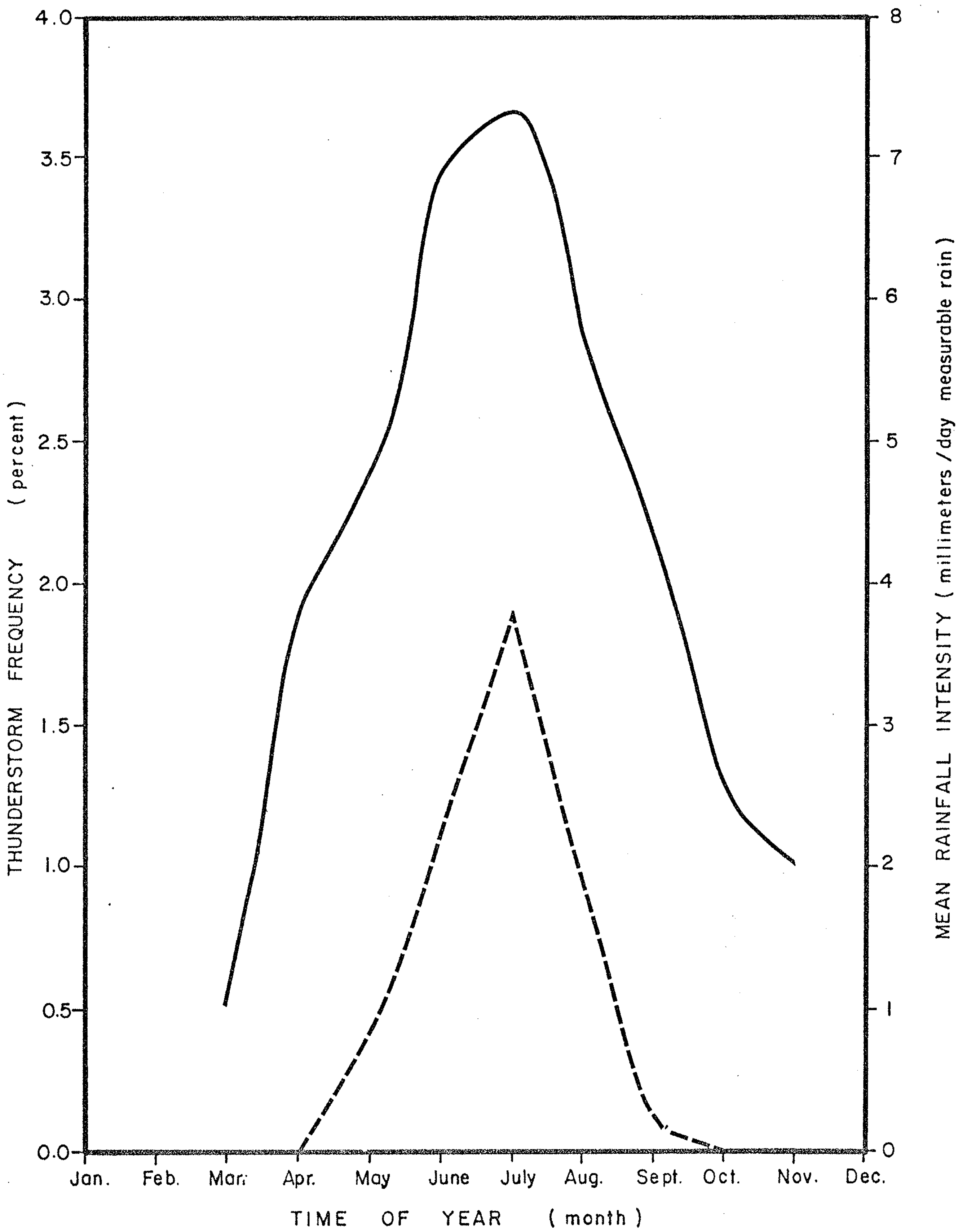


Figure 3.7 THUNDERSTORM FREQUENCY and MEAN RAINFALL INTENSITY AS A FUNCTION OF TIME OF YEAR BASED ON A 10 YEAR PERIOD (1957-1966) and A 30 YEAR PERIOD (1941 - 1970) RESPECTIVELY OF DATA GATHERED AT ROCKY MOUNTAIN HOUSE.

is at Lacombe Experimental Farm. The mean annual bright sunshine for Lacombe totals 2094 hours. Figure 3.8 shows the mean number of hours of bright sunshine for a 30-year period (1931 - 1960, inclusive).

Table 3.2 presents the cloud normals for the Rocky Mountain House area based on 20 years of data (1941 - 1960, inclusive). Considering the month of January, for example, it may be expected that from zero to two-tenths of the sky will be covered by cloud 34 percent of the time.

3.1.5.5 Humidity

The mean relative humidity as a function of time of year is shown in Figure 3.9. These data are based on 10 years of observations (1957 - 1966, inclusive) at Rocky Mountain House. The mean annual relative humidity is 69 percent.

During the winter, the relative humidity remains fairly constant at approximately 75 percent throughout a 24-hour period. During the summer, the relative humidity drops from approximately 84 percent at night to 55 percent during the day.

3.1.5.6 Fog

Table 3.3 lists the monthly percentage frequency of fog occurrence observed at Rocky Mountain House 1957-1966. These data serve as a guide to the minimum amount of fog occurrence expected in the Brazeau area, since the Brazeau Reservoir and the large amount of surface water in the area would likely increase the incidence of fog formation.

3.2 Biological Environment

The biological features that would be affected include the existing vegetation communities and wildlife populations.

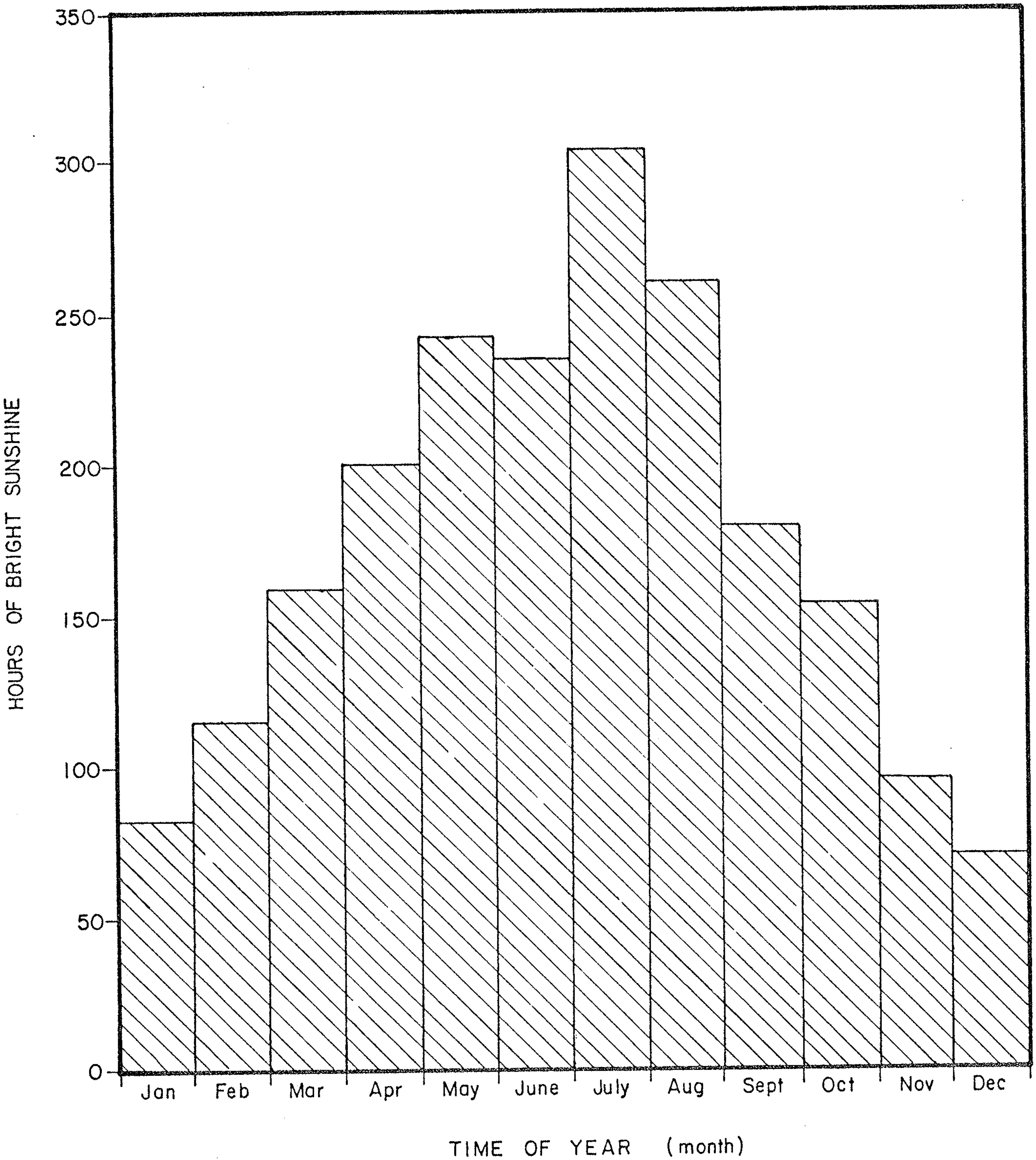


Figure 3.8 THE NUMBER OF HOURS OF BRIGHT SUNSHINE AS A FUNCTION OF TIME OF YEAR BASED ON 30 YEARS OF DATA GATHERED AT THE LACOMBE EXPERIMENTAL FARM (1931 - 1960).

Table 3.2

CLOUD COVER AT ROCKY MOUNTAIN HOUSE

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean Cloud cover (%)		59	61	63	60	61	68	54	56	57	56	56	57	59
Frequency of occurrence	8-10/10 cover	51	53	57	51	52	57	39	43	47	46	47	48	49
	3-7/10 cover	15	19	15	19	20	24	30	26	22	21	20	19	21
	0-2/10 cover	34	28	28	30	28	19	31	31	31	33	33	33	30

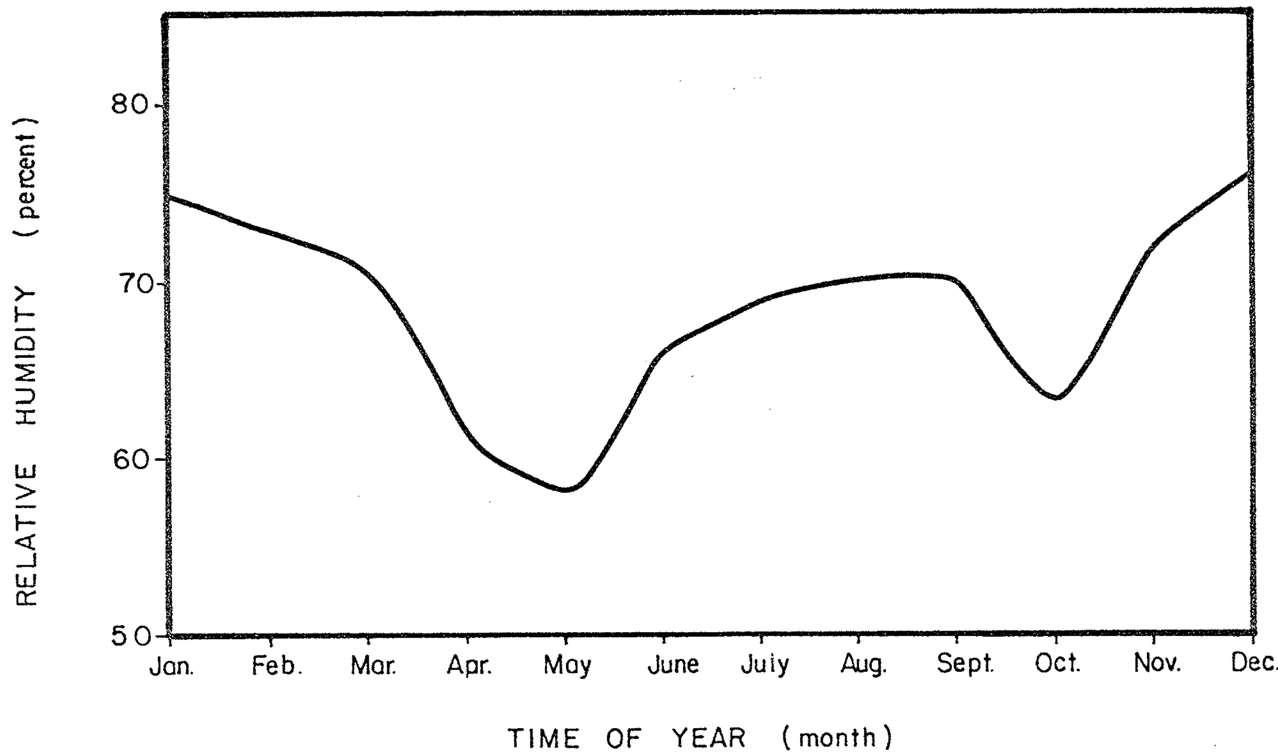


Figure 3.9 MEAN RELATIVE HUMIDITY AS A FUNCTION OF TIME OF YEAR BASED ON 10 YEARS OF DATA GATHERED AT ROCKY MOUNTAIN HOUSE (1957 - 1966).

Table 3.3

INCIDENCE OF FOG FORMATION BASED ON HOURLY OBSERVATIONS OVER A 10-YEAR PERIOD (1957-1966) AT ROCKY MOUNTAIN HOUSE

Month	Observation Fog (% frequency)
January	1.4
February	2.8
March	2.8
April	2.3
May	1.7
June	2.6
July	1.6
August	2.9
September	2.2
October	0.9
November	5.1
December	1.7
Annual	2.3

3.2.1 Vegetation communities

Although the study area lies within the lower foothills of the Boreal Forest Region, the forest vegetation of the area is transitional between the Boreal Forest Region and the Sub-Alpine Region (Rowe, 1959).

Figure 3.10 shows the major tree associations of the study area. A comprehensive list of vegetation species common to the area is given in Appendix B.

The area is dominated by conifers, primarily lodgepole pine, which have regenerated after fires, and black spruce and white spruce which are predominant in the older stands. Aspen is the most abundant of the deciduous trees, and occurs over a large portion of the area either as isolated stands or mixed with black spruce and lodgepole pine. The tallest of these trees range up to 26 meters (85 feet) in height.

A large portion of the study area is covered by muskeg and wet, low lying grassland areas. Black spruce (sometimes dwarfed) and tamarack are the most abundant trees in these areas, while the understory is composed primarily of swamp birch, willow, alder, labrador tea, and horsetail. The height of the trees in these areas ranges between three and ten meters (10 to 30 feet).

The most abundant understory vegetation species within the drier portions of the study area include raspberry, chokecherry, dogwood, prickly rose, hazelnut, gooseberry, buffaloberry, bearberry, blueberry, low bush cranberry, and silverberry. Grasses and herbs in the area provide native pastures for wild ungulates and include hairy wild rye grass, blue grass, and wild vetch.

A detailed study of forest-soil relationships was undertaken by Lesko and Lindsay (1973) on a large area of land north of the study area. In the study the researchers identified fifteen forest types which they

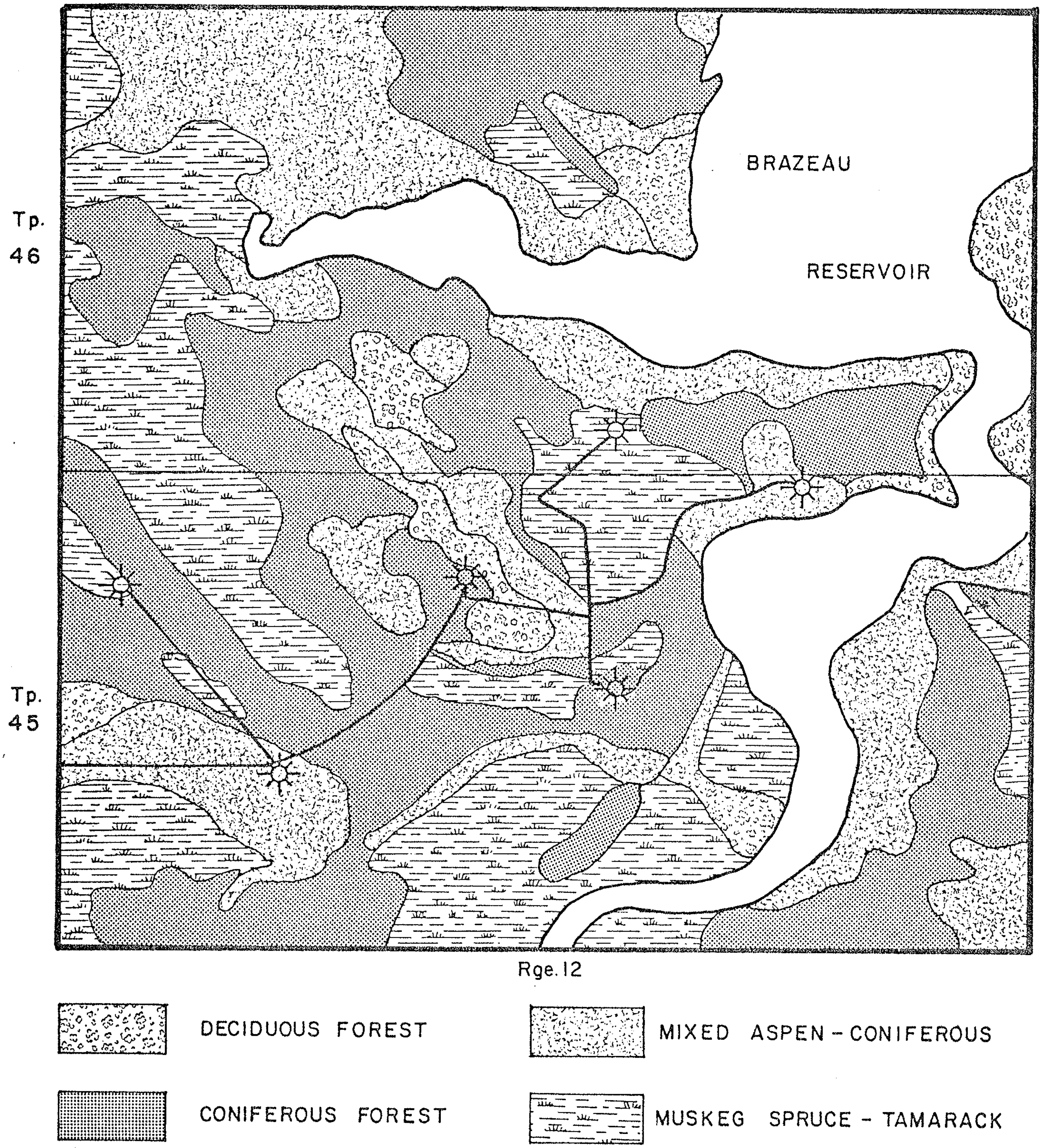


FIGURE 3.10 MAJOR TREE ASSOCIATIONS OF STUDY AREA

classified according to the vegetation associations of each. Of the fifteen forest types identified by Lesko and Lindsay, ten forest types are considered typical of forest types that are likely to occur within or in the vicinity of the study area, based on similar patterns in parent material, soil type, and drainage between the two areas. The typical forest types and related edaphic factors are listed in Table 3.4.

The major stand characteristics of each of these typical forest types is given in Table 3.5.

Based on a measure of site index, Lesko and Lindsay grouped each forest type according to white spruce and lodgepole pine productivity. Four groups were recognized and arranged in decreasing order of productivity. Table 3.6 lists the productivity rating of all forest types likely to occur within the study area.

3.2.2 Wildlife populations

The study area lies within a transitional wildlife zone between the grasslands and aspen forest of the drier, low-lying elevations and the cooler and moister coniferous forest of the alpine region.

The environment of the study area affords good habitat for a wide range of wildlife, including various species of ungulates, carnivores, small mammals and birds. Recent human intervention has apparently depleted the abundance of some species, as reported by the Foothills Resource Allocation Study (1973):

> "The valley of the Brazeau and nearby lands were once home to many big game animals, especially elk. The rolling terrain choked with dense forest and muskeg permitted little access by hunters to the isolated meadows and river breaks where game

Table 3.4

TYPICAL FOREST VEGETATION TYPES AND EDAPHIC FACTORS LIKELY TO OCCUR WITHIN THE STUDY AREA

Parent Material	Soil Type	Drainage Characteristics	Major Forest Vegetation Types
Till	Gray wooded	Imperfect to well drained	Black spruce - aspen - blueberry White spruce - feather moss - birch White spruce - feather moss - fir White spruce - club moss White spruce - sarsaparilla
Alluvial - aeolian	Gray wooded	Moderately well drained	Lodgepole pine - black spruce - bearberry Lodgepole pine - white spruce - bearberry White spruce - sarsaparilla - dogwood Alluvial complex
Outwash	Gray wooded	Well drained	Lodgepole pine - black spruce - bearberry Lodgepole pine - white spruce - bearberry Alluvial complex
Organic	Organic soil	Very poorly drained	Black spruce - peat moss bog

Source: Data modified from Lesko and Lindsay (1973)

Table 3.5

STAND CHARACTERISTICS OF TYPICAL FOREST VEGETATION TYPES LIKELY
TO OCCUR WITHIN THE STUDY AREA

	Site Index *		Basal Area (square feet per acre)								Number of Trees (per acre)								Vegetation Cover (percent)					
	White Spruce	Lodgepole Pine	White Spruce	Lodgepole Pine	Black Spruce	Alpine Fir	Asepn	Poplar	Birch	Total	White Spruce	Lodgepole Pine	Blace Spruce	Alpine Fir	Aspen	Poplar	Birch	Total	Upper Crown Layer	Lower Crown Layer	High Shrub Layer	Low Shrub Layer	Herb Layer	Moss Layer
Black Spruce-Aspen-Blueberry	-	70	0	74	39	0	12	1	1	127	0	280	392	0	49	6	9	736	46	32	2	15	43	70
White Spruce-Feather Moss-Paper Birch	87	-	160	0	0	0	0	20	5	185	460	0	0	0	0	20	48	528	87	5	0	10	50	80
White Spruce-Feather Moss-Alpine Fir	67	-	53	0	0	11	13	6	1	84	177	0	0	70	20	10	7	284	56	15	0	18	46	91
White Spruce-Club Moss	70	65	23	73	0	0	19	2	2	119	52	233	0	0	65	5	17	372	56	27	6	21	80	44
White Spruce-Sarsaparilla	78	75	41	41	0	6	39	3	4	134	91	92	0	12	60	6	23	284	52	9	23	21	77	14
Lodgepole Pine-Black Spruce-Bearberry	-	59	0	36	10	0	1	0	0	47	0	109	137	0	8	0	0	254	38	29	2	20	50	58
Lodgepole Pine-White Spruce-Bearberry	73	65	8	33	0	0	5	0	0	46	30	289	0	0	25	0	0	344	40	2	2	40	70	65
White Spruce-Sarsaparilla Dogwood	79	-	79	0	0	0	41	20	7	147	170	0	0	0	62	37	36	305	64	7	2	49	77	18
Alluvial Complex	70	68	109	7	0	1	6	3	1	127	290	7	6	4	10	4	6	327	51	12	5	7	30	45
Black Spruce-Peat Moss Bog Complex	-	-	0	0	48	0	0	0	0	48	0	0	580	0	0	0	0	580	32	0	2	64	12	96

Source: Lesko and Lindsay (1973)
*Height in feet of 70-year age

Table 3.6

PRODUCTIVITY RATING OF TYPICAL FOREST VEGETATION TYPES
LIKELY TO OCCUR WITHIN THE STUDY AREA

	White Spruce		Lodgepole Pine	
	Site Index	Forest Type	Site Index	Forest Type
Group I[1]	79 ± 10[2]	White Spruce-Feather Moss-Paper Birch White Spruce-Sarsaparilla-Dogwood White Spruce-Sarsaparilla	72 ± 9	White Spruce-Sarsaparilla Black Spruce-Aspen-Blueberry White Spruce-Black Spruce-Blueberry
Group II	75 ± 4		65 ± 6	White Spruce-Club Moss Lodgepole Pine-White Spruce-Bearberry Alluvial Complex
Group III	70 ± 8	Lodgepole Pine-White Spruce-Bearberry Alluvial Complex White Spruce-Club Moss White Spruce-Feather Moss-Alpine Fir	60 ± 8	Lodgepole Pine-Black Spruce-Bearberry
Group IV	Non-productive	Black Spruce-Peat Moss Bog Complex Lodgepole Pine-Black Spruce-Bearberry Black Spruce-Aspen-Blueberry	Non-productive	White Spruce-Feather Moss-Alpine Fir White Spruce-Feather Moss-Paper Birch Black Spruce-Peat Moss Bog Complex

[1] All groups are significantly different from each other at the 95 percent probability level

[2] Mean with standard deviation

> was abundant. As recently as the later 1950's the twenty-mile journey from Lodgepole to the present dam site took seven hours by jeep. Since then dam construction and geophysical exploration have opened up the country considerably, leading to increased hunting each fall."

Table 3.7 is a non-comprehensive list of some of the more common mammal and bird species that are expected to occur in the study area. The list is based on available literature that indicates the presence of these species some time in the past; other than this, little is known about the actual existing relative distribution and abundance of these species in and around the study area. Field observations were of limited assistance as the study area contains very dense forest, bush and swamp areas that would require many days of exhaustive field observations in order to document the existence of the wildlife and bird species listed.

Nearly all of the land of the study area is capable of supporting ungulates, mainly elk, mule deer, and moose. The area provides a variety of coniferous and aspen forest, river flats, grassy slopes and wet meadows which provide excellent all around habitat for supporting ungulates. Key ungulate range, which is critical winter range vital for the survival of existing herds of elk, has been identified in the area by Alberta Fish and Wildlife, and is shown in Figure 3.11. Key ungulate range also exists along the Elk River, and along the Brazeau River between the Brazeau Reservoir and the Forestry Trunk Road.

When the Brazeau Dam was built in the early 1960's the resulting reservoir flooded 17-1/2 square miles of prime moose, elk and mule deer winter range. The winter range carrying capacity of the Brazeau Valley was consequently reduced by 229 ungulates: 193 elk, 18 moose, and 18 mule deer (Stelfox in FRAS, 1973).

There have been two recent limited aerial surveys of big game populations in the vicinity of the study area by Alberta Fish and Wildlife. An aerial survey was conducted in early January 1976 during which time the

Table 3.7a

MAMMALS COMMON TO THE VICINITY OF THE BRAZEAU STUDY AREA

	Common Name	Scientific Name*	Relative Abundance
1.	Ungulates		
	Elk	Cervus canadensis	Regular
	Mule deer	Odocoileus hemionus	Regular
	White-tailed deer	Odocoileus virginianus	Sporadic
	Moose	Alces alces	Regular
2.	Carnivores		
	Coyote	Canis latrans	Regular
	Timber wolf	Canis lupis	Sporadic
	Red fox	Vulpes fulva	Sporadic
	Black bear	Euarctos americanus	Regular
	Rocky Mountain Grizzly bear	Ursus arctos dusorgus	Sporadic
	Canada lynx	Lynx canadensis	Sporadic
	Bobcat	Lynx rufus	Sporadic
3.	Small mammals		
	Shrew	Sorex spp.	Regular
	Varying hare	Lepus americanus	Regular
	Woodchuck	Marmota monax canadensis	Sporadic
	Chipmunk	Eutamias minimus	Regular
	Red squirrel	Tamiasciurus hudsonicus	Regular
	Flying squirrel	Glaucomys sabrinus	Sporadic
	Beaver	Castor canadensis	Regular
	White-footed mouse	Peromyscus maniculatus	Regular
	Lemming vole	Synaptomys borealis	Regular
	Red-backed vole	Clethrionomys gapperi	Regular
	Meadow vole	Microtus pennsylvanicus	Regular
	Muskrat	Ondatra zibethicus	Regular
	Jumping mouse	Zapus hudsonias	Regular
	Porcupine	Erethizon dorsatum	Sporadic
	Badger	Taxidea taxus	Sporadic
	Ermine (weasel)	Mustela erminea	Regular
	Mink	Mustela vison lacustris	Regular

* Taxonomy based on Soper (1964), The Mammals of Alberta

Table 3.7b

BIRDS TYPICAL OF THE BRAZEAU STUDY AREA

Common Name	Scientific Name*	Resident Status**
1. Waterfowl and shorebirds		
Common loon	*Gavia immer*	SR
Grebe	*Podiceps* spp.	SR
American bittern	*Botaurus lentiginosus*	SR
Whistling swan	*Olor columbianus*	M
Canada goose	*Branta canadensis*	M
Snow goose	*Chen hyperborea*	M
White-fronted goose	*Anser albifrons*	M
Surface feeding and diving ducks (various)	Family Anatidae	SR
Coot	*Fulica americana*	SR
Killdeer	*Charadrius vociferas*	SR
Snipe	*Capella gallinago*	SR
Sandpiper	*Actitis macularia*	SR
Yellowlegs	*Totanus* spp	SR
Phalarope	*Steganopus tricolor*	SR
Franklin's Gull	*Larus pipixcan*	SR
Common tern	*Sterna hirundo*	SR
Black tern	*Chlidonias niger*	SR
Sandhill crane	*Grus canadensis*	M
Sora	*Porzana carolina*	SR
2. Predatory birds		
Goshawk	*Accipiter gentilis*	R
Sharp-shinned hawk	*Accipiter striatus*	SR
Red-tailed hawk	*Buteo jamaicensis*	SR
Broad-winged hawk	*Buteo platypterus*	SR
Golden eagle	*Aquila chrysaetos*	M
Bald eagle	*Haliaeetus leucocephulus*	M
Osprey	*Pandion haliaetus*	SR
Sparrow hawk	*Falco sparverius*	SR
Great horned owl	*Bubo virginianus*	R
Long-eared owl	*Asio otus*	SR
Short-eared owl	*Asio flammeus*	SR
Nighthawk	*Chordeiles minor*	SR
3. Grouse		
Spruce grouse	*Canachites canadensis*	R
Ruffed grouse	*Bonasa umbellus*	R

Table 3.7b (Continued)

Common Name	Scientific Name	Resident Status
4. Perching birds		
Mourning dove	*Zenaidura macroura*	SR
Woodpeckers, Flickers, Sapsuckers (various)	Family Picidae	V
Flycatchers	Family Tyrannidae	SR
Swallows	Family Hirundinidae	SR
Gray Jay	*Perisoreus canadensis*	R
Blue Jay	*Cyanocitta cristata*	R
Magpie	*Pica pica*	R
Crow	*Corvus brachyrhynchos*	SR
Chickadee	*Parus* spp	R
Nuthatches	Family Sittidae	SR
Wrens	Family Troglodytidae	SR
Thrushes	Family Turdidae	SR
Cedar waxwing	*Bombycilla cedrorum*	SR
Bohemian waxwing	*Bombycilla garrulus*	R
Vireos	*Vireo* spp	SR
Wood warblers	Family Parulidae	SR
Blackbirds	*Euphagus* spp	SR
Grosbeaks, buntings, finches, sparrows	Family Fringillidae	V

* Taxonomy based on Robbins et al. (1966), Birds of North America

**Resident Status
R = resident
SR = summer resident
M = migrant
V = varies between species

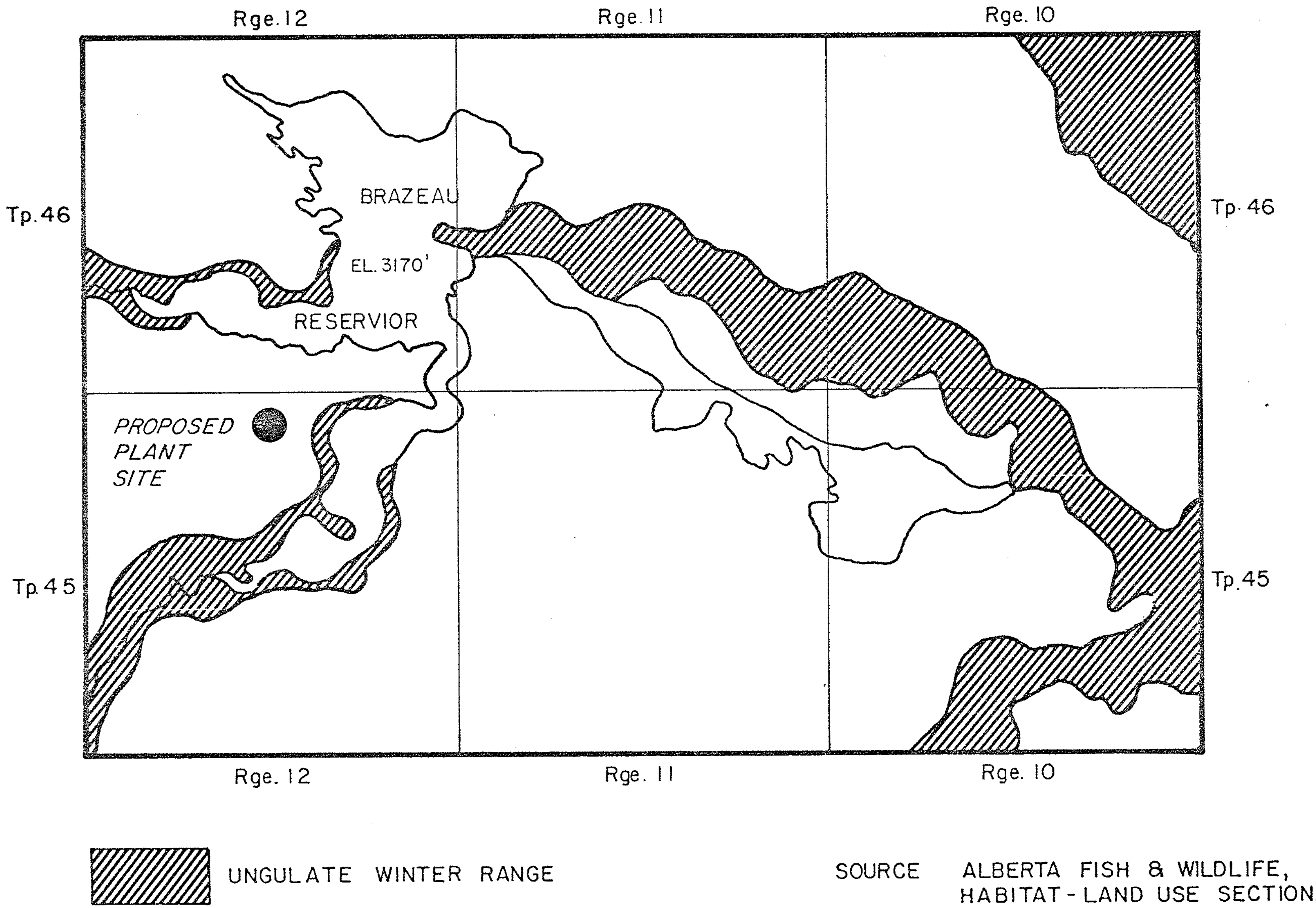


FIGURE 3.11 UNGULATE WINTER RANGE IN VICINITY OF STUDY AREA

following drainages, among others, were flown in order to estimate big game numbers: Baptiste River, Nordegg River, Brazeau River, Elk River, Pembina River, Blackstone River, Cardinal River. The results of this particular survey are summarized in Table 3.8.

A survey was conducted in a one day flight in March 1974 during which time straight line transects were flown north and south at one mile intervals throughout the study area and surrounding region. The results of this survey were as follows (Wingert, 1974):

> "The nineteen lines were flown for a total of 270 miles, with a total of 21 moose, six elk, and one deer being observed. Also, the Nordegg and Brazeau Rivers were flown, but only two elk were seen on the Brazeau and none on the Nordegg. Observing conditions were poor due to a bright sun and many shadows."

Due to the time of year these surveys were undertaken no bears were observed. Local drilling and maintenance workers report, however, that black bears are often observed along the roads and in the vicinity of the drilling camps.

3.3 Social and economic environment

The description of the social and economic environment includes:

(a) the existing land uses in the vicinity of the proposed development;
(b) the human populations in the region;
(c) the capability of the land in terms of human-oriented natural resources.

3.3.1 Existing land use

The primary land uses in the vicinity of the proposed development are petroleum extraction, hydro-electric power generation, and occasional timber removal. In addition to these primary uses, there is human activity in the form of fur trapping, big game hunting and sport fishing.

Table 3.8

RESULTS OF BRAZEAU RIVER AND SURROUNDING REGION ANIMAL SURVEY, JANUARY 6-9, 1976

	Moose				Elk				
River	Bulls	Cows	Calves	U/C*	Bulls	Cows	Calves	U/C	Other
Baptiste River	9	21	14	1	3	11	2		2 Mule deer does 3 horses
Nordegg River	5	12	9	3	5	5	2	25	1 U/C deer 3 wolves
Brazeau River		3	3		8			13	20 horses
Elk River	1	4	1					14	
Pembina River	2	9	3					13	
Blackstone River	2	2		1				3	25 Bighorn sheep
Cardinal River								6	

Source: Region III Mountain Moose (Drainage) Survey. Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division. January 1976

* Unidentified calves

3.3.1.1 Timber removal

Although forestry activity in the vicinity of the proposed development is only sporadic, some large stands of merchantable timber have been removed from the area. The most recent activity includes the removal, in 1961, of merchantable timber from the site of the Brazeau Reservoir before it was flooded. Additional timber was removed in 1969 when the level of the reservoir was raised six feet. Christmas trees are occasionally harvested in the area.

The present market value of timber in the area is difficult to establish without a detailed timber census and market survey. The majority of the timber in the region has been classified by the Alberta Forest Service as medium density stands that typically yield between 8,000 and 15,000 board-feet per acre. The 1976 wholesale value for saw logs cut from lodgepole pine and white spruce is approximately $140 to $150 per thousand board feet. Manufacturing costs including transportation to the mill generally average about half of the wholesale value. Black spruce is generally of little or no value as it is not of sufficient size for saw log production.

Based on the above data, the timber value per acre in the Brazeau area varies between $1120 (8,000 board-feet per acre x $140 per thousand board-feet) and $2250 (15,000 board-feet as per acre x $150 per thousand board-feet) for a stand of pure merchantable lodgepole pine on white spruce. Pure stands of black spruce would generally have no commercial timber value.

3.3.1.2 Hydro-electric power development

Initial construction of the Calgary Power Ltd. Brazeau Storage and Power Development project was undertaken in 1961. The first generating unit with a capacity of 165,000 kw was in service by 1965. A second 190,000 kw unit was installed in 1967, bringing the plants total power output to 350,000 kw, the largest hydro-electric development in the province.

Additional information on the power development was given in Section 3.1.4.1. Figure 3.12 is a general plan of the Brazeau Storage and Power Development.

3.3.1.3 Natural gas production

The study area is within the Brazeau Gas Field, which consists of the Brazeau-Elk-Shunda pools A and B. Geophysical exploration for oil and gas began along the Brazeau thrust about 1940, although commercial quantities of gas were not discovered until 1959 (FRAS, 1973).

The Hudson's Bay Oil and Gas Company Limited is operating a gas processing and sulphur recovery plant about 10 miles west of the proposed Western Decalta plant site. The present capacity of the Hudson's Bay plant is 196 MMSCFD raw gas with a production of 176 MMSCFD sales gas and 91 LTD sulphur.

Tenneco Oil of Canada Ltd. is also operating a gas plant 10 miles south of the proposed Western Decalta plant site. The capacity of Tenneco's plant is 67 MMSCFD raw gas with a production of 60 MMSCFD sales gas and 45 LTD sulphur.

3.3.1.4 Fur trapping

No recorded fur trapping has taken place within four miles of the proposed gas processing plant. The closest trapping activity is situated northwest of the proposed plant site within Township 46, Range 13 (Trapline Number 1030). Two trappers, Mr. Tom Helm and Mr. Lorne Karlston, of Bluffton, Alberta, have been working this area since 1970. Their combined fur-harvest history is given in Table 3.9.

Table 3.10 shows the average value of each of the animal pelts taken in this area for the years 1974-1975 and 1975-1976. The value of fur pelts varies widely from year to year, primarily as a function of demand, but also with respect to supply of pelts (which in turn is partially due to

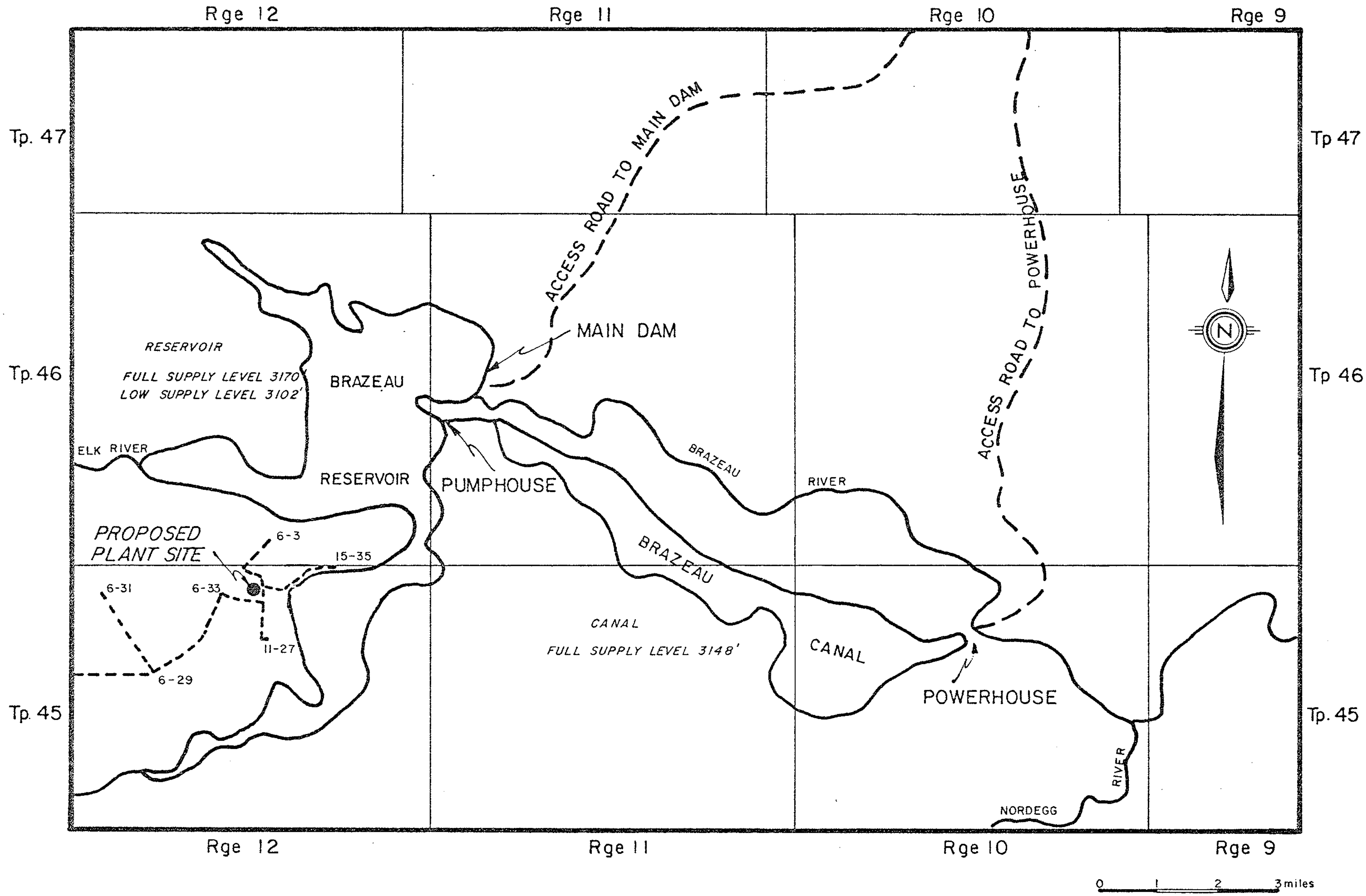


FIGURE 3.12 GENERAL PLAN OF CALGARY POWER LTD. BRAZEAU STORAGE AND POWER DEVELOPMENT.

Table 3.9

FUR-HARVEST HISTORY IN THE VICINITY OF THE PROPOSED WESTERN DECALTA GAS PLANT

Year	Number and species taken
1970-1971	10 badgers, 10 muskrats, 20 beavers, 24 ermine, 1 lynx, 4 mink.
1971-1972	58 muskrats, 202 red squirrels, 17 coyotes.
1972-1973	32 beavers, 12 ermine, 10 lynx, 5 mink, 12 muskrats, 250 red squirrels, 37 coyotes, 3 skunk.
1973-1974	25 beavers, 10 bobcats, 5 red fox, 5 mink, 5 muskrats, 100 red squirrels, 19 coyotes.
1974-1975	42 beavers, 1 lynx, 6 mink, 151 squirrels, 20 ermine, 22 coyotes, 37 muskrats.

Source: Alberta Recreation Parks and Wildlife

Table 3.10

AVERAGE FUR PELT VALUE 1974 TO 1976

Fur Species	Pelt Value ($) 1974-1975	1975-1976
Badger	13.37	25.87
Muskrat	2.22	3.31
Beaver	13.60	19.52
Ermine	1.22	1.12
Lynx	102.84	237.90
Mink	12.65	17.69
Coyote	30.65	50.00
Skunk	1.50	1.50
Red Squirrel	0.78	0.80
Bobcat	66.00	86.00
Red Fox	33.25	49.78

Source: Alberta Recreation Parks and Wildlife animal population levels, some of which are cyclical, and partially due to trapping effort).

As an indication of the fur production value of the area, the total value of furs taken each year for the period 1970 to 1975 is given in Table 3.11. The table shows that the highest value, assuming 1975-1976 fur prices, would have been for the years 1972-1973 when the total value of furs taken was $5160.71. Foxes and lynx accounted for 82 percent of this value.

3.3.1.5 Recreation

Other than hunting and fishing activities, the recreational value of the study area is low due to large areas of muskeg and wet marsh, homogeneous tree stands and a lack of unique topography. The Brazeau Reservoir was expected to be a popular recreational lake for nearby residents, within commuting distance, such as those from Lodgepole or Drayton Valley. However, boating, swimming and associated activities are not popular on the reservoir as much of the timber on the site was not removed prior to flooding, with the result that the reservoir contains standing timber, floating logs and branches, sunken logs and trees, and other debris. In addition to this, the reservoir experiences widely fluctuating water levels. These factors combined make the land surrounding the reservoir unsuitable for serviced campsites, picnic areas, or residential development.

3.3.2 Population

There are no occupied residences within the study area. The location and size of the closest population centers to the proposed plant site are given in Table 3.12.

Table 3.11

ANNUAL VALUE OF FUR HARVEST IN THE VICINITY
OF THE PROPOSED WESTERN DECALTA GAS PLANT

Year	Total value of furs taken (dollars)*
1970-1971	1017.74
1971-1972	1203.58
1972-1973	5160.71
1973-1974	2731.90
1974-1975	2529.55
Mean annual value	2528.70

* Based on 1975-1976 fur prices.

Table 3.12

LOCATION AND SIZE OF CLOSEST POPULATION CENTERS
TO THE PROPOSED WESTERN DECALTA GAS PLANT

Place	Location	Population Size 1961	1966	1971
Cynthia	50-10-W5	165	108	82
Violet Grove	48-7-W5	200	116	94
Lodgepole	47-10-W5	508	207	144
Drayton Valley	49-7-W5	3854	3352	3900
O'Chiese Indian Reserve	- 43, 44-10-W5	120 (1947)	275 (1971)	
Sunchild Indian Reserve	- 42, 43-10-W5	100 (1945)	300 (1971)	

Source: Dominion Bureau of Statistics (1961, 1966)
Statistics Canada (1971)
Foothills Resource Allocation Study (1973)

3.3.3 Natural resource capability

The study area possesses varying degrees of capability for ungulate range, outdoor recreation, sport fish, agriculture, forestry, and grazing. The various resource capabilities are illustrated in Figures 3.13 through 3.18. The maps show that the land that would be affected posseses good to excellent capability as ungulate range. Some potentially highly productive forest timber land would be affected. In terms of outdoor recreation, agricultural, and grazing capability, the land that would be affected is of no or low to moderate capability. The sportfish capability would not be affected.

The resource capability maps are based on data taken from "The Foothills Allocation Study Phase 1: Lower Brazeau Drainage District". A discussion of the purpose and content of the Foothills Resource Allocation Study (FRAS) follows.

FRAS was "a comprehensive planning program designed to determine the most beneficial allocation of resources in the Alberta Foothills region on the basis of productivity and economic considerations" (FRAS, 1973). It was established as a joint federal-provincial agreement funded by the federal office of the Canada Land Inventory but designed and administered by the Alberta Department of Lands and Forests.

One of the primary objectives of FRAS was to evaluate the information compiled in the Canada Land Inventory, including agriculture, forestry, recreation, sportfish, ungulates and waterfowl. Some aspects of resource management were not incorporated into the Canada Land Inventory (for example non-renewable resources, forestry, watershed, grazing). Additional data was therefore assembled to give a more complete inventory of the resources of the foothills. The suppliers of all resource inventories incorporated into FRAS is given in Table 3.13.

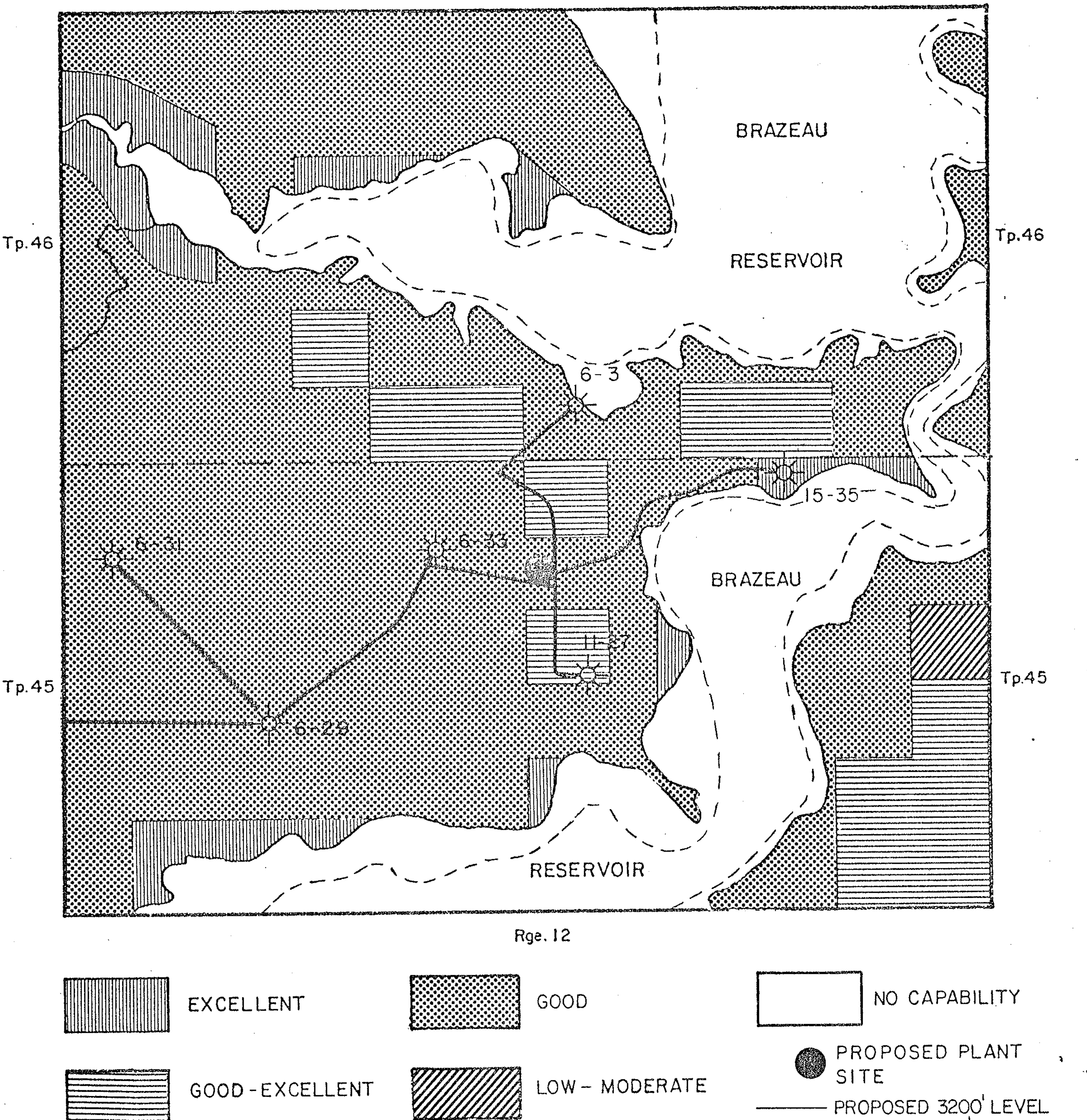


FIGURE 3.13 LAND CAPABILITY FOR UNGULATE RANGE

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

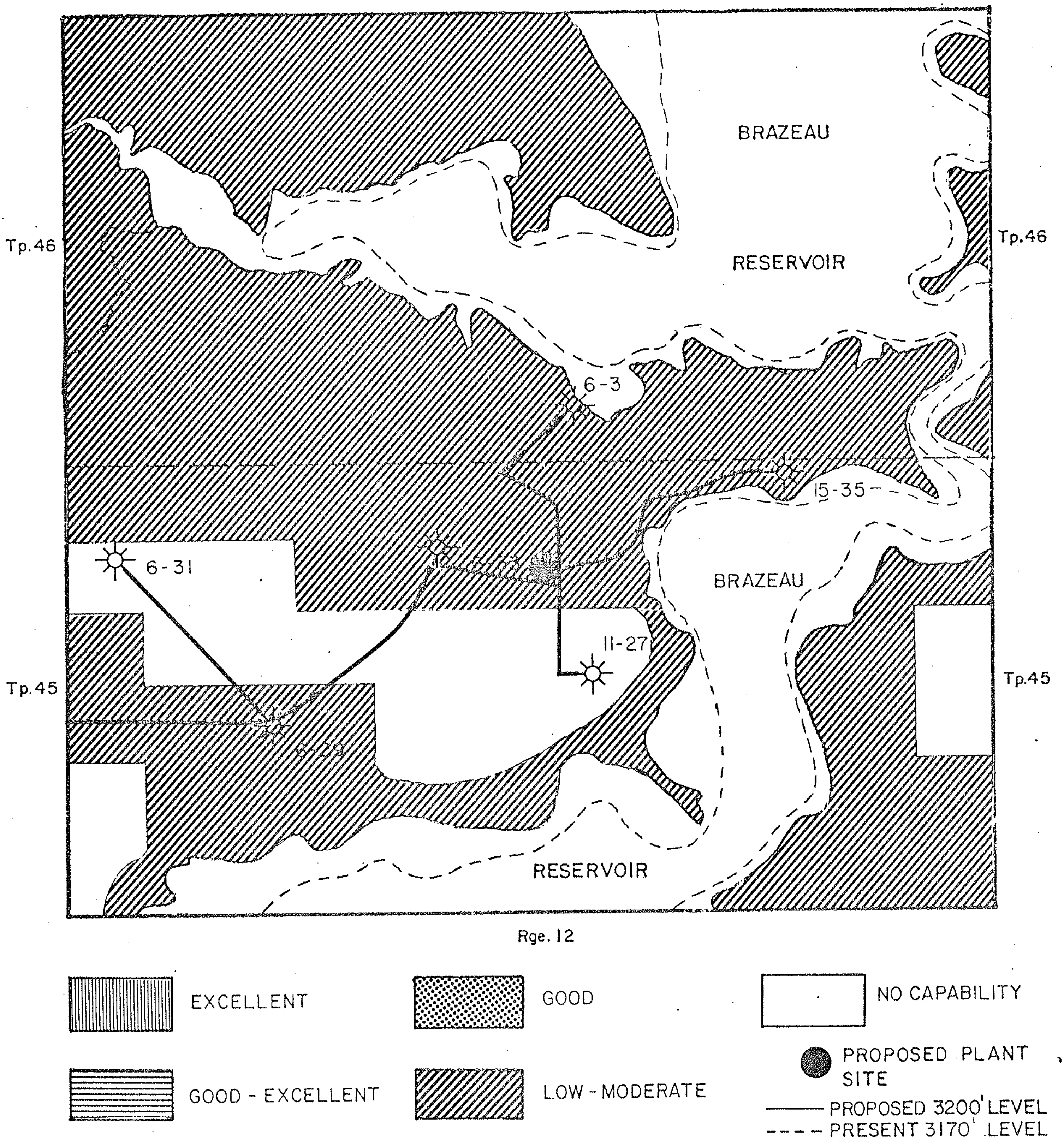


FIGURE 3.14 LAND CAPABILITY FOR OUTDOOR RECREATION

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

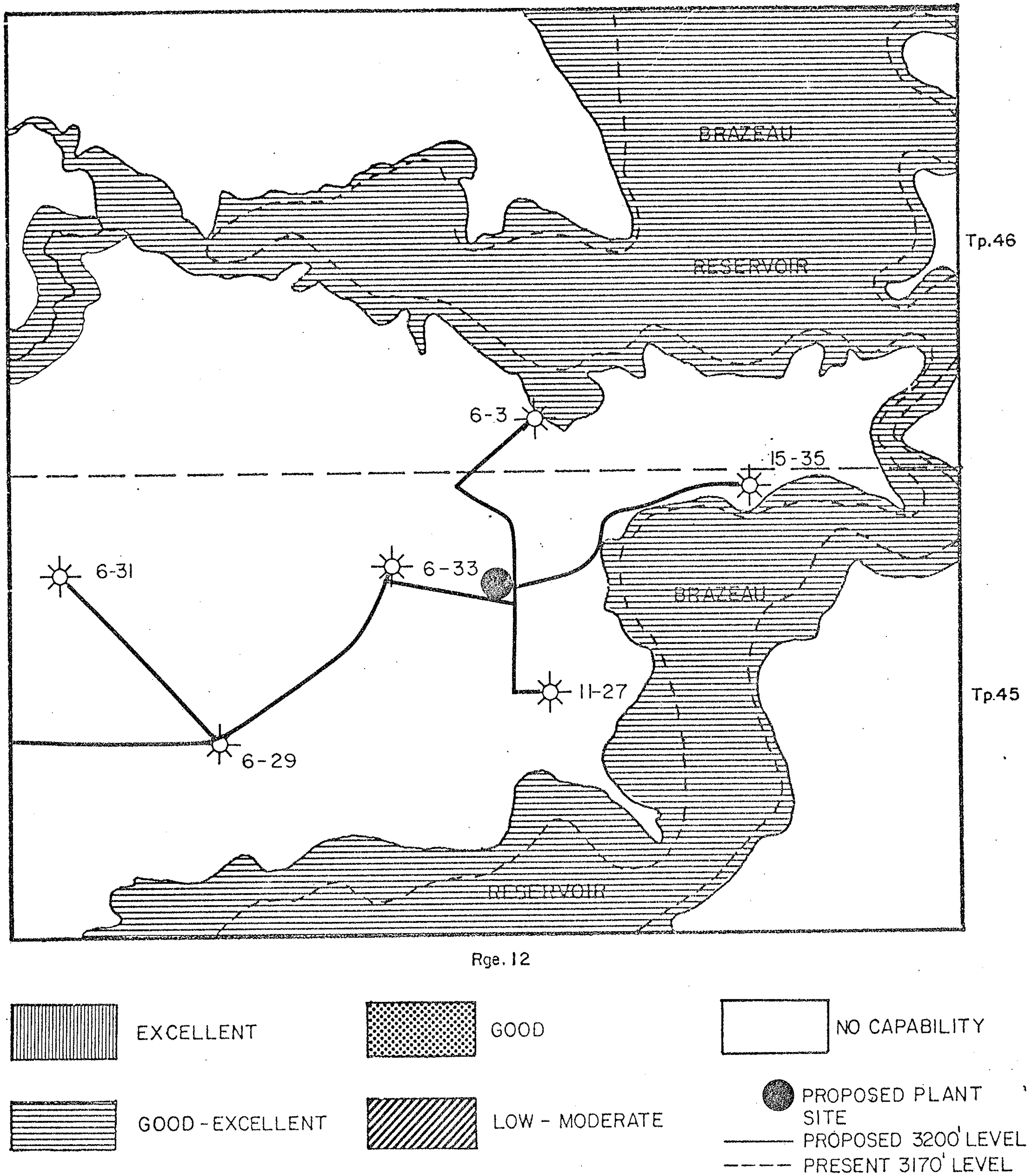


FIGURE 3.15 WATER CAPABILITY FOR SPORTFISH

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

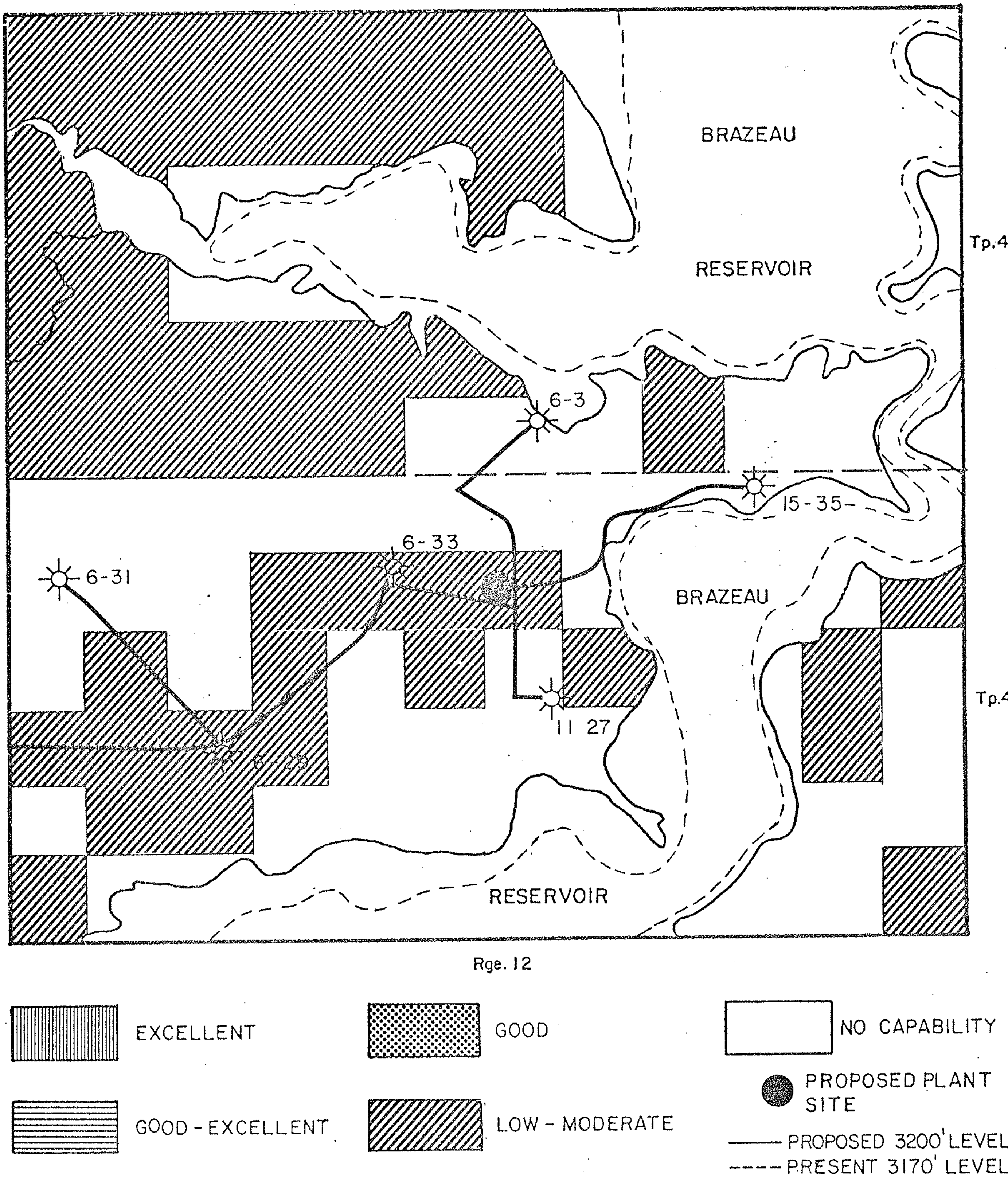


FIGURE 3.16 LAND CAPABILITY FOR AGRICULTURE

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

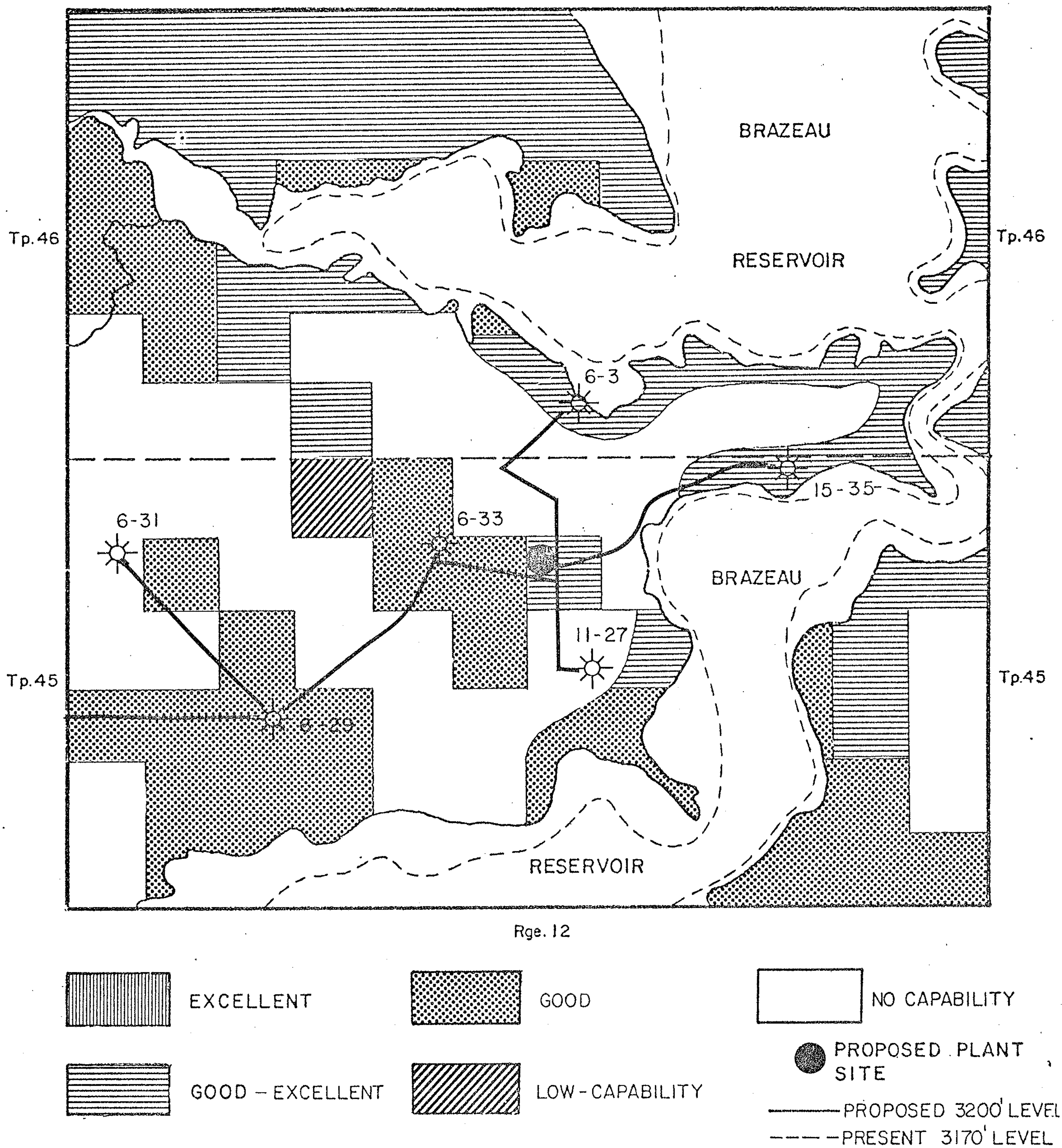


FIGURE 3.17 FORESTRY CAPABILITY FOR LOGGING

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

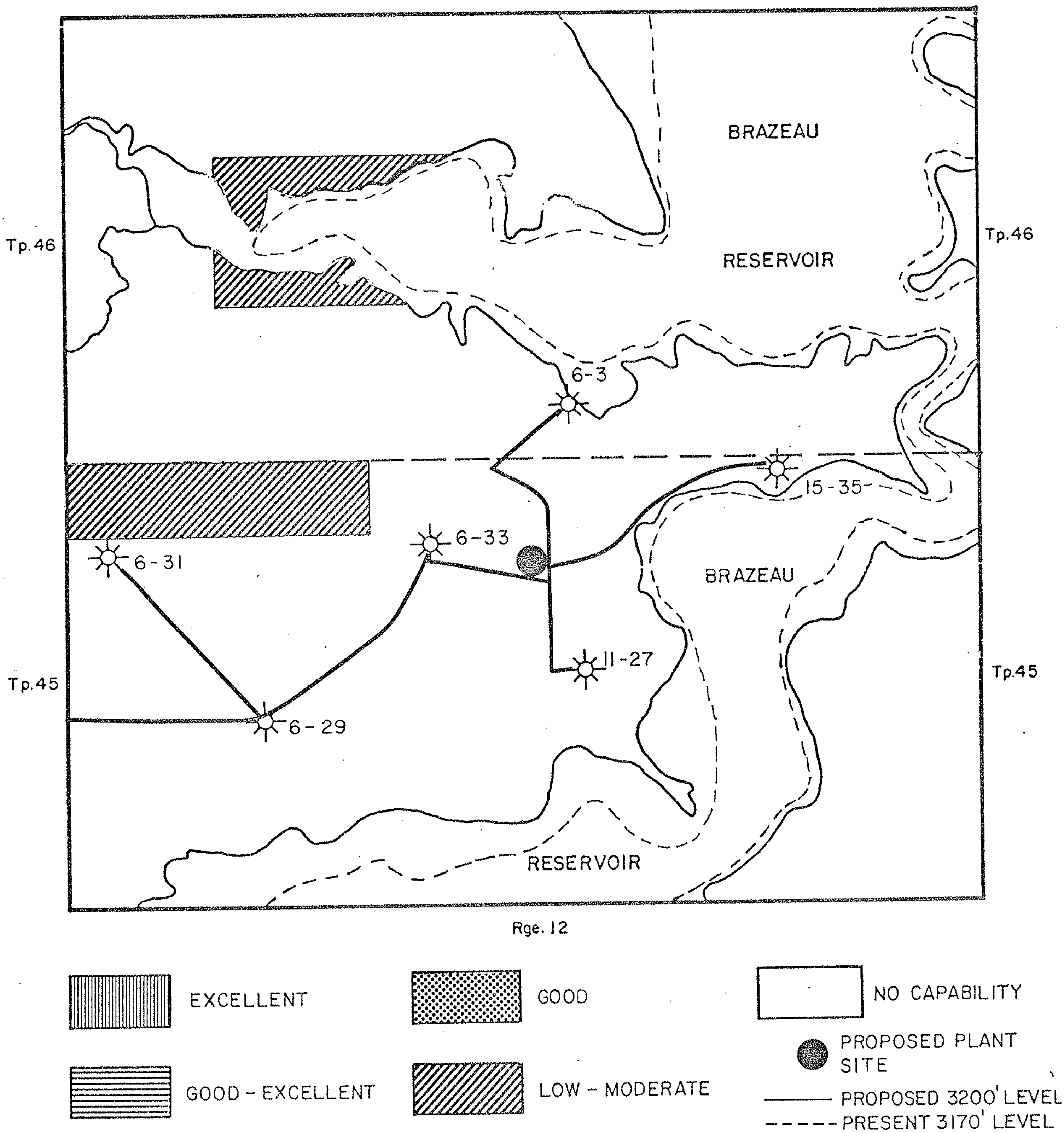


FIGURE 3.18 LAND CAPABILITY FOR GRAZING

SOURCE: FOOTHILLS RESOURCE ALLOCATION STUDY 1973

Table 3.13

FOOTHILLS RESOURCE ALLOCATION STUDY:
SUPPLIERS OF RESOURCE INVENTORIES

Resource	Supplier
Archaeology	University of Calgary, Department of Archaeology
Agriculture Capability	C.L.I. Soil Capability for Agriculture
Coal	Research Council of Alberta, Geology Division
Forest Capability	C.L.I. Soil Capability for Forestry
Forest Cover	Detailed Forest Inventory, Timber Management Branch, Alberta, Forest Service, Alberta Department of Lands and Forests
Industrial Minerals	Research Council of Alberta, Geology Division
Key Ungulate Range	Fish and Wildlife Division, Alberta Department of Lands and Forests
Livestock Grazing	Forest Land Use Branch, Alberta Forest Service, Alberta Department of Lands and Forests
Metallic Minerals	Research Council of Alberta, Geology Division
Oil and Gas	Alberta Energy Resources Conservation Board
Recreation Capability	C.L.I. Land Capability for Outdoor Recreation
Sport Fish Capability	C.L.I. Land Capability for Sport fish
Ungulate Capability	C.L.I. Land Capability for Ungulates
Waterfowl Capability	C.L.I. Land Capability for Waterfowl
Watershed Inventory	Department of Lands and Forests in co-operation with other water management and research agencies

FRAS divided the Alberta foothills and eastern slopes into a number of sub-regional planning units, based primarily on watershed divisions or drainage districts. Within each drainage district studied there was an initial assessment of the physical capability of the land to supply the various resources. Physical capability is used in the study to describe the productive capacity of land, which is evaluated in terms of natural conditions. It assumes no enhancement of the natural situation (such as drainage and fertilization of soils for agriculture).

4.0 ENVIRONMENTAL IMPACT

This chapter considers the major physical, biological and cultural resources that would be affected by the construction and operation of the processing plant and gathering system.

4.1 Effects on air quality

The primary source of impact to the ambient air quality would be the gaseous contaminants emitted by the processing plant. Some disturbance would result from the increased dust, noise and odour levels associated with the project. However, consideration of air quality effects will be restricted to the chemical atmospheric pollutants for the following reasons:

(a) Increased dust levels would be associated primarily with construction and should result in minor overall disturbance.

(b) The noise levels associated with the processing plant must be within the guidelines given in Section 2.6.1 and would generally result in only a minor disturbance. The most significant noise disturbance would likely be from occasional gas flaring operations (which would generally be less than half an hour duration).

(c) The potential sources of odour outlined in Section 2.6.3 would be controlled within the process. Occasionally odours may arise from the sulphur plant and the sulphur block storage area, however, they would generally be detectable only on the plant sites.

    The Hudson's Bay Oil and Gas Company Ltd. Brazeau gas plant, located 17 kilometers (10 miles) west of the proposed plant site, was visited during the field trip in June. This plant's operations are an order of magnitude larger than those of the proposed plant, yet little or no odour could be detected during the visit.

In addition to the normal process emissions, consideration will be given to the potential impact that would be associated with a possible pipeline rupture in the gathering system.

The only atmospheric contaminant that would be emitted in quantities sufficiently high to be of concern would be sulphur dioxide. The major source of sulphur dioxide emissions, under normal operating conditions, would be the sulphur plant incinerator stack. During plant upsets, sulphur dioxide may be released from the flare stack. The estimated sulphur dioxide concentrations from these two sources have been evaluated and the results are given below.

The maximum permissible concentrations of sulphur dioxide in the ambient air are given in Table 4.1.

4.1.1 Sulphur dioxide emissions from incinerator stack

The incinerator stack emission parameters are given in Table 4.2. The emission parameters have been based on the design specifications of Western Decalta Petroleum Ltd. with the following exceptions:

(a) The emission rate of stack gases was calculated by means of Western Research & Development Ltd. computer program INCWRD.

(b) The value of 5 percent for excess oxygen was used to ensure complete combustion of the tail gas.

(c) The estimated sulphur dioxide emission was multiplied by 1.4, the safety factor recommended by the Province of Alberta (Energy Resources Conservation Board, Informational letter No. IL-OG 74-5, 1974).

Ground and treetop level sulphur dioxide concentrations were estimated by employing the Alberta Department of the Environment atmospheric dispersion model. This method calculates downwind contaminant ground-level concentrations along a plume axis from a continuous point source. In using this method it is assumed that:

Table 4.1

MAXIMUM PERMISSABLE LEVEL OF SULPHUR DIOXIDE
IN THE AMBIENT AIR

Duration	Maximum average concentration $\mu g/m^3$	ppm equivalent
30 minutes	525	0.20
One hour	450	0.17
24 hour	150	0.06
Annual	30	0.01

Source: Alberta Department of the Environment. Clean Air Regulations 218/75 Part I

Table 4.2

INCINERATOR STACK EMISSION PARAMETERS

Raw gas inlet flow (MMSCFD)[1]	19.41
Acid gas to sulphur plant (MMSCFD)[1]	1.19
Sulphur plant efficiency (%)	95.0
Sulphur production (LTD)	10.4
Stack gas emission rate (SCFS)[2]	36.91
Sulphur emission rate (LTD)	0.55
Sulphur dioxide emission rate (SCFS)[2]	0.24
Stack gas exit temperature (°F)	1000.0
Stack gas exit velocity (ft/sec)	35.8
Excess oxygen (%)	5.0
Stack exit diameter (ft)	2.0

1 At 60°F and 14.7 psia

2 At 70°F and 14.7 psia (actual value multiplied by 1.4)

(a) The plume has a Gaussian distribution, with lateral and vertical standard deviations as given by Pasquill (1961) for neutral atmospheres. An outline of the Gaussian model is given in Appendix C.

(b) Plume rise for flat terrain is equal to 3/4 of the plume rise predicted by the Bosanquet, Carey, and Halton (1950) formula for stable atmospheres. An outline of this formula is given in Appendix D.

(c) Terrain influences may be estimated by subtracting 3/4 of the terrain height above the stack base from the plume rise calculated for flat terrain.

Due to the manner in which the last assumption incorporates terrain influences, details of topographic features in the vicinity of the plant are necessary. In addition, due to this assumption, the magnitude of the estimated ground-level concentration of sulphur dioxide is dependent on wind direction.

Treetop allowance may be subtracted from the calculated plume rise or added to the designed physical stack height. The maximum height of the trees in the area is about 85 feet (26 meters).

The maximum terrain elevations above the plant base at distances up to 10,000 feet from the plant site are given in Table 4.3. The maximum elevations are northwest of the proposed plant site.

Figure 4.1 shows the maximum calculated sulphur dioxide concentration as a function of wind speed. Figure 4.2 shows the maximum calculated sulphur dioxide concentration as a function of downwind distance. With the proposed 61 meter incinerator stack, the maximum ground-level sulphur dioxide concentration was calculated to be 0.08 ppm. This maximum occurs at a downwind distance of 1370 meters (4500 feet) and is associated with wind speeds of 5-10 mph (8-16 kilometers per hour). The maximum treetop-level concentration was calculated to be 0.19 ppm at a distance of 580 meters (1900 feet) and is associated with a wind speed of about 13 mph (20 kilometers per hour).

Table 4.3

MAXIMUM ELEVATIONS ABOVE PLANT BASE IN THE VICINITY OF THE PROPOSED PLANT SITE

Distance from plant site (feet)	Elevation above plant base (feet)
0	0
1,000	0
2,000	50
3,000	50
4,000	100
5,000	150
6,000	150
7,000	150
8,000	200
9,000	200
10,000	200

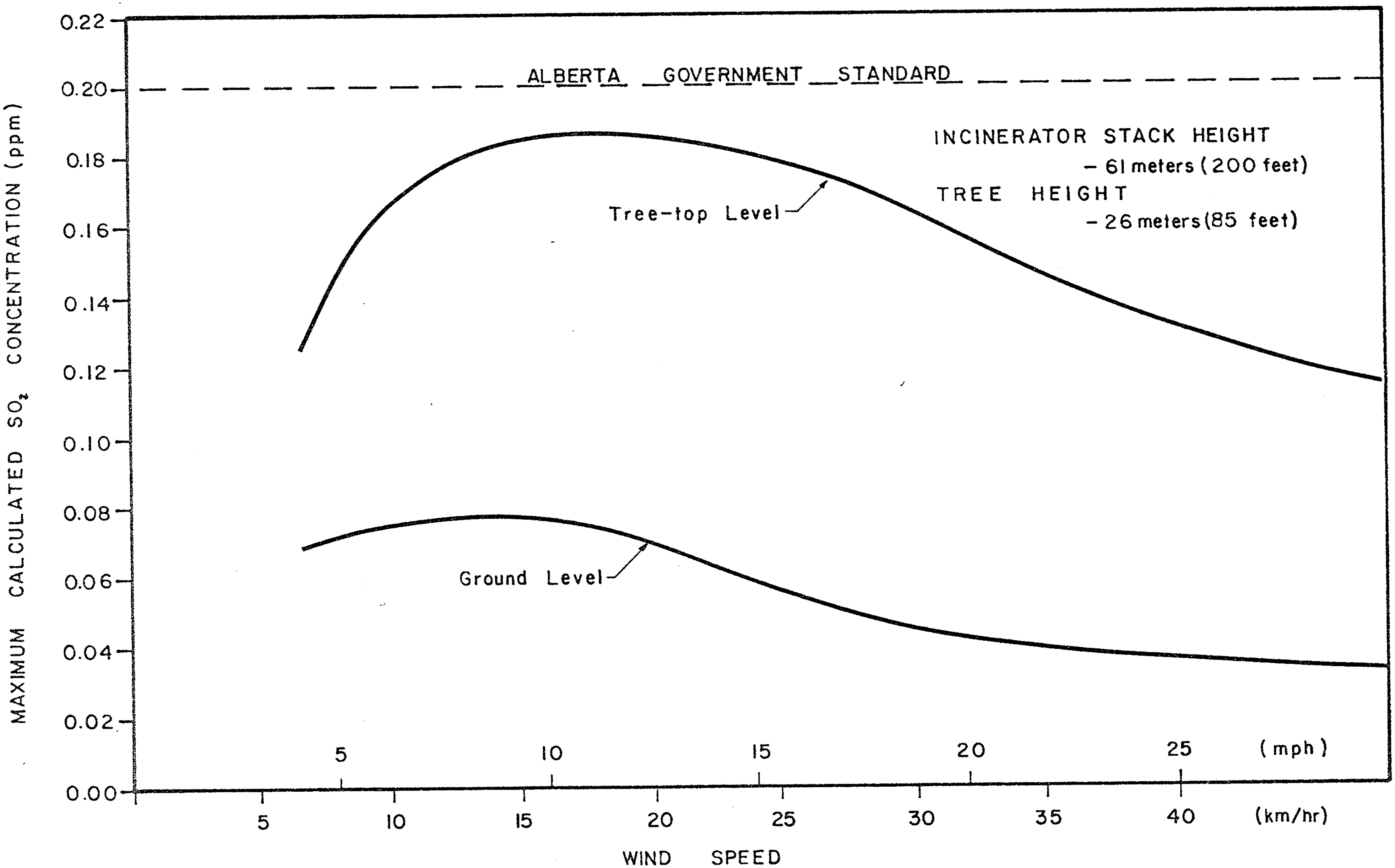


FIGURE 4.1 MAXIMUM CALCULATED SULPHUR DIOXIDE CONCENTRATION AS A FUNCTION OF WIND SPEED

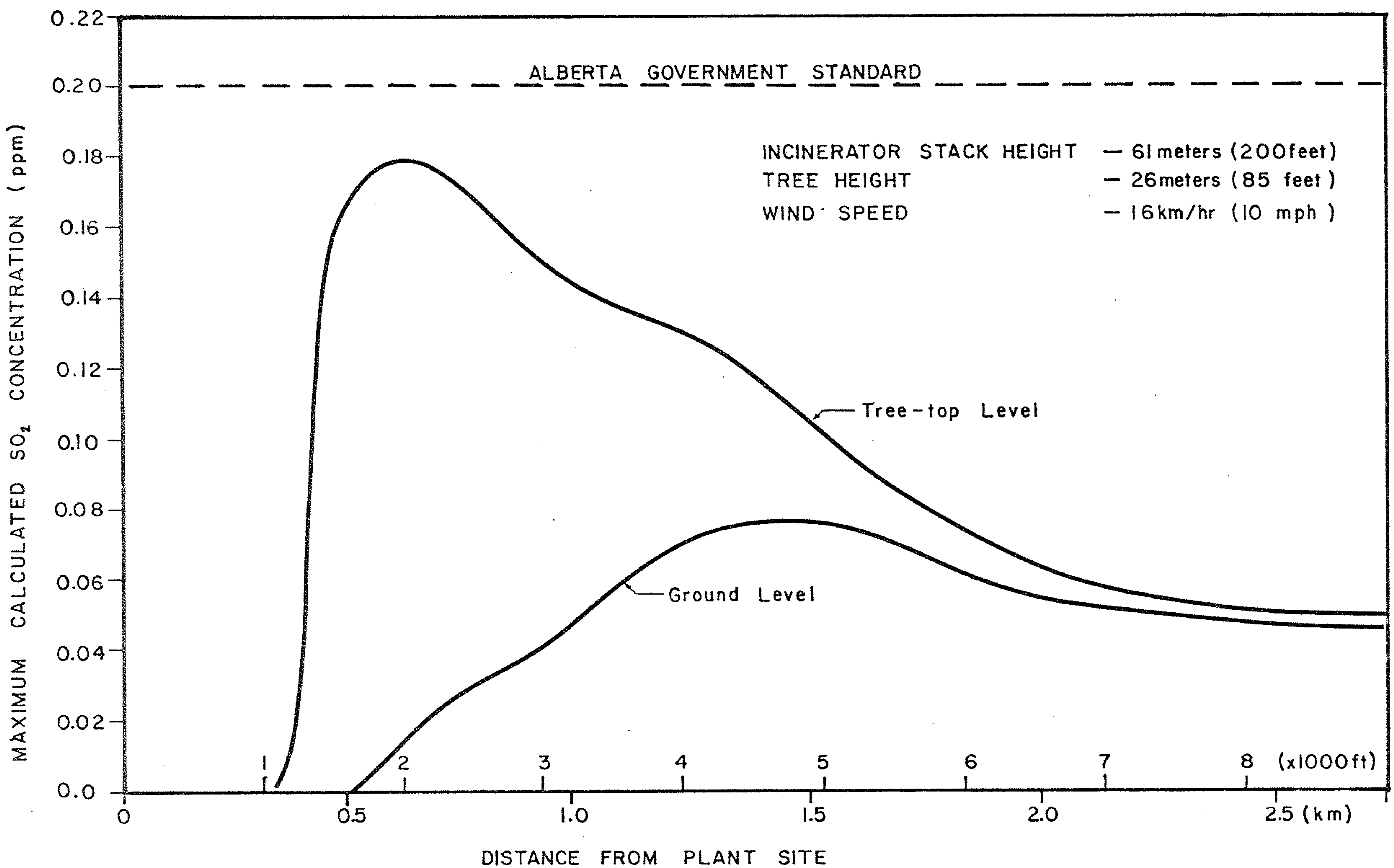


FIGURE 4.2 MAXIMUM SULPHUR DIOXIDE CONCENTRATION AS A FUNCTION OF DISTANCE FROM THE PLANT SITE

Two other gas processing plants are operated in the region. The Hudson's Bay Oil and Gas Co. Ltd. Brazeau plant is located 17 kilometers west of the proposed plant site and the Tenneco Oil of Canada Ltd. Nordegg plant is located 16 kilometers south of the proposed plant site. The proposed plant incinerator stack plume would line up with the Tenneco stack plume with either a north or south wind and with the Hudson's Bay stack plume with either an east or west wind.

Diffusion calculations, using the approved emission rates for the neighbouring plants given in Table 4.4, determined that in all cases the maximum sulphur dioxide concentration resulting from plume overlap would be less than 0.01 ppm.

4.1.2 Sulphur dioxide emissions from the flare stack

During periods of gas plant upset it may be necessary to flare all or part of the raw gas feed stream. If the sulphur plant shuts down the acid gas stream may be flared until sulphur processing can be resumed. The maximum ground-level sulphur dioxide concentrations that may result from each of these conditions was calculated.

4.1.2.1 Flaring raw gas

A severe gas plant upset may occasionally necessitate flaring the total raw gas stream of 19.4 MMSCFD. Using the flare stack raw gas emission parameters of Table 4.5 and the Briggs two-thirds plume rise formula for large heat sources given in Appendix E, the maximum ground-level sulphur dioxide concentrations were calculated to be less than 0.01 ppm in all cases.

4.1.2.2 Flaring acid gas

Acid gas flaring may be required during sulphur plant upsets. The maximum flare rate would occur during sulphur plant shutdown when the total acid gas stream of 1.19 MMSCFD containing 24 percent hydrogen sulphide would be flared. The gross heating value of the acid gas without a fuel gas

Table 4.4

EMISSION PARAMETERS[1] AND DETAILS OF NEIGHBOURING GAS PROCESSING PLANTS

	Hudson's Bay Oil and Gas Company Ltd. (Brazeau)	Tenneco Oil of Canada Ltd. (Nordegg)
Raw gas (MMSCFD)	196	67
Sulphur production (LTD)	90	45
Sulphur emissions (LTD)	8.4	4.0
Stack SO_2 concentration (ppm)	8300	9900
Distance from proposed plant (km)	16.6	16.0
Elevation (ft ASL)	3700	3400

[1]Based on Energy Resources Conservation Board approval rates

Table 4.5

FLARE STACK RAW GAS EMISSION PARAMETERS

Flare gas flow rate (MMSCFD)	19.4
Hydrogen sulphide concentration (%)	1.5
Sulphur emission rate (LTD)	10.9
Flame temperature (°F)	1800
Stack height (feet)	160
Stack exit diameter (inches)	15

supplement is 173 Btu/SCF, which is less than the minimum value of 250 Btu/SCF recommended by the Alberta Government (Department of Health, Division of Environmental Health Services, 1969). Thus, approximately 0.11 MMSCFD of fuel gas with a gross heating value of 1073 Btu/SCF would be required to supplement the acid gas during flaring in order to maintain the minimum gross heating value. Diffusion calcuations using the Briggs two-thirds plume rise formula showed that with this fuel gas supplement, half-hourly average ground-level sulphur dioxide concentrations of 0.54 ppm may result under the worst conditions. This is above the maximum allowable half-hourly average of 0.2 ppm.

There are two alternatives that may be used to maintain the half-hourly average below the limit. Either the flare time may be limited to less than half an hour, or alternatively, more fuel gas than the minimum required to raise the heating value could be used to supplement the acid gas. Diffusion calculations using the Briggs two-thirds plume rise formula were performed to determine the volume of additional fuel gas that would be required. The calculations showed that if the acid gas was supplemented by 1.5 MMSCFD fuel gas, the maximum half-hourly average sulphur dioxide ground-level concentration would be 0.18 ppm.

If only the minimum fuel gas supplement, 0.11 MMSCFD, were added to the acid gas, flaring would have to be limited to 10 minutes or less during any half-hour period.

The flare stack acid gas emission parameters are given in Table 4.6.

4.1.3 Sour gas release from pipeline failures

The operation of the sour gas gathering system presents a potential for the accidental release of hydrogen sulphide gas. Concentrations of hydrogen sulphide greater than 150 ppm for more than one hour are hazardous (Alberta Industry Government Sour Gas Environmental Committee, 1974). In Alberta, sour gas pipeline breaks averaged seven per year in the period 1971 to 1974, although only one rupture per year was considered

Table 4.6

FLARE STACK ACID GAS EMISSION PARAMETERS

	Acid gas	Acid gas plus 0.11 MMSCFD fuel gas	Acid gas plus 1.5 MMSCFD fuel gas
Flare gas flow rate (MMSCFD)	1.19	1.3	2.7
Hydrogen sulphide concentration (%)	24.0	22.0	10.59
Sulphur emission (LTD)	10.9	10.9	10.9
Flame temperature (°F)	1800	1800	1800
Stack height (feet)	160	160	160
Stack exit diameter (inches)	15	15	15

major. During the period 1970 to 1974, an average of one sour well blowout per year occurred in Alberta. The primary cause of pipeline ruptures was corrosion (Alberta Industry Government Sour Gas Environmental Committee, 1974).

For the purpose of being conservative it is considered in this report that concentrations greater than 100 ppm hydrogen sulphide would be hazardous for a period of exposure greater than one hour.

Diffusion calculations were performed in order to evaluate the ground-level hydrogen sulphide concentrations that would result from a pipeline rupture, assuming worst case conditions. The worst case is a surface release under Pasquill stability category F (moderately stable) with wind speeds of 4.4 mph (6.5 fps) (Alberta Industry Government Sour Gas Environmental Committee, 1974). The emission rate of hydrogen sulphide is assumed to be equal to the raw gas pipeline flow capacity of 19.41 MMSCFD.

The ground-level hydrogen sulphide concentration was calculated from the Gaussian plume model:

$$\chi = \frac{Q \cdot 10^6}{\pi \, \sigma_y \, \sigma_z U}$$

Where χ = time averaged ground-level concentration (ppm);

Q = hydrogen sulphide emission rate (SCFS);

σ_y σ_z = lateral and vertical standard deviations of the plume (ft);

U = wind speed (fps)

In order to estimate the most unfavourable hydrogen sulphide concentration, it is assumed that no check valves would be installed in any of the laterals feeding the plant. Thus the total raw gas flow of 19.41 MMSCFD would be released through a rupture at any point in the gathering system. The corresponding hydrogen sulphide emission rate would be 3.37 SCFS.

Assuming the worst cases as stated above, the product of the lateral and vertical standard deviations of the plume, with a concentration of 100 ppm hydrogen sulphide, was calculated to be 1634 ft^2 (152 m^2). The corresponding 100 ppm isopleth is predicted to occur at a downwind distance of 0.5 km (1650 feet) (Turner, 1969).

4.2 Effect on water resources

The potential impact to water resources in the vicinity of the proposed plant would be associated with the process water requirements, waste water disposal, and process area runoff.

4.2.1 Process water requirements

The proposed five Igpm process water requirements that would be obtained from a well would not have a significant effect on the groundwater resources of the area. The estimated groundwater 20-year safe yield is 25 to 100 Igpm (See 3.1.4.2).

4.2.2 Waste water disposal

No significant impact would be associated with waste water disposal. Waste water from the sour water stripper would be stored in a 2000 gallon wastewater storage tank and periodically trucked out to a waste water disposal well. No emissions would be associated with the storage tank as it is a closed system that would be vented into the low pressure flare. Pressure would be maintained in the storage tank by fuel gas.

The floor washings would be pumped to the wastewater storage tank, and the total waste water volume would not exceed 4 Igm. The tank would be emptied two or three times a day. Domestic wastewater would be handled by a conventional septic tank and disposal field.

4.2.3 Process area runoff

Surface rainwater runoff from the process area would be collected in ditches and directed to a 250,000 Imperial gallon storm holding pond lined with impermeable clay. The pond volume was determined on the basis of a process runoff area of 160,000 square feet. The estimated runoff volume for this area from a 3-inch rainfall and based on a 75 percent runoff is 187,500 Imperial gallons. The additional capacity is a safety factor. Following a rainstorm, water in the pond would be monitored and treated, if required, before being released to the surface water drainage system. Overflow would not occur unless there was an extremely heavy rainfall (approximately 4 inches) in a 24-hour period. Rainfall of this intensity is unlikely as the mean total precipitation for June, the month with heaviest rainfall, is less than four inches (see Figure 3.6).

4.3 Physical land changes

Physical land changes would be in the form of disruption of the natural vegetation component and topsoil from two major sources; (a) construction of the gas plant and site facilities, and (b) construction of the gathering system.

The proposed plant site, well locations and associated road and pipeline rights-of-way are shown in Figure 2.1. Since the roads to the wells and the well sites themselves have already been cleared and built, discussion of physical effects is restricted to physical land changes associated with the proposed plant site and pipeline corridors.

4.3.1 Proposed plant site

The processing plant would require a site approximately 1000 feet (305 meters) square and would cover an area of approximately 23 acres.

The existing landform on the proposed site would be graded to make the surface more uniform and to improve drainage. Essentially all of the 23 acres would be stripped, levelled to grade with clay fill and recovered with topsoil, except in those areas where permanent plant buildings and other structures are to be built. Site levelling and process unit foundations would not penetrate beneath the present land surface to a depth greater than 12 feet (4 meters).

4.3.2 Proposed gathering system

With exception of the pipeline to 6-3, the gathering system corridors would be constructed alongside the existing well access roads. As shown in Figure 2.1, the corridor to 6-3 would be located adjacent to the access road as it runs north until the road swings west. The pipeline would continue straight north until it connects again with the access road. From that point it would run adjacent to the south side of the road to the well site.

Pipelines constructed adjacent to the existing roads would require a 33 foot (10 meter) right-of-way. Otherwise a 50-foot (15 meters) right-of-way would be required.

For these right-of-way specifications, the approximate land areas that would be affected by each individual pipeline are:

Well	Length of pipeline - feet (meters)	Land area - acres
15-35	9930 (3027)	7.5
6-3	5089 (1551)	4.6
11-27	6120 (1805)	4.6

4.4 Effects on vegetation, soil, and wildlife

Essentially all of the natural vegetation communities, soil, and associated wildlife habitat that fall within the boundaries of the proposed plant site and pipeline routes, as given in Section 4.3, would be changed. The consequences of these changes are discussed below.

4.4.1 Effects on vegetation

The effects that the proposed development would have on vegetation within and around the plant site and pipeline routes is related to three general considerations:

(a) Direct elimination of vegetation communities on the proposed plant site and along the pipeline routes.
(b) Changes in soil moisture resulting from modification of topography that may change the species composition of immediately adjacent vegetation communities.
(c) Possible effects to vegetation from the release of sulphur dioxide to the atmosphere.

4.4.1.1 Direct elimination of vegetation communities

Figure 3.10 shows the location of the proposed plant site and pipeline routes in relation to the existing major vegetation groups.

The proposed plant site of 23 acres would be located on a slightly elevated piece of land that presently is covered by a dense mixed aspen-coniferous forest, which averages approximately 70 feet (21 meters) in height. Essentially all of the trees and understory vegetation within the proposed plant site would be removed.

Construction of the pipeline to well 6-3 would result in the removal of approximately five acres of muskeg-type forest, primarily black spruce averaging about 40 feet (12 meters) in height. The route to 11-27 would run through mixed aspen-coniferous, coniferous, and muskeg-type forest. The vegetation along this pipeline right-of-way would be cleared from approximately five acres of land. The pipeline to 15-35 would run through coniferous (black spruce and lodgepole pine) and mixed aspen-coniferous forest averaging approximately 70 feet (21 meters) in height. Approximately eight acres of land adjacent to the road would be cleared.

4.4.1.2 Changes in soil moisture

Topographical alterations arising from construction of the plant and pipeline would modify the existing surface water flow pattern within and in the vicinity of the development. This disruption may result in successional changes in the immediately adjacent vegetation communities, as these natural communities have established themselves as a result of the existing physical conditions.

Within the proposed plant boundaries all surface water that would normally run off would be collected and contained. This would result in drier than normal conditions in the immediately surrounding lands, which may lead to the eventual replacement of such species as black spruce and tamarack that customarily require moist conditions, by such species as aspen, white spruce, or pine that are capable of withstanding the drier soil environment.

Similarily, the existing surface water pattern along pipeline routes may result in different moisture conditions than normally exist, particularly if they intersect small stream channels which may cause the normal surface water flows to be diverted. This would likely result in long-term successional changes along the pipeline route to species more tolerant of the ensuing conditions.

4.4.1.3 Possible effects to vegetation from sulphur dioxide

The tolerance of a plant species to the effects of sulphur dioxide varies according to the different environmental conditions or the physical condition of the plant. Tolerance is lowest under the following conditions: high light intensity, high temperature, daylight, growing season, high relative humidity, water on leaves, very moist soil, old plants, low vigour, low nutritional levels, susceptible species and genetic effects (Loman et al. 1972). If the environmental factors and growth stages of the plants are not conducive to injury, damage will not take place even in the presence of potentially damaging concentrations of sulphur dioxide (Linzon, 1971).

Sulphur dioxide may cause acute or chronic leaf injury to plants. Acute injury is produced by high concentrations for relatively short periods, while chronic injury results from the gradual accumulation of excessive amounts of sulphate in the leaf tissue.

The susceptibility of several of the tree species found in the study area is given in Table 4.7. The diffusion calculations by Western Research & Development Ltd. show that the half-hour average ground-level concentration of sulphur dioxide resulting from the 61 meter (200 foot) incinerator stack and from the 49 meter (160 foot) flare stack would be less than 0.2 ppm provided a restricted flaring period or extra fuel gas assist is adopted (see section 4.1.1). It is generally accepted that this concentration should not adversely affect higher forms of vegetation.

It has been found that the most sensitive species of lichens are unable to survive in areas where annual sulphur dioxide levels are greater than 0.011 ppm and no lichen species survive where annual concentrations of sulphur dioxide exceed 0.035 ppm. No damage to lichens in the vicinity of the proposed plant should occur as the Alberta standard of 0.01 ppm average annual concentration of sulphur dioxide would be met with the stack design specifications given in Section 4.1.

Sulphur dioxide emissions may also have a positive impact on vegetation as plants have a nutritional requirement for the elemental sulphur. Sulphur dioxide may be absorbed through the leaves of plants and act as a plant nutrient.

Table 4.7

MINIMUM AVERAGE CONCENTRATION OF SULPHUR DIOXIDE (PPM)
AT WHICH INJURY TO VEGETATION HAS OCCURED

Exposure Durations	30 min.	1 hr.	2 hr.	4 hrs.	8 hrs.	24 hrs.
Trembling aspen		0.42	0.39	0.26	0.13	
White birch		0.46	0.38	0.28	0.21	
Balsam poplar		0.82	0.65	0.45	0.26	
White spruce		0.87	0.79	0.70	0.50	
Ambient air quality standards	0.20	0.17				0.06

Source: Loman et al. 1972, adapted from Dreisinger et al. 1970 and Alberta Department of the Environment, January 1973

Sulphur dioxide may also affect vegetation by changing the pH of the soil. The rate of soil acidification is slow but a shift on one unit of pH over a number of years in forests and grasslands would eventually result in more acid-tolerant species developing (Hocking and Nyborg, 1974). The minimum pH for good plant growth varies from 6.0 for alfafa to 3.5 for aspen. The pH range of most Alberta soils is 6.0 to 8.0. The normal pH of the upper horizon of the gray wooded and organic soils in the Brazeau region ranges from about 6.5 to 6.9.

4.4.2 Effects on soil

As described in Section 3.1.3 there are two major soil types in the vicinity of the proposed development, gray wooded soils and organic soils. Generally the gray wooded variety is located on moderate to well drained sites, while the organic soils are restricted to poorly drained muskeg areas.

The proposed 23 acre plant site is covered by moderately well drained gray wooded soil, which would be stripped off prior to construction to even the surface contours and improve drainage characteristics. The topsoil would be replaced in depressions and in those areas where permanent process structures were not erected.

The pipeline route to 6-3 would encounter primarily organic soils, while pipelines to 15-35 and 11-27 would run mainly through gray wooded soil areas. During pipeline construction the topsoil along the right-of-way would be stripped, the pipe would be buried, and the topsoil replaced.

Both major soil types have high erosion potential once the stabilizing vegetation cover is removed. The organic soils are generally located on level ground so erosion hazards would normally be slight.

Some localized topographical changes would be encountered along the pipeline routes to wells 15-35 and 11-27. The potential for soil erosion on slopes would be high, especially if construction took place during the spring runoff and during summer rain storms. Most of the discharge experienced during these periods would flow along the surface as the fine textured subsoils are not very permeable. Suitable engineering procedure would have to be employed to ensure that erosion damage is minimized.

Soils downwind of the gas plant would be potentially susceptible to a certain degree of acidification by sulphur dioxide emissions. The magnitude of this acidification would be very slight due to the low level of sulphur emissions from the proposed plant, and would vary with the existing sulphur and calcium content of the affected soil.

4.4.3 Effects on wildlife

The proposed development would have both direct and indirect effects upon wildlife populations within and in the vicinity of the plant site and pipeline corridors. These effects, which range from direct elimination of existing wildlife habitat to increased grazing land for ungulates, would have both a negative and a positive aspect with respect to wildlife populations in the area.

The deleterious effects that the proposed development would have on wildlife within and around the plant site and pipeline corridors is related to four general considerations:

(a) alteration of habitat that lowers an area's ability to support particular wildlife species;
(b) activity that can divert wildlife from important range areas and normal movements;

(c) improved access that increases hunting pressure on certain wildlife populations;

(d) human activity that attracts certain wildlife species (eg. black bear) resulting in conflict.

Habitat alteration on the plant site and along the pipeline corridors would have the greatest effect on those wildlife species that have very specific habitat requirements, have limited distribution, or concentrate in specific areas. However, clearing activities may also improve habitat conditions for other species of rodents, birds, and ungulates.

The following discussion will deal with particular categories of wildlife that would be affected by the proposed development.

4.4.3.1 Ungulates

In areas of mixed-wood and coniferous forest, construction that eliminates large tracts of tree cover has a negative effect on elk, deer, and moose populations. The areas of land that would be cleared for this development are considered relatively small and should not result in any major deleterious effects to ungulate populations.

However, a positive impact may also take place when thick forest that is presently unsuitable as ungulate grazing land is cleared along the pipeline corridors which would result in a new food source of colonizing vegetation types preferred by ungulates. Revegetation with suitable species should be undertaken as soon as possible after construction, especially on slopes, so that soil erosion on the exposed surfaces would not preclude vegetation recolonization.

During construction, intensive human and machinery activity would result in the short-term retreat of individual ungulates from the vicinity.

As shown in Figure 3.11, the proposed plant site and pipeline corridors are situated adjacent to an area of land along the Brazeau Reservoir that has been designated as key ungulate winter range. It is anticipated that the disturbance created by the proposed plant and facilities would substantially lower the capability of the winter range that exists on the Brazeau Reservoir south and east of the development, especially during the construction phase. Ungulates normally inhabitating this portion of the Brazeau Reservoir during the winter may restrict their activity to the extensive winter range areas east along the Brazeau River, or northeast along the Elk River. The limited field surveys that have been done in the area suggest that ungulate populations are not large enough to result in an overcrowding situation.

Improved road access would likely result in increased big game hunting pressure in the vicinity of the plant site and pipeline corridors.

4.4.3.2 Carnivores

The red fox and coyote have proven their adaptability and maintained their populations even in areas of high human activity. The proposed development would likely not produce negative effects to these species or to less tolerant and less abundant wolf and lynx populations unless construction results in the direct disturbance of active denning sites.

Black bears in the region may be affected in three ways:

- i) increased hunting pressure;
- ii) poor food waste disposal practices;
- iii) disturbance of denning sites.

The potential magnitude of increased hunting pressure is difficult to estimate. Regarding waste disposal, if easily obtainable garbage is available to black bears, they will tend to concentrate in the vicinity. They may lose their natural fear of man and thus become targets for hunters or gas plant personnel that may over-react to the presence of bears. For this reason it is essential that all food waste be carefully contained to avoid this problem.

It has been observed that activities 450 meters or more away from dens did not disturb normal black bear activity, and that in wooded areas black bears would remain at denning sites within 90 meters of highway construction activity (Environment Protection Board, 1974).

4.4.3.3 Small mammals

The impact of construction activity upon small mammals, particularly rodent species, can be considered major for the limited areas where individuals are eliminated. No extensive deleterious effects are anticipated. Construction activities may destroy individual home ranges on pipeline rights-of-way, access roads, and at the plant site. Resultant vegetative changes will tend to exclude some species from recolonizing the disturbed areas while encouraging colonization by others. Because small mammals have restricted home ranges, do not concentrate, and have high reproductive potential, the chances of a single, concentrated disturbance within a relatively narrow area destroying an entire population is remote. In fact, the edge effect created by the pipeline routing will probably increase the density of certain small mammal species along the cleared area.

Complete tree clearing and ground levelling at the proposed site will have a major adverse impact on resident small mammal species. A number of squirrels, chipmunks, voles and mice may be destroyed during construction and others will relocate. The magnitude of loss for the region is expected to be minor.

Hares are very mobile and it is unlikely that they will be affected by any construction activity except for direct destruction of home areas.

The porcupine has a low density, wide population distribution, and is solitary by nature. Therefore only a few individuals, if any, might be disturbed during clearing operations.

4.4.3.4 Waterfowl

The proposed development would result in little impact upon waterfowl and waterfowl habitat. Pipeline and plant site construction would create a certain amount of activity and noise that may occassionally disturb waterfowl resting on the Brazeau Reservoir, but the consequences would not be significant.

4.4.3.5 Other birds

Habitat clearing would eliminate a certain amount of desirable habitat which presently provides favourable shelter and nesting areas for perching birds and grouse. Grouse tend to be territorial and may be disrupted from their normal activities by the development. Song birds and perching birds are able to respond quickly and positively when environmental conditions are unfavourable. Combined with their wide spread distribution and large population numbers for most species, the long term effects of disturbances caused by man's activities would be minimal (Brooks et al., 1971). The impact of construction activity would be short term and although habitat would be destroyed, a favourable edge effect would develop around the plant site and along the pipeline corridors creating new habitat.

Birds of prey would not be significantly disturbed. No nesting sites were observed within the plant site or along the proposed pipeline corridor.

4.5 Social and economic impact

This section discusses the social and economic effects related to the proposed development. A summary is given in Table 4.8.

4.5.1 Economic characteristics of the proposed development

The immediate economic characteristics of the proposed development, which would involve establishment of a new gas processing plant and gathering lines, would be direct employment, gas production and a change in land use associated with the scheme. The estimated capital costs of the project are $4 million for the processing plant, and $1 million for the gathering system.

The positive aspects of the development would include direct employment opportunities during the construction and operating phases to people of the surrounding region, and increased revenues to the province of Alberta through royalty and tax payments on gas production. The negative socio-economic impacts of the proposed development consist of minor opportunity costs associated with land required for the processing plant, access roads and gathering lines.

4.5.1.1 Direct employment

The proposed development would provide employment opportunities during both the construction phase and during plant operation. The labour force required for pipeline and processing plant construction, and for operation and maintenance of the processing plant, would be composed of highly skilled tradesmen and labourers, typically consisting of machine operators, pipefitters, welders, carpenters, plant operators, and steam engineers.

It is estimated that pipeline construction would require a seven man crew over a period of 40 days. Construction of the plant and related facilities would take about eight months and would employ on the average 30 workers. The actual number of plant construction personnel would

Table 4.8

SUMMARY OF SOCIAL AND ECONOMIC EFFECTS RELATED

TO THE PROPOSED DEVELOPMENT

Item	Relative Effect	Refer to (report sections)
Employment opportunities	292 man-years total	4.5.1.1
Natural gas royalties	Approx. $1,550,000 per year for 20 years	4.5.1.2
Condensate royalties	Approx. $150,000 per year for 20 years	4.5.1.2
Value of timber cleared	Net value $15,000 maximum	4.5.1.3.1
Loss in timber royalties	Approximately $1000	4.5.1.3.1
Loss in existing fur production	Nil	4.5.1.3.4
Loss in potential fur production	Less than $2529 average per season	4.5.1.3.4
Loss in recreation opportunities	Minor	4.5.1.3.5
Populations changes	Minor	4.5.1.4

vary between 20 and 60 over the eight-month construction period. The plant construction personnel would be temporarily located at a construction camp located adjacent to the plant site.

The actual operation and maintenance of the facility would require 13 permanent staff working 10-hour shifts over an estimated minimum plant life of 20 years. Outside service and maintenance personnel would occasionally be required for specialized duties.

The scale and nature of the proposed development is small, thus it would not be expected to put a strain on the regional labour market. The majority of the construction workers and permanent employees would be drawn from Drayton Valley, Edson, Edmonton, or Calgary and smaller communities such as Lodgepole and Violet Grove that are within commuting distance of the plant site.

A summary of the minimum anticipated employment opportunities is given below:

		Labour force	Duration of employment	Man years employment
(a)	Construction phase			
	(1) Pipeline	7	40 days	1.2
	(2) Plant and facilities	30	8 months	30
(b)	Operation	13	20 years	260
			TOTAL	292

4.5.1.2 Natural gas, sulphur, and condensate production

At normal production rates of 14.0 MMSCFD sales gas and 8.3 LTD sulphur, and based on 355 days of operation per year, the proposed plant would produce 4970 MMSCF per year of natural gas, 2950 LT per year of elemental sulphur, and 69,000 barrels per year of condensate.

Assuming a conservative value of $1.00 per MCF of natural gas when the plant goes onstream, and a provincial royalty rate of 31 percent, natural gas production from the proposed development would result in royalty payments to the province of about 1.55 million dollars in the first year of production. Although decreasing reservoir pressures would be experienced, gas production is expected to last for a minimum of 20 years.

Sulphur marketing would not be economical under present conditions, so all elemental sulphur produced would be stored in block form on the site. The condensate would be stored in a 5000 barrel tank and would be sold and trucked out periodically.

The royalties paid to the province on condensate sales would approximate $150,000 per year.

4.5.1.3 Effects on existing land use

The proposed development would have a minor impact on the existing land use of the area. The most significant effects that would result to the existing land use pattern are discussed below.

4.5.1.3.1 Timber production

The proposed development would not affect existing timber operations. A total of approximately 40 acres of forest would be removed on the plantsite and pipeline rights-of-way. The value of timber removed cannot be accurately estimated without a detailed timber census and market survey.

A conservative approximation of the value of timber removed assumes that 20 acres of the forest cleared is or will develop into merchantable lodgepole pine or white spruce, yielding 10,000 board-feet per acre. At a wholesale value of $150 per thousand board-feet the total value of merchantable timber cleared would be $30,000. Assuming transportation and milling costs amount to half this value, the net value of timber removed would be $15,000. This is considered to be a high estimate as:

(a) The 40 acres that would be affected consists of mixed aspen-coniferous or muskeg-black spruce forest types. It is likely that substantially less than 20 acres of the land affected would be capable of yielding 10,000 board-feet per acre of merchantable white spruce or lodgepole pine.

(b) Merchantable timber in this area may not be economical to develop due to prohibitive costs in transporting the product to the closest saw mill.

It is assumed that all merchantable timber removed will be transported to the closest sawmill.

An additional factor is timber royalties. For timber that is removed as saw log or post material under the authority of a timber license, a royalty of $3 per thousand board - feet is paid to the Alberta government. For timber that is removed for industrial operations (eg. gas plant) the present provincial royalty is approximately $20 per acre. This means that approximately $800 in royalties would accrue from the proposed gas plant and gathering system if the land was cleared for development purposes only. If the same volume of timber were to be removed under the authority of a timber license, up to $1800 would be paid in royalties. This loss in timber royalties is rather insignificant when compared with the petroleum royalties that would be paid.

4.5.1.3.2 Hydro-electric power development

The proposed development would have no significant effect on power development. However if Calgary Power Ltd. should raise the maximum level of the Brazeau Reservoir to 3200 feet from the present maximum 3170 feet, the 6-3 lease would be flooded. The 6-3 well site corner elevations are as follows: (All-Can Engineering & Surveys Ltd., 1975)

NE 3195.8 feet
SE 3197.5 feet
SW 3198.7 feet
NW 3197.3 feet

Since the lease slopes upward to the south, the proposed 3200 foot water level would not flood far past the lease. If the water level is raised, the Energy Resources Conservation Board (ERCB) would require the wellhead to be elevated 3 to 4 feet above the maximum water level. A pad and upgraded road would also have to be built around the well for access purposes. The pad would probably be rip-rapped in order to decrease erosion potential.

4.5.1.3.3 Natural gas production

The proposed development would increase raw gas production in the region from the existing 263 MMSCFD (combined capacity of Hudson's Bay Oil & Gas Ltd. and Tenneco Oil of Canada Ltd.) to 280 MMSCFD. Sulphur production would be increased from 136 LTD to 146 LTD.

4.5.1.3.4 Fur trapping

The proposed development would not affect existing trapping activities in the area. These have been restricted to one township, the closest boundary of which is located approximately four miles northwest of the proposed plant site. The existing trapline is also about the same distance from the existing Hudson's Bay Oil & Gas Ltd. Brazeau gas plant.

It is possible that the proposed development may discourage fur trapping on the land immediately adjacent to it but it is difficult to estimate the area of land in which future fur trapping activities would be discouraged. However, it may be confidently assumed that substantially less than one township would be affected.

The average historical value of the fur-harvest for one township in the area is $2,529 per season (see Table 3.11). It follows that the potential fur trapping opportunity costs associated with the proposed development would be substantially less than this amount per season.

4.5.1.3.5 Recreation

The proposed development should have little effect on present human recreation activity in the area. Since big game hunting is the primary recreation activity in the area, negative effects may be related to disturbance of big game animals. Noise and activity would result in higher disturbance during the eight month construction period than during normal plant operation. In the same context, positive aspects (as far as hunters are concerned) may be associated with the additional four miles of access road and pipeline rights-of-way into the area, allowing better penetration of the heavy bush.

4.5.1.4 Effects on population

The small labour force required for the construction and operation of the proposed development would have little effect on the existing population of the region. As discussed in Section 4.5.1.1, construction of the plant would employ about 30 workers over an eight month period. Construction of the pipeline would require a seven man crew over a period of 40 days. The construction personnel would likely be drawn from major urban centers in Alberta and would be temporarily located at a construction camp.

Operation of the facility would require 13 permanent staff who would probably live in Drayton Valley with their families or be located in a camp at the proposed plant site and commute on a weekly basis to and from their homes.

4.5.2 Changes in natural resource capability

As discussed in Section 3.4, the land within the study area possesses various degrees of capability for ungulate range, outdoor recreation, logging, grazing, and agriculture. In addition the Brazeau Reservoir, Brazeau River and Elk River provide sportfish capability. The anticipated changes in each of these resource capabilities is discussed below.

4.5.2.1 Land capability for ungulate range

The plant site and gathering lines would be constructed in areas that are classified by FRAS as providing good to good-excellent capability for ungulate range. Regarding the ungulate resource, FRAS (1973) reports

> " The Brazeau area has already undergone some deterioration such as erosion along cutlines on steep grades and the impediment of drainage along some tracks and service roads. Even more evident has been the decline in elk populations in the past twenty years. In the 1940's hunters commonly encountered herds of 50 or 60 elk daily. With improved access to hunters and the loss of habitat caused by the building of Brazeau Dam, this is no longer the case."

> "The ungulate resource is in danger of deterioration if other resource capabilities are to be exploited on the same land unit. There is evidence that the cutting of overstocked timber stands can cause a reversion to an early stage of plant succession and a condition better suited for grazers such as elk and browsers such like deer and moose. Increased access, however, may offset the resultant increase in populations."

4.5.2.2 Land capability for outdoor recreation

The proposed development would occur in an area that provides low to moderate capability for outdoor recreation. FRAS reports:

" Exploration for and extraction of oil and gas generally detract from the beauty of the countryside and harm its recreational value. The importance of this conflict may be less than elsewhere, because the muskegs, dense forests, and uniform terrain do not offer any great appeal for most tourists."

4.5.2.3 Land capability for logging

The ability of the land to produce commercial timber that would be cleared by the proposed development varies between no capability to good-excellent. The overall effect on the timber resource of the area has been discussed in Section 4.5.1.3.1.

4.5.2.4 Land capability for grazing

The land area that would be affected by the proposed development provides no capability for grazing.

4.5.2.5 Land capability for agriculture

Most of the land that would be affected possesses no capability for agriculture due to generally unfavourable soil and a short growing season. A small area of land surrounding the plant site provides low-moderate capability for agriculture, but would require timber clearing and soil upgrading in order to produce forage crops.

4.5.2.6 Water capability for sport fish

The Brazeau Reservoir, Brazeau River and Elk River provide good-excellent capability for sport fish. FRAS reports that the area has few limitations to the production of sport fish. The most common species is dolly varden, but smaller populations of Rocky Mountain whitefish and brook trout are present. Lake sturgeons are also occasionally recorded in the Brazeau River below the power development.

The proposed development should not affect the sportfish capability of the region. There would be some surface water runoff and erosion associated with pipeline construction, but this would not result in significant siltation of the reservoir.

4.5.3 Aesthetic impact

An evaluation of the aesthetic impact of the proposed gas processing development involves consideration of the type and magnitude of the anticipated change in quality of the landscape in terms of physical attractiveness and uniqueness of landform.

The landscape to be affected is typical of the general area which consists of large tracts of mixed forest and muskeg-marsh areas. The recreational value of the area is generally low which may be attributed largely to the homogeneity of the landscape and lack of unique landform.

The development of the proposed gas project, particularly the processing plant, would permanently reduce the existing aesthetic quality of the area due to the introduction of an industrial facility. However, previous development of two similar plants (one ten miles south and one ten miles west of the proposed project), development of the Brazeau Reservoir and Power Facility, and a network of service roads and seismic lines has already had significant impact on the area.

The following facilities would comprise the most conspicuous features at the plant site:

One 200 foot, 2 foot diameter incinerator stack, that would be painted with red and white stripes.

One 160 foot, 15 inch diameter flare stack, that would be painted an inconspicuous colour.

Four processing towers, less than 100 feet high, that would be painted with inconspicuous colours.

One sulphur storage block less than 30 feet high.

Several plant buildings less than 20 feet high that would be painted an inconspicuous colour.

The plant site is surrounded by trees averaging 75 feet in height. These will effectively screen the processing towers, plant units, sulphur storage block and plant buildings until the viewer is in close proximity to the plant.

The incinerator and flare stack will project above the surrounding forest by approximately 130 and 90 feet respectively. These stacks would be visible throughout the reservoir area and from as far away as two to five miles in the east and west directions. Due to the river valleys that develop north and south of the proposed site the stacks would be visible from up to ten miles away.

When viewed from the east at distances greater than four miles the plant stacks would not project against the skyline but would be presented against a forested hill or mountain background that would reduce the impact considerably.

There are no permanent residences in the study area and for the most part, persons in the area are involved with the oil and gas industry or forestry operations and the service industries associated with them.

The viewing public on whom the aesthetic impact must be considered is, therefore, primarily the recreational public, walking, boating, fishing or hunting in the area. The number of persons involved in these pursuits in this area is small.

The overall aesthetic impact of the proposed development is anticipated to be minor, due to the remoteness of the area from the general public and the existing industrial development. The height of the surrounding forest would screen most of the plant structures with the exception of the top 90 to 130 feet of the stacks which would be visible over most of the study area.

REFERENCES

Alberta Industry Government Sour Gas Environmental Committee (1974) "Guidelines for Urban Development in Relation to the Sour Gas Industry", Edmonton.

All-Can Engineering & Surveys Ltd. (1975) Plan showing location of Decalta et al. Brazeau N 6-3-46-12, Map.

Berlie, E.M. (1971) "Processing of Natural Gas", Texasgulf Sulphur Company Ltd., Okotoks, Alberta.

Brooks, J.W., J.C. Bartonek, D.R. Klein, D.C. Spencer, and A.S. Thayer (1971) "Environmental influences of oil and gas development in the Arctic slope and Beaufort Sea", U.S. Department of the Interior, Bureau of Sport, Fish and Wildlife Resources, Publication 96, 24 pp.

Farvolden, R.N. (1961) "Groundwater resources Pembina area, Alberta" Research Council of Alberta, Preliminary Report 61-4, Edmonton.

Government of Alberta, Department of the Environment (1975) Clean Air Regulations, 218/75.

____________________ (1975) Alberta Environmental Impact Assessment System Interim Guidelines.

________________, Department of Labour (1971) Alberta Regulation 30/71 "Protection of workers from the effects of noise".

________________, Department of Health (1969) "Air Pollution Control at Gas Processing and Sulphur Recovery Plants".

Government of Alberta and Government of Canada (1973) "The Foothills Resource Allocation Study Phase 1 - Lower Brazeau Drainage District" Alberta Department of Lands and Forests, Alberta Environment, Environment Canada, Edmonton.

Government of Canada, Department of Transport, Meteorological Branch "1968 Climatic Normals Volume 3 - Sunshine, cloud, pressure and thunderstorms", Toronto.

________________ Department of Transport, Meteorological Branch "1968 Climatic Normals Volume 4 - Humidity", Toronto.

________________ Department of Transport, Meteorological Branch, "1968 Climatic Normals Volume 5 - Wind", Toronto.

________________ Department of Transport, Meteorological Branch "1968 Hourly Data Summaries - No. 47 - Rocky Mountain House".

________________ Department of the Environment (1973) "Temperature and precipitation - 1941 to 1970 - Prairie Provinces" Atmospheric Environment, Downsview, Ontario.

________________ Department of the Environment (1973) "Canadian Normals Volume 1 - Temperatures 1941 to 1970" Atmospheric Environment, Downsview, Ontario.

________________ Department of the Environment (1973) "Canadian Normals Volume 2 - Precipitation 1941 to 1970" ATmospheric Environment, Downsview, Ontario.

________________ Department of the Environment (1974) "Environmental Impact Assessment of the portion of the McKenzie gas pipeline from Alaska to Alberta" Environment Protection Board, Winnipeg, Volume 4, Research Report.

__________________ Department of the Environment, Water Survey of Canada, Analytical water quality data and flow data of the Brazeau River.

__________________ (1968) "1966 Census of Canada - population unincorporated places" Dominion Bureau of Statistics Catalogue 92 - 633, Bulletin S-3, Ottawa.

__________________ (1973) "1971 Census of Canada - population unincorporated settlements", Statistics Canada Catalogue 92 - 771 (SP-1)

__________________ (1967) "1966 Census of Canada, Population - Divisions and Subdivisions, Western provinces" Dominion Bureau of Statistics Catalogue No. 92-606, Ottawa.

__________________ (1962) "1961 Census of Canada, Population, Divisions and Subdivisions" Dominion Bureau of Statistics Catalogue 92-534, Ottawa.

Haltiner, G.J. and F.C. Martin (1957) "Dynamical and physical meteorology" McGraw Hill, Toronto, 470 pp.

Hare, F.K. and M.K. Thomas (1974) "Climate Canada" Wiley Ltd., Toronto 256 pp.

Hocking, D. and M. Nyborg (1974) "The problem of soil acidification by sulphur dioxide", Proceedings of workshop on reclamation of disturbed lands in Alberta" Alberta Environment and Environment Canada.

Lesko, G.L. and J.D. Lindsay (1973) "Forest/soil relationships and management considerations in a portion of the Chip Lake map area, Alberta" Alberta Research Report 731, Edmonton 66 pp.

Linzon, S.N. (1971) "Effects of sulphur dioxide on vegetation" Air Management Branch, Ontario Department of the Environment, Toronto.

Loman, A.A., R.A. Blauel and D. Hocking (1972) "Sulphur dioxide and forest vegetation" Northern Forest Research Center, Information Report NORX49, Edmonton.

Nibourg, J. and B. Hall (1976) "Region III Mountain Moose (Drainage) Survey" Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division, unpublished report, Edmonton.

Peters, T.W. and W.E. Bowser (circa 1950) "Soil Survey of Rocky Mountain House sheet" Alberta Soil Survey Report No. 19, Edmonton.

Rowe, J.S. (1959) "Forest regions of Canada" Canada Department of Northern Affairs and Natural Resources, Forestry Branch, Bulletin 123, Ottawa.

Toharsky, O. (1971) "Hydrogeology of the Rocky Mountain House Area, Alberta" Research Council of Alberta Report 71-3, Edmonton.

Turner, A.B. (1969) "Workbook of atmospheric dispersion estimates" U.S. Department of Health, Education and Welfare, Cinncinati, Ohio.

Twardy, A.G. and J.D. Lindsay (1971) "Soil survey of the Chip Lake area" Alberta Soil Survey Report S-71-28.

Western Decalta Petroleum Ltd. (1976) "Brazeau East Gas Plant Approval Submission", Calgary, Alberta.

Wingert, K. (1974) "Brazeau Reservoir land use assignemtns ungulate survey" Alberta Recreation, Parks, and Wildlife, Fish and Wildlife Division, Habitat Land Use Section, unpublished report, Edmonton.

APPENDIX A

Water Quality Data - Brazeau River

Source: Environment Canada, Analytical Services Section

WATER QUALITY DATA

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	02061S TEMP. WATER DEG.C.	02041S SPECIFIC CONDUCT. US/CM	10301S PH PH UNITS	08101S OXYGEN DISSOLVED DO O2 MG/L	02061L TEMP. WATER DEG.C.	02041L SPECIFIC CONDUCT. US/CM	02073L TURBIDITY JTU	10301L PH PH UNITS
8	6	72	12	50	20.0							
6	9	72	14	30	13.0	290	8.0					
20	6	73	09	50	16.0	260	8.7					
1	7	73			21.0		7.9		24.5	285	1.4	8.3
22	1	74	12	45	1.0	380	8.4		22.2	343	1.1	7.9
29	5	74	11	10	11.0	216	8.3		19.8	291	4.5	7.9

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	02011L COLOUR APPARENT REL. UNITS	10602L HARDNESS TOTAL (CALCD.) CACO3 MG/L	10603L HARDNESS TOTAL CACO3 MG/L	10451L RESIDUE FILTERABLE MG/L	10551L RESIDUE FIXED FILTERABLE MG/L	10401L RESIDUE NONFILTR. MG/L	10501L RESIDUE FIXED NONFILTR. MG/L	10151L ALKALINITY PHENOL PHTHALEIN CACO3 MG/L
1	7	73			8		145.					0.
22	1	74	12	45	10		167.					0.0
29	5	74	11	10	40		144.					

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D M Y	TIME MST H M	20101L CALCIUM DISSOLVED CA MG/L	12102L MAGNESIUM DISSOLVED MG MG/L	12101L MAGNESIUM DISSOLVED (CALCD.) MG MG/L	11103L SODIUM DISSOLVED NA MG/L	17203L CHLORIDE DISSOLVED CL MG/L	16303L SULPHATE DISSOLVED SO4 MG/L	06201L BICARBONT. (CALCD.) HCO3 MG/L	00201L TOTAL DISSOLVED SOLIDS (CALCD.) MG/L
1 7 73		41.0		10.4	3.2	1.3	30.0 04L		161
22 1 74	12 45	48.0		11.4	3.8	0.8	41.0 04L	163	191
29 5 74	11 10	40.0		10.7	4.0	1.0 06L	33.0 04L	146	167

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D M Y	TIME MST H M	10101L ALKALINITY TOTAL CACO3 MG/L	09105L FLUORIDE DISSOLVED F MG/L	19103L POTASSIUM DISSOLVED K MG/L	14102L SILICA REACTIVE SIO2 MG/L	06711L CHLORO- PHYLL A MG/L	26102L IRON DISSOLVED FE MG/L	26304P IRON EXTRBLE. FE MG/L	06531P PHENOLIC MATERIAL PHENOL MG/L
8 6 72	12 50							0.26	
6 9 72	14 30							L.05	
20 6 73	09 50							0.16	
1 7 73		116	0.06	1.1	4.6	0.009		0.05	
22 1 74	12 45	134	0.11	0.8	4.8	L.001		L.05	
29 5 74	11 10	120	0.08	0.7	5.6	L.001		0.12	0.007

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	15255L PHOSPHORUS DISSOLVED ORTHO PO4 P MG/L	15413L PHOSPHORUS TOTAL P MG/L	07108L NITROGEN DISSOLVED NO3 & NO2 N MG/L	07001L NITROGEN TOTAL KJELDAHL N MG/L	07602L NITROGEN TOTAL (CALCD.) N MG/L	06051L CARBON TOTAL INORGANIC C MG/L	06001L CARBON TOTAL ORGANIC C MG/L	03301P LITHIUM EXTRBLE. LI MG/L
8	6	72	12	50								L.005
6	9	72	14	30								L.005
20	6	73	09	50								L.005
1	7	73				L.005	0.010 06L	0.5	0.51	23.0	3.0	
22	1	74	12	45		0.006	0.100 06L	L.5	0.10	18.0	3.0	
29	5	74	11	10		0.013	0.020 06L	L.5	0.02	25.0	11.0	

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE			TIME MST		25101L MANGANESE DISSOLVED MN MG/L	25304P MANGANESE EXTRBLE. MN MG/L	29105L COPPER DISSOLVED CU MG/L	29305P COPPER EXTRBLE. CU MG/L	82101L LEAD DISSOLVED PB MG/L	82302P LEAD EXTRBLE. PB MG/L	30105L ZINC DISSOLVED ZN MG/L	30305P ZINC EXTRBLE. ZN MG/L
D	M	Y	H	M								
8	6	72	12	50		0.02		L.001		0.001		L.001
6	9	72	14	30		0.01		0.001		L.001		0.001
20	6	73	09	50		0.02		L.001		L.001		0.02 04P
1	7	73				L.01		0.002		0.005		0.015
22	1	74	12	45		0.01		0.004		L.001		0.001
29	5	74	11	10		0.02		0.002		L.001		0.003

STATION 00AL05D00006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	24052L CHROMIUM DISSOLVED CR MG/L	24302P CHROMIUM EXTRBLE. CR MG/L	28101L NICKEL DISSOLVED NI MG/L	28302P NICKEL EXTRBLE. NI MG/L	27102L COBALT DISSOLVED CO MG/L	27302P COBALT EXTRBLE. CO MG/L	42101L MOLYBDENUM DISSOLVED MO MG/L	42301P MOLYBDENUM EXTRBLE. MO MG/L
8	6	72	12	50		L.010		L.001		L.001		L.05
6	9	72	14	30		L.010		0.005		0.003		L.05
20	6	73	09	50		L.010		0.005		0.003		L.05
1	7	73				L.010		0.004		0.003		L.05
22	1	74	12	45		L.010		0.003		0.001		L.05
29	5	74	11	10		L.010		L.001		L.001		

WATER QUALITY DATA

REQUEST 0008 PAGE 1

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE			TIME MST		48101L CADMIUM DISSOLVED CD MG/L	48302P CADMIUM EXTRBLE. CD MG/L	13101L ALUMINUM DISSOLVED AL MG/L	13302P ALUMINUM EXTRBLE. AL MG/L	23301P VANADIUM EXTRBLE. V MG/L	38301P STRONTIUM EXTRBLE. SR MG/L	56301P BARIUM EXTRBLE. BA MG/L	05105L BORON DISSOLVED B MG/L
D	M	Y	H	M								
8	6	72	12	50		L.001		0.30	L.05	0.27	0.1	
6	9	72	14	30		L.001		L.10	L.05	0.24	L.1	
20	6	73	09	50		L.001		L.10	L.05	0.16	L.1	
1	7	73				L.001		0.18			L.1	L.02
22	1	74	12	45		L.001		L.10		0.30	L.1	0.04
29	5	74	11	10		0.002		0.25		0.25	L.1	0.08

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	33103L ARSENIC DISSOLVED AS MG/L	33303P ARSENIC EXTRBLE. AS MG/L	34102L SELENIUM DISSOLVED SE MG/L	80311P MERCURY EXTRBLE. HG UG/L	80111L MERCURY DISSOLVED HG UG/L	47301P SILVER EXTRBLE. AG MG/L	47101L SILVER DISSOLVED AG MG/L
8	6	72	12	50	0.006			L.05		L.01	
6	9	72	14	30				L.05		L.01	
20	6	73	09	50	L.005			L.05		L.01	
1	7	73						0.07		L.01	
22	1	74	12	45				L.05		L.01	
29	5	74	11	10	L.0005 04L			L.05		L.01	

STATION 00AL05DD0006 LATITUDE 52D 54M 45S LONGITUDE 115D 21M 50S

BRAZEAU RIVER BELOW POWERHOUSE, ALBERTA

SAMPLE DATE D	M	Y	TIME MST H	M	18140L ENDRIN UG/L	18520L MCPA UG/L	18161L AROCLOR 1248 (PCB'S) UG/L	18160L AROCLOR 1254 (PCB'S) UG/L	18162L AROCLOR 1260 (PCB'S) UG/L	18163L AROCLOR 1016 (PCB'S) UG/L	51301P ANTIMONY EXTRBLE. SB MG/L	81302P THALLIUM EXTRBLE. TL MG/L
8	6	72	12	50							L.20	L.10
6	9	72	14	30							L.5	L.10
20	6	73	09	50								L.2 01P
29	5	74	11	10			L.02	L.03	L.06			

APPENDIX B

Vegetation Species in Vicinity of Study Area

Source: Lesko, G.L. and J.D. Lindsay (1973) Forest/Soil relationships and management considerations in a portion of the Chip Lake map area, Alberta. Alberta Research Report 73-1

APPENDIX B

VEGETATION SPECIES IN VICINITY OF STUDY AREA

Common Name	Scientific Name
1. Trees	
Alpine Fir	*Abies lasiocarpa*
Paper Birch	*Betula papyrifera*
Tamarack	*Larix laricina*
White Spruce	*Picea glauca*
Black Spruce	*Picea mariana*
Lodgepole Pine	*Pinus contorta*
Balsam Poplar	*Populus balsamifera*
Aspen	*Populus tremuloides*
2. Shrubs	
Green Alder	*Alnus sinuata*
River Alder	*Alnus tenuifolia*
Saskatoon-berry	*Amelanchier alnifolia*
Common Bearberry	*Arctostaphylos uva-ursi*
Swamp Birch	*Betula pumila*
Dogwood	*Cornus stolonifera*
Beaked Hazelnut	*Corylus cornuta*
Silverberry	*Elaeagnus commutata*
Labrador Tea	*Ledum groenlandicum*
Bracted Honeysuckle	*Lonicera involucrata*
Twining Honeysuckle	*Lonicera dioica*
Choke Cherry	*Prunus virginiana*
Golden Current	*Ribes aureum*
Wild Gooseberry	*Ribes hirtellum*
Bristly Black Current	*Ribes lacustre*
Prickly Rose	*Rosa acicularis*
Wild Red Raspberry	*Rubus strigosus*

Common Names	Scientific Name
2. Shrubs	
Willow	*Salix myrtillifolia*
Willow	*Salix* spp.
Canadian Buffalo-berry	*Shepherdia canadensis*
White Meadowsweet	*Spiraea lucida*
Mountain Ash	*Sorbus scopulina*
Snow Berry	*Symphoricarpos albus*
Tall Bilberry	*Vaccinium membranaceum*
Blueberry	*Vaccinium myrtilloides*
Low Bilberry	*Vaccinium myrtillus*
Grouse-berry	*Vaccinium scoparium*
Low-bush Cranberry	*Viburnum edule*
3. Herbs	
Yarrow	*Achillea sibirica*
Red and White Baneberry	*Actaea rubra*
Monkshood	*Aconitum delphinifolium*
Wild Sarsaparilla	*Aralia nudicaulis*
Arnica	*Arnica cordifolia*
Lindley's Aster	*Aster ciliolatus*
Lady Fern	*Athyrium filix-femina*
Grape Fern	*Botrychium virginianum*
Bluejoint-Marsh Reed Grass	*Calamagrostis canadensis*
Pine Grass	*Calamagrostis rubescens*
Marsh Marigold	*Caltha palustris*
Venus'-slipper	*Calypso bulbosa*
Bluebell Harebell	*Campanula rotundifolia*
Bitter Cress	*Cardamine pensylvanica*
Sedge	*Carex capillaris*
Sedge	*Carex concinna*
Sedge	*Carex disperma*
Sedge	*Carex douglasii*

Common Names	Scientific Name
3. Herbs	
Sedge	Carex media
Sedge	Carex sprengelii
Common Red Paint Brush	Castilleja miniata
Enchanter's Nightshade	Circaea alpina
Purple Clematis	Clematis verticillaris
Pale Coral-root	Corallorhiza trifida
Bunchberry	Cornus canadensis
Bladder Fern	Cystopteris fragilis
Broad Spinulose Shield Fern	Dryopteris dilatata
Smooth Wild Rye	Elymus glaucus
Hairy Wild Rye	Elymus innovatus
Fireweed Great Willow-hero	Epilobium angustifolium
Common or Field Horsetail	Equisetum arvense
Scouring Rush	Equisetum hyemale
Horsetail	Equisetum scirpoides
Woodland Horsetail	Equisetum sylvaticum
Wild Strawberry	Fragaria virginiana
Cleavers	Galium aparine
Northern Bedstraw	Galium boreale
Toad-Flax	Geocaulon lividum
Crane's-bill	Geranium richardsonii
Purple or Water Avens	Geum rivale
Rattlesnake Plantain	Goodyera repens
Oak Fern	Gymnocarpium dryopteris
Northern Green Orchid	Habenaria hyperborea
Hedysarium	Hedysarium alpinum
Cow Parsnip	Heracleum lanatum
Woolly Hawkweed	Hieracium albertinum
Rush	Juncus sp.
Pea Vine	Lathyrus ochroleucus

Common Names	Scientific Name

3. Herbs

Western Wood Lily	Lilium philadelphicum
Twin-flower	Linnaea borealis
Stiff Club-moss	Lycopodium annotinum
Common or Running Club-moss	Lycopodium clavatum
Ground Cedar	Lycopodium complanatum
Tree Club-moss Ground Pine	Lycopodium obscurum
Wild Lily-of-the-Valley Two-leaved Solomon's Seal	Maianthemum canadense
White Sweet Clover	Melilotus alba
Tall Mertansia	Mertensia paniculata
Bishop's cap	Mitella nuda
Bishop's-cap	Mitella trifida
One-flowered Wintergreen	Moneses uniflora
Round Leaved Orchid	Orchis rotundifolia
Rice Grass	Oryzopsis asperifolia
Sweet Cicely	Osmorhiza depauperata
Small Bog Cranberry	Oxycoccus microcarpus
Palmate-Leaved Coltsfoot	Petasites palmatus
Arrow-Leaved Coltsfoot	Petasites sagittatus
Bluegrass	Poa glaucifolia
Common Pink Wintergreen	Pyrola asarifolia
Large Wintergreen	Pyrola bracteata
White-veined Wintergreen	Pyrola picta
One-sided Wintergreen	Pyrola secunda
Greenish-flowered Wintergreen	Pyrola virens
Buttercup	Ranunculus sp.
Cloudberry Baked-Apple Berry	Rubus chamaemorus
Creeping Raspberry	Rubus pedatus
Dewberry Running Raspberry	Rubus pubescens
False Melic	Schizachne purpurascens
False Solomon's-seal	Smilacina racemosa

3. Herbs

Common Names	Scientific Name
Star-flowered Solomon's-seal	*Smilacina stellata*
Chickweed	*Stellaria* sp.
Twisted-stalk	*Streptopus amplexifolius*
Veiny Meadow Rue	*Thalictrum venulosum*
Common Nettle	*Urtica gracilis*
Bog Cranberry Cow-berry	*Vaccinium vitis-idaea*
	Valeriana sitchensis
Wild Vetch	*Vicia americana*
Western Canada Violet	*Viola rugulosa*

APPENDIX C

THE GAUSSIAN MODEL
FOR PREDICTING DIFFUSION
FROM A CONTINUOUS POINT SOURCE

Source: Dr. D. Leahey
Western Research & Development Ltd.
Calgary, Alberta

The well-known Gaussian distribution has been assumed as a continuous source diffusion model by Sutton (1932), Frenkiel (1953), and many others. Rectangular co-ordinates are used in the model with the x co-ordinate in the direction of the mean horizontal wind $\bar{U}$, z in the vertical direction and y in the lateral.

The usual simplifying assumptions are:

(i) Diffusion in the x direction is neglected in comparison to transport by the mean wind.

(ii) Within the plume, the pollutant is considered to have a Gaussian distribution with lateral and vertical standard deviations $S_y(x)$ and $S_z(x)$ respectively.

(iii) The turbulence is considered to be homogeneous and stationary.

(iv) The ground is considered to be a perfect reflector of the pollutant.

Within these assumptions, the continuous point source diffusion formula can be derived:

$$\frac{\bar{u}\,X\,(x,y,z)}{Q} = \frac{1}{2\pi S_y S_z}\, e^{-\frac{y^2}{2S_y^2}} \left[e^{-\frac{(z+H)^2}{2S_z^2}} + e^{-\frac{(z-H)^2}{2S_y^2}} \right] \quad \text{(a)}$$

Where:

X = time average value of the concentration
Q = rate of emission from a continuous point source
H = effective height of the plume above the terrain

Any consistent set of units may be used.

The problem in using equation (a) arises in predicting the values of S_y, S_z and H.

Strictly speaking, the Gaussian diffusion model applies only under very regular terrain conditions. Batchelor (1949) conjectured, however, that the Gaussian function may provide a general description of average plume dispersion because of the essential random nature of turbulence by analogy with the central limit theory of statistics. Lin and Reid (1963) also point out that the turbulence generated wind fluctuations which result in plume dispersion approximate a Gaussian distribution fairly closely. Moreover, experimental studies by Hay and Pasquill (1957), and Barad and Haugen (1959), indicate that the Gaussian plume formula should have a wide area of practical applicability in the atmosphere.

REFERENCES: Appendix C

Barad, M.L. and D.A. Haugen (1959) *A Preliminary Evaluation of Sutton's Hypothesis for Diffusion from a Continuous Point Source* J. Meteor. 16 (1), pp 12-20

Batchelor, G.K. (1949) *Diffusion in a Field of Homogeneous Turbulence I. Eulerian Analysis* Australian J. Sci. Res. 2 pp 437-450

Frenkiel, F.N. (1953) *Turbulent Diffusion - Mean Concentration Distribution in a Flow Field of Homogeneous Turbulence* Advan. Appl. Mech. (3) pp 61-107

Hay J.S. and F. Pasquill (1957) *Diffusion from a Fixed Source at a Height of a Few Hundred Feet in the Atmosphere* J. Fluid Mech. 2 (Part 3), pp 299-310

Lin C.C. and W.H. Reid (1963) *Turbulent Flow Theoretical Aspects* Handbuch der Physik Vol. 8, Part 2, pp 438-523

Sutton, O.G. (1932), *A Theory of Eddy Diffusion in the Atmosphere* Proc. Roy. Soc. (London), Ser. A. Vol. 135, pp 143-165

APPENDIX D

BOSANQUET, CAREY, HALTON PLUME RISE FORMULA FOR STABLE ATMOSPHERES

Source: Dr. D. Leahey
Western Research & Development Ltd.
Calgary, Alberta

The Bosanquet, Carey and Halton plume rise formula for the maximum plume rise in a stable or neutral atmosphere is as follows:

$$\Delta h_{max} = h_v + h_t$$

where Δh_{max} = maximum plume rise

h_v = plume rise due to momentum

h_t = plume rise due to bouyancy

$$h_v = \frac{4.77}{1 + 0.43U/V_s} \quad \frac{(Q_t V_s)^{1/2}}{U}$$

$$h_t = \frac{6.37g\ Q_t\ \Delta T_1}{U^3 T_1} \quad (\ln J^2 + \frac{2}{J} - 2)$$

where $J = \dfrac{U^2}{(Q_t V_s)^{1/2}} \left[0.43 \dfrac{(T_1)^{1/2}}{(g\psi)} - 0.28 \dfrac{V_s}{g} \dfrac{T_1}{\Delta T_1}\right] + 1$

U = wind speed

V_s = stack gas ejection speed

Q_t = volume emission rate of stack gas at temperature T_1

g = acceleration due to gravity

T_1 = absolute temperature at which density of stack gas would be equal to that of the ambient atmosphere

$\Delta T_1 = T_s - T_1$

T_s = absolute temperature of stack gas (at stack top)

ψ = potential temperature gradient of ambient atmosphere

REFERENCE

1. Bosanquet, C. H., W. E. Carey, and E. M. Halton (1950) "Dust Depositions from Chimney Stacks" Proc. Inst. Mech. Congress (London) 162 pp 355-357.

APPENDIX E

THE 2/3 LAW PLUME RISE FORMULA FOR NEUTRAL ATMOSPHERES

Source: Dr. D. Leahey
Western Research & Development Ltd.
Calgary, Alberta

In the last ten years, there have been many studies of plume rise from large heat sources. There seems to be a general consensus (eg. Slawson and Csanady, 1967; Briggs, 1965; Bringfelt, 1969; Carpenter et al., 1971; Hewett et al., 1971; Thomas et al., 1970) that these buoyancy-dominated plumes rise in a neutrally stratified atmosphere according to the "2/3 law."

$$h = \frac{C\, x^{2/3} F^{1/3}}{u} \qquad \text{(b)}$$

Where: C = a dimensionless constant

x = downwind distance

F = bouyancy flux

u = mean wind speed along direction of plume

For hot, dry effluents whose mean molecular weight is close to that of air, the bouyancy flux may be defined as:

$$F = \frac{g}{\pi}\left(\frac{T_s - T_a}{T_a}\right) Q_T$$

Where: g = acceleration due to gravity

T_s= absolute temperature of the stack gases

T_a= absolute temperature of the air

Q_T= rate at which total effluent is leaving stack

This definition of F assumes that the effective density of the stack gases is approximately constant and equal to that of the air which is a valid assumption away from the immediate vicinity of the stack.

For sources of known heat release such as flare stacks, the bouyancy flux F may be defined as:

$$F = \frac{g}{\pi} \quad \frac{Q_H}{C_p \rho T_a}$$

Where: Q_H = rate of heat release
C_p = specific heat of air at constant pressure
ρ = density of dry air

The above equation may be applied with any consistent set of units.

It may be shown that the "2/3 law" expressed in equation (b) has a sound theoretical basis which incorporates energy, momentum and mass conservation laws.

There have been many empirically derived values for the dimensionless constant C, ranging from 1.2 to 2.6. After reviewing the literature, Briggs (1972) recommends that a conservative value of 1.6 be adopted.

Studies have been performed in Alberta in order to determine plume rise behaviour from two large heat sources: the Edmonton Power Clover Bar generating station and the Petrogas sulphur plant at Balzac. The first study was undertaken by Western Research & Development, while the second was done by Mr. Vinodh Kumar as a master's thesis in Mechanical Engineering at the University of Calgary. Both studies showed that plume rise was well-approximated by the 2/3 law when C = 1.6. Results of these two plume rise experiments have been communicated to the Alberta Department of the Environment.

Following a recommendation by Briggs (1971), Equation (1) was applied for values of $x < 3.5\ x^*$. For downwind distances greater than this amount, however, x was assumed to have a constant value equal to $3.5x^*$ where:

$$x^* = 14\text{m}\ (F/\text{m}^4/\text{sec}^3)^{5/8} \text{ when } F < 55\ \text{m}^4/\text{sec}^3$$
$$x^* = 34\text{m}\ (F/\text{m}^4/\text{sec}^3)^{2/5} \text{ when } F > 55\ \text{m}^4/\text{sec}^3$$

REFERENCES - Appendix E

Briggs, G.A. (1965) *A plume rise model compared with observations* J. Air Pollut. Control Assoc. 15 pp 433-438

__________ (1971) *Some Recent Analyses of Plume Rise Observations* in Proceedings of the Second International Clean Air Congress H.M. Englund and W.T. Berry, Editors - Academic Press, New York and London 1029-1032

__________ (1972) *Chimney plumes in neutral and stable surroundings* Atmospheric Environment pp 507-510

Bringfelt B. (1969) *A Study of Bouyant Chimney Plumes in Neutral and Stable Atmospheres* Atmospheric Environment 3 pp 609-623

Csanady, G.T. (1973) Turbulent Diffusion in the Environment D. Reidel Publishing Company, Dordrecht, Holland and Boston, U.S.A.

Hewett, T.A., J.A. Fay and D.P. Hoult (1971) *Laboratory experiments of smokestack plumes in a stable atmosphere* Atmospheric Environment 5 pp 767-789

Slawson, P.R. and G.T. Csanady (1967) *On the mean path of buoyant bent-over chimney plumes* J. Fluid Mech. 28 pp 311-322

Thomas, F.W., S.B. Carpenter, and W.C. Colbaugh (1970) *Plume rise estimates for electric generating stations* J. Air Pollut. Assoc. 20 pp 170-177