ATHABASCA TAR SANDS GATHERING SYSTEM STUDY

prepared for

Alberta
ENVIRONMENT

by

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Office of
the Deputy Minister

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

Dear Sir:

The undersigned has the honour to transmit herewith the "Athabasca Tar Sands Gathering System Study".

This is the first of two reports commissioned in 1973 to provide information required for long range resource management planning related to pipelines in development of the Tar Sands. The authors have considered the feasibility of establishing a corridor for pipelines, utilities and transportation routes, and have identified the major environmental constraints which need to be satisfied in planning a pipeline gathering system for the area.

Respectfully submitted,

E. E. Ballantyne, D.V.M., P.Ag., F.R.S.H.
Deputy Minister.

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1.0 INTRODUCTION

1.1 TERMS OF REFERENCE

This study reviews constraints that should be considered in connection with synthetic crude pipe line gathering systems and routes within the Athabasca tar sands area. Specifically the terms of reference of this study were defined as:

a) Study and identify all the important constraints in locating a route for synthetic crude pipe line gathering systems in that area of the Athabasca tar sands amenable to open-pit mining. Assumed plant locations will be supplied to the consultant by the Department of the Environment. The gathering system should be considered to extend to the northern terminus of the main pipe line corridor.

b) Make recommendations with respect to the feasibility and desirability of combining services supplying the plants; gas, power and water lines; and transportation systems; in the same corridor as the gathering line.

c) Make recommendations which will enable the Government of Alberta to select the optimum routes or patterns for a synthetic crude gathering system and for utilities as part of a long-range tar sands development policy.

The bases of recommendations were agreed to be:

i) Examination of existing technology respecting pipe line, transportation, and utility corridors, extrapolated to conditions which will exist during development of the tar sands.

ii) Mining and reclamation plans of companies who are, or will be, engaged in mining the tar sands.

iii) A route which will have minimum destructive effects on the environment and the ecosystems involved.

iv) Current planning for urban and recreational areas to minimize the potential detrimental impact of a gathering system on the human environment.

1.2 APPROACH

In reviewing gathering systems within the tar sands area, we have been aware that we are dealing with one small part of an immense project. The recoverable reserves of upgraded synthetic crude in the tar sands are 25 times the total Canadian crude oil reserves, three times the Western Hemisphere reserves and almost 40 per cent of the world crude oil reserves. The tar sands represent not only a large resource of great provincial and national significance, but also a major world resource comparable in size to the Middle East oil pool. It is of utmost importance that these reserves be developed in accordance with the long-term interests of Albertans.

While the gathering systems represent a small part of the overall tar sands development, attempting to recommend answers to questions concerning them involves consideration of the total planning of the area. We have found it necessary to review very broadly many important factors which may determine the manner in which the tar sands development proceeds, before considering specifically those factors affecting pipe line route selection. Changes in the technology of mining the tar sands, or changes in lease ownerships, for example, could drastically alter the way in which the area develops.

The study approach has been to identify the probable development pattern based on the development to date, the known plans of the oil companies, the location and ownership of the leases, and the known plans of the public agencies, such as the Department of Highways and Transportation and the town of Fort McMurray. Based on this probable pattern, the likely pipe line routes and the constraints on them have been identified.

Possible impacts of changes in technology or public policy on the routes and constraints have been assessed and discussed. From this discussion, questions are raised concerning broader policies affecting the whole tar sands development.

1.3 REPORT OUTLINE

The report begins with a summary of findings and recommendations from the study. This is followed by a section outlining the broad background to the tar sands area development against which the likely trends and their impact on gathering systems route selection are assessed. Separate sections then consider the transportation and community restraints, the engineering considerations, and the environmental factors affecting route selection and construction.

Based on these considerations, a review is made of the way in which the various decisions on gathering system routes design and regulation may be integrated with overall general policy planning for the area.

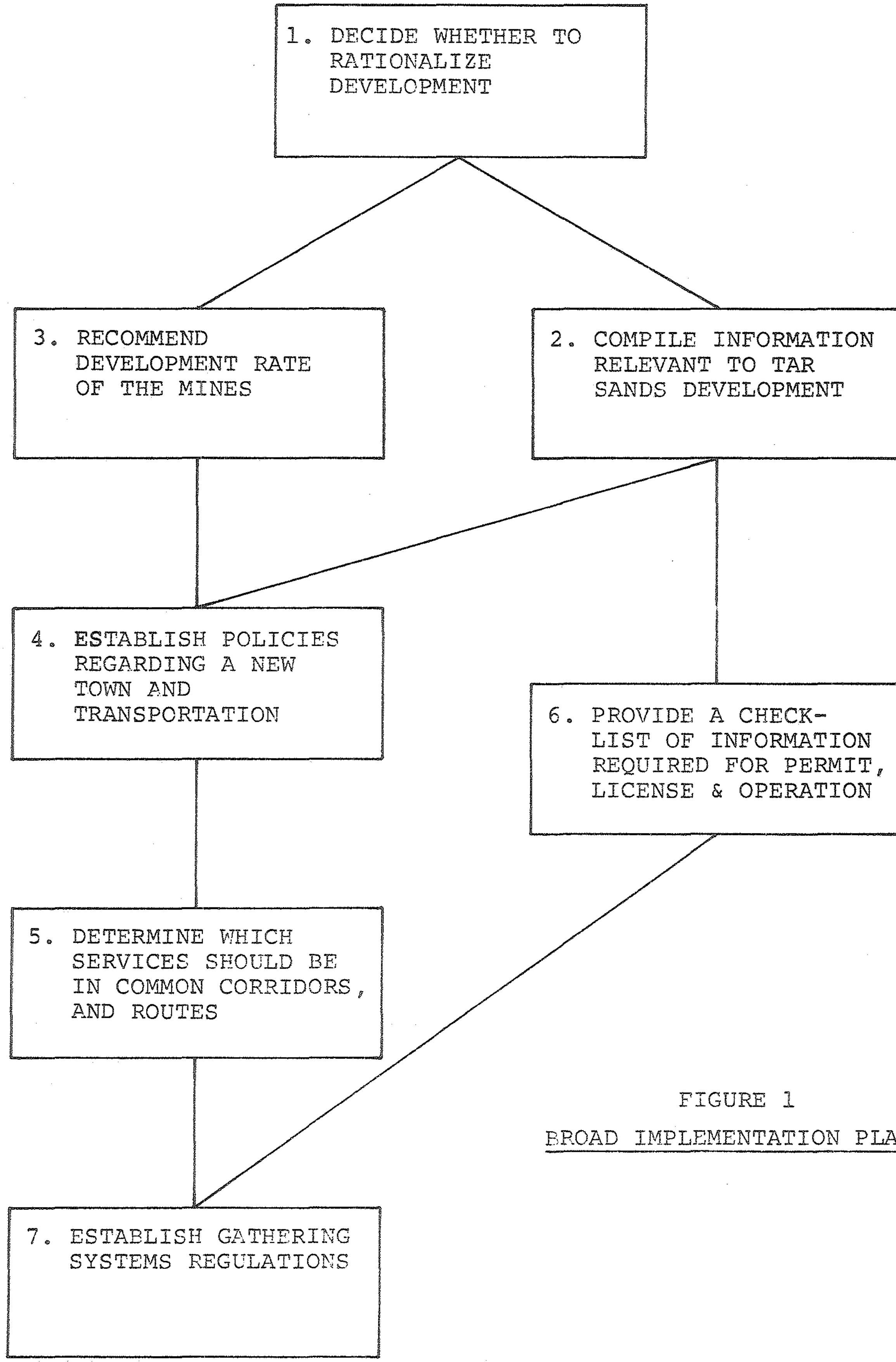

FIGURE 1

BROAD IMPLEMENTATION PLAN

2.0 OUTLINE OF RECOMMENDATIONS

Addressing the terms of reference of this study, the following brief summary is presented:

1) Many community, engineering and environmental constraints in locating gathering systems have been identified and are discussed in Sections 4.2, 5.0, and 6.2 of this report.

2) From an engineering viewpoint generally, a common corridor concept is desirable, but cost and environmental factors must be evaluated for each case, and may show decisive reasons for rejection of this concept in a specific case. Advantages and disadvantages are discussed without making a conclusive general recommendation.

3) To enable the Government of Alberta to select routes for gathering systems; and further, to efficiently manage the development of the tar sands, seven steps are recommended. These are arranged in logical order as illustrated in Figure 1 (opposite) and summarized in Section 2.4. A detailed explanation of them is to be found in Section 7.0.

The more comprehensive summary which follows consists of an outline of recommendations from each of the three sections; community (4.0), engineering (5.0), and environmental factors (6.0); and a brief guide to the steps in planning for orderly development from Section 7.0, "Broad Implementation Plan".

2.1 TRANSPORTATION AND COMMUNITY FACTORS

2.1.1 Probable Development Pattern

Based on a consensus of individuals in the oil industry and in government, we have attempted to predict the probable development pattern in the tar sands, assuming no major government intervention to affect the current trends. Within this context, the probable development rate appears to be that of one new plant being added approximately every three years, with pressure to reduce this time if resources of skilled labour permit. The likely sequence of plants is GCOS, Syncrude, Shell and Petrofina, with no clear indication of the order of further plants. The first four plants will probably use the Clark hot water process, but there is no assurance of extraction method beyond that time.

GCOS and Syncrude are served by a road from Fort McMurray along the west side of the Athabasca River, Shell and Petrofina are on the east side of the Athabasca about 40 to 50 miles from Fort McMurray, and too far away for acceptable commuting by conventional methods.

The likely transportation pattern will be that of a road north along the west side of the Athabasca, ultimately to Fort Chipewyan. A crossing will be made to the east side to serve the potential mines there and a new town will probably be required in the location of the Fort Hills or McClelland Lake.

Based on present indications, the railway will not enter the area, maintaining its present terminus at Fort McMurray. There are several potential sources of power and natural gas, but within the tar sands area, the power and natural gas supply can probably parallel the roads and/or the synthetic crude pipe lines.

2.1.2 Transportation Alternatives

As alternatives to the probable development pattern outlined above, other variants are possible, which would have major implications for transportation and community development in the area.

2.1.2.1 If the Alberta Government controls the order of development by rationalization of leases, the first few mines could be located within 30 miles of Fort McMurray and construction of a new town could be delayed and might never be necessary. Such control would constitute a major departure from past policy with many ramifications but with major implications on government and industry costs and community benefits.

2.1.2.2 If mass high-speed transportation were introduced through the use of STOL aircraft, high-speed passenger rail or hovercraft, it might be possible to serve the whole area from Fort McMurray. Economic and social advantages would result to the community in the provision of better services for less cost and the ability to attract and retain skilled personnel.

2.1.2.3 A crossing of the Athabasca as near GCOS as practical, with a road up the east side to a new town, crossing back in the north to the west bank, would serve the potential mine sites more directly, although the disadvantages of the double crossing of the river might outweigh the gains of shorter travel.

Whichever development pattern is followed, the least cost gathering system is likely to bring the synthetic crude to GCOS and south along the present pipe line alignment to cross the Athabasca River in the existing crossing location. The southern part of this route has no significant community constraints and no apparent engineering or environmental disadvantages on present evidence (subject to detailed studies). Thus for planning purposes the southern terminal may be taken as the present GCOS pipe line crossing of the Athabasca.

The one minor community constraint occurs across the river from Fort McMurray where the line crosses the proposed Area #5 development. Provision of a synthetic crude pipe line right-of-way with its corresponding strip of greenery would not appear to cause any severe community problems. However, should it be considered normally desirable to incorporate overhead power lines in the same corridor, this policy would have to be reconsidered through the development itself.

2.2 ENGINEERING CONSIDERATIONS

An economic factor in the selection of a specific pipe line route is the extent to which the pipe line locks in tar sands reserves. Relocation of service facilities could be minimized if overburden/bitumen relationships were known during the planning of routes; and tailings storage areas could be avoided by routes of service facilities if their location was defined at the time of planning.

Cooperation between adjacent plants is recommended, whereby mined areas of existing plants are made available for initial tailings disposal from new plants, and whereby recycle water from existing plants is made available for startup of new plants.

Use of a common corridor for pipe lines and other service facilities is recommended, where feasible, and subject to environmental constraints.

The concept of a common carrier for transportation of petroleum liquids has several advantages.

In Sections 5.5, 5.6, and 5.7 modern technological considerations dealing with design, construction and operation of pipe lines are discussed.

Safe and efficient gathering systems will require route selection and design to accommodate the muskeg-intense terrain. Particular care will be necessary in selection and installation of river crossings. Placing and use of valves is important as well as provision of access to them. Powered block valves can prevent forward draining in the event of a line break in a stream crossing. An effective corrosion monitoring and prevention system is necessary for any pipe line, and a modern communications/control system should be expected for the gathering system to allow over/short control and upset monitoring. Air and ground patrol procedures should be instituted; and, very important, a DISASTER CONTINGENCY PLAN should be defined and kept current; ready to contain and repair any major line failure.

Security from damage due to construction and consequent spills or leaks could be improved by the establishment of a central registry of all pipe lines and other ground facilities, to be consulted by anyone planning construction or demolition.

Information needs are listed in Section 5.9 with the recommendation that the Alberta Government consider developing some of this information both for its own use in the determination of policies and possible legislation, as well as for the assistance of companies seeking to develop the tar sands.

The Alberta Government can maintain control over engineering factors in the design and construction of the gathering system if it requires pertinent information to be supplied at the time of permit and license applications. These recommendations are listed in Sections 5.9.1 and 5.9.2. Recommendations for reporting requirements during operations are listed in Section 5.10.

2.3 ENVIRONMENTAL CONSIDERATIONS

Because of the scarcity of available data, the environmental study has concentrated on the delineation of potential environmental effects and the determination of guidelines to minimize the detrimental effects of pipe lines and roads on the environment. It also recommends education and information programs to back up the guidelines and monitoring programs to ensure that environmental quality is being maintained.

A "matrix approach' has been used in Section 6.2.1 to portray the interactions between the activities associated with constructing, operating and maintaining pipe lines and roads, and various environmental parameters. The matrix is a method of indicating which parameter of the environment may be affected by certain of the various activities, i.e. it provides a kind of two-dimensional check-list.

The major activities are those of survey, geotechnical investigation, construction and operation. These have been sub-divided into camps, clearing, grading, vehicle passage, borrow pits, excavating, ditching, and so on.

The major environmental measures are those of physiography, hydrology, vegetation, atmosphere and human use. These have been subdivided into streams and river beds, surface drainage, water quality, climax vegetation, noise, dust, recreation, settlement, and so on.

Another matrix has been prepared to portray the interactions between the environmental parameters and fish, wildlife and aesthetic qualities of the region.

Combined use of the matrices provides a check-list to note, for example, that waste disposal, if not properly managed, may affect submergent aquatic vegetation, and that changes in submergent aquatic vegetation may affect fur bearing animals and ungulates. Waste disposal regulations and permits, and education programs should therefore be designed to prevent problems occurring in this area. Similar uses may be made of the other interactions of the matrices, as a check-list on required regulations and guidelines.

The question of a common corridor is discussed in Section 6.3. In general, it might appear that concentration of all facilities in a common corridor would reduce land requirements, and thereby minimize ecological impact. However, in some environmentally sensitive areas, the damage could be greater than in a dispersed system. Moreover, the wide right-of-way of a corridor and the route restraints imposed by the different criteria for the design of each of the different services and utilities may give the designer less flexibility in avoiding small environmentally sensitive sites.

The utilization of the corridor concept in the tar sands area should be viewed with reservations at this time and a flexible policy adopted.

Environmental guidelines which should minimize adverse environmental effects are recommended in Section 6.4. These recommendations are related to the location, construction, and operation and maintenance of the gathering system development.

2.4 BROAD IMPLEMENTATION PLAN

The recommendations of this report should be integrated with other aspect of tar sands development as discussed in Section 7.0. A broad outline of the manner in which decisions on gathering systems may be integrated with other decisions on tar sands development is presented in Figure 1 (opposite Page 5).

2.4.1 Decide Whether to Rationalize Development

A decision on whether to rationalize development must precede all other decisions, because such a rationalization could significantly limit the area over which much of the information and control is needed.

2.4.2 Compile Information Relevant to Tar Sands Development

Certain information (as explained in Section 7.2) would be useful both to the Alberta Government in developing policies, and also to companies planning development of the tar sands. The following information could be assembled while other decisions are being made:

a) Determination of environmentally sensitive areas.

b) Records of overburden/bitumen relationships.

c) Definition of areas suitable for tailings storage.

d) Factors influencing reciprocal agreements for tailings disposal.

e) Factors influencing use of recycle water for initial operation of new plants.

f) Formation of a central registry for all ground facilities in the province.

2.4.3 Recommended Development Rate of the Mines

An appropriate rate of development for the mines depends on such factors as short and long term crude oil requirements, availability of skilled labour, the possibility of better extraction techniques becoming available in the next ten years, and the speed with which information can be developed to ensure economic and environmental feasibility of projects. A desired rate should be established, based on these factors, for use in planning the development of the area.

2.4.4 Establish Policies Regarding a New Town and Transportation

When the rate of development and the location of environmentally sensitive areas have been established, the cost and environmental trade-offs should be evaluated in order to make a choice between providing a new form of rapid commuter transportation, or creating a second town. If rationalization of leases restricts development to the southern area, then a choice between a new town and rapid transportation will not be necessary.

2.4.5 Determine which Services should be in Common Corridors, and Routes

The particular services to be located in specific common corridors can be decided when the main transportation links have been determined; when the origin and destination of each service (power, natural gas, etc.) has been defined; and when environmentally sensitive areas have been identified.

2.4.6 Provide a Check-List of Information Required for Permit, License, and Operation

Based on the requirements of the environmentally sensitive areas, a check-list should be prepared of information to be supplied with permit and lisence applications, and reporting requirements during operation. This report recommends many items for inclusion on these check-lists; more items might be added after further site specific transportation, engineering, and environmental studies.

2.4.7 Establish Gathering Systems Regulations

The report makes a variety of recommendations which should be reviewed in the light of existing provincial regulations. Modifications could be considered to existing regulations, or special gathering systems regulations formulated.

3.0 BACKGROUND TO THE TAR SANDS DEVELOPMENT

To appreciate the alternative development patterns that may occur, it is necessary to review the following aspects of the tar sands area:

a) Reserves: The quantities, qualities, and locations of the tar sands at various depths affect the number and likely location of plants.

b) Leases: The ownership of leases affects the timing and order in which development will take place.

c) Technology: Present technology has a number of undesirable features, such as the large tailings ponds.

d) Manpower: The availability of manpower for construction may impose limitations on the rate of development.

These factors are discussed in detail in the following sections.

3.1 RESERVES

The reserves in place in the Athabasca tar sands are estimated [1] as 625.9 billion barrels. From this

(1) A Description and Reserve Estimate of the Oil Sands of Alberta - (October 1963) - Oil and Gas Conservation Board.

TABLE 1

RECOVERABLE RESERVES OF UPGRADED SYNTHETIC CRUDE OIL (BILLIONS OF BARRELS)

Overburden	Rich	Intermediate	Lean	Total
0 - 50'	5.3	1.6	0.5	7.4
50' - 100'	14.1	4.3	1.2	19.6
100' - 250'	27.8	7.9	2.1	37.8
250' - 500'	23.8	9.3	2.5	35.6
500' - 1000'	58.5	19.9	5.4	83.8
1000' - 1500'	49.8	14.8	4.0	68.6
1500' - 2000'	9.1	4.0	1.1	14.2
TOTALS *	188.3	61.9	16.7	266.9

* Individual values do not add exactly to column totals because of rounding errors.

resource, there are estimated to be 266.9 billion barrels of recoverable reserves of upgradable synthetic crude oil. These reserves lie at depths of up to 1,700 feet, but only the reserves with overburden of less than 200 feet are considered to have potential for economic mining by present open-pit techniques. All ten potential open-pit operations specified for us by the Department of Environment have overburden of less than 100 feet. Their locations (at the centres of estimated half-townships) are shown on the map of Figure 4. Site 1 is that of GCOS; Site 2 is the proposed Syncrude development; Sites 3 and 4, the next possible two developments; Sites 5 to 10, the next possible six developments; with no particular order of development indicated.

Table 1 shows the recoverable reserves of synthetic crude oil according to overburden cover. The reserves with overburden less than 100 feet amount to 27 billion barrels, (or 1.5 million barrels a day for 50 years). This would be equivalent to 25 plants producing 150,000 barrels per day, if a plant life of 20 years is assumed. Therefore, unless the oil is substantially richer under certain areas of high overburden (which there is no reason to assume), the open-pit mines to the year 2000 will probably be those with overburden of under 100 feet.

In-situ mining has also been proposed for deeper areas of the tar sands. Shell is considering a location 25 miles west of Fort MacKay and Amoco a site 25 miles south of Fort McMurray (See Figure 2). The reserves in these locations are at depths of approximately 900 feet. So far, the technology is experimental.

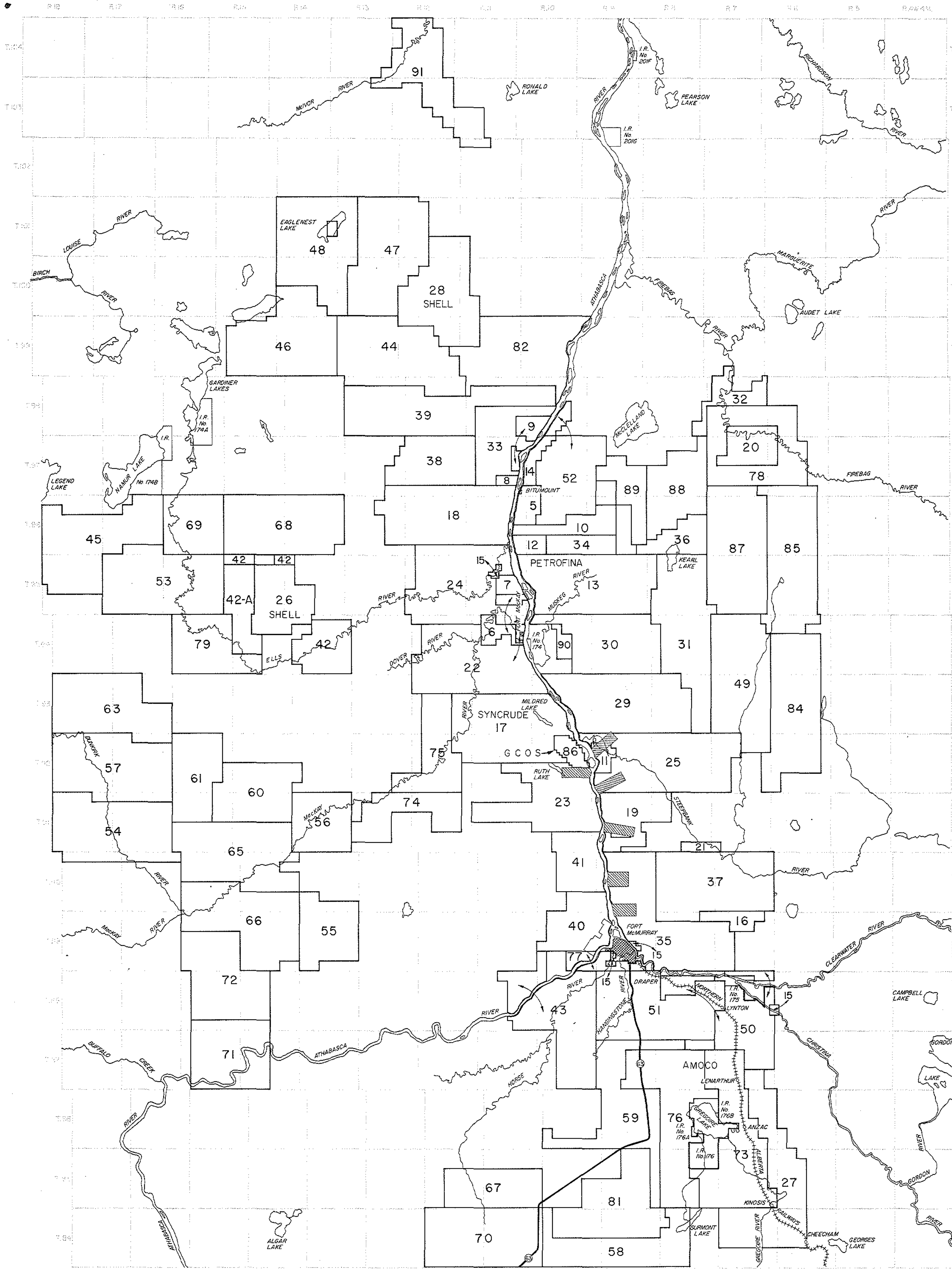

FIGURE: 2

TAR SANDS LEASES

If it is successful, and competitive with open-pit mining, then the area of potential mining will be radically changed. Moreover, the scale of the gathering system will change completely. Instead of consisting of one or two corridors extending for 50 miles from the north to the general area of Fort McMurray, the gathering system from in-situ mines located over a 6 million acre area would require many corridors, not necessarily travelling to Fort McMurray.

3.2 LEASES

Various lessees own rights to mine the tar sands in specific leases in the area as shown in Figure 2. Under present procedures, these rights will determine where and when mining takes place. At the present time, Great Canadian Oil Sands is mining in an area some 20 miles north of Fort McMurray on the west bank of the Athabasca River. (Lease 86, See Figure 2). Syncrude has submitted an application to mine an adjacent area, Lease 17, and is expected to announce on September 17, 1973, whether it intends to proceed. Shell has applied for permission to mine Lease 13 in the Muskeg Creek area, 50 miles north of Fort McMurray, on the east side of the Athabasca River. Petrofina is reported to be close behind in its planning, and its development on a lease slightly north of Shell's Lease 13 may follow shortly afterwards. This order of development is speculative but it represents the accepted view within the industry.

No probabilities can be placed on the timing or order of subsequent developments on the basis of oil company planning. Rationalization of development or the intervention of the Alberta Government to encourage or enforce development in a different sequence (e.g. working from Fort McMurray systematically north) would, of course, change the pattern and requirements radically.

3.3 TECHNOLOGY

Present extraction technology is based on the Clark hot water process. Oil-bearing sand is transported from a mine to an extraction plant, where the bitumen is separated from the sand. The bitumen is then processed into synthetic crude in an upgrading plant.

The quantities of water used by the Clark hot water extraction process are significant. For the proposed Syncrude plant, 50,000 U.S. gallons per minute will be used. Initially this will be the draw of river water, but after tailings water recycle is established, the river water draw will drop to approximately 20,000 U.S. gallons per minute. Syncrude is confident that methods will soon become available to permit the process to operate on tailings water recycle only but this has yet to be established. Meanwhile, the present tailings area at GCOS is almost full, and preparations are being made to convert the present mined-out area to tailings storage as mining proceeds to a new area of the lease. This imbalance requires continued stockpiling of tailings. At this point, it is not clear what proportion of the area will be taken over by tailings ponds, but even at the rate of 15,000 U.S. gallons per minute the GCOS lease would be covered to a depth of 150 feet in 20 years.

Developments in technology may change the extraction process. The companies have examined the possibility of piping a slurry, rather than conveying oil-bearing sand from mine to plant. Research is proceeding toward development of a "dry process" to supplant the Clark hot water process. In-situ mining, if developed to a point where it is preferable to open-pit mining, would produce mainly bitumen. If such a process were developed, it could combine the mining and extraction facilities at mine site and permit bitumen to be transported to an upgrading plant distant from the mine. This could change transportation and town-site requirements significantly.

The Clark hot water process was initially demonstrated in 1948. Its first application was in a plant whose construction started in 1964 and a second application may be in a plant starting construction in 1974. Pressure for development of the tar sands may lead to a more intense search for alternatives. Although the Clark process may be used in the next two or three plants, another as yet unproven or undiscovered process may form the basis for extraction in the mid-1980's, permitting concentration of upgrading plants, e.g. at Fort McMurray, with only mining, or mining and extraction dispersed through the area.

3.4 MANPOWER

During construction of a single plant, the number of workers reaches a peak of approximately 1,840 [1] in

(1) The Impact of a Proposed Synthetic Crude Oil Project on Fort McMurray - (February 1973) - Reid Crowther and Partners Limited.

the fourth year of construction. If two or more plants were constructed simultaneously, the peak demand would be proportionately higher, but if the starts were staggered, then lower peaks in demand would occur as follows:

	2 Plants	10 Plants
Simultaneous:	3,680	18,400
One-year intervals:	3,010	4,600
Two-year intervals:	2,510	2,520
Three-year intervals:	1,960	1,960
Four-year intervals:	1,840	1,840

The present consensus of opinion appears to be that the supply of skilled and unskilled labour is only sufficient to construct plants at three-year intervals. On the other hand, the resource available under overburden of up to 100 feet is capable of supplying 25 plants, i.e. building a plant a year for 25 years. It appears probable that the market could absorb the oil produced.

The rate of plant construction could exceed the presently foreseen rate of one every three years depending on the development of the market; the willingness of the government to train or recruit more labour of appropriate skills; and the capacity of the environment to accept the additional loads of water demand, tailings disposal, and air pollution. However, in this report, we have considered that construction of ten plants by the year 2000 will be the most likely rate of development.

4.0 TRANSPORTATION AND COMMUNITY FACTORS

In this section of the report four possibilities have been considered as typical of differing approaches to transportation and land use, each with a different impact on the choice of a gathering system route or routes. The constraints for pipe line routing and the possible combination of pipe line and other services are presented. The general locations of probable routes are identified.

4.1 THE TRANSPORTATION ALTERNATIVES

The four possible transportation outlines to be considered are:

a) The likely trend.

b) Modification of the likely trend through other transportation connections.

c) A radical transportation change through the use of high-speed transportation.

d) Rationalization of development to control the order of mining.

4.1.1 The Likely Trend

Based on the plans of the companies and the respective government departments and service agencies, the likely trend will be:

a) a paved road north from Fort McMurray to Fort MacKay and on to Fort Chipewyan.

b) a crossing of the Athabasca to provide access to the east side.

c) a new town on the east side of the Athabasca, perhaps in the Fort Hills or by McClelland Lake.

d) a road on the east side to connect the potential mine sites with the new town.

4.1.1.1 <u>Route of Road</u>

Figure 5 shows one road plan which follows this forecast. The roads and bridges follow preliminary locations identified by the Department of Highways and Transportation in their location study report for Highway No. 963 north from Fort McMurray for a distance of 46 miles.(1) The intention is that this road should ultimately be extended to Fort Chipewyan. (Figure 3).

The Department has also made preliminary appraisals of potential locations for roads on the east side of the Athabasca River, crossing the Clearwater River at Fort McMurray and continuing north by one of three possible routes. The most

(1) Location Study Report - Highway No. 963 - Secondary Road Fort McMurray North - (November 1971) - Department of Highways and Transportation.

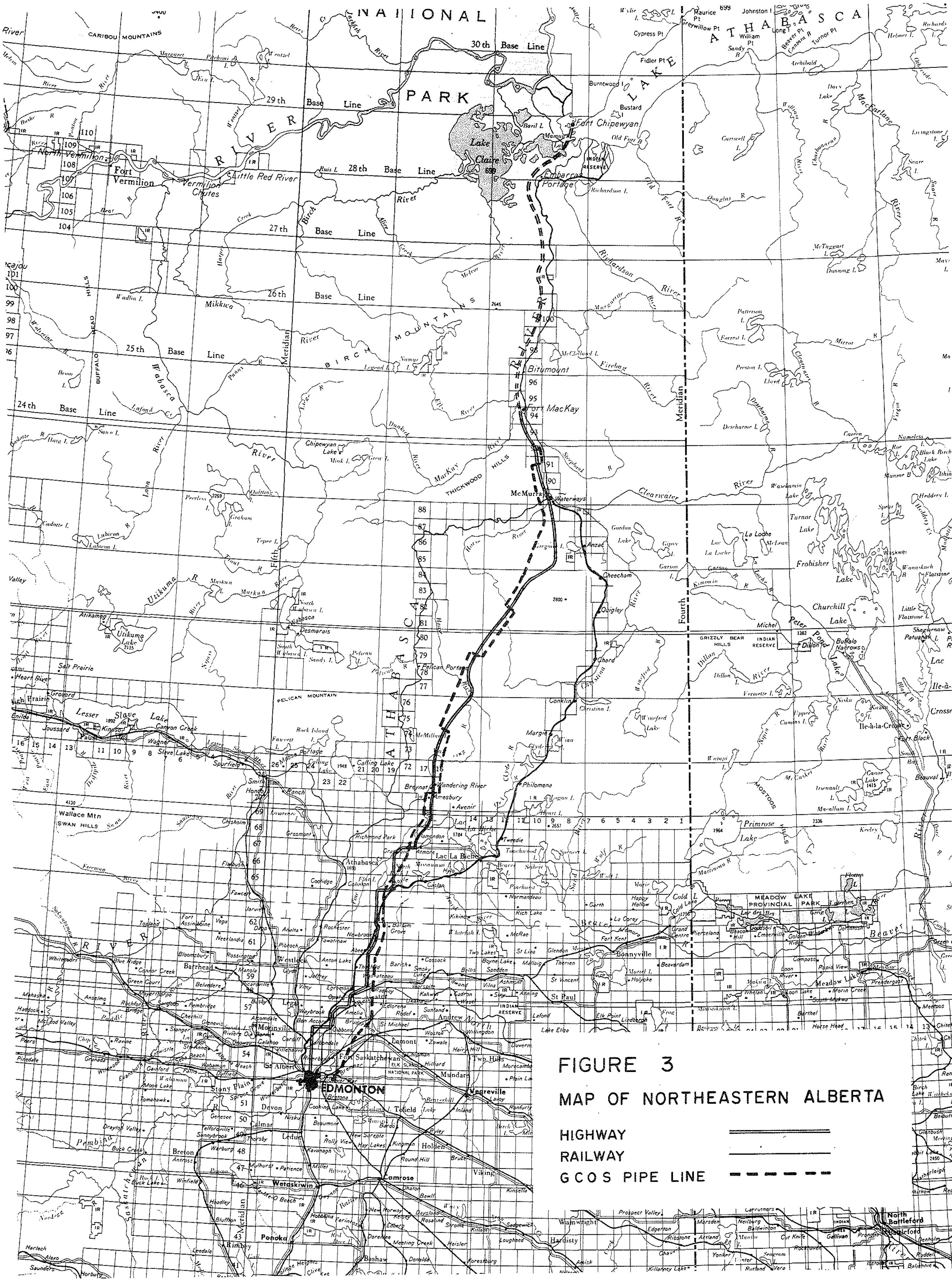

FIGURE 3

MAP OF NORTHEASTERN ALBERTA

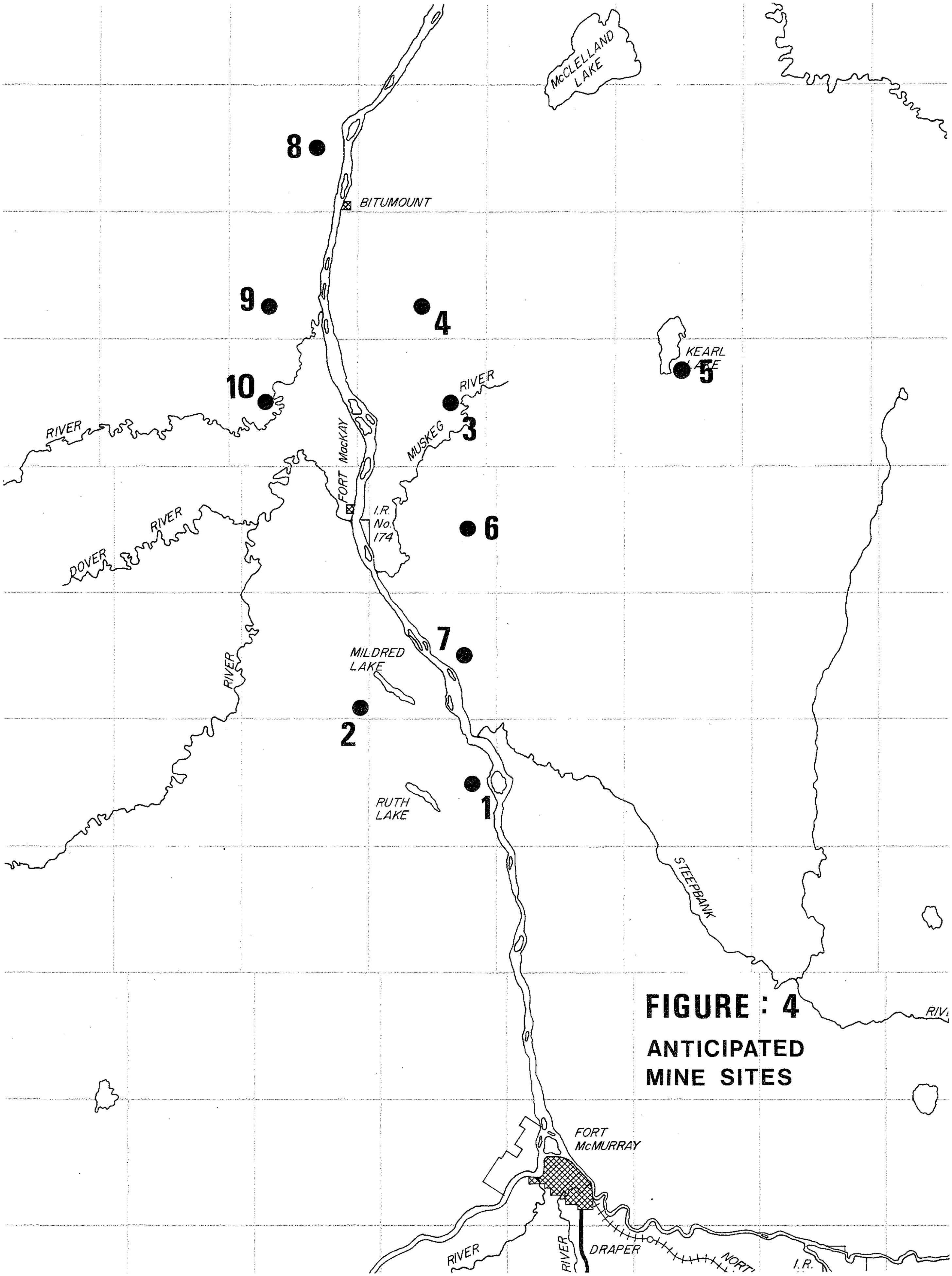

FIGURE : 4

ANTICIPATED MINE SITES

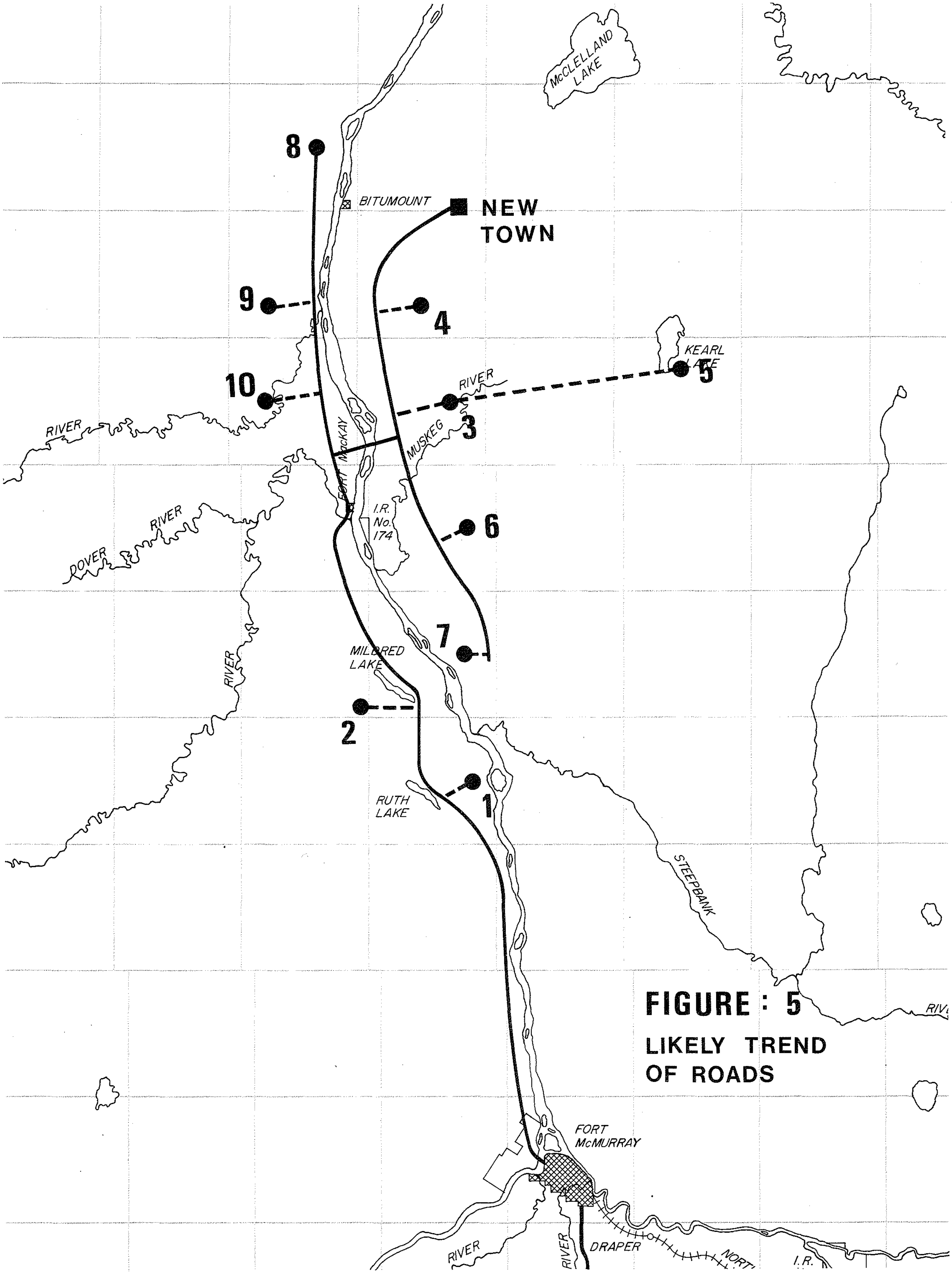

FIGURE : 5

LIKELY TREND OF ROADS

westerly of these could serve potential mine sites. The Department has also made preliminary identification of some possible bridge crossings of the Athabasca north of Fort McMurray.

4.1.1.2 Location of New Town

For both GCOS and Syncrude, the commuting distance of less than 30 miles from Fort McMurray is acceptable. However, company managements and other knowledgable individuals in the area agree that distances significantly longer than this would not be acceptable for daily commuting. In their view, commuting times of one hour each way would result in high labour turnover, and a stable labour force could not be attracted. Although some individuals commute this far in large cities, only a small proportion of the public accepts these times; and the privacy, open space, and lower taxes are achieved at the price of higher travel time.

When the decision is made to proceed with the Shell and Petrofina developments, the question of a new townsite will have to be resolved. A site in the Fort Hills or the McClelland Lake area (Figure 3) would appear suitable as it would be located on tar sands with over 200 feet of overburden. Also, every proposed plant after GCOS or Syncrude would be within 30 miles of the new town. Assessment of environmental suitability and of the underlying oil reserves will be necessary before a final decision is made on the location of the new town.

Under this plan the new town would become the major town in the area. It would serve all the other eight mine sites (after GCOS and Syncrude) and even Syncrude's location would be about equidistant from Fort McMurray and the new town. Fort McMurray's population would then level off at 15,000 to 20,000, with the new town's population increasing to 50,000 to 60,000 people, and serving seven or eight mines at any one time. As some mines become worked out after 20 years and other new ones are developed within the 100-foot overburden isopach, the new town would remain central to the open-pit mineable area.

4.1.1.3 Advantages

The advantages of the new town would be:

a) It would be within reasonable commuting distance of almost all of the open-pit mineable areas.

b) It would provide an alternative to Fort McMurray, allowing residents of each town to have another community to visit.

c) It would not have the expansion constraints of Fort McMurray.

4.1.1.4 <u>Disadvantages</u>

The disadvantages of a new town would be:

a) The additional capital costs of a second major town, e.g. another airport, arterial road, vocational schools, hospitals, etc.

b) A lower level of services in each town; two smaller communities may not be able to support the same level of services as one larger community (specialized shopping, higher education, major medical facilities, cultural and recreational complexes).

c) More costly services (e.g. frequent air service from Edmonton to two towns will be more costly than frequent service to one centre).

d) Social costs of "bypassing" Fort McMurray.

e) The new site may be subject to a higher air pollution risk than Fort McMurray; depending on townsite location, air quality, standards of upgrading plants, and climatic factors such as prevailing winds.

4.1.2 Modifications of the Trend

Still based on the two-community concept, other transportation connections are possible. Figure 6 shows the shortest network linking all ten mine sites and the town of Fort McMurray. The shortest network would be expected to have the lowest cost and least environmental impact (unless it were to pass through difficult terrain or environmentally sensitive areas).

The difference between Figure 5 and Figure 6 is that the shortest network crosses the Athabasca in the general area of GCOS and Syncrude and proceeds north up the east bank from there, crossing back to reach the three northerly sites on the west bank.

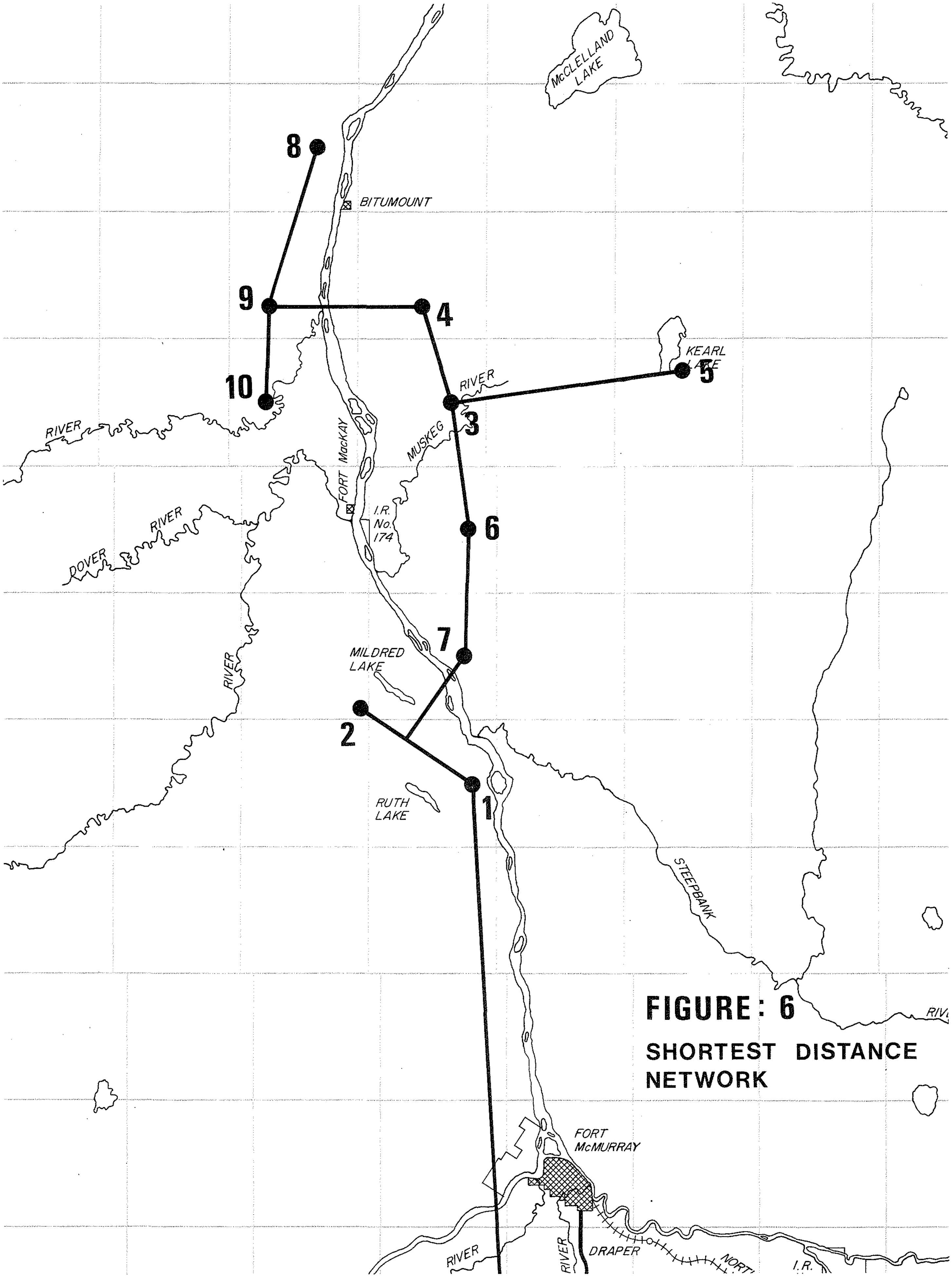

FIGURE: 6

SHORTEST DISTANCE NETWORK

There are problems in crossing the Athabasca with a road in the region of GCOS (the Highways and Transportation Department has not identified a feasible location there), but an alternative would be a link from Fort McMurray across the Clearwater and up the east side. This presents traffic problems at the Fort McMurray end in connecting with Highway 63, but solutions to these problems can be found at a cost.

4.1.2.1 Advantages

Assuming a road crossing of the Athabasca as near to GCOS as possible and another crossing in the north, the advantage of the shortest network pattern would be:

a) More direct access between Fort McMurray, the likely first four mines, and the new town.

b) A better connection between the new town and the northerly west side mines.

c) A shorter total road length.

d) Reasonable phasing (a short road with one bridge built first; another short road and crossing later).

4.1.2.2 Disadvantages

The disadvantages of the shortest network pattern would be:

a) Two bridge crossings rather than one.

b) Less direct connection between the northerly west side mines and the south (however, the development times of these are not known and they could be connected directly south later on if desired).

c) No connection by this system with Fort MacKay.

4.1.3 Radical Transportation Change

There are significant community gains to be made through the economies of scale possible if all population is concentrated in one town. Educational, medical, recreational, and transportation services can be provided to a higher level for the same cost (or to the same level at less cost) in one larger city than in two smaller ones. The higher level of services may reflect itself in greater population stability and less labour turnover in the plants.

The possible development of a second town could also cause social problems by converting Fort McMurray into a stagnant by-passed community.

However, concentration in one town could be achieved only with high-speed transportation from the town to the mine sites. The only likely means to provide such high-speed transportation would appear to be STOL aircraft or high-speed rail. Hovercraft might possibly be used if the speed requirements can be met.

Inasmuch as this high-speed transportation would not be required until approximately 1980, these possibilities appear worth investigating. The DHC7 48-seat plane should be operational by 1976 and larger versions may well be operational by 1980. The 24-hour nature of the work means that workers need not change shifts at the same time. Groups of positions could be relieved at hourly intervals. Subject to its meeting required reliability and safety standards, a single plane flying a full load both ways on a continuous shuttle basis could transport all the men between Fort McMurray and a mine. The unit costs of such an operation might be justified by the benefits of concentrating development in Fort McMurray. Ground access to the plants would then likely be by low-quality road following the routes of Figure 5. A rather unlikely alternative to the road would be rail-only access for freight.

Another high-speed alternative would be railway. Train speeds of 80 to 100 m.p.h. would be needed to produce acceptable travel times. A high quality of track would be required, which could be provided at considerable cost. With this system, it would be possible to provide rail access only to the plants, with both worker and freight transported by rail. A road would not be essential, although a low quality road would likely exist. Even a pipe line would not be essential with rail access, although the economics would almost certainly favor it.

4.1.3.1 Advantages

The advantages of the single town concept with high-speed transportation access would be:

a) Capital savings in the town.

b) Higher level of services.

c) Lower cost of services.

d) Possible social advantages including lower labour turnover.

e) Delay in building a new town, which may never be needed with improved or changed technology.

f) Initial plant construction costs would be reduced with rail transportation.

4.1.3.2 Disadvantages

The disadvantages would be:

a) Possible higher capital and operating costs of transportation (although the costs may not compare unfavorably with private car transportation).

b) Greater difficulty of access for visitors and trucks with a lower standard of road.

c) For air transportation, possible weather or mechanical problems, and safety considerations.

4.1.4 Control of Development

If the Government of Alberta decides to change the sequence of development, including rationalization of leases, it would be possible for the first four or five mines to be within 30 miles of Fort McMurray. The advantages of a single town could be gained without incurring higher transportation costs. Road access to the east bank of the Athabasca would be required either by bridging the Athabasca or the Clearwater. Construction of a new town could be delayed, and might prove unnecessary with faster means of transportation and improved technology.

Rationalization of development would involve a major government intervention in the marketplace. Negotiations with lessees might mean that the exploration and development work already done fifty miles north of Fort McMurray would not be immediately useful and additional work would have to be done in the south.

Plans for development in the north might be upset, even if the lessees were willing to reach an accommodation and operate first in the south.

4.2 TRANSPORTATION CONSTRAINTS ON PIPE LINE ROUTING

4.2.1 Opportunities for Routing

The desired route for a pipe line will essentially follow the shortest path, deviating from it only as may be necessary to avoid environmentally sensitive areas and severe terrain. These areas have not been identified at this time.

River crossings present the areas of greatest environmental concern because of potential spills and leakage into the Athabasca River system. GCOS has a map showing the watershed configuration along the length of the route, indicating where oil can be intercepted if there is a spill.

Community disturbance may present problems where towns are situated on the route.

If the ten mine sites proceed in the likely sequence, the gathering system would follow a pattern somewhat similar to that of Figure 5. Investigation might show that Syncrude oil could be carried south in the GCOS line. The oil from four mines on the east bank could then be carried south in one corridor, crossing to the west bank to flow south in a common corridor with GCOS and Syncrude. The pipe line from the fifth could also join this corridor.

The only community which would be located on the corridor would be the expansion of Fort McMurray across the river. This appears to be going ahead although it was opposed in the COHOS-PARD report.[1]

If it proceeds, a corridor should be reserved for oil and natural gas pipe lines. The other utilities would probably not be included in

(1) Town of Fort McMurray and Tar Sands Region Planning Analysis - (September 1972) - Cohos, Delasalle and Evamy, P.A.R.D. Associates Ltd.

the corridor in this location, since power lines would not be desirable through the middle of the community. The road is not adjacent to it at this point.

The oil from the three northern mines on the west bank can either cross the Athabasca and join the corridor on the east, or it can flow south on the west bank to join the GCOS and Syncrude system. The route which would cross to the east bank would involve a river crossing and a longer pumping distance, but could be economical if the capacity on the east side is designed to receive it. When the time comes for this routing decision to be made, the factors to be taken into account will be:

a) The relative economics of the route in terms of additional capacity, pumping stations, looping, etc.

b) The additional right-of-way clearing costs in financial and environmental terms.

c) Definition of environmentally sensitive areas on the west side in the general area of Fort MacKay.

d) The additional river crossing costs in financial and environmental terms.

There would appear to be no significant community constraints as Fort MacKay can easily be by-passed.

It would appear now that serving the northern mines on the west bank by an oil pipe line routed on the west side is likely to be safer, because it has no major river crossing; however, the costs and environmental penalties should be weighed when the time comes to make the final decision regarding the route. Figure 7 shows this probable route (where the pipe lines may or may not be combined with the roads).

If the development is restricted to the south by a rationalization and control of leases, then a reduced gathering system towards the GCOS line would appear most economic.

4.2.2 Combination with Road Links

The GCOS line is located on the west side of the Athabasca (Figure 3) crossing near Fort McMurray to follow the general course of Highway 63 to Edmonton, although located on a separate right-of-way and proceeding generally in a straighter line. Over the first section of the route, the pipe line is laid in the stable higher ground above the road, while the road is, in places, within one of the former channels of the Athabasca River.

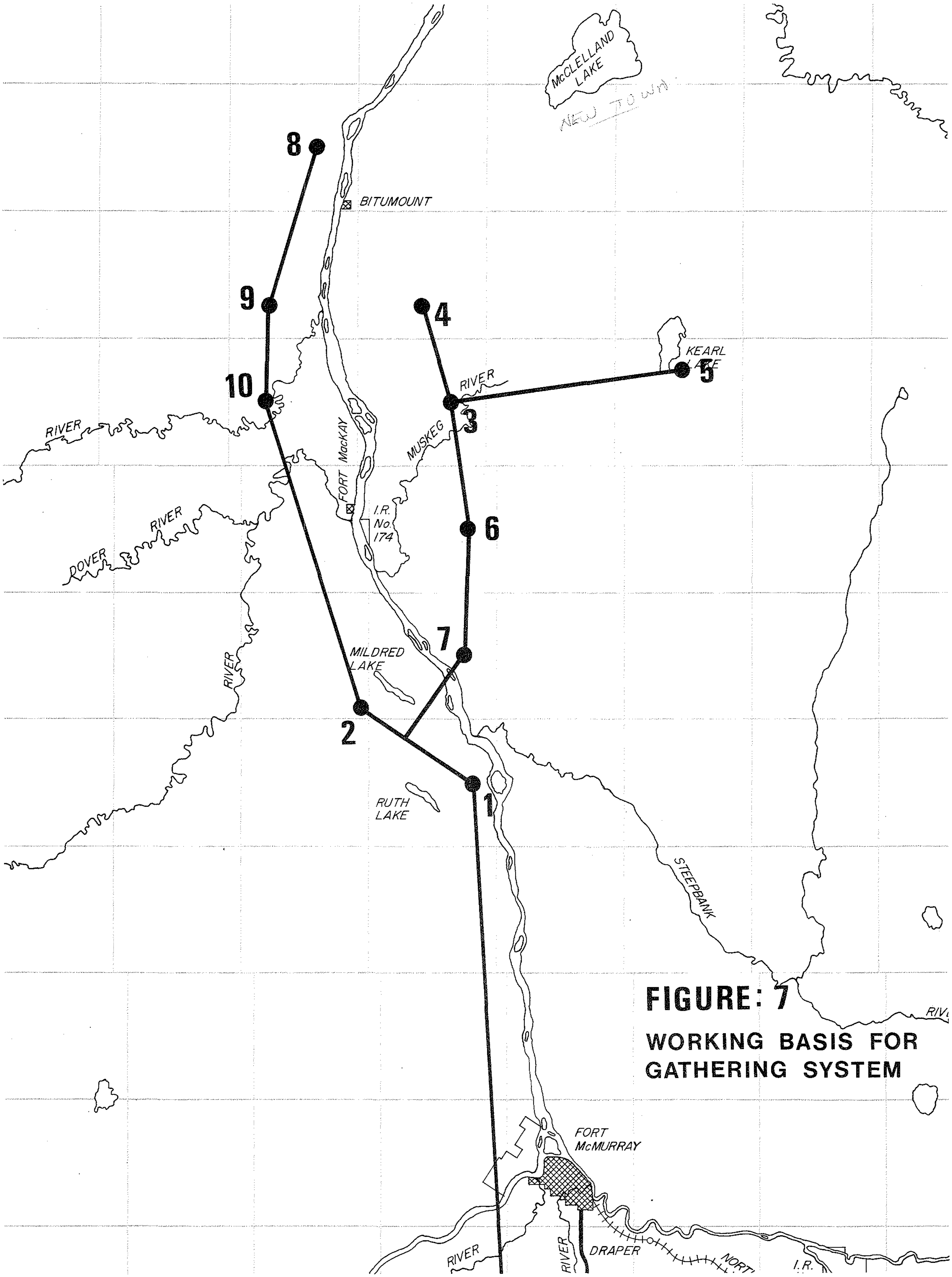

FIGURE: 7

WORKING BASIS FOR GATHERING SYSTEM

Because pipe lines and roads have different requirements and because the road is planned first, the possibility of a joint corridor has to be considered when the initial planning is done for the road.

The advantages and disadvantages of a common corridor are discussed in Sections 5.3 and 6.3.

If desired, the pipe line from the northern mines on the west bank (and any possible southern link from them to GCOS) could be placed in a common corridor with the road. On the east side of the river, the roads and pipe lines can also be placed in a single corridor, provided a corridor suitable for a pipe line is identified when the road is planned. The small Indian community on the east bank can be by-passed by a pipe line with no significant effect.

The logical crossing point from east to west for an oil pipe line would appear to be in the general area of GCOS, but a road crossing here is difficult. It will therefore be necessary either to identify a pipe line crossing point in this area where the banks are stable or to consider a somewhat more northerly location where road and pipe line can both cross the river in the same general area. There appears to be no advantage in bringing the pipe line down the east side all the way to Fort McMurray (even if there is a road to parallel), since a river crossing (of the Clearwater) would still be involved and a wide loop would be required to by-pass the town.

4.2.3 Combination with a Rail Route

The major advantage of the railway would be during the construction phase when major machines, assemblies, and vessels could be shipped in by rail, directly from suppliers or from ports of entry. Following this period (based on GCOS experience), there would be about 20 trucks per day bringing chemicals, parts, and supplies into the plant, with almost no movement of goods out. At GCOS, about 40 buses per day bring in the majority of the workers and about 700 vehicles per day bring in foremen, car-pooled workers and visitors. These movements of goods and people could be transferred to a railway, if one existed, at some change in cost and convenience.

The Northern Alberta Railway presently comes as far as Fort McMurray (Figure 3). The possibility of extending the railway to the proposed Syncrude development has been examined, but the $15 million cost has not been considered warranted by either the railway or the oil company.

If a railway proceeds further north, its probable route is north from Fort McMurray, across the Clearwater River, and north along the east side of the Athabasca. This would serve more mines during their construction phase for the given length of track.

If such a railway extension takes place to serve the east side mines, the oil pipe line could follow the railway right-of-way in part. It would have to by-pass Fort McMurray, and there would be no apparent advantage for it to cross the Athabasca to join the GCOS pipe line corridor. Hence the pipe line could follow the railway in part but would likely cross to the west bank at an appropriate point.

4.2.4 Combination with Power Lines

The tar sands plants are self-sufficient in power, but power lines are desirable as an intertie, to provide stand-by power for the plants and to make surpluses available for use in Fort McMurray and elsewhere in the system. The 200 Megawatt power supply for the proposed Syncrude operation may come from the west from Mitsue and Wabasca, (Figure 3) and a route into the plant site has been determined. This would traverse the southern boundary of the lease, turn north along the boundary with GCOS and enter the plant beside the road. If such a source is used, an intertie could be provided between the plant and the power line from GCOS to the town of Fort McMurray to allow interchange of power. However, this source of power is not definite, and power may be supplied instead from the north, or from the south, and could follow the road and/or pipe line, especially if a power supply is needed for pumping.

4.2.5 Combination with Natural Gas

GCOS uses natural gas in the plant as a source for hydrogen production, but the heating fuel for the power plant is coke from the refining process. However, the coke is sulphurous, and Syncrude proposes to use 55 million cubic feet per day of the cleaner fuel, natural gas, both in hydrogen production and in the power plant. This presents a clear conflict between environmental protection and energy conservation, with the selection being made one way in the GCOS operation and the other way in the Syncrude proposal. Future government policies on natural gas prices and/or subsidies to encourage purification of gaseous effluent from coke-burning will affect the decisions at future plants.

A supply of natural gas will be required but the source is not definite at this time. Natural gas to the area may be supplied by Albersun from Lac la Biche in the south but a gas supply from the Arctic, or the Marten Hills is also possible.

If gas is supplied from the south, it might enter the region in the same corridor as the GCOS pipe line. Common corridors could then be used for gas supply lines and oil pipe lines serving each refinery.

4.2.6 Combination with Water Supply Lines

As long as the Clark hot water process is used, each mine will require a major source of water. This may be obtained from the Athabasca, from tributaries, or from stream diversions of tributaries. It is unlikely that any water pipe line route would correspond with the desired pipe line route, but if it did, the two could be located together.

4.3 LIKELY ROUTE LOCATIONS

Faced with the transportation constraints presented in Section 4.2, and the limited environmental information available at this time, a route system as shown in Figure 7 would appear to offer a good working basis. This system would be compatible with all the probable developments, excluding that of restriction of all development to the south. Variants are possible, depending on the timing of specific mine developments, and the trade-offs in costs and environmental risks. If the west bank of the river has environmentally sensitive areas, then the alignments of Figure 6 could be preferable. Cost trade-offs could also lead to the latter route if a line with spare capacity exists when the northern mines on the west bank are ready for development. There are no significant community constraints if the pipe line remains on the west bank south of GCOS, but Fort McMurray would be situated on an east side route.

Rationalization, in order to concentrate development in the south, would lead to a much small gathering system on each side of the river, but a common corridor via a river crossing to exit along the GCOS line would still seem the simplest solution at the southern end.

5.0 ENGINEERING CONSIDERATIONS

This section of the study defines engineering considerations important to gathering systems for the surface-mineable areas of the Athabasca tar sands. Modern technology of pipe line design, construction, and operation is in general, adequate for a gathering system in the tar sands area, if applied efficiently and with accommodation of the specific constraints that exist there.

5.1 LOCKING IN RESERVES

The route from a lease will normally be selected to avoid locking in reserves as far as this is practicable. The price of oil and the overburden/bitumen ratio will determine which areas are least economic for mining. From an economic viewpoint, these areas will then become preferred locations for pipe lines. On the other hand, environmental considerations may suggest that pipe lines be placed in areas of prime mining potential (to be moved in due course) so as to minimize impact on the environment.

In any event, the overburden/bitumen relationships are required data before the necessary decisions can be made on routing. Existing information should be expanded through further exploratory hole drilling, which will be necessary in order to select the route for any facility into a particular plant.

5.2 TAILINGS DISPOSAL

Areas where tailings are to be stored should be avoided by pipe lines and other facilities, but definition of these areas may have to wait for further research and operating experience. With present technology, the tailings disposal areas take the form of enormous sand dikes bounding deep, slowly evaporating tailings lakes, with actual reclamation postponed for many years. Plants using the Clark hot water extraction process will have to use this method, due to the large amounts of water required.

GCOS has a mining plan which it is following, but Syncrude and the other oil companies do not have firm mining or reclamation plans at this time. Even with a definite plan, tailings initially placed on top of bitumen may have to be relocated to allow subsequent mining of the bitumen. An alternative to this might be developed if mined areas from plants in earlier operation were made available to plants built later, to be used for initial tailings disposal. In a reciprocal arrangement, the new plants would repay in kind once they had mined areas of their own available for tailings disposal. The transportation facility built to carry tailings to the mined areas would then be reversed. This procedure would minimize relocation of tailings disposal areas, and would simplify route selection for ground facilities.

The source of initial water inventories for extraction processing of plants built later is also a problem that could be solved by co-operation between new and older plants. The capability of each plant to recycle some water with suspended fines is not used on initial startup, and may not be used until each individual plant has enough tailings water of its own to begin recycling. New plants might start by using some recycle water from their older neighbours, rather than relying on a large initial draw of water from the Athabasca River or other possible source.

If a dike and lake topography develops, the dike tops will be the only places available to locate land facilities, if they must cross the affected areas.

5.3 CO-USE OF GATHERING SYSTEM CORRIDOR

From a technological point of view there are both constraints and advantages to co-use of a gathering system pipe line right-of-way by other facilities. These alone should not form a basis for decisions because environmental constraints and advantages must also be considered. However, the following points should be given consideration:

5.3.1 Constraints

5.3.1.1 Topographical Constraints

Pipe lines are not restricted in their location by topography to the same degree as are some of the other required facilities. Their routing must avoid sidehills and make use of suitable stream crossings but can otherwise be built over most ground conditions. The few topographic constraints on a pipe line would likely have no influence on the route selection for any other facility.

5.3.1.2 Timing Constraints

The pipe line to take the product from a plant is one of the last facilities required by the plant. Before it is built, a road to the site and a full size communications system will be needed for construction, as well as a railroad if one is to be built. Power and gas supply lines could possibly wait until about the same time as the market line. However, as both would be useful during construction, it might be advantageous to build them some years sooner than the market line.

Time allows options, and the market line is the last facility required. It seems reasonable to delay its final planning unless it must share a facility corridor.

5.3.1.3 Destination Constraints

Facilities to each tar sands plant will include roads and a communications system, and most likely power and gas lines. A railroad also is possible. Of these, it is very unlikely that all of the routes will have both a common source and a common destination.

In the case of the communications system, it could be via a satellite or a micro wave system, rather than a land line.

5.3.1.4 Relocation Constraints

If all the ground facilities to a plant are adjacent and located through an area amenable to surface mining, there is a likelihood of having to move them all at once at some future time.

5.3.2 Advantages

If other constraints allow and destinations are compatible, careful evaluation of the following advantages should be made for each case.

5.3.2.1 Land Use Advantages

If several facilities can be placed on the same right-of-way, less bush will have to be cleared, less land surface will be lost to other uses; and in areas mineable from the surface, less bitumen will be locked in. These are positive reasons for endeavouring to locate plant facilities such as gas lines and communications land lines (if buried) on a common right-of-way with the market line.

Power lines or any other pole lines could use adjacent narrow rights-of-way, with the use of the pipe line right-of-way for working room. An adjacent high voltage line might be convenient for powering intermediate pump stations.

Within the shallow overburden parts of the tar sands area, roads should preferably be placed adjacent to the market line and other facilities, to minimize the amount of bitumen locked in. Where surface mining is not a consideration, a belt of bush should be left between a road and other facilities for aesthetic reasons.

This approach could necessitate relocation of all of the adjacent facilities at one time, but the greater efficiency of surface land use would allow more time before such relocation would be necessary. In the meantime, there is the possibility that other options might be developed. Within the perspective of tar sand plant operating costs, the few hundred thousand dollars per mile that wholesale facility relocation would cost is not a major expense.

5.3.2.2 Construction Advantages

The transportation of equipment, men, and materials to a construction site is a major cost factor. While it may not be economically practical to constrain a road and one pipe line to a corridor, if a second pipe line and other services can also be included, the advantage of having all these facilities adjacent likely outweighs any individual disadvantages.

5.3.2.3 Maintenance Advantages

If the several land facilities to an individual plant are installed in a common corridor, each may use the same access for maintenance purposes. The access provided may then be built to a higher standard, likely improving the quality of maintenance to all facilities.

From economic and technological considerations, there is a strong case for the provincial government to expect, and perhaps require co-use of tar sands gathering system rights-of-way and/or common corridors for needed facilities; as far as is environmentally practical, and particularly where surface mining is a possibility. However, each pipe line should be considered individually.

5.4 COMMON CARRIER

In most conventional situations the transportation of petroleum liquids from a particular area is handled by a common carrier, which owns and operates the pipe line that services all of the shippers in the area. The common carrier may be a company owned by the major shippers, or it may be an independently owned business.

All of the shippers from one point are charged the same tariff on a volume basis for shipments of similar products made through the line. The carrier may own the line fill, or each shipper may own a part of it.

Liquids are metered accurately on entering and again on exiting the line, and equipment and procedures are used that limit the amount of mixing when different products are shipped in consecutive 'batches' through a single line. The carrier normally has sufficient storage capacity to hold batch volume and allow some surge in its operation relative to the producer(s) served. The common carrier accommodates growing throughput volumes, first, by adding power at its stations or at new stations; and second, by looping parts of the pipe line with an adjacent line, possibly in conjunction with the addition of more power.

The tar sands area development will not be conventional, but should be similar enough to developments in other areas using a common carrier, to make this approach advantageous, both from ecological and economic considerations.

5.4.1 Advantages

Compared with separate pipe line entities taking products from one plant each, a common carrier with responsibility for movement of all of the products from the area would have the following advantages:

a) If successive plants from the same area come on stream at intervals of three years or less, it might be economically advantageous to build a line large enough to handle product from two or more plants, with full powering of the line postponed until volume increases. The cost of building a pipe line is nearly proportional to the diameter of the line size being considered, while the volume capacity is proportional to the square of the diameter. Thus, a 20 inch line will handle the same volume as two 14 inch lines, but cost only 5/7 as much to install. Therefore, a capital saving of about 28.6% can be realized by building one 20 inch line to service two plants, instead of two 14 inch lines.

b) Such a carrier could specialize and operate efficiently, with minimum administrative overhead. As well as a single administration and office staff serving the whole area, the single maintenance staff would be large and could be more effective. Use of one communications/control system should be efficient and could economically be of the best quality.

c) A common carrier will normally have some storage, particularly if it is using one pipe line to carry different types of products being moved in batches. This could reduce the amount of product storage required at each plant, which might be economically attractive to the plant operators.

d) Larger volumes allow a proportionately stronger position from which to work in dealing with the major carrier receiving shipments for continuing transportation.

e) Single party responsibility for the whole area should allow establishment and maintenance of good communication and working relationships with government authorities having responsibility over pipe lines.

5.4.2 Constraints

Some constraints also exist that may limit the suitability of a common carrier to service the tar sands area. The following are possible disadvantages:

a) The product from each plant will likely be destined for delivery to a different refinery.

b) Timing of successive plants may not be firm enough to allow a plant in the planning stage to participate with a plant whose production will start at an earlier date, in building sufficient pipe line capacity to serve the eventual needs of both.

These constraints may come to have less and less weight as the tar sands development proceeds.

5.4.3 Equity Basis

Depending on the individual operator's interest, equity participation in the common carrier may be desired by some shippers. Most likely, the producers will define their interests by negotiation, unless the government or the public has an equity position.

Traditionally, except for the very few wholly Canadian-owned pipe lines in Alberta, pipe line companies within the province have used the constraints legislated by the United States Government as a basis for setting tariffs and defining earning expectations.

Since there will be a high United States financial input in the tar sands development, it is likely that the plant owners will expect the pipe line carrier to operate on this traditional, utility-type basis.

The Government of the Province of Alberta may wish to consider taking an equity position, or requiring a public equity holding in a common carrier, and giving direction to its development in the area.

5.5 GATHERING SYSTEM DESIGN

The tar sands area is a relatively new section of the Province of Alberta for pipe lines, and the volumes to be moved by lines fron individual plants are large. The Alberta Government will naturally be concerned that pipe lines for the area be designed and built according to the most modern and secure practices. Technological considerations are discussed herein, and recommendations made for aspects of good practice that the government may wish to see encouraged or enforced; by use of existing general regulations for pipe lines or by special regulations for gathering systems in this area.

5.5.1 Terrain

Although there are only a few terrain constraints on a pipe line, gathering line routes should be selected and their installation designed and built in accordance with the terrain crossed. The following should be considered:

5.5.1.1 Side Hills

Side hills are hazardous to a pipe line because soil movement is downhill, and if soil movement is lateral to a line, the line will be endangered. If pipe lines are laid straight up and down slopes soil movement will normally be parallel to the line, sliding past the pipe without displacing it. It is important not to attach anchors to a pipe line in any way that might cause them to be caught by soil sliding by.

5.5.1.2 River Crossings

The serious consequences of oil spilling into water demand a sound engineering approach to river and stream crossings.

If a crossing location occurs where the river channel is cut in rock and therefore stable, it should be used. Otherwise the following considerations are necessary:

a) Bends in streams have one bank turning the flow, and therefore eroding, gradually moving the bend downstream.

Line crossings should not be installed immediately downstream from a bend, but should be located with a long stretch of straight channel upstream.

b) Rivers may be either depositing material, or cutting their flood plains deeper. In the case of cutting, a secure crossing can be made by installing the pipe at a sufficient depth below the channel. In the case of a river that is filling, the line must be installed securely in the area adjacent to the actual stream. The stream level may be higher than the ground surface some distance from it, so the flooding of ground adjacent to the stream is a probability.

c) The low scour point in the stream bed profile moves back and forth across the flood plain, and crossings must be designed to maintain a required burial below this deepest point, for the full width of the crossing.

d) Unless fairly high, the stream edge banks are not secure, and the full valley floor must be considered the stream's flood plain. The crossing must be designed on that basis.

e) Islands in a river are not stable and should be either avoided or treated as part of the flood plain.

5.5.1.3 Climafrost

Climafrost, where thawing occurs once in several years, is likely to be encountered in the tar sands area. Permafrost, where thawing never occurs, is not likely to be found. If possible, the existence and location of climafrost should be determined before route selection for a gathering line is finalized. Failing definition beforehand, it may be encountered during construction. Installation through it will depend on the following:

a) Whether or not excavation through it is economic.

b) Whether or not it has a high ice content, which might melt, leading to settlement that could endanger the line.

c) Whether or not construction through it may initiate deterioration of delicate ground areas, which could endanger the line and potentially damage the surrounding area.

5.5.2 Pipe and Coating

Wall thickness, diameter, and steel quality (minimum yield strength) of pipe for tar sands gathering service will be selected according to the volume and pressure expectations, pump station spacing, and design philosophy of the firm building the line. The river crossings and the sections of line through major river valleys should use heavier wall pipe to make them the most secure part of the line.

The coatings in general use for pipe lines in Alberta are quite satisfactory for the tar sands area. They may be coal tar enamel, shop-applied polyethylene, or a primer and tape coating.

Selection from the various methods of coating should be made by the pipe line company, taking into account the time of year planned for construction; and also possibly by using comparative testing.

To avoid damage from the extra handling involved in installing stream crossings, pipe for river crossings should be double-coated before weighting. Weighting may consist of river weights, or concrete cladding, which has the added benefit of giving some scour protection.

5.5.3 Technical Service Branch Information of Rivers

Before the design of major stream crossings in the tar sands area is finalized, any pertinent information available from the Technical Services Branch of the Department of the Environment of the Province of Alberta should be reviewed. This branch has information on stream bank and bed stability for many of the province's larger rivers, as well as flow volume history, and ice behavior (freezeup and breakup).

5.5.4 Block and Check Valves

The gathering system lines should be equipped with check valves downstream of each major river crossing, to prevent return drainage as a result of a line break in the crossing. Also block valves should be located upstream of such crossings. Unless the block valves are powered and perhaps remote-controlled, forward drainage and possibly pumping of product into the stream will continue until the valve is manually closed. This is a strong reason for requiring powered block valves at river crossings. Also, block valves should be placed in the line not more than 20 miles apart, with access, procedures, and procedural training to be established and maintained to allow closure of any of these valves within one hour.

5.5.5 Use of a River Valley

Depending on the type of terrain adjacent to a river valley, it may be practical to use the comparatively uniform ground within the valley for installation of pipe lines and other facilities. In the tar sands area the Athabasca river valley is not very wide and thus not particularly useful compared with the relatively flat adjacent land. Together with the fact that the areas with minimum overburden covering the bitumen deposits are found near the river, this makes it desirable for the gathering lines and other facilities to be routed out of the river valley if possible.

Keeping the product line away from the river may also make containment of petroleum from any line failure possible before it can reach the river.

In any areas where the line must parallel a stream, definition should be made of natural catchment features to rely on in the case of a line break. Installation of berms or dikes in critical places may also be necessary.

5.5.6 Corrosion Prevention and Monitoring System

Pipe lines built in the tar sands area should be serviced with a cathodic protection system as soon as they are completed, with a routine checking procedure on the system initiated immediately. This is necessary because a perfectly continuous coating job is impossible, and even a small coating break in a corrosive soil will allow attack on the steel. Formation of a hole is possible in several months.

The lines should have scraper traps that will accommodate instrumented pigs, such as 'Linalog', for later survey of internal corrosion; in case products having some corrosive capacity may have to be carried at a future time.

5.5.7 Control and Communications System

A modern control and communications system is essential for secure operation of the tar sands gathering system, and its definition (in terms of general scope and capacity) should be a permit requirement.

5.5.8 Leak Detection

An effective control and communications system is necessary to provide facilities to measure, monitor, and control the volumes into and out of the gathering system lines. Data and status information can be provided to the control center and make possible the immediate detection of leakage from a line. To accomplish this, the control center must receive information from the meter(s) that measure the product into and out of each line. Volume measurement from each plant to the pipe line may be obtained from the custody transfer meters. If there is no custody transfer at the delivery end of the gathering line, an 'operating meter' should be installed for this sole purpose.

Some means of holding a back pressure at the delivery end of each gathering line is necessary. A control valve should be used where the line delivers or may deliver into tankage. If it can deliver only into the suction of an ongoing pump station, that station can be controlled to hold the required back pressure. The functions of such back pressure are to:

a) Hold the pipe line full with no vapour voids. (Unless the line is run fully packed, no immediate correlation can be made between in and out volumes).

b) Provide a constant pressure at which the delivery meter(s) can operate, making measurement more accurate.

5.5.9 Telescoped Pipe

In normal pipe line design practice, expected pump station locations are chosen and the pipe wall thickness is 'telescoped' in anticipation of a declining pressure profile from these points. Some repercussions are possible and do occur from this practice:

a) A decision may later be made to change the intended station spacing, perhaps because of a product change or addition and/or perhaps because of a volume growth other than as expected. In such a case, the line will not be optimum to the new station spacing.

b) If for some reason the lighter delivery end of the line is shut in without the stronger shipping end and pumps being stopped, the pumps will very quickly pressure the whole line to the initial shipping pressure or higher, and the lighter parts of the line will be in danger of failing.

For these reasons, and depending on the intended mode of operation, a critical look should be taken at how a gathering line is designed. Each line will be unique as to length, pumping pressure, capacity, and other factors, and should therefore be considered individually.

5.6 GATHERING SYSTEM CONSTRUCTION

Normally when having a pipe line built, the owner requires thorough specification and inspection of the construction, to assure a good quality installation. Some of the more pertinent considerations that apply to pipe lines in the tar sands area are the following:

5.6.1 Timing

Construction in this area should be done in winter because of the muskeg-intense terrain; as well as river or stream crossing considerations, including lowest water levels, easiest stream crossing (on ice), and least hazard to fish life from silt disturbance.

5.6.2 Bush Disposal

Bush should be burned if practicable. If it must be buried, this should be done off the right-of-way, or with more than 48 inches of cover to prevent interference with installation of succeeding lines.

5.6.3 Weighting

Weights for negative buoyancy must be installed very carefully to avoid damage to the wrap, and at correct spacing to provide a negative buoyancy to the line.

5.6.4 Bending

Bending, horizontal or vertical, should be done carefully, with stringent maximum limits on the amount of distortion; no wrinkling to be accepted. If welded into a line, wrinkles can stop the passage of scrapers; and are subject to stress corrosion cracking, which can cause failure.

5.6.5 Testing

Once in place and physically complete, the lines should be pressure tested for a full 24 hour period. The full period is necessary to allow a 24 hour recorder chart to close through a full night/day time and temperature frame, thereby detecting even the smallest leaks. Leaks of any size must be located and corrected. River crossings should be tested separately before being tied into the rest of the line.

5.6.6 Cleanup

Completion of construction ends with cleanup of the right-of-way; including roaching dirt over the ditch line to allow for settlement with time, final disposal of any brush or debris, installation of sand bags and diversion berms to deflect or control run-off water and to stabilize stream banks, and reseeding of the right-of-way to an acceptable grass cover. In muskeg sections particular attention to roaching is necessary to prevent excessive settlement and subsequent washing of backfill material. This is most critical in climafrost or permafrost areas. Perhaps because rainfall is adequate, re-vegetation can be expected to be quite successful, with grass and bush covering rights-of-way in a few years.

5.7 GATHERING SYSTEM OPERATION

The gathering system in the tar sands area will consist of pipe lines from 20 to 80 miles in length built from individual or adjacent plants to the northern terminus of the corridor from the area. These pipe lines will be important, and should be operated in accordance with good pipe line practice.

5.7.1 Control System

As the gathering system develops it should be expected that a modern communications and control system will be installed and used. This will mean a control center with a telemetering network to the gathering system, whereby all of the physical functions of the gathering system will be initiated and monitored. Computer assistance to the operation may become useful as the system is developed to service several plants.

5.7.2 Over-Short Control

With such a control system, the control center normally has a data update at least once each hour, as well as continuous upset monitoring. For the large volumes of liquid to be moved from each plant, it would be good practice to monitor the volumes in and out of the gathering system in the same manner. To do this is not difficult, but should include the following:

a) If the ground profile makes it necessary, back pressure should be held on each line to make sure that the line stays packed tight, with no vapour voids. Otherwise, there can be no immediate correlation between the volume measured into the line in a given time and the volume measured out in the same time.

b) Meter readings from either end of each line in the gathering system should be taken by the data system at one particular time during each hour and then transmitted to the control center for in-out comparison. If necessary, meter factors (to correct the individual meter readings to true volume) could be applied at the control center. These procedures would allow detection of a leak as small as one per cent of throughput from any part of the pipe line system, on a fairly immediate basis.

5.7.3 Air Patrol

It is normal practice for pipe lines to be inspected from the air at regular intervals. The objectives of this are as follows:

a) To detect any spill from the line which has reached the ground surface.

b) To detect any threats to the line. These could take several forms:

i) Construction approaching the line.

ii) Earth movement (sliding, washing).

iii) Stream or river crossing deteriorating (e.g. the line may be exposed by the water, which might only be apparent from the air).

c) To monitor the right-of-way condition.

In order to detect such threats before serious damage can result, the frequency of flights should be at least weekly.

5.7.4 Ground

Traditionally, it is good practice to walk a pipe line right-of-way once each summer. This can be done in a muskeg terrain with all-terrain vehicles, and it allows a careful inspection of the right-of-way.

Similarly, inspection should be made of all major stream crossings, by boat if possible, at least once each summer; but preferably each spring and fall, to check that they are intact.

5.7.5 Corrosion Monitoring and Control

The synthetic crude from the tar sands plants is not corrosive, and there should not be a need for the use of inhibitors in the gathering system, nor any expectation of internal corrosion. The gathering system lines will be threatened by external corrosion, against which there should be protection. To do so, the following measures should be undertaken:

a) The cathodic protection system should be operated without lapse.

b) Regular soil to pipe voltage monitoring should be carried out, recorded, and reported, from the cathodic test points.

c) The system's cathodic behavior should be reviewed by an expert at the time of line extension and/or at a maximum interval of possibly five years.

If product specification ever changes, making internal corrosion a possibility, internal monitoring should be instituted. This can be done by use of corrosion coupons, and by the occasional removal and analysis of test spools of line pipe. If it becomes necessary, the internal condition of the line can be inspected with an 'instrumented pig', such as 'Linalog'.

5.7.6 Disaster Contingency Plan

To allow immediate decisions and action in the event of a major line break in some part of the gathering system, it is necessary to have an up-to-date contingency plan for all of the system. Such a plan should define:

a) The drainage basins into which spilled product will flow.

b) The cut off points and suitable method of cut off for each drainage basin.

c) The volumes of line drainage to be expected from breaks at various points.

d) The location of check valves and the location and method for closing block valves to limit the amount of line drainage. This is a situation when powered remote-controlled block valves may become desirable.

e) Specialized portable equipment to be kept on hand and operative; including booms, boats, clean burners, hand tools, hoses, pumps, and all-terrain vehicles.

f) Where to obtain ordinary construction equipment which may also be needed; including bulldozers, backhoes, side booms, welders, forced air heaters, compressors, swamp pads, trucks, etc.

g) Where pipe and other material to effect repairs is available.

h) The location, means of contacting, and the responsibility of the personnel who will be needed to repair the break.

5.8 SECURITY FROM HUMAN ERROR

With good quality design and installation, pipe line failure due to natural causes will be almost eliminated. However, a large portion of the pipe line breaks in Alberta are caused by construction equipment. Human error in the operation of pipe lines is also a significant cause.

5.8.1 Security From Damage Due to Construction

In Alberta there is a legal survey for each pipe line, except minor flow lines, and this information is available to the public through the Land Titles Registry. Too often a search is not made of the location by investigating the legal survey, and consequently pipe lines are broken by some type of construction activity.

In the tar sands area, where almost all of the land is covered with bush, pipe line rights-of-way are quite well defined; however, if the line is immediately adjacent to a road, power line, or other facility, its exact location may not be obvious. The normal use of road crossing signs, aerial marker signs, and cathodic test posts, together with specially painted fence posts, should be adequate to indicate the location of the gathering lines.

There is a strong case for a central registry of all pipe lines and other ground facilities in the province, with a formal requirement that everyone planning any type of construction or demolition consult it before proceeding with operations on the site. The function of the registry would be to advise what ground facilities (if any) exist on the land intended for work, and the name of the operator. The location and contacting procedure for each operator should also be furnished. The party planning work should be required to formally contact the operator(s) affected, who should then be required to provide onsite facility location and guidance.

If such a registry is established, the scope of its service and responsibility should include the tar sands area gathering system.

5.8.2 Security From Operator Error

If the gathering system in the tar sands is designed and operated as a modern, remote-controlled pipe line system, the likelihood of breakage due to operator error is slight.

The control center will have data on pressure and volume, and pump and valve status and control; and will be alerted by any upset. The powered parts of the pipe line system should be designed to locally sense any serious upset, with 'fail safe' action initiated automatically if the control center is unable to take the appropriate action.

5.9 INFORMATION NEEDS

The Government of the Province of Alberta can exert control over each of the matters raised above, if it requires certain relevant information to be supplied along with both permit and license applications.

In addition, availability of the following information by the government would assist in the planning for tar sands development.

a) In areas where surface mining may take place, estimates of the overburden/bitumen relationship should be available.

b) Areas to be used for tailings storage should be defined regardless of lease boundaries so that they can be avoided in planning for ground facilities.

c) The economic and environmental considerations should be defined, regarding reciprocal agreements for tailings disposal between plants in operation and plants to be built later. (see Item 5.2).

d) The economic and environmental considerations should be defined regarding the use of recycle water from plants in operation for the initial operation of new plants.

e) Development of a central registry of all pipe lines and other ground facilities in this province might be considered by the Provincial Government. (see Item 5.8.1).

5.9.1 <u>Requirements for Permit Applications</u>

The following are technological considerations which should be satisfied at the time of permit application for gathering system pipe lines in the tar sands area:

a) Details should be provided on the overburden/bitumen relationships on the route, from best information available; an explanation should also be provided on how locked-in bitumen is to be handled both inside and outside of the lease being serviced.

b) Plans should be provided for the placing of the pipe line relative to other required ground facilities; if co-use of the right-of-way is not planned, an explanation for the divergence of facilities should be provided.

c) Explanation should be required of intentions to join existing gathering line operators as part of a common carrier; or not to join, as the case may be.

d) An estimation of the status of reclamation technology should be made in order to determine the possibility of placing the pipe line on reclaimed areas, and/or the likelihood of its eventual relocation onto such areas.

e) Details should be provided of planned access to the pipe line and other ground facilities.

f) Information should be provided regarding streams to be crossed and the choice of crossing points, allowing for possible channel changes.

g) Detailed design plans of stream crossings should be provided.

h) Locations should be provided of intended block and check valves, both as related to streams and the line in general, as well as plans for powering block valves and providing access to them.

i) An explanation should be provided of the type of communications/control system intended for the tar sands gathering line.

j) The philosophy of operations that will guide design and installation of the line should be stated. A 'fail safe' approach should be followed.

k) Explanation should be provided of the facilities and practices that will be installed and used to monitor volumes in and out of the line; or any alternate plans for leak detection.

l) Explanation should be provided of intended corrosion protection of the line. Wrap or coating, anode placement, cathodic protection systems, and any other corrosion protection measures should be defined.

m) Design features and protective devices that will be used to prevent damage from overpressure should be explained.

n) Explanation should be made of the surface markings that will be installed to indicate location of the pipe line.

o) Explanation should be made of provision for future expansion by way of additional pump stations or looping.

p) The planned construction period should be outlined, with winter being the most, if not the only, acceptable time in muskeg-intense terrain.

q) Explanation should be made of investigations and procedures planned for areas where climafrost occurs, and for other sensitive areas.

5.9.2 <u>Requirements for License Application</u>

At the time of application for a license to operate, construction of the line will be completed and the line will be ready to go into operation. The following information will be available and should accompany license application:

a) The location and method of operation of all valves in the line.

b) The location and quality of access to the line.

c) (Most important) A detailed contingency plan of actions to be taken in the event of a failure of the line anywhere. (see Item 5.7.6)

d) As-built information on stream crossings.

e) As-built information on construction in areas of climafrost.

5.10 REPORTING REQUIREMENTS

Once a gathering line is in operation, reporting procedures should be in effect for the following:

a) The commissioning of each of the various parts of the gathering line and associated equipment.

b) A yearly status report including operating problems and changes.

c) The inspection by air patrol of the gathering line right-of-way.

d) Annual, or preferably spring and fall reports, of the status of major stream crossings.

e) Investigations of the cathodic protection system at a maximum of every 5 years, or whenever additions or changes are planned to the pipe line.

6.0 ENVIRONMENTAL CONSIDERATIONS

This section of the report discusses the environmental considerations to be taken into account in locating a gathering system in those areas of the Athabasca tar sands amenable to open-pit mining.

Our approach and the environmental constraints are outlined first. The concept of interaction matrices is presented, and matrices are developed to identify pipe line and road-associated activities which may affect the environment; and the consequential effect these environmental impacts may have on mammals, birds, fish, and aesthetics. The advantages and disadvantages of the transportation corridor concept are discussed. Finally, recommended guidelines are presented for minimizing any potential adverse environmental effects.

6.1 INTRODUCTION

Two key questions form the basis for our approach to the study, and consequently the report:

1. What are the environmental constraints important in locating, building, and maintaining gathering system components in the tar sands area?

2. What are the guidelines which will minimize the detrimental effects of gathering systems on the environment?

To address the first question, a thorough synthesis was made of the ecological factors and principles associated with the development of roads and highways in the north, and factors important in protection planning were identified. The potential effects were classified under four distinct phases where impact may occur; survey, geotechnical investigations, construction, and operation and maintenance. These potential effects were assessed on the basis of the following:

a) Whether there is likely to be a direct impact upon the physical/chemical environment.

b) Whether there may be direct and/or indirect impacts upon biological and aesthetic environmental parameters within the region.

To address the second question, the potential adverse environmental effects of pipe line and road development were reviewed, and recommendations for specific guidelines were developed which would tend to minimize adverse effects.

6.1.1 Scope of Study

The area potentially affected by development of the tar sands is immense. The baseline physical, chemical and biological data necessary for environmental impact assessment and protection planning is inadequate at this point in time. However, there are a number of ongoing and proposed programs designed to provide some of the essential physiographic, hydrologic, atmospheric, and ecological information. Some base line data, such as for fisheries, wildlife and forestry are presently available.

The scope of this section of the project relates to providing a comprehensive approach to environmental impact assessment and protection planning for tar sands gathering systems. It is not the intent, nor is it feasible within time and budget constraints, to conduct a detailed environmental impact assessment of gathering system components at alternative locations. This can only be done through major site specific studies, and after a number of policy decisions are made by the Alberta Government.

To assess the implications of possible environmental impacts, it is essential that they be placed in perspective with regard to location, order of magnitude and duration. The methodology outlined provides a basis for mitigating multidiscipline environmental studies, synthesizing their findings, and assisting researchers and decision makers in gaining this perspective.

With respect to protection planning our intent is to provide a comprehensive but broad based set of location, construction and operation phase guidelines for the tar sands. They are designed to provide a focus for forming tar sands policy. After guidelines are implemented by legislation, they may be applied to site specific cases.

6.2 ENVIRONMENTAL CONSTRAINTS

The environmental impact of the development of a petroleum gathering system upon the Athabasca tar sands region can be looked upon as two part phenomenon. First, there is a category of direct impacts upon certain environmental factors such as regional physiography, hydrology, vegetation, and atmosphere. Second, there is a category of effects that result from these impacts. These are the impacts upon the ecological and aesthetic qualities of the region. There is also the potential for further long-term indirect, sublethal and/or cumulative effects of which little is known at this point in time. Thus, to evaluate the potential impact of a gathering system, a precise identification must be made of:

a) The components of all key environmental factors.

b) The way in which these factors interact with each other.

c) The way in which each of these factors is affected by the various activities related to the construction and operation of gathering system components.

6.2.1 Interaction Matrices

A matrix approach has been used initially to portray:

a) The interactions between the activities associated with constructing, operating, and maintaining pipe lines and roads; and environmental parameters.

b) How changes in these parameters might affect the ecological and aesthetic qualities of the region.

Considerable care must be taken in utilizing and evaluating matrices, but they can be useful in the planning exercise. Our use of matrices is based upon the rationale outlined in Appendix I.

The potential interactions resulting from the activities associated with the construction and operation of pipe lines are presented in Figure 8, and those for roads in Figure 9. The potential interactions between environmental changes and possible ecological and aesthetic impacts are presented in Figure 10.

It must be emphasized that these matrices are in a simplistic form and must be related to site and time specific activities. Each category could be considerably expanded and/or modified when applied to a specific location within the tar sands. For example, a specific

FIGURE 8

INTERACTION MATRIX

FOR PIPE LINES

ENVIRONMENTAL PARAMETERS	SURVEY	Camps	Clearing	Fire	GEOTECHNICAL INVESTIGATIONS	Camps	Clearing	Fire	Vehicle passage	Drilling	CONSTRUCTION	Access roads	Grading	Camps	Clearing	Fire	Vehicle passage	Temporary creek crossings	Excavation and ditching	Disposal and backfill	Borrow pits	**Waste disposal**	OPERATION	Physical presence	Access roads	Spills or leaks	Pumping stations	Chemical treatment
PHYSIOGRAPHY																												
Steep slope			X	X			X	X	X			X	X		X	X	X		X	X	X			X				
Topography		X				X						X	X	X			X		X	X	X	X		X				
Potential climafrost			X	X			X	X	X			X	X		X	X	X		X	X				X				
Stream and river bank			X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X			X				
Stream and river beds		X	X				X	X	X	X		X	X		X	X	X	X	X	X	X	X		X				
Poorly cohesive materials			X	X			X	X	X			X	X		X	X	X	X	X		X			X				
Organic terrain				X				X	X			X	X			X	X		X	X				X				
HYDROLOGY																												
Internal drainage			X	X				X				X	X		X	X			X		X			X		X		
Surface drainage		X	X	X			X	X	X			X	X	X	X	X	X		X	X	X			X				
Running water quality		X	X	X		X	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X		X		
Running water quantity			X	X			X	X				X	X		X	X	X		X	X	X			X				X
Ponds, lakes									X										X	X	X					X		
VEGETATION																												
Submergent aquatic																			X	X		X				X		X
Emergent aquatic									X								X	X	X	X		X				X		X
Early seral stage			X	X			X	X	X			X	X		X	X	X	X	X	X						X		X
Later seral stage		X	X	X			X	X				X	X	X	X	X			X									X
Regional climax vegetation		X	X	X			X	X				X		X	X	X			X									X
ATMOSPHERE																												
Noise		X	X				X		X	X		X	X	X	X		X		X	X	X				X		X	
Dust		X	X				X		X			X	X	X	X		X		X		X				X			
Micro-climatic change			X	X				X							X	X										X		
HUMAN USE																												
Recreation		X	X	X		X	X	X				X		X	X	X								X	X	X		X
Settlement		X										X		X										X	X			
Archaeological & historic sites		X	X			X	X	X				X	X	X	X				X	X	X					X		
Visual compatibility		X	X	X		X	X	X				X	X	X	X	X			X	X	X	X		X	X	X		X

CONSTRUCTION & OPERATING ACTIVITIES

FIGURE 9

INTERACTION MATRIX

FOR ROADS

CONSTRUCTION & OPERATING ACTIVITIES

ENVIRONMENTAL PARAMETERS	SURVEY	Camps	Line clearing	Fire		GEOTECHNICAL INVESTIGATIONS	Camps	Clearing	Fire	Vehicle passage	Drilling		CONSTRUCTION	Camps	Clearing	Fire	Vehicle passage	Temporary creek crossings	Temporary access roads	Bridge, culverts, ditches	Borrow pits	Cut	Fill	Waste disposal	Landscaping		OPERATION & MAINTENANCE	Existence	Chemical treatment	Gravel supply	Vehicle passage
PHYSIOGRAPHY																															
Steep slope deposits			X	X				X	X	X					X	X	X		X		X	X	X		X			X		X	
Topography		X					X							X					X	X	X	X	X		X			X		X	
Potential climafrost			X	X				X	X	X					X	X	X		X			X	X					X		X	
Stream and river bank			X	X				X	X	X	X				X	X	X		X	X	X	X	X					X		X	
Stream and river beds		X	X				X	X	X	X	X			X	X	X	X		X	X	X	X	X	X				X		X	
Poorly cohesive materials			X	X				X	X	X					X	X	X		X	X	X	X	X					X		X	
Organic terrain				X						X							X		X			X	X					X			
HYDROLOGY																															
Internal drainage			X	X				X	X						X	X			X		X	X								X	
Surface drainage		X	X	X			X	X	X	X				X	X	X	X		X		X	X	X		X			X		X	
Running water quality		X	X	X			X	X	X	X				X	X	X	X		X	X	X	X	X	X				X	X	X	
Running water quantity			X	X					X							X				X	X	X	X					X			
Ponds, lakes										X							X				X	X	X	X				X			
VEGETATION PHOTOPLANKTON																															
Submergent aquatic																X	X		X			X	X	X					X		
Emergent aquatic										X					X	X	X		X			X	X	X					X		
Early seral stage			X	X				X	X	X					X	X	X		X			X	X						X		
Later seral stage		X	X	X			X	X	X					X	X	X			X			X			X				X		
Regional climax vegetation		X	X	X			X	X	X					X	X	X			X			X			X				X		
ATMOSPHERE																															
Noise		X	X				X	X		X	X			X	X		X		X		X	X	X							X	X
Dust		X	X				X	X		X				X	X		X		X		X	X								X	X
Micro-climatic change			X	X					X							X															
HUMAN USE																															
Recreation		X	X	X			X	X	X					X	X	X								X				X	X		X
Settlement																												X			
Archaeological & historic sites		X	X				X	X	X					X	X	X			X		X	X	X		X					X	
Visual compatibility		X	X	X			X	X	X					X	X	X			X	X	X	X	X	X	X			X	X	X	

FIGURE 10

ENVIRONMENTAL

INTERACTIONS MATRIX

ECOLOGICAL & AESTHETIC IMPACT / ENVIRONMENTAL CHANGES

ECOLOGICAL & AESTHETIC IMPACT	PHYSIOGRAPHY (terrain)	Steep slope deposits	Topography (terrestrial & aquatic)	Potential climafrost	Stream and river bank	Stream and river beds	Poorly cohesive materials	Organic terrain		HYDROLOGY	Internal drainage	Surface drainage	Running water quality	Running water quantity	Ponds, lakes		VEGETATION	Submergent aquatic	Emergent aquatic	Early seral stage	Later seral stage	Regional climax vegetation		ATMOSPHERE	Noise	Dust	Micro-climatic change		HUMAN USE	Recreation	Settlement	Archaeological & historic sites	Visual compatibility
MAMMALS																																	
Fur bearer					X							X	X	X	X			X		X					X					X	X		
Ungulates			X									X	X		X			X	X	X	X	X			X					X	X		
Predators			X		X							X	X		X						X	X			X					X	X		
Small mammals					X							X	X	X	X					X	X	X			X	X	X			X	X		
BIRDS																																	
Waterfowl					X							X	X	X	X			X	X						X	X				X	X		
Upland								X				X	X	X	X					X	X	X			X	X	X			X	X		
Shorebird					X							X	X	X	X			X	X	X					X	X	X				X		
Wading bird					X							X	X	X	X			X	X						X	X	X				X		
FISH																																	
Migratory		X	X	X	X	X	X	X			X	X	X	X	X			X												X			
Resident		X	X	X	X	X	X	X			X	X	X	X	X			X												X			
AESTHETICS																																	
Visual interest		X	X	X	X	X	X	X				X			X						X	X				X					X	X	X
Historic interest			X																													X	

development activity, such as vehicle passage and access could be subdivided into the following components:

- Fixed wing aircraft and helicopters
- Airstrips and landing pads
- Wheeled vehicles - trucks, automobiles, sand buggies, jeeps
- Tracked vehicles, skidoos, weasels, caterpillars
- Small vessels, barges, tugs, hovercraft

The following section presents a brief discussion of each of the key environmental constraints important for locating, building, and maintaining gathering system components in the Athabasca tar sands area. These general constraints must be evaluated on a site specific basis to assess whether potential effects will be widespread or site specific, of low or high impact, and of short or long duration. They must also be related to the survey, geotechnical investigation, construction, and operation and maintenance phases.

6.2.2 Physiography

Upon disturbance by construction and/or operation activities, the following processes may be initiated or accelerated:

a) erosion

b) slumping

c) sedimentation

d) destruction of soil structure

e) topographic alteration

6.2.2.1 Erosion

Erosion may result from exposing bare soil to the elements directly, as by excavation or bulldozing; or indirectly, by fire, removal of vegetation and/or clearing. The resultant washing away of the soil has two potential consequences. First, the aesthetics of the landscape are marred by gullies and expanses of exposed bare soil. Second, the redeposition of eroded material in water bodies may result in the alteration of the hydrologic regime (Section 6.2.3) and in the destruction of aquatic feeding habitat and spawning grounds (Section 6.2.3.3).

6.2.2.2 Slumping

Slumping may result from the same factors as erosion, particularly where cuts are made into stream banks, hillsides, and deposits of poorly cohesive materials. This may cause considerable terrain subsidence and severe slumping, especially along streams and banks. Consequences of slumping in road development are similar to those of erosion, with the major effects being on aesthetics and aquatic fauna. In certain cases, when very large slumps or landslides occur along streams, the whole flow pattern of the streams may be completely altered. This can bring about total habitat alteration and consequent destruction of much of the aquatic fauna.

Consequences of slumping along a pipe line route are likely to be much more severe. If the terrain under a pipe line subsides or slumps, or a landslide affects the line, a break or leak may occur. The resultant spill could cause widespread effects to fish and wildlife habitat, particularly if the break occurs near a body of water (Section 6.2.3.3).

6.2.2.3 Sedimentation

Severe consequences to the environment of a stream or river can be the result of sedimentation caused by disturbance of a stream bed, and/or the redeposition of material carried away by erosion or slumping. Aquatic flora and fauna, as well as spawning and rearing areas can be reduced or destroyed. In certain cases fish and aquatic insects can be directly affected by the mechanical action of silt on their breathing apparatus.

6.2.2.4 Destruction of Soil Structure

Soil disturbance can result from the passage of heavy vehicles over ground which is unable to support their weight. This may occur in wet, silty, or clay areas, or in organic terrain. Areas of climafrost are liable to disturbance if the insulating organic ground cover is disrupted and the climafrost permitted to melt. Besides being aesthetically unattractive, areas of disturbance may interrupt natural drainage patterns (Section 6.2.3.1), and if extensive, may greatly increase the erosion potential by channelling surface runoff.

6.2.2.5 Topographic Alteration

Topographic alteration may be both terrestrial and aquatic. Borrow pits, gravel excavation, filling, bridges, culverts, levelling for camps, and the very presence of a road or pipe line can alter the regional topography to some extent. The effects of topographic alteration can vary from affecting scenery and disrupting surface drainage patterns, to affecting migration patterns. The presence of roads and culverts across rivers and streams can alter the flow of water to such an extent as to constitute barriers to migration by fish and aquatic mammals. Increased downstream sedimentation can also result due to physical destruction of the stream bed during installation of these structures. On land, an elevated roadbed, and particularly an elevated pipe line may act as a migration barrier for some of the larger mammals.

6.2.3 Hydrology

Of prime importance in maintaining the integrity and stability of the hydrologic system of a region is the dependence upon that system of a great variety of fauna. Many organisms can be affected at some stage of their life history by hydrologic changes; fish; aquatic and terrestrial insects; migratory waterfowl; shorebirds such as swans, ducks, geese, cranes, herons, and loons; and aquatic, semi-aquatic, and shoreline mammals such as muskrat, beaver, otter, weasel, and mink. The main processes which can influence the hydrologic system are changes in:

a) distribution of water

b) rate of flow

c) water quality

6.2.3.1 Distribution of water

Changes in the distribution of water in the various parts of the hydrologic system can result from the disturbance of internal and surface drainage patterns. This may be brought about as a consequence of excavation, filling, channeling of water through erosion gullies, thermokarst, and blockage or alteration of water movement by the presence of a road or pipe line. Such a change may result in the decrease of flow or the drying up of streams, ponds and small lakes, with consequent effects on fish and wildlife habitat; or shoreline habitat may be flooded out and water conditions changed by increased flow rates. The timing and quantity of water distribution is of critical importance to the life cycles of many species of flora and fauna.

6.2.3.2 Rate of Flow

The rate of water flow depends on the volume of water reaching the hydrologic system and the topography through which it flows. Changes in amounts reaching the system may occur when the balance of internal drainage to surface drainage is disturbed. For example, increased runoff can result from removal of vegetation by clearing or fire, and/or removal of soil by excavation or erosion. Increased flow due to topographic change can also result when gravel is removed from a stream bed, when pipe lines are laid across streams, and when road culverts are installed.

Possible detrimental consequences of changed flow rates are:

a) The reduction or destruction of feeding and spawning habitat for fish.

b) The reduction or destruction of aquatic insects essential in the food chain.

c) The destruction or alteration of aquatic mammal habitat, (i.e., flooding of beaver lodges).

d) The increased fluctuation in water levels of lakes and ponds which affect shoreline vegetation, and consequently affect waterfowl and shore-birds using this vegetation for food or cover.

6.2.3.3 Water Quality

The consequences of alteration of water quality through increased sedimentation and siltation have been dealt with in Section 6.2.2.3.

Degradation of water quality may also result from toxic wastes and sewage resulting from construction activities and from pipe line spills or leaks. Effects from a major pipe line break are likely to be direct, serious, and widespread. Fish, aquatic invertebrates, aquatic mammals, waterfowl, and shore birds may be affected directly or indirectly through habitat destruction. The extensive, connective nature of the hydrologic system makes the potential results even more serious since contaminants may be carried far from the original source of pollution.

6.2.4 Vegetation

Vegetation serves as habitat and a food source for regional fauna. Maintenance of vegetation cover is also important to the aesthetics of an area, to the regulation of the hydrologic cycle, and to the protection of the soil from erosion and slumping. The zoning of vegetation as it relates to wildlife habitat and food production can be characterized by dividing it into the following classes:

a) submergent aquatic

b) emergent aquatic

c) early seral stage

d) later seral stage

e) regional climax

Submergent aquatic vegetation provides habitat for fish and a food source for waterfowl. Emergent aquatic vegetation provides habitat for waterfowl, shore birds, and some of the semi-aquatic mammals such as muskrat; and a food source for ungulates such as moose.

Early seral stage vegetation constitutes habitat and a food source for small mammals such as rodents, and upland birds such as grouse and ptarmigan. It also provides a summer food source for ungulates such as moose and deer. Later seral stage and regional climax vegetation provide habitat for the predator mammals such as lynx, wolf, fox, and bear, and for many small upland birds; as well as habitat and a winter food source for the ungulate species.

Disturbance to vegetation can occur through many activities such as clearing, fires, excavation, and change in the hydrologic regime, with consequent loss of, or change in habitat and food source for the fauna dependent on each vegetation zone.

6.2.5 Atmosphere

Processes affecting the quality of the atmosphere involve changes to air quality and changes to the climatic regime. Noise and dust from roads can cause a significant change in air quality which could affect fauna and aesthetics. Noise from construction activities, camp power plants, the passage of vehicles, and pumping stations may be particularly disturbing to wildlife during critical stages of their life cycle; e.g. nesting, brooding, and staging in the case of birds, and mating and rearing in the case of mammals. Similar disturbance, although not as severe, may result from dust blown up from roads. A further consequence of road dust is alienation of habitat along the highway.

Any significant change to the climatic regime would be mainly at the microclimatic level. Such change would probably occur only as the result of fire or major clearing activities. For example, removal of vegetation from a hillside by fire would increase the exposure to wind, and eliminate shading capacity formerly provided by trees. The result would be the destruction of habitat for any animals requiring a sheltered, protected environment.

6.2.6 Human Use

Human use of the resources of a region will increase as soon as the construction phase of a development begins and will expand considerably once a road network is completed. The use of an area for recreational purposes usually puts pressure directly on wildlife resources through hunting and fishing. The aesthetic qualities of the area may be affected by injudicious disposal of waste and litter. Permanent settlement in a region adds a long term dimension to the above factors. Settlement near a critical wildlife habitat, such as migratory waterfowl nesting ground, or fish spawning grounds, could have deleterious effects.

Past use of a region is recorded in archeological and historic sites. Valuable sites can be lost by levelling areas for camps, cut and fill operations, and gravel excavations.

6.3 CORRIDOR CONCEPT

Locating all components of a gathering system within a joint corridor is a currently popular concept. If a common corridor can be utilized for all roads, pipe lines, power lines, and railways, arguments can be made for economic efficiency in construction and maintenance, and for limiting environmental disturbance to a comparatively small area.

If the conveyance components are proceeding from a common source to a common destination, the engineering and economic arguments may be valid. However, reductions in total environmental disturbance will not necessarily result.

In general environmental and ecological terms the combined corridor concept might seem most acceptable since a smaller total land area could be affected. However, if the corridor is to be situated in a large environmentally sensitive area, the damage done may be more serious than for a dispersed system. Also, the considerably wider right-of-way required, and the route restraints imposed by each of the conveyance components, present the designer with less flexibility in route selection, and thus less possibility of avoiding environmentally sensitive sites.

A further factor for consideration is the potential cumulative effect upon the environment of combining routes of conveyance components in a common corridor. This may be most significant for factors such as the disruption of migration routes, erosion, stream bank stability, and stream siltation. A single conveyance right-of-way may not present much of a barrier to movement of animals such as moose and caribou, but a combined conveyance corridor may prove sufficiently wide and foreign to these animals to prevent them from moving across it. Similarily, while erosion and stream bank slumping resulting from the construction of a single conveyance right-of-way may affect some fish habitat and cause some migration problems, the intensification of these results from a combined conveyance corridor may have much more serious effects on downstream habitat and disruption of fish migrations.

The specific objective of conveyance components of the gathering system must also be taken into consideration. If, for example, roads or railways were constructed for use during the construction phase and to provide maintenance access to the mining areas and extraction plants, the location of transmission lines and pipe lines in a common corridor with them would be logical. If, on the the other hand, the roads and/or railways were to be part of a more extensive system providing recreational and tourist access to points within the tar sands area and north of it, then the corridor concept might be incompatible with this objective.

The question of aesthetics may also be pertinent to corridor policy. For example, traveller enjoyment would probably be greater on a separate road rather than on one with a continual view of power lines, pipe line cuts, and/or railroads.

The utilization of the corridor concept in the Athabasca tar sands area should be viewed with some reservations at this time, and a flexible policy adopted. A combined conveyance corridor is only one option to be considered in the selection of the final routes.

6.4 RECOMMENDATIONS AND GUIDELINES

The following section recommends guidelines which would tend to minimize adverse environmental effects resulting from the development of the tar sands gathering system. These recommendations are related to the location, construction, and operation and maintenance phases of development. Only when extensive resource information becomes available will it be possible to develop activity, site, and species specific guidelines.

6.4.1 Location Phase

a) It is imperative that from the beginning, environmental considerations are taken into account in the planning, design, construction, and operation of a gathering system. The location of the gathering lines and all services must be planned so as to avoid areas of potentially high impact. This can only be accomplished by preliminary investigation and identification of areas of both high and low impact. Where possible, the evidence of environmentally sensitive areas obviously provides the most effective means of maintaining environmental integrity.

b) It is important that the pipe line and road network of the gathering system be designed and installed in such a way as to allow migratory wildlife free passage through the area. Otherwise, the blocking of migration routes will be a major factor in the effects of the operation upon the environment.

c) Pumping stations and compressors should be located away from any critical wildlife habitat since noise may prove a disturbing factor.

6.4.2 Construction Phase

Once a route has been selected, construction timing and methods should be adapted to minimize any potential impact. The following practices are recommended:

a) Vehicle passage over sensitive terrains, such as organic deposits or climafrost, should take place only in winter when the ground is frozen.

b) Precautions should be taken to prevent forest fires.

c) Care should be taken at creek crossings to prevent slumping of banks.

d) Excavations and fill operations should be designed to avoid erosion, channeling of run-off water, and consequent stream sedimentation.

e) Bridges, culverts, and pipe line crossings of streams and rivers should be designed to allow normal passage of fish.

f) During the installation of bridges, culverts, and pipe line crossings of streams and rivers, care should be taken to avoid excessive sedimentation.

g) Construction activities should be avoided in critical wildlife habitat during sensitive times of year such as mating, brooding, and rearing seasons.

h) Construction camps should be located away from critical wildlife habitat.

i) Care should be taken to avoid disruption of the hydrologic regime by designing roads and pipe line beds so that a cross-flow of water can occur.

j) Toxic and human wastes should be disposed of with care.

k) The exploitation of fish and game by construction workers should be carefully regulated.

l) Programs for education and information should be undertaken to inform construction personnel of construction guidelines and further measures which would minimize environmental degradation.

m) Monitoring programs should be undertaken to ensure maintenance of environmental quality at an acceptable level.

n) Archaeological surveys should be undertaken to locate and examine any important archaeological or historic sites which may be disturbed by construction activities.

o) A program of re-vegetation of disturbed areas should be undertaken wherever it is deemed necessary to improve soil stability or restore disturbed wildlife habitat.

6.4.3 <u>Operation and Maintenance Phase</u>

Use of toxic plant growth control spray should be avoided in right-of-way maintenance.

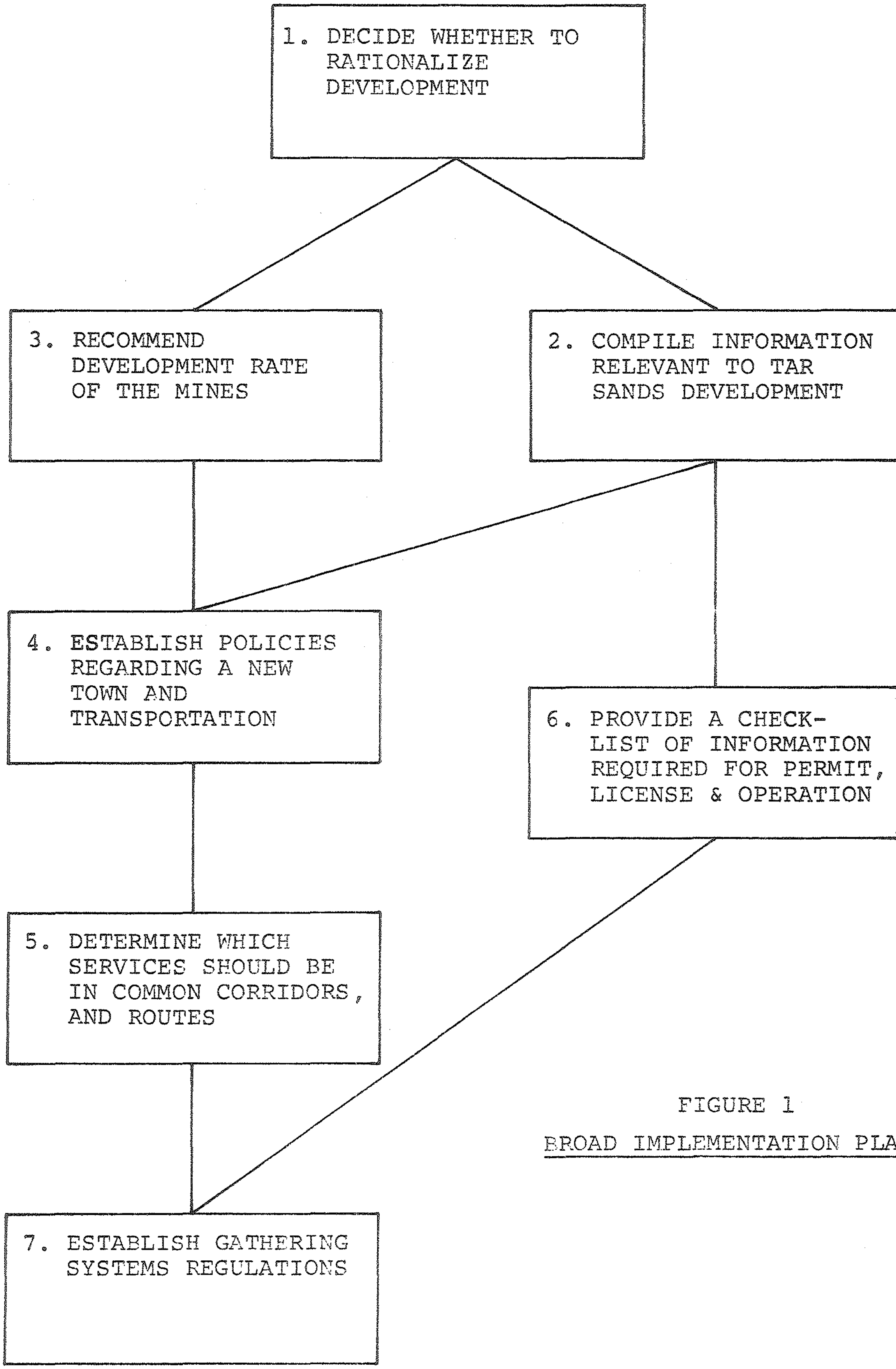

FIGURE 1

BROAD IMPLEMENTATION PLAN

7.0 BROAD IMPLEMENTATION PLAN

The implementation of the recommendations of this report has to be integrated with other aspects of the development of the tar sands area. A decision on rationalization of development must be made first, but other steps can proceed in parallel. Figure 1, opposite, shows the logical sequence of decisions.

1) Decide whether to rationalize development.

2) Compile information relevant to tar sands development.

3) Recommend development rate of the mines.

4) Establish policies regarding a new town and transportation.

5) Determine which services should be in common corridors, and routes.

6) Provide a check-list of information required for permit, license, and operation.

7) Establish gathering systems regulations.

These are discussed in the following sections:

7.1 DECIDE WHETHER TO RATIONALIZE DEVELOPMENT

The rationalization of leases, which is only one part of controlling the development, has major implications for the tar sands area. The potential cost savings would obviously be high in terms of new town infrastructure, transportation facilities, and the provision of services to people.

On the other hand, rationalization would require a large government intervention in the market place. Finalizing arrangements between existing lessees with different quantities and qualities of reserves may be difficult.

A decision on the question of whether or not to rationalize leases must precede all other decisions.

7.2 COMPILE INFORMATION RELEVANT TO TAR SANDS DEVELOPMENT

Availability of certain information would be useful both to the government itself in developing policies, and also to companies planning operations in the tar sands area.

The information could be assembled while other decisions, e.g. rationalization of leases, are being made, and would then be available when needed for input to subsequent decisions by the government and for companies seeking authority to construct or operate plants.

Development of the following information is recommended:

7.2.1 Determination of Environmentally Sensitive Areas

The area within at least the 100-foot isopach should be evaluated to determine the environmentally sensitive areas. This analysis may be based on the matrix approach of Section 6, with particular emphasis on areas adjacent to the transportation links identified in Section 4. More detailed inventories of fish, wildlife, and soils than are presently available, will be required; and a program of work will be needed to develop these.

7.2.2 Records of Overburden/Bitumen Relationships

Existing records of overburden/bitumen relationships should be expanded, to facilitate the determination of areas of rich bitumen deposits. In planning for future development, these areas can be avoided by tailings storage areas and ground facilities.

This information would be essential in determining the areas suitable for surface mining, and planning for the most efficient use of all areas of the tar sands.

7.2.3 Definition of Areas Suitable for Tailings Storage

Areas suitable for tailings storage could be defined after the overburden/bitumen relationships have been determined, and regardless of lease boundaries.

If these locations are established prior to the commencement of construction of ground facilities or utility lines, and avoided by them, the likelihood of having to later relocate any facilities would be reduced.

7.2.4 Factors Influencing Reciprocal Agreements for Tailings Disposal

A policy decision is needed to define whether or not reciprocal agreements for tailings disposal should be required.

The cost of relocation of tailings to allow access to bitumen is so great, that it would appear to be economic common sense to use mined areas of existing plants for initial tailings disposal from new plants.

Detailed analysis of the engineering and costs, together with the economic and environmental benefits should be made to assist the government in making a policy decision.

7.2.5 Factors Influencing Use of Recycle Water for Initial Operation of New Plants

A study should be made of the costs, both economic and environmental, of the high initial draw of water from drainage systems, required for startup of plants using the Clark hot water extraction process.

Definition of the costs of new plants drawing on used water from existing plants for startup, would also be needed before a policy decision could be made on making the use of recycle water a requirement.

7.2.6 Formation of a Central Registry for All Ground Facilities in the Province

If all pipe lines and other ground facilities in the province were registered, and everyone planning any type of construction or demolition was required to consult the registry before commencing operations on the site, there would be far less danger from broken pipe lines caused by construction activity.

This central registry would contribute to the minimizing of damage from oil spills or leaks due to pipe line breaks.

7.3 RECOMMEND DEVELOPMENT RATE OF THE MINES

The rate of development of mines has a significant bearing on the economics of the various transportation facilities. For example, a high rate of development would make more economic the installation of a railway. The construction of ten mines in ten years would have a markedly different impact than ten mines in thirty years.

This report has assumed a maximum rate of one plant every three years, which means not more than ten plants would be completed by the year 2000.

The desirability of a high development rate is dependent on:

a) The anticipated market in the next twenty or thirty years.

b) The market foreseen beyond the next thirty years.

c) The availability of skilled construction labour.

d) The capacity to train unskilled construction labour.

e) The probability of better extraction techniques becoming available in the next ten years.

f) The ability of the environment to withstand a high development rate.

g) The ability of the town or towns to cope with a high population growth rate.

h) The relative economics of a high as compared with a lower rate of growth.

An acceptable maximum development rate should be established, and suitable procedures established to encourage or control growth at that rate.

7.4 ESTABLISH POLICIES REGARDING A NEW TOWN AND TRANSPORTATION

Comparative evaluations should be made of transportation facilities and services to people both with and without a new town. Questions to be asked for each possibility are:

a) Where should a new town be located, dependent on site conditions, access to potential mines, environmental impact, and livability?

b) What major investments will be required for a new town and when?

c) What major investments will be required at Fort McMurray, with and without a new town?

d) How feasible is continued expansion at Fort McMurray?

e) What kinds of services can a single large town offer that two smaller towns cannot?

f) What commuting methods could be used and what would be the cost, convenience, reliability, and safety of each?

g) How would the communities be linked by transportation with Edmonton and elsewhere?

7.5 DETERMINE WHICH SERVICES SHOULD BE IN COMMON CORRIDORS, AND ROUTES

We could not establish any general rule regarding the desirability of locating facilities in common corridors. Through many areas, if the facilities proceeded in the same general direction, there would be evident cost and land-use advantages. However, in some environmentally sensitive areas, separate smaller corridors might be preferable to one large corridor. When facilities follow approximately the same direction, then there could be cost and environmental trade-offs in rerouting into a common corridor.

These trade-offs would have to be evaluated as to what level of diminution in environmental impact would be achieved: at what extra costs, and to what extent of rerouting?

By the time environmentally sensitive areas and the main transportation services have been identified, then the specific choices between single rights-of-way, and common conveyance corridors can be evaluated more rationally, and decisions made on corridor locations.

7.6 PROVIDE A CHECK-LIST OF INFORMATION REQUIRED FOR PERMIT, LICENSE, AND OPERATION

When the environmentally sensitive areas have been determined, a check-list can be prepared of information that should be required of companies at the time of permit and license application, relative to the pipe line that they propose to install. Items are outlined in Sections 5.9.1, 5.9.2, and 6.4. Information which should be reported regularly once the system is in operation is listed in Section 5.10.

The recommendations of this report may provide a preliminary basis for these check-lists. More information may be required as the necessary site specific transportation, engineering, and environmental studies are carried out.

7.7 ESTABLISH GATHERING SYSTEMS REGULATIONS

Gathering system regulations should govern the construction and control of pipe line gathering systems. The specific recommendations of this report may be considered for inclusion in special gathering system regulations, or revision may be considered of existing provincial regulations on pipe lines generally. These regulations may in certain circumstances require the laying of pipe lines in specified corridors as determined in Section 7.5 above.

APPENDIX I

INTERACTION MATRICES

Ideally, in a decision-making process, all possible relevant facts and data are assembled, alternatives and implications assessed, and a course of action selected. Decisions made under these circumstances cannot be questioned on the basis of data, which are complete and consistent, but only on interpretive and philosophical grounds. However, these ideal circumstances rarely prevail; in most instances decisions must be made without the benefit of all desired and/or necessary data. Thus a subjective human valuation process becomes a paramount necessity.

What kind of consistent method can be formulated for assigning weights and priorities in a relatively subjective decision-making process, at least to the extent of providing a logical basis for assessing differences of opinion? One key requirement is that all available information be displayed in a logical and easily interpreted form.

A mechanism that assists in structuring a consistent basis for comparison is an interaction matrix. This methodology consists of listing potential modifying actions on one axis of a table, and information requirements to assess the impact of the modification on the other. When an action precipitates a need for information on a prospective effect, an X can be placed in the appropriate square and the information requirement is illuminated.

Matrix Benefits

The use of the matrix technique has five important implications:

1. In-House Document

   An interaction matrix, developed as an in-house document, encourages staff personnel to think extensively about physical/biological/socio-economic factors in the study area, and all potential modifiers that can have a significant influence. Decisions have to be made whether:

   a) there will be a significant interaction,

   b) there might be a significant interaction, or

   c) there will not be a significant interaction.

   Through an iterative process of individual effort, group discussion, and then re-synthesis, a comprehensive matrix can be developed.

2. Weights

   This iterative process is also of considerable value in delineating the order of magnitude that should be assigned to a particular interaction. Weighting values can be a sensitive and controversial task, but the matrix technique permits a consistent approach to the problem.

3. Visual Aid

   A matrix assists in portraying the initial complex interrelationship among variables so key relationships are illuminated to all discipline interests. Problem areas often stand out in a visual portrayal thereby suggesting research priorities.

4. Comparisons and Contrasts

   The matrix method can be a valuable tool for making comparisons between alternative development strategies or plans. In the case of alternative pipe line routes, for example, a comprehensive matrix can be developed and analyzed independently for each route, and then the resulting tables compared and contrasted.

5. Qualitative Judgement

   A matrix can be used in the display of qualitative information which can then be criticized as to its comprehensiveness.

Matrix Restrictions

The above is a listing of the benefits of the matrix technique, but the matrix is not a panacea that will illuminate all considerations associated with development activities. One must realize the problems and restrictions regarding the use of matrices.

1. Misinterpretation
   Visual display can also be a liability as well as an asset. There is a tendency to overlook the text and concentrate upon the visual presentation of data found in the matrix. Individual interactions and classes of interacting variables must have specific mention and elaboration in the text.

2. Superficiality

   a) Development activities often precipitate environmental impacts which have multi-order consequences, for example, irrigation, a necessity for crop farming, may be a "causal factor" leading to increased cliff erosion as a "consequent condition", and finally to undermining of residential structures as a "second order condition". Consideration of second and third order effects deserve consideration in surveillance programs, but are very difficult to portray in a matrix.

   b) Superficiality also relates to the unsuitability of the matrix to illustrate more than about three characteristics of an impact. Impacts may be of high or low magnitude, they may be of long or short duration and have

widespread or site specific impacts.
Duration/time considerations can not
be integrated in a sequential manner.

An interaction matrix is not a panacea, rather it is a mechanism that assists in providing a comprehensive approach to ecological protection. It is not an end in itself, but a means to comprehensive environmental protection and must be used within the perspective of a wide variety of decision making strategies.

GLOSSARY

Bitumen:	any natural mixture of solid and semi-solid hydrocarbons.
Cathodic protection:	the control of the electrolytic corrosion of an underground metallic structure (as a pipe line) by the application of an electric current in such a way that the structure is made to act as the cathode instead of the anode of an electrolytic cell.
Cladding:	metal or other form of coating bonded to a (metal) core by heat and pressure or by casting; or in the case of concrete cladding, by forming or guniting.
Clark hot water process:	the process in present use (GCOS) for separating bitumen from sand by the use of hot water, developed by Dr. K. A. Clark during his service to the Alberta Research Council.
Climafrost:	ground that remains frozen through one or more summers, but thaws occasionally (see permafrost).
Common carrier:	a carrier such as a trucking or pipe line firm providing like or "common" service to all shippers desirous of using its service for movement of similar products from an area.
Common corridor:	a strip of land of restricted width, wherein several various facilities such as pipe lines, power lines, roads, etc. are placed.
Ecology:	the study of the mutual relationships between organisms and their environments.
Erosion:	the wearing away of the earth's surface by action of wind, water, glaciers, etc.
Fauna:	the animals living within a given area or environment or during a stated period.
Flora:	the plants collectively of any given formation, age or region.

Flood plain:	a plain bordering on a river, subject to flooding by the river.
Habitat:	the region or environment where a plant or animal is normally found.
Hydrology:	the branch of physical geography that deals with the waters of the earth, their distribution, characteristics, and effects in relation to human activities.
Instrumented pig:	a pig equipped with instruments to measure and record the conditions existing within the pipe line through which it passes (see "pig").
Inhibitors:	a substance for reducing corrosion or rust formation.
Isopach:	an isogram that connects points of equal thickness of a particular geological stratum formation or group of formations.
Linalog:	trade name for a type of "instrumented pig".
Muskeg-intense:	an area with a large portion of its ground surface consisting of muskeg.
Open-pit:	a mine working in which excavation is performed from the surface.
Overburden:	material overlying a deposit of useful geological materials.
Permafrost:	the part of the earth's surface in arctic regions that is permanently frozen.
Pig:	a circular plug of length greater than its diameter, and diameter equal to the inside diameter of the pipe, through which it is forced by the moving fluid.
Rationalization:	the act or process of making rational or reasonable.
Recycled water:	water, having been previously used in a process, which is returned to the process.

Roaching:	placing of dirt in an elongated mound to allow for settlement, as in the backfilling of a trench or ditch.
Scour:	the scouring action of a current of water.
Scraper:	(see "pig").
Scraper traps:	closures, normally at the ends of a pipe line, through which the flow can be directed, or which can be isolated and by-passed; and are used to send and receive scrapers.
Sedimentation:	the action or process of depositing sediment.
Siltation:	the deposition or accumulation of silt.
Slurry:	a usually thin mixture of water or other liquid with a finely divided substance.
Tailings:	refuse or residue from processing.
Tar sands:	a natural impregnation of sand or sandstone with petroleum from which the lighter portions have escaped.
Telescoped pipe:	term applied to the practice in the pipe line industry of using successively lighter sections of pipe according to distance downstream from a pumping station; according to the expected pressure profile of the line.
Test spools:	short sections of pipe in a pipe line, identical to adjacent permanent sections of pipe, but flanged at either end to allow easy removal for laboratory investigation of corrosion behaviour.
Ungulate:	having hoofs

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