ENVIRONMENTAL IMPACT ASSESSMENT

VOLUME IV

SUPPORTING STUDIES

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PREFACE

Volume IV of the Environmental Impact Assessment is an accumulation of documents relating to studies completed in support of project engineering and management activities. Four study areas are documented.

TABLE OF CONTENTS

SECTION

SECTION 1.

ECONOMIC AND SOCIAL IMPACT OF THE SYNCRUDE PROJECT

1. ECONOMIC AND SOCIAL IMPACT OF THE SYNCRUDE PROJECT

A. INTRODUCTION

The Overview Volume incorporated discussions of the environmental impact resulting from resource use and the specific requirement for development of the resource represented by the tar sands. Consequential to most resource uses are both cost and benefit factors. The most easily identifiable benefit is the positive economic impact resulting from the development. Social impact may be viewed as both incurring costs and providing benefits.

The first study (made in November, 1971, as partial consideration of the justification of the project) reviews the potential regional economic impact. The impact (in this case a benefit) of the project upon the economy of Alberta was found to be significant. The study found that in the 1970's the project could add from 8,000 to 10,000 additional jobs of every kind to the labour force, generate sufficient additional income of more that $100 million annually, and support more than 20,000 additional people in the province. The tax revenue of the provincial government would increase substantially from income generated by the project itself and from the general expansion of the Alberta economy. The latter would continue to undergo the transformation and modernization which it has experienced since the discovery of the Leduc oil field in 1947.

The second study, completed in February, 1973, outlines the impact of the project on Fort McMurray.

The three sections of the study as reported cover:- Fort McMurray as it is today, the impact of the proposed Syncrude plant on Fort McMurray, and the potential impact of additional plants should they occur.

The report outlines the anticipated requirements for facilities in Fort McMurray should it be decided to proceed with the Syncrude project. You will note that the anticipated population, when the plant is in operation in 1979, is 15,500 people. There will be a peak population occurring in the Town in 1977 due to this project, of approximately 16,900.

This influx of population will result in a major demand for housing with emphasis on the single family style of accommodation. This demand is, as well, being strongly expressed by the current population.

The report was prepared, utilizing manning information made available from Syncrude Canada Ltd., combined with analysis of the generally accepted planning criteria related to this type of expansion, together with a review of the actual experience of the impact of the Great Canadian Oil Sands Ltd. plant and related experience in other similar situations.

The consultants who made the study stated that they believed the study to reflect the best analysis at this time, of the situation which may be anticipated in Fort McMurray upon completion of the Mildred Lake project, should it proceed, as well as the impact of additional plants should they proceed.

SECTION 1.

ECONOMIC AND SOCIAL IMPACT OF THE SYNCRUDE PROJECT

B. POTENTIAL REGIONAL ECONOMIC IMPACT

November, 1971

TABLE OF CONTENTS

A. SUMMARY

Alberta has awaited the utilization of its bituminous deposits for a long time. It took decades to develop the appropriate technology for extracting and producing synthetic crude oil and associated products from these deposits of Northern Alberta. Today large-scale production is both technically and economically feasible in the case of the richest and most favorably located deposits.

With the rising demand for oil, synthetic crude from the Alberta tar sands can help to meet the growing deficiency of oil in North America. Both synthetic and conventional crude oil will be required in the decades ahead to meet expanding North American requirements.

The proposed project is a logical and timely step in the growth and development of the petroleum industry in Alberta. It is logical because it is the result of the know-how and techno-structure which have been generated in the course of the growth of the petroleum industry in Alberta. It is timely because the deficiency between the consumption and production of domestic oil in the United States is becoming large, and because the Alberta economy requires additional export activities to maintain continuous growth. The conventional crude petroleum industry has expanded at a high rate during the past two decades, inducing substantial growth of the Alberta economy. It cannot be expected to be the prime generator of growth much longer since the life index is projected to fall to the critical range of 12-13 years by 1974. Mutually-supporting and associated economic activities, like the production of synthetic crude, require development to keep the Alberta economy strong and growing.

The proposed project is but a beginning of a potential development which could make Alberta synthetic crude competitive in regions, like District I in the United States, which are becoming highly dependent upon offshore oil. Large-scale plants in Northern Alberta and high-capacity pipelines would make synthetic crude very competitive.

The impact of the project proposed by Syncrude Canada upon the economy of Alberta would be significant. In the 1970's it could add from 8,000 to 10,000 additional jobs of every kind to the labour force, generate sufficient additional income of more than $100 million annually, and support more than 20,000 additional people in the province. The tax revenue of the provincial government would be increased substantially from income generated by the project itself and from the general expansion of the Alberta economy. The latter would be continuing to undergo the transformation and modernization which it has experienced since the discovery of the Leduc oil field in 1947.

The Syncrude project provides an indication of the growth and development to come. Additional projects of the same type, and the development of associated by-product industries, the undertaking of power projects in Northern Alberta, the building of new pipelines, and the opening up of new markets for oil would augment substantially the economic impact of the Syncrude Canada project in Alberta.

B. GROWTH OF THE PETROLEUM INDUSTRY IN ALBERTA

The crude petroleum industry has expanded and developed rapidly in Western Canada, particularly in Alberta, since 1947 with the discovery of the Leduc oil field. Currently Alberta produces more than 70 per cent of the crude oil, over 95 per cent of the natural gas liquids, in excess of 80 per cent of the natural gas, and almost 99 per cent of the sulphur in Canada.(1) The production of synthetic crude oil began in Alberta in 1967, and it can be expected to become highly significant and integral in the future development of the petroleum industry and the economy in Alberta.

The gross production revenue of the conventional crude petroleum industry in Alberta increased from $85 million to about $1,300 million during the two decades 1950 - 1970.(2) The province accounted for 80 per cent of the gross production revenue of Western Canada in 1970. Nearly three-quarters of the net cash expenditures of the conventional crude petroleum

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(1) See Tables A-1 and A-2 in Appendix A.

(2) See Tables A-3 and A-4 in Appendix A.

industry in Canada has been made in Alberta since 1947. As a result substantial reserves of oil and gas have been discovered in the province.[(3)] Along with this development, the synthetic crude petroleum industry has made outlays on research, pilot plants, and one operational plant in recent years. These are beginnings which point toward continuing growth and expansion of the Alberta economy.

The production of Alberta conventional crude and pentanes plus amounted to 1,009,000 barrels per day in 1970. Production is expected to rise to 1,792,000 barrels per day in 1975 and decline slightly thereafter to 1,635,000 barrels per day by 1980. Synthetic crude, on the other hand, is forecast to increase from 33,000 barrels per day in 1970 to 65,000 barrels per day in 1975 and 300,000 barrels per day in 1980.[(4)]

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(3) For a detailed account of the growth and evolution of the Alberta petroleum industry during the first ten years after the Leduc discovery, see E. J. Hanson, Dynamic Decade, McClelland and Stewart, Toronto, 1958. An updated exposition is set out in E. J. Handson, "Regional Employment and Income Effects of the Petroleum Industry in Alberta", Council of Economics, American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), Proceedings, Annual Meeting, New York, March, 1966, pp. 276 - 313.

(4) Forecasts as contained in The Application to the Energy Resources Conservation Board to Amend Approval No. 1223 of The Oil and Gas Conservation Board by Atlantic Richfield Canada Ltd., Canada-Cities Service, Ltd., Gulf Oil Canada Limited and Imperial Oil Limited.

C. ECONOMIC IMPACT OF THE PETROLEUM INDUSTRY UPON ALBERTA

The conventional crude petroleum industry has spent more than $12 billion in Alberta upon exploration, development, and production since 1947. This includes outlays for land acquisition, geological and geophysical surveys, exploratory drilling, development drilling, other development projects, operation of wells, natural gas plants, royalties, and associated activities. The level of annual expenditure accelerated from $29 million to $214 million between 1947 and 1950. It more than doubled during the decade of the 1950's to $480 million in 1960, and more than doubled again during the 1960's to $1,023 million in 1970. The 1971 level of expenditure is estimated at about $1,200 million.(5)

The expansion and development of the petroleum industry has been the main generator of growth in Alberta and in the prairie provinces during the postwar period. The high and rising level of expenditures by the petroleum industry, financed largely by funds from outside the province, has induced a growing level of investment by other industries, as well as substantial rates of growth of the population, employment, income, and government revenue.

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(5) See Tables A-5 and A-6 in Appendix A.

Alberta has the highest level of private and public investment per capita in Canada, with an estimated $1,541 per capita for 1970, about 43 per cent above the Canadian average of $1,081, and considerably above the average of $1,312 for Western Canada.[6] The province has led in this respect since 1947. This increasing level of investment has induced a substantial rate of about 9 per cent during the postwar period.[7] Output in the petroleum, construction, electric power, manufacturing, and agricultural industries has risen markedly throughout the past quarter century, transforming and expanding the Alberta economy to the point where this province has become one of the three most prosperous ones in Canada.

In 1946, before the intensive development of the petroleum industry, population decline was imminent. During the postwar period, Alberta has been the second fastest-growing province in Canada, with a population increase of 103 per cent between 1946 and 1971. British Columbia, assisted by the petroleum industry, led the Canadian provinces in population growth, with an increase of 119 per cent for the quarter century 1946 - 1971.[8] In Manitoba

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(7) See Table A-8 in Appendix A.

(8) See Table A-9 in Appendix A.

and Saskatchewan the population increased at the modest rates of 36 and 11 per cent respectively 1946 - 1971, while the overall Canadian rate of increase was 72 per cent.

The petroleum industry, by its high and rising level of spending, created many new jobs in the Alberta economy in its own ranks, but even more throughout the whole labour force. There are many thousands of workers in the wholesale and retail trades and manufacturing who supply the petroleum industry with machinery, equipment, and materials. Many more service this machinery and equipment, and many others transport the equipment and supplies. These workers and proprietors are direct recipients of petroleum-industry outlays. So also are workers engaged in constructing temporary buildings and roads in the oil fields. The investment of the petroleum industry in its various operations has added many workers to the construction industry. There are also many workers in professional, financial, and service industries who specialize in petroleum-oriented work, such as geologists, petroleum engineers, lawyers, landmen, and their staffs.[9] Furthermore, employment has increased

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(9) In 1961 Alberta had 42 per cent of the total number of professional geologists in Canada, and 30 per cent of the professional mining engineers. These persons have a large number of technical, administrative, and clerical workers associated with them. (Data from DBS, Census of Canada, 1961.)

markedly in the public services, education, and health to provide a high level of government services for the population. Finally, the addition of all these workers who depend more or less directly upon the outlays of the petroleum industry, has induced the addition of workers in nearly every kind of industry and occupation in the province.

In 1946 the total labour force of Alberta was just over 300,000.[10] Without the development of the petroleum industry this number could have declined with the downward trend in employment in agriculture which has become a more capital-intensive and managerial industry since the end of World War II. Since 1946 the number of persons employed directly in agriculture in Alberta has declined from over 120,000 to less than 90,000. Employment in agribusiness and activities associated with agriculture has risen, however, so that agriculture is of substantial importance in the economy. Currently the total labour force in Alberta is about 650,000, of which the petroleum industry, directly and indirectly accounts for well over one-half. Between 1946 and 1970, the industrial composite employment index increased by 158 per cent in Alberta, a much higher rate

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(10) From DBS, Census of the Prairie Provinces, 1946.

than those achieved by neighboring provinces and Canada. In British Columbia the index rose by 87 per cent in the period 1946 - 1970, in Saskatchewan by 51 per cent, in Manitoba by 45 per cent, and in Canada by 70 per cent.[11]

In 1946 the labour force in Alberta equalled 37.7 per cent of the population so that, on the average, a worker supported 2.65 people. Currently the labour force equals an estimated 40 per cent of the population, with each worker supporting, on the average, about 2.5 people. Many young people and women have entered the labour force in recent years, producing a downward trend in the number of persons supported per worker.

On the basis of the expansion of the labour force, induced by the growth of the petroleum industry, the population of Alberta has increased by more than 800,000 since 1946. The industry has provided the basis for an addition of close to one million people in Alberta since 1946.

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(11) See Table A-10 in Appendix A.

With respect to the growth of income, total personal income in Alberta increased by 507 per cent between 1946 and 1970.(12) The petroleum industry, directly, indirectly, and through associated activities currently is responsible for the generation of more than half the personal income in Alberta, and the agricultural industry in all its aspects for about one-third.(13) At one time agriculture, including agribusiness, generated about four-fifths of the toal income, but despite its relative decline, its absolute contribution has been growing with the expansion of the economy. The continuous opening up of new oil and gas markets, and growth in old ones, as well as a great build-up of technology and know-how, has added a new dimension to the Alberta economy which enables most economic activities to grow within an expanding framework. We have elaborated on this theme at length in previous publications.(14)

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(12) See Table A-11 in Appendix A.

(13) The rest of the "export" industries are relatively small. They include pulp manufacture, non-metallic products manufacture, coal, northern development, and activities financed by resident funds.

(14) E. J. Hanson, Dynamic Decade and "Regional Employment and Income Effects of the Petroleum Industry in Alberta."

The petroleum industry has had a great impact upon the finances of the provincial government of Alberta. Between the fiscal years 1950 - 1951 and 1970 - 1971, the revenue that government collected directly from the conventional crude petroleum industry increased from $44 million to $229 million. There have been fluctuations in the level of revenue with the timing of discoveries of new oil fields. For the two decades from 1950 to 1970, the revenue from the oil and gas industry provided, on the average, about 37 per cent of the total revenue of the provincial government.(15) The petroleum revenues have enabled the provincial government to postpone tax increases and the introduction of additional taxes.

The provincial revenues derived from mining operations, including oil sands, have been much more modest. The amounts are set out in Table A-13. The revenue from oil sands increased from $0.7 million in the fiscal year 1960-61 to $2.4 million in 1970-1. The revenue from coal rose from $0.1 million to 1.6 million during this period. The total mining revenue expanded from $2.4 million in 1960-61 to 7.0 million in 1970-71, providing less than one per cent of total provincial revenue during the decade. The processing of the oil sands was very much a marginal operation

(15) See Table A-12 in Appendix A.

economically during the 1960's, and the industry was not capable of generating a substantial flow of income. This will continue to be the case during the 1970's, although the rate of growth can be accelerated so that a large revenue base could be available in the 1980's.

D. THE PROPOSED PROJECT OF SYNCRUDE CANADA LTD.

The proposed project of Syncrude Canada Ltd. set out in the application dated August 7, 1971 to the Energy Resources Conservation Board to amend Approval No. 1223 of the Oil and Gas Conservation Board, is timely and crucial at the present stage of the development of both the petroleum industry and the Alberta economy. It is proposed to construct a plant in the tar sands area which can produce 125,000 barrels per day of synthetic crude and about 5,500 barrels per day of residual fuel.(16) The output would be sold in oil deficient markets, making the proposal an additional export industry or "oil field" in the province, with a significant impact upon the growth of employment, population, and income in Alberta.

We concur with the demand-supply analysis set out in Pages IV-1 to IV-12 of the 1971 Application of the four associated companies which own Syncrude Canada Ltd. The United States faces a continuously growing deficit in its internal production and consumption of petroleum. By 1980, the United States

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(16) Atlantic Richfield Canada Ltd., Canada-Cities Service, Ltd., Gulf Oil Canada Limited, and Imperial Oil Limited, An Application to the Energy Resources Conservation Board to Amend Approval No. 1223 of the Oil and Gas Conservation Board, August 7, 1971.

is expected to consume 24.0 million barrels of petroleum products per day whereas its domestic crude production, including that of Alaska, is projected at only 12.8 million barrels per day. The conventional industry in Alberta will be able to supply only a small part of the U.S. deficiency since the life index here will have dropped to 12-13 years by 1973 or 1974 and the industry will be hard pressed to maintain supplies to established markets, with little or no scope for expansion. For the decade 1970 to 1980 the worldwide consumption of oil is projected to increase by more than 80 per cent, from 46.6 million barrels per day in 1970 to 85.7 million barrels in 1980.[17] It will be difficult to match this great worldwide growth in demand with additional offsetting crude supplies. Certainly Athabasca synthetic crude will be required in large quantities along with other new sources.

As indicated the conventional crude petroleum industry is achieving a certain degree of maturity in Alberta. During recent years there has

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(17) Oil and Gas Journal, November 15, 1971, p. 124. The consumption in countries outside Communist countries is expected to rise from 39.6 million barrels per day to 71.2 million barrels per day 1970 to 1980. In the U.S.S.R. and other Communist countries the consumption is projected to increase from 7.0 million barrels per day to 14.5 million barrels per day during the decade 1970 - 1980.

been some levelling off in rates of increase of expenditures on land acquisition and exploration activities, and a growing importance of expenditures on production.[18] One can expect reduced rates of increase in the years ahead, depending upon successes in discovering major oil fields within the province. Projects and economic activities outside the conventional petroleum industry must be developed in Alberta to maintain a continuing increase in population, employment, and income.

The Syncrude Canada project would induce further growth of the Alberta economy, bolstering the economic base built up by the conventional petroleum industry. With the decline of conventional supplies, one can expect that the synthetic section of the crude petroleum industry will expand greatly, after Syncrude Canada Ltd. has demonstrated that it can produce and sell synthetic crude successfully on the scale envisaged in the Application of its four associated companies. The research and development involved, as well as the planning and completion of a project such as this, takes a long time. There is a need for continuous review of the situation, and Syncrude Canada Ltd. requires the opportunity to demonstrate what can be done in the development of the tar sands.

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(18) See Tables A-5 and A-6 in Appendix A.

Associated with the whole process of extracting and refining the Northern Alberta deposits will be the production of many mineral, chemical, and petrochemical products, stimulating growth in the manufacturing sector of the Alberta economy. To service the mining operations in the tar sands, a new industry may move to Alberta to provide, maintain, and repair the machinery and equipment required for continuous, large-scale operations in the tar sands. Currently such equipment and its servicing is imported from the United States; large projects located in the Alberta tar sands would make the movement of mining equipment manufacture and servicing to Alberta economical. The potential development of electric power projects is indicated, encouraging the development of the northern parts of the province. Finally, synthetic crude is one of the few sources of petroleum in the world with a low sulphur content, so that it can meet the strongest requirements called for in maintaining environmental quality in the generation of power and other activities.

E. THE ECONOMIC IMPACT OF THE SYNCRUDE CANADA LTD. PROPOSAL UPON THE ALBERTA ECONOMY

1. HISTORICAL

The four parent companies of Syncrude Canada Ltd. have been active in conducting research, development, and pilot plant operations since the 1950's. They have spent considerable amounts of money up to this point, with a significant effect upon the Alberta economy.

The approval of the present Application before the Energy Resources Conservation Board of Alberta would have a major economic impact. It would also provide the incentives and inducements required to develop the potential of the bituminous deposits in Northern Alberta in high degree, without disturbing the growth of the conventional crude petroleum industry.

2. TOTAL EXPENDITURES

With approval of the project it is anticpated that detailed engineering and construction would begin in 1972, with the level of expenditure reaching peaks in 1975 and 1976. The estimated expenditure would be about $410 million for the five-year period 1972 - 1976.[19] This estimate allows for potential

(19) See Table B-1 of Appendix B.

increases in prices and costs of the plant facilities in the years ahead. The figures quoted, however, do not include the necessary capital expenditures for the associated utility plant, the synthetic crude and natural gas pipelines to service the project and the townsite facilities. Thus, the total capital outlays for this one project will be in excess of $500,000,000.

The first full year of operation would be 1977. In that year about $80 million would be spent upon plant operations, pipeline transportation from Mildred Lake to Edmonton, and crown royalties.

Beyond 1977 the expenditure on plant operations and construction could be expected to rise in keeping with an upward trend in prices, costs, and incomes. The cost of pipeline transportations would be less subject to potential cost increases, and might be reduced by the construction of large-diameter, high-capacity pipelines. The crown royalty is subject to negotiation with the provincial government.

In this analysis we have concentrated upon the six-year period 1972 - 1977, during which the construction of the project would be completed, and the operating plant would be on stream for one full year (1977).

3. THE GENERAL ECONOMIC EFFECTS OF THE PROJECT

The Syncrude Canada Ltd. project would provide the Alberta economy with an additional export activity. The funds would come chiefly from outside the province, stimulating economic activities in Alberta. The direct employment provided by Syncrude Canada in its own operations and construction would lead to a substantial increase in employment in wholesaling, retailing, manufacturing, transportation, finance, utilities, services, and other industries in Alberta which would grow in order to service the activities of Syncrude Canada. There would also be increases outside Albera, in import industries supplying the province. Here however, we are primarily concerned with the impact upon Alberta.

In general, for each employee of Syncrude Canada Ltd., a number of additional employees are required in the industries servicing Syncrude Canada. These employees require various consumer and government goods and services to provide them with the wide range of goods and services which make up their standard of living. It is estimated (see Section 4 (e)) that the Syncrude project will generate an annual income stream of approximately $110 million in new income when it enters full operation in 1976. If we divide this income total by the estimated average wage or salary of workers in this industry in this time period (see Table B-4) we see that the equivalent of between 9,000 and 9,500 new jobs will be created in the economic expansion generated by the Syncrude project. This income stream will support approximately 23,000 individuals if we include the families of those working.

There are further effects. A project may induce investments in additional facilities of existing industries in the region or in the establishment of new plants and industries. The Syncrude project is likely to stimulate some new manufactures in Alberta from synthetic crude, to encourage new power projects, to require additional pipelines and associated facilities, and to attract new industries to provide and service the required mining machinery. Another factor which augments the expansionary effect is that the remuneration per worker in the Syncrude Canada project is above the average level of remuneration for the whole labour force. Thus the average salary and wage per worker of the 1,100 employees to be engaged in plant operations by 1977 is estimated to be about 50 per cent above the average income per member of the Alberta labour force.[20]

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(20) Included in the labour force are farmers and self-employed businessmen. The average income of full-time employees is higher than the average income of self-employed persons, so that the Syncrude average is somewhat lower in relation to the average income of employees.

4. SPECIFIC ECONOMIC EFFECTS

(a) OPERATIONAL EXPENDITURES

The first prospective full year of operation of the completed plant is 1977. It is estimated that about 1,100 persons would be employed by Syncrude Canada Ltd. in its operations in 1977 and succeeding years. About 1,000 would be employed at the Mildred Lake plant for activities involving mining and materials handling, extraction and froth treatment, upgrading, control laboratory work, maintenance, administration, and management. Approximately 100 would be employed in the Edmonton office and research laboratory of the company.

The disbursements for operations have been analyzed for regional content. The salaries and wages paid out have an immediate regional impact, creating primary income within Alberta. Other items of expenditures, such as overhead items, purchases of materials and supplies, local taxes, insurance, utilities, and natural gas supplies have varying percentages of regional content.

(b) OTHER PRODUCING EXPENDITURES

In addition to the net operating expenditures, there are the outlays for pipeline transportation from Mildred Lake to Edmonton and crown royalties. Table B-2 provides a summary of the estimated regional income that will be reated in Alberta by the operational activities of the Syncrude project combined with the regional effects of the pipeline tariffs and crown royalties. Not included is any allowance for the regional content of interest, profits, and income taxes for the period 1972 - 1977. Some Albertans have invested in the companies concerned so that investment income would accrue to Alberta residents from the project. The Alberta government is sharing increasingly in the revenue collected from income taxes.

(c) CONSTRUCTION EXPENDITURE

The regional content of the construction expenditures have been analyzed, and the estimates are also shown in Table B-2 of Appendix B. The impact of construction upon the Alberta economy could be greatest during the years 1974 - 1976.

(d) THE TOTAL PRIMARY INCOME

The total estimated regional content or primary income created by all estimated expenditures is shown in Table B-2 in Appendix B. The primary income created would average over $40 million per year during the construction period 1972 - 1976. In 1977, the first complete operating year, it is estimated at about $49 million.

(e) TOTAL INCOME GENERATED

The primary income created is subject to a multiple effect which is reduced by import and savings leakages. The multiple for Alberta is estimated conservatively at about 2 1/4.[21]

The primary income data, multiplied by 2 1/4, produce estimates of the personal income generated by the Syncrude Canada project. These are shown in the first column of Table B-4 in Appendix B. The personal income generated in the province by the project during the construction phase would average over $90 million per year during the five-year period 1972 - 1976. The income generated in 1977, mainly from operations, would be about $110 million. This level would rise yearly with increases in wages, salaries, and other costs of operation.

Projections of the population, employed workers, and personal income in Alberta are provided in Table B-3 of Appendix B. The estimated additional income of $110 million generated by the Syncrude

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(21) In the 1950's the estimated import content of expenditures by Albertans was about 40 per cent. The proportion has been declining gradually since that time with the growth of manufacturing and service establishments to supply the growing provincial market. The ratio of savings to income is a little less than one-tenth. With an import ratio of 0.38 and a savings ratio of 0.90, the multiplier is 2.26. (See Table B-4 in Appendix B for a formula.)

project would be about 1 1/4 per cent of the total personal income of the province, and one would expect this proportion to be maintained beyond 1976 for the current proposed project.

(f) ADDITIONAL EMPLOYMENT

Estimates of the prospective additional employment in Alberta induced by the Syncrude project have been made by reference to the ratio of the population to the number of employed workers in Alberta. This ratio declined from 2.72 to 2.51 between 1961 and 1971 with the rapidly-rising proportion of women and young persons in the labour force. Increasingly the economy is becoming one in which there is a growing number of households with more than one employed worker. The ratio of population to employment is projected to decline to 2.43 in Alberta by 1977. On the basis of the trend, the number of additional jobs provided by the Syncrude project in Alberta is estimated at 9,500 for 1977, stabilizing at about 9,000 in subsequent years. This estimate pertains to the average remuneration of the members of the labour force. With a substantial number of persons among the additional workers with above-average earnings, the actual number of jobs added becomes somewhat less than the data in Table B-4 of Appendix B indicate.

(g) ADDITIONAL POPULATION

The prospective additional population growth induced by the Syncrude project is estimated by multiplying the number of average-remuneration jobs shown in Column 2 of Table B-4 in Appendix B by average of ratios of population to employment shown in Column 3, Table B-3, Appendix B for 1972 - 1976 and by the population-employment ratio for 1977. The resulting estimates are shown in Column 3 of Table B-4 of Appendix B. The additional population growth is estimated to average about 22,000 for the period 1972 - 1976. The estimate for 1977 is 23,000. Thus the project implies a permanent increase in the population of the province of about these levels.

F. CONCLUDING REMARKS

The growth of the Alberta economy would be stimulated by the Syncrude Canada project set out in the Application of the four associated companies. The current 1971 proposal would add more than $100 million of annual income in Alberta in 1977 from the operational activities. The ultimate effects can be expected to be several times this figure for several reasons.

First, the project will provide impetus and experience in the development of the Northern Alberta bituminous deposits. Production from the tar sands will undergo expansion and technological advancement following the successful demonstration of the Syncrude project. Second, because of a growing deficit between supply and demand, additional markets will develop which will call for more and larger plants which could produce synthetic crude at declining costs per barrel. It is unlikely that Alberta conventional producers will be able to increase output significantly beyond the mid 70's. Third, regional power projects could be developed, providing a basis for much economic growth in Northern Alberta. Fourth, the production of many new products in association with synthetic crude would expand the manufacturing, construction, wholesaling, and transportation sectors of the Alberta economy. All of these factors and forces, if released to work together, would provide the basis for substantial economic growth in Alberta in the decades ahead.

APPENDIX A

REGIONAL STATISTICS

PETROLEUM INDUSTRY AND ALBERTA

TABLE A-1
PRODUCTION OF LIQUID HYDROCARBONS
ALBERTA AND CANADA
ACTUAL DATA FOR SELECTED YEARS 1950-1970, AND ESTIMATED 1971
IN THOUSANDS OF BARRELS PER DAY

Product and Years	Alberta	Rest of Western Canada	Total Western Canada	Total Canada
CRUDE OIL				
1950	74	3	78	78
1960	358	159	516	519
1970	892	333	1,225	1,228
1971	989	331	1,320	1,323
% of Total In 1970	72.6	27.1	99.7	100.0
SYNTHETIC CRUDE OIL[(a)]				
1967	1	-	1	1
1968	16	-	16	16
1969	28	-	28	28
1970	33	-	33	33
1971	45	-	45	45
GAS LIQUIDS[(b)]				
1950	2	-	2	2
1960	20	6	26	26
1970	206	9	215	215
1971	235	10	245	245
% of Total In 1970	95.9	4.1	100.0	100.0

(a) Production began in 1967 at the average monthly rate of 1,243 barrels.

(b) Condensate, pentanes plus, propane, and butanes.

SOURCE: Canadian Petroleum Association, 1970 Statistical Year Book, pp. 100-106, for 1950 to 1970 data, and Oilweek, October 18, 1971, p. 50, for 1971 estimates.

TABLE A-2
PRODUCTION OF NATURAL GAS AND SULPHUR
ALBERTA AND CANADA
ACTUAL DATA FOR SELECTED YEARS 1950-1970 AND ESTIMATED 1971

Product and Year	Alberta	Rest of Western Canada	Total Western Canada	Total Canada
NATURAL GAS (BILLIONS OF MCF) [a]				
1950	72	1	73	81
1960	411	137	548	565
1970	1,942	419	2,361	2,379
1971				2,700 [b]
% of Total In 1970	81.6	17.6	99.2	100.0
SULPHUR (THOUSANDS OF LONG TONS)				
1952 [c]	8	-	8	8
1960	348	55	404	404
1970	4,182	60	4,242	4,242
1971	6,000 [d]	60 [e]	6,060	6,060
% of Total In 1970	98.6	1.4	100.0	100.0

(a) Raw natural gas production less storage and injection.

(b) Estimated from sales data published by Statistics Canada.

(c) Production began in 1952.

(d) Forecast of Alberta Energy and Resources Conservation Board, Summary of Monthly Statistics.

(e) Estimated.

SOURCE: Canadian Petroleum Association, op. cit., p. 99, for 1950 to 1970 inclusive.

TABLE A-3
GROSS PRODUCTION REVENUE
CRUDE PETROLEUM INDUSTRY
WESTERN CANADA
1947, 1950, AND 1960-1971
IN MILLIONS OF DOLLARS

Year	N.W.T.	B.C.	Alberta	Sask.	Man.	Total Western Canada
1947	0.5	-	20.3	0.6	-	21.4
1950	0.4	-	85.4	1.0	-	86.7
1960	1	11	362	107	11	492
1961	1	14	452	120	10	597
1962	1	30	505	146	10	691
1963	1	39	592	164	9	806
1964	1	39	652	192	11	895
1965	1	47	704	207	12	972
1966	1	58	792	219	13	1,083
1967	1	72	912	219	14	1,217
1968	1	80	1,026	215	16	1,338
1969	1	90	1,131	208	16	1,446
1970	1	94	1,304	208	15	1,622
1971	1	101	1,683	230	16	2,031 (a)
1971						1,955 (b)
Percentages of 1970 Total	0.1	5.8	80.4	12.8	0.9	100.0

(a) Forecast in Oilweek, February 22, 1971, p.58.

(b) Forecast in ibid., October 18, 1971, p. 52.

SOURCE: Canadian Petroleum Association, op. cit., pp. 131-133, for 1947 to 1970 data inclusive.

TABLE A-4
GROSS PRODUCTION REVENUE
CRUDE PETROLEUM INDUSTRY
ALBERTA AND WESTERN CANADA
BY PRODUCTS
ACTUAL 1960 AND 1970 WITH 1971 ESTIMATES
MILLIONS OF DOLLARS

Products	Alberta	Rest of Western Canada	Total Western Canada
CONVENTIONAL CRUDE OIL			
1960	318	116	434
1970	844	276	1,120
1971			1,372
SYNTHETIC CRUDE OIL			
1967 (a)	1	-	1
1970	33	-	33
1971			45
NATURAL GAS LIQUIDS			
1960	9	3	12
1970	156	6	162
1971			193
NATURAL GAS			
1960	31	10	42
1970	244	36	280
1971			325
SULPHUR			
1960	4	1	5
1970	27	0	28
1971			20
TOTAL PRODUCTS			
1960	362	130	492
1970	1,304	318	1,622
1971			1,955

(a) Production began in 1967.

SOURCES: Canadian Petroleum Association, op. cit., pp. 131-133 for 1960 to 1970 inclusive. The 1971 estimates have been made from data in *Oilweek*, October 18, 1971.

TABLE A-5
NET CASH EXPENDITURES
CRUDE PETROLEUM INDUSTRY
WESTERN CANADA
1947, 1951, AND 1960-1971
IN MILLIONS OF DOLLARS

Year	Yukon, N.W.T. and Arctic	B.C.	Alberta	Sask.	Man.	Total Western Canada
						(a)
1947	-	-	28	3	-	31
1951	1	5	214	17	9	246
1960	16	56	480	58	10	620
1961	17	61	544	79	9	710
1962	14	80	496	88	7	686
1963	16	70	553	125	10	773
1964	21	85	622	130	9	866
1965	23	76	714	159	7	978
1966	25	97	738	154	8	1,022
1967	24	124	851	146	8	1,153
1968	45	103	951	140	9	1,248
1969	87	113	1,011	140	9	1,361
1970	126	121	1,023	125	7	1,402
1971 (b)	168	154	1,229	140	9	1,699
1971						1,605

(a) Excludes Hudson Bay and west coast offshore.

(b) Forecast in <u>Oilweek</u>, February 22, 1971, p. 59.

(c) Forecast in <u>ibid.</u>, October 18, 1971, p. 52. A breakdown for the regions is not available on this basis.

SOURCE: Canadian Petroleum Association, <u>op. cit.</u>, pp. 122-127, for 1951 to 1970, and previous editions for 1947.

TABLE A-6
NET CASH EXPENDITURES
CRUDE PETROLEUM INDUSTRY
ALBERTA
1965-1971
IN MILLIONS OF DOLLARS

	Activity	1965	1966	1967	1968	1969	1970	1971
1.	Land Acquisition[(a)]	198	170	167	174	180	107	120
2.	Surveys[(b)]	42	68	100	87	86	82	185
3.	Exploratory Drilling[(c)]	70	76	77	88	90	82	185
4.	Development Drilling[(c)]	99	88	77	74	68	64	75
5.	Production Facilities[(d)]	57	56	76	86	112	90	140
6.	Production Costs[(e)]	67	77	80	96	94	121	170
7.	Natural Gas Plants[(f)]	65	80	135	138	145	231	189
8.	Royalties	79	91	107	126	136	157	200
9.	Others [(g)]	37	32	31	83	100	89	150
10.	Total	714	738	851	951	1,011	1,023	1,229
Operations Total (Nos. 6 + 7 + 8)		211	248	322	360	375	509	559
% of Total		30	34	38	38	37	50	45

(a) Fees, rentals, and land purchases.

(b) Geological and geophysical exploration.

(c) Includes both dry holes and productive oil, gas and condensate wells.

(d) Field equipment, secondary recovery projects, pressure maintenance projects, and other.

(e) Operation of wells, including flow lines and related facilities.

(f) Includes both capital and operational expenditures.

(g) Includes overhead, non-income taxes, interest expenses, and all other expenses.

SOURCE: Canadian Petroleum Association, Statistical Year Book, 1970, p. 125, for 1965 to 1970 included, and forecasts for 1971 from Oilweek, February 22, 1971, p. 59.

TABLE A-7
PRIVATE AND PUBLIC INVESTMENT
CAPITAL AND REPAIR EXPENDITURE
WESTERN CANADA AND CANADA
1950, 1960, AND 1965-1971

Year or Period	B.C. (a)	Alberta	Sask.	Man.	Total Western Canada	Total Canada
MILLIONS OF DOLLARS						
1950	592	521	346	318	1,777	5,453
1960	1,225	1,221	641	658	3,745	11,247
1965	2,181	1,664	973	734	5,552	16,792
1966	2,552	1,944	1,153	860	6,509	19,455
1967	2,717	2,094	1,200	948	6,959	20,022
1968	2,579	2,172	1,193	1,052	6,996	20,473
1969	2,956	2,399	1,012	1,148	7,515	22,190
1970 (b)	2,991	2,465	886	1,148	7,490	23,101
1971 (c)	3,657	2,671	934	1,099	8,361	25,359
RATES OF GROWTH						
1950-1970	405	373	156	261	321	324
1960-1970	144	102	38	74	100	105
1965-1970	37	48	-9	56	35	38
DOLLARS PER CAPITA						
1950	510	571	415	414	484	398
1970	1,368	1,541	941	1,170	1,312	1,081
PER CAPITA INDEXES (Canada = 100)						
1950	128	143	104	104	122	100
1970	127	143	87	108	121	100

(a) Includes Yukon and Northwest Territories.

(b) Preliminary actual.

(c) Revised forecast.

SOURCE: Government of Canada, Department of Trade and Commerce, Private and Public Investment annuals.

TABLE A-8
CENSUS VALUE ADDED
COMMODITY-PRODUCING INDUSTRIES
ALBERTA
SELECTED YEARS, 1945-1969

Year or Period	Agri-culture	Mining, Oil & Gas (a)	Manu-facturing	Con-struc-tion	Electric Power	Other (b)	Total Commodity-Producing Industries
MILLIONS OF DOLLARS							
1945	213	42	79	53	8	9	403
1950	331	123	124	148	14	11	750
1955	332	304	263	339	29	16	1,283
1960	329	349	339	446	49	24	1,536
1965	512	691	475	471	69	9	2,227
1966	659	775	527	558	74	10	2,603
1967	517	898	574	647	78	10	3,725
1968	577	1,020	605	665	85	9	2,961
1969	582	1,109	703	753	94	11	3,252
AVERAGE ANNUAL RATES OF GROWTH, %							
1945-69	4.2	14.5	9.5	11.7	10.8	0.4	9.1
1960-69	6.6	13.7	8.4	6.0	3.5	-5.0	8.7
1965-69	3.3	12.5	10.3	12.4	8.0	5.0	10.0
PER CENT OF TOTAL							
1945	52.9	10.4	19.6	13.2	2.0	2.2	100.0
1965	23.0	31.0	21.3	21.1	3.1	0.4	100.0
1969	17.9	34.1	21.6	23.2	2.9	0.3	100.0

(a) Coal, oil, gas, and other hydrocarbons chiefly.
(b) Forestry, fishing, and trapping.

SOURCE: Statistics Canada, Survey of Production, 1969, Ottawa, October, 1971.

TABLE A-9
TOTAL POPULATION
WESTERN CANADA AND CANADA
CENSUS YEARS AND RECENT YEARS, 1946-1971

Year or Period	Yukon & N.W.T.	B.C.	Alberta	Sask.	Man.	Total Western Canada	Total Canada (a)
THOUSANDS							
1946	24	1,003	803	833	727	3,390	12,617
1951	25	1,165	939	832	776	3,737	14,009
1956	31	1,399	1,123	881	850	4,284	16,081
1961	37	1,629	1,332	925	922	4,845	18,238
1966	43	1,874	1,463	955	963	5,298	20,015
1967	44	1,947	1,490	958	963	5,402	20,405
1968	46	2,007	1,526	960	971	5,510	20,744
1969	47	2,067	1,561	959	979	5,613	21,061
1970	49	2,137	1,600	942	981	5,709	21,377
1971	53	2,196	1,634	928	988	5,799	21,681
RATES OF GROWTH, %							
1946-71	121	119	103	11	36	71	72
1961-71	43	35	23	0	7	20	19
1966-71	23	17	12	-3	3	9	8
PER CENT OF TOTAL CANADA							
1946	0.2	7.9	6.4	6.6	5.8	26.9	100.0
1956	0.2	8.7	7.0	5.5	5.3	26.6	100.0
1966	0.2	9.4	7.3	4.8	4.8	26.5	100.0
1971	0.2	10.1	7.5	4.3	4.6	26.7	100.0

(a) Includes Newfoundland throughout, with estimate for 1946.

SOURCE: Statistics Canada, Population of Canada by Provinces, 1932-1971, Ottawa, September, 1971.

TABLE A-10
EMPLOYMENT INDEXES
INDUSTRIAL COMPOSITE[a]
SELECTED YEARS, 1946 TO DATE

Year or Period	B.C.	Alberta	Sask.	Man.	Total Canada
OLD INDEX, 1949 = 100.0					
1946	83.6	82.6	92.2	89.6	88.2
1951	106.1	112.4	106.0	103.9	109.1
1956	121.5	148.5	121.1	108.6	120.7
1961	112.3	154.2	123.1	110.0	118.1
NEW INDEX, 1961 = 100.0					
1961	100.0	100.0	100.0	100.0	100.0
1966	126.2	120.5	116.5	111.2	120.7
1970	139.3	138.2	113.2	117.7	127.1
CONVERTED INDEX, 1946 = 100.0					
1946	100.0	100.0	100.0	100.0	100.0
1951	126.9	136.1	115.0	116.0	123.7
1956	145.3	179.8	131.3	121.2	136.8
1961	134.3	186.7	133.5	122.8	133.9
1966	169.5	225.0	155.5	136.6	161.6
1970	187.1	258.0	151.1	144.5	170.2

(a) The index excludes agriculture, fishing, trapping, domestic service, public administration, defence, health, and education.

SOURCE: Statistics Canada, Canadian Statistical Review, for the 1949 and 1961 base years.

TABLE A-11
TOTAL PERSONAL INCOME
WESTERN CANADA AND CANADA
CENSUS YEARS AND RECENT YEARS, 1946-1970
IN MILLIONS OF DOLLARS

Year or Period	Yukon & N.W.T.	B.C. (a)	Alberta	Sask.	Man.	Total Western Canada	Total Canada
1946	(b)	949	696	644	602	2,891	9,887 (c)
1951	26	1,602	1,220	1,053	907	4,808	16,159
1956	54	2,400	1,683	1,181	1,168	6,486	22,817
1961	55	3,003	2,141	1,060	1,425	7,684	29,411
1966	72	4,763	3,337	2,057	2,073	12,302	45,702
1967	96	5,244	3,604	2,001	2,318	13,263	50,208
1968	106	5,689	4,056	2,300	2,581	14,732	55,213
1969	122	6,449	4,555	2,414	2,783	16,323	61,398
1970	128	7,037	4,919	2,252	2,939	17,275	66,100
RATES OF GROWTH, %							
1964-70	n.a.	642	607	219	388	498	569 (d)
1961-70	133	134	130	112	106	125	125
1966-70	78	48	47	9	42	40	45

(a) Includes Yukon and N.W.T. for 1946.
(b) Included in British Columbia.
(c) Excludes Newfoundland.
(d) Excludes Newfoundland in calculation.

SOURCE: Statistics Canada, National Income and Expenditure Accounts, new series.

TABLE A-12
OIL AND NATURAL GAS REVENUE[a]
AND TOTAL REVENUE
GOVERNMENT OF THE PROVINCE OF ALBERTA
FISCAL YEARS 1950-51 TO DATE
IN MILLIONS OF DOLLARS

Fiscal Year	Fees & Rentals	Crown Reserve Sales	Royalties	Total Oil and Gas Revenue	Total Revenue of Provincial Government (b)	Oil & Gas Revenue, % of Provincial Government Revenue
1950-51	10	29	5	44	123	36
1951-52	16	13	11	40	122	33
1952-53	20	24	13	57	158	36
1953-54	25	53	19	97	204	48
1954-55	21	40	20	81	198	41
1955-56	22	76	29	127	248	51
1956-57	26	69	37	132	267	49
1957-58	31	59	33	123	277	44
1958-59	30	54	26	109	306	36
1959-60	33	81	27	142	343	41
1960-61	31	44	28	103	327	31
1961-62	33	44	39	116	358	32
1962-63	39	30	51	120	403	30
1963-64	39	53	57	148	443	33
1964-65	48	92	62	202	507	40
1965-66	57	121	69	247	594	42
1966-67	52	106	80	239	635	38
1967-68	54	70	94	218	748	29
1968-69	56	121	105	282	927	30
1969-70	61	70	121	252	953	26
1970-71	58	27	144	229	1,022	22
1971-72	58	41	170	269	1,041	26

(a) Excludes mining, and oil sands revenue, which is set out in Table A-13.

(b) Includes both income and capital account.

SOURCES: Province of Alberta, Public Accounts, 1950-51 to 1970-71 and Estimates, 1971-72.

TABLE A-13
MINING REVENUE
GOVERNMENT OF THE PROVINCE OF ALBERTA
FISCAL YEARS 1960-61 TO DATE

Fiscal Year	Oil Sands (a)	Coal (a)	Mineral Taxation Act (b)	Other (c)	Total Mining Revenue	% of Provincial Government Revenue
	MILLIONS		OF DOLLARS			%
1960-61	0.7	0.1	1.3	0.3	2.4	0.7
1961-62	0.9	0.2	1.3	0.3	2.7	0.8
1962-63	0.8	0.2	1.7	0.3	3.1	0.8
1963-64	0.8	0.2	1.9	0.3	3.3	0.7
1964-65	1.1	0.2	1.9	0.3	3.6	0.7
1965-66	0.9	0.3	1.9	0.4	3.4	0.6
1966-67	0.9	0.3	1.9	0.4	3.5	0.6
1967-68	1.0	0.4	1.9	0.4	3.8	0.5
1968-69	2.3	0.6	2.4	0.4	5.8	0.6
1969-70	3.1	0.7	2.4	0.4	6.7	0.7
1970-71	2.4	1.6	2.6	0.4	7.0	0.7
1971-72	3.0	1.4	2.5	0.4	7.3	0.7

(a) Fees, rentals, and royalties.

(b) Non-producing area tax, producing area tax, and certificate fees.

(c) Fees, rentals and royalties from salt, quarrying, quartz, and miscellaneous, and Pipe Line Act Revenue, administration sundry revenue, and landsman licence fees.

SOURCES: The same as for Table A-12.

APPENDIX B

REGIONAL IMPACT

OF

SYNCRUDE CANADA LTD. PROPOSAL

TABLE B-1
ESTIMATED NET CASH EXPENDITURES
SYNCRUDE CANADA LTD.
1971 PROJECT PROPOSAL
1972-1976 AND 1977
IN MILLIONS OF DOLLARS

Year or Years	Construction (a)	Production (b)	Total
1972-1976 (c)	410	10	420
1977 (d)	1	80	81

(a) Does not include cost of associated power plant, synthetic crude and natural gas pipelines servicing the project, and townsite facilities.

(b) Includes plant operations, pipeline tariffs, and crown royalties.

(c) Construction expenditures for the five-year period, peaking in 1975, and falling to replacement level in 1977. The production expenditures would be concentrated in the year 1976. The data have been adjusted for price level and cost increases.

(d) Adjusted for price level and cost increases projected for 1977. The expenditures in subsequent years would rise with the price level.

SOURCE: Syncrude Canada Ltd.

TABLE B-2
ESTIMATED PRIMARY REGIONAL INCOME IN ALBERTA
CREATED BY PROPOSED SYNCRUDE CANADA LTD. PROJECT
FROM CONSTRUCTION AND PRODUCTION ACTIVITIES
1972-1976 AND 1977
IN MILLIONS OF CURRENT DOLLARS

	Construction			
Year or Years	Salaries and Wages	Other	Production	Total
	(a)	(b)	(c)	
1972-1976	105	92	6	203
1977	1	0	48	49

(a) From data of Syncrude Canada Ltd.

(b) Estimated at 30 per cent of non-wage expenditures of $305 million, consisting of contractors' margins, other remuneration, wholesaling, and other margins.

(c) Estimated at 60 per cent of total operational expenditures shown in Table B-1.

TABLE B-3
POPULATION, EMPLOYED WORKERS, AND PERSONAL INCOME
ALBERTA
ACTUAL 1961 AND 1966, ESTIMATED 1971, AND PROJECTED 1972-1977

Year	Population in Thousands	Civilian Employed Workers in Thousands	Ratio of Population to Employed Workers	Personal Income per Employed Worker	Total Personal Income in Millions of $
	(a)	(b)		$ (c)	
1961	1,332	490	2.72	4,369	2,141
1966	1,463	549	2.66	6,078	3,337
1971	1,634	652	2.51	8,167	5,325
1972	1,667	668	2.50	8,657	5,783
1973	1,700	685	2.48	9,176	6,286
1974	1,734	702	2.47	9,727	6,828
1975	1,769	720	2.46	10,311	7,424
1976	1,804	738	2.44	10,930	8,066
1977	1,840	756	2.43	11,586	8,760

(a) Data from Table A-9 for 1961, 1966, and 1971, and projected to increase at an average annual rate of 2.0 per cent per year 1972-1977, approximately the average rate of growth for 1961-71. The figures are for June of each year.

(b) Data for 1961, 1966, and 1971 from DBS, Census of Canada, and Special Surveys Division, and projected to increase at an average annual rate of 2.5 per cent per year 1972-1977, somewhat below the rate for 1961-1971. The figures are for June of each year.

(c) Data for 1961 and 1966 are derived from Table A-11. The figure for 1971 is an estimate. The data for 1972-1977 are projected on the basis of an average annual rate of growth of 6 per cent, somewhat below the average rate for 1961-1971.

TABLE B-4
POTENTIAL PROJECTED INCOME, EMPLOYMENT, AND POPULATION
GENERATED BY PROSPECTIVE PROJECT OF
SYNCRUDE CANADA LTD.
ANNUAL AVERAGE, 1972-1976 AND 1977

Year	Additional Income Generated In Millions Of $	Additional Employment In Thousands	Addional Population In Thousands
	(a)	(b)	(c)
Construction Phase, Five-Year Period, 1972-1976, Annual Average	91	9	22
First Full Year Of Operation 1977	110	9.5	23

(a) Calculated from total income created, as shown in Table B-2, multiplied by 2.25. The regional multiplier is derived from the import and savings ratios of the Alberta economy. It may be expressed as follows, where M is the import ratio, S is the savings ratio, and R is the regional multiplier:

$$R = \frac{1}{1 - (1-M)\ (1-S)}$$

(b) Income generated as shown in Column 1, divided by the average personal income per worker for the period 1972-1976, as shown in Column 4 of Table B-3.

(c) Employment added, as shown in Column 2, multiplied by the average population-employment ratios for 1972-1976, as shown in Column 3 of Table B-3.

S E C T I O N 1.

ECONOMIC AND SOCIAL IMPACT OF THE SYNCRUDE PROJECT

C. COMMUNITY IMPACT - FORT MCMURRAY

February, 1973

REPORT ON THE IMPACT OF A PROPOSED SYNTHETIC OIL PROJECT ON FORT McMURRAY

CONTENTS

cont'd-----

PART II

COMMUNITY IMPACT OF THE PROPOSED SYNCRUDE PROJECT

PART III

FORECASTED ADDITIONAL TAR SANDS DEVELOPMENTS AND THEIR POSSIBLE IMPACT ON FORT McMURRAY 1976 - 1981

LIST OF TABLES

cont'd-----

LIST OF TABLES - continued

PART III

LIST OF CHARTS

PREAMBLE

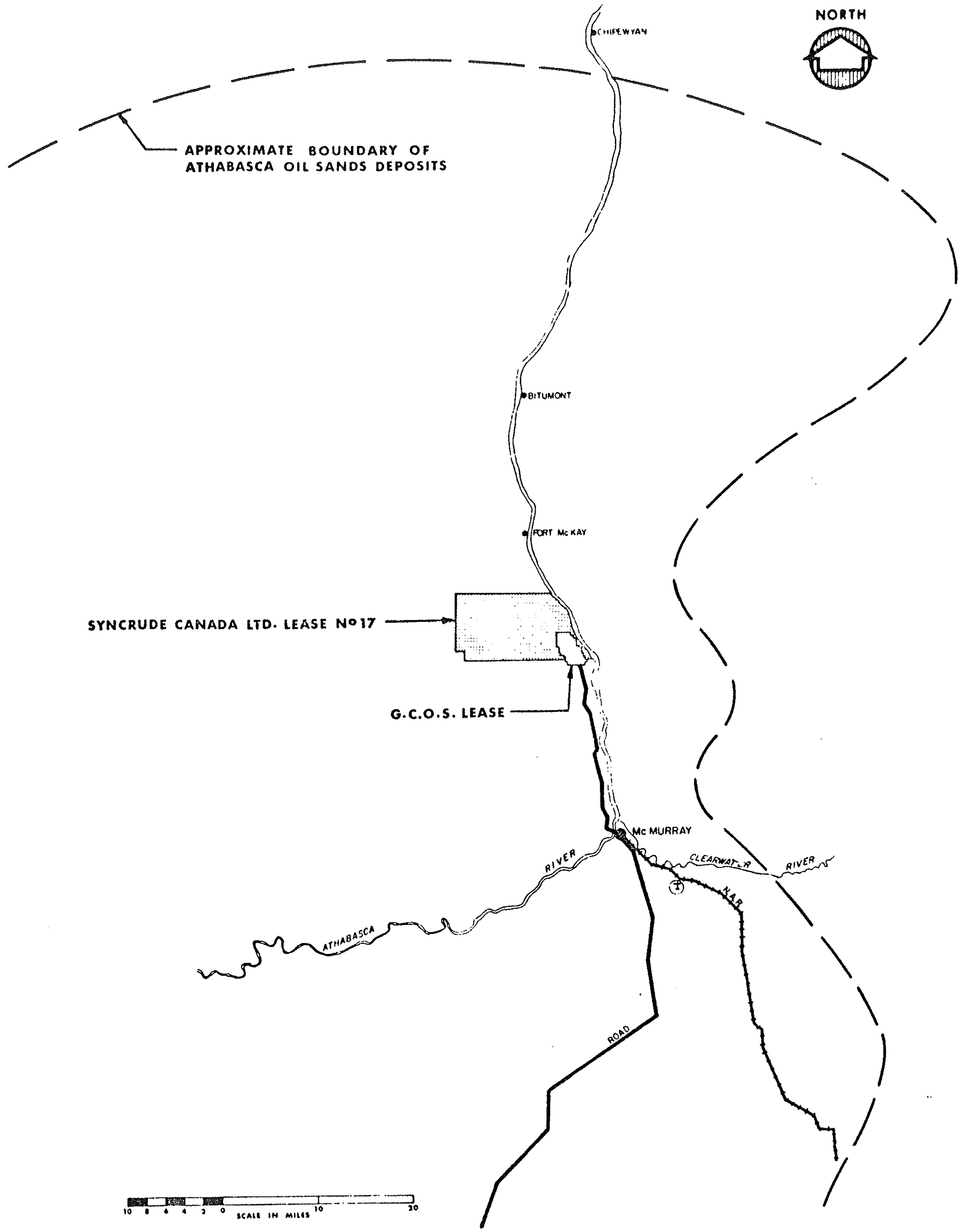
Syncrude Canada Ltd. is currently reviewing the practicability of proceeding with a synthetic crude oil production project. As part of this analysis, the company deemed it desirable to assess the potential impact of this project on the community of Fort McMurray including the demands to be placed on the Town for expansion of facilities.

Syncrude commissioned the authors of this report to examine the current status of Fort McMurray and its facilities, the impact of the work force during construction, and the requirements for the operational work force once construction is complete. The authors were also asked to examine other projects which may have an impact on Fort McMurray during the period under study - 1973-1981.

The terms of reference of the Study have included development of population forecasts and identification of the facilities to serve these populations. Particular attention has been directed, as well, to the specific situation that has developed in Fort McMurray with the advent of the Great Canadian Oil Sands Ltd. plant.

In proceeding with this Study, particular attention has been given to sources of existing data, such as the General Plan for Fort McMurray prepared by the Department of Municipal Affairs, and to data derived directly from businesses, particularly from Great Canadian Oil Sands Ltd. Great Canadian Oil Sands Ltd. can be regarded as a living laboratory of community impact. Special examination has been made, wherever possible, of current physical, social and economic factors to identify the unique characteristics of the community, and to make forecasts on the basis of this knowledge rather than to use 'standard' numerical indices. Identification of these characteristics was derived, not only from data analysis, but also from a number of lengthy interviews with knowledgeable and reputable sources in Fort McMurray and elsewhere in the Province.

This three part report deals with:- (I) the current status of Fort McMurray and its facilities; (II) forecasts to 1979 of the impact on Fort McMurray of the synthetic crude oil project at Mildred Lake, now under consideration by Syncrude Canada Ltd; (III) forecasts to 1986 of the impact on Fort McMurray of three additional possible synthetic crude oil projects, located within a 45 mile radius of Fort McMurray and which may proceed into construction by 1981.



LOCATION MAP

SUMMARY OF FINDINGS

PART ONE

The present Town of approximately 7,000 persons and occupying a developed area of about 880 acres, exhibits many of the symptoms of a growing isolated resource oriented community. These include a much higher than normal number of residents living in multiple or mobile home accommodation and expressing some unhappiness at the shortage of single family type homes, a particular shortage of certain public facilities such as school classrooms, and an imminent likelihood that the currently available and developable land supply will be exhausted.

PART TWO

Should the Syncrude project proceed, it is forecast that, by 1979, the population could grow to 15,500 and the developed area of the Town to 3,160 acres. The young age character of the population will require the provision of significant increases in educational facilities that will be needed on a long term and sustained basis. All elements of the infrastructure, in fact, will undergo rapid and extensive expansion with large areas and amounts of single family and lower density residential development being required to achieve a more acceptable housing mix. The growth of the community at the forecasted rate and magnitude creates an immediate need for planning and action by public agencies and the private sector.

PART THREE

Should other companies (possibly three in number) also decide to construct synthetic crude oil plants in the next eight years, the population of Fort McMurray could be forecasted to achieve the 30,000 range in about 1986 with its developed land area rising to between 4,500 and 5,500 acres.

NOTE: This summary is generalized in nature and should not be taken out of context from the various factors and considerations discussed in the body of this report.

FORT McMURRAY IMPACT STUDY

PART I

EXISTING CONDITIONS AT FORT McMURRAY

FORT McMURRAY IMPACT STUDY
PART I
EXISTING CONDITIONS AT FORT McMURRAY

Fort McMurray is a community of approximately 7,000 people located in the Athabasca River Valley at the junction of the Clearwater River some 240 miles north of Edmonton.

1.1 HISTORICAL

Indications of Fort McMurray becoming a major northern centre existed before the Tar Sands development. Historically, the Town had functioned as a lumbering centre and was important as a transportation break point for freight heading north into the MacKenzie River system. As the north terminus for the Northern Alberta Railway and the south terminus for MacKenzie barge traffic, Fort McMurray had promise of growth as long as goods were shipped on this route. The building of the Great Slave Lake Railway to Hay River and increasing air freight to the north, however, marked the beginning of new transportation routes to the north and a decline in Fort McMurray's importance on the northern transportation route.

The community had little new impetus to grow until the semi-dormant interests in the Athabasca Tar Sands were revived and Great Canadian Oil Sands Ltd. made initial inroads to tar sand exploration. With this renewed interest came the prospect of new growth for Fort McMurray.

The magnitude of the proposed Great Canadian Oil Sands Ltd. development was fully realized in 1963, when the construction phase began. The influx of workers into a town of 1,200 was a staggering experience. The promise that a majority of those men would soon be replaced by plant operating personnel and their families who would

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want to live in town and not in site camps, was even harder to comprehend.

A town which had all its facilities geared to the needs of 1,200 residents would find extremely difficult, the provision of facilities for 5,000 residents in a short four year span. To assist in handling the impact of this growth, the Town administrative system was altered with the original Town Council being replaced by a New Town Board style of administration.

The New Town status gave Fort McMurray an increased ability to cope with its new problems by permitting it to borrow capital funds for land development and servicing in advance of having the population and assessment base required of ordinary municipalities. It also permitted direct inputs and assistance by municipal government experts from the Provincial Government staff in the directing of local development.

Fort McMurray had realized early in development considerations that the servicing of a town growing to four times its present size in a quick four years would be extremely difficult given the usual resources available to a town of Fort McMurray's size. The Alberta Provincial Government, which had seen these problems arise before, had provided legislation in the form of the New Towns Act in 1956. The New Towns legislation allowed a town to take out improvement debentures far in excess of what would normally be allowed a town of that size. The Town Council of Fort McMurray, realizing its constraints, applied to the Province on November 16, 1962, for New Town status.

After a period of public hearings and technical studies, Fort McMurray became the "New Town of Fort McMurray" on June 30, 1964. The Town, in the process, had exchanged its Town Council for a New Town Board of Administrators consisting of two government officials and one appointed town member. The composition of the Board of Administrators was quick to change, with first an increased Town representation, then

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public election replacing the appointment procedure, and finally, the government representatives being replaced by Town elected members. The present Board of Administrators now consists of six members and one Chairman, all of whom are elected. The Town, using its increased borrowing powers, has managed to accommodate seven times the population it had at the outset of the Great Canadian Oil Sands Ltd. tar sands development.

1.2 POPULATION

Prior to the tar sands development, Fort McMurray's populace of 1,200 was employed mainly in lumbering or transportation activities, reflecting the Town's main functions as a resource extraction centre and as a transfer point for northbound freight. In present day Fort McMurray, the employment has changed drastically, with the Great Canadian Oil Sands Ltd. project employing more than 1,300 people at that plant site alone.

The workers attracted to Fort McMurray by the tar sands development have, for the large part, been young marrieds. This is especially true with the operational staff where permanency is more likely than with the short term construction crews. Seventy nine percent of the 1971 Town population was under 35 years of age and sixty four percent of these were in the 0 - 19 age group, indicating a large number of young families in Town. The typical family unit in Fort McMurray is a young married couple with an average of 2.03 children.*

As the Town matures and the population proceeds through its aging pyramid, the present disproportion between young and old age groups will decrease, leaving a more balanced populace. In the interim, however, Fort McMurray will have to accommodate relatively higher proportions of young people than would be expected in a more mature town.

*Data from 1971 Census Information.

cont'd----

This youth orientation will be reflected in most Town facilities, as indeed, it is now in the school system where the Fort McMurray school boards must accommodate almost 100 more children per thousand population than are found in Edmonton and Peace River. This youth factor in Fort McMurray is prevalent throughout the Town with most facilities orienting on the young family needs.

1.3 HOUSING

Coincidental with the recent rapid increase in Town population is a relatively sound stock of housing units. Of 2,048 dwelling units in Town in 1972, 1,653 are considered in good to excellent condition, while the remaining 395 are considered substandard.* It is interesting to note that the majority of the substandard housing is pre-1960 housing which pre-dates the recent Town expansions.

The average 1971 household size in Fort McMurray of 3.87 people per dwelling unit, reflects the high proportion of families in the Town and indicates a strong demand for family oriented housing.** The existing housing stock in Fort McMurray, shown in Table No. 1-1, indicates a responsiveness to the family group and respects the autonomy of the family unit through the single family residence.

TABLE NO. 1-1
1972 HOUSING COMPOSITION

TYPE OF HOUSING	NUMBER OF UNITS	PERCENTAGE OF TOTAL
Single Family	1,031	50.3%
Two Family	146	7.2%
Apartment	281	13.7%
Trailer and Mobile Home	590	28.8%
TOTAL	2,098	100.0%

*Information from the General Plan and a recent survey by ACT.

**Figures based on November 30, 1972 housing stock count conducted by AGT.

cont'd----

The large number of mobile home units should not necessarily be interpreted as an indication that temporary residences are preferred. Instead, it would be more appropriate, in the Fort McMurray situation, to see the mobile units in the role of the best temporary alternative to a single family residence. This situation has arisen because the housing supply has not kept pace with the rapidly expanding demand for single family housing in Fort McMurray.

Local development and real estate operators are tuned to the wishes of the people; they feel that if given the choice between their present mobile home and a permanent single family structure, all but a few families would accept the additional cost and move to the single family house.* With a relative vacancy rate in Town of zero, the chances to exercise this choice are limited, and many people have opted for the next best single family residence in Town. Cost of the housing unit would not seem to be a major concern in this choice as many of the trailers are in the $10,000 to $15,000 price range, while a typical house will sell for $12,000 more.**

Although there are no apartment vacancies in Town, this is probably a result of the tight housing market and not purely a reflection of personal choice of apartment style living. Typical apartment rents, as shown in Table No. 1-3, are not likely to make apartment living a particularly cheaper alternative to owning a home. As well, the family orientation of the Town will, at least in the immediate future, desire family style accommodation.

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* Based on Great Canadian Oil Sands Ltd. figures which indicated that a majority of Great Canadian Oil Sands Ltd. employees presently in other types of housing are applying for single family dwellings.

** Central Mortgage and Housing Corporation figures for 1971-72 indicated that the average price for a single family dwelling in Fort McMurray was in the $27,000 range.

cont'd----

Typical monthly payments which face homeowners in Fort McMurray are provided in Table No. 1-2 . The average single family dwelling price of $27,000 would require a monthly payment of $270 to pay principal, interest and tax charges. Great Canadian Oil Sands Ltd. employees benefit slightly -- lower monthly payment -- as a result of special mortgaging arrangements for their homes.

TABLE NO. 1-2

TYPICAL MONTHLY PAYMENTS ON SINGLE FAMILY DWELLINGS

	COST IN DOLLARS		
House Value	20,000	25,000	30,000
Insurance Loan	19,000	23,750	28,500
Mortgage Insurance Fee	190	237	285
Total Loan	19,190	23,987	28,785
Down Payment	810	1,012	1,215
Monthly Principal & Interest @ 9¼% over 25 years	162	203	243
Monthly Taxes (Based on $5,000 lot with 50 ft. frontage)	36	45	56
Total Monthly Payment Including Taxes	198	248	299
Total Monthly Payment if Great Canadian Oil Sands Ltd. Employee	190	237	286

SOURCE: Central Mortgage and Housing Corporation.

TABLE NO. 1-3

SAMPLE APARTMENT RENTS

	Bachelor	1 Bedroom	2 Bedroom	3 Bedroom
Unfurnished	$145	$180	$210	$240
Furnished	$165	$200	$225	

cont'd----

The number of building permits issued in Fort McMurray in 1972, (Table No. 1-4), showing 120 apartments and 160 single family units, would indicate a growing emphasis on apartment construction. Rather than reflecting this as a general trend or preference in apartment style living, these figures should be considered instead, as a response to both the heavy demand for dwelling units in Town as well as a shortage in available land within the existing Town site.

TABLE NO. 1-4

RESIDENTIAL BUILDING PERMIT ISSUES TO DECEMBER, 1972

TYPE OF UNIT	NUMBER OF UNITS
Single Family	160
Duplex	32
Apartment	120

This table was compiled from a list of building permits issued by the Town of Fort McMurray and does not include some units which are planned and waiting to obtain building permits.

1.4 DEVELOPABLE LAND

Developable land is defined, for the purpose of this section of the Study, as the usable land available after deducting those portions which, due to topographic, soil, access utility servicing or other characteristics, currently display no potential for practical or economical utilization for any urban community purpose other than natural park.

The present corporate area of Fort McMurray is 2,739 acres of which about 1,100 acres are developed for urban purposes. Of the balance, there is about 300 acres in and around the currently built-up area which is available for development. Of this amount, approximately 100 acres could be used for residential purposes, following the 3 zoning recommendations of the General Plan. Additionally, about 220 acres are available and developable on the plateau which is in the southwest part of the townsite.* Using a population development density of 14 persons per acre, which density reflects a single family housing philosophy towards residential accommodation, the 320 acres could accommodate about 4,500 persons, over and above the present population of approximately 7,000. This would indicate a total capacity of 11,500 persons within that part of the present municipal area which lies east of the Athabasca River.

The present area of the Town of Fort McMurray also includes about 680 acres of land on the west side of the Athabasca River.** Population capacity estimates prepared to date by the Department of Municipal Affairs in the General Plan prepared for the Town, have not suggested what this latter area could contain. If this area is considered, even though it is not yet serviced, it would increase the potential of the corporate land area to accommodate a population considerably in excess of 11,500 persons.

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* Described as Area 1 in the report prepared by Stanley & Associates Engineering Ltd., November, 1971.

** This land is in the same general area as that which is designated as Area 5 in the report prepared by Stanley & Associates Engineering Ltd., November, 1971.

cont'd----

A number of possible developable areas were analyzed by Stanley & Associates Engineering Ltd. in a report released in November, 1971. Those potential growth areas, shown on the following map, were compared on the basis of developable area (net) and the population capacity each site could accommodate, if placed in residential use at 14 persons per acre. The resulting figures are summarized in Table No. 1-5, to provide an indicator of potentially developable land within and adjacent to the present corporate limits.

TABLE NO. 1-5

POSSIBLE ADDITIONAL DEVELOPABLE AREAS

ACREAGES AND POPULATION CAPACITIES

(Refer to map for location of numbered areas)

AREAS	NET ACREAGE	POPULATION
1	220 acres	3,080
2	120 acres	1,680
3	1,400 acres	19,600
4	650 acres	5,300
4A	380 acres	9,100
5	830 acres	11,600
5A	800 acres	
6	800 acres	11,200

SOURCE: Stanley & Associates Engineering Ltd. report November, 1971

It should be noted that a number of further considerations such as drainage, access, servicing and location were also considered by Stanley & Associates Engineering Ltd., each area having specific characteristics which enhanced or retarded its potential. As yet, no final selection has been made as to which areas will be first to be developed, but the choice will necessarily be made in the near future.

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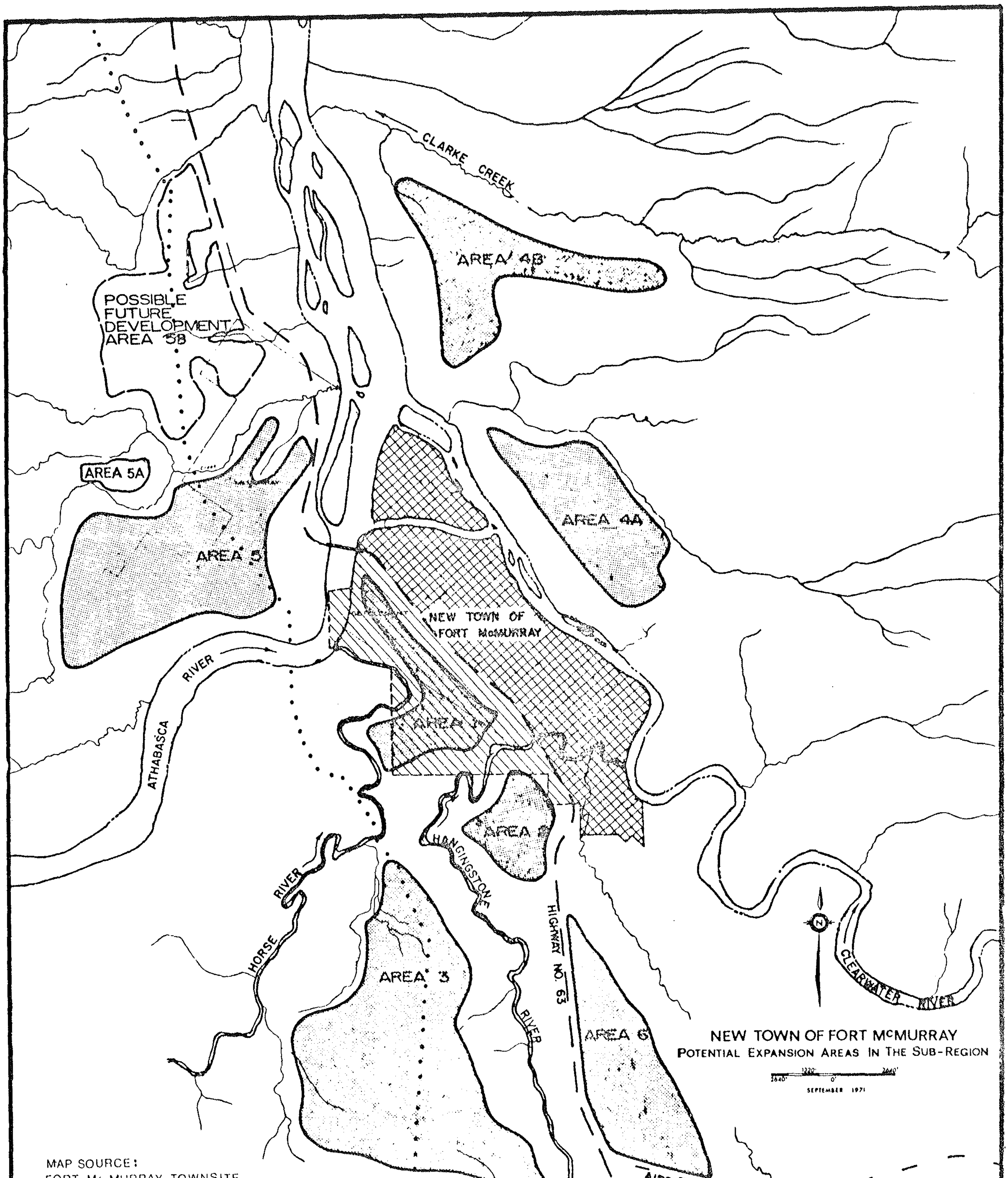

CLARKE CREEK
AREA 4B
POSSIBLE FUTURE DEVELOPMENT AREA 5B
AREA 5A
AREA 4A
AREA 5
NEW TOWN OF FORT McMURRAY
ATHABASCA RIVER
HANGINGSTONE RIVER
HORSE RIVER
HIGHWAY NO. 63
AREA 3
AREA 6
CLEARWATER RIVER
N
AIRPORT ROAD
NEW TOWN OF FORT McMURRAY
POTENTIAL EXPANSION AREAS IN THE SUB-REGION
SEPTEMBER 1971
MAP SOURCE:
FORT Mc MURRAY TOWNSITE
DEVELOPMENT STUDY
NOVEMBER 1971
STANLEY ASSOC. ENG. LTD.

At the present time, there are only 100 acres or less of physically suitable land that is proposed (in the General Plan) for residential development, and which, subject to the owners' wishes, is immediately available for use. Further residential development and accommodation for additional population beyond about 1,400 more people would appear to involve a major decision to 'open up' a new development sector of the Town.

1.5 EXISTING MUNICIPAL UTILITIES

The Town of Fort McMurray owns and operates the waterworks and sewerage systems:- the capacity and expandibility of which are discussed in the report "Townsite Development Study" prepared for the Town in November, 1971, by Stanley & Associates Engineering Ltd., from which the following material is extracted.

1.5.1 Water Consumption

Design based on:-

- Average demand: 80 Imperial gallons per capita per day.

- Maximum daily demand for sizing of supply and treatment facilities: 160 Imperial gallons per capita per day.

- Storage needs based on Canadian Underwriters Association's requirements for fire flows and duration, distribution equalization and an allowance for emergency storage.

The 1971 report states that "the water supply system as constructed in 1966 and 1967, consists of a river intake on the Athabasca River Bridge, a supply line to a raw water storage reservoir in the Townsite, and a water treatment plant adjacent to the raw water storage reservoir. Both the intake and plant capacities can be increased by expansion of the existing facilities, although not sufficient to meet the demand of the fully developed townsite area at its population expectation of 11,800." (The 11,800 population expectation was prepared by the Provincial Planning Branch of the Department of Municipal Affairs.)

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1.5.2 Sewage Flows

Design based on:

- Average daily: 80 Imperial gallons per capita, and using the Harmon formula for peaking factors.

The 1971 report states that "the existing sewage collection and treatment facilities were designed to serve a project population of 10,500 in the valley and 2,500 outside of the valley or a design population of 13,000. These facilities include a sewage lagoon, a sewage force main, a sewage pumping station and an outfall sewer from Franklin Avenue at Hospital Street to the pumping station. The sewage lagoon can be modified further by creating additional cells and installing aeration equipment to handle increased sewage flows."

Table No. 1-6 shows the flow capacities of the existing waterworks and sewerage facilities, as given in the 1971 report. Population capacities have been added to the table using the design criteria established by the Provincial Department of the Environment.

TABLE NO. 1-6

CAPACITIES OF EXISTING WATERWORKS AND SEWERAGE FACILITIES

ITEM	EXISTING	EXISTING POPULATION CAPACITY	MAXIMUM EXPANSION	MAXIMUM POPULATION CAPACITY
Waterworks - maximum daily (Imp. gpm)				
Water Intake *	600	5,400	900	8,100
Water Supply Line	1,500	13,500	1,500	13,500
Water Treatment Plant*	600	5,400	1,200	10,800
Sewage Collections - peak flows (Imp. gpm)				
Outfall Sewer	2,250	13,500	2,250	13,500
Sewage Lift Station	2,500	15,000	3,600	21,600
Sewage Force Main	3,600	21,600	3,600	21,600
Sewage Treatment - average daily (Imp. gpm)				
Sewage Lagoon**	820	14,800	1,640	29,600

* & ** See footnotes on following page.

cont'd-----

* Expansion reported as underway 1971-73 to capacity 10,000 persons.

** Reportedly not practical to use existing lagoons for sewage collection from possible additional development Area 5 because of the problems associated with crossing the Athabasca River (see map).

1.6 COMMERCIAL FACILITIES

A comparison of Fort McMurray to other similar towns in Alberta (see Table No.1-7) indicates that the Town has a relatively low land utilization for commercial uses. Alberta towns of similar population, average 0.60 commercial acres (gross)/100 population as compared to 0.24 commercial acres (gross)/100 population in Fort McMurray. Towns of similar function show even greater variance with an average 0.97 commercial acres (gross)/100 population, which is more than four times the land utilization in Fort McMurray. The overall average for Alberta is 0.82 commercial acres (gross)/100 population.

TABLE NO. 1-7

COMPARISON OF COMMERCIAL LAND UTILIZATION

(Selected Alberta Communities)

(Gross Acreages)

(SOURCE: Urban Land Analysis - Selected Alberta Communities)

TOWN	ACRES	NO. OF COMMERCIAL ACRES/100 PEOPLE	PERCENT OF NET DEVELOPED LAND
Drayton Valley	25.09	0.08	5.25
High Level	27.80	1.34	2.86
Slave Lake	15.21	0.93	4.50
Whitecourt	52.83	2.06	4.28
Hinton	49.23	1.10	3.12
Fort McMurray	13.98	0.24	1.29
5,000 - 9,999	---	0.60	--
Resource oriented	---	0.97	--

Fort McMurray's seemingly low utilization of land for commercial purpose is, in part, attributable to the lack of a significant hinterland

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population around the Town. Most towns provide a commercial function for rural communities which can often be as large a market as the in-town population.

Fort McMurray services an extremely low rural population and requires less commercial land than would normally be expected.

Generally, the 32.4 acres of commercial land in Town is located adjacent to Franklin Avenue. There is a difficulty in defining the limits of the downtown core area, however, as the 'Main Street' core area of government offices and stores is located within a block of the Peter Pond Shopping Plaza. There is no clear separation of servicing here and it is necessary to visit both areas to satisfy the shopping experience.

The commercial building stock in Fort McMurray is in fair to good shape, with much of it being of recent construction. The business community would appear to have a healthy interest in Fort McMurray as evidenced by the many renovations, additions, and increased facilities which have been the trend in the past years. Over one million dollars of building permits have been issued in the past year for commercial buildings alone.

Table 1-8 reveals that on a per capita basis, the retail sales in Fort McMurray, when compared to similar towns, show the same low figures as were seen in the land utilization comparison. In the usual town-market situation, the local rural population spends money in Town but does not show up in the Town population figure. This can result in very high per capita spending figures for some towns with large rural markets and very low per capita spending figures for towns such as Fort McMurray which have a very contained in-town market.

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TABLE NO. 1-8

COMPARISON OF PER CAPITA SALES

COMMUNITY	POPULATION (1969)	GROSS RETAIL SALE (1969)	PER CAPITA SALES
Drayton Valley	3,326	7,330,840	2,204
High Level	2,077	4,137,747	1,992
Swan Hills	1,186	1,697,352	1,389
Whitecourt	2,852	4,731,440	1,659
Hinton	4,461	6,010,454	1,347
Fort McMurray	5,993	6,414,377	1,096

Source: Alberta Bureau of Statistics

The lack of a rural market makes Fort McMurray difficult to compare to other Alberta centres as it will almost invariably show up on the low end of the scale. Generally, the best indicator of the state of Fort McMurray's commercial enterprises would be the confidence that Fort McMurray businessmen have shown in the community through their spending in new construction and improvements.

1.7 EDUCATION

There are basically three bodies concerned with providing education services in Fort McMurray.

1. Fort McMurray Roman Catholic Separate School District No. 32, which this year, 1972-73, has an enrollment of 848 students; 539 in grades 1 to 5 at the J. A. Turcotte School and another 309 in grades 6 to 9 at the St. John's School.

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2. Fort McMurray Public School District No. 2833, which has a 1972-73 enrollment of 1,537; 901 in grades 1 to 6 at the Dr. K. A. Clark School, and a combined separate and public enrollment of 636 in grades 7 to 12 at the Peter Pond School.

3. The Alberta Vocational Centre, this year, is providing job oriented training courses for 260 people of all age groups as well as academic upgrading.

1.7.1 Facilities

The Alberta Vocational Centre is the only facility which has its short term needs satisfied. Although future requirement could see a need for a 100 acre campus site in addition to the 320 acre field site, the present 9.1 acres in Town plus an out-of-town field work site of 320 acres, provides for the immediate needs of the centre.

AVC, as it is commonly referred to, has, as is seen in Table No. 1-9, attempted to orient its program to providing job training which reflects the local job market. Heavy equipment operation and driving are the two most popular courses, with other construction and maintenance courses being the next most popular. Courses in cooking and clerking are also offered, with additional courses being started as interest appears in the particular skill. AVC seems to be of particular interest to the native people in the area, who, due to many circumstances, failed to obtain a level of formal education which is considered a necessary prerequisite for employment. The future of AVC is somewhat unpredictable as yet and will depend on the future development and employment needs at the Athabasca Tar Sands.

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TABLE NO. 1-9

ALBERTA VOCATIONAL CENTRE COURSE OUTLINE - 1972

COURSE	NUMBER OF SESSIONS
Heavy Equipment Operating	7 sessions
Backhoe Operating	3 sessions
Career Driving	5 sessions
Journeyman Upgrading for Carpenters	1 session
Retail Clerking	2 sessions
Academic Upgrading	3 sessions
Domestic Help	2 sessions
Automotives	2 sessions
Pipe Trades	2 sessions
Welding	2 sessions
Building Construction	2 sessions
Commercial Cooking	2 sessions
Cooking Upgrading	1 session
Business Education	2 sessions

The pubic and separate school boards in Fort McMurray presently have all their facilities overloaded and are experiencing extreme difficulty in rectifying the situation.

To understand the hardships which the school boards are facing in providing adequate facilities, it is necessary to understand the basic process involved in school building in the Province of Alberta. Before any funding is arranged for new buildings, a statement is prepared on the basis of an actual child head count present in the town. Future needs are then determined by extrapolating the needs of each age group as it passes through the school system. There is normally a 3 year lag time involved between the prediction of the needs and the eventual completion of the required facility.

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In a stable community receiving a low proportion of immigration, such a planning and construction system can prove adequate, but in Fort McMurray, where mass influxes of people have almost doubled the population for each 3 year period since 1964, a dependency on an existing head count has proven inadequate. The high proportion of school age children (310: 1,000) which has been typical of the immigrant population, has placed an even heavier load on the school facilities of the Town. Even a reduction of the normal lag time, from 3 to 1½ years and a drop in enrollment for 1970-71 and 1971-72 (Table No. 1-10), has not helped to alleviate the over crowding problem, and with a sharp increase in enrollment in 1972 - a new high and a projected increase of over 100 students per year (Table No.1-11), it would appear that the brief breathing spell may be over.

TABLE NO. 1-10

PAST SCHOOL ENROLLMENT

YEAR	ENROLLMENT	ACTUAL INCREASE	PERCENTAGE INCREASE OVER PRIOR YEAR
1965	645	0	0
1966	878	+233	+35
1967	1,615	+737	+84
1968	2,030	+415	+25
1969	2,350	+320	+15
1970	2,280	- 70	- 3
1971	2,167	-113	- 4
1972 (Nov.30)	2,386	+219	+ 9

SOURCE: Fort McMurray Roman Catholic Separate School District No. 32 and Fort McMurray Public School District No. 2833.

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TABLE NO. 1-11

PROJECTED SCHOOL ENROLLMENTS

(Assuming no Syncrude development)

GRADES	1970-71	1971-72	1972-73	1973-74	1974-75
1 - 8	1,666	1,723	1,854	1,947	2,023
9 - 12	346	453	505	585	654
TOTAL	2,012	2,176	2,359	2,532	2,677

SOURCE: Fort McMurray School Boards.

A look at the capacity of present facilities and their enrollment capacity figures, shown on Table No. 1-12, demonstrates the need for increased facilities.

TABLE NO. 1-12

PRESENT SCHOOL FACILITIES AND CAPACITIES

	J.A.Turcotte	St. John's	Dr. Clark	Peter Pond
Date of construction	1968	1936	1967	1961
Date of additions	1971	1950 1962 1971 (1973)	1969	1963 1965
Site sizes (Acres)	2.0	3.87	4.52	9.24
Square footage	35,000	13,000 (33,000)	63,035	41,804
Number of classrooms*	21	10 (16)	30	24
System	Separate	Separate	Public	Public
Grades	1 - 5	6 - 9	1 - 6	7 - 12
Stated capacity	525	250 (400)	750	550
Enrollment	539	309	901	636
Capacity shortage	14	59	151	86

SOURCE: Fort McMurray School Boards.

cont'd-----

* Classroom figures include ancillary (staff rooms, storage rooms) and portable rooms which are not considered as permanent classrooms and should be replaced by permanent facilities, i.e.-two classrooms in Dr. Clark School were built by enclosing a courtyard.

1972-73 figures show the facilities operating with 310 more students than the stated capacities. The severity of this space shortage is heightened further when it is realized that a number of the classrooms now in use, are remodelled ancillary rooms such as staff rooms which were put into use to help handle some of the regular classroom overflow.

The most serious result of this space shortage is its retarding effect on the attempts of the school boards to provide the curriculum variety required for a high quality education. Specialized education facilities such as shops which require large areas are simply impossible to provide at the present time. Some limited programs are provided at the Peter Pond and St. John's School and are generally restricted to typing, industrial arts and home economics, (Table No. 1-13). However, due to heavy enrollment, many option courses cannot be provided for all who wish to take them.

TABLE NO. 1-13

ADDITIONAL COURSES AVAILABLE

DR. CLARK	PETER POND	ST. JOHN'S
Help in Remedial Reading	Home Economics	Typing
	Industrial Arts	Communication
	Business Education	Drama

cont'd-----

The need for a new high school which could provide these specialized courses is critical and the school boards would like to provide such a facility in 1973-74. Even if a high school is completed in 1973, enrollment projections would place the school at operating capacity by 1974.

It is essential to note that even with the St. John's addition and the construction of a new 450 student elementary school on the Clearwater site in 1973, the elementary system will be operating at full capacity on the day of completion.

The Boards are also faced with the problem of finding sites on which to locate new facilities. The existing sites are utilized far beyond prescribed limits already, with overcrowding resulting in such measures as a shared playground on the adjoining sites of the J. A. Turcotte and Dr. K. A. Clark Schools. The new Clearwater site will not provide any expansion room due to the risk of spring flooding over a large portion of the site. Lack of an adequate site is the major constraint in building the proposed new 425 student high school. The most desirable site within the present town which is of adequate size to hold the high school is on MacDonald Island. The island has been dedicated as a recreational area and the school board has been unable to receive Town approval for the MacDonald Island site.

It is important to realize that the school board, which is having extreme difficulty in providing facilities for its present enrollment, has not included the possibility of any future tar sands developments beyond the existing Great Canadian Oil Sands Ltd. plant in its student enrollment projects. Extensive pre-planning will be necessary before any subsequent tar sands developments to ensure that the education facilities in the Town will be able to provide adequate space and a quality curriculum for the increased student body which will arise out of another development such as Great Canadian Oil Sands Ltd. has undertaken.

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1.8 CULTURAL

As can be expected in a town the size of Fort McMurray, cultural activities are more often a matter of personal involvement than spectator observation. The Town does boast its own local radio station which plays a variety of "Top 40" and easy listening music, and it has a local cable television station which carries community announcements and special features. As well, a town cable system carries Edmonton radio and television stations. It would appear that any upgrading in television service would not likely be via the use of the new Anik communications satellite but through improved microwave facilities to Edmonton. For those interested in movies, there is a movie theatre in Town which offers an up-to-date selection of films, and for those who wish to read, there is a 10,000 volume library from which to select reading material.

The people in Fort McMurray come from a wide variety of backgrounds, and nowhere is this more apparent than in the composition of the religious community. Anglicans, Baptists, Jehovah's Witnesses, Lutherans, Mormans, Pentecostals, Roman Catholics, Unitarians and Uniteds, all have representation in the Town; many with new buildings of contemporary design. Although these institutions do not represent every existing organized religion, they do offer a choice of worship which is not always common to a town of 7,000 people.

The greatest number of cultural activities, however, are a result of personal participation in one of the many service or hobby oriented clubs in Town. The number of clubs varies subject to the whims of taste. A recent survey of organizations active in Fort McMurray produced the lists in Table No.1-14 and No. 1-15.

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TABLE NO. 1-14

CLUBS AND ORGANIZATIONS

Following is a list of some of the facilities available to residents of Fort McMurray.

Oilsands Curling Club	Public Library
Mistie-Sepee-Ski Club	Community Centre
Camp Nee Chee Nogen, Anzac, Alberta	Miskanaw Golf Club
Tennis Courts	Indoor Swimming Pool

Fishing, Boating, Water-Skiing, etc., can be enjoyed at Gregoire Lake or on the Clearwater and Athabasca Rivers. There is a Centennial Park for recreation.

SOURCE: Great Canadian Oil Sands Ltd. questionnaire.

TABLE NO. 1-15

Following is a list of clubs and organizations in Fort McMurray:

Al-Anon	Miskanaw Golf Club
All Saints Anglican Parish Guild	Nistawoyou Association
Baptist Youth Fellowship	Open Stage Society
Brownies	People's Park (Youth Club)
Catholic Women's League	Royal Canadian Legion
Civil Service Association	Saint Aidens Women's Auxiliary
Clearwater Ladies' Fastball	Tar Island Ladies
Cosmopolitan Club	Philatelic (Jr. - Adult)
Elks	Masons
Fort McMurray Badminton Club	Metis Association
Fort McMurray Figure Skating Club	Voice of Alta. Native Women's Society
Fort McMurray Minor Baseball	Home and School Association
Fort McMurray Senior Hockey League	McMurray Broadcasters
Fort McMurray Tennis Club	Friends of Music

cont'd-----

Table No. 1-15 continued

Girls' Club	Army Cadets
Girl Guides	Fort McMurray Art Club
Junior Forest Wardens	Boy Scouts
Kinette Club	Candy Stripers
Knights of Columbus	Chamber of Commerce
Miskanaw Golf Club	Clearwater Boxing Club
Clearwater Light Horse and Rodeo Assoc.	Fish & Game Association
Cubs	Fort McMurray Men's Fastaball League
Fort McMurray Basketball League	Fort McMurray Sno-Trakkers
Fort McMurray Soccer League	Guide Association
Fort McMurray Minor Hockey League	Junior High School Girls' Club
Indian-Eskimo Assoc. of Canada	Ladies' Order of the Royal Purple
Kinsmen Club	Oilsands Curling Club
Mistie-Seepee-Ski Club	Peter Pond High School Students' Union
Overture Concert Society	Swimming
Skating	Bridge Club
Teen-Time (Youth Group)	Boating Club
Art Club	

SOURCE: Great Canadian Oil Sands Ltd. questionnaire.

The feeling was expressed, in Fort McMurray, that if proper facilities were constructed which could handle drama and music groups, certain shows, which are presently available only by going to Edmonton, could be provided in the Town itself. The present community hall is small and inflexible in design and does not lend itself to this type of use. Nor is there a school facility in Town which could be used flexibly either as a theatre or an auditorium. The arena, too, has a limited facility and its small seating capacity of 450 does not warrant the showing of any major ice events. With many of the Fort McMurray immigrants coming from urban backgrounds, the interest in cultural activities can be expected to grow.

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1.9 RECREATION

Fort McMurray's setting endows the Town with abundant treed landscape for aesthetic beauty as well as placing McMurrayites within minutes of a potentially vast array of outdoor activities.

The Athabasca and Clearwater Rivers provide immediate potential for boating, swimming, fishing, water skiing and canoeing, while the surrounding Athabasca Forest interests hunters, hikers, campers, skiers and snowmobilers.

The internal recreation facilities, Table No. 1-16 , of the Town further develop this variety of recreation choices.

TABLE NO. 1-16

RECREATIONAL FACILITIES

FACILITY	PARTICULARS
Golf Course	9 Holes
Ski Development	2 Runs - Tow Rope
Swimming Pool	Heated - Indoor
Hangingstone Park	Museum & Swimming Area
Ice Arena	Seating - 425
Curling Rink	4 Sheets
Community Hall	Small
Ball Diamonds	7
Tennis Court	2 Hard-surfaced
Outdoor Rinks	1 Permanent location 3 Floating
Toboggan Run	1
Soccer Fields	2
Playgrounds	5
Parks & Reserves	6
Undeveloped Sites	3

cont'd-----

The Town has facilities for ice skating, swimming (year round), curling, golf, as well as a wide assortment of land available for more passive forms of recreation.

Statistically, Fort McMurray's internal recreation land supply rates high when compared to towns of like size and function. Alberta towns in the 5,000 - 9,999 population groups average 2.90 acres/100 population while towns of similar resource function as Fort McMurray average 3.76 acres/100 population. Fort McMurray far exceeds any of these figures at 5.07/100 population.*

Although the overall internal recreation picture looks good for the Town, there are problems. The distribution of parkland within the Town is very uneven with the majority of acreage being distributed between MacDonald Island and the community centre. The area in between, which accounts for most of the residential and commercial land in Town, is almost completely devoid of recreation land, other than school grounds. It may be impossible to rectify this situation in the existing Town but neighborhood parks should not be overlooked in the future development of the Town.

There are other difficulties in supplying a well rounded recreation program which are confronting the seven man recreation board and the Town's recreation superintendent. At a time when the recreation budget is doing little more than providing maintenance to existing facilities, the Town finds that its arena and community hall are in need of replacement or at least expensive upgrading if they are to be properly operated for the rapidly growing population.

Despite its budgetary problems, the recreation department, with the help of service clubs, is able to provide a fairly well balanced recreational program for the young population of the Town, which includes a

*SOURCE: Alberta Land Use Analysis.

cont'd----

minor hockey program in the winter and a ball league in the summer. A girls' minor hockey team has even evolved this year. Inter-town competition in sports, however, is all but non-existent in Fort McMurray due to the expense and time involved in travelling.

The recreation department and the Town school boards are very cooperative in attempting to provide as many recreational activities as possible within the Town. The schools have daily swimming time at the indoor pool which they put to good use providing the students with swimming experience. The school boards, in turn, allow certain school rooms and facilities to be used for both recreational and cultural types of activities. The Town is presently making the most possible use of the recreational facilities which it has. For example, the arena is booked almost solidly except for maintenance time, seven days a week from 6:00 a.m. to 12 midnight, (Table No. 1-17). With such a schedule, the only way of providing a similar quality service to a greatly increased population, will be by expanding or duplicating the facility. It appears, at this time, that some of Fort McMurray's recreational facilities which were adequate before the Town's rapid development, are coming of age and will require some immediate improvement.

Recreation is an expensive operation, however, and rarely are its costs covered through fees. The typical child in minor hockey pays the equivalent of 50¢ per month for his experience and gets to play two games per week. In a 450 seat arena, where admission charges do not cover operating costs, the facility becomes a budgetary liability.* This situation is common to a town providing a recreational program and should be realized by anyone who wishes a high quality in town recreation facilities.

* Figures on recreation supplied by Fort McMurray Recreation Department.

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TABLE NO. 1-17

NEW TOWN OF FORT McMURRAY PARKS AND RECREATION
ARENA SCHEDULE

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
6:00 - noon Minor Hockey	6:00 - 8:00 am Figure Skating	6:00 - 8:00 am Figure Skating	6:00 - 8:00 am Figure Skating	6:00 - 8:00 am Figure Skating	6:00 - 8:00 am Figure Skating	6:00am-6:00pm Minor Hockey
1:00 - 3:30 pm Figure Skating till Jan, 1973 3:30 - 5:30 pm General Skating 6:00 - 7:00 pm Figure Skating Adult Session	Noon - 2:00 pm General Skating 3:00 - 4:00 pm Figure Skating Tots 4:15 - 7:15 pm Figure Skating	Noon - 2:00 pm General Skating 3:00 - 5:30 pm General Skating 5:30 - Midnight Minor Hockey	Noon - 2:00 pm General Skating 3:00 - 4:00 pm Figure Skating Tots 4:15 - 7:15 pm Figure Skating	Noon - 2:00 pm General Skating 3:00 - 5:30 pm General Skating 5:30 - Midnight Minor Hockey	Noon - 2:00 pm General Skating 3:00 - 4:00 pm Figure Skating Tots 4:15 - 7:15 pm Figure Skating	Minor Hockey Minor Hockey
7:00 - 8:30 pm Adult Skating 9:00 - 11:30 pm Old-Timers Fun League	8:00 - Midnight Senior Hockey	Minor Hockey	8:00 - Midnight Senior Hockey	Minor Hockey	8:00 - Midnight Senior Hockey	6:00 - Midnight Minor Hockey till Jan. 1973

1.10 TRANSPORTATION

The internal transportation facilities of Fort McMurray are oriented to personal vehicle traffic. Franklin Avenue, the four lane boulevarded main street, would have little difficulty in handling the free flow of traffic which may be generated by the Town in the immediate future. Highway No. 63 bypasses the Town, thus, relieving the Town of trucks and cars which would otherwise pass through.

Bus service is provided in Town for Tar Island workers, with some 500 men per day using buses to travel to work. An internal bus route system within the Town provides a bus pickup service for school children. This service is especially appreciated in the harsh cold of winter. However, much of the route is not covered by provincial grant and must be paid for directly by the child's parents.

External transportation modes employ air, water, rail and road. The two means of transportation which were responsible for Fort McMurray's earlier growth, Northern Transportation, operating barges north along the Athabasca River, and the Northern Alberta Railway, operating rail service between Edmonton and Fort McMurray, are still in operation despite the heavy competition presented by trucking and air traffic and alternate rail service to the north.

At the same time, road and air transportations are receiving a continual upgrading which will hopefully see, in 1975, the completion of the paving of Highway No. 63, which links Edmonton and Fort McMurray, and establishment of a regular jet service between Edmonton and Fort McMurray.

In the air, Pacific Western Airlines is the main scheduled carrier, with five passenger flights a week stopping at Fort McMurray. Three days a week a 50 seat Electra* carrying both passengers and freight, connects Fort McMurray with Fort Chipewyan, Uranium City and Edmonton.

*Special seating configuration to accommodate passengers and freight.

cont'd----

The other two days, a 50 seat Convair 640 flies an Edmonton to Fort Chipewyan return flight. This Convair is soon to be replaced by a 737, giving Fort McMurray two days of jet service to Edmonton each week. It should be noted, however, that existing schedules do not allow for day long business trips between the two centres. This day trip facility is desirable now and will be in even greater demand should future tar sands developments proceed.

P.W.A. passenger records show that more than four time as many passengers were flown to Fort McMurray during Great Canadian Oil Sands Ltd. construction than during the post construction period - 41,000 total passengers in 1966 as opposed to 10,000 total passengers in 1970.

Air passenger traffic is on the increase, however, with 1972 figures showing approximately 15,000 total passengers, hence, the improved jet service. In the event of another development boom in Fort McMurray, Pacific Western Airlines has demonstrated the ability to adjust its scheduling and accommodate the increased demand.

On the ground, Pacific Western's Trucking Division is showing a marked increase in volumes. Unfortunately, only 1971 and 1972 figures were readily available, but these revealed that trucked freight for the line more than doubled in the space of one year, with every indication that it will continue to expand.

Coach service, both passenger and express freight is provided between Fort McMurray and Edmonton by Greyhound Bus Lines. The daily service is reliant on the existence of Highway No. 63 and looks forward to the completion of paving on this route. Highway No. 63 provides the only access for auto transportation and is a vital surface transportation link to the south.

Fort McMurray appears to be well serviced with transportation facilities offering a broad range of choice for both freight and passenger service, (see Tables No. 1-18 and No. 1-19). The one vital link, however,

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which psychologically changes Fort McMurray from an isolated town to merely a distant town, is Highway No. 63. It allows a person living in Town to always feel, no matter what problems the other carriers are having, he has the option, if he wants, to drive into or out of Fort McMurray.

Coincidental to the external transportation network of Fort McMurray, is the Town's facility to provide accommodation to the large number of persons in Town on business trips. There are, presently, four hotels in Town, which offer this accommodation service. These facilities are under heavy use with one being used full time as a residence for AVC, while two others are undergoing expansion programs to try to provide for the heavy demand should tar sands developments proceed as anticipated. A great increase in short term business type trips may be expected and the hotel facilities will need to rapidly expand to meet the demand.

TABLE NO. 1-18

PACIFIC WESTERN AIRLINES PASSENGER AND FREIGHT

	1965	1966	1967	1968	1969	1970	1971	1972 (approx.)
FREIGHT								
Edmonton to Ft. McMurray	524,000	440,000	88,000	54,000	35,000	44,000	50,000	50,000
Ft. McMurray to Edmonton	166,000	194,000	130,000	88,000	74,000	81,000	86,000	100,000
PASSENGERS								
Edmonton to Ft. McMurray	12,000	22,000	12,000	9,000	7,000	5,000	6,000	7,865
Ft. McMurray to Edmonton	13,000	19,000	12,000	9,000	7,000	5,000	6,000	7,330

Pacific Western Airlines operates flights five days a week to Fort McMurray.

MWF - a 50 seat Electra carrying passengers and freight stops in Fort McMurray.
T.R. - a 50 seat Convair flies return to Fort McMurray only.

As of February 18, 1973, the Convair flight will be replaced by a jet service employing a 117 seat '737'.

Schedule is flexible to demand.

*Source - Pacific Western Airlines Public Relations.

TABLE NO. 1-19

PACIFIC WESTERN TRUCKING DIVISION

(Freight Hauling - Edmonton to/from Fort McMurray 1971-72)

	1971	1972
Edmonton to Ft. McMurray	21,000,000	50,000,000
Ft.McMurray to Edmonton	4,000,000	9,000,000
TOTAL	25,000,000	59,000,000

(Rounded to nearest million pounds)

* Figures for any other years are difficult to locate.

1.11 MEDICAL

Fort McMurray has relatively sound medical facilities, with one optometrist, three dentists and a 54 bed hospital with a complement of one surgeon, one obstetrician and three general practitioners, fifteen registered nurses and eleven nursing assistants.

Due to a great deal of variation in local conditions, it is difficult to create formal standards for establishing the number of medical personnel required to service each area. Certain guidelines, however, such as one dentist per 4,000 population, one general practitioner per 2,500 population, and one surgeon per 15,000 population, when adjusted to the local situation, can provide useful in recognizing any possible short comings in existing medical servicing. (See Table No. 1-20).

When compared to these guidelines, Fort McMurray would appear to have sufficient medical servicing for the Town population. The medical personnel in Fort McMurray, however, also provide much of the medical servicing as far away as Fort Chipewyan. These out-of-town patients account for some 25% of the admissions at the Fort McMurray Hospital and keep four public health nurses busy administering aid in the individual centres.

TABLE NO. 1-20

LEVEL OF EXISTING MEDICAL SERVICING

GUIDELINE	1 dentist/4,000	1 general practitioner/ 2,500	1 surgeon/15,000
FORT McMURRAY	1 dentist/2,500	1 general practitioner/ 1,900	1 surgeon/7,500

Guidelines provided by Alberta Department of Health and Social Development.

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The hospital is the major medical unit in the Town. It is interesting to note that guidelines which would have been used to gauge the hospital's effectiveness have now been partially set aside and replaced by a functional planning study approach which treats each hospital as an individual part of a system which has its own specific pecularities with respect to the people it serves, how it serves them, and why.

Using the national average of 7 beds/1,000 population as a guideline, the Fort McMurray Hospital, which is presently operating in the 7 beds/1,000 category, would appear to have sufficient bed space. Yet 1972 bed occupancy rates show that there was a 75.8% bed occupancy over the year. Allowing for peaks and lows, it can be seen that the hospital was operating with most of its beds occupied throughout the year. Considering the high ratio of beds per population such a high occupancy rate at first appears unusual.**

A hospital committee study of the situation revealed that a number of beds were being occupied by out-of-town patients who had been brought into Town for clinical testing and, due to a lack of other accommodation, were kept in a hospital bed while the testing was being carried out. This time lag is often necessitated because much of the test analysis is done in laboratories in Edmonton and it is often a few days before test results are telexed back to the Fort McMurray hospital. A hostel style operation is being planned for the hospital which will alleviate some of this unnecessary bed occupancy.

This time lag in receiving test results does not have an easy solution. Often the trained personnel who are required to analyze the test results are not required frequently enough to be hired permanently, on the local level. However, some improvements are being planned for the near future in areas such as blood testing.

** Hospital data provided by Hospital Administrator.

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Although minor surgery such as tonsilectomies and appendectomies are performed in Fort McMurray, more serious operations requiring greater specialization in a particular field are performed in Edmonton. The air ambulance can have a person in Edmonton in about two hours, weather permitting.

One factor to note is that the hospital has site capabilities for expansion to well over double its present size. Such an expansion would provide for a greater amount of specialist care. The use of ambulatory care and hostel units will relieve some pressure from the hospital facilitiy itself, and this will allow optimum utilization of the major facility.

Other medical personnel in Town consist of four public health nurses and the aforementioned dentists and one optometrist. These medical practitioners provide primarily corrective and hygenic services and therefore, they function on a supply and demand basis more so than do hospitals.

1.12 PUBLIC OFFICES IN FORT McMURRAY

Fort McMurray is administered under the terms of the New Towns Act and is governed by a local Board of Administrators consisting of members elected by the citizens of the town. The local Board of Administrators is responsible for carrying out all of its legislative functions within the scope of the New Towns Act. The significant point of difference is the potentially expanded borrowing powers given to the local Board of Administractors under the New Towns Act. The New Towns Act was created to permit rapidly expanding communities an increased availability of funds related to unusual growth. Towns operating under this legislation are subject to a greater degree of supervision by the senior government.

A number of other agencies exist which play a role in the development of Fort McMurray or in administration of programs within Fort McMurray and the region around it.

1.12.1 Department of Municipal Affairs

This department, as its name implies, is responsible for the administration of the Municipal Government Act. All municipalities, urban and rural, are creatures of the Provincial Government and their powers are delegated to them by the Provincial Government. They, in fact, exist at the pleasure of the Government. The Department of Municipal Affairs is the branch of government concerned with regulations relating to urban and rural municipalities. A number of branches within the department are concerned with specific areas of activity.

A number of these are directly involved in the affairs of Fort McMurray. The roles of operation of these are outlined herein.

1.12.2 Provincial Planning Branch

This branch of government is the approving authority for land

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subdivision throughout the province except where this authority has been delegated to City or Regional Planning Commissions. In the case of Fort McMurray, the Provincial Planning Branch provides this service. The Provincial Planning Branch also provides professional assistance in the preparation of General Plans, zoning bylaws, development plans or development control bylaws for the municipality. Under the New Towns Act, the Provincial Planning Branch is the planning advisor for New Towns.

1.12.3 Acting Development Coordinator for Government Programs in Fort McMurray

This position has recently been created by the Provincial Government to ensure the orderly development of Fort McMurray. The function of the coordinator is to coordinate the activities of all the various Provincial Government agencies in the specific area, thereby providing a coordinated approach from the senior level of government to the local government. Under the present arrangements, the coordinator reports to the Deputy Minister of the Department of Intergovernmental Affairs. The future status of this position is not known at this time as there has been no precedent to follow.

1.12.4 Central Mortgage and Housing Corporation

Central Mortgage and Housing Corporation is a federal crown corporation charged with administering federal funds made available for housing. In this role Central Mortgage and Housing Corporation sets standards for development and housing and establishes the basis on which it will make funds available. This agency has been a major lender in Fort McMurray on a guarantee basis from the major incumbent industry. It has, as well, made funds available to the Alberta Housing Corporation.

The above are the basic agencies with which the Board of Administrators of the Town of Fort McMurray must deal in reflecting the wishes of its citizens. The local administration is the most sensitive to the desires of the citizens of Fort McMurray and one of its main functions is

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to reflect these needs to the more remote agencies who, in fact, may be implementing policies or programmes which effect the Town. The success in this communication has, in many respects, a marked impact on the character of the physical development within the community.

1.13 CURRENT FINANCING STATUS*

As of December 31, 1971, Fort McMurray had a Gross Unmatured Debenture Debt totalling $4,104,880.19, of which $1,084,056.58 was Utility Debt (the water supply system) and $3,020,823.61 was General Debt (includes the sewerage system, curbs, streets and roads, plus other items as well). The General Debenture Debt of $3,020,823.61 consists of $285,608.20 as Owner's Share and $2,735,215.41 as Municipality's Share. On the basis of a population of 7,000, the Municipality's Share of the General Debenture Debt is approximately $390 per capita, taxable assessment of $9,876,970 and a mill rate of 80. Owners of single family dwellings paid taxes in the $500 to $700 range.

Further major development will require additional major infusion of capital and budget proposals for 1973 have indicated a possible mill rate of 135.

*Figures provided by Town of Fort McMurray and Central Mortgage and Housing Corporation.

1.14 RESOURCES AVAILABLE TO THE NEW TOWN OF FORT McMURRAY TO TACKLE ITS PROBLEMS

The resources available to the Board of Administrators of the New Town of Fort McMurray are really no different from those available to any normal municipality with the one exception that the New Town may extend its municipal debts beyond the normal ratios found in a normal municipality. This provision is, of course, to permit the new town to provide water, sewer, roads and other services in advance of the people actually being in the town and providing assessment. The equipment and staff resources of the Town are comparable to most urban municipalities of its size. The Province of Alberta through its many departments and programs can provide a multitude of services to the Fort McMurray town and region around. In return, of course, there are further resources available through federal agencies.

At this particular time with the New Town of Fort McMurray facing a further probable and large extension, probably in the order of doubling its population, the Town faces a number of problems - specifically as to which areas to develop and the means to develop them. There is also the question as to which new resource developments will look to Fort McMurray as the location for employees, and which developments, by reason of distance and more remote location, might require a community infrastructure of their own.

The Board of Administrators was originally a government appointed board. Subsequently, the Board has been enlarged to include local appointees, however, considerable pressure was applied by the residents of the community to have an elected Board, which it now has.

It is, therefore, extremely evident that the Town requires the assistance and the application of the resources of the Provincial Government. On the other hand, it is also evident that the people are anxious and able to control local matters.

FORT McMURRAY IMPACT STUDY

PART II

COMMUNITY IMPACT OF
THE PROPOSED SYNCRUDE PROJECT

FORT McMURRAY IMPACT STUDY
PART II
COMMUNITY IMPACT OF
THE PROPOSED SYNCRUDE PROJECT

2.1 INTRODUCTION

Syncrude Canada Limited tentatively plans to construct and operate a synthetic crude oil production facility near Mildred Lake, 25 miles north of Fort McMurray. A decision on whether to proceed with this project will be made by August 31,1973 on the basis of cost and engineering studies now under way. If constructed, the project will cost an estimated 650 million dollars and will require approximately 2,000 men to construct and more than 1,100 men to operate. The Project will take between four and five years to complete construction.

The advent of a plant of the magnitude of the proposed development at Mildred Lake by Syncrude Canada Limited would have a major impact on Fort McMurray. The purpose of this section of the study is to assess the likely demands generated by the project on housing, commercial facilities and community services in Fort McMurray. If one visualizes a community of 7,000 people faced with absorbing an additional work force of 1,200 people, with attendant support facilities, it is not difficult to realize the added demand this community will experience.

2.2 EMPLOYMENT GENERATED AT THE PROPOSED SYNCRUDE PROJECT

There are two distinct areas of activity related to the proposed synthetic crude oil project which will result in a demand for accommodation and facilities in Fort McMurray.

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The first area of activity is, of course, the construction phase of the plant. This will cause an influx of temporary workers. The result will be an immediate demand for high quality camp facilities for single men plus a demand for housing and other facilities in town for married personnel.

The second area of activity is the actual operating phase of the facility. This will require a labour force which is generally oriented to a permanent type of accommodation and facilities which will cater to their demands for a life style suited to making this locality their permanent domicile.

It is necessary, therefore, to look at both phases and the likely composition of the personnel and their requirements. It is, as well, necessary to look at overlaps and possible demands related to the changing character of the population.

The following table describes this work force and its probable composition, both during the construction phases and the operating phases.

TABLE NO. 2.1

PROJECTED WORK FORCE SYNCRUDE MILDRED LAKE PROJECT

(Year-end Totals)

	1973	1974	1975	1976	1977	1978	1979
Construction Phase - in camp	95	470	860	1500	610	0	0
Construction Phase - in town	30	198	315	339	172	12	0
Operations Phase - in town	0	0	42	225	862	1108	1108
Sub-total in town	30	198	357	564	1034	1120	1108
TOTAL	125	668	1217	2094	1644	1120	1108

NOTE: 1. A peak combined force of 2,200 is anticipated in the first quarter of 1977.

2. During normal operating, two annual maintenance phases, each of 45 days will occur when approximately 350 workers will be employed. This is not included in the previous table. During the start up phase of the project in 1977-78 this additional work force will be on site continuously and thus will create some additional support requirements within Fort McMurray.

At the present time, basic employment at Fort McMurray consists of an estimated Great Canadian Oil Sands work force of 958 plus approximately 410 contract workers in camp. Thus the proposed Syncrude operation would increase basic employment in the town by about 81%. (The assumption has been made that the Great Canadian Oil Sands work force currently on contract and basically living in camp will become residents of the town within the next few years.)

2.3 CHARACTERISTICS OF EMPLOYEES AT THE PROPOSED SYNCRUDE PROJECT

Family size indices for Fort McMurray will be higher than normally anticipated due to the higher than normal numbers in the younger age group (25 to 34) and the higher total fertility rates in Fort McMurray compared to the national and provincial experience. Analysis of work force from data supplied by Great Canadian Oil Sands indicates that the persons per family is 4.03 and the persons per household is 3.87. This may be compared to the 1966 figure for the Province of Alberta which indicated 3.7 persons per family and 3.4 persons per household. This discrepancy is even more significant with the knowledge that fertility rates for the Canadian population, as a whole, have continued to drop in the intervening period. It is reasonable to assume that the Syncrude work force will repeat the Great Canadian Oil Sands experience.

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As may be expected, the age of the comparatively high number of children (1971) of the Great Canadian Oil Sands married employees (882) exhibited a very young age profile. A significant number of young children may be expected to join the school systems in the next six years while, because of the young age of the wives, further child birth may be expected. Cross reference and comparison between the age pyramids of the Great Canadian Oil Sands work force and that of Fort McMurray as measured by the D.B.S. census of 1971 would indicate that the current Great Canadian Oil Sands experience represents a useable sample of the whole community age, family and child situation.

The situation respecting the construction phase workforce can be considered in two elements. A majority will live in camp on a single man basis and inasmuch as their families (if any) will be living elsewhere, all may be considered to be "single" persons for the purpose of this study. A smaller element comprising about one sixth of the construction work force will consist of married personnel of administration or non-manual categories who can be expected to have their families with them (in town). Based on the experience of previous projects, this smaller element will exhibit similar family profiles to those of existing families and to those forecasted to occur with Syncrude employees.

The larger number of the prospective employees forecast to be required for the Syncrude project will come from Western Canada, including a not insignificant number from the Fort McMurray region. The size of this latter group in part will depend upon the increase of local personnel who become available by virtue of local training programmes. The overall representation by persons from other parts of Canada or from other countries is not, at this time, forecasted to exceed approximately twenty percent.

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2.4 CHARACTERISTICS OF SUPPORT EMPLOYMENT

Indications based on past and current experiences show that the family characteristics of personnel engaged in support (or non-basic) activities within the town in the foreseeable future will not deviate significiantly from those of basic (tar-sand processing plant) employees. At the present time, it is estimated that for every basic employee there is a total of 1.61 employees in town. This represents a somewhat higher amount of non-basic employment than would be normally found in a community at the 7,000 population level. Allowance has to be made, however, for the particular situation as it applies to a resource oriented community and to the trend towards larger numbers of non-basic employees found as a community grows in size. The two counter effects have been taken to balance each other for the purposes of forecasting the basic/non-basic ratios that might apply at the approximate 14,000-16,000 population level.

At the present time, it is estimated that there are approximately 831 persons engaged in support (non-basic) employment activities. In 1979, this number will rise to about 1,500, an increase of about 81%. It should be noted that during the peak construction phase in 1977, support (non-basic) employment within the town could slightly exceed this number.

2.5 THE EXPANDING COMMUNITY

On the basis of the forecasted number of employees that could work at the proposed Syncrude plant and applying the indices previously described, taking into account the limitations that are associated with such formulae, it may be calculated that the population of Fort McMurray in 1979 will be in the range of 15,500 persons. It should be recognized that inevitably there will be variations between the indices forecasted for 1979 and those that actually occur, and hence the actual population may be slightly higher or lower than forecast.

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2.6 COMMUNITY IMPACT

2.6.1 Land Use

In transforming the employment data into likely demands upon the community, it was necessary to assess the particular characteristics of the population, the characteristics of the local geographical area and other influences that may affect the total community needs. In additon, the experience in other areas and in developments which are judged to be similar in character to the proposed project, have been analyzed. Based on these assessments, indices have been developed.

Adjustments to basic indices were carried out to reflect the current situation in Fort McMurray related to its changing role as development proceeds. Land requirements were assessed on the basis of the residents' strongly stated desire for single family type homes, the potential increase in light industry and the increase of demand for facilities for public use. The current heavy proportion of mobile homes was accounted for in the assessment, which has tended to increase current densities. The strong demand for single family homes and the general unpopularity of the trailer homes (demonstrated by the rapid changeover) leaves little doubt that the emphasis will be on single family type accommodation in the future. Higher density types of residential development will not prove satisfactory to the work force, nor will they be conducive to a satisfactory working environment. The normal index for light industrial uses has been adjusted upward in keeping with the anticipation that the proposed Syncrude Plant will facilitate the development of support businesses which provide goods and services to both the plant and the residents of Fort McMurray.

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In consideration of the increasing role that can be anticipated for Fort McMurray, as a regional centre, a higher index has been developed for public and semi-public land uses. These include education, medical, government and recreational requirements. This assumption is based upon such considerations as the selection of Fort McMurray as a centre for vocational training within north-eastern Alberta and the town's continuing role in providing regional medical facilities.

Utilizing the above inputs, the following indices have been developed:-

TABLE NO. 2.2

LAND USE INDICES, 1979 FOR FORT McMURRAY

USE	GROSS ACRES/100 POPULATION
Total Developed	20.50
Total Residential	4.75
Single Family	3.67
Two Family	0.60
Mobile & Trailer	0.25
Multiple Residential	0.13
Institutional Residential	0.10
Commercial	0.32
Wholesale & Warehousing	1.55
Light Industry	0.69
Heavy Industry	0.02
Transportation & Communication	6.00
Parks & Playgrounds	4.14
Public & Semi-Public	2.41
Utilities	0.62

(See foot notes on following page)

cont'd---

NOTE:

1. The high index for Transportation and Communication is a particular reflection of the exceptionally high percentage of land currently so utilized in rapidly growing resource oriented communities.

2. The index for Parks and Playgrounds takes into account the land encompassing the Golf Course and those lands which, because of liability to flood or other adverse conditions such as slope, might likely be dedicated to park (public) purposes.

The foregoing indices are not radically different to those which now appear in Fort McMurray or those that have been used in making land requirement forecasts in the General Plan, with the exception of residential requirements, which have been calculated in this study on a lower density basis in the light of sociological evidence.

Analysis of the data related to construction work force and operating work force should Syncrude Canada Limited decide to proceed, indicates that the population in Fort McMurray will peak in 1977, with an anticipated population of 16,900. As construction activity comes to an end, and the basic population is made up of operating personnel, the population should drop to approximately 15,500 by 1979.

It must be realized that there is potential variance in the several projections made and that a deviation from the established figures is possible due to a number of factors. The indices used, however, yield the best projections which can be made at this time related to the data available and experience related to other situations where similar growths have occurred.

Translating these figures into absolute numbers yields the following requirements for Fort McMurray to handle the impact of the Syncrude Canada development.

cont'd---

TABLE NO. 2.3

ANTICIPATED GROSS LAND REQUIREMENTS
FORT McMURRAY 1979

(Estimated Population 15,500)

USE	GROSS ACRES
Total Developed	3,163
Total Residential	733
Single Family	566
Semi-Detached & Row Home	93
Mobile & Trailer	39
Multiple Residential	20
Institutional Residential	15
Commercial	49
Wholesale & Warehouse	239
Light Industry	106
Heavy Industry	3
Transportation & Communication	926
Parks & Playgrounds	639
Public & Semi-Public	372
Utilities	96

NOTE:

1. The footnotes and text applying to Table 2.2, also apply to this table.

2. The above land areas are derived from values which have not been "rounded off".

cont'd---

The impact of growth forecast to occur on a yearly basis is summarized in table 2.4 on the following page.

Direct comparisons between table 2.4 and the forecasts made in the General Plan are not possible due to the different imputs that have been available and have been used regarding allocation of land uses and densities and forecast work force sizes and build-ups.

TABLE NO. 2.4

SUMMARY OF ANTICIPATED GROSS LAND REQUIREMENTS

FORT McMURRAY 1971-79

TYPE OF USE	TOTAL AREA 1971	TOTAL AREA REQUIRED 1972	1973	1974	1975	1976	1977	1978	1979	NEW AREA REQUIRED BETWEEN 1971 & 1979
Total Developed	883	1025	1525	2125	2400	2725	2925	3025	3163	2280
Total Residential	395	425	450	550	600	750	775	750	733	338
Commercial	24	25	25	25	50	50	50	50	49	25
Secondary Commercial, Industrial, Communication & Transportation	165	200	400	800	900	1000	1100	1200	1274	1109
Parks & Recreation	205	275	350	425	500	550	600	600	639	434
Public & Semi-Public (including Education)	67	75	250	275	275	300	300	325	372	305
Public Utilities	27	25	50	50	75	75	100	100	96	69

2.6.2 Housing

Reference is made to evidence that single family type housing or variations thereof is strongly sought by present residents of Fort McMurray and on the basis of information gathered in Fort McMurray and elsewhere, it is considered to be an essential ingredient in the establishment of a satisfactory working and living environment for new employees located within the town. Thus, the housing mix which presently has a significant mobile home and apartment element should, with further development, reflect a mix more directly related to the natural desire for a single family type home. Table 2.5, in forecasting annual additional dwelling requirements, reflects both total annual development needed and the swing towards the above objective. It has been definitely indicated that the employees of both the construction company and the operating company cannot be satisfactorily accommodated in mobile homes and that the majority of the latter group will not accept apartment type accommodation.

It should be noted that the 1979 projections relate to the immediate impact of the possible addition of a single synthetic crude oil project at Mildred Lake. Further, it should be noted that demand for such facilities as multi-family, medium density and trailer park facilities would, in all probability, be at its peak. Due to the changing nature of the work force in subsequent years (insofar as age and required type of accommodation), the acceptibility of multi-family facilities will diminish in favour of single family homes.

There will be a sector of the Fort McMurray population which, although desiring their own property, will not wish to incur the expense of utilities and ohter similar improvements. These people, for reasons of income level and other factors, will wish to have property available to them without the need to acquire all of the amenities. Provision should be made to accommodate this requirement.

cont'd---

TABLE NO. 2.5

PROJECTED DWELLING REQUIREMENTS

TYPE	1972 PROVISION	REQUIREMENTS 1973	1974	1975	1976	1977	1978	1979	TOTAL NEW BETWEEN 1972-79
Single Family	1,031	1179	1671	1885	2127	2576	2576	2,576	1,545
Two Family & Row Home	146	168	298	406	509	801	889	1,003	857
Apartment Including Business Suites	281	316	432	432	432	432	432	432	151
Mobile Homes	590	645	881	900	1326	870	539	324	-266
TOTAL	2,048	2308	3282	3323	4396	4679	4436	4,335	2,287

2.6.3 Public Utilities and Services

Fort McMurray owns, operates and maintains the community's water, sewerage and drainage facilities. The population capacity of each of the major components of the waterworks and sewageworks systems were examined on the basis of both the existing and the maximum possible flow capacities reported by the town's engineers. These results were compared to the required design capacities for a forecasted population of 15,500 persons (i.e., Syncrude project completed) as determined from the design standards established by the Alberta Department of Environment. This comparison provides a measure of the impact of the demands which would be placed upon these facilities if housing is provided in Fort McMurray for the population which would be generated by the proposed Syncrude project.

The three major components of the waterworks system are the raw water intake, the water treatment plant and the water supply line. The existing situation with each of these three components indicates that at a forecasted population of 15,500 persons in 1979, there would be population capacity deficiencies of: intake - 10,100; plant - 10,100 and supply line - 2,000 persons. After maximum possible expansion of these three components there would still be population capacity deficiencies of: intake - 7,400; plant - 4,700 and; supply line - 2,000 persons.

The three major components of the sewage collection system are the outfall sewer, the sewage lift station and the sewage force main. The existing situation with respect to the outfall sewer indicates that at a forecasted population of 15,500 in 1979, there would be a population capacity deficiency of 2,000 persons; which deficiency can be overcome by building a second outfall sewer. It is forecasted that in 1979 the sewage lift station would be under capacity by an amount equivalent to 500 persons, but this facility is reportedly expandable to a maximum total population capacity of 21,600 persons.

cont'd---

The sewage treatment plant (lagoons) have a population capacity for 14,800 persons on the system, which indicates a 1979 deficiency equivalent to 700 persons. However, the sewage lagoons are reportedly expandable to handle a total population of 29,600 persons.

Surface water drainage in the community is provided on an "as required" basis and utilizing a number of separate systems to carry run off water to the most convenient acceptable discharge locations. Special attention must be given to the design of these facilities where they will traverse areas of unstable or potentially unstable terrain. (i.e., escarpments)

The provision of the internal utility distribution systems, (water, power, gas and telephone), waste collection systems (sewage and surface run-off water), and road and sidewalk networks required to serve the forecasted population expansion is not expected to create problems that are markedly different from those which have been encountered in this community to date. However, as is the case in any fully serviced residential area, the cost of providing these facilities represents a substantial portion of the cost of housing. Depending on the method of cost recovery from property owners, provision of these facilities can require substantial borrowing by the community.

2.6.4 Retail Trade

The proposed Syncrude plant both in its construction and operations phases will inject very considerable sums into the Fort McMurray retail trade. While the construction phase workers living in camp will live on an "all provided" basis, they too, on the basis of past experience, will inject income into the retail and service economy of the town.

cont'd---

In terms of 1973 dollars, it is estimated that there will be a retail trade expenditure of $701.00 per capita. This expenditure has the average apportionment shown in Table No. 2.6.

TABLE NO. 2.6

PERSONAL CONSUMPTION EXPENDITURE (PER CAPITA)

GROUPS OF MERCHANDISE	1973 PER CAPITA EXPENDITURE	PERCENTAGE OF TOTAL EXPENDITURE
Groceries and other food	$372.00	53%
Clothing and accessories	101.00	14%
Hardware	22.00	3%
Furniture and appliances	56.00	8%
Drugs	53.00	8%
Other Retail	64.00	9%
Personal and repair services	33.00	5%
TOTAL	$701.00	100%

NOTE: Based on D. B. S. Census of Canada. Volume 6 - 1. Table 2. Estimate based on increase in consumer price index from 100.0 in 1961 to approximately 143 at the beginning of 1973 and allowing for 1% annual rise in real income.

The estimated total gross (before tax) payroll of the forecasted construction and operational work force is shown in Table No. 2.7.

cont'd---

TABLE NO. 2.7

ESTIMATED GROSS (BEFORE TAX) PAYROLL

OF PROPOSED PROJECT WORKFORCE

(in thousands of dollars)

	1973	1974	1975	1976	1977	1978	1979
Construction Workforce	800	11,800	38,800	41,400	4,600	0	0
Operational Workforce	0	174	463	2,316	7,917	12,485	12,636
TOTAL	800	11,974	39,263	43,716	12,517	12,485	12,636

NOTE: Payroll of construction and operational workforce is given in terms of 1972 dollars and excludes employees of Syncrude located in Edmonton and employees of Canadian Bechtel located in Edmonton respecting fabrication and office functions.

In general terms the total personal income generated by the project, both through the project and through associated economic growth and activities, would level off at approximately $110,000,000.00, or about 1½% of the total personal income of Alberta by 1979.

In terms of immediate effect upon the retail trade within Fort McMurray, a forecast of the increase in retail expenditure is given in Table No. 2.8.

cont'd---

TABLE NO. 2.8

FORECAST INCREASES IN RETAIL EXPENDITURE

(in thousands of dollars)

ADDITIONAL PERSONAL	1973	1974	1975	1976	1977	1978	1979
Syncrude & Bechtel employees and families	81	540	969	1612	2805	3038	3006
Support (non-basic) employees and families	480	2089	3117	4555	3828	2977	2955
TOTAL	562	2629	4085	6167	6633	6015	5961

NOTE: Values are given in terms of constant 1973 dollars and no real income increase is included.

Based on D.B.S. Census of Canada. Volume 6-1, Table 2, adjusted to 1973 allowing for increases in the consumer price index and a 1% annual rise in real income.

Paralleling the increase in retail expenditures there will be an increase in the required commercial building facilities. On the basis of an analysis prepared by the Urban Land Institute in 1969, ("The Dollars and Cents of Shopping Centres") the forecast increases in square footage requirements between 1972 and 1979 are shown in Table 2.9. It is difficult to show a breakdown into separate groupings of retail business on a yearly basis as variations from the norm will likely occur until 1979, while the single man camp clientele is exercising choices which are obviously different from those of married residents in town.

TABLE NO. 2.9

FORECAST INCREASES IN COMMERCIAL SPACE REQUIREMENTS

(1973 - 1979)

YEAR	TOTAL SQUARE FEET REQUIRED
1973	89,500
1974	123,500
1975	147,750
1976	182,250
1977	189,750
1978	181,500
1979	189,000

NOTE: There is a need to add 10 - 15% for incidential, storage and management space. Numbers given are for floor area only and excludes walls, partitions, yards and parking.

2.6.5 Primary and Secondary Education

It is noted that the existing school plant is over taxed and that space normally used for special purposes has been pressed into routine service, thus reducing the ability of the systems to offer the breadth and spectrum of courses that would normally be expected in a community of this size. The additional requirements needed between 1972 and 1979 are given in Table 2.10 and in view of existing shortages as well as the demand that would be created by the Syncrude operation, the need for early and rapid expansion of the System is very apparent.

TABLE NO. 2.10

FORT McMURRAY SCHOOL SYSTEM

TYPE OF CLASSROOM	1972 PROVISION	CURRENT REQUIREMENT BY 1979 *	SYNCRUDE PLANT REQUIREMENT	TOTAL 1979 CLASSROOM REQUIREMENT
Primary	56	56	63	119
Junior High	18	31	22	53
Senior High	11	30	16	46
TOTAL	85	117	101	218

* Current requirement by 1979 includes existing shortfall in provisions plus additional facilities required for children of existing families who will enter school between 1972 and 1979.

Reference is made to similar projections in the Fort McMurray General Plan and to the fact that the forecasted requirements given in Table 2.10 are somewhat higher than those in the General Plan. The higher numbers given in this study are derived from indications that the school population in 1979 will be in the 380 per 1000 population level rather than the 310 per 1000 population level used in the General Plan. Evidence of a much higher than normal family size can be seen in both the data provided respecting the Great Canadian Oil Sands workforce and in the 1971 Census.

2.6.6 Vocational Education

At the present time, the Alberta Vocational Centre in Fort McMurray has an "at any one time" capacity for 260 students. This capacity is used approximately half for academic upgrading and half for basic trade skills. It is understood that the Department of Advanced Education foresees a need for considerable expansion of these facilities which would not only continue and expand the academic upgrading and basic trade training, but would also include technical trade (para-professional) training and courses from which graduates could proceed directly to University. As a long term estimate, the total annual enrollment of such a College serving Northern and North-Eastern Alberta could reach several thousand (not all students coming from or going to work within the Fort McMurray region).

Syncrude Canada Limited has proposed that to facilitate greater participation by regional residents in their and other Company and agency employment forces that, Syncrude and other companies and agencies should actively support vocational or college institutionsin conjunction with government by the establishment of labour hiring and management procedures that encourage local labour participation and by inputs either financial, or by kind (i.e., use of plant and factory facilities for practical training). This would permit more local and regional labour resource potential to be tapped and what might be an overall regional shortage in the rate of supply of qualified personnel may thus, in part, be rectified.

2.6.7 Medical

In projecting additonal hospital requirements, it is assumed that the present utilization of beds for care of persons from remote and other situations who normally would be released for home care will be rectified by the provision of hostels, an auxiliary hospital or other facilities that would release hospital beds for "normal use". It is understood that it is possible to handle an increasing demand for beds in the hospital by adding temporary wings. These temporary wings would be utilized until the demand reaches a level justifying the provision of additonal permanent facilities. The existing hospital site has sufficient space to permit both additional temporary wings and subsequently a new permanent addition. Table 2.11 forecasts the hospital bed and professional staff requirements needed in 1979. It is reported that current plans for hospital expansion includes a provision for additional parking facilities.

TABLE NO. 2.11

MEDICAL FACILITIES

	HOSPITAL BEDS	DOCTORS	SURGEONS	DENTISTS
1972 Provision	54	4	1	3
1979 Requirement	108	7	1	6

2.6.8 Recreational Facilities

Table 2.12 indicates certain facilities which are generally considered desirable by various recreational authorities related to average communities of the size anticipated for Fort McMurray. The particular uniqueness of communities whose situation is "frontier in nature", very generally demands a higher level of facility than those indicated below. The level of facility achieved, however, is a direct function of the community interest of the residents of the particular area in question.

TABLE NO. 2.12

RECREATIONAL FACILITIES

ACTIVITY	IDENTIFIED 1972 FACILITIES	INDICATED 1979 REQUIREMENTS
Active Recreation Children's Play Area	2.3	7.7 acres
Field Play Areas Young Children		23.1 acres
Field Play Areas Older Children & Adults		23.1 acres
Tennis - Outdoor Basketball	1 court	3.1 acres
Swimming Pool (1)	1 pool indoor 250 capacity	1 - minimum capacity 200
Golf	1 - 9 hole course	1 - 18 hole course
Arenas, Artificial Ice - Indoor	1 with limited seating	1 with adequate seating
Natural Outdoor Rink	5 (varies)	3
Skiing	1	1 per region
Curling	4 sheets	8 sheets
Passive Recreation (2)		
Community Centre	1 with limited multi use capability	1 with multi purpose capability
Library	1 part-time	1 full time

NOTE: 1. The existing swimming pool is presently operating near capacity. Thus while, in a general sense, an additional pool for a 15,000 population level would not be required, the particular situation in Fort McMurray may, in fact, require such additional facilities.

2. The influx in any size of a population group of a particular ethnic background would likely lead to the need and development of special active or passive recreational and cultural facilities over and above the general forecast given in this table.

2.6.9 Cultural and Religious Facilities

Part I of this Study relates the situation as it presently exists within the community. All projections concerning the characteristics of persons who have not yet "arrived on the scene" are to some extent speculative in nature, but it becomes particularly hazardous to attempt to determine that newcomers will have a particular type of religious interest or cultural pursuit. In the case of Fort McMurray, the size of the forecasted influx of people is not such that average Alberta or other situations can be safely used as a sample standard.

In very general terms, one could expect the physical facilities serving cultural and religious groups could double in size and number from the present level. The range of activities, while not particularly becoming larger in number than those already found in town will however, intensify and increase their operations.

The creation and operation of any cultural or religious activity is very fundamentally of a "grass root" nature and public participation is usually limited to assistance in ensuring that land areas required are incorporated in the planning of new development areas.

2.6.10 Transportation

The present (1972) and forecasted (1979) internal local road traffic (Table No. 2.13) and Highway No. 63 traffic between Fort McMurray and the Great Canadian Oil Sands and proposed Syncrude plant site (Table 2.14) are based on the information obtained from the Alberta Deptartment of Highways, Great Canadian Oil Sands and its contractors and supplemented by statistical data developed for similar communities.

TABLE NO. 2.13

INTERNAL LOCAL TRAFFIC

(Existing and Forecasted)

YEAR	CARS PER 100 PERSONS	CAR REGISTRATION	TRIPS PER DAY PER PERSON	TRIPS PER DAY PER VEHICLE	TOTAL PER DAY PERSON TRIPS	TOTAL PER DAY VEHICLE TRIPS
1972 approximate population 7,000	35	2,500	2.3	3.5	16,000	9,000
1979, with no population increase	45	3,200	2.6	3.4	18,000	12,000
1979, forecasted population 15,500	45	7,000	2.6	3.4	40,000	25,000

TABLE NO. 2.14

EXISTING AND FORECASTED HWY. # 63 TRAFFIC
BETWEEN FORT McMURRAY AND THE G.C.O.S.
AND PROPOSED SYNCRUDE PLANT SITES

YEAR	SHIFT WORKERS FROM TOWN USING CARS			ONE WAY TRAFFIC		TOTAL TRAFFIC
	%	No./Car	Cars/Hr.	PEAK V./Hr.	AVERAGE V./Day	V./Day
1972	73	2.4	145	160	900	1,800
1978	74	2.2	460	500	2,800	5,600
1979	74	2.0	350	400	2,300	4,600

Table No. 2.13 provides a measure of the impact on the community in respect to car sales and servicing, and indirectly, on taxi and car rental businesses.

The internal localtraffic is forecasted to increase even if there is no population increase in Fort McMurray, which is similar to the experience of most North American communities. The forecasted internallocal traffic increase inFort McMurray for the period 1972 to 1979 is 33% if there is no population increase, and 280% if the proposed Syncrude development procedes to completion.

Because the location of new development areas is not yet determined, it is difficult to make any reliable allocation to specific internal roads of the forecasted traffice volumes. However, it should be expected that some existing roadways would have to be upgraded and that special attention should be given to the existing Athabasca River Bridge and approach roadways with respect to the combined effect of local internal traffic and Highway # 63 traffic to the north.

The forecasted Highway # 63 traffic is subject to considerable variation due to presently indeterminate factors such as :-

1. highway freight movement to Fort McMurray from the south and from Fort McMurray to the plant sites;

2. recreation and business trips from the plant site camps to the town and to Edmonton;

3. recreation and business trips to Edmontonby both temporary and permanent residents of Fort McMurray;

4. business and recreation trips to Fort McMurray from Edmonton and other centres.

Freight to Fort McMurray is estimated to be 300,000 tons per year and although any allocation between road, rail and air is somewhat speculative, this volume of freight movement would have a significant, but presently unmeasurable impact on both employment and road traffic.

Air carriers too would share in the projected freight movements, and as well, they would see a substantial increase in business and pleasure passenger traffic between Edmonton and Fort McMurray. It is expected that approximately one third of the construction work force living in the plant site camps would desire transportation (air or car) from Fort McMurray to Edmonton on Friday nights, and returning on Sunday nights. Business visitors will be looking to improved air travel time schedules and, incidentially,extendedhotel accommodations in Fort McMurray.

2.7 CONCLUSION

In general terms the impact of the proposed Syncrude project would to increase population by approximately 125% and the developed land area by 260% with the town maintaining many of the special characteristics presently found within the community due to the young age of many of its residents.

The following Tables 2.13 to 2.17 contain basic data supplied by Syncrude Canada Limited and giving their forecasts of the nature and characteristics of the labour force that would be employed at the proposed plant.

ESTIMATED SYNCRUDE EMPLOYMENT FORCE

TABLE 2.15 . TYPE OF EMPLOYMENT

TYPE	PERMANENT	TEMPORARY	TOTAL
Executive and Professional	54	0	54
Administrative	70	20	90
Clerical	69	5	74
Tradesmen and Technical	548	250	798
Semi-Skilled and Labourers	350	75	425
TOTAL	1,091	350	1,441

TABLE 2.16 SEX

TYPE	MALE	FEMALE	TOTAL
Executive and Professional	49	5	54
Administrative	90	0	90
Clerical	39	35	74
Tradesmen and Technical	798	0	798
Semi-Skilled and Labourers	425	0	425
TOTAL	1,401	40	1,441

TABLE NO. 2.17

ESTIMATED EMPLOYMENT FORCE

FOR SYNCRUDE CANADA LTD.

AGE AND MARITAL STATUS

Numbers by Employment Group, Age and Marital Status

AGE	Executive & Professional		Administrative		Clerical		Tradesmen & Technical		Semi-skilled & Labourers		TOTAL	
	Married	Single	Married	Single	Married	Single	Married	Single	Married	Single	Married	Single
Under 25					6	16	15	10	55	75	76	101
26 - 29					13	16	100	50	80	30	193	96
30 - 34		3	1	1	12		175	25	60	15	248	44
35 - 39	4	1	12	1	12		80	13	25	10	133	25
40 - 44	8	1	25				75				108	1
45 - 49	30		20				30				80	0
50 - 54	5		10								15	0
55 - 59	2										2	0
TOTAL	49	5	68	2	43	32	475	98	220	130	855	267

TABLE NO.2.18

ESTIMATED PERMANENT EMPLOYMENT FORCE

FOR SYNCRUDE CANADA LTD.

EMPLOYEE'S PREVIOUS LOCATION OF RESIDENCY*

TYPE	Fort McMurray Region** Native	Fort McMurray Region** Non-Native	Prairie Urban	Prairie Rural	Eastern Canada - Except French Speaking	Eastern Canada - French Speaking	British Columbia	U. S. A.	European	TOTAL
Executive & Professional		3	39	3	3		5		1	54
Administrative	2 - 4	7 - 13	41 - 49	4	4		4			70
Clerical	15 - 25	32 - 40	0 - 14	3 - 8						69
Tradesmen & Technical	66 -100	67 -115	98 -180	137	35		46	5	12	548
Semi-Skilled & Labourers	68 -100	75 -108	0 - 55	52	50	10	25		15	350
TOTAL	151*	184	337	204	92	10	80	5	28	1091

* These estimates are, to some extent, preliminary and speculative.

** Numbers of 'native' or other local source employees can go upwards from the minimum stated. Minimum figure represents estimated number of these currently available and trained for particular role. Higher local source employee numbers could result if local training programs are undertaken by Government.

FORT McMURRAY IMPACT STUDY

PART III

FORECASTED ADDITIONAL TAR SANDS DEVELOPMENTS AND THEIR POSSIBLE IMPACT ON FORT McMURRAY 1976 - 1981

FORT McMURRAY IMPACT STUDY
PART III
FORECASTED ADDITIONAL TAR SANDS DEVELOPMENTS AND THEIR POSSIBLE IMPACT ON FORT McMURRAY 1976 - 1981

3.1 INTRODUCTION

This part of the Study is a "futures forecast" developed from the best evidence that can be gleaned from a study of those aspects of developers' plans that have been made public, together with interviews carried out with the principals of potential development firms.

Forecasts of this kind should be read with caution and a full understanding of the limitations of forecasting as an art and science. Actual developments will be strongly influenced by changing local, provincial, national and even international conditions. In the light of these fluid variables, forecasts beyond the designated period - the present to 1981 - are unwarranted. Even then, forecasts should be seen as a planning device only.

In reviewing future tar sand plant development possibilities and their potential impact, several factors are of importance. In any final decision on whether a project proceeds into construction, consideration has to be given, by the developers involved, to the economics of the project, which includes assessment of the process economics itself, general market considerations, negotiations with Government concerning royalties, environmental guidelines and provincial investor participation, and to some extent, the decisions of other tar sand developers to proceed or not to proceed. Thus, the largest uncertainty surrounding future developments in the tar sands is the fate of the Syncrude project itself. Other developers are

cont'd-----

watching the progress of the Syncrude project with intense interest. The final decision on construction of the Syncrude project, due to be made by August 31, 1973, will have a critical bearing on the timing of other possible projects, indeed, on whether some other projects proceed at all.

Affecting this matter, too, is the fact that some of the projected plants propose use of "in situ" extraction rather than the "mining" process and as yet, the "in situ" technology has not been demonstrated to be commercially feasible.

3.2 POSSIBLE TAR SANDS PROJECTS BEFORE 1981 IN THE FORT McMURRAY REGION

The advent of further tar sands plants in the Fort McMurray region, especially those within commuting range of the Town, would have vary major impacts upon the future growth of the community. The purpose of this section of the Study is to assess the likely impacts these various possible future plants would have upon the community. With five possible plants, three of which are in the Fort McMurray region and each involving a possible work force of about 1,000 plus required support services and the families of all these workers, the population of Fort McMurray could, with the addition of each plant within commuting distance, grow by an increment equal to its present population.

The best available evidence indicates that there are five heavy oils or tar sands projects which have some possibility of being built or initiated by 1981. However, two are more than 100 miles from Fort McMurray and are discounted for the purpose of this Study. The available information is somewhat speculative and some of the potential developers concerned have not yet made public announcements regarding their plans. The most likely developments foreseeable at this time, are described below.

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The best current estimates of the capital, time and manpower that would be required to develop a tar sands project today, are those developed by and for Syncrude Canada Ltd. in the course of this Study. In calculating the capital, time and manpower requirements for future additional tar sands projects between now and 1981, these figures have been used as a "base case" roughly applicable to the development of other similar projects. In cases where developer companies have proceeded far enough to have generated their own specific cost, time and manpower data, these have been used; otherwise, the Syncrude "base case" data has been assumed.

<u>Development A</u> - The company estimates that it may proceed with a "mining" project and commence construction in 1975-76. Its construction work force would peak at approximately 1800 and its operational staff would number about 1000. It would be located approximately 45 miles north of Fort McMurray.

<u>Development B</u> - The company is currently undertaking pilot work and may be looking at an "in situ" project after 1980. It would involve a construction work force reaching 1800 in number and its operating contingent would consist of 720 operating and 200 contract workers. (For the purposes of this Study, an assumed commencement of construction in 1981 has been made by the consultant.) The plant would be located approximately 35 miles southeast of Fort McMurray.

<u>Development C</u> - The company is currently undertaking pilot work which may be expanded to about 50 workers in the period of 1975-77. Construction of an "in situ" operation might commence in or after 1980. The construction work force would peak at 1800 and operational staff are estimated at approximately 1000. The plant would be located approximately 10 miles south of Fort McMurray.

cont'd----

The question as to whether the operating staff of Development A would reside in Fort McMurray or would live in a community located closer to the plant will be difficult to resolve. This Study, therefore, examines the impact upon Fort McMurray in both situations, and in the latter case, assumes that the Town would be a regional centre servicing the smaller community.

3.3 THE EXPANDING CITY

To convert the foregoing crude data into numbers which indicate timing of construction work force peaks and operating staff build-up, the assumption has been made that construction of each plant would range over a 5 year period and would reflect the same profile of construction workers on site as has been estimated for the Syncrude project. Likewise, the estimated Syncrude performance in build-up of operational staff has been used for the purpose of this Study. This time period and profile is used on the basis that Developments A, B and C would, because of the time leads involved in negotiations and a shortage of availability of skilled labour, have to follow the estimated Syncrude timing rather than follow a shorter, more concentrated construction plan which would be possible if facilities for the training and supply of skilled labour were available. The assumption has also been made that the proposed Syncrude project and Developments A, B and C are all constructed to the indicated time schedule independently of any other project proposed to be underway during the same period of time. Hence, this part of the report shows the cumulative effect of all projects.

The forecasts made in this part of the Study have not been adjusted for the probable manpower and time scheduling problems which would result from competition for skilled labor if more than one major project is under construction at any one time. The competition for labour can result from conflicting time schedules for two major tar sands projects, or from time schedule conflicts between any one of the proposed tar sands

cont'd-----

plants, and one or more major developments such as another petroleum industry project, the MacKenzie Valley pipeline, MacKenzie Valley highway, and the James Bay project. Competition of this nature can have an important influence on costs and timing, and even on the final decision on whether or not a tar sands development proceeds into construction.

For the purposes of Part II of this Study, certain work force, family and land use indices were developed, taking into account the special characteristics of Fort McMurray, at this time, and the likely characteristics it would have at the 15,500 population level in 1979 (which population assumes Syncrude plant completion).

In developing indices (see Tables 3-1 and 3-2) for use beyond the 1979 population level generated by the Syncrude project, some basic assumptions are made. It is assumed that, if Fort McMurray continues to grow, the ratio of non-basic workers to basic workers will continue to increase as is exhibited in most Canadian cities. It is assumed that the number of non-basic workers required in Town to provide goods and services to construction workers living in camps will be the same as that used for the Syncrude project forecasts. Construction and operating forces are also assumed to have the same mix of married and single workers as were forecasted for the Syncrude project.

For the purposes of this Study, no allowance for natural population growth has been calculated. Any estimates of this phenomenon requires some input as to the family structure of the personnel which will be engaged for the forecasted additional tar sands development, which input is not availabe at this time.

Household sizes are assumed to be decreasing, reflecting a stabilizing and aging of the existing Town population, and a continued general fall in fertility rates. The effect of this assumption is that as Fort McMurray reaches a larger size, its age and family profiles will start to approach those applying to the Province as a whole.

cont'd----

TABLE NO. 3-1

WORK FORCE INDICES

Population Level	Ratio of Total Employment to Basic Employment
15,000 ±	1.61
21,000 ±	1.68
27,000 ±	1.75
33,000 ±	1.83

NOTE: For the purpose of forecasting the support (non-basic) employment force of Fort McMurray, as a regional centre servicing a separate community created for the work force of Development A, it has been assumed, respecting use of Table No. 3-1, that the ratio of support employment will be one-third of what it would have been if the work force for Development A was living in Fort McMurray.

TABLE NO. 3-2

HOUSEHOLD SIZE INDICES

Population Level	Household Size
15,000 ±	3.87
21,000 ±	3.75
27,000 ±	3.50
33,000 ±	3.25

NOTE: Table No. 3-2 assumes that, as higher population levels are achieved, the time span is moving from 1975 to 1985.

cont'd----

It is assumed that land use indices will continue to change towards reflecting the usual area requirements of a middle sized western Canadian city. Table No. 3-3 indicates the probable land use indices when Fort McMurray reaches a population of 30,000.

TABLE NO. 3-3
LAND USE INDICES FOR FORT McMURRAY
WITH A 30,000 POPULATION RANGE
(Gross Acres per 100 Population)

Total Residential	4.70
Commercial	0.32
Secondary Commercial Industry, Communication and Transportation	6.00
Parks and Recreation	3.13
Public and Semi-Public (Incl. Education)	1.53
Public Utilities	0.62
Total Developed Area	16.30

3.4 THE IMPACT

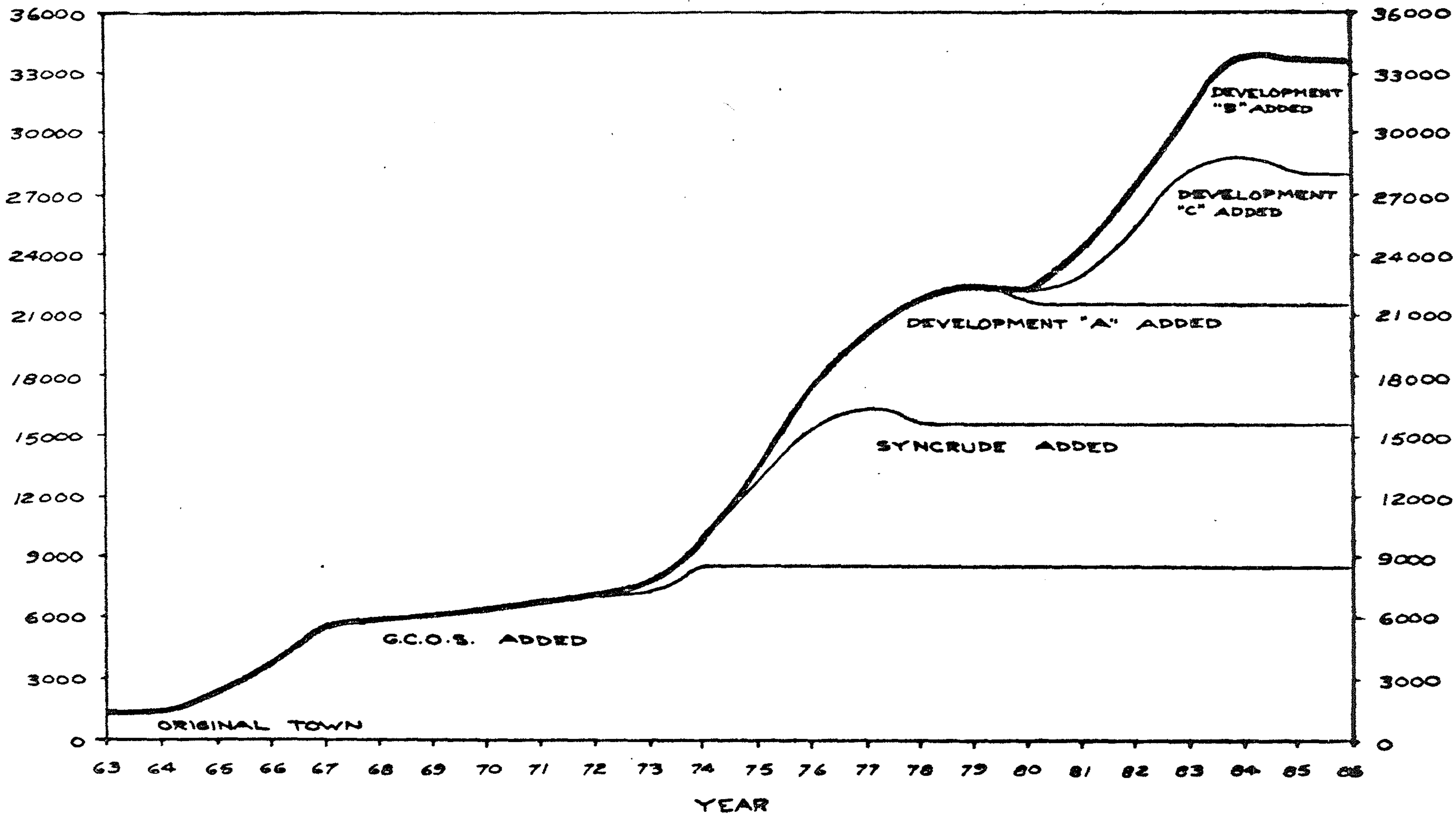
The impact of the successive construction of the proposed plants in terms of construction forces, operational staff, supporting (non-basic) employment, and the families of all of these groups, has been forecasted and is shown on Chart No. 3-1, which chart assumes that all new developments have their operational forces living in Fort McMurray, and on Chart No. 3-2, which assumes that Development A's operational force would live in a separate community.

cont'd----

CHART NO. 3-1

PROJECTED GROSS POPULATION OF FORT McMURRAY

(Assumes Operational Forces of Developments "A", "B" and "C" Live in Town)

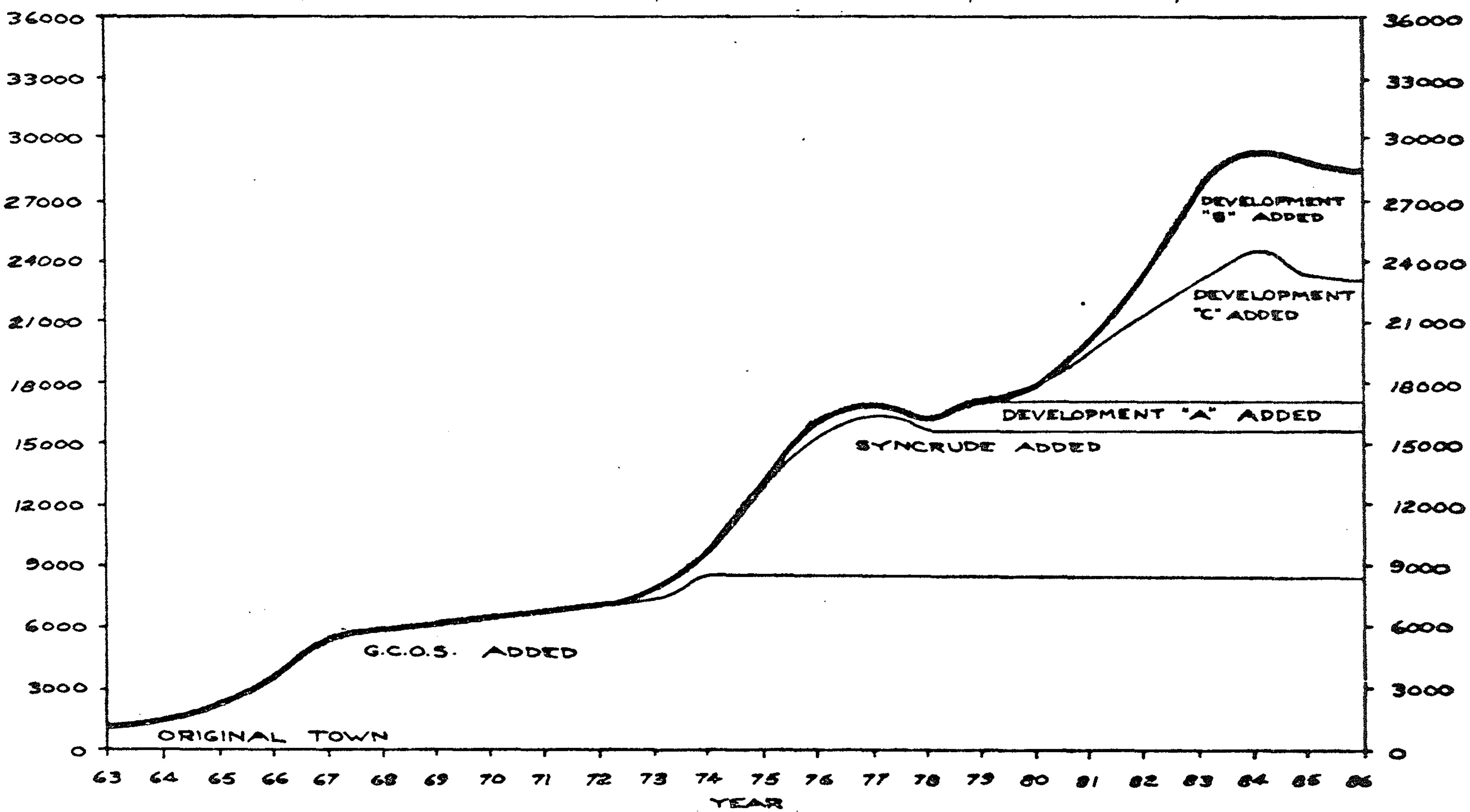


NOTE:
This chart does not include any natural population growth, and it is assumed that the Great Canadian Oil Sands Ltd. and Syncrude Canada Ltd. work forces living in Town will not change after 1974 and 1979, respectively. It is further assumed that no significant business activity will be initiated in the region during the forecast period.

CHART NO. 3-2

PROJECTED GROSS POPULATION OF FORT McMURRAY

(Assumes Operational Forces of Developments "B" and "C" Live in Town and Operational Force of Development "A" Lives in a Separate Community)



NOTE:
This chart does not include any natural population growth, and it is assumed that the Great Canadian Oil Sands Ltd. and Syncrude Canada Ltd. work forces living in Town will not change after 1974 and 1979, respectively. It is further assumed that no significant business activity will be initiated in the region during the forecast period.

It is emphasized that the charts are forecasts only, and that the achievement of estimated population levels is dependent upon the construction of any or all of the proposed plants (the Syncrude project, Development A, Development B and Development C), and that these forecasts may also vary according to future changes in the indices for both family sizes and support (non-basic) employment. The forecasts may further vary upon the occurrance of an expansion of the Great Canadian Oil Sands Ltd. plant, or upon the occurrance of industries providing secondary and support services to the community, and also, if any decision were made to construct and operate industries which process and manufacture products derived from the synthetic crude oil production in the Fort McMurray region. Apart from this latter variation, which could cause sizeable but unestimated population increases, other economic activities could occur within the region causing population increases, i.e. - increased forestry activity, metals fabrication, market gardening or greenhousing, major tourist development, etc.

The forecasted land use areas required in 1986, given in Table No. 3-4, are likewise subject to the foregoing described variations.

TABLE NO. 3-4

FORECASTED GROSS LAND REQUIREMENTS FOR FORT McMURRAY IN 1986

	Operational Work Forces of all Developments Living in Town	Development A Operational Work Force Living in Separate Community
	(Fort McMurray=32,500)	(Fort McMurray=28,500)
Total Residential	1,535	1,340
Commercial	105	90
Secondary Commercial Industry, Communication and Transportation	1,960	1,710
Parks and Recreation	1,025	890
Public & Semi-Public (Incl. Education)	500	435
Public Utilities	205	180
Total Gross Developed Acres	5,330	4,645

cont'd----

In summary, this part of the report forecasts that the Town of Fort McMurray could grow to the 30,000 population level by 1986 if all the described potential tar sand projects were developed within the commuting distance of the community, and it forecasts that the area of the Town developed for all urban uses and associated purposes could gross between 4,500 and 5,500 acres (i.e. - between 7 and 8 square miles).

In concluding this part of the Study, emphasis is again placed upon its purpose, namely, to provide a "futures forecast" of possible potential urban impact in the Fort McMurray region. The findings of this part, therefore, cannot be used to state, in any definite terms, the forecasted population sizes or land requirements.

SECTION 2.

WATER MANAGEMENT PLANNING -LEASES 17 AND 22

2. WATER MANAGEMENT PLANNING - LEASES 17 & 22

A. INTRODUCTION

The generalized concepts of water management planning were discussed in the overview, specifically in Section 3D. Two major elements of the overall plan now being considered in detail are sufficiently well defined to merit documentation in this planning stage of the Environmental Impact Assessment.

It has been found necessary to divert Beaver Creek which, at present, flows through the centre of the planned initial mining area and the area proposed for the retention pond. The distance from the lease boundary to the confluence with the Athabasca River is approximately sixteen miles. The project would effectively eliminate the lower reaches of Beaver Creek through the mining area, the retention pond and downstream as a result of the proposed diversion.

The first document included in this section is an application to the Department of The Environment for the diversion of Beaver Creek. This application completely details the plans, procedures and consequences of the diversion.

The second document is a report on the water supply system study. This study is included because of the magnitude of the water requirements for the project. The requirements, to be met by withdrawal from the Athabasca River, are for 50,000 USGPM during the initial three years of operation reducing to about 31,000 USGPM thereafter. These rates are required on a continuous basis in the periods indicated.
Note: Deletions from this report were necessary as they were inapplicable to the purposes of the document.

SECTION 2.

WATER MANAGEMENT PLANNING
-LEASES 17 AND 22

B. THE DIVERSION OF BEAVER CREEK

May, 1973

INTRODUCTION

Syncrude Canada Ltd. in its development plans for the mining area on Lease No. 17 finds it necessary to divert Beaver Creek. At present Beaver Creek flows through the centre of the initial mining area and the area proposed for the retention pond. The distance from the lease boundary to the confluence with the Athabasca River is approximately sixteen miles. This development will effectively eliminate the lower reaches of Beaver Creek through the mining area, the retention pond and downstream as a result of the proposed diversion.

Beaver Creek in a Regional Context:

Map measurements were carried out to ascertain the status of Beaver Creek in a regional context. Data were obtained from 1:50,000 scale maps and provide a generalized perspective of the relationship of Beaver Creek to other streams in the region. Within the fifty-mile radius of the Syncrude plant site there are twenty-nine streams, nine of which are accessible by automobile. These streams constitute a total estimated length of 2,308 miles. Of this amount, 34% are rivers larger than Beaver Creek; 28% are approximately the same size; and 38% are tributary streams. These figures have been corrected by using a meander factor of 1.6 per lineal mile of stream measured to obtain the actual length. The average meander factor is 1.6 for the larger streams and should be considered as an absolute minimum for smaller rivers, creeks and tributaries. The point of diversion is located in SW19-92-10-W4.

Beaver Creek Diversion--Description and Design Basis:

In this proposal, a dam will be built on Beaver Creek approximately 1500 feet downstream from the south boundary of the

Syncrude Lease No. 17. The crest of the dam will be elevation 1025. A canal joining Beaver Creek channel will be built which will divert water in a southeasterly direction through Ruth Lake towards the Poplar Creek basin. This will permit the use of a natural drainage channel (which is at present well vegetated) for temporary detention storage and slow velocity until the channel narrows and becomes the north fork of Poplar Creek. At this point another dam (crest elevation 1024) will be built to regulate the flow into Poplar Creek.

The invert elevation of the diversion canal is assumed to be 1010 feet. The bottom elevation of Beaver Creek is approximately 980'. This would result in a minimum impoundment on the Chevron lease. Maximum design flow through the canal will be less than 3,800 cubic feet per second on a 1:20 year basis. Ruth Lake is approximately 1,000 feet wide by 10,000 feet long by 6 feet deep, with present water elevation of 1013. Ruth Lake level will be maintained to preserve waterfowl habitat and minimize detrimental environmental effects.

This proposal is based upon the following assumptions:

1. It is desirable to limit storage of water from Beaver Creek and its tributaries to a minimum.
2. That an area of sufficient size acceptable to Chevron can be used for detention storage of the peak flows of Beaver Creek, and that the channel of the north fork of Poplar Creek is sufficient to handle the regulated flow so that in the fall of the year water retention in the impoundment

area will be minimal.

3. Some "trade-offs" between possible contamination and siltation may have to be made relating to the quality of the diverted water. At present, detailed examinations by soils consultants and hydrologists are being made to ensure the validity of our assumptions. The main channel of Poplar Creek should be able to carry sufficient volumes of water after some channel improvement to provide minimum fall retention storage, drop and control structures including a spillway and flip bucket.

4. If the Poplar Creek channel is to be utilized, it will be necessary to replace the large culvert on the road with a concrete bridge. This bridge will allow the migration of anadromous fishes to spawning grounds higher in Poplar Creek, a condition which is not possible with the present culvert.

5. This proposal also assumes some channel improvement on Poplar Creek east of the highway to assure passage of migrating Arctic grayling.

DESIGN CRITERIA

The design criteria and basic assumptions used in the development of the proposed scheme, attempts to minimize the cost without jeopardizing its safety. It becomes evident that the development of storage at the Beaver Creek Dam substantially reduces the outflow and thereby the size of the hydraulic conveyances and appurtenances.

Some of the assumptions and criteria in the development of this scheme have been noted.

1. Beaver Creek Catchment Area and Runoff

Area	127 sq miles
1:20 year runoff	140,000 AF
1:20 year peak flow	3,800 cfs
Gross storage	20,000 AF
Live storage	12,000 AF (drawdown elevation - 1013)

Drawdown to elevation 1013 was assumed so that the permanently flooded area would be minimum.

2. Beaver Creek Dam

Crest elevation	1025
Crest width	20 feet
Downstream slope	2:1
Upstream slope	3:1
Wave protection	Soil-cement 2 feet thick from elevation 1005 to top of dam
Freeboard	5 feet

The muskeg is stripped and a toe drain 5 feet thick by 30 feet in width, or one third the width of the base is constructed from a pervious material.

3. Diversion Canals and Drainage Ditches

Diversion Canal A:

Bottom width	10 feet
Side slopes	2:1
Invert elevation	1010

Spoil bank at least 25 feet from canal.

Diversion Canal B:

Bottom width	36 feet
Side slopes	2:1
Invert elevation	1000

300 cfs Drainage Ditch:

Bottom width	8 feet
Side slopes	2:1
Flow depth	6 feet
Freeboard	2 feet
Embankment width	6 feet

Muskeg stripped on downstream side and replaced with a compacted embankment.

500 cfs Drainage Ditch:

Bottom width	10 feet
Side slopes	2:1
Flow depth	7 feet
Freeboard	2 feet
Embankment width	7 feet

Muskeg stripped on downstream side and replaced with a compacted embankment.

4. Control Weir

Crest elevation	1013	
Upstream slope	5:1	12" gravel
Downstream slope	10:1	24" rip rap over 12" gravel
Stop logged section elevation		1010

5. Control Dam

Crest elevation	1024
Crest width	20 feet
Downstream slope	2:1
Upstream slope	3:1
Wave protection	Soil cement 2 feet thick over upstream face
Freeboard	4 feet
Low level outlet	24" pipe terminating in USBR type impact basin

The required slope for the drainage ditches is determined from Manning's formula from the expression:

$$S = \frac{v^2 n^2}{2.22\ R^{4/3}}$$

Where S - slope
n - Manning roughness assumed as 0.035
R - hydraulic radius in feet

Basis of design for drainage ditches was

$$Vs = CD^{\frac{1}{2}} \quad \text{(Kennedy)}$$

Where Vs - non scour velocity, fps
D - depth of flow in feet
C - Kennedy coefficient, assumed as 1.20 for the drainage ditches

6. Spillway

Head	200 feet
Length	1,000 feet
Width	12 feet
Height	4 feet
Manning 'n'	0.014
Rated capacity	900 cfs

The spillway chute terminates in a flip bucket.

ESTIMATED QUANTITIES

Items	Unit	Quantity
1. Beaver Creek Dam		
Muskeg Stripping	c.y.	140,000
Compacted Embankment	c.y.	300,000
Compacted Impervious Core	c.y.	180,000
Gravel for Toe Drains	c.y.	40,000
Soil-Cement for Slope Protection	c.y.	22,000
2. Control Dam		
Muskeg Stripping	c.y.	50,000
Compacted Embankment	c.y.	270,000
Gravel for Toe Drains	c.y.	3,000
Soil-Cement for Slope Protection	c.y.	7,000
Reinforced Concrete for Intake Manhole & Impact Basin	c.y.	60
24" Dia. Concrete Pipe	L.F.	1,200
3. Control Weir		
Common Excavation	c.y.	100
Rip Rap, 18" thick	c.y.	500
Pit Run Gravel	c.y.	300
Reinforced Concrete	c.y.	60
4. Spillway, Flip Bucket & Spillway Canal		
Muskeg Stripping	c.y.	15,000
Common Excavation	c.y.	25,000
Gravel Backfill	c.y.	1,000
Reinforced Concrete	c.y.	700

5. Diversion Canals

Muskeg Stripping	c.y.	75,000
Common Excavation	c.y.	120,000
Compacted Embankments	c.y.	70,000

6. Drainage Ditches

Muskeg Stripping	c.y.	350,000
Common Excavation	c.y.	120,000
Compacted Embankments (incl. 50% Borrow Material)	c.y.	200,000

7. Allowances

Poplar Creek Channel Improvements	$100,000
Highway Bridge	$150,000

Area Solution to Drainage Problem of Beaver Creek:

Any diversion of Beaver Creek requires some detention storage if the scheme is to be at all economic. Syncrude has been in consultation with the adjacent leaseholder, Standard Oil of B. C. Ltd. (Chevron) and the two companies are working out a joint agreement for the proposed detention storage and water regulation structures.

Chevron voiced no objection to flooding Beaver Creek basin south of the boundary of Lease 17. It was evident from the discussion that the Chevron staff definitely favors our present scheme over others examined.

Mr. McNamara indicated that they would be willing to share construction costs of the Poplar Creek drainage work at such a time as they might be required to use it. They would also be willing to contribute to an area solution and those related costs, but the timing at present is poor; also, they did not want to make expenditures ahead of actual need.

We are now reviewing our position in this matter in order to finalize the best drainage scheme and then commit it to writing as soon as possible with respect to presentation to both the government and Chevron. Lead time for the legal arrangements must be given consideration.

ENVIRONMENTAL CONSIDERATIONS

The upper section of the stream is composed almost entirely of slackwater flowing over heavily silted substrate. Slackwater is evenly flowing smooth-surfaced water and is the characteristic stream type upstream at a distance of greater than ten miles from the confluence with the Athabasca. In the lower ten miles of the stream, the gradient becomes steeper resulting in alternating riffles and long pools. The sinuousity ratio at the stream is quite high when evaluated by the formula: Stream length $\div$ valley length.

In the fast water areas, adjacent banks are steep and heavily wooded. White spruce (*Picea glauca*), Bog birch (*Betula glandulosa*), and poplar (*Populus* spp.) are the dominant trees. Further upstream, willow (*Salix* spp.) gradually replaces birch as the dominant brush species. Throughout all areas, Reed canary grass (*Phalaris* spp.) grows along the stream bank as well as clumps of other reed grass (*Calamagrostis* sp.). For the most part, the banks which support this vegetation are well-covered and stabilized. The area will be cleared prior to flooding.

ENVIRONMENTAL STUDIES

In 1971 an aerial survey of the creek was carried out to ascertain its general habitat characteristics. The aerial survey encompassed the upper reaches of the stream and its tributaries. Ground access to some sections of the stream were impossible at this time of year; however, a series of nine sample stations was established along the stream at one mile intervals beginning at the south lease boundary. The stations were marked with wooden stakes with a total length of each station comprising 200 feet of stream. Transects of 90 degrees across the stream at the upper, lower, and middle sections of the stations were used for sampling purposes. At each transect, physical and chemical measurements were made. Width was measured to the nearest foot at the existing water line and depth to the nearest inch to assist in determining the average depth of the stream. Pool depths were similarly measured at all sample stations.

Two classes of water surface were established: pools and riffles. The designation of a pool was largely subjective. Pool quality classes were designated on the basis of pool size, water depth and fish shelter as described by Herrington and Dunham (1967). Six types of bottom material were noted and recorded as follows:

1. Debris
2. Silt
3. Sand
4. Gravel--rocks .1 to 2.9 inches in diameter
5. Rubble--rocks 3 to 11.9 inches in diameter
6. Boulder--rocks greater than 12 inches in diameter.

Banks were rated as stable or unstable with one, two, or three points assigned depending on stability. Bank ratings are subjective and based upon the amount of vegetative cover and fish shelter they provide.

The chemical environment was sampled for dissolved oxygen, methyl orange alkylinity, total hardness and pH, using Hach chemical kits. Total dissolved solids were measured with a conductivity meter. Continuous water temperatures were recorded with a Taylor maximum-minimum thermometer read every two days. When collecting fish, temperatures were measured with a pocket thermometer.

To assess food availability drifting organisms were sampled in two riffles. Each riffle was sampled with two one-millimeter mesh nets having a mouth size of one foot by two feet. Drift samples were gathered in the net for twenty-four hours. Nets were emptied at three-hour intervals. To determine the effect of tar sand substrate on insect production as well as to quantify the production of bottom fauna in the stream, eight twelve-inch by twelve-inch bottom samples were taken. Four samples in tar sand rubble substrates and four in areas of rubble substrate were taken to allow comparison of the number of organisms in the two substrates. This procedure was carried out twice during the study period. All organisms collected were sorted, classified by order, counted, and their volumes measured.

Water Quality Data:

Available water quality data are not numerous. The following pages give results for several spot samplings of Beaver Creek and the Athabasca River and also Poplar Creek. These samples were not made during the 1971 Study *per se*. Note that in general, Beaver and Poplar Creeks have higher contents of dissolved solids than the Athabasca River.

The high phenolic content found in Beaver Creek is interesting. Is this from oxidation of tar sand in the creek bed? The result should be verified as the stream above the sample point has had little or no human disturbance.

1. The phenol conc. of Beaver Creek (0.12 mg/l) is above standards (0.005 mg/l).
2. A large NH_3 difference exists between sample points on the Athabasca bridge and dock.
3. The C.O.D. at each sampling location is quite high.
4. The T.O.N. numbers at the Bridge (3) and Dock (10) are substantially different.
5. The color no. at Beaver Creek is 60 and at MacKay River, 80.
6. No sulfides at any location could be found.

RESULTS

Physical Habitat:

From the aerial survey it was observed that Beaver Creek is divided into two major habitat zones. The first, extending from its confluence with the Athabasca River upstream ten miles, is characterized by good riffle-pool separation and generally fast flow. The second, extending from that point to the headwaters, consists almost entirely of slow moving slackwater. The only exceptions were three small riffle areas approximately 40 miles from the confluence. The upper areas of the stream were more open than the lower areas and were heavily populated by beaver as evidenced by the many beaver dams observed.

Between its confluence and the south lease boundary, the river is sixteen miles in length, has an average width of 33 feet and an average depth of 28 inches (Table 1). These values represent close to minimum dimensions for this stream since data was collected during the seasonal low flow period.

Pool areas are generally regarded as ideal habitat for most fish species. In the area surveyed, 68% of Beaver Creek was classified as pool. Seventy-nine percent of the total pools, scored as quality Class I (Appendix II).* Only three percent of the pool areas were assigned to a quality class lower than Class III (Fig. 4).

Silt was the predominant substrate type present, comprising 48% of the total bottom area sampled (Fig. 4). Conversely ideal spawning habitat for Arctic grayling, i.e.; sand and/or gravel, comprised six percent of the total habitat sampled.

The study area included portions of both habitat zones previously mentioned. The upper zone, which includes the river above the plant site, exhibits a rather uniform gradient consisting of slackwater flowing over heavily silted substrate. The second zone from the test pit area downstream to Beaver Creek recreational area, has a moderate gradient, generally fast flow and a series of pools and riffles with boulder and rubble substrates (Fig. 5).

The calculation of habitat percent of optimum is a measure of the suitability of the stream to salmonid production. A perfect score of 100% indicates the stream has a perfect environment for salmonid species. Beaver Creek percent of optimum scored at 55% (Appendix I). This low rating was due primarily to the high proportion

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*Quality classes are assigned on the basis of several habitat criteria. These are presented in detail in Appendix II.

of slackwater in the river and scores calculated for stream bottom characteristics. A score of 55% indicates Beaver Creek is not a good stream for salmonid habitat even though abundant bank cover is present.

Water Chemistry:

Total dissolved solids were quite high in spite of their fluctuations throughout the length of the stream. Alkalinity, hardness and pH remained fairly constant while dissolved oxygen fluctuated with the type of water habitat (Fig. 2, 3). In slackwater sections of the stream the oxygen content was low with a saturation of 43% recorded at one point. Values for the lower portions of the stream (more riffle area) increased to a high saturation of 115%. In general, the percent of saturation was low for a stream of this type.

The average recorded water temperature during the study period was 62.8^{O}F with a maximum recorded temperature of 71^{O}F and a minimum recorded temperature of 57^{O}F. These temperatures are within the tolerance range of salmonid species (Fig. 1).

Invertebrate Sampling:

Repeated benthic sampling revealed seven orders of invertebrates present in riffle areas of Beaver Creek (Table 2). The order Trichoptera (Caddis flies) were by far the most numerous followed by the order Diptera, Coleoptera, and Ephemeroptera.

In Beaver Creek the mean volume for the sixteen bottom samples measured 0.6 cc. and the average number per square foot 23 indicating that insect production is extremely poor. Two factors which may account for the low insect production observed are:

a) The presence of a tar sand substrate in many of the riffle areas.

b) Heavily silted slackwater stretches.

An average of three times as many organisms were found in riffle areas with rubble substrates compared to riffle areas with a tar sand substrate (Fig. 6). Similar results are shown with volumes of insects (Table 3). The actual proportions of the stream with a tar sand substrate could not be ascertained in the present study.

Five orders of aquatic insects (Coleoptera, Diptera, Plecoptera, Ephemeroptera and Trichoptera) composed an average of 94% of the total drift numbers in a 24-hour drift net set (Table 4). Aquatic insects exhibited the alternans* pattern of nocturnal activity with a major peak in numbers occurring in the 2:00 a.m. sample (Table 3), (Fig. 7). Therefore, the majority of aquatic insects entered the drift nets when they were probably unavailable to actively feeding grayling.

RECREATIONAL USE OF BEAVER CREEK

Beaver Creek was utilized solely by the people of the Fort McMurray area during the survey period. No people from outside the Fort McMurray area were noted in data collected from the six days of the use count.

Fishing was the major form of recreational use on four of the six days with a mean of 26 angler hours per week recorded--all confined to the weekend. Camping and picnicking were the next most important recreational uses. These were observed on both weekdays and weekends (Table 1). It should be noted that present recreational use of the stream is restricted by access to two locations, the first at the recreation area, five miles above the confluence, on the road to Fort McKay and the second two miles south of the recreation area near sample station number seven.

Fish Composition:

Samples of fish population composition were taken at locations over 16 miles of the river encompassing the lease area and downstream. Species of fish collected were:

Lake Chub, *Couesius plumbeus* (Agassiz)
White Sucker, *Catostomus commersoni* (Lacepede)
Arctic Grayling, *Thymallus arcticus* (Pallas)

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*Greater activity during dark periods.

Burbot, Lota lota (linnaeus)
Slimy Sculpin, Cottus cognatus (Richardson)
Northern Pike, Esox lucius (Linnaeus)

The relative abundance of six species of fish sampled by prima cord explosives is indicated in Fig. 8. Lake Chub were the most numerous species, comprising 50% of the total sample. Chub and suckers together constituted 88% of fish collected. The total number of fish sampled was 659. Chub ranged in size from 1½" to 4½" and suckers were from 1½" to 12" long. The majority of suckers were in the smaller size ranges.

Of the five major habitats samples (slackwater, pools riffles, backwater, and beaver dams), only two mature grayling* out of a total of 59 specimens were collected. These were taken from pool areas. Chub and suckers occurred in all water types (Fig. 9). Pools were the most productive areas for fish with an average of 25 fish collected per blast. Backwater areas were least productive with an average of 0.8 fish per blast.

The density of young-of-the-year and age I+ Arctic grayling is related independently to depth, substrate, and water type when density is related to the individual parameter. Since there is a correlation between parameters, e.g.; rubble substrate associated with riffle, the separation of habitat for individual analysis does not represent the actual pattern of habitat occupancy. However, it allows comparison of immature grayling for each parameter and time. Univariate analysis (i.e.; one independent variable vs. the dependent variable) demonstrates the importance of sand and pools as variables influencing young-of-the-year grayling density in August (Table 6). Brown (1938) and Ward (1951) reported grayling spawned in sand and fine gravel respectively. It is in these areas where most young-of-the-year were found. Grayling of age I+ on the other hand showed a clear preference for rubble substrate but other parameters were not as

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*12" and 13" in size.

well defined as to preference.

The length frequencies of immature grayling collected in the Beaver Creek formed three distinct modes when plotted. The modes measured 1½", 3-3/4" and 7" respectively and represented the total lengths of age groups 0+, I+, and II+.

Gillnetting of Mildred Lake resulted in five white suckers being taken in 3½" stretch mesh net. These fish averaged 14" in length. Using prima cord sampling, 197 lake chub (average size 2") and 29 brook stickleback, Culaea inconstans (Kirtland) were obtained. In neither instance were sport fish found in Mildred Lake. It is doubtful if sport fish would overwinter in Mildred Lake in any event because of its shallowness. Horseshoe Lake could not be sampled due to the heavy weed growth covering the lake's surface. This made conventional sampling methods impossible.

BEAVER CREEK AS FISHERIES HABITAT

Results of this study indicate fisheries habitat in Beaver Creek is marginal for sport fishes, in particular Arctic grayling. The stream ecosystem appears quite stable and does not appear to have undergone any major changes in the past few years which would affect fish populations. Since the habitat rating derived in the present study differs from that presented by Robertson (1970) this aspect warrants separate discussion.

Habitat Ratings:

The 1970 study established a habitat rating of 70% of optimum and concluded the stream had excellent potential for salmonid production. In contrast, the current study has derived a value of 55%, or low quality rating for salmonid production. The discrepancy is due primarily to the higher pool area (68%) calculated in the present study. More slackwater areas, which are classed as pools, occurred at stations* established in this study, hence a larger pool environment (Appendix I). The lower reaches contain a much more favorable pool to riffle ratio,

*Stations were set at one mile intervals to avoid biases.

however the rating includes the entire area of the stream to be altered by the development. The aerial survey revealed slackwater as the predominant habitat type extending some 30 miles upstream from the plant site. However, data presented in this report are accurate only for the study area and the foregoing is a general observation of the major habitat condition upstream on the stream.

We do not feel that differences in flow conditions between the time of the two studies are a significant factor influencing the habitat rating since pool:riffle separations are most evident during low water conditions which prevailed at the time of the survey.

Beaver Creek exhibits streamflow patterns typical of most small streams--high spring discharge, then dropping steadily throughout the summer except during periods of high precipitation when they rise slightly. Fluctuating water levels destroy bottom organisms, lowering the productivity of a stream. However, in general we consider that other factors discussed in this report have a more significant bearing on the fisheries of the creek than does the flow regime.

The chemical environment of the river appears stable except for dissolved oxygen values which are minimal for salmonids in the slackwater. Total dissolved solids can be considered as a gross measure of the primary production of a stream. Generally, high productivity is associated with high total dissolved solids. Total dissolved solids vary according to many factors and differences in values between the 1970 study and current data can be attributed to the time of year. However, both studies indicate relatively high T.D.S. values. These values of potential productivity are not reflected in actual fisheries production. This is attributed to habitat factors such as the pool:riffle ratio, generally low substrate quality and low dissolved oxygen values at certain times of the year.

Sport Fisheries Potential:

Forage and coarse fish are the most abundant species in Beaver Creek. Suckers and chub represent 88% of the total species composition and we conclude that these are the major species present in the stream. Of the fish collected, grayling and pike are considered sport fishes. However, both species were negligible in occurrence. Arctic grayling, of catchable size, which can be considered the most desirable species present, represented less than one percent of the fish taken.

Available data are insufficient to quantify factors limiting grayling. However, we believe that a combination of habitat and food restrictions are the main limiting factors.

Arctic grayling require small gravel or sand substrates on which to spawn. This type of substrate on Beaver Creek is estimated at 5% of the total streambed, confined mainly to the lower reaches. Silt substrates, which are unsuitable for the survival of grayling eggs, are estimated at 50%, mainly occurring 10 - 40 miles upstream where the river is almost entirely slackwater. Data on water chemistry indicated low dissolved oxygen concentrations occur in the slackwater areas. Concurrent with dissolved oxygen values as low as 4 ppm., saturation values as low as 45% were recorded. Six ppm. and 65% saturation was the most common condition. These low values likely result from a combination of factors including:

a) Abundant streamside cover which may inhibit wind action.
b) The low gradient of the stream in its upper reaches.
c) The presence of numerous beaver dams which would tend to produce low oxygen concentrations.

Composition of benthic invertebrate samples indicate food may be limited in Beaver Creek. Robertson (1970) found low numbers of benthic organisms and attributed it to sampling phenomenon. Our sampling also produced low numbers in both rubble and tar sand substrate. Since the two independent samples agree with one another, it is likely that insect production is actually low rather than a sampling phenomenon. Numbers of insects in drift samples support this interpretation. Production of benthic organisms in riffle areas over rubble-tar sand substrates was negligible, while over straight rubble areas invertebrate numbers increased by a factor of three to five times. However, in terms of volume and numbers, invertebrate production is generally low.

THE ECOLOGICAL IMPACT OF THE TAR SANDS DEVELOPMENT ON BEAVER CREEK

Evidence collected during this study indicates that Arctic grayling production is low, however this species utilizes Beaver Creek as a spawning and rearing area. The presence of young-of-the-year fish all taken from similar habitat is evidence of a spawning run. Since grayling are a spring spawning species, no indication of the size of the run could be obtained from our investigation. Presumably adult fish move up Beaver Creek from the Athabasca River in the spring, spawn, and then return gradually to the Athabasca. The majority of this habitat occurs in the lower ten miles where pool-riffle ratios, cover, and substrate are favorable. The construction of a retention pond and dam upstream of the recreation area would eliminate the main rearing area mentioned and effectively obstruct any spawning migrations into the upper reaches of the stream, thus eliminating the existing grayling population.

The impact on other fish populations would be similar downstream of the dam. In the upper reaches the impact of the Beaver Creek dam and diversion would not likely affect existing populations of suckers and chub.

Studies of the extent of spawning in Beaver Creek and the tagging and subsequent tracing of fish movements are being carried out beginning 9 April 1973. A supplemental report to be added to this application will follow when results are known.

HYDROLOGY

For Beaver Creek partial flow data are available from the Water Survey of Canada for the period 1961 to 1966, and the data for 1961 - 1965 follow. The highest flow measured was 314 cfs. on

May 9th, 1962.

Other estimates from culverts and water level indications on the stream bank exceed 2,000 cfs. but are less than 5,000 cfs. A rough estimate from regional precipitation data and generalized correlation by D. Milliken of Bechtel (personal communication February, 1973) suggested that the 100-year flood flow could be as high as 8,000 cfs. This is based on a 4" summer rain over a period of three hours.

For the Beaver Creek Diversion study by Canadian Bechtel of January 10th, 1973, a maximum flow of 3,000 cfs. and a flood volume of 12,000 acre ft. were used.

A hydrological study to estimate the flood flow and volume to be used for the Beaver Creek Diversion is being carried out by LGL Environmental Research Associates to confirm the feasibility of the diversion.

TABLE 1

SUMMARY OF BEAVER CREEK, PHYSICAL CHARACTERISTICS, AUGUST 1971

Number of Stations	9
Length of Stations	200'
Average Depth	28"
Average Width	33'
Adjusted Stream Length	16 miles
Riffle Area	32%
Pool Area	68%
Total Length of Pools	1,471'
Maximum Possible Points for Bank Observations	36
Total Points for Bank Observations	26
Estimated Amount of Gravel	30'
Estimated Amount of Rubble	540'
Streamside Vegetation	
Forest	24%
Brush	42%
Grass	34%

TABLE 2

SUMMARY OF BENTHIC ORGANISMS BY NUMBER
IN SIXTEEN SQUARE FOOT BOTTOM SAMPLES
FROM BEAVER CREEK, AUGUST 1971

Group Sampled	Number	Number/Square Feet
Order Trichoptera	197	12.3
Order Diptera	51	3.2
Order Coleoptera	46	2.9
Order Ephemeroptera	34	2.1
Order Plecoptera	23	1.4
Class Oligochaeta	13	0.8
Class Arachnida	4	0.3
TOTAL	368	23.0

Numbers alone do not provide an adequate supply; volume is also an important consideration. Standards of richness have been developed as an aid in classification of stream as to food supply (Lagler, 1956). This classification is as follows:

FOOD GRADE I: (Exceptional richness)
Volume $\geq$ 2 cc., numbers $\geq$ 50/sq. ft.

FOOD GRADE II: (Average richness)
Volume 1-2 cc., numbers $\geq$ 50/sq. ft.

FOOD GRADE III: (Poor in food)
Volume $<$ 1 cc., and/or numbers $<$ 50/sq. ft.

TABLE 3

SUMMARY OF INSECT SAMPLING VOLUMES (cc.)

BEAVER CREEK, AUGUST 1971

A. Surber Samples (taken August 11th, 20th)

		Tar Sand Substrate (cc. per sq. ft.)	Rubble Substrate (cc. per sq. ft.)
August 11th Samples:			
	1	Trace	1.0
	2	Trace	1.0
	3	0.2	0.4
	4	0.1	0.6
August 20th Samples:			
	1	Trace	1.3
	2	0.1	1.5
	3	Trace	1.1
	4	0.1	0.9

B. Drift Samples (taken August 11th)

Time Sample Taken	Terrestrial Insects	Aquatic Insects	Total
2:00 p.m.	1.4	1.0	2.4
5:00 p.m.	0.4	0.8	1.2
8:00 p.m.	0.9	0.4	1.3
11:00 p.m.	0.6	1.9	2.5
2:00 a.m.	0.1	1.3	1.4
5:00 a.m.	0.4	1.4	1.8
8:00 a.m.	0.6	0.6	1.2
11:00 a.m.	0.4	0.2	0.6

TABLE 4

NUMBER OF DRIFT ORGANISMS TAKEN IN FOUR NETS SET 24 HOURS AND EMPTIED EVERY THREE HOURS, BEAVER CREEK, AUGUST 1971

Terrestrial Orders Occurring in Drift Nets	No.	Aquatic Groups Occurring in Drift Nets	No.
Hymenoptera;		Order Coleoptera (adult)	66
Fam. Formicidae	52	Order Trichoptera	51
Fam. Apidae	2	Order Diptera	41
Diptera	19	Order Ephemeroptera	39
Hemiptera	18	Order Plecoptera	25
Arachnida	5	Order Coleoptera (larvae)	15
Lepidoptera	3	Order Hemiptera	7
Trichoptera (adult)	1	Order Arachnida	4
Odonata	4	Platyhelminthes (Flatworms)	3
		Order Odonata	1
TOTAL	104	Class Hirudinea	1
		TOTAL	253

TABLE 5

SPECIES DISTRIBUTION ACCORDING TO HABITAT TYPES,

BEAVER CREEK, AUGUST 1971

A. Water Type

Species	Slackwater	Riffle	Backwater	Beaver Dam	Pool
Grayling	0%	12.5%	3.5%	0%	84.0%
Chub	19.0%	5.0%	0%	6.5%	69.5%
Sucker	19.0%	3.5%	0.5%	70.0%	70.0%
Other	0%	25.0%	0%	0%	75.0%

B. Water Depth

Species	1'	2'	3'	4'	5'
Grayling	31.5%	5.0%	58.5%	0%	5.0%
Chub	14.0%	9.0%	74.0%	24.0%	10.0%
Sucker	16.0%	11.5%	57.0%	9.5%	6.0%
Other	37.5%	0%	50.0%	12.5%	0%

C. Substrate Type

Species	Silt	Sand	Gravel	Rubble	Boulder
Grayling	17.0%	64.0%	0%	22.0%	17.0%
Chub	35.0%	2.0%	9.5%	43.0%	10.5%
Sucker	27.0%	11.0%	5.0%	37.0%	20.0%
Other	0%	50.0%	12.5%	25.0%	12.5%

TABLE 6

OCCURRENCE OF IMMATURE ARCTIC GRAYLING
IN THREE HABITAT PARAMETERS,
BEAVER RIVER, AUGUST 1971

Age Group	Water Type			Depth (feet)					Substrate		
	Backwater	Pool	Riffle	1	2	3	4	5	Sand	Silt	Rubble
0+	1	31	-	4	-	28	-	-	32	-	-
1+	-	9	7	11	1	1	-	3	1	3	12

TABLE 7

SUMMARY OF RECREATIONAL USE OF BEAVER CREEK DURING AUGUST, 1971

	Fishing			Other Recreation*		
Sample Week:	1	2	3	1	2	3
Estimated Hours On:						
a) Week-ends	22	30	36	14	0	136
b) Week-days	0	0	0	36	0	0
TOTAL HOURS	22	30	36	50	0	136

*Includes camping, picnicking and other outdoor recreation.

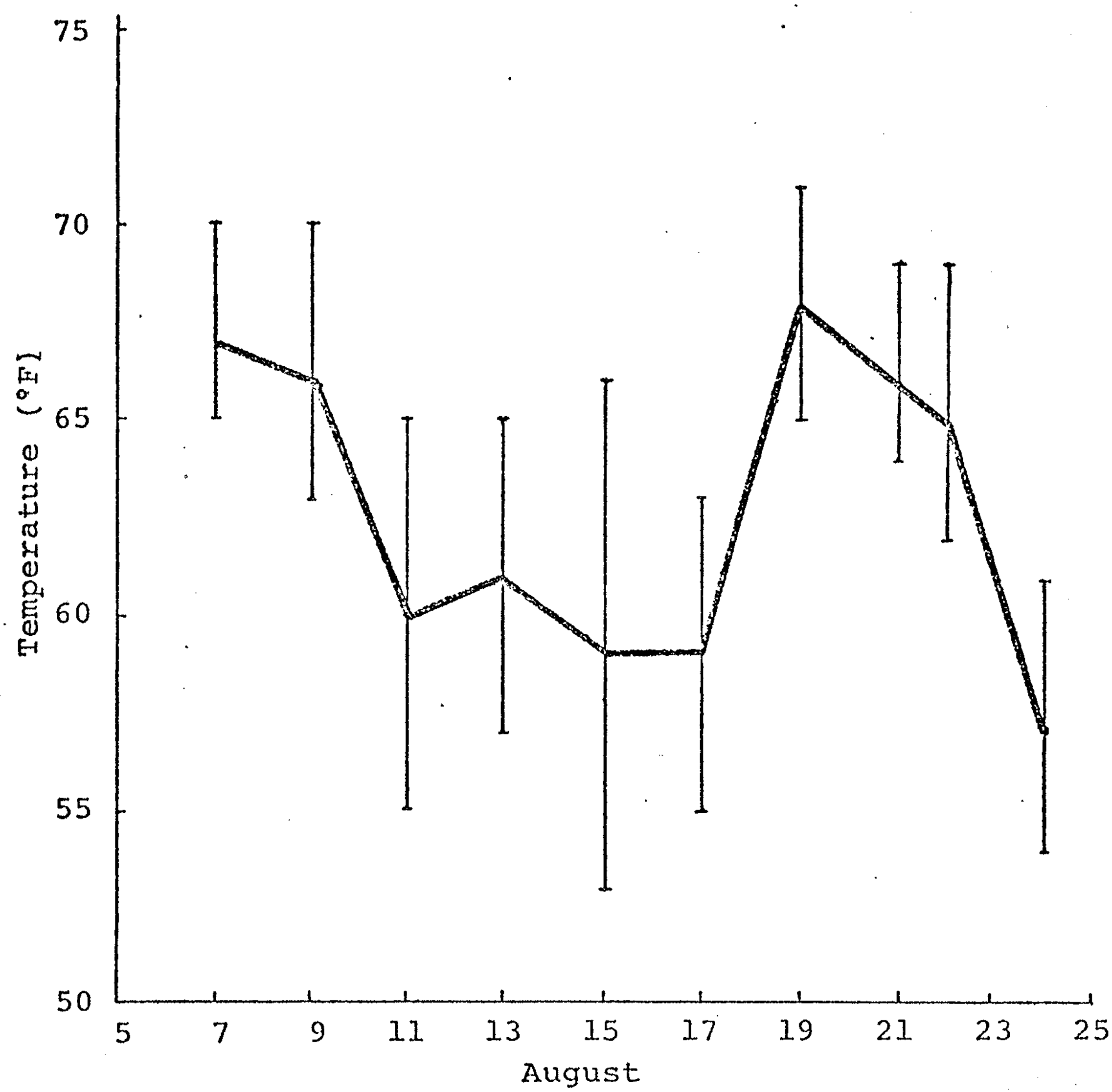


Figure 1: Mean Water Temperature with maximum - minimum values indicated, Beaver Creek, August 1971.

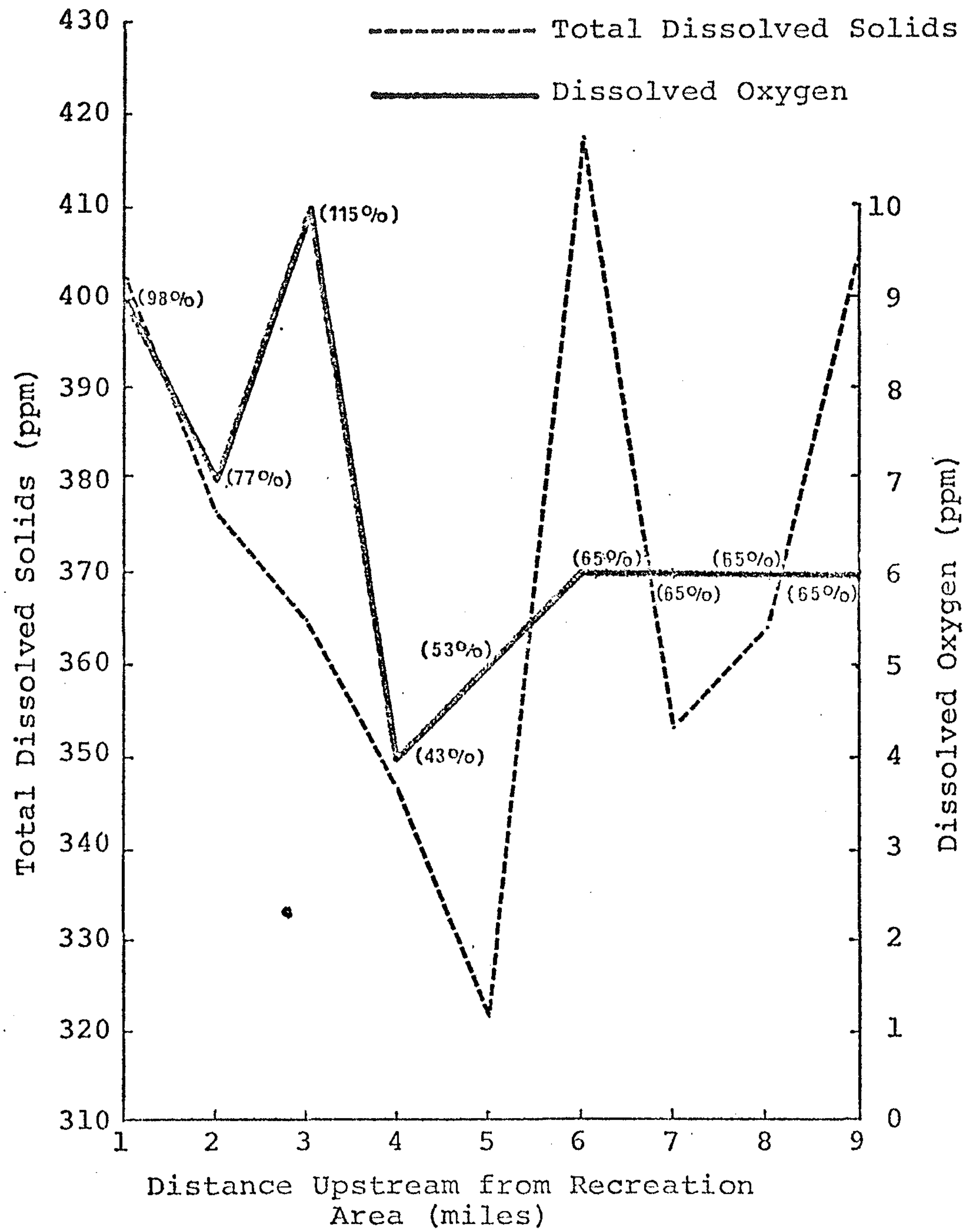


Figure 2: Total dissolved solids (25°C) and dissolved oxygen concentrations in Beaver Creek, August 1971. Percentages indicate the amount of oxygen saturation in the sample.

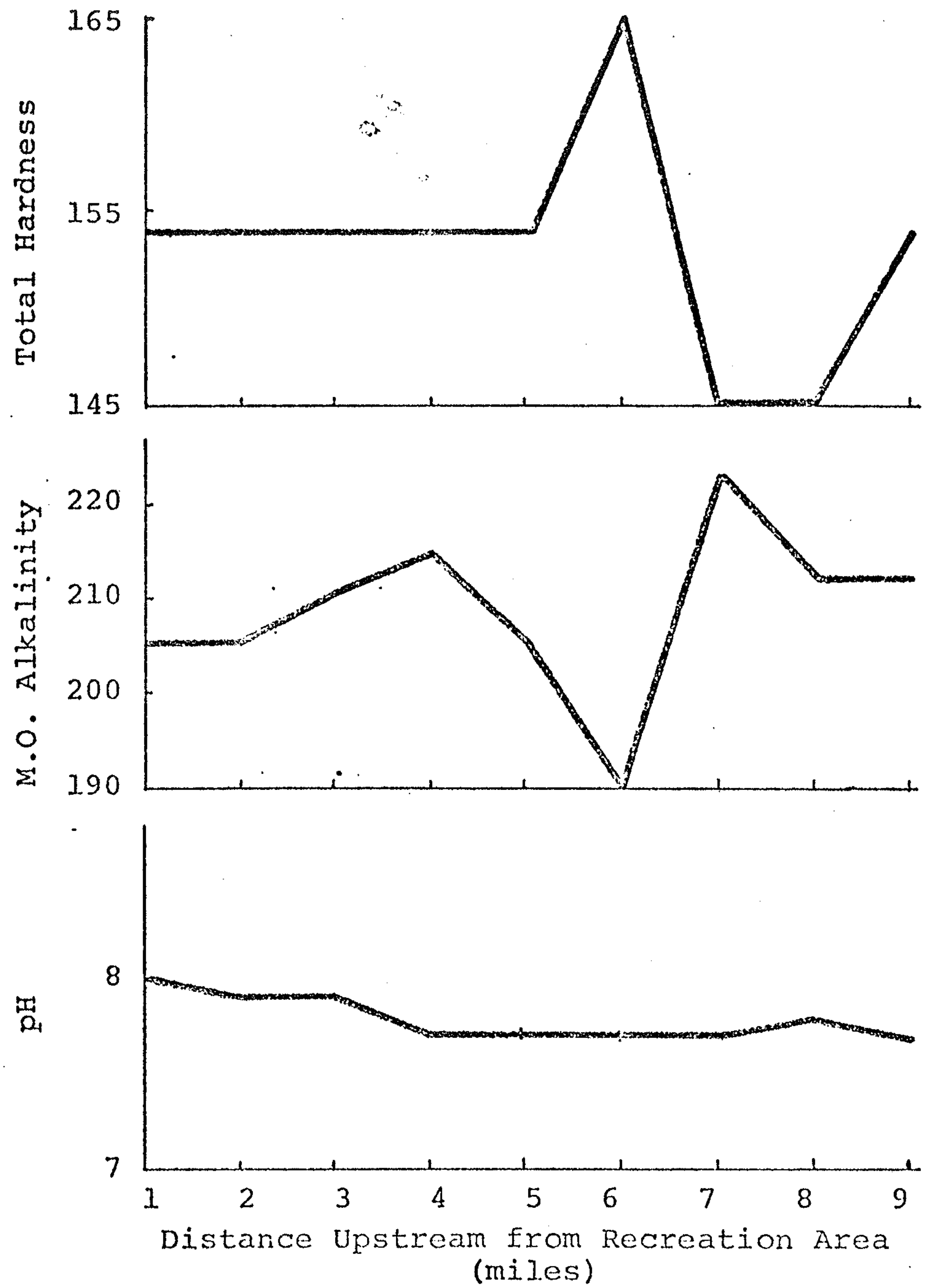


Figure 3: Water Chemistry Analysis of total hardness, methyl orange alkalinity and pH, Beaver Creek, August 1971

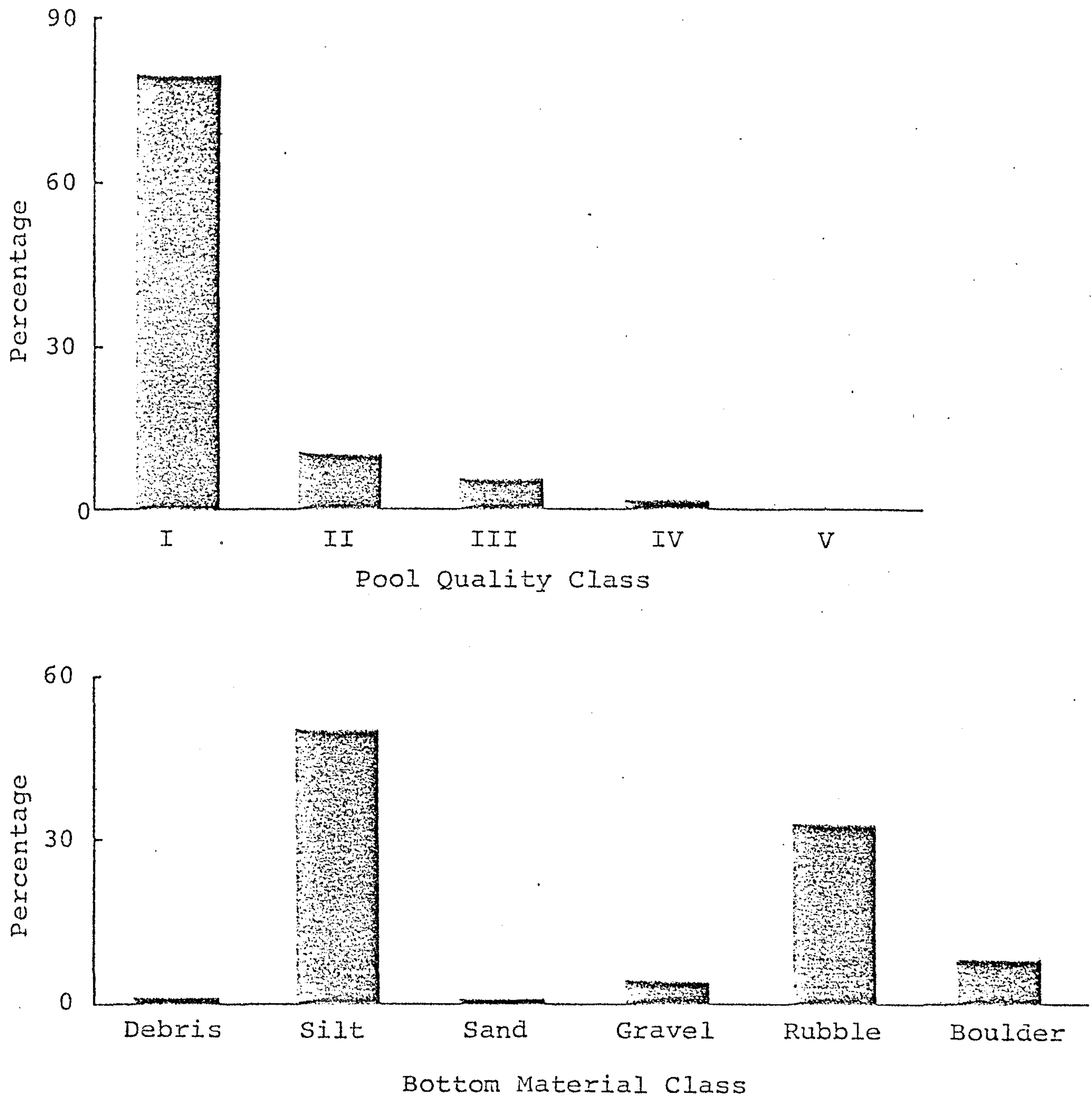


Figure 4: The estimated percentage of pool quality and bottom material classes found in Beaver Creek, August 1971.

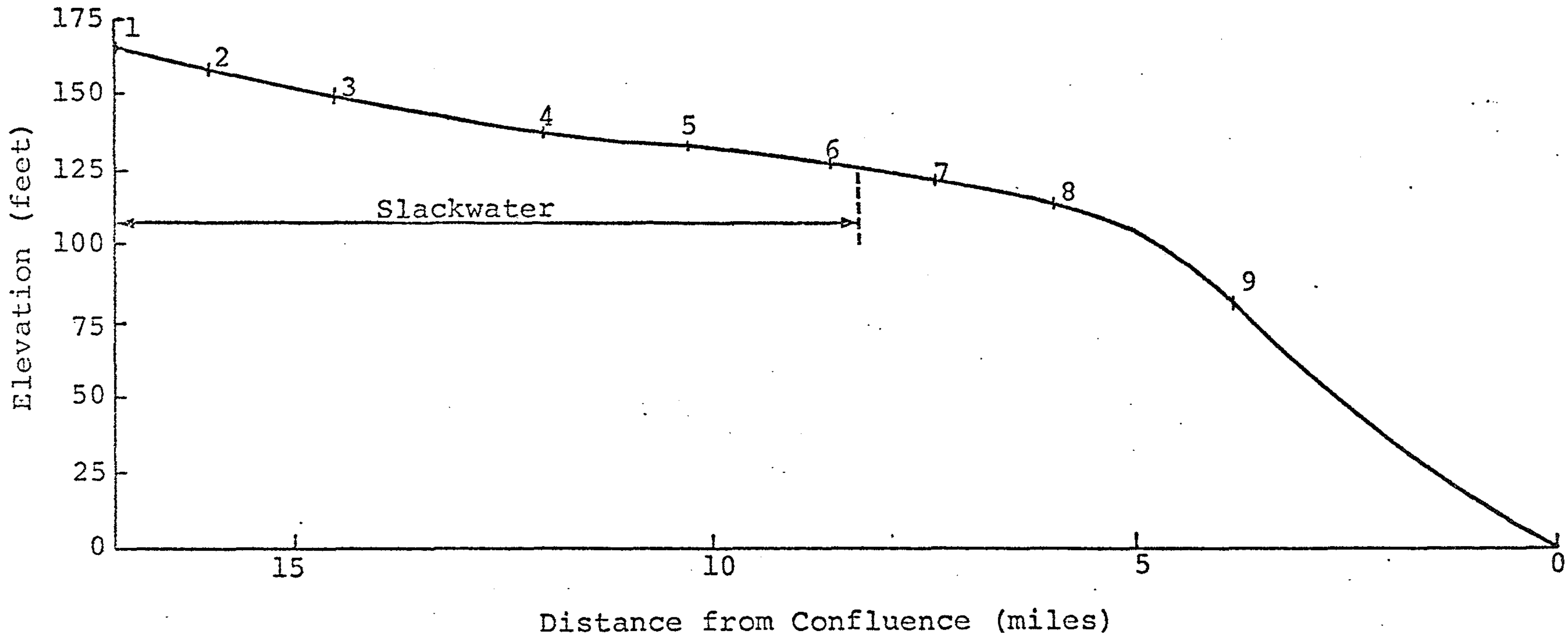


Figure 5: Stream profile of the Beaver Creek Study Area. Numbers indicate the sites of the sample stations. August 1971.

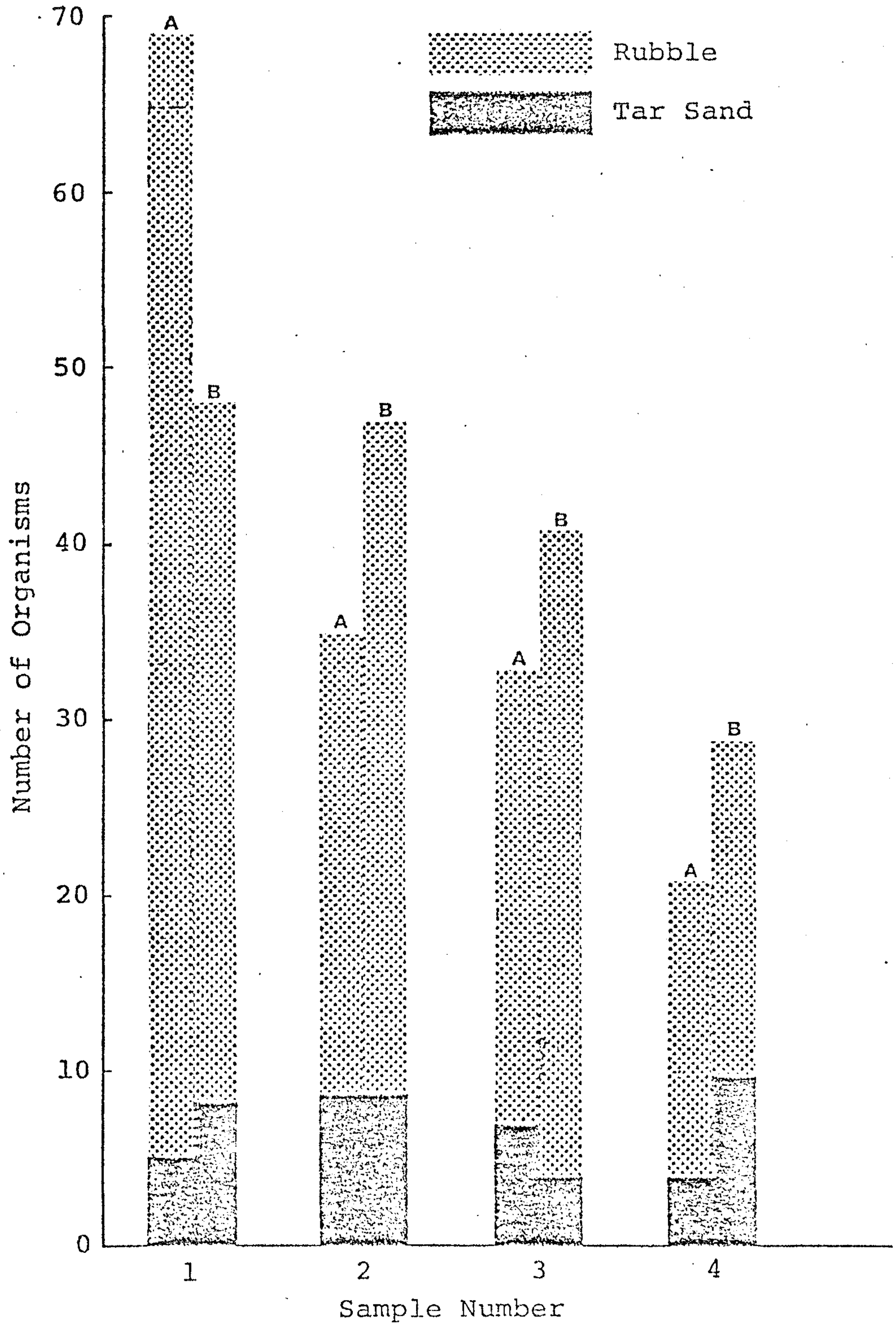


Figure 6: Comparative results of two sets (A & B) of Surber sampling in rubble and rubble-tar sand substrates in Beaver Creek, August 1971.

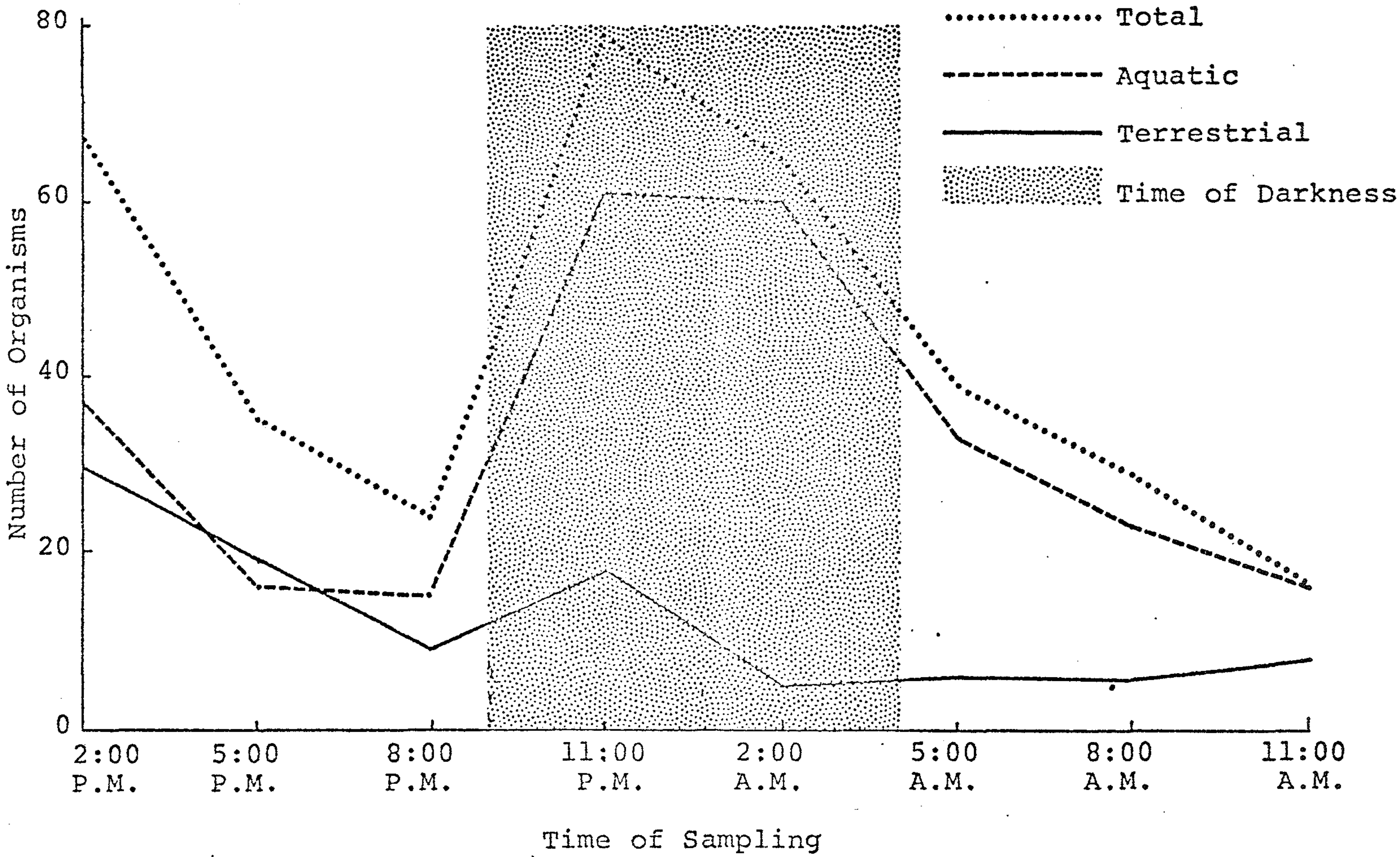


Figure 7: Number of drifting organisms taken every 3 hrs. from 4 drift nets placed in two riffle areas, Beaver Creek, August 1971.

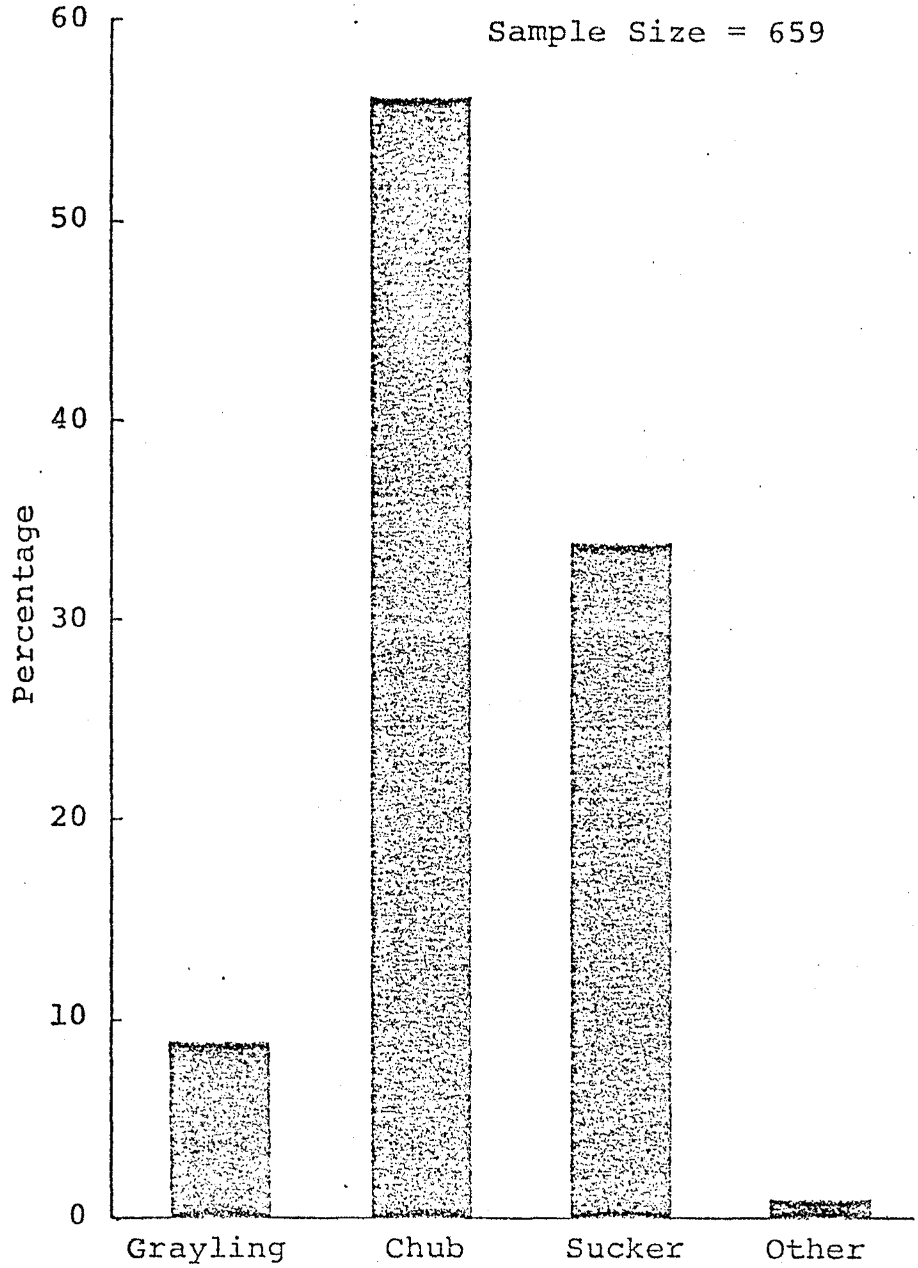


Figure 8: Relative Abundance of species as indicated by prima cord sampling in the Beaver Creek, August 1971.

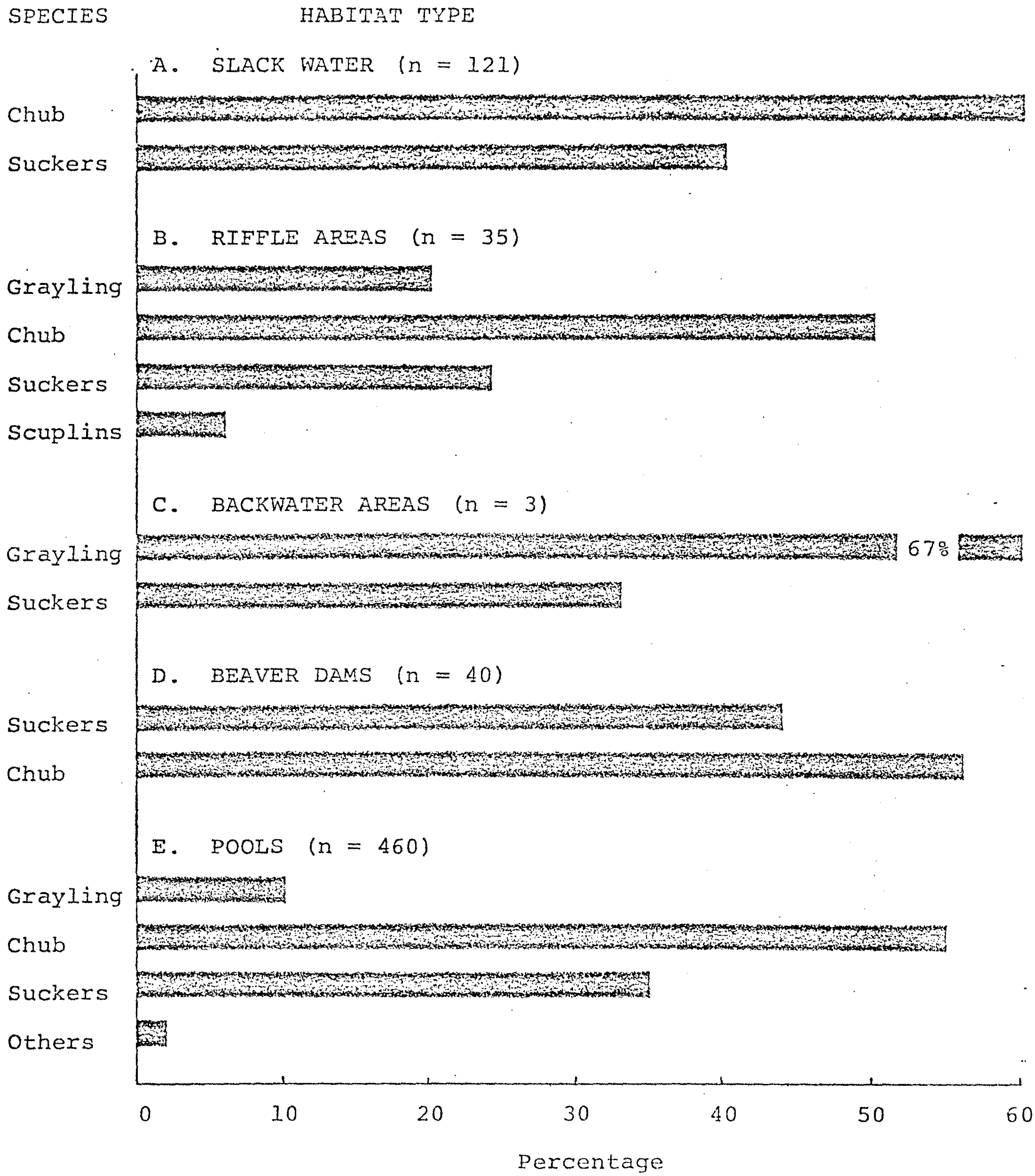


Figure 9: The relative abundance and distribution of species according to water habitat, Beaver Creek, August 1971.

STREAM FLOW

No actual stream flow data exists at the site of the proposed Beaver Creek dam. Therefore data available from adjacent streams, as well as Beaver Creek further downstream, and a channel x-section area and estimated velocity are used to evaluate the stream flow characteristics of Beaver Creek at the proposed dam site. The following data is used in evaluating the stream flow characteristics of Beaver Creek:

River Basin	Drainage Area (Sq. Miles)	Recorded Period	Months of Record
Clearwater River @ Draper	9,380	1958-71	Jan.-Dec.
Hangingstone River @ Ft. McMurray	344	1970-71 66-69	Jan.-Dec. May.-Oct.
Beaver Creek @ gravel pit crossing north end of Mildred Lake	170	1961-63	May -Oct.
Poplar Creek	54	1972 only	May -Nov.

DRAINAGE BASINS

The area storage curve for the routing evaluation is obtained by planimetering contour areas from topographical maps of the Department of Mines and Technical Surveys, Ottawa. The available contour interval is 25 feet and the scale, 1:50,000.

a) Beaver Creek:

The drainage basin of Beaver Creek is covered with muskeg and sparse to medium tree cover. There are no large lakes, but flow attenuation due to the retention of flow in muskeg areas will be considerable.

The longest water course rises in the headwaters at about elevation 1700, flowing for about 35 miles before discharging into the Athabasca River at about elevation 760. The total drainage area of the Beaver Creek is estimated at about 185 square miles. At the site of the diversion dam, Beaver Creek is about 23 miles long; the channel elevation is at about 985 and the drainage area is about 127 square miles.

. . . 33

b) Poplar Creek:

The Poplar Creek drainage basin is adjacent to the Beaver Creek basin and, therefore, is presumed to be covered by similar vegetation. The headwaters originate at about elevation 1350, the main stream of Poplar Creek is about 15 miles in length discharging 15 miles upstream of the confluence of Beaver Creek and the Athabasca River. The total area of the Poplar Creek catchment is 54 square miles.

MAXIMUM ANNUAL RUN-OFF

For the basis of this study a 1:20 year high flow run-off is assumed for the design of the diversion system. The 1:20 year high annual run-offs for the Clearwater Rivers and Hangingstone Rivers are evaluated to be as follows:

Water Course	Area	1:20 Run-off, (Acre Feet) (A.F.)
Clearwater River @ Draper	9,380	5,400,000
Hangingstone River @ McMurray	344	400,000

By comparison the estimated 1:20 year run-off of Beaver Creek at the proposed site is assumed as 140,000 A.F. The monthly distribution of these flows is assumed to be similar to the adjacent streams and is tabulated as follows:

Month	% of Annual Run-off	Run-off (Acre Feet)
May	37	52,000
June	32	45,000
July	20	28,000
August	4	5,000

PEAK RUN-OFF

For this drainage area the high flows indicated for May would normally result from snow melt. This condition usually produced moderately high flow for sustained periods which can be more easily regulated than the high peak flows that are generated by summer storms. Therefore, although the highest run-off is shown for May, storage conditions will likely be more critical for June and July since storage must be available for high run-off over short periods.

Advice was solicited from the Water Resources Division of the Alberta Department of Environment on the estimated 1:20 year peak unit runoff for the project area. This authority suggested a range of from 25 to 50 cfs per square mile. Other experience with peak flows in Northern Alberta suggests the use of a value of 30 cfs per square mile or 3,800 cfs for the Beaver Creek catchment above the diversion dam.

Following is a note by the late Gordon Moore, Syncrude, written in 1963:

> "Talked to Mr. Grimble of Grimble & Associates today. He said the culverts at Beaver Creek on the road to McKay were 2-9 ft. diameter culverts.
>
> "First time were supposed to be 10 ft. apart but contractor put them 3 ft. apart and compacted them by hand but put material in too fast. The banks washed out between the culverts. The contractor moved them to another location where there was a spring under one of the culverts which no one noticed. The spring washed material from around the culvert. Pipes should have been installed to take away the spring water. The pipes never overtopped and Mr. Grimble feels they were large enough. The culvert collapsed some but not completely.
>
> "Bob says the Forest Ranger said they were worried about the water overtopping the road as the culverts were running full. Suggest using 10 ft. diameter culverts."

STORAGE REGULATION

The function of the diversion dam is to divert flows from Beaver Creek as well as to provide storage for regulating outflow and thereby reducing the cost of the hydraulic conveyances from the reservoir. Preliminary routing studies, on a monthly basis, were carried out for the 1:20 year inflow indicated in 3.3 to evaluate the flow regulation for two dam crest elevations. The result of this study are tabulated as follows:

Dam Crest Elevation	Maximum Water Elevation	Gross Storage A.F.	*Live Storage A.F.	Regulated Outflow, cfs
1025	1020	20,000	12,000	900
1020	1015	12,000	4,000	1,600

*The indicated live storage is based on a drawdown elevation of 1013.

The values used for the area storage curve for the Beaver Creek reservoir are obtained from the following table obtained from the available topography.

Beaver Creek Reservoir
Including Ruth Lake
Area-Storage Table

Elevation	Flooded Area in Acres	Storage A.F.
995	5	100
1,013	450	8,000
1,020	2,500	20,000

CHEMICAL & GEOLOGICAL LABORATORIES LTD.

14240-115 AVENUE, EDMONTON, ALBERTA

Date Reported: January 10, 1973

LABORATORY REPORT NUMBER: E73-1696

SYNCRUDE CANADA LTD.

KIND OF SAMPLE: Water

WELL: Beaver Creek

DATE SAMPLED: November 28, 1972

DATE RECEIVED: November 29, 1972

E73-1696-1: Beaver Creek (Upper) Sampled at 9:50 A.M. at Diversion Site.

E73-1696-2: Beaver Creek (Lower) Sampled at 2:10 P.M. Temperature 0°C.

		E73-1696-1	E73-1696-2
CALCULATED SODIUM (Mg/1)		56	----
CALCIUM (Mg/1)		36	----
MAGNESIUM (Mg/1)		12	----
SULFATE (Mg/1)		8	----
CHLORIDE (Mg/1)		4	----
CARBONATE (Mg/1)		Nil	----
BICARBONATE (Mg/1)		302	----
pH @ 70°F.		8.2	----
DISSOLVED SOLIDS (Mg/1):	Evaporated	448	----
	Ignited	272	----
SUSPENDED SOLIDS (Mg/1):	Dried	10.0	----
	Ignited	6.4	----
OIL & GREASE (Mg/1)		0.6	0.1
PHENOLS (Mg/1)		0.024	0.002
SULPHIDES (Mg/1)		<0.05	----
COLOR NUMBER		140	110

Continued...

Syncrude Canada Ltd. Laboratory Report Number: E73-1696

	E73-1696-1	E73-1696-2
BIOCHEMICAL OXYGEN DEMAND (Mg/1)	<1.0	----
CHEMICAL OXYGEN DEMAND (Mg/1)	314	----
THRESHOLD ODOR NUMBER	5	----
TOTAL AMMONIA AS N (Mg/1)	0.21	----
NITRATES (Mg/1)	<0.5	----
SILICA (Mg/1)	13.2	13.2
TOTAL PHOSPHATE (Mg/1)	0.15	0.13
ORTHO PHOSPHATE (Mg/1)	0.13	0.07
NICKEL (Mg/1)	0.04	----
MANGANESE (Mg/1)	0.05	----
IRON (Mg/1)	3.28	2.45
LEAD (Mg/1)	0.02	----
ZINC (Mg/1)	0.07	----
CHROMIUM (Mg/1)	<0.01	----
COPPER (Mg/1)	0.02	----
ARSENIC (Mg/1)	<0.01	----
SELENIUM (Mg/1)	<0.005	----
CADMIUM (Mg/1)	<0.01	----
URANIUM (Mg/1)	<0.001	----
MERCURY (PPB)		
BORON (Mg/1)	0.24	----
ALUMINUM (Mg/1)	0.24	----
COBALT (Mg/1)	0.02	----

CHEMICAL & GEOLOGICAL LABORATORIES LTD.

14240-115 AVENUE, EDMONTON, ALBERTA

Date Reported: January 4, 1973

LABORATORY REPORT NUMBER: E73-1699

SYNCRUDE CANADA LTD.

KIND OF SAMPLE: Water

WELL: Poplar Creek

DATE RECEIVED: November 29, 1972

DATE SAMPLED: November 29, 1972 @ 1:40 P.M.

TEMPERATURE: 0°C.

PHENOLS	0.003 Mg/1
CHEMICAL OXYGEN DEMAND	34.4 Mg/1
COLOR NUMBER	120
SULPHIDES	<0.05 Mg/1
BORON	<0.2 Mg/1
VANADIUM	<.001 Mg/1
LEAD	0.03 Mg/1
IRON	1.78 Mg/1
MERCURY	0.12 PPB

CHEMICAL & GEOLOGICAL LABORATORIES LIMITED

10 [illegible] [illegible]

OPERATOR: SYNCRUDE CANADA LTD.

REPORT NUMBER: E72-801

DATE SAMPLED: See Below

DATE RECEIVED: September 29, 1972

DATE REPORTED: November 7, 1972

KIND OF SAMPLE: Water

E72-801-1: Athabasca River @ Bridge. Sampled at 11:30 A.M. on September 29, 1972
E72-801-2: Beaver Creek @ Campsite. Sampled at 4:30 P.M. on September 28, 1972
E72-801-3: Athabasca River @ Dock. Sampled at 8:30 A.M. on September 29, 1972
E72-801-4: Mackay River. Sampled at 9:30 A.M. on September 29, 1972
E72-80105: Poplar Creek. Sampled at 1:00 P.M. on September 30, 1972

DETERMINATION		LABORATORY NUMBER E72-801-1	E72-801-2	E72-801-3	E72-801-4	E72-801-5
Dissolved oxygen	Mg/l.	11.9 @ 5°C	12.0 @ 4°C	12.1 @ 4°C	12.5 @ 3°C	---
Calculated sodium	Mg/l.	10	66	11	62	110
Calcium	Mg/l.	37	41	37	46	47
Magnesium	Mg/l.	10	13	10	19	24
Sulphate	Mg/l.	28	16	29	60	18
Chloride	Mg/l.	4.5	9.8	5.2	20	126
Carbonate	Mg/l.	Nil	2.2	Nil	2.0	Nil
Bicarbonate	Mg/l.	146	325	146	284	317
pH @ 77°F	-----	8.1	8.3	8.1	8.4	8.2
Dissolved Solids: Evap.	Mg/l.	209	522	207	406	531
Ignited	Mg/l.	131	290	140	329	385
Suspended solids: Dried	Mg/l.	10.8	3.6	10.8	1.6	3.2
Ignited	Mg/l.	8.0	3.2	10.4	1.2	2.0

Continued........

OPERATOR: SYNCRUDE CANADA LTD. REPORT NUMBER: E72-801

DATE SAMPLED: See Page 1 DATE RECEIVED: September 29, 1972 DATE REPORTED: November 7, 1972

DETERMINATION		E72-801-1	E72-801-2	E72-801-3	E72-801-4	E72-801-5
Oil and grease	Mg/l.	2.4	1.2	1.3	1.5	0.4
Phenols	Mg/l.	0.002	0.012	0.004	0.003	---
Sulphides	Mg/l.	<0.05	<0.05	<0.05	<0.05	---
Colour number	-----	15	60	20	80	---
Biochemical oxygen demand	Mg/l	4	6	6	5	9
Chemical oxygen demand	Mg/l.	34.7	102.8	71.6	92.7	---
Threshold odour number	-----	3	3	10	20	4
Ammonia (total as N)	Mg/l.	0.13	0.14	0.18	0.09	---
Nitrates as NO_3	Mg/l.	<0.5	<0.5	0.6	0.5	0.5
Silica	Mg/l.	25.7	20.6	30.0	15.3	9.4
Total phosphate as PO_4	Mg/l.	0.07	0.12	0.05	0.15	0.06
Ortho phosphate as PO_4	Mg/l.	0.04	0.07	0.01	0.08	0.05
Nickel	Mg/l.	0.04	0.04	0.03	0.03	0.04
Manganese	Mg/l.	0.02	0.02	0.02	0.02	0.03
Iron	Mg/l.	0.34	0.84	0.46	0.47	1.25
Lead	Mg/l.	0.03	0.04	0.03	0.04	0.05
Zinc	Mg/l.	0.02	0.03	0.02	0.03	0.03

Continued..........

CHEMICAL & GEOLOGICAL LABORATORIES LIMITED

OPERATOR: SYNCRUDE CANADA LTD. REPORT NUMBER: E72-801

DATE SAMPLED: See Page 1 DATE RECEIVED: September 29, 1972 DATE REPORTED: November 7, 1972

DETERMINATION		LABORATORY NUMBER E72-801-1	E72-801-2	E72-801-3	E72-801-4	E72-801-5
Chromium	Mg/1.	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	Mg/1.	0.01	0.01	<0.01	0.01	0.01
Arsenic	Mg/1.	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	Mg/1.	<0.005	<0.005	<0.005	<0.005	---
Cadmium	Mg/1.	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	Mg/1.	<0.001	<0.001	<0.001	<0.001	---
Mercury	P.P.B.	2.15	6.75	3.28	1.63	---
Boron	Mg/1.	<0.2	<0.2	<0.2	<0.2	---
Aluminum	Mg/1.	0.52	0.49	0.70	0.52	0.42
Cobalt	Mg/1.	0.01	0.02	0.02	0.02	0.02

SECTION 2.

WATER MANAGEMENT PLANNING
-LEASES 17 AND 22

C. WATER SUPPLY SYSTEM

May, 1973

SYNCRUDE MILDRED LAKE PROJECT

WATER SUPPLY STUDY

TABLE OF CONTENTS

Table of Contents

LIST OF FIGURES

LIST OF DRAWINGS

SYNCRUDE MILDRED LAKE PROJECT

WATER SUPPLY STUDY

CHAPTER 1

INTRODUCTION

1.1 SCOPE OF STUDY

This study has been carried out by Underwood McLellan & Associates Limited in accordance with Agreement No. 9776-EA-32-A-1 Amendment No. 1 with Canadian Bechtel Limited. This Report summarizes conceptual engineering investigations defined as Phase 1 and as outlined in Section 1.3 of Exhibit D, a copy of which is appended to this Report.

1.2 PROJECT BACKGROUND

Syncrude Canada Limited proposes building a mining and extraction plant in the Athabasca Tar Sands deposit approximately twenty-five miles north of Fort McMurray and five miles west of the Athabasca River in Lease 17.

1.3 WATER SYSTEM CRITERIA

The proposed water supply system is to provide a firm supply of 50,000 USGPM during the initial 3 years of operation reducing to approximately 31,000 USGPM thereafter. This rate is to be met on a continuous basis 24 hours per day and 365 days per year.

The criteria which have influenced the study are:

(i) safety

(ii) reliability

(iii) economy

(iv) minimize environmental impact

(v) avoid conflict of land use with mining area and plant site

(vi) locate all facilities inside boundaries of Lease 17.

Because of the magnitude of investment dependent on a firm water supply "reliability" has replaced economy as the second most important design criteria behind safety.

The magnitude of the water supply required precludes the use of all possible water sources except the Athabasca River.

1.4 DESCRIPTION OF AREA

In broad terms the study area consists of the Athabasca River as the eastern boundary, a low river valley plain approximately 3,000 feet wide, a steep escarpment rising 200 to 250 feet above river level, and relatively flat terrain extending westward to Beaver Creek some five miles inland. Other significant surface features include Horseshoe Lake along the valley plain and Mildred Lake on the table lands west of the escarpment.

The pilot plant, dock, camp, and airstrip established in the early '60's by Cities Services Ltd. are located in the extreme southeast corner of Lease 17 adjacent to the Athabasca River.

1.5 STUDY ORGANIZATION

The study team was headquartered in the Edmonton offices of Underwood McLellan & Associates Limited. Direct communication on technical matters was maintained between the Liaison Engineer for Canadian Bechtel Ltd. and the UMA Project Engineer. Communications regarding contractual matters was carried out by the UMA Project Manager and Canadian Bechtel's Contract Manager.

The study was organized into several phases including:

(i) Data search and review

(ii) Analysis of river regime

(iii) River soundings

(iv) Soil test borings (carried out by others)

(v) Study of alternative schemes

(vi) Refinement of recommended scheme

(vii) Preparation of report and drawings

CHAPTER 2

RIVER REGIME - ATHABASCA RIVER

2.1 STREAMFLOW, STAGE RELATIONSHIPS

The Athabasca River at Lease 17 has a drainage basin of about 50,000 square miles. Daily streamflow records have been maintained by the Water Survey of Canada about three miles downstream of McMurray since 1958. Mean annual discharge is 22,900 CFS. Maximum recorded instantaneous discharge is 150,600 CFS on June 30, 1960, and minimum recorded daily discharge is 3,410 CFS on February 3, 1964. These extreme discharges correspond to gauge height readings of 18.6 feet and 1.9 feet, respectively. In other words, the maximum discharge recorded at the McMurray station resulted in a river level 16.7 feet higher than the minimum level recorded - over a 14-year period. The stage-discharge relationship for open water conditions at the McMurray gauging station is shown on Figure 1. The mean monthly discharges for the period of record are shown on Figure 2.

2.2 ICE JAM, STAGE RELATIONSHIPS

Little data is available on ice jam occurances in the vicinity of Lease 17. One Syncrude employee who has resided at the Company's campsite for the past eight years reports that an ice jam which occurred about a half mile downstream of the Syncrude dock during breakup in 1970 or 1971 created the highest flood levels during his period on site - about four feet of water over the existing pumphouse floor level, with large ice flows spilling onto the camp air strip area. This water level corresponds to about 24 feet above normal winter ice level.

A study carried out by T. Blench & Associates Ltd. for the Provincial Planning Board in 1964, titled "Flood Protection Proposals for McMurray", contains valuable information regarding the frequency and magnitude of flood levels caused by ice jams at the Town of Fort McMurray. It must be pointed out that the river regime with respect to ice jam formation at Fort McMurray presents different factors than exist at Lease 17.

The conditions at McMurray prior to construction of the Snye Dyke are considered to have been more conducive to severe ice jam formation due to the confluence with the Clearwater River. The ice jam frequency and stage curves prepared by T. Blench & Associates Ltd. at McMurray and shown on Figure 3 are, therefore, considered to be conservative for the river reach through Lease 17.

2.3 SUSPENDED SEDIMENT

Miscellaneous suspended sediment measurements were taken in the Athabasca at McMurray during 1967 and 1968 by the Water Survey of Canada. Daily samples have been collected since 1969 and records are available for suspended sediment content. In addition, particle size analyses have been done for selected samples during this period.

A fairly good correlation exists between river discharge and suspended sediment content, particularly for the higher discharge rates. Based on this correlation and the duration curve for discharges at McMurray as calculated by the Water Resources Division, Department of the Environment, the duration curve for suspended sediment loadings has been prepared shown on Figure 4. Using the median sediment duration curve the cumulative percent of suspended sediment vs percent of time was prepared and is shown as Figure 5. It can be readily seen that 50 percent of the annual river sediment loading occurs in 10 percent of the year - namely the flood season.

During the short period of record the maximum suspended sediment loading measured was 4,800 ppm. The particle size distributions as shown on Figure 6 indicate that the suspended sediment contains about 25 percent sand particles, and is thus of an abrasive nature. In addition, the moving "bed load" for which quantitative measurements are not available probably consists of a fluid layer of coarse sands, gravel and cobbles, several feet thick travelling immediately above the riverbed during high discharges. One particle size analysis of "bed load" material is available and is shown on Figure 6.

THIS HIGH SEDIMENT CONTENT CONSTITUTES ONE OF THE MAJOR DIFFICULTIES TO BE OVERCOME IN PUMPING WATER FROM THE ATHABASCA RIVER TO THE SYNCRUDE PLANT SITE.

2.4 RIVER SOUNDINGS AND CHANNEL CHARACTERISTICS

The Athabasca River can be classified as a young-to-mature river, of relatively straight alignment, with a slope of about one foot per mile, and an average width of 1,500 to 2,000 feet.

In the river reach through Lease 17, the riverbed is bedrock controlled. Limestone outcrops control channel locations at the sites shown on Drawings No. 113 & 114. Between these outcrops the river channel is free to shift, alternately eroding and depositing alluvial material.. Abandoned channels exist at several locations - in particular, Horseshoe Lake and Saline Lake are undoubtedly ancient channels.

In order to define channel location and depth along the reach of river in Lease 17, a river sounding survey was carried out by UmA in January, 1973. Drawings No. 113 & 114 show the locations of the cross-sections sounded. Additional soundings were intended in the vicinity of Site No.1 but due to unsafe ice conditions they were impossible to obtain.

The results of the soundings confirmed our earlier assessment of channel location with one exception. It was expected that the main channel at Site No.2 would lie along the west bank. The soundings revealed that the channel was split and that the deepest channel in fact was along the east bank.

Discussions were held with an employee of Northern Transport Co. who had logged 40 years on the river as a tugboat captain. His knowledge of channel location and depth were later confirmed by our river soundings again with the exception of the split channel at Site No.2.

2.5 INTAKE SITE SELECTION

From the point of view of channel stability of location and adequate depth, Site No.1 offers the best intake location. Site No.2 may be subject to periodic channel shifting as evidenced by the split channel. Site No.3 is not bedrock controlled and is currently subject to severe erosion.

From the point of view of foundation conditions for construction of a major concrete structure, Site No.2 offers the most competent bedrock formation with Site No.1 only slightly less massive and perhaps more weathered. Site No. 3 shows no evidence of bedrock.

In summary, it is our opinion that Site No. 1 offers the best intake site in Lease 17 in terms of river stability and will provide satisfactory foundation conditions.

CHAPTER 3

RECOMMENDED WATER SUPPLY SCHEME

3.1 GENERAL

The recommended scheme which is detailed in the following sections has been selected primarily because it offers the greatest degree of RELIABILITY, and at the same time, is one of the more economical arrangements evaluated. The high degree of reliability is due to the following:

- (i) large volume of system storage in Mildred Lake which allows shutting down pumping units during heavy river silt loadings;
- (ii) less wear and tear on lo-lift and hi-lift pumps due to (i) - in fact, more rugged pumping units would be required without (i);
- (iii) simplicity of system operating controls due to greater reaction time provided by storage in the system.

While the environmental impact on Mildred Lake has not been studied in detail, it is probable that the ecosystem created by increased Mildred Lake levels, while different, will in fact be an improvement over the existing ecosystem.

As detailed in the following sections, the recommended water supply system consists of:

- (i) a river intake and low-lift pumping station at Site No. 1;
- (ii) a sedimentation basin of about 265 acres contained by earthen embankments;
- (iii) a high-lift pumping station in the northwest corner of the sedimentation basin;
- (iv) 6400 lineal feet of 48-inch I.D. concrete cylinder pipe;

(v) a storage reservoir of approximately 7400 acre feet created by raising Mildred Lake to about elevation 1015;

(vi) a raw water pumping station along the northwest shore of Mildred Lake and conduit to the plant site distribution system.

The final size of the sedimentation basin and Mildred Lake reservoir will be determined during Phase II detailed engineering.

Drawings No. 106 and No.107 show the general arrangement of structures while Drawing No. 108 shows the center line profile along the recommended supply scheme.

Access roads to the structure sites have been the subject of a separate study; where applicable proposed dykes will serve as extensions of the road system.

3.2 RIVER INTAKE AND LOW LIFT PUMPING STATION

Site No.1 has been selected as the most suitable river intake site with respect to stable river channel location and depth. It also offers suitable foundation conditions in terms of a limestone outcrop and likely shallow bedrock offshore.

The headwall type of intake has been selected in order to minimize conflict with river navigation. The intake is projected into the river channel and skewed at an angle to river alignment to promote river current deflection and thereby create a self-scouring action across the intake face. In this manner, deposition of alluvial material at the intake face will be minimized. This type of structure has been found to work very successfully on the recently constructed river intake for Edmonton Power at the Clover Bar thermal generating station on the North Saskatchewan River.

Additional river soundings plus bore holes are required to determine the optimum location of the structure in relation to bedrock depths.

The low-lift pumping station shown on Drawing No. 109 utilizes three mixed-flow pumping units, two of which will deliver 60,000 USGPM with the third unit as standby under normal conditions but also available to provide make-up water to refill depleted storage. The mixed-flow pumps operating at a low speed of 585 rpm will provide low maintenance and high reliability factors under all but the most severe river sediment loading conditions. In the same regard, low-level and high-level intake openings are provided in the headwall to each pump bay - the low level gates to be closed during higher river levels when fluid bed loading conditions exist to prevent admission of these coarse particles to the pumping chambers.

While gates have been shown for the upper intake openings, it is recommended that equalizing openings be provided to prevent inadvertent dewatering of pump bays when river level exceeds about elevation 775. Water levels above 775 occur for relatively short periods; dewatering of pump bays at these higher levels will impose severe structural design criteria on the foundation walls and slab.

Coarse trashracks and fine travelling screens have been provided for each pumping bay to prevent entry of large floating debris and ice flows in the former case, and to exclude marine life in the latter as required by the Department of the Environment. The travelling screens have been sized to maintain velocities below 2 fps through gross screen areas at minimum river level. At higher river levels, when suspended and floating debris will be in higher concentrations, the velocities through gross screen areas will be considerably less. Ice buildup on trashracks may present operating difficulties - the retractable weather curtain and heaters shown above the trashracks should eliminate this problem. Stoplog slots have been provided in the event that maintenance is required on inlet gates.

A service bay has been provided to allow space for assembly, maintenance, etc. of equipment. It is recommended that this bay be constructed identical to the others in the event that a fourth pumping unit is required in the future to provide for an expanded plant requirement.

The pump control system should be operable only from the pumphouse though a monitoring system to detect pump shut-down and reservoir level should be installed at the main plant site operating room.

Automatic motor and pump protection devices are required for wetwell low level, motor bearing overheat, excessive vibration, motor overload, high and low discharge pressure. Automatic control valves are required at each pump discharge to maintain a constant pumping head because of the variable river level.

3.3 SEDIMENTATION BASIN

Heavy sediment loading during high river discharges presents the most difficult design condition to be overcome. Experience at G.C.O.S. and at installations on the North Saskatchewan River have shown that the combination of high river sediment content and high head - high volume pumps results in very high pump maintenance cost and low system reliability. It has, therefore, been our philosophy to (a) remove sediment content before high-lift pumping, and (b) be able to stop or reduce pumping during extreme sediment conditions by providing adequate system storage. As a by-product, this system will also deliver water of superior quality to the plant site.

An additional problem would result if sediment were not removed as proposed; a direct pumping system terminating in a raw water pond at the plant site would deliver about 20 to 30 acre feet (about 50,000 cubic yards) of sediment to the pond each year, of which about 80 percent would settle out in the pond. Unless the pond were constructed to a very large size, it would be necessary to periodically dredge the pond, creating a sludge disposal problem.

The sedimentation basin proposed has been sized as shown for the following reasons:

(i) the estimated period for 5 feet of deposition is 150 years - eliminating the need for dredging and sludge disposal;

(ii) between 65 percent and 85 percent of total suspended solids will be settled out including some colloidal particles;

(iii) results in the shortest pipeline length to Mildred Lake and eliminates pipeline in the low-lying muskeg area along the river valley.

Figure 7 shows the estimated rate of deposition in the sedimentation basin vs basin area.

The top of basin dykes are required to be elevation 795 to prevent overtopping by high river levels caused by ice jam conditions. Dyke section "X" (Dwg #106) serves a dual purpose in that it is also intended to decrease the possibility of an ice jam occuring near the intake by preventing spillage into the old river channel to the west which causes river velocities to drop and ice jam formation to occur. Dyke "X" and to some extent Dyke "B" will improve river hydraulics during breakup conditions moving ice jams downstream. A tree screen and heavy rip rap are required on the river side of Dykes "X" and "B" to prevent scouring due to ice action and high velocities.

Preliminary soils data has shown that Dyke "E" crosses a zone of deep muskeg and that the material underlying Dykes "B" and "X" is sand. The sedimentation basin area lies in an abandoned river channel and may be underlain by coarser alluvial deposits that could permit excessive seepage to occur. A more detailed soil testing program is required in order to accurately determine the seepage losses that will occur.

The maximum basin size recommended is 265 acres with FSL at elevation 790 as shown on the General Arrangement. Figure 7 shows that the estimated time for 5 feet of deposition to occur in a 265 acre basin is 150 years (assuming 10 percent shut-down time during high river loadings). Should further soil testing reveal that seepage losses or dyke construction costs will be excessive, a reduction in the size of basin should be considered. Again, from Figure 7, it is estimated that a basin of 130 acres surface area will have a "5-foot life" of 75 years assuming 10 percent shut-down. Basins of smaller size will require periodic dredging.

3.4 HIGH LIFT PUMPING STATION

The high lift pumping system consists of four vertical turbine pumps, three of which operating in parallel will deliver the design capacity of 61,000 USGPM to Mildred Lake. This capacity allows for 11 month's pumping per year, a 5 percent loss in pump and motor efficiency and a 5 percent allowance for seepage and evaporation losses from Mildred Lake Lake. One additional pumping unit is available on a standby basis. Four units offer the most economical arrangement and will also suit the lower future pumping rate.

Foundation conditions at the pumping station are unknown though it is suspected that the surface knoll is caused by shallow bedrock. Test drilling is required to locate bedrock surface and to determine its competence. Wetwell floor elevation should be at elevation 765 to provide adequate pump submergence and may be lower dependent on bedrock conditions.

A preliminary economic comparison of capital cost of pipeline, pumps and motors and operating cost has indicated that the most economical line size is 48-inch I.D. Figure 8 shows the system curve using 6400 lineal feet of 48-inch I.D. pipe with "C" factors of 120 and 140 and with the maximum range of static head.

A preliminary analysis has shown that the water hammer resulting from a power failure presents a very severe condition. The high velocity (12.4 fps) which will occur with 3 units running at minimum static head could result in severe water column separation and resultant hammer in the event of a power failure unless surge protection equipment is provided. A more detailed analysis is underway to determine the best method of dampening surge pressures to approximately plus or minus 50 percent of normal operating pressure. For the moment, we suggest that an allowance be made for surge protection equipment in the order of $100,000. The equipment could consist of combination air inlet and surge release anticipating valves as shown on Drawing No. 111, or an enclosed surge tank with compressed air cushion. Further information will be forwarded on the surge protection system when this analysis is completed.

3.5 PIPELINE

An economic comparison was carried out to determine optimum pipeline size. Several key assumptions were made in the comparison, changes in which could alter the final pipeline size. For example, the supply rate of 50,000 USGPM is assumed to be required for the first three years only, dropping to 31,000 USGPM thereafter. Three different electrical energy costs (1¢/KW Hr., 1½¢/KW Hr. and 2¢/KW Hr.) have been used. The interest rate in determining present worth of consumed energy has been taken as 8 percent. Based on these factors the optimum pipe size is 48-inch I.D., except for the 2¢/KW Hr. energy cost where the optimum size is 54-inch I.D. Figure 9 shows the cost comparison curves.

As discussed in Section 3.4, further study of the water hammer conditions may indicate that the additional cost of larger pipe will be offset by lower costs for surge protection equipment.

The recommended water supply scheme results in the shortest possible length of pipeline, 6400 lineal feet, and eliminates pipeline in deep muskeg areas. The most difficult pipeline construction problem will be construction up the escarpment, an average slope of more than 20 percent. The section west of the escarpment to Mildred Lake is through relatively easy ground conditions. Terminal pipe sections at the high-lift pumping station and the Mildred Lake outlet structure will present some special difficulties. All pipeline should be buried with 6 to 8 feet of cover to prevent frost penetration and provide protection. Special measures will be required to prevent erosion of backfilled trench in the steep escarpment section.

Two types of pipe have been considered for the pressure main - concrete cylinder pipe and insitu lined thin-wall steel pipe. To be economically competitive it is our experience that steel pipe must be of sufficiently thin wall that the surrounding bedding forms part of the structural system of the pipe. "Rigid wall" steel pipe does not compete favourably with concrete cylinder pipe. The availability, placing, and compaction of suitable bedding material can become a costly and technically difficult problem. It is likely that pipeline construction will be carried out during winter conditions which will further aggravate bedding placement.

Concrete cylinder pipe, on the other hand, provides structural strength and minimizes the problems of bedding and backfill control. It also offers excellent corrosion resistance properties. We are, therefore, recommending that concrete cylinder pipe be utilized. For the moment, 48-inch I.D. pipe has been shown. Further information on water hammer and power costs may indicate that 54-inch I.D. pipe is required.

3.6 MILDRED LAKE RESERVOIR

Creating a storage reservoir in Mildred Lake builds a very high degree of RELIABILITY into the supply system. Up to 7400 acre feet of live storage can be created, which would provide sufficient water for shut-downs up to four weeks in duration from the river supply. Drawing No. 106, sheet No. 2, shows the storage volumes and surface areas created for various water levels. Figure 10 shows the relationship between pumping rate required and live storage volume available. The operating range required will be established in Phase II.

Utilizing Mildred Lake as part of the water conveyance system reduces the length of pipeline required and subsequently the pumping horsepower and pipe diameter. It also eliminates the very difficult crossing of the Mildred Lake trench that would otherwise be required.

The proposed provincial highway south of Mildred Lake would form the closure dyke at the southeast end of the Lake. The roadway would likely be built to an elevation higher than is required for the reservoir. The quantities shown in Chapter 5 include this closure dyke in the event the highway is not built. The south tailings pond dam would close the northwest end of the reservoir with a small spur dyke along the lake shore. The natural drainage into Mildred Lake would thus be utilized in the water system, eliminating a problem in disposing of it into or around the tailings pond. Chapter 5 quantities include the spur dyke but not the south tailings pond dam.

3.7 WATER QUALITY

In addition to the greater reliability afforded by the recommended scheme, the water delivered to the plant site will be of a higher quality than would be available from a system having little or no storage and sedimentation capacity. The large system capacity makes it possible to eliminate water treatment facilities sized to handle extreme river turbidities (up to 5000 PPM of suspended solids), by:

a) permitting shut-down of river pumps during periods of extreme sediment loading;

b) providing sedimentation, dilution and buffering effects resulting in more constant year-round treatment requirements.

Since treatment works will not be subject to extreme fluctuation in raw water quality:

(i) treatment operation will be simplified

(ii) costs for chemical additives will be reduced

(iii) backwash water volumes will be reduced

(iv) sludge blowdown and disposal volumes will be reduced.

The diversion of Athabasca River water into Mildred Lake should not result in adverse conditions in Mildred Lake. The available test data shows the two water bodies to be chemically similar:

	Athabasca River	Mildred Lake
p^H	7.8 to 8.1	7.8
Langelier Index	+0.3 to-0.3	+0.2
Ryznar Index	7.5 to 8.6	7.4

Raising the level of Mildred Lake by 15 to 20 feet will cause the flooding of approximately 250 acres of shoreline, consisting of heavy tree cover in well-drained areas and muskeg in low, flat areas. Trees will be cleared prior to flooding with root systems left in place. The organic decompostion of the predominantly cellulose material will occur at a slow rate over a number of years. Normally, this would result in low dissolved oxygen contents, particularly under winter ice cover. The high pumping rate from the Athabasca River will create a rapid turnover rate (4 weeks) in Mildred Lake which will tend to minimize these side effects and the proposed lake will likely exhibit a residual dissolved oxygen content throughout the year.

3.8 OTHER SYSTEM FACILITIES

Amendment No.1 to the Agreement deleted several items from the Phase I Conceptual Engineering Study, including: the raw water pond pumping station, the recycle water pond pumping station, pond weirs, and the temporary construction water supply. The conceptual engineering for these facilities is to be carried out in Phase II.

CHAPTER 4

ALTERNATIVE SUPPLY SCHEMES

4.1 ALTERNATE No. 1

A number of alternative schemes and variations of schemes have been assessed during the study. These include:

Alternate No. 1 - Low-lift pumping station at Site No. 1 or Site No. 2, a large reservoir created by flooding Horseshoe Lake to elevation 790$^{\pm}$, a high-lift pumping station delivering water directly to the plant distribution system through 19,000 lineal feet of 54-inch I.D. pipeline. The Horseshoe Lake impoundment would afford over 10,000 acre feet of live storage with a 10-foot operating range - about 6 week's supply- and would also serve as the sedimentation basin. Direct pumping to the plant system would eliminate the need for a raw water pond and pumping station at the plant site. The main disadvantages of the system are:

(i) the possible environmental impact on Horseshoe Lake - a stop-over spot for migrating waterfowl;

(ii) the supply system is vulnerable to a breakage in the main pipeline - this could be overcome by twinning the line, or providing a raw water pond and pumping station at the plant site.

4.2 ALTERNATE No. 2

Low-lift pumping station at Site No. 1 utilizing screw pumps, a small 20,000 square foot sedimentation basin in two cells, a high-lift pumping station delivering water directly to the plant site through 25,000 lineal feet of 54-inch pipeline.

The main disadvantages of Alternate No. 2 are:

(i) lower system reliability since river withdrawals would be made continuously during periods of high river sediment loadings;

(ii) to compensate for (i), low-lift pumps would be a more rugged and costly type such as Archimedes screw pumps;

(iii) the small sedimentation basin would remove approximately 25 percent of the sediment - namely sand and coarser material. A sludge collection system would be required to collect and dispose of as much as 2 feet of deposition per day. Figure 11 shows the percent of sediment removal for smaller sedimentation basins;

(iv) the high-lift pumps would be more rugged since 75 percent of the suspended sediment would remain in the water. Greater standby pumping capacity for both pumping stations (50 percent or more) would be required because of the small system storage available.

(v) sediment deposition would occur in the raw water pond which would require dredging periodically; sludge disposal could constitute a problem;

(vi) the capital cost of the scheme is greater due to the long pipeline required, the rugged type of pumps, the greater standby pumping capacity. Annual costs would also be higher because of operating costs to dredge and dispose of sludge at the sedimentation basin and raw water pond.

(vii) the control system for river pumps and high-lift pumps would be much more sophisticated since little system storage is available. Pump start-up and shut-down would be automatically regulated by water level in the raw water pond to prevent over-topping or rapid depletion in the event of sudden changes in plant demand.

(viii) the main pipeline would cross difficult areas of deep muskeg along the river valley bottom, south of Mildred Lake, and to some extent west of Mildred Lake.

4.3 MISCELLANEOUS ALTERNATIVES

Other variations considered included a gravity river intake, various sedimentation basin sizes in the Horseshoe Lake area, a combined low-lift and high-lift pumping station, etc. At one stage, the diversion of Beaver River into Mildred Lake was contemplated - this scheme would be compatible with the recommended water supply scheme with a subsequent reduction in the pumping required from the Athabasca River.

CHAPTER 5

SUMMARY

In conducting this study, we have identified certain items which are the key physical factors affecting the design of a water supply system to the proposed Syncrude Plant site. These are:

(i) difficult river intake design due to shifting, shallow river channel, ice jams, and navigation aspects of the river;

(ii) heavy river sediment loadings at flood flows;

(iii) pipeline crossings of deep muskeg zones;

(iv) very high system reliability required.

It is our opinion that the recommended scheme, described in detail in Chapter 3 and shown on the drawings, can best cope with these physical factors and satisfy the criteria established for the system - namely safety, reliability, economy, and minimal environmental impact.

In summary, the recommended scheme:

(i) Is designed to deliver a firm water supply of 50,000 USGPM on a continuous basis for the initial 3 years of operation, reducing to 31,000 USGPM thereafter.

(ii) Utilizes the best available intake site in terms of river channel stability and depth, and pending drilling confirmation, will afford suitable bedrock foundations. The intake should project into the channel and be skewed to promote a self-scouring action along the face. This arrangement is most compatible with the navigational requirements on the river. The operating floor should be 30 feet above winter ice level to be above probable flood levels due to ice jams.

(iii) Utilizes three low-lift mixed-flow pumps of slow speed which will afford a high reliability factor and low maintenance cost. Pump controls will be operated only from the intake station although remote indication of operation will be provided.

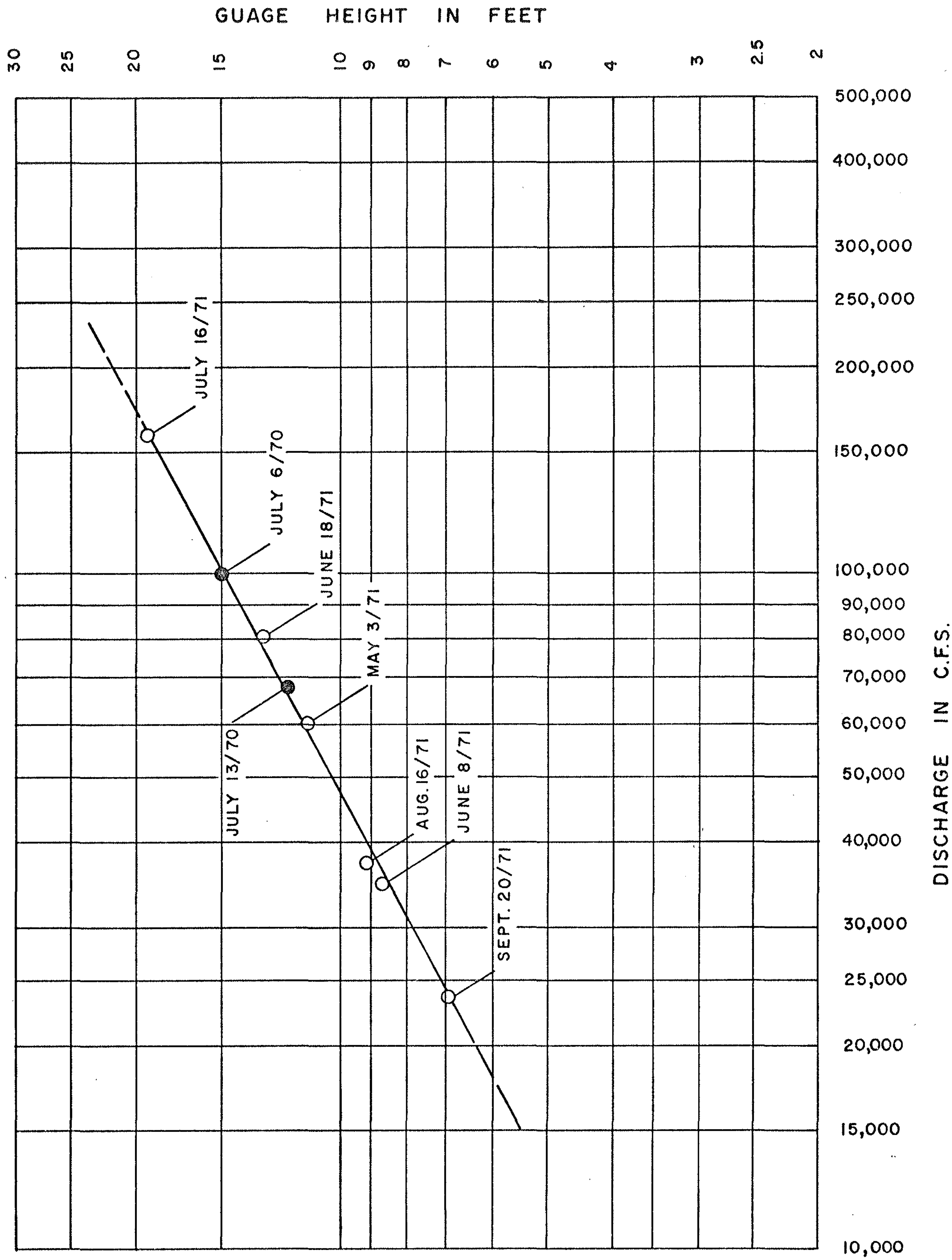
(iv) Employs a sedimentation basin of sufficient size to eliminate the requirement for periodic dredging. Dyke elevations should be sufficiently high (elevation 795) to prevent overtopping due to flood levels in the river caused by ice jams. Further soils investigations may locate pervious alluvial deposits which may necessitate a reduction in the size of the basin.

(v) Utilizes four high-lift vertical turbine pumps at 900 rpm and 1750 HPeach. Three units will deliver the design capacity of 61,000 USGPM required to refill depleted storage and allow for losses due to seepage, evaporation and reduction in pump efficiency. Studies now underway will better define the water hammer conditions and allow for a refinement of the method and cost of surge suppression.

(vi) Reduces to a minimum, the length of major pipeline required by utilizing natural conveyance through the sedimentation basin and Mildred Lake reservoir. Crossings of deep muskeg areas are eliminated. The economic pipeline size is 48-inch I.D. based on an assumed reduction in pumping rate after 3 years. Water hammer studies may indicate that a larger size is desirable. Concrete cylinder pipe will offer the most economical installation in the difficult terrain.

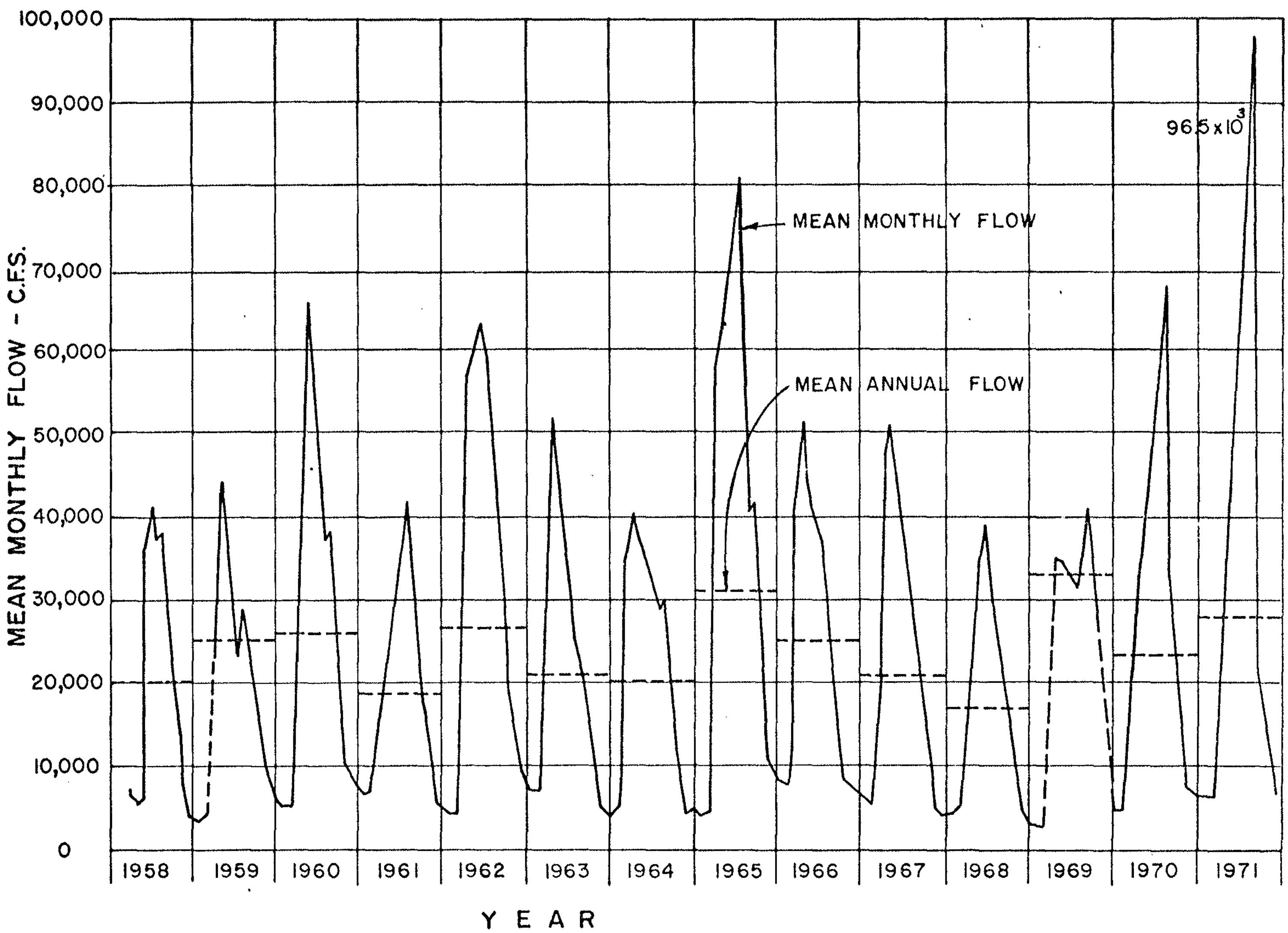
(vii) Will provide a high degree of system reliability by utilizing live storage in Mildred Lake. Minor interruptions in service at the river pumping stations will not affect the water supply to the plant site. In addition, withdrawals from the river can be reduced, or curtailed during heavy silt loadings to reduce wear on pumping equipment and to prolong the life of the sedimentation basin indefinitely. About four weeks of storage in Mildred Lake would be desirable for these purposes.

FIGURES



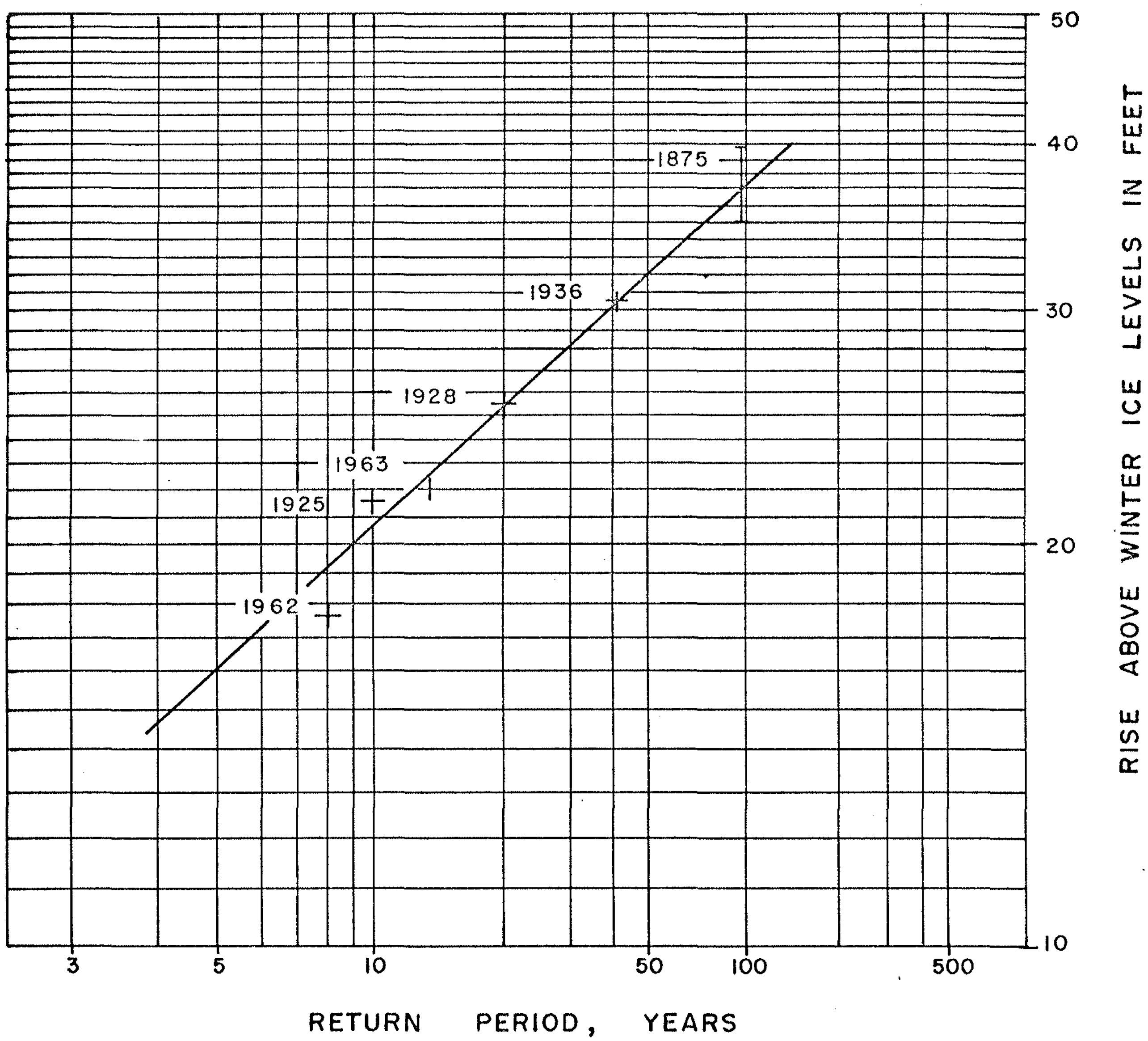
ATHABASCA RIVER
STAGE - DISCHARGE RELATIONSHIP
AT FORT McMURRAY GUAGING STATION

Figure 1



ATHABASCA RIVER
AT FORT McMURRAY

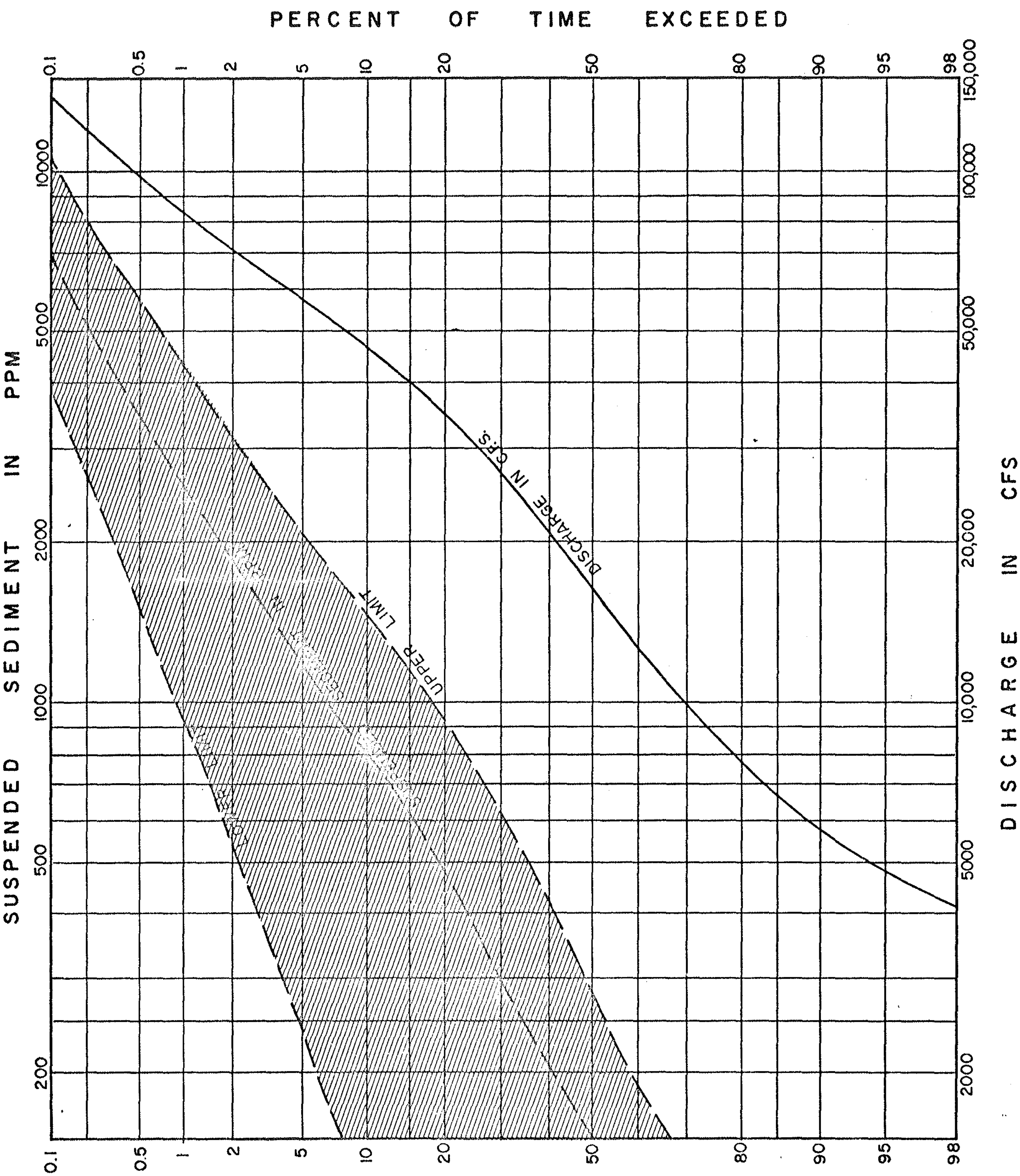
Figure 2



NOTE :
THIS GRAPH PREPARED BY
T. BLENCH & ASSOCIATES LIMITED, 1964

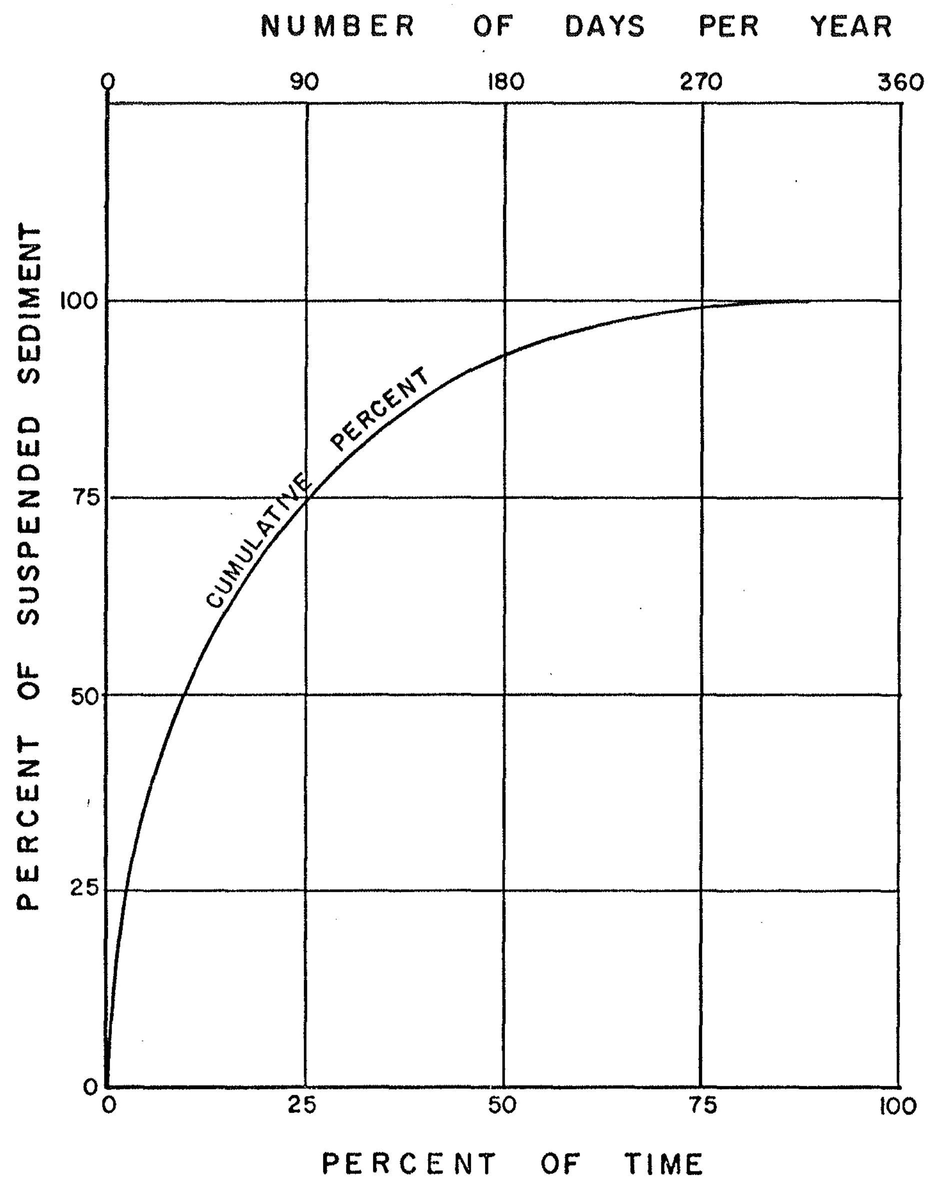
AVERAGE RETURN PERIODS
OF
ICE JAM FLOODS AT FORT McMURRAY

Figure 3



ATHABASCA RIVER
DURATION CURVES FOR
DISCHARGE AND SUSPENDED SEDIMENT

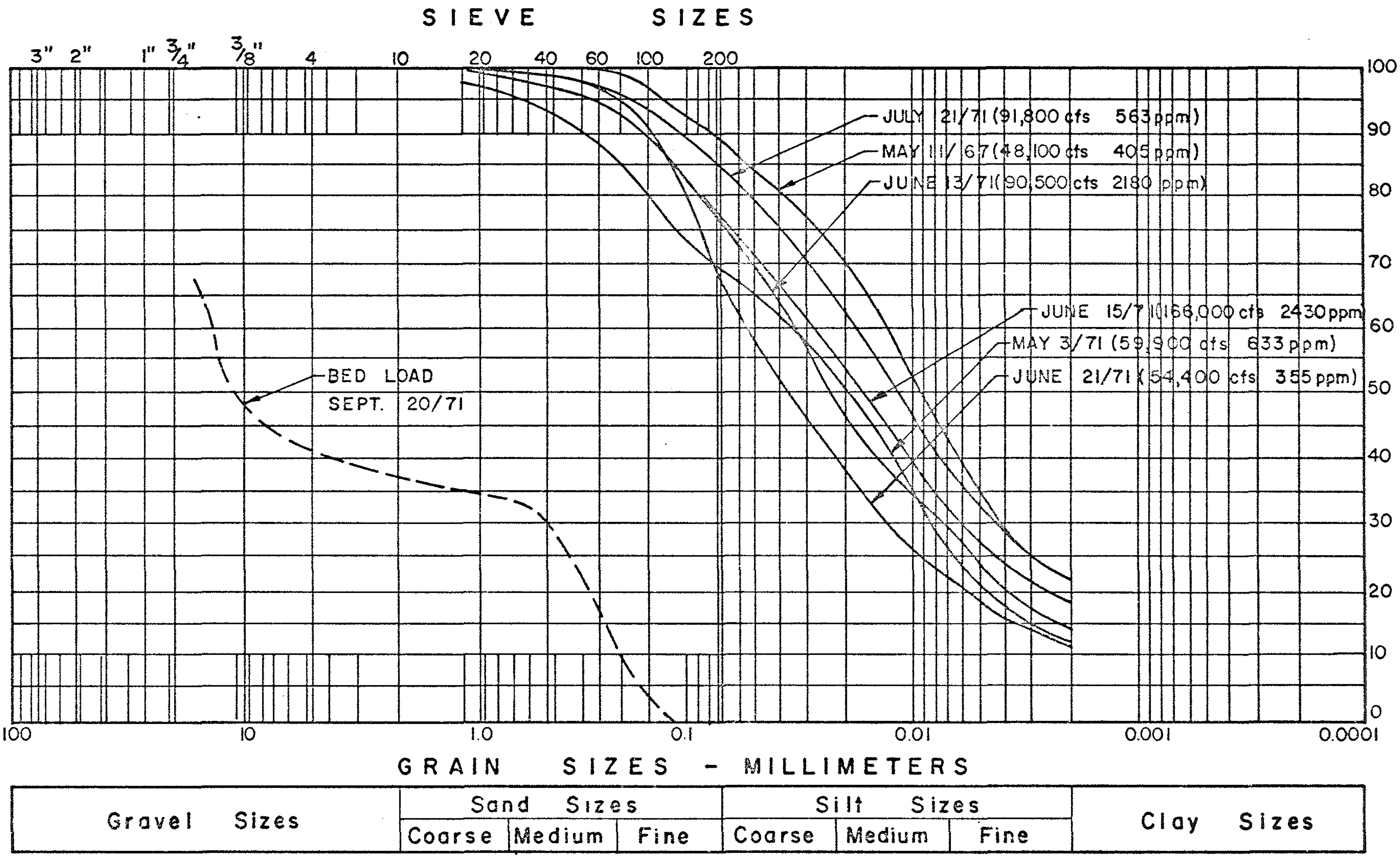
Figure 4

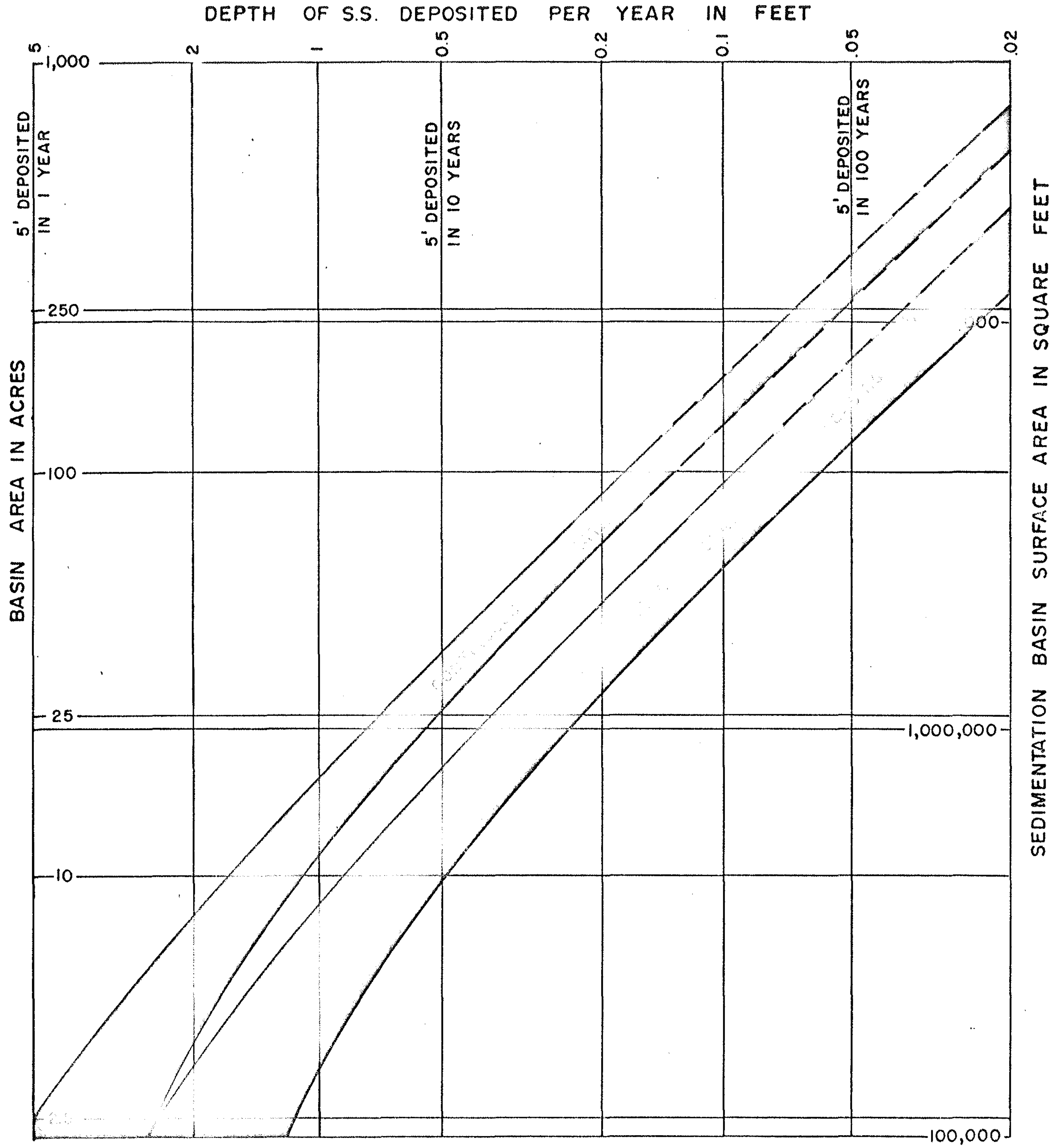


ATHABASCA RIVER
PERCENT OF ANNUAL SUSPENDED SEDIMENT
VS TIME

ATHABASCA RIVER

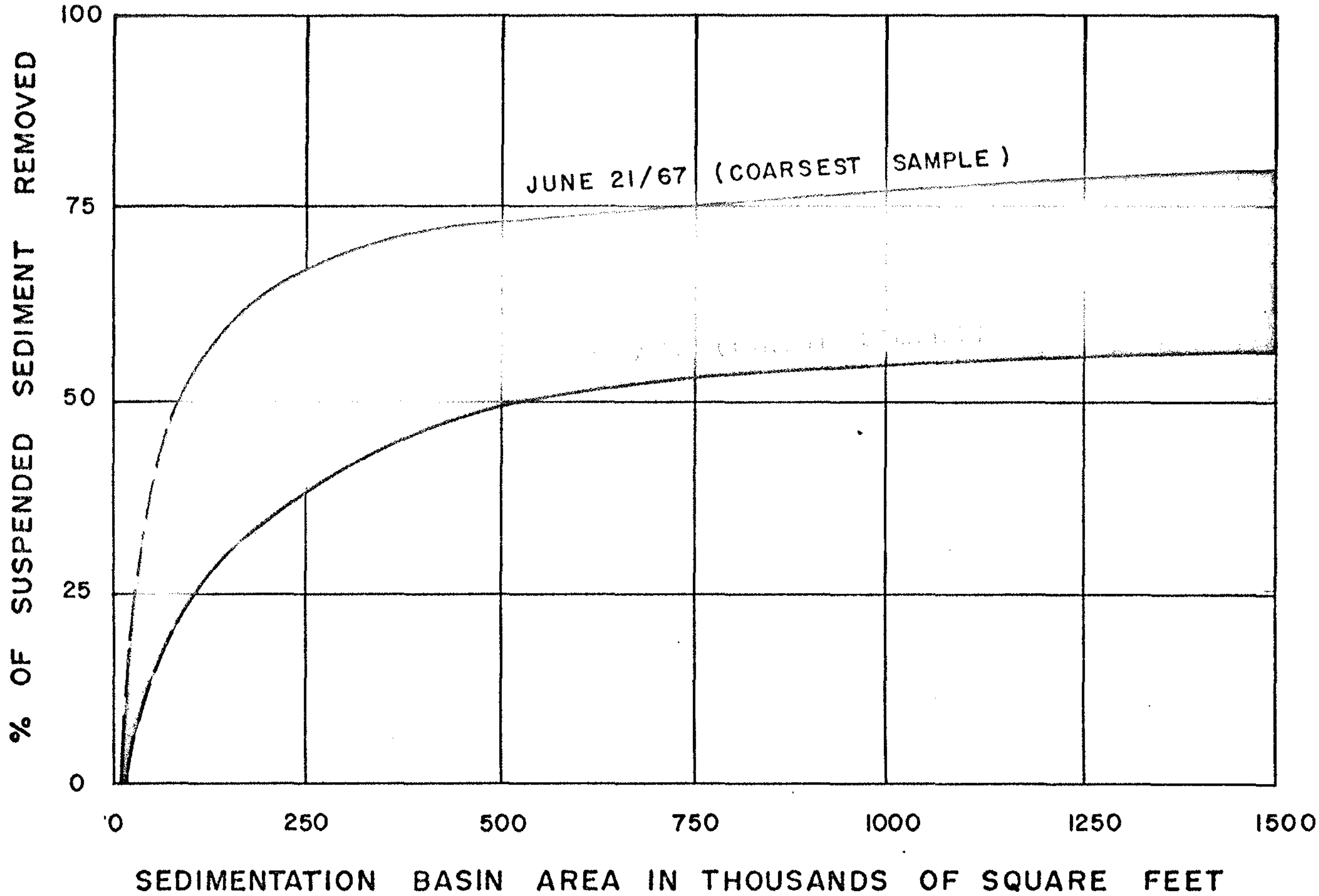
PARTICLE SIZE ANALYSES OF SUSPENDED SEDIMENT





SEDIMENTATION BASIN
DEPTH OF DEPOSITION PER YEAR
VS BASIN AREA

Figure 7

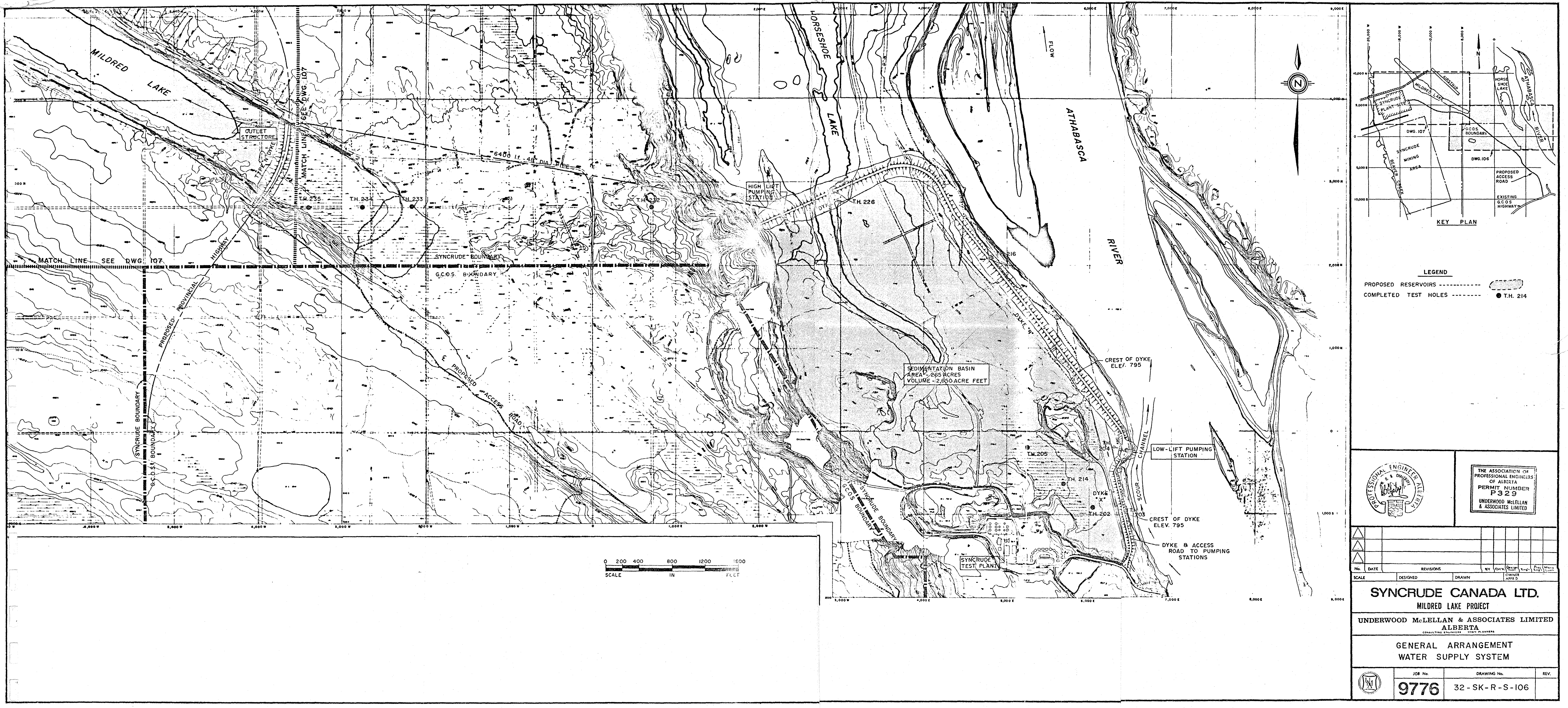


SEDIMENTATION BASIN AREA
VS
PERCENT OF SUSPENDED SEDIMENT REMOVED

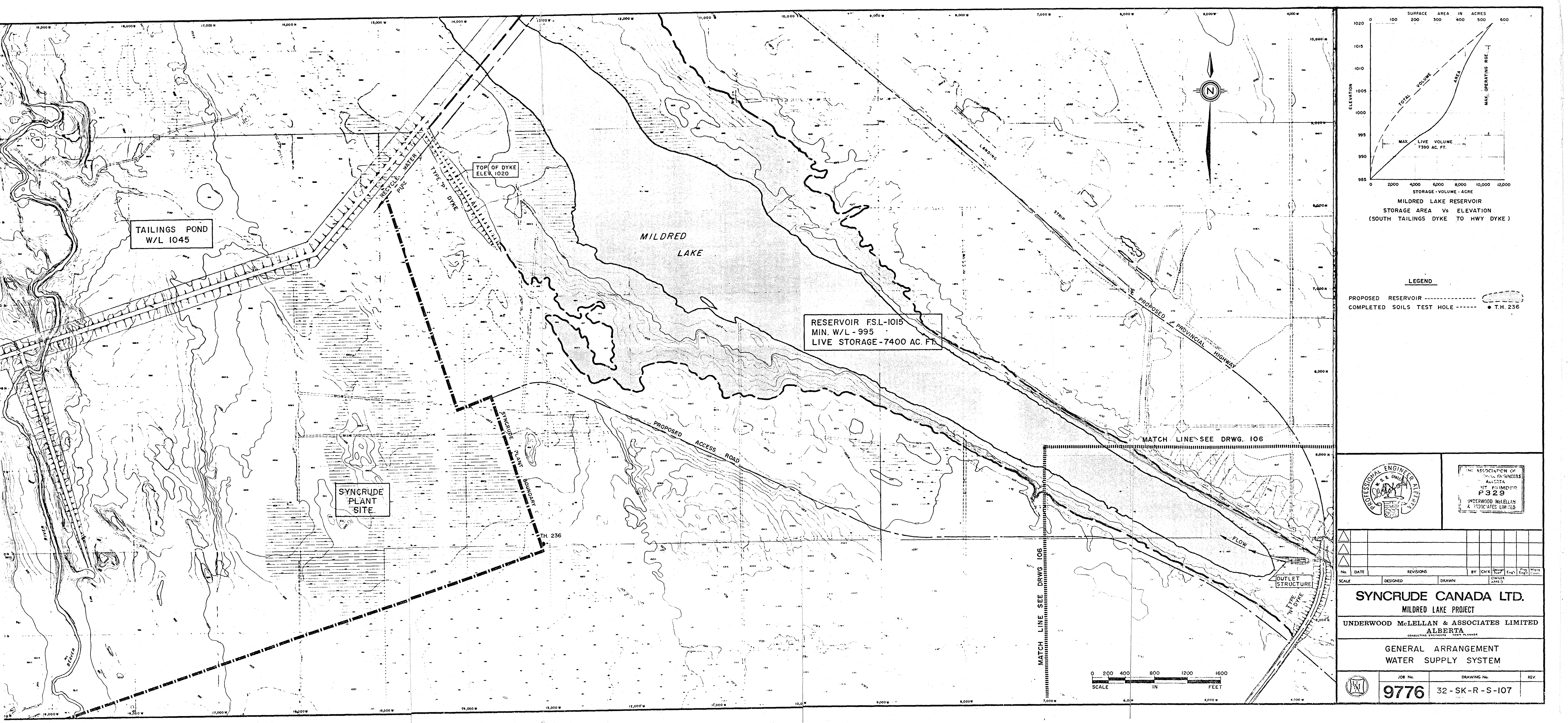
8

Figure

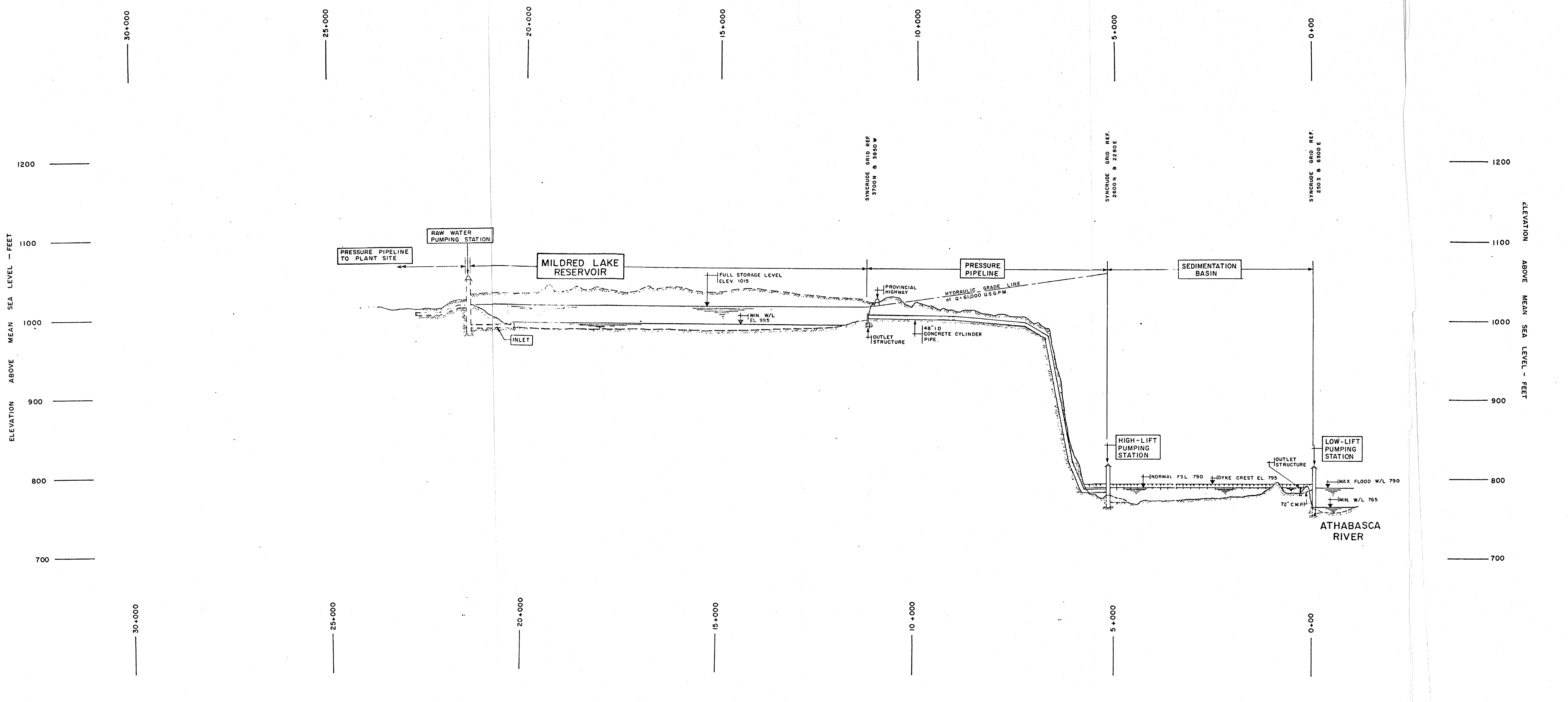
DRAWINGS



MILDRED LAKE
OUTLET STRUCTURE
TYPE N DYKE
MATCH LINE SEE DWG. 107
6400 LF 48" DIA. PIPE
T.H. 235
T.H. 234
T.H. 233
T.H. 232
HIGH LIFT PUMPING STATION
HORSESHOE LAKE
FLOW
ATHABASCA RIVER
T.H. 226
T.H. 216
DYKE
SYNCRUDE BOUNDARY
G.C.O.S. BOUNDARY
PROPOSED PROVINCIAL HIGHWAY
PROPOSED ACCESS ROAD
SEDIMENTATION BASIN
AREA - 265 ACRES
VOLUME - 2,650 ACRE FEET
CREST OF DYKE
ELEV. 795
T.H. 205
T.H. 204
T.H. 214
T.H. 202
DYKE "X"
LOW-LIFT PUMPING STATION
SCOUR CHANNEL
DYKE & ACCESS ROAD TO PUMPING STATIONS
SYNCRUDE TEST PLANT
0 200 400 800 1200 1600
SCALE IN FEET
KEY PLAN
SYNCRUDE PLANT SITE
MILDRED LAKE
AIRSTRIP
HORSE SHOE LAKE
ATHABASCA RIVER
DWG. 107
DWG. 106
G.C.O.S. BOUNDARY
SYNCRUDE MINING AREA
BEAVER CREEK
PROPOSED ACCESS ROAD
EXISTING G.C.O.S. HIGHWAY
LEGEND
PROPOSED RESERVOIRS
COMPLETED TEST HOLES
T.H. 214
PROFESSIONAL ENGINEER ALBERTA
THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF ALBERTA
PERMIT NUMBER
P329
UNDERWOOD McLELLAN & ASSOCIATES LIMITED
No. DATE REVISIONS
SCALE DESIGNED DRAWN
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
UNDERWOOD McLELLAN & ASSOCIATES LIMITED
ALBERTA
CONSULTING ENGINEERS TOWN PLANNERS
GENERAL ARRANGEMENT
WATER SUPPLY SYSTEM
JOB No.
9776
DRAWING No.
32-SK-R-S-106
REV.



TAILINGS POND W/L 1045
RECYCLE WATER PIPE
TYPE "D" DYKE
TOP OF DYKE ELEV 1020
MILDRED LAKE
RESERVOIR F.S.L-1015
MIN. W/L - 995
LIVE STORAGE - 7400 AC. FT.
LANDING STRIP
PROPOSED PROVINCIAL HIGHWAY
PROPOSED ACCESS ROAD
SYNCRUDE PLANT BOUNDARY
SYNCRUDE PLANT SITE
TH. 236
MATCH LINE SEE DRWG. 106
OUTLET STRUCTURE
FLOW
TYPE "N" DYKE
SCALE IN FEET
0 200 400 800 1200 1600
SURFACE AREA IN ACRES
STORAGE - VOLUME - ACRE
ELEVATION
TOTAL VOLUME
AREA
MAX. OPERATING RGE.
MAX. LIVE VOLUME 7390 AC. FT.
MILDRED LAKE RESERVOIR
STORAGE AREA Vs ELEVATION
(SOUTH TAILINGS DYKE TO HWY DYKE)
LEGEND
PROPOSED RESERVOIR
COMPLETED SOILS TEST HOLE • T.H. 236
PROFESSIONAL ENGINEER ALBERTA
P329
UNDERWOOD McLELLAN & ASSOCIATES LIMITED
No. DATE REVISIONS BY CH'K
SCALE DESIGNED DRAWN OWNER APPR'D
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
UNDERWOOD McLELLAN & ASSOCIATES LIMITED
ALBERTA
CONSULTING ENGINEERS TOWN PLANNER
GENERAL ARRANGEMENT
WATER SUPPLY SYSTEM
JOB No. 9776
DRAWING No. 32-SK-R-S-107
REV.



PROFESSIONAL ENGINEER ALBERTA

THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF ALBERTA
PERMIT NUMBER
P329
UNDERWOOD McLELLAN & ASSOCIATES LIMITED

No.	DATE	REVISIONS	BY	CH'K	Design Supv	Proj. Eng'r	Proj. Eng'r	Mgr.

SCALE | DESIGNED | DRAWN | OWNER APP'D

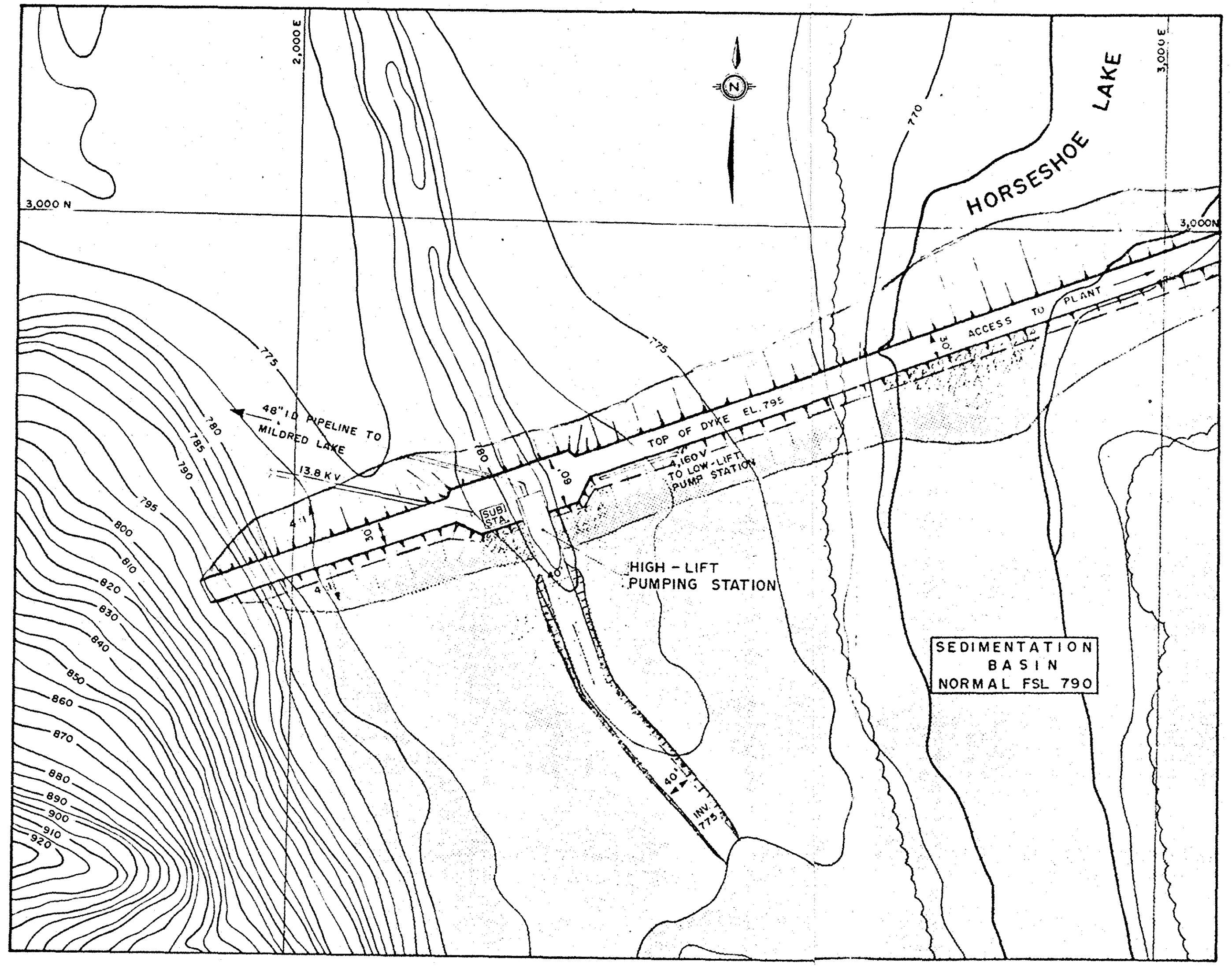
SYNCRUDE CANADA LTD.

MILDRED LAKE PROJECT

UNDERWOOD McLELLAN & ASSOCIATES LIMITED
ALBERTA
CONSULTING ENGINEERS · TOWN PLANNERS

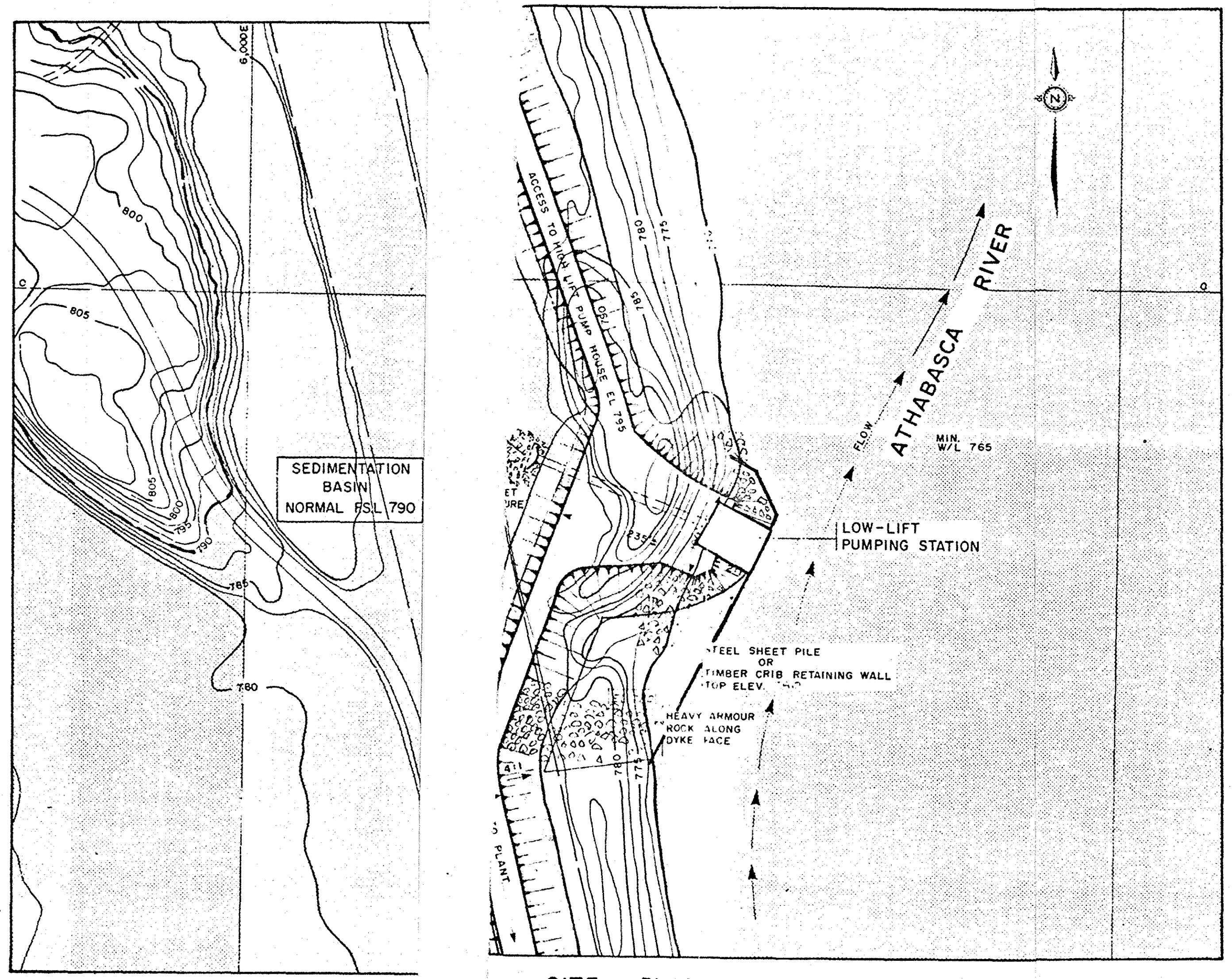
PROFILE ALONG CENTERLINE
OF
PROPOSED WATER SUPPLY SYSTEM

JOB No.	DRAWING No.	REV.
9776	32-SK-R-S-108	



SITE PLAN
HIGH-LIFT PUMPING STATION

0 25 50 75 100 200
SCALE IN FEET



SITE PLAN
LOW-LIFT PUMPING STATION

0 25 50 75 100
SCALE IN FEET

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No	DATE	REVISIONS	BY	CHK

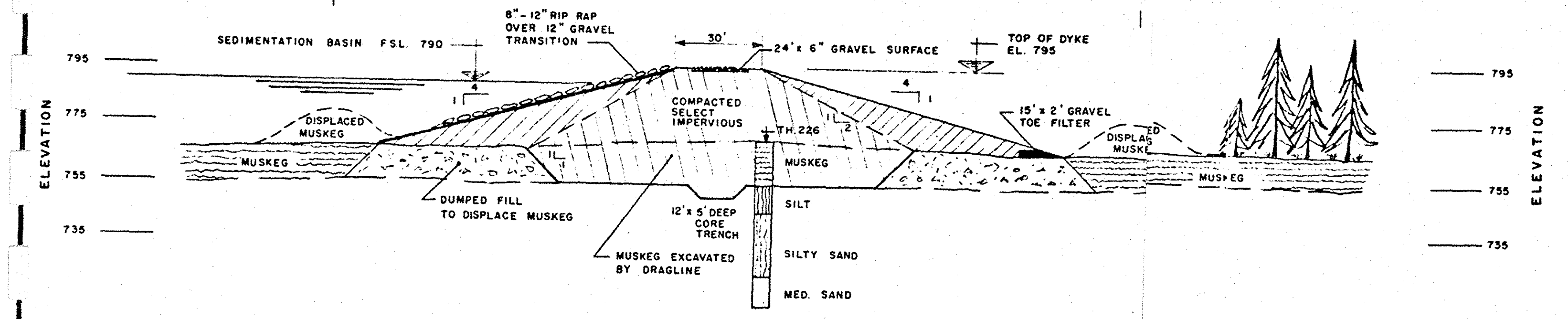
SCALE | DESIGNED | DRAWN

SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT

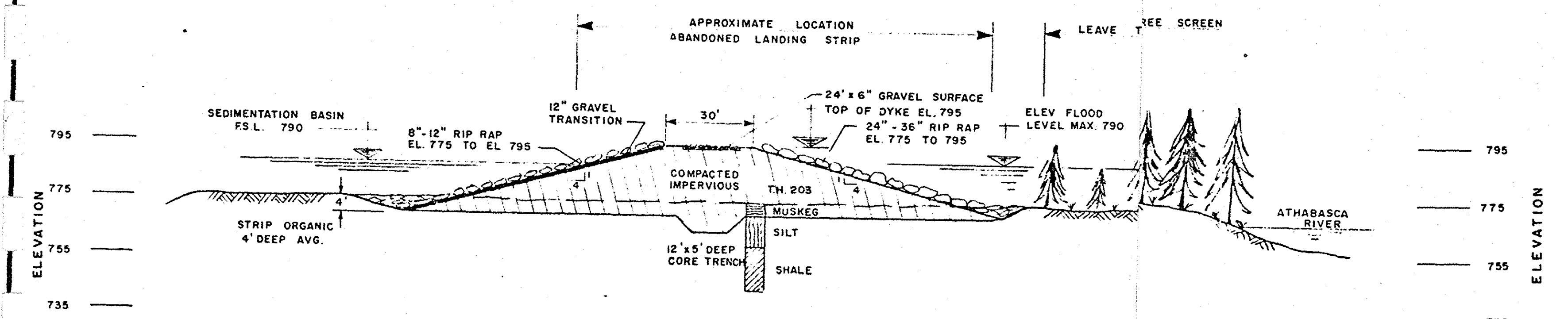
UNDERWOOD McLELLAN & ASSOCIATES LIMITED
ALBERTA

HIGH & LOW LIFT PUMPING STATIONS
SITE PLANS

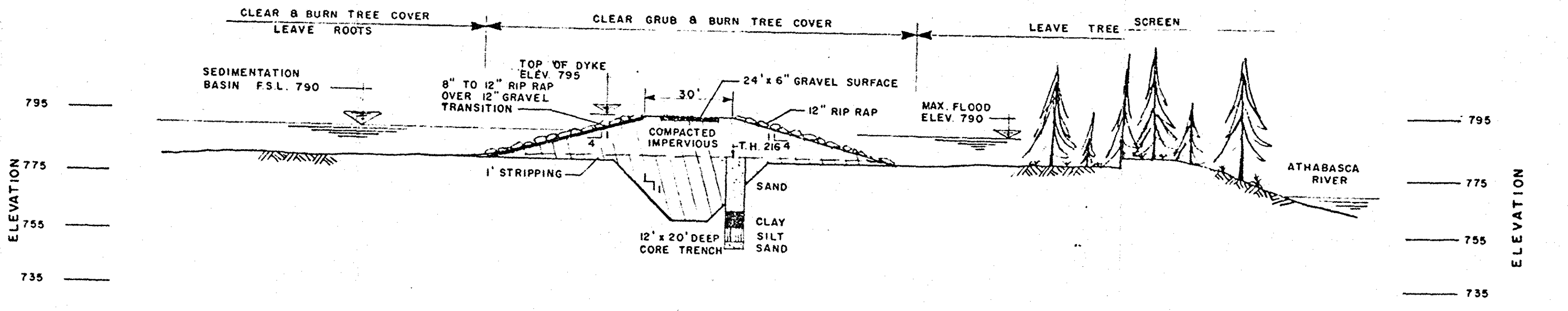
JOB No 9776 | DRAWING No. 32-SK-R-S-109 | REV



DYKE "E"



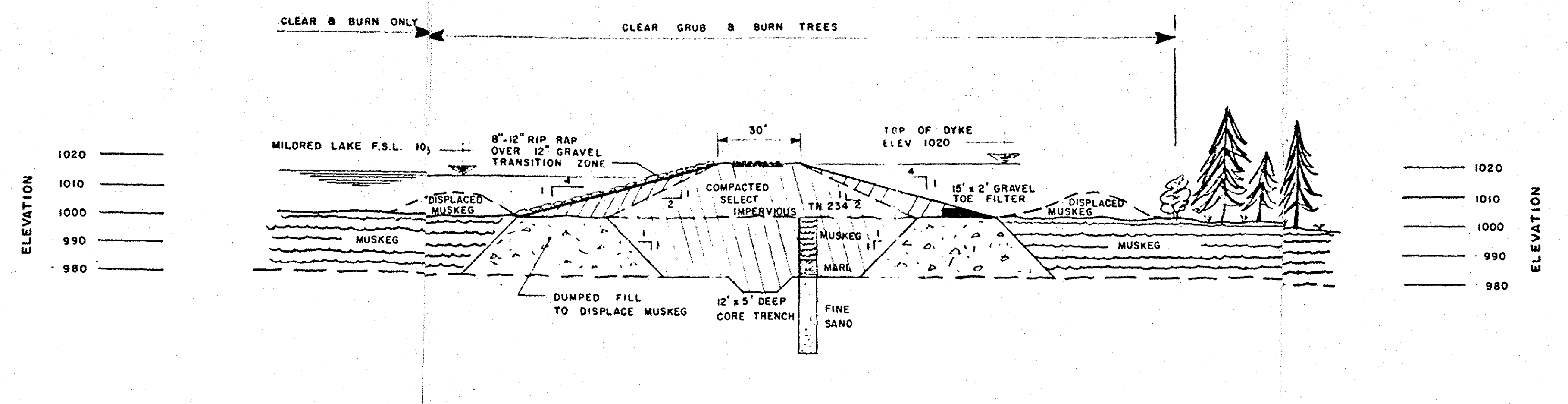
DYKE "X"



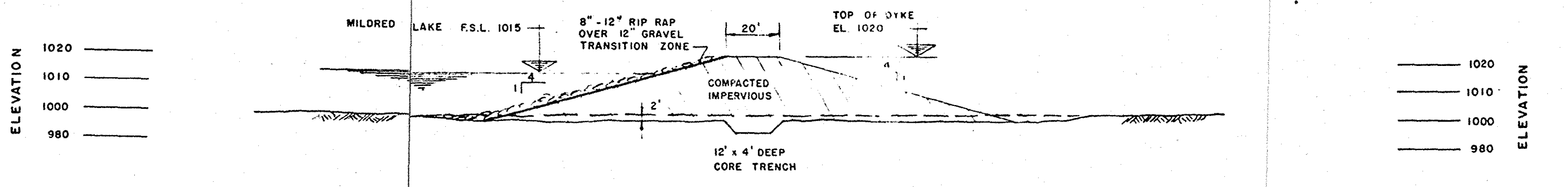
DYKE "B"

SEDIMENTATION BASIN DYKES
TYPICAL SECTIONS

0 10 20 30 60 90
SCALE IN FEET



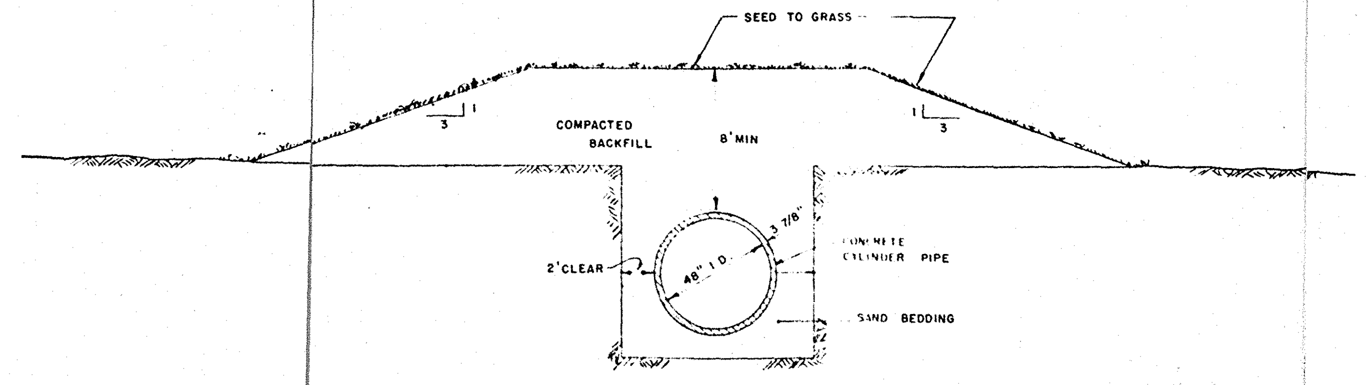
DYKE "N"



DYKE "P"

MILDRED LAKE RESERVOIR
TYPICAL SECTIONS

0 10 20 30 60 90
SCALE IN FEET



TYPICAL PIPELINE SECTION
NTS

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THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF ALBERTA
PERMIT NUMBER P329
UNDERWOOD McLELLAN & ASSOCIATES LIMITED

No.	DATE	REVISIONS	BY	CH'K	Design Supv	Eng'r	Proj. Mgr.

SCALE	DESIGNED	DRAWN	OWNER APPR'D

SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT

UNDERWOOD McLELLAN & ASSOCIATES LIMITED
ALBERTA
CONSULTING ENGINEERS TOWN PLANNERS

TYPICAL SECTIONS
DYKES AND PIPELINE

JOB No.	DRAWING No.	REV.
9776	32-SK-R-S-112	

e) <u>Main Tailings Pond Data</u>

Area	6400 acres
Volume to EL 1095	27,600,000,000 CF
Minimum Freeboard Allowance	10 ft.

f) <u>Plant 6 Tailings</u>

Area	960 acres
Volume to EL 1100	1,280,000,000 CF
Minimum Freeboard Allowance	5 ft.

g) <u>Dyke Criteria</u>

Materials of Construction for Starter Dykes	Compacted Earth Fill
Materials of Construction for Dykes	Compacted Sand Tailings
Side Slopes	1:3
Crest Height	EL 1105
Crest Width	20 ft.
Width of Downstream Slope Access Berms	20 ft.
Gravel Filters	50' wide x 3' thick on all perimeter dykes @ 50' maximum vertical distance.

4.0 TAILINGS DISPOSAL - EXTRACTION & FROTH TREATMENT

4.1 Extraction Plant Tailings to the Pond

Tailings will be pumped from the Extraction Plant to the Tailings Pond at 24,000 tons per hour, 50 percent solids by weight and 170° F. Effluents from the upgrading units and useable water from the mine pit will also be pumped to the pond.

The tailings sludge fraction, and other influent waters will flow to the northern section of the pond for settlement where the surface topography is the lowest. After the solids have settled out to less than 3 percent by weight, water will be reclaimed by pumps mounted on a floating barge and recycled to the Extraction Plant. The reclaiming of this partly clarified water will commence about 1980.

The method of hydraulically constructing dykes through a series of cells is a conventional operation. The sand tailings dykes are hydraulic fill structures involving a compacted downstream shell. The thickness of the shell has been designed to resist the hydrostatic pressure from contained water and the uncompacted tailings solids.

Because the pond will be filled gradually, and a rapid draw-down condition cannot occur, safety of the dykes poses no problem.

Seepage through the dykes will be controlled by the use of continuous internal gravel filters, and will be monitored by piezometers. The seepage will reduce with time as voids in the sands are sealed by sludge fines; thus contributing further to the safety of the dykes.

This method of dyke building with tailings sands is to be used because of its inherent flexibility.

The ultimate height of the dykes is governed by the rate of development of the mine pit. Figures 1 to 3 indicate the life of the main tailings pond, its areas and volumes at various elevations, and rate of construction of the dykes necessary to keep the crests well above the rising pond level.

4.2 Extraction Plant Tailings to the Mine Pit

As soon as it is feasible to do so, the Extraction Plant tailings will be discharged into the mine pit. The timing is dependent upon the method employed to open the pit and the volume of the excavated pit - to avoid interfering with the mining operation.

The currently planned method of opening the mine indicates that the earliest time tailings can be economically placed will be about five and one half years from start-up. Then, the pit will be approximately 4,500 ft wide x 14,000 ft long.

As the pit opens, the overburden and reject materials are cast back into it, levelled and consolidated as required.

One of the problems associated with reclamation of a tar sands mine is that the residual solids and associated waters will occupy a volume up to 30 percent greater than the void space created by the mining operation. As a consequence of this volumetric swelling, the final elevation of the reclaimed mine area could be up to 100 ft higher than the surrounding terrain.

The location and height of the internal dykes will be as shown by sketches 51D-SK-A-101 and 103. The method of building the inpit dykes using sand tailings will be by conventional hydraulic fill.

After Extraction Plant tailings have been turned into the pit a low density sludge will collect along the north face of the mine. It will be pumped into the main Tailings Pond, using barge mounted pumps. Coarse sands will remain as pit fill.

Mine pit cell No. 1 per 51D-SK-A-101 will be filled by 1990. Reclamation work at the southern end will commence soon after the de-watering process is completed and the placed tailings materials are sufficiently consolidated.

At the end of mining operations, cells 1, 2A and 2B will be completely filled with tailings. Only overburden and rejects will have been placed in cells 3A and 3B. There will be enough volume in these outflanking cells to accommodate the contents of the Tailings Pond should the transfer be made at a future time; but, perimeter dykes would be necessary.

4.3 Froth Treatment Tailings

Tailings from the Froth Treatment Plant at 1000 tons per hour, containing 20 percent solids by weight at 170°F, will be pumped to a separate pond. These solids contain heavy minerals and will be settled for future recovery. Hydrocarbon float will be skimmed and free water decanted to the main Tailings Pond. The dykes for the Froth Treatment tailings impounding area will be built from suitable earthfill materials, borrowed locally.

4.4 Slope Stabilization of Dykes

To stabilize the embankment slopes from erosion, due to wind, rain and snow, the downstream surfaces of all the dykes will be vegetated.

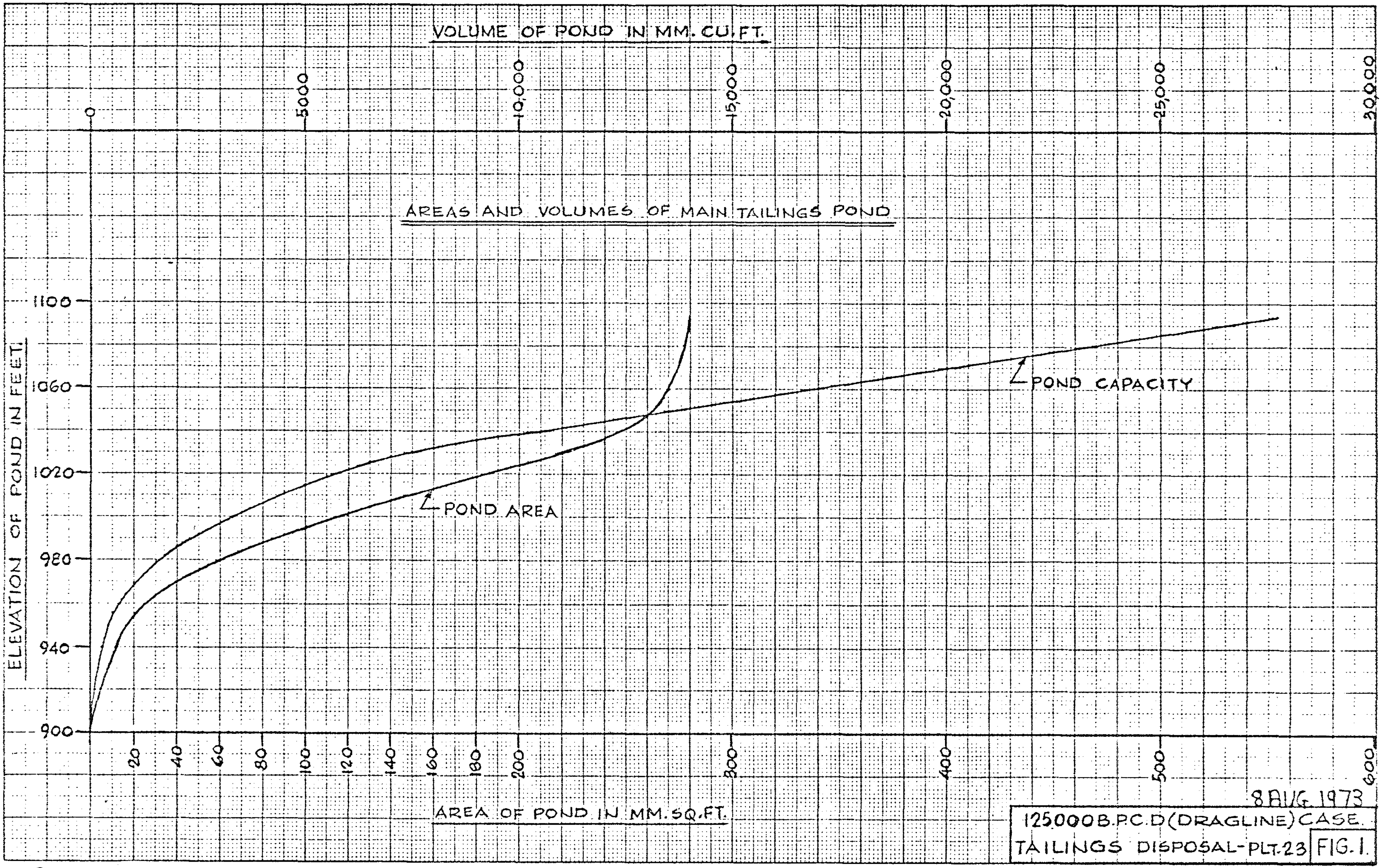
Year	Area to be Seeded in Acres
1978	100
1980	600
1983	250

Vegetating and revegetating studies and programs are reported separately.

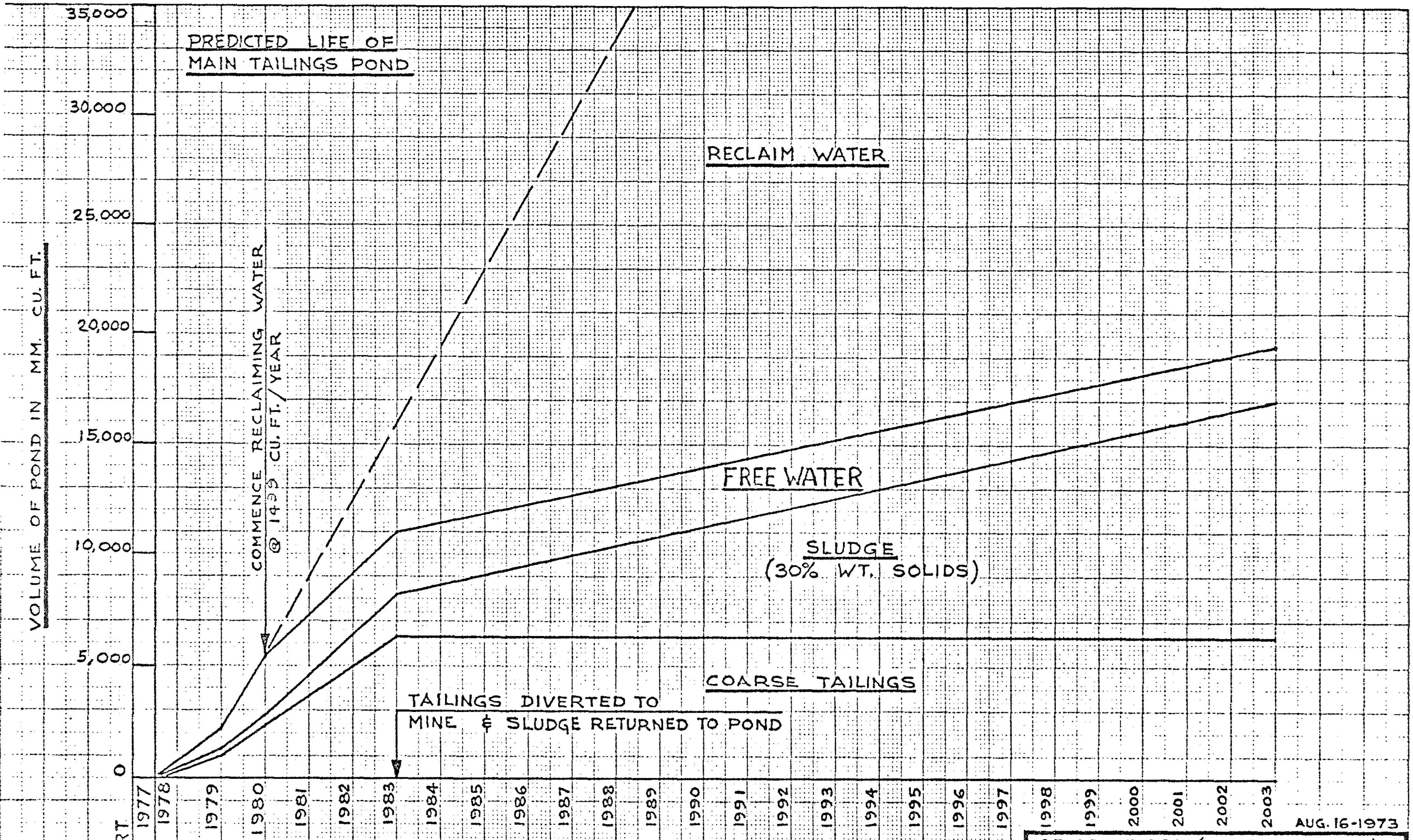
4.5 Vegetation of Mine Pit Cells

Cell surfaces will be prepared for subsequent soil amendments as noted on sketch 51D-SK-A-103. Surface readying will follow the following approximate schedule:

Cell	Period Available	Area to be Seeded in Acres
1-slopes	1985-1989	70 (ends only)
1-surface	1988-1990	1060
2-slopes	1995-2002	510
2-surface	2000-2002	1850

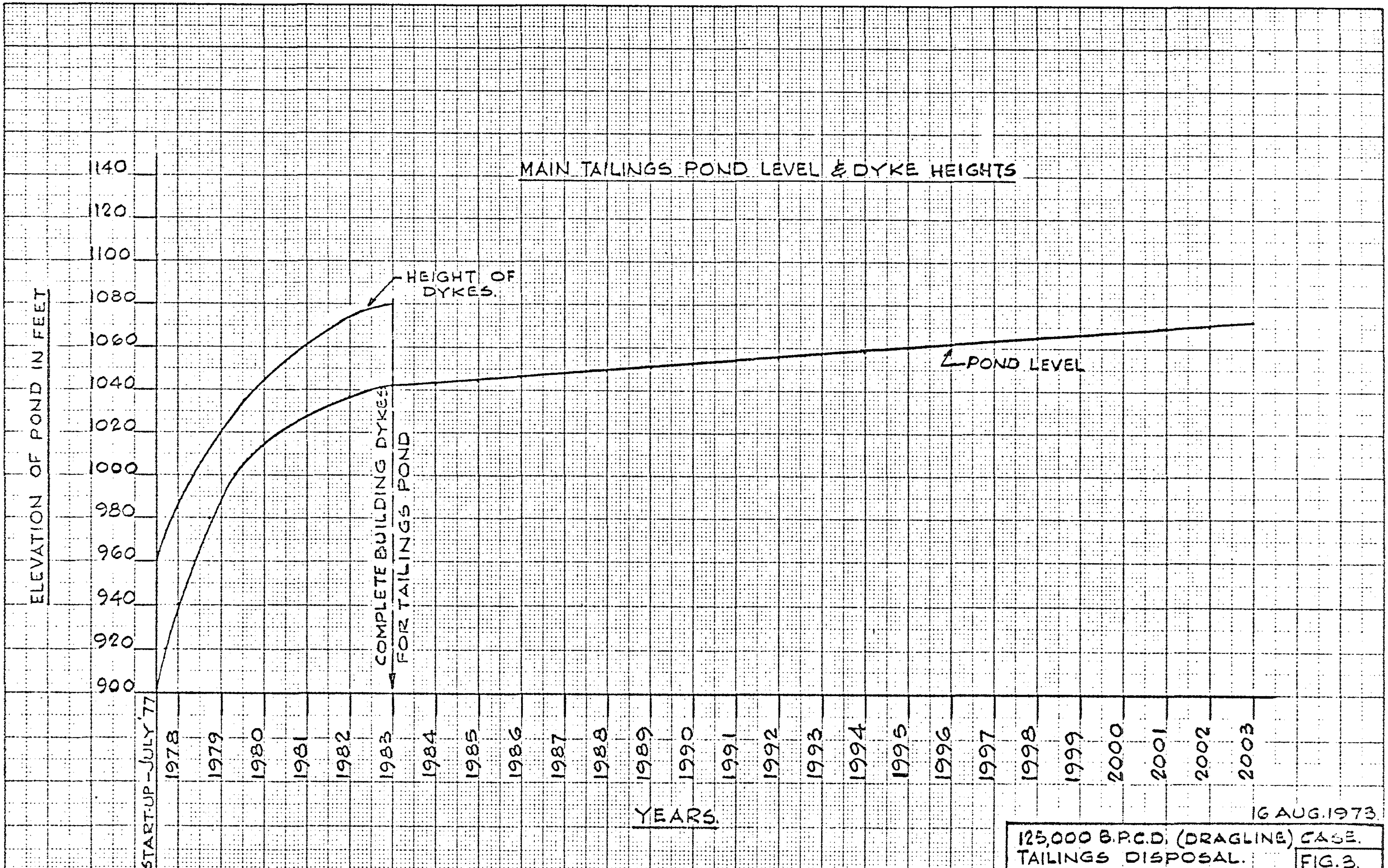


335-5021 20×20



AUG. 16-1973

125,000 B.P.C.D. (DRAGLINE CASE)
TAILINGS DISPOSAL-PLANT 23 FIG. 2



16 AUG. 1973.

125,000 B.P.C.D. (DRAGLINE) CASE.
TAILINGS DISPOSAL.

FIG. 3.

S E C T I O N 3.

SITE RECLAMATION

3. SITE RECLAMATION

A. INTRODUCTION

A major concern related to any tar sands project using the proposed mining approach is the reclamation of the site. As will be evident upon examination of the first report in this section, related to planning considerations, reclamation and mining plans are strongly interdependent.

Since the final configuration of the mine and details of the mining scheme are yet to be finalized, it is not possible to provide a detailed and final plan at this point in time.

The reclamation plan described in this report was selected from a number of alternatives by sytematic analysis of the fit of each alternative to carefully developed and weighted objectives.

Included as unconditional objectives in the site reclamation plan are:

1. The area left as land must be biotically productive.
2. The area left as water must be acceptable relative to chemical, biological, circulatory and hydrological considerations.
3. The plan must be feasible in terms of existing technology.
4. The plan must not depend on any subsequent plant.

Included as objectives to make best use of resources, to provide maximum results and returns and to minimize disadvantages are:

1. To achieve the required results at minimum cost and to defer expenditure to the extent possible where economic.
2. To provide maximum design flexibility.
3. To minimize interference with mining, transportation and water reclaim systems.
4. To minimize unreclaimed land area at any one time over the next 25 years.
5. To allow operational flexibility.

6. To create positive public reception to plans.
7. To initiate a self-perpetuating and maintenance free vegetation cover compatible with wildlife within two years of the termination of the project.

Revegetation, of areas disturbed or reclaimed during and subsequent to the lifetime of the project, is the subject of a current research and development program. The second document in section 3 of this volume is a present status report of that program.

SECTION 3.

SITE RECLAMATION

B. PLANNING CONSIDERATIONS

August, 1973

I N D E X

1.0 INTRODUCTION

This report outlines the current status of development for items involving Site Reclamation and associated operations.

It is meant to be a source document for a comprehensive Environmental Study as assembled by Syncrude Canada Ltd. for presentation to the Minister of the Environment for the Province of Alberta.

Methods of recovery of the bitumen reserves beneath the Tailings Pond are to be developed as a separate document, in response to a requirement of the ERCB.

2.0 SCOPE

Inter alia, the following matters are covered:

A) Establishing of a Tailings Pond and the water balances connected thereto.

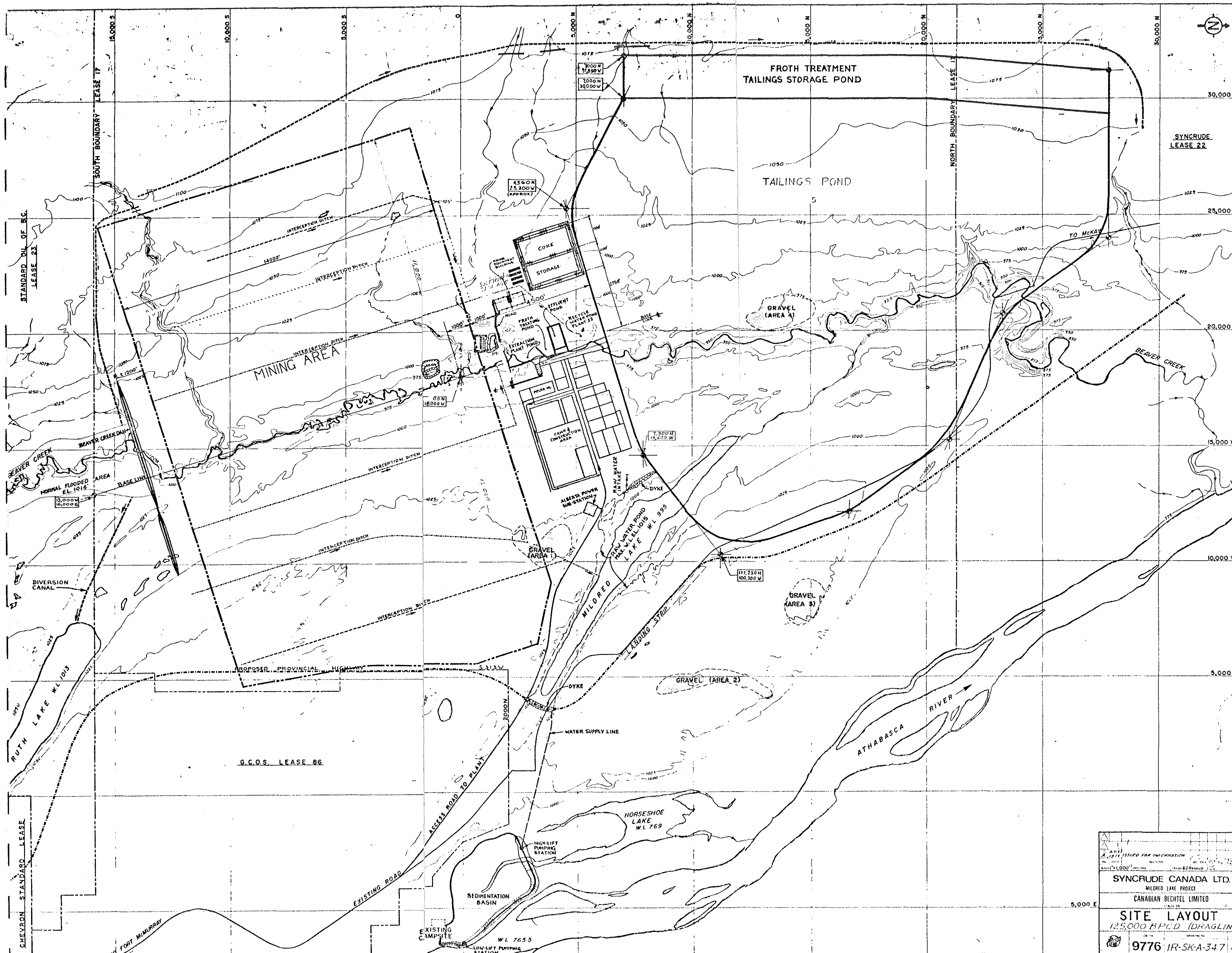
B) Description of mining methods and tailings disposal to allow a revegetation program to initiate in the 2nd and 3rd year of operation for side slopes, and the 12th year of operations for mined out areas.

C) Methods for muskeg handling, storage and disposal.

D) Illustrations of the Beaver Creek Diversion Scheme.

E) Means of coke disposal.

F) Froth treatment tailings storage.



FROTH TREATMENT
TAILINGS STORAGE POND
TAILINGS POND
SYNCRUDE LEASE 22
TO McKAY
COKE
STORAGE
EFFLUENT POND
RECYCLE WATER POND
FROTH TREATING POND
EXTRACTION PLANT POND
POWER HL
CAMP & CONSTRUCTION AREA
RAW WATER INTAKE
DYKE
ALBERTA POWER SUB-STATION
RAW WATER POND MAX.W.L.EL.1015
MILDRED LAKE W.L. 995
LANDING STRIP
GRAVEL (AREA 1)
GRAVEL (AREA 2)
GRAVEL (AREA 3)
GRAVEL (AREA 4)
BEAVER CREEK
ATHABASCA RIVER
MINING AREA
INTERCEPTION DITCH
BEAVER CREEK DAM
NORMAL FLOODED EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L.1013
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
CHEVRON STANDARD LEASE
G.C.O.S. LEASE 86
PROPOSED PROVINCIAL HIGHWAY
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
WATER SUPPLY LINE
HORSESHOE LAKE W.L 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
W.L 765.5
LOW-LIFT PUMPING STATION
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
ISSUED FOR INFORMATION
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE LAYOUT
125,000 BPCD (DRAGLINE)
9776 IR-SK-A-347 A

3.0 DESIGN CRITERIA

All quantities appearing as Design Criteria are averages. Variations can be expected on a day to day and year to year basis.

a) The Mining Pit has been selected for a continuous 25-year operation.

b) The area of the Tailings Pond is based on settling time such that a minimum of fines are to be contained in the effluent, which is recycled to the Extraction Plant.

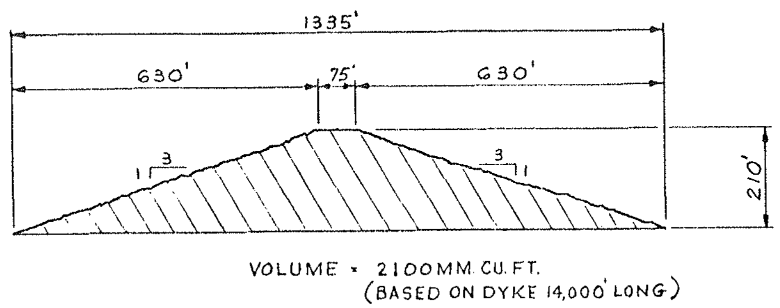
c) Material Data:

Tar Sand Mining Rate		92,800,000 T/yr
Bitumen Production Rate		125,000 BPCD
Tailings from Extraction Plant		143,000,000 T/yr
	Sand	62,000,000 T/yr
	Silts & Clays	9,500,000
	Water	71,500,000
		143,000,000 T/yr
Tailings from Froth Treatment Plant		7,200,000 T/yr
	Sand	1,300,000 T/yr
	Silts & Clays	300,000
	Water	5,600,000
		7,200,000 T/yr
Sour Water from Naphtha Recovery & Waste Waters from the Upgrading Units		220,000,000 CF/yr
Ground Water * from the Mine Pit		281,000,000 CF/yr (estimated)

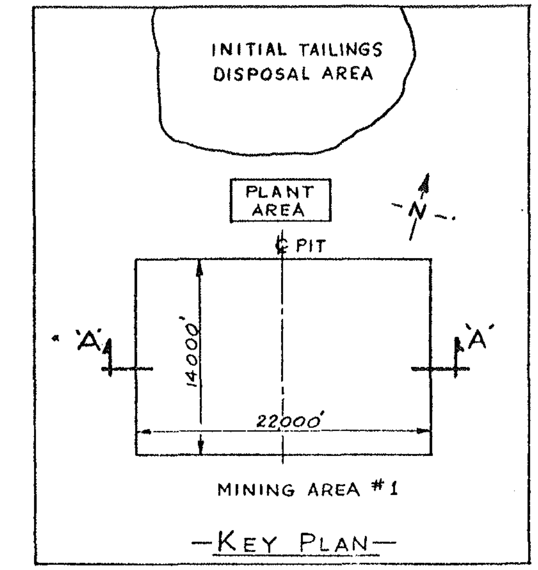
* Possibly saline

d) Plant Production Rate

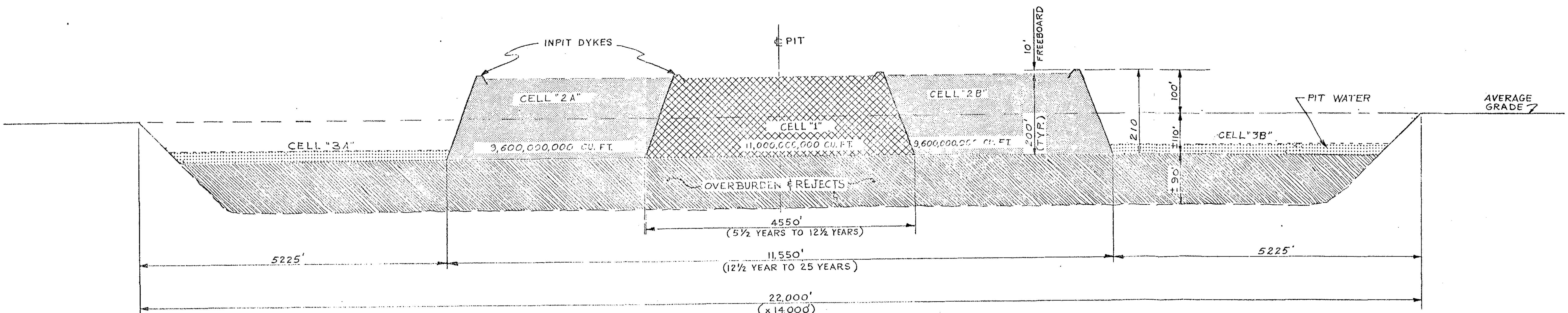
YEAR	PRODUCTION
1977	7%
1978	58%
1979	86%
1980-2002	100%



INPIT DYKE SECTION
(TYPICAL)



—KEY PLAN—



SECTION (A)

INDICATES YEAR 5½ TO 12½ TAILINGS PLACEMENT

INDICATES YEAR 12½ TO 25 TAILINGS PLACEMENT

INDICATES PIT WATER

OVERBURDEN & REJECTS

No.	DATE	REVISIONS	BY	CH'K	Design Supv	Eng'r	Proj Eng'r	Appr
B	AUG. 21 1973	UPDATED	W.H.					
A	AUG. 6 1973	ISSUED FOR INFORMATION	W.H.					

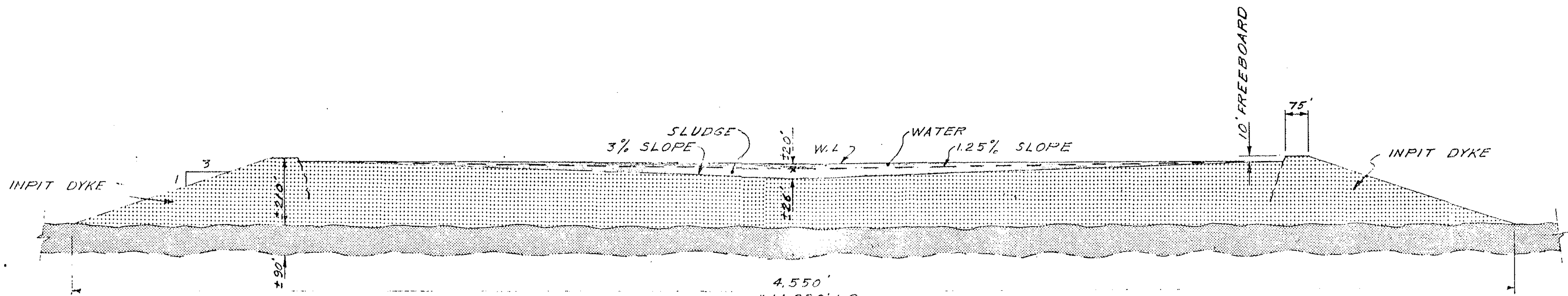
SCALE N.T.S. | DESIGNED | DRAWN | CHIEF ENG'R

SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT

CANADIAN BECHTEL LIMITED
EDMONTON

TAILINGS & REJECT MATERIAL PLACEMENT IN MINE PIT
125,000 B.P.C.D. (DRAGLINE)

JOB No.	DRAWING No.	REV.
9776	51D-SK-A-101	B



TOTAL TAILINGS VOLUME 11,000,000,000 CU.FT. (INCL. SLUDGE & WATER)

TYPICAL SECTION THRU CELL 1

SCALE 1" = 200'

NOTES:

1. SEE DWG. 51D-SK-A-101 FOR COMPLETE SECTION THRU TOTAL PIT.
2. WATER AND SLUDGE WILL BE PUMPED FROM THE CENTER LOW POINT UNTIL IT IS POSSIBLE TO BRING IN COARSE TAILINGS TO STABILIZE THE CENTER SECTION FOR VEGETATION.

LEGEND

- WATER
- SLUDGE
- SAND TAILINGS
- OVERBURDEN & REJECT

No.	DATE	REVISIONS	BY	CH'K	Design Supv	Eng'g	Proj Eng'r	App
B	AUG 21, 1973	UPDATED	W.M.				G	
A	AUG. 8, 1973	ISSUED FOR INFORMATION	W.M.					

SCALE 1" = 200' | DESIGNED | DRAWN | CHIEF ENG'R

SYNCRUDE CANADA LTD.

MILDRED LAKE PROJECT

CANADIAN BECHTEL LIMITED

EDMONTON

MINE PIT TAILINGS
SECTION THRU CELL 1
125,000 B.P.C.D. (DRAGLINE)

JOB No.	DRAWING No.	REV.
9776	51D-SK-A-103	B

5.0 WATER BALANCES

The Water Balances, which follow this section, illustrate the anticipated yearly balances, viz.

Figure 1	-	1978
Figure 2	-	1979
Figure 3	-	1983
Figure 4	-	1992 to 2002

For purposes of this report, Figure 3 was selected to represent long term average conditions.

Pumped water requirements of the extraction and upgrading complexes are to be served by an integrated system and will be supplied in nearly equal portions of river and reclaimed waters.

The need for make-up water is governed by three mechanisms,

i) processing losses to the atmosphere.

ii) losses due to water held in the coarse sand tailings and pond bottom sludges; these mechanical losses are:

Coarse Tailings: 440#/ton coarse sands @ 78% sol's.

Sludges: 1400#/ton silts & clays @ 30% sol's.

iii) natural losses to percolation, evaporation and precipitation gains.

There are a number of factors which can govern a particular balance; usually as related to the amount of free water available for recycle from the Tailings Pond.

Principal factors are:

a) Mine ground water; quality determines if useable as part of reclaim water circuit.

b) Net balance of natural evaporation vs. precipitation within the tailings impounding area. (Thermal evaporation will tend to be proportional to production).

c) Precipitation run-off to the Recycle and Raw Water Ponds from surrounding drainage areas.

d) Sludge compaction; as hydrostatic head increases with the rising pond level, bottom sludges densify thus releasing free water. Expected maximum densification is 40 percent solids by weight.

e) Percent of sludge forming silts and clays present in the freshly mined tar sands.

f) Bottom percolation - this mechanism tends to decrease, perhaps almost stopping, with time, as sludge fines seal off the pond bottom.

g) Atmospheric losses from cooling towers.

Figures 5, Percent Sludge Solids vs. River Water Requirements, and 6, Percent Sludge Forming Silts and Clays vs. River Water Requirements illustrate aforementioned causes d) and e).

Figure 7, illustrates the Tailings Pond contents, as derived from the Water Balances labeled Figures 1 through 4. It should be noted here that the depth of free water available for recycle can be manipulated by pumping above or below the particular balance posture needs.

FORM A-12-M

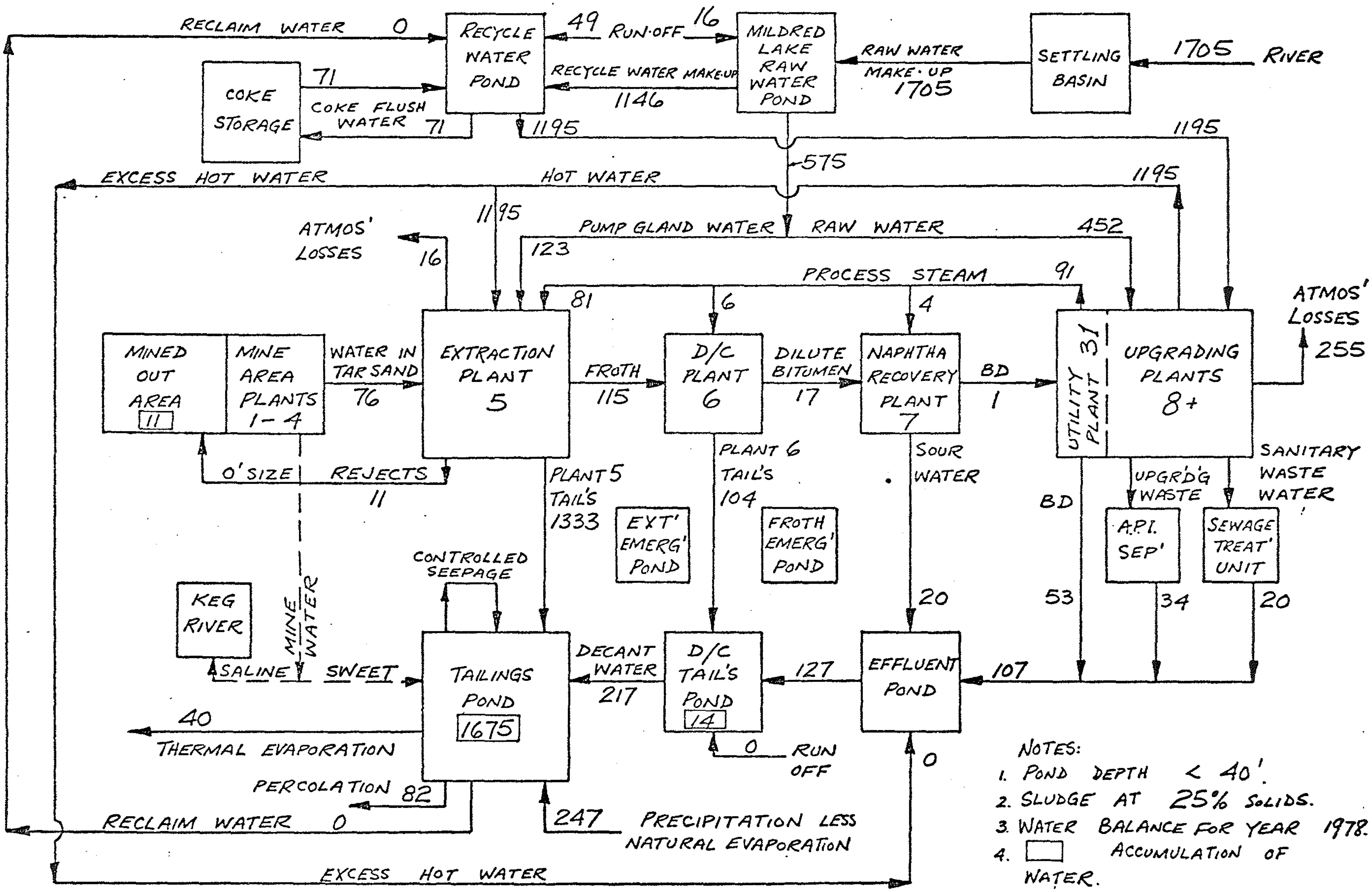
BECHTEL MONTREAL

CALCULATION SHEET

JOB No. 9776 SUBJECT SIMPLIFIED WATER BALANCE.

BY [illegible] DATE 17 Aug '73 PAGE

Production Year 1978.
58% of rated thruput, i.e. 53.8 MMTTS.
All water flows in MM cfy.



NOTES:
1. POND DEPTH < 40'.
2. SLUDGE AT 25% SOLIDS.
3. WATER BALANCE FOR YEAR 1978.
4. ☐ ACCUMULATION OF WATER.

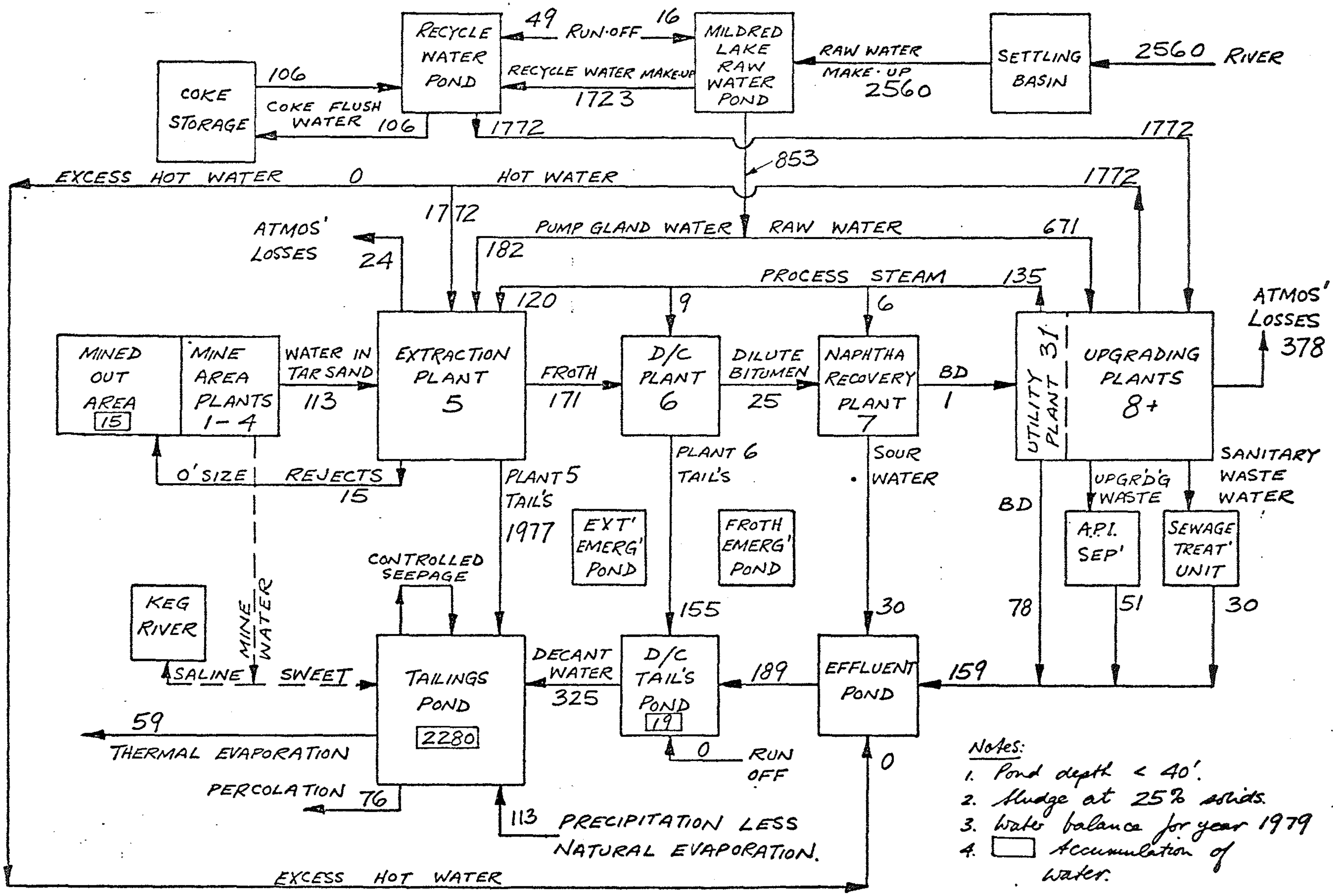
FIGURE 1:

CALCULATION SHEET

JOB No. 9776 SUBJECT SIMPLIFIED WATER BALANCE.

BY [illegible] DATE 17 aug '73 PAGE

Production Year - 1979.
86% of rated thruput, i.e. 79.8 MMTS
All water flows in MM cfy.



Notes:
1. Pond depth < 40'.
2. Sludge at 25% solids.
3. Water balance for year 1979
4. [ ] Accumulation of water.

FIGURE 2:

FORM A-12-M

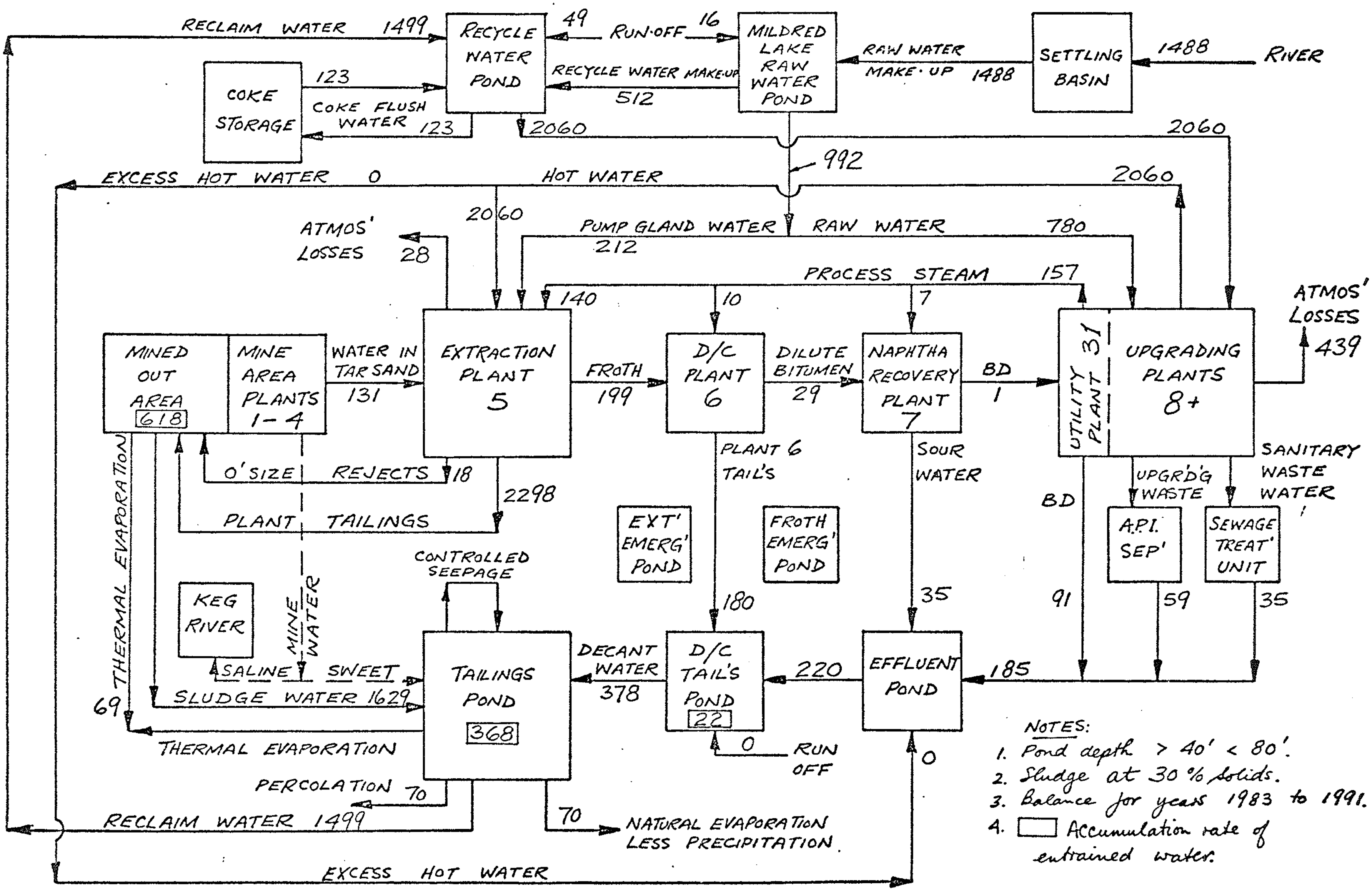
BECHTEL MONTREAL

CALCULATION SHEET

JOB No. 9776 SUBJECT SIMPLIFIED WATER BALANCE.

BY [initials] DATE 16 aug '73 PAGE

92.8 MM TPY TAR SAND
125,000 BPCD SYNTHETIC CRUDE
ALL WATER FLOWS IN MMCFY.



NOTES:
1. Pond depth > 40' < 80'.
2. Sludge at 30% Solids.
3. Balance for years 1983 to 1991.
4. ☐ Accumulation rate of entrained water.

FIGURE 3:

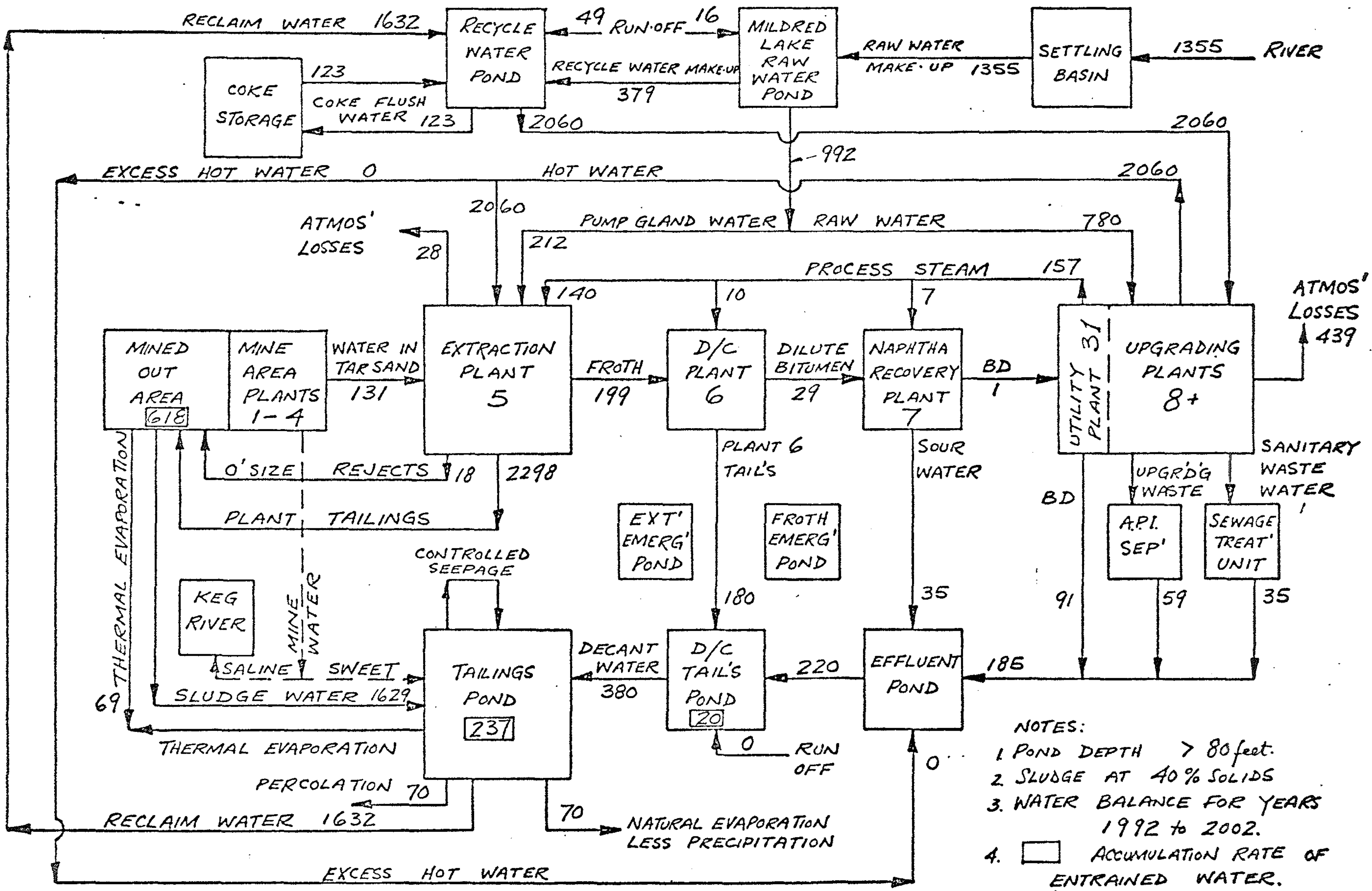
Sludge at 30% Solids. Years 1980 to 1991.

CALCULATION SHEET

JOB No. 9776 SUBJECT SIMPLIFIED WATER BALANCE.

BY GK DATE 17 aug '73 PAGE

92.8 MM TPY TAR SAND
125,000 BPCD SYNTHETIC CRUDE
ALL WATER FLOWS IN MMCFY.



NOTES:
1. POND DEPTH > 80 feet.
2. SLUDGE AT 40% SOLIDS
3. WATER BALANCE FOR YEARS 1992 to 2002.
4. ☐ ACCUMULATION RATE OF ENTRAINED WATER.

Sludge at 40% Solids; Years 1992 - 2002.

FIGURE 4:

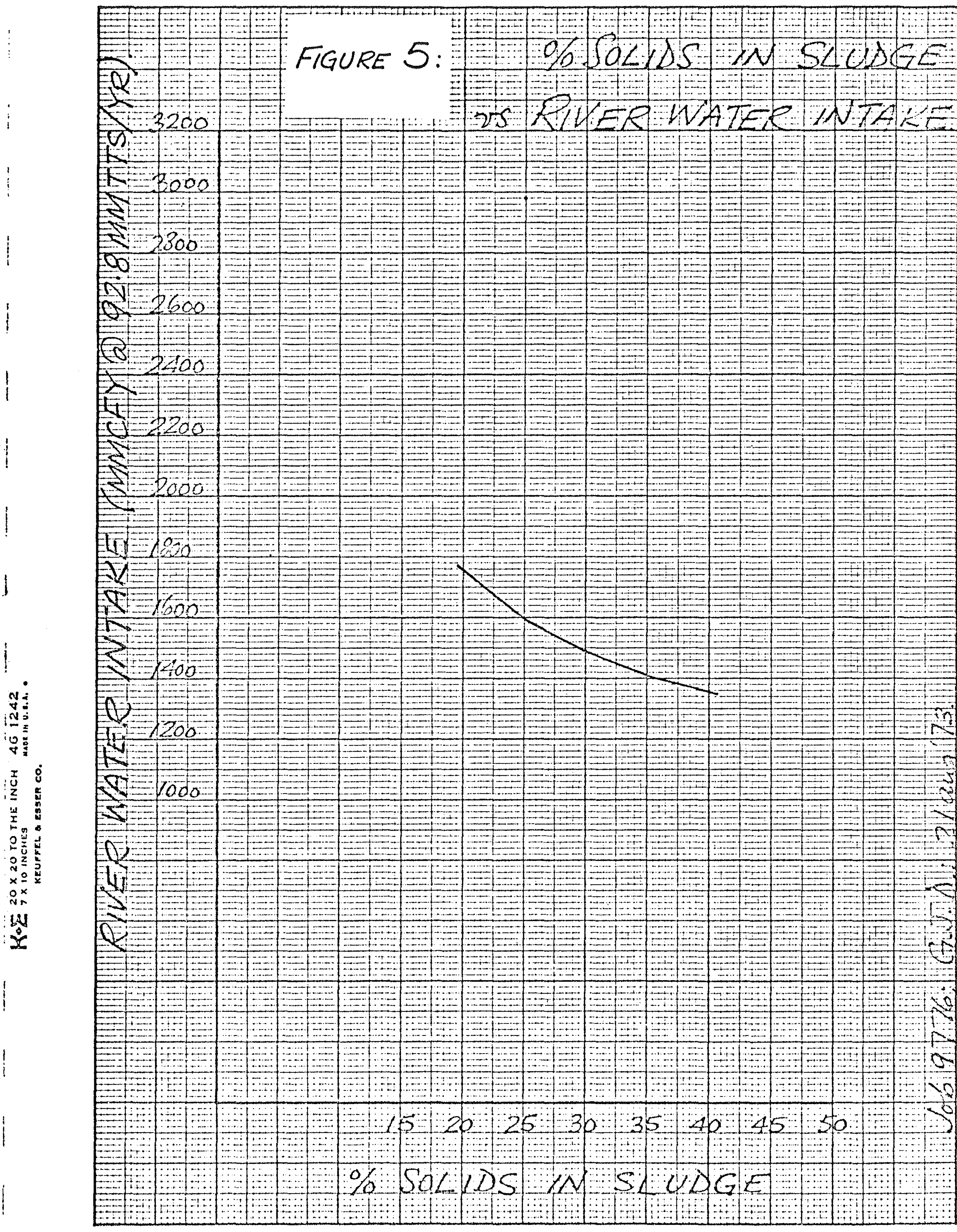
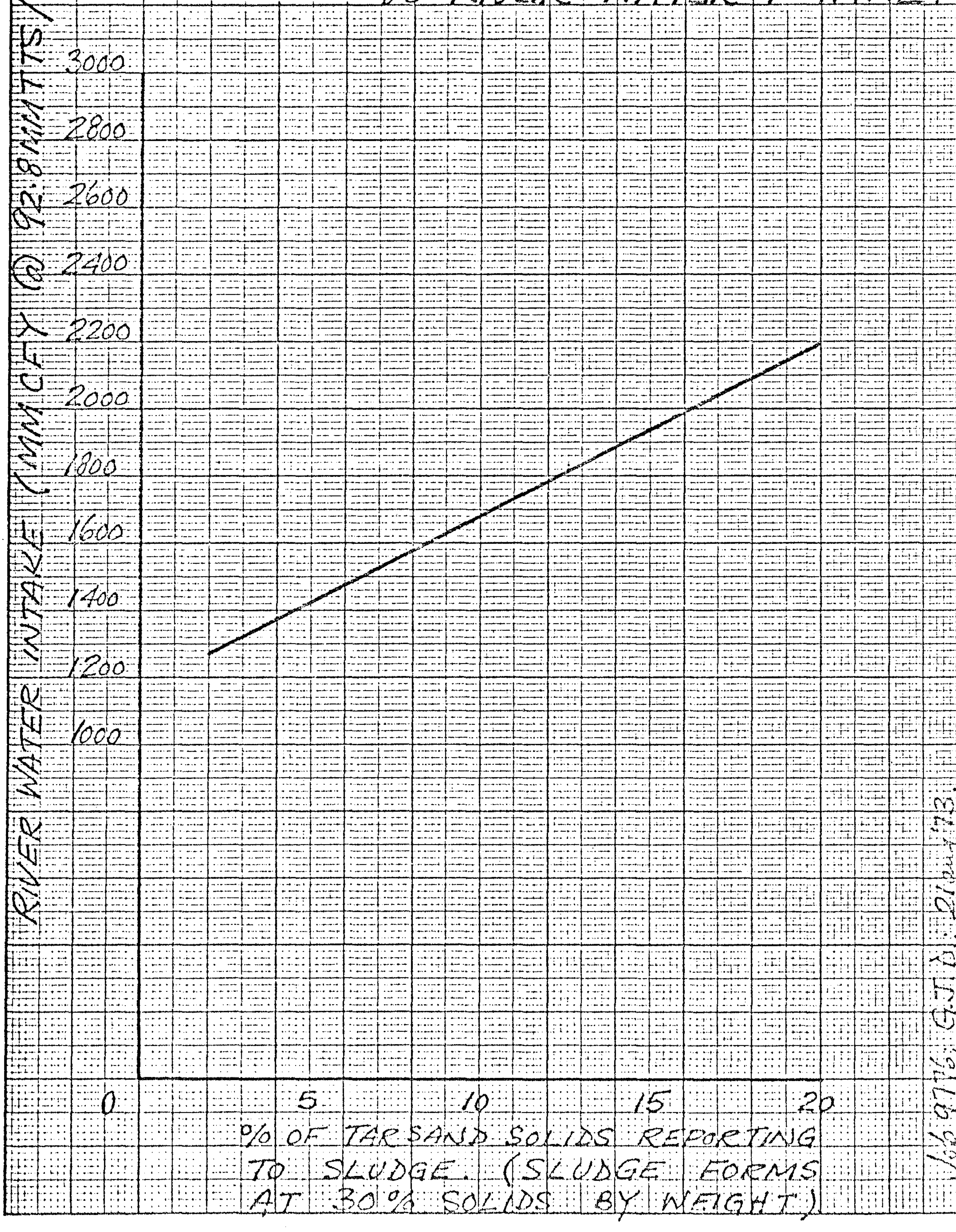


FIGURE 5: % SOLIDS IN SLUDGE vs RIVER WATER INTAKE
RIVER WATER INTAKE (MMCFY @ 92.8 MMTS/YR)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
15
20
25
30
35
40
45
50
% SOLIDS IN SLUDGE
Job 9776, G.J.A., 21 aug 73
20 X 20 TO THE INCH 46 1242
7 X 10 INCHES
MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 6: SLUDGE FORMING FRACTION vs RIVER WATER INTAKE.



FORM A-12-M

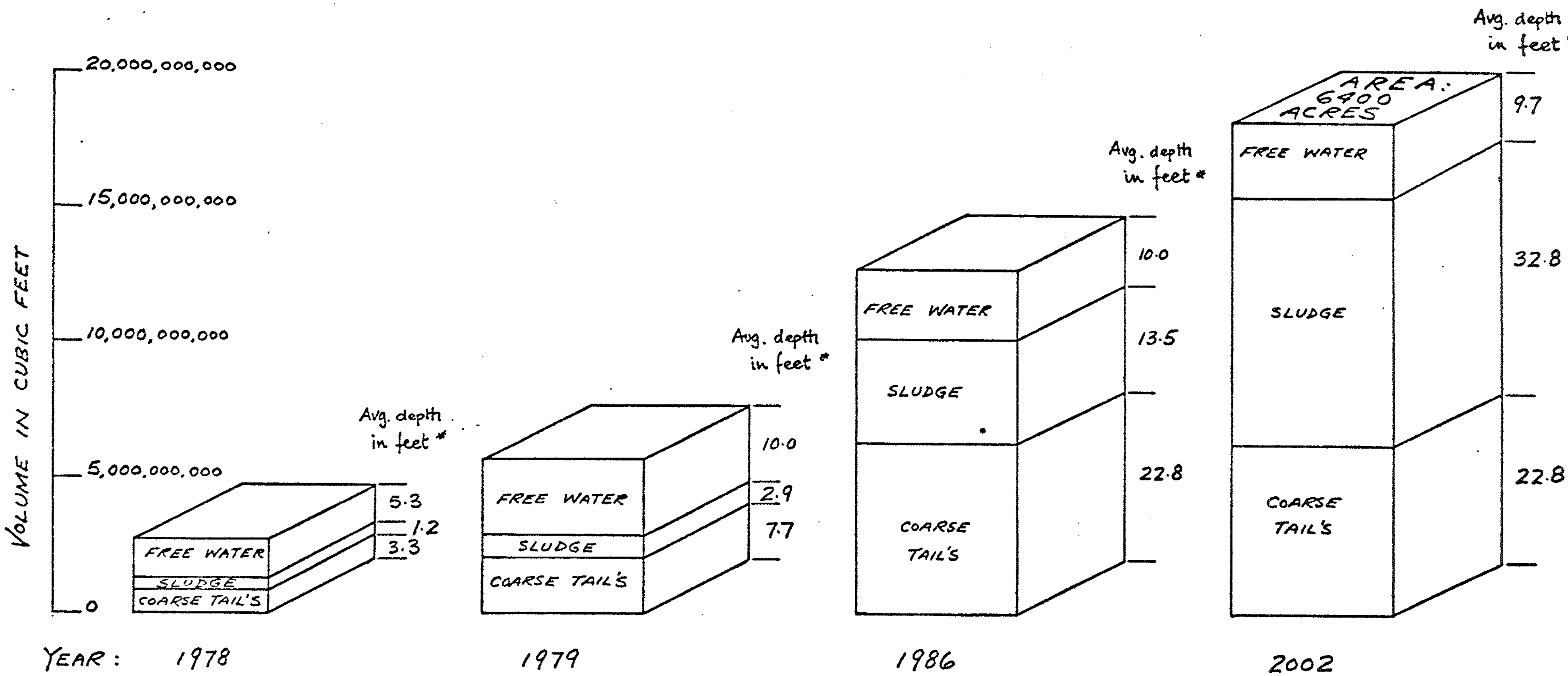
BECHTEL MONTREAL

CALCULATION SHEET

JOB No. 9776 SUBJECT Tailings Pond Calcs.

BY [signature] DATE 21 aug '73 PAGE

PLANT 5 TAILINGS POND CONTENTS.



1978	1979	1986	2002
Sludge at 25% solids	Sludge at 25% solids	Sludge at 25-30% solids	Sludge at 25-40% solids
Coarse tails at 78% solids	Coarse tails at 78% solids	Coarse tails at 78% solids	Coarse tails at 78% solids

* Assuming a level plain.

Note: Free water is considered to contain less than 3 wt.% solids.

FIGURE 7:

6.0 LAND RECLAMATION

6.1 Beaver Creek Diversion Dyke

It is proposed to commence land reclamation by means of a vegetation program at the earliest date consistent with efficient operating procedures. The program will apply to side slopes of dykes and the final surface of the mined out areas which have been back-filled with tailings.

Starter dykes will be constructed of borrow materials. The Beaver Creek diversion dyke will be completely constructed at the commencement of operations. The vegetation program can, therefore, initiate on its north side in 1978, the first full summer of operations.

6.2 Tailings Pond Dykes

Construction of the Tailings Pond dykes, although started with borrow materials, will build-up using tailings sand. Because the up stream method of build-up will be used, the off water side of the dyke will be available for a vegetation program in parallel with the work on the Beaver Creek Diversion Dyke - probably in the summer of 1978.

6.3 Mined Out Area

Tailings disposal within the mined out area will commence after five and one half years of operations. Referring to sketch #51D-SK-101, sand dykes enclosing cell No. 1 will be built to final elevation over a seven year period. While this operation is in progress tailings will be placed within cell No. 1. By the time cell No. 1 is filled to its final grade, cells 2A and B will be ready to receive tailings.

7.0 TERMINATING THE TAILINGS OPERATIONS: AT THE POND AND IN THE PIT

7.1 Tailings Pond

At the termination of the initial 25-year mining operation, the tailings pond will be made up of,

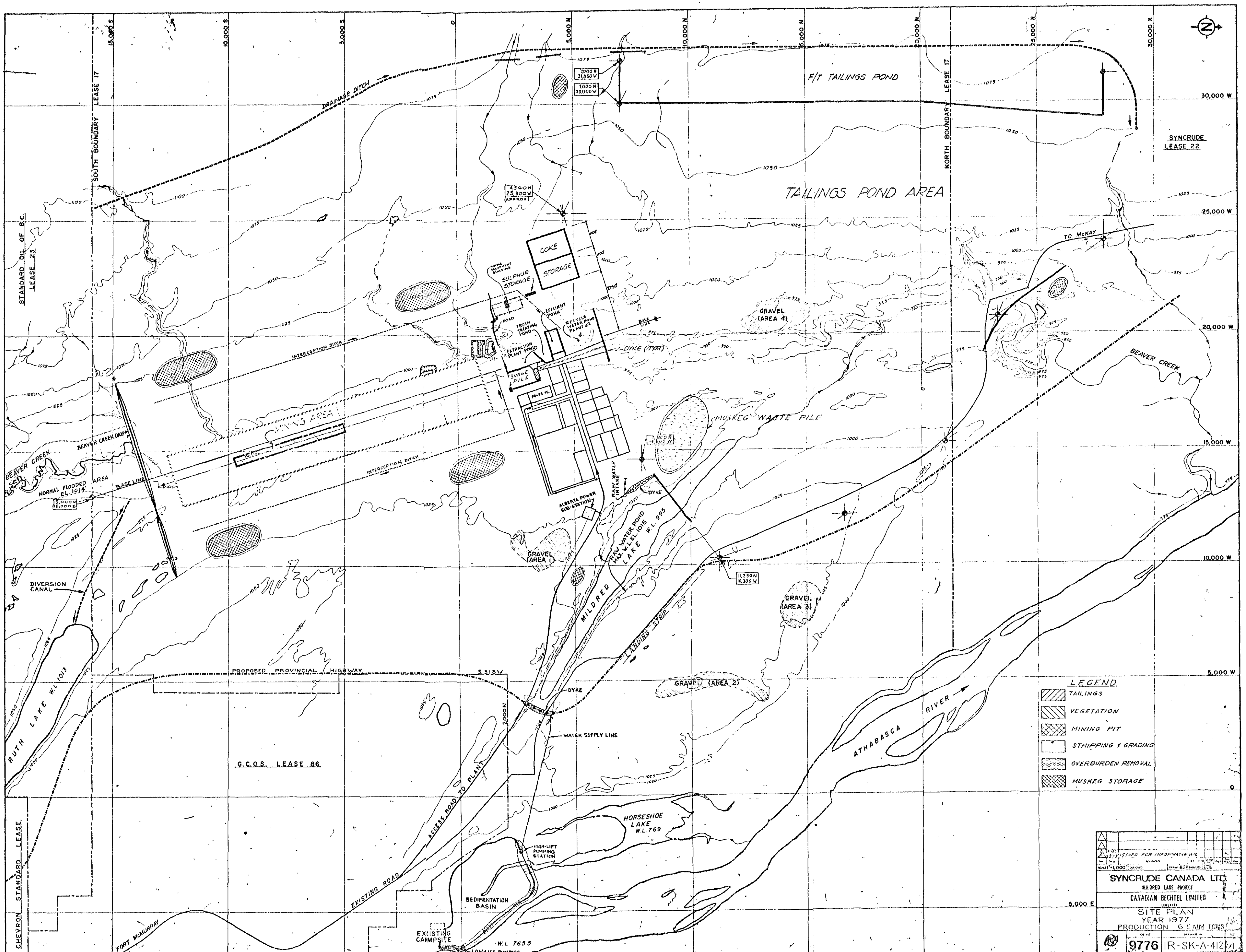
2,720,000,000	CF of free water
10,540,000,000	CF of sludge @ 30% solids (avg.)
6,370,000,000	CF of coarse sands @ 78% solids
19,630,000,000	CF total volume

Oily floats on the surface will be reclaimed using conventional equipment; as designed to clean up crude oil spills off water bodies. This operation is expected to proceed for less than two years. Oily float materials could be impounded for future use as a road bedding stabilizer, or could be recycled to a bitumen extraction plant.

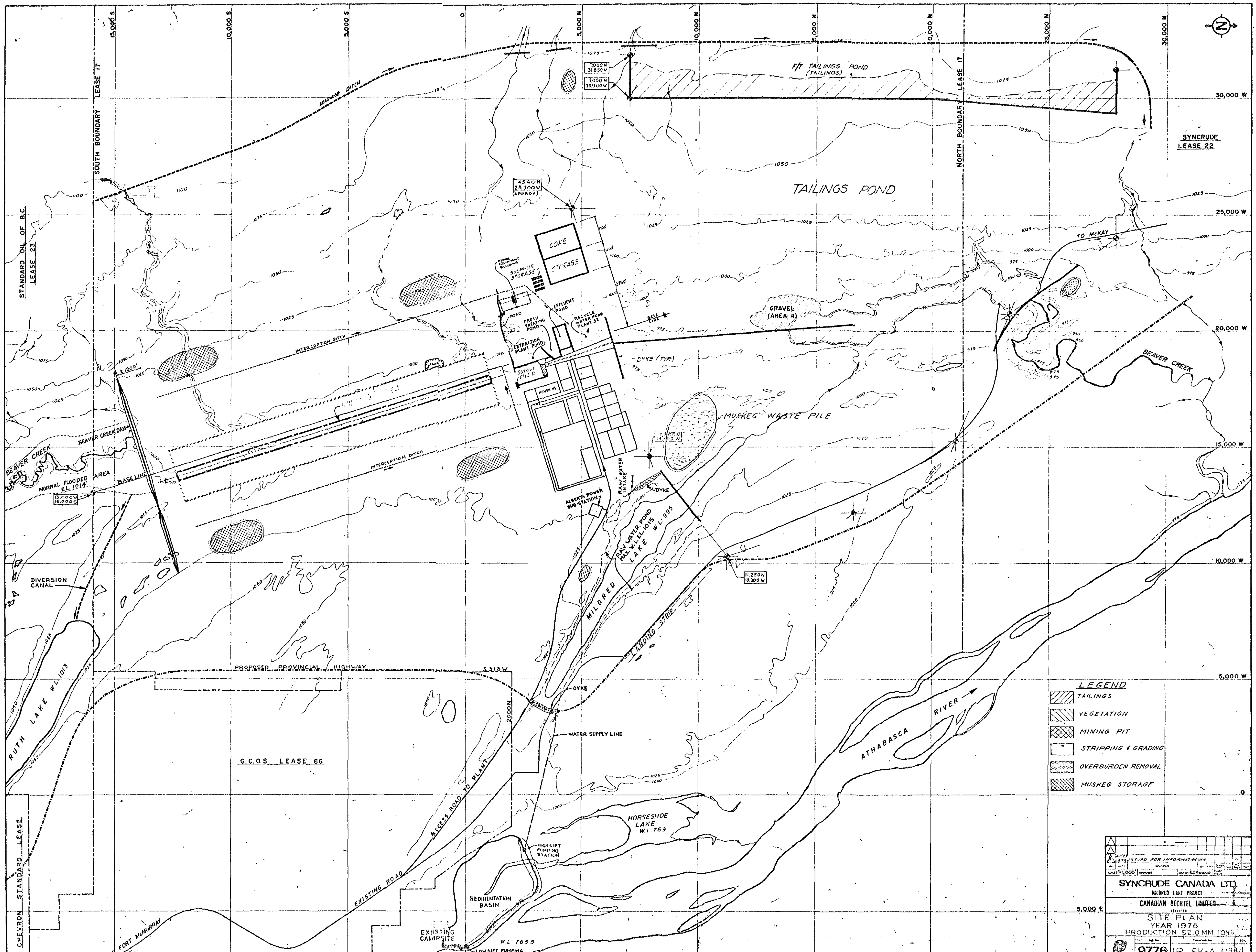
7.2 Mine Pit

Sketch 51D-SK-101 depicts the mine pit at the end of year 2002. Revegetation will have been initiated about fourteen years before. Cells 3A and B will be empty above the overburden and rejects layer. The system will be returned to nature whence ground water, precipitation and runoff will partially fill the cells.

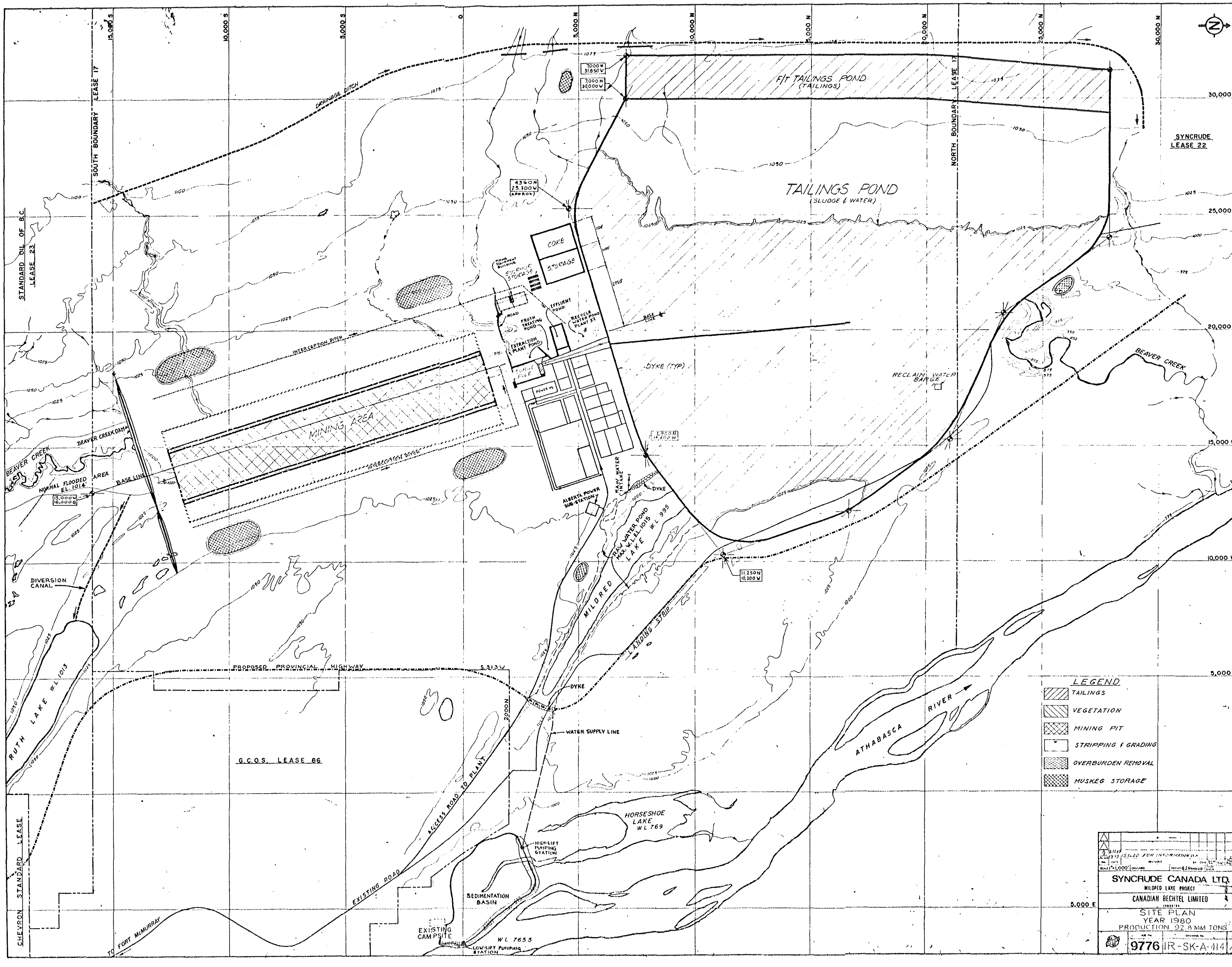
The series of site plan renditions which follow this text illustrate the gradually changing surface configuration over the working section of Syncrude's tar sands lease.

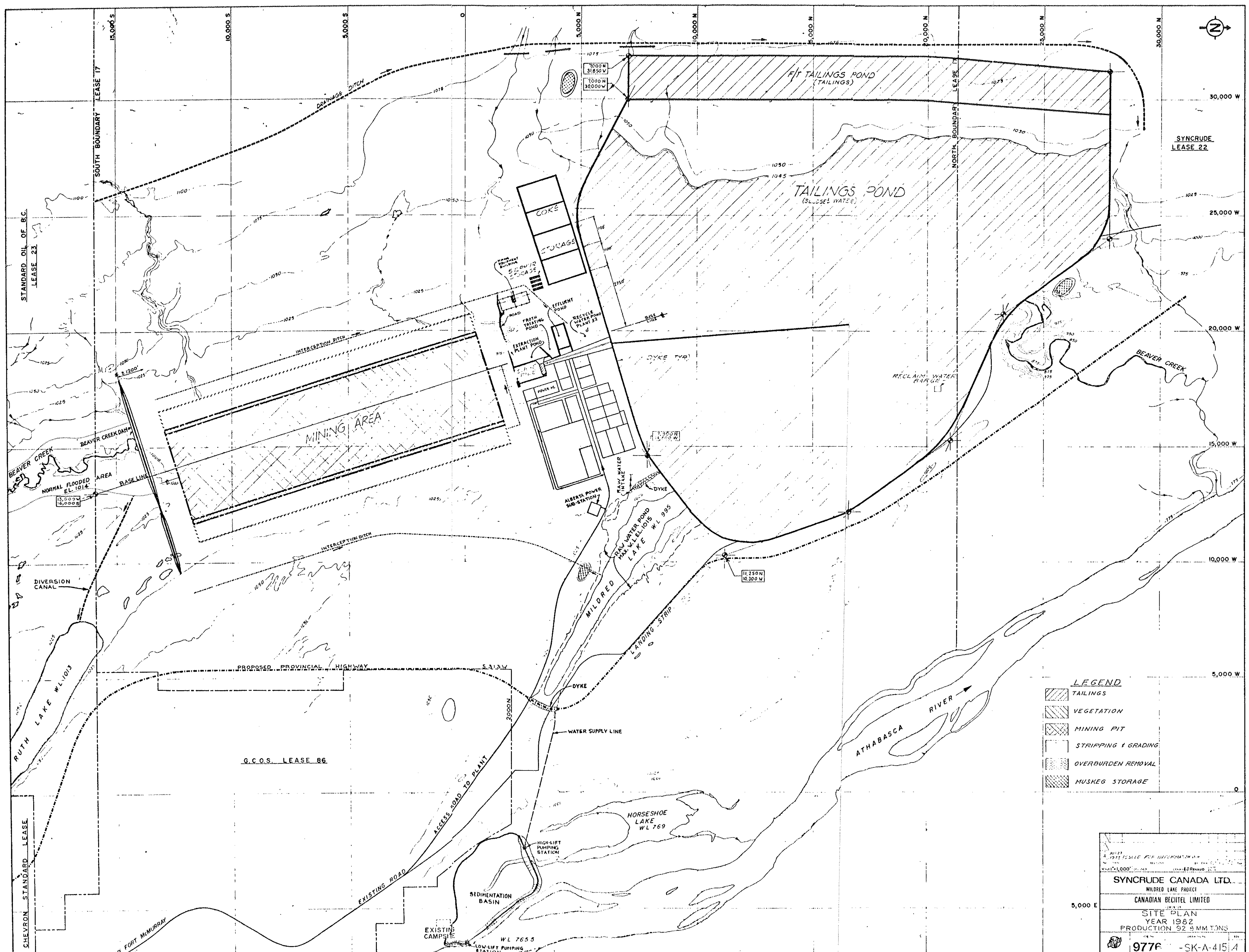


F/T TAILINGS POND
TAILINGS POND AREA
DRAINAGE DITCH
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
SYNCRUDE LEASE 22
COKE STORAGE
SULPHUR STORAGE
EFFLUENT POND
FROTH TREATING POND
RECYCLE WATER POND
EXTRACTION PLANT POND
SURGE PILE
DYKE (TYP.)
INTERCEPTION DITCH
MINING AREA
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
MUSKEG WASTE PILE
GRAVEL (AREA 4)
GRAVEL (AREA 1)
GRAVEL (AREA 3)
GRAVEL (AREA 2)
TO McKAY
RAW WATER INTAKE
ALBERTA POWER SUB-STATION
RAW WATER POND MAX. W.L. EL. 1015
MILDRED LAKE W.L. 995
LANDING STRIP
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
WATER SUPPLY LINE
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
15,000 S
10,000 S
5,000 S
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
ISSUED FOR INFORMATION
SCALE 1" = 1,000'
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1977
PRODUCTION 6.5 MM TONS
9776
IR-SK-A-412

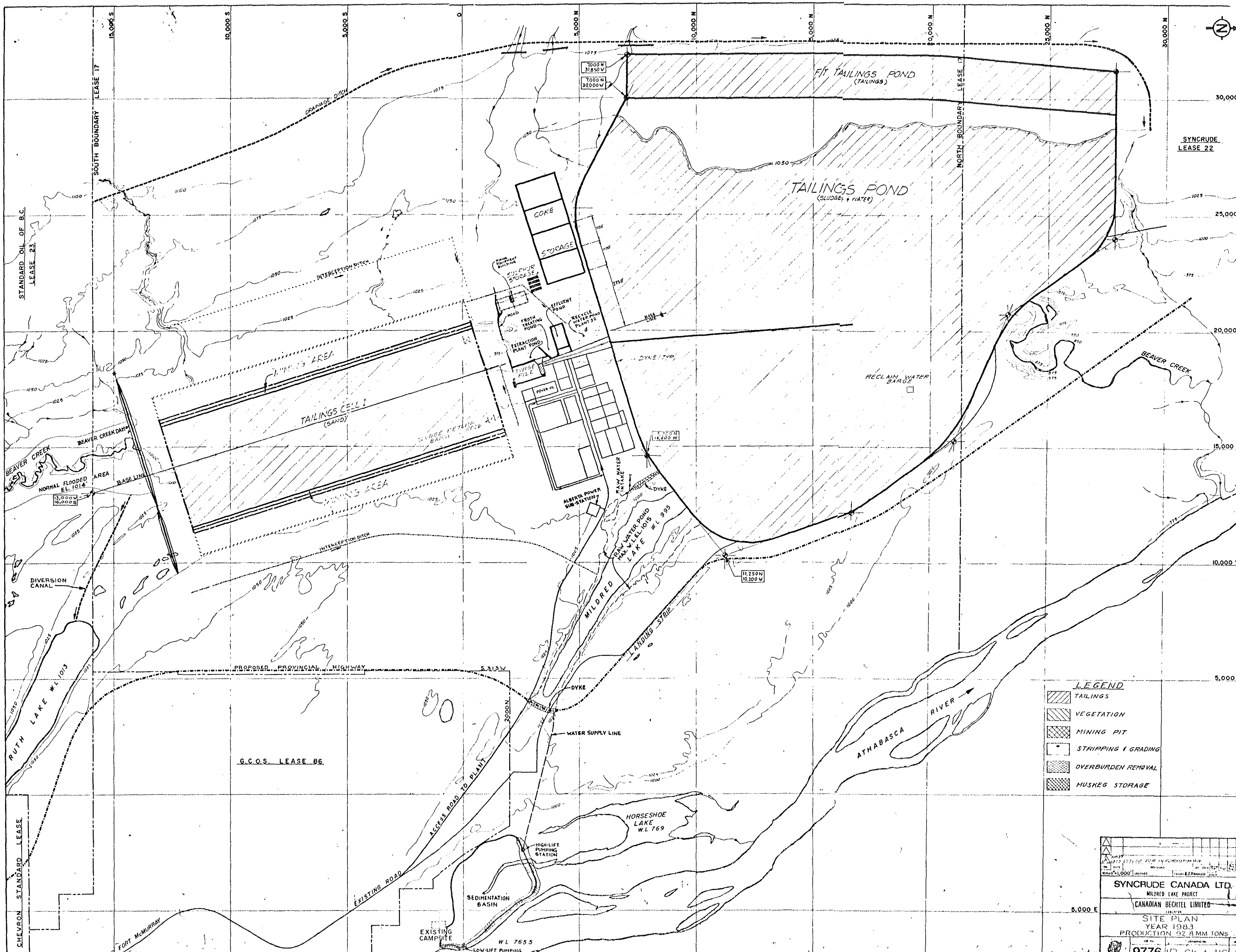


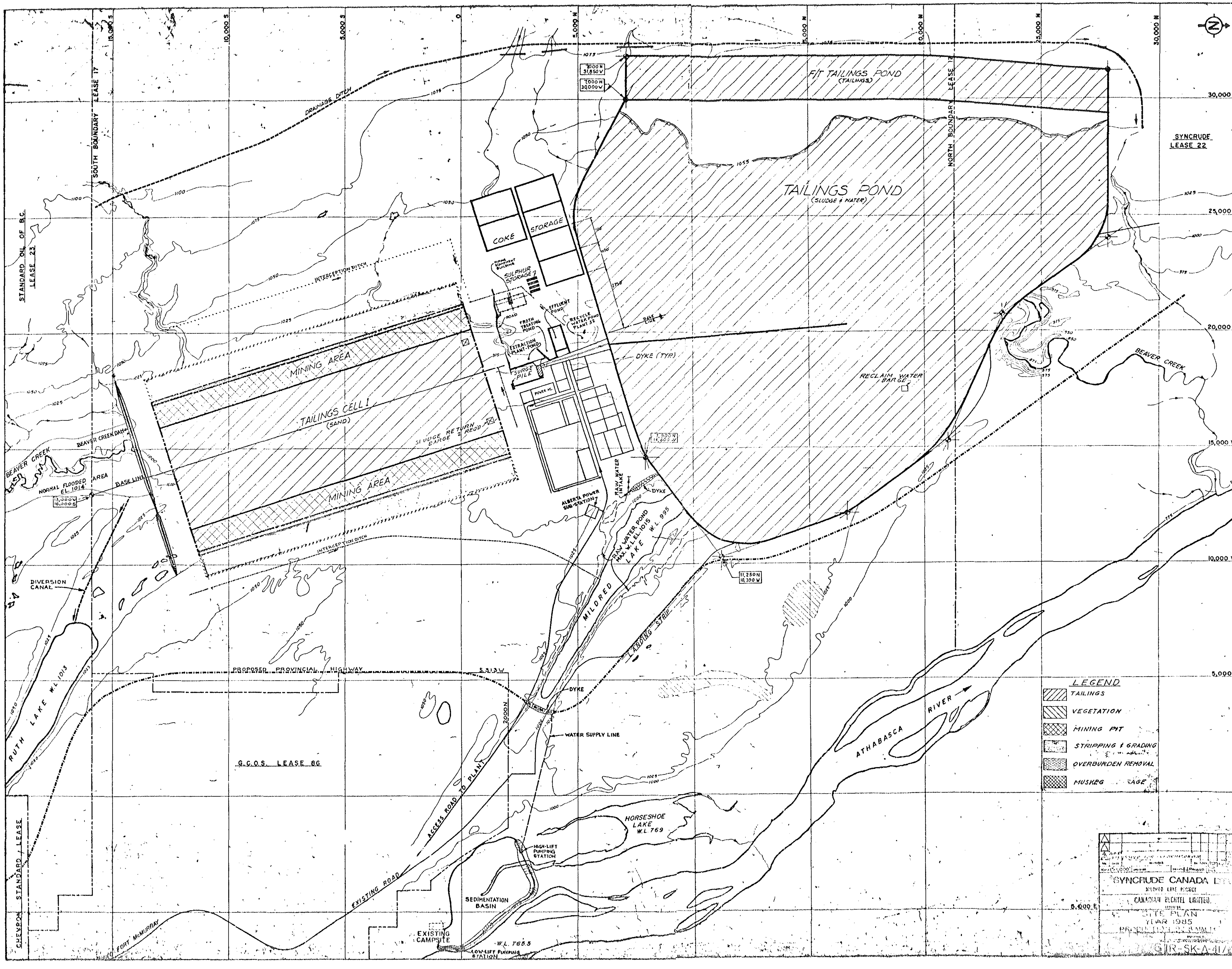
TAILINGS POND
F/T TAILINGS POND (TAILINGS)
SYNCRUDE LEASE 22
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
COKE STORAGE
SULPHUR STORAGE
EFFLUENT POND
FROTH TREATING POND
RECYCLE WATER POND PLANT 32
EXTRACTION PLANT POND
SURGE PILE
INTERCEPTION DITCH
GRAVEL (AREA 4)
MUSKEG WASTE PILE
DYKE (TYP)
TO McKAY
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
ALBERTA POWER SUB STATION
RAW WATER INTAKE
DYKE
RAW WATER POND MAX. W.L. EL. 1015
MILDRED LAKE W.L. 995
LANDING STRIP
PROPOSED PROVINCIAL HIGHWAY
RUTH LAKE W.L. 1013
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
WATER SUPPLY LINE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
ISSUED FOR INFORMATION
SCALE 1" = 1,000'
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1976
PRODUCTION 52.0 MM TONS
9776
IR-SK-A-4134


F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
COKE
STORAGE
MINING AREA
INTERCEPTION DITCH
DRAINAGE DITCH
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
SYNCRUDE LEASE 22
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L.1013
PROPOSED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
MILDRED LAKE W.L. 995
RAW WATER POND MAX. W.L. EL. 1015
RAW WATER INTAKE
ALBERTA POWER SUB-STATION
LANDING STRIP
DYKE
DYKE (TYP)
RECLAIM WATER BARGE
WATER SUPPLY LINE
HORSESHOE LAKE W.L 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
EXTRACTION PLANT POND
FROTH TREATING POND
EFFLUENT POND
RECYCLE WATER POND
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
30,000 W.
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
15,000 S
10,000 S
5,000 S
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1980
PRODUCTION 92.8 MM TONS
9776 IR-SK-A-414

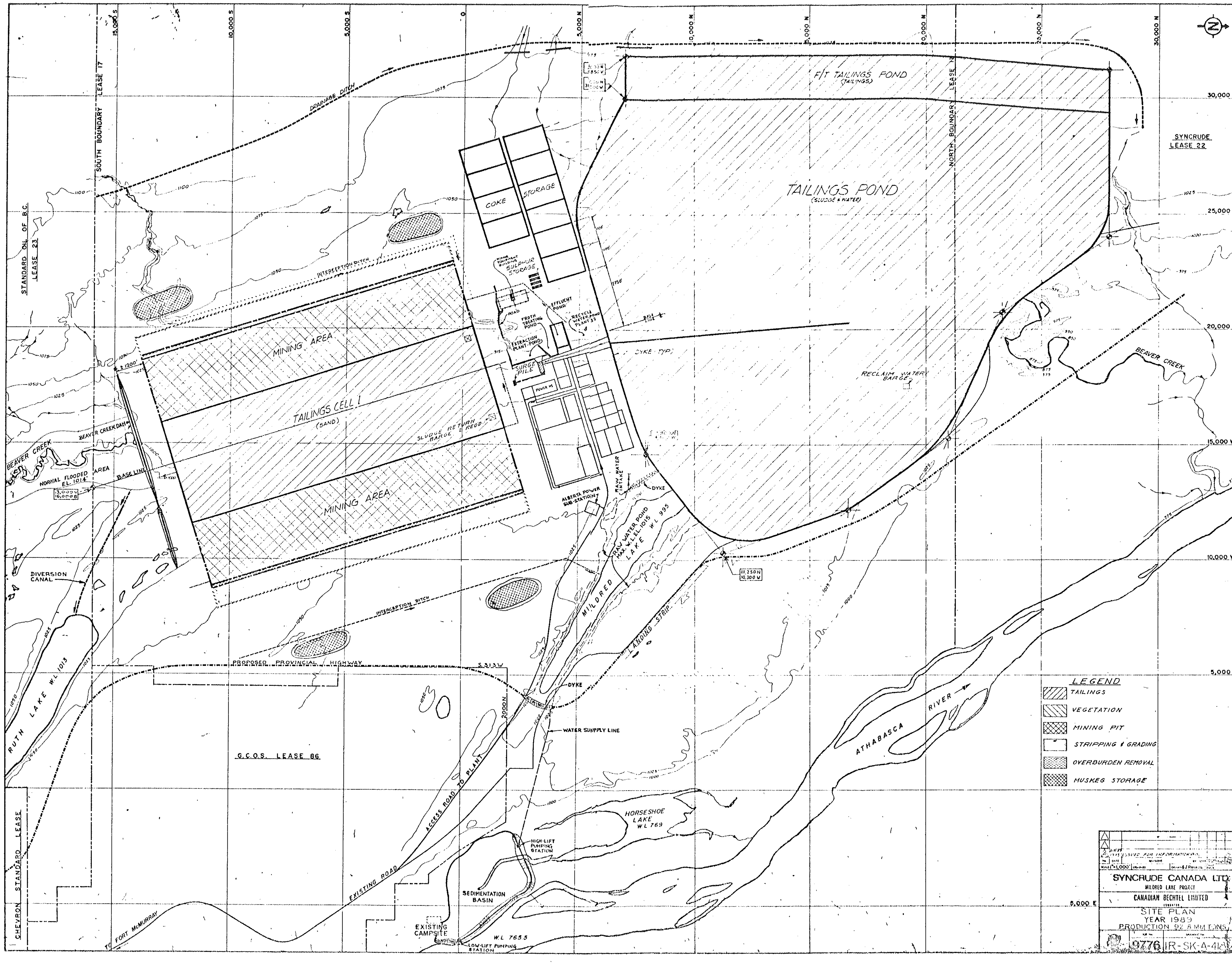


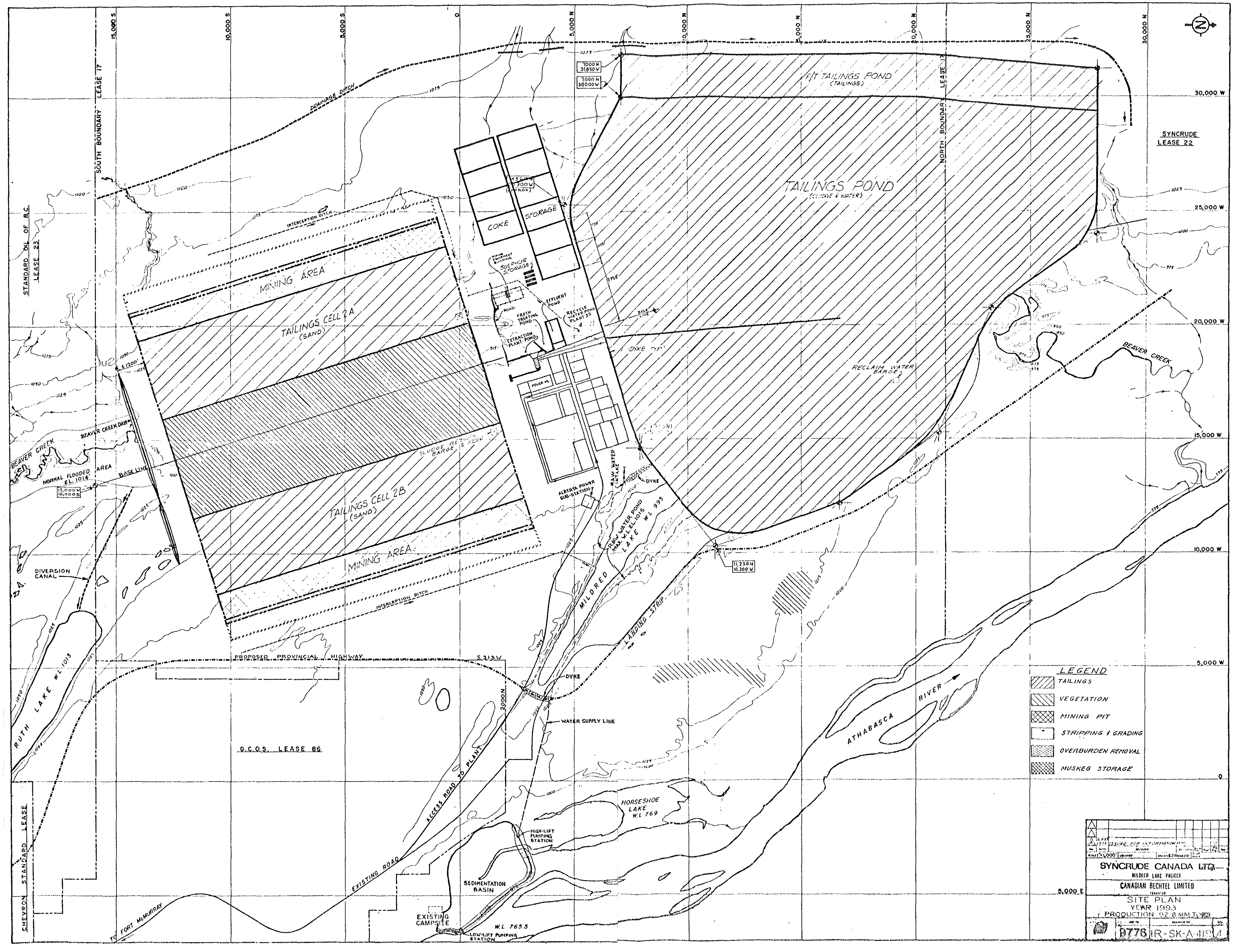
F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE WATER)
COKE
STORAGE
MINING AREA
INTERCEPTION DITCH
DRAINAGE DITCH
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
SYNCRUDE LEASE 22
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED PROVINCIAL HIGHWAY
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
MILDRED LAKE W.L. 995
RAW WATER POND MAX. W.L. EL. 1015
LANDING STRIP
DYKE
WATER SUPPLY LINE
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
W.L. 765
HORSESHOE LAKE W.L. 769
ATHABASCA RIVER
RECLAIM WATER BARGE
ALBERTA POWER SUB-STATION
EXTRACTION PLANT POND
FROTH TREATING POND
EFFLUENT POND
RECYCLE WATER POND PLANT 82
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
SCALE 1" = 1,000'
J. RENAUD
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1982
PRODUCTION 92.8 MM TONS
9776 -SK-A-415 A


F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
COKE
STORAGE
SULPHUR STORAGE
EFFLUENT POND
FROTH TREATING POND
RECYCLE WATER POND PLANT 35
EXTRACTION PLANT POND
SURGE PILE
POWER HS.
MINING AREA
TAILINGS CELL 1
(SAND)
INTERCEPTION DITCH
DRAINAGE DITCH
BASE LINE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA
EL. 1014
DIVERSION CANAL
RUTH LAKE W.L. 1013
STANDARD OIL OF B.C.
LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
SYNCRUDE
LEASE 22
CHEVRON STANDARD LEASE
G.C.O.S. LEASE 86
PROPOSED PROVINCIAL HIGHWAY
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
RAW WATER INTAKE
DYKE
DYKE (TYP.)
ALBERTA POWER SUB-STATION
RAW WATER POND
MILDRED LAKE W.L. 995
LANDING STRIP
WATER SUPPLY LINE
RECLAIM WATER BARGE
HORSESHOE LAKE
W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
W.L. 765.5
ATHABASCA RIVER
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
ISSUED FOR INFORMATION
SCALE 1" = 1,000'
DRAWN J. S. RENAUD
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1983
PRODUCTION 92.8 MM TONS
9776
R-SK-A-416
4

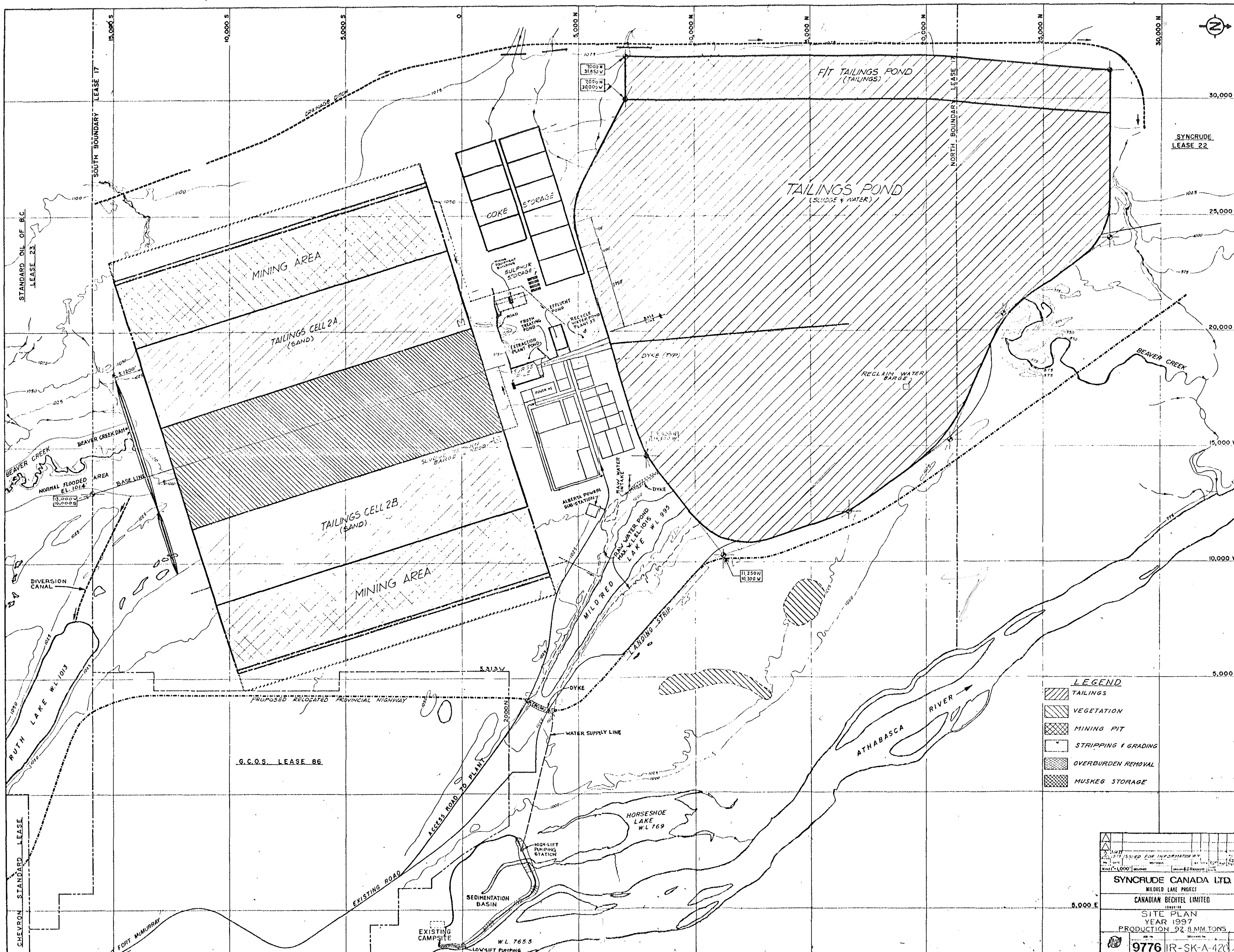


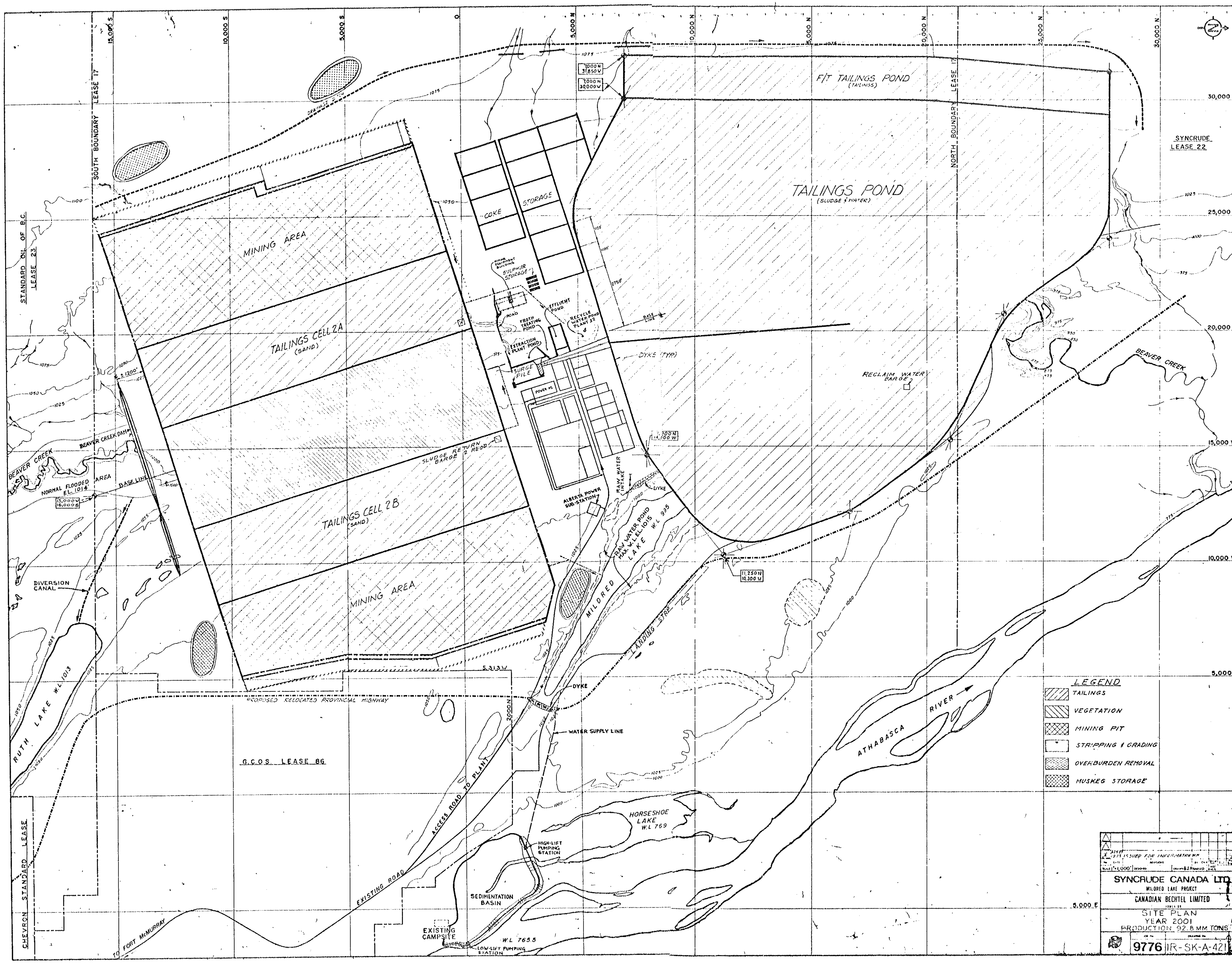
F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
SYNCRUDE
LEASE 22
NORTH BOUNDARY LEASE 17
SOUTH BOUNDARY LEASE 17
STANDARD OIL OF B.C.
LEASE 23
DRAINAGE DITCH
INTERCEPTION DITCH
COKE
STORAGE
SULPHUR
STORAGE
FROTH
TESTING
POND
EFFLUENT
POND
RECYCLE
WATER POND
EXTRACTION
PLANT POND
SURGE
PILE
DYKE (TYP)
MINING AREA
TAILINGS CELL 1
(SAND)
SLUDGE RETURN
BARGE
RECLAIM WATER
BARGE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA
EL. 1014
BASE LINE
DIVERSION
CANAL
RAW WATER
INTAKE
DYKE
ALBERTA POWER
SUB-STATION
RAW WATER POND
MAX. W.L. EL. 1015
LAKE W.L. 995
MILDRED
LANDING STRIP
PROPOSED PROVINCIAL HIGHWAY
RUTH LAKE W.L. 1013
G.C.O.S. LEASE 86
ACCESS ROAD TO PLANT
WATER SUPPLY LINE
HORSESHOE
LAKE
W.L. 769
HIGH-LIFT
PUMPING
STATION
SEDIMENTATION
BASIN
EXISTING ROAD
TO FORT McMURRAY
EXISTING
CAMPSITE
W.L. 765.5
LOW-LIFT PUMPING
STATION
ATHABASCA RIVER
CHEVRON STANDARD LEASE
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG
SYNCRUDE CANADA LTD
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1985


F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
SYNCRUDE
LEASE 22
NORTH BOUNDARY LEASE 17
SOUTH BOUNDARY LEASE 17
STANDARD OIL OF B.C.
LEASE 23
COKE STORAGE
SULPHUR STORAGE
DRAINAGE DITCH
INTERCEPTION DITCH
MINING AREA
TAILINGS CELL I
(SAND)
SLUDGE RETURN BARGE & REQD.
MINING AREA
FROTH TREATING POND
EFFLUENT POND
RECYCLE WATER POND
EXTRACTION PLANT POND
SURGE PILE
DYKE TYP.
RECLAIM WATER BARGE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA
EL. 1014
BASE LINE
ALBERTA POWER SUB-STATION
RAW WATER INTAKE
DYKE
RAW WATER POND
MAX. W.L. EL. 1015
LAKE W.L. 995
MILDRED
LANDING STRIP
11,250 N
10,300 W
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
ACCESS ROAD TO PLANT
WATER SUPPLY LINE
HORSESHOE LAKE
W.L. 769
ATHABASCA RIVER
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING ROAD
TO FORT McMURRAY
EXISTING CAMPSITE
W.L. 765.5
LOW-LIFT PUMPING STATION
CHEVRON STANDARD LEASE
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
0
5,000 E
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
ISSUED FOR INFORMATION
SCALE 1"=1,000'
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1989
PRODUCTION 92.6 MM TONS
9776
IR-SK-A-4184

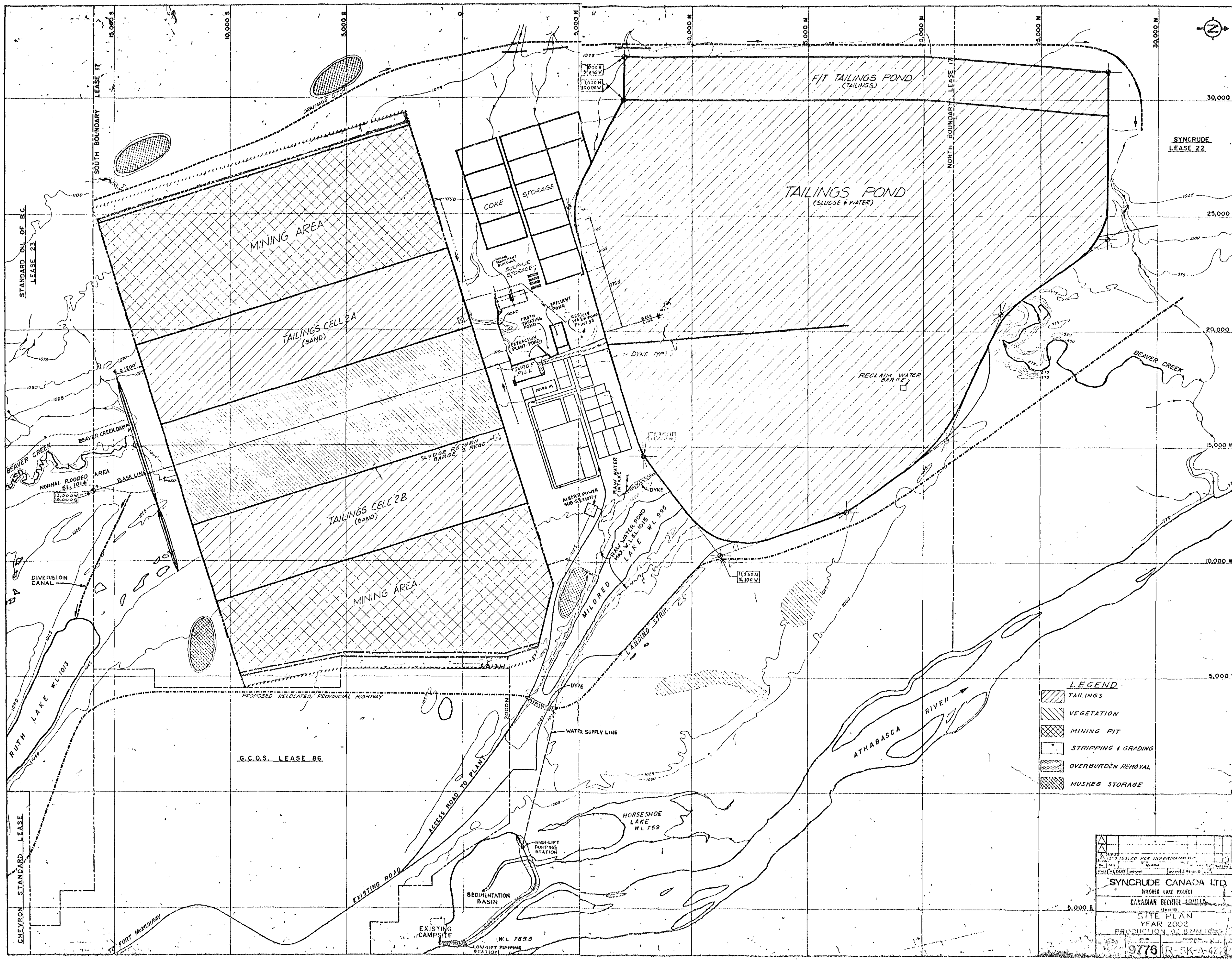


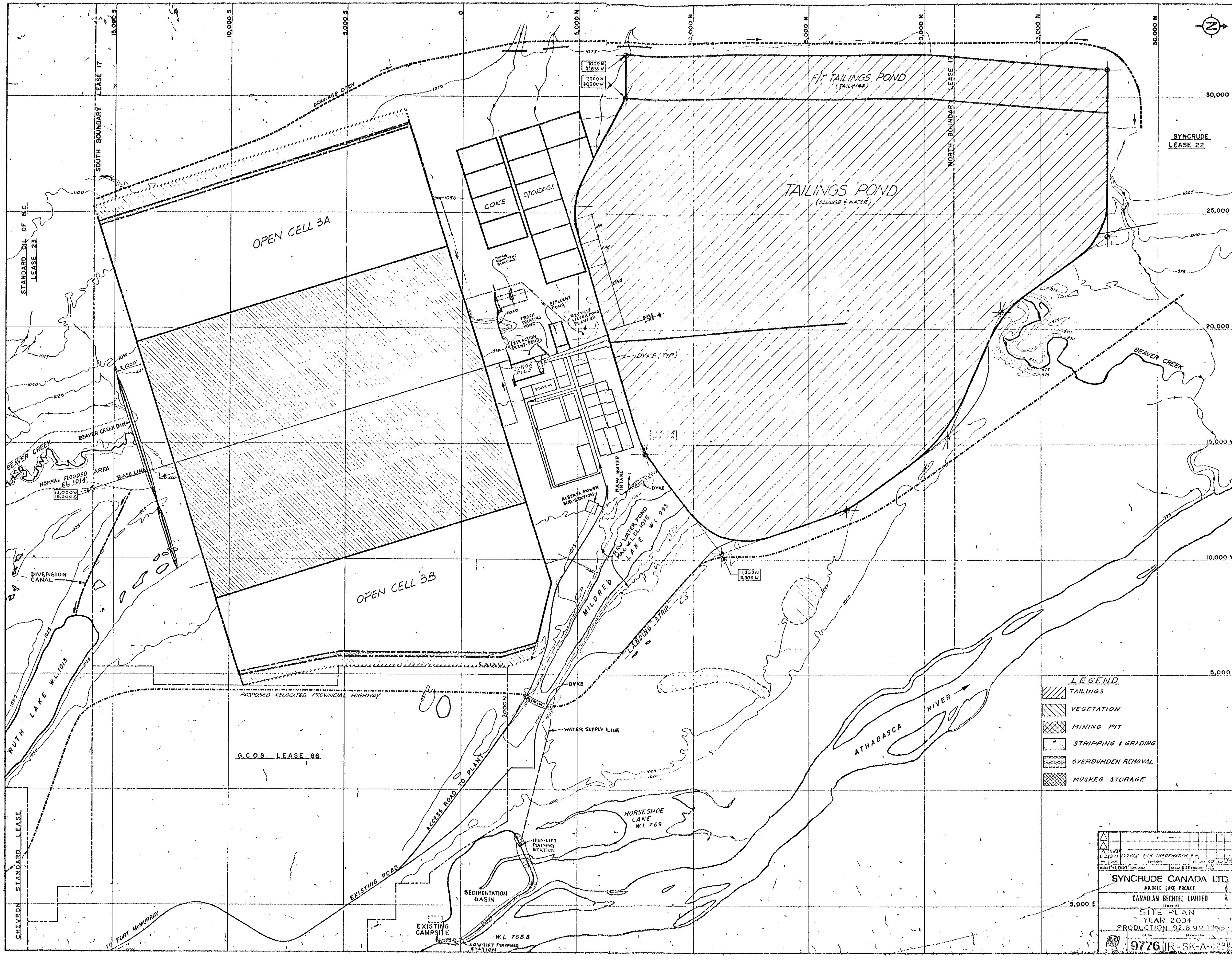
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
0
5,000 E
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
SYNCRUDE LEASE 22
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
DRAINAGE DITCH
INTERCEPTION DITCH
F/T TAILINGS POND (TAILINGS)
TAILINGS POND (SLUDGE & WATER)
COKE STORAGE
SULPHUR STORAGE
MINING AREA
TAILINGS CELL 2A (SAND)
TAILINGS CELL 2B (SAND)
SLUDGE RETURN BARGE
FROTH TREATING POND
EFFLUENT POND
RECYCLE WATER POND
EXTRACTION PLANT POND
POWER PL.
ALBERTA POWER SUB-STATION
RAW WATER INTAKE
DYKE
RECLAIM WATER BARGE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L. 1013
MILDRED LAKE W.L. 995
RAW WATER POND
LANDING STRIP
PROPOSED PROVINCIAL HIGHWAY
ACCESS ROAD TO PLANT
WATER SUPPLY LINE
EXISTING ROAD
TO FORT McMURRAY
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
W.L. 765.5
ATHABASCA RIVER
11,250 N 10,300 W
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
1971 ISSUED FOR INFORMATION
SCALE 1" = 1,000'
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1993
PRODUCTION 92.8 MM T/YR
8778
IR-SK-A-4194


F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
COKE STORAGE
SULPHUR STORAGE
MINING AREA
TAILINGS CELL 2A
(SAND)
TAILINGS CELL 2B
(SAND)
MINING AREA
EFFLUENT POND
FROTH TREATING POND
EXTRACTION PLANT POND
RECYCLE WATER POND
DYKE (TYP)
RECLAIM WATER BARGE
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED RELOCATED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
SYNCRUDE LEASE 22
DRAINAGE DITCH
ALBERTA POWER SUB-STATION
RAW WATER POND MAX. W.L. 1015
MILDRED LAKE W.L. 995
LANDING STRIP
DYKE
WATER SUPPLY LINE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
W.L. 765.5
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
11,250 N
10,300 W
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
ISSUED FOR INFORMATION
SCALE 1"=1,000'
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 1997
PRODUCTION 92.8 MM TONS
9776 IR-SK-A-420 A



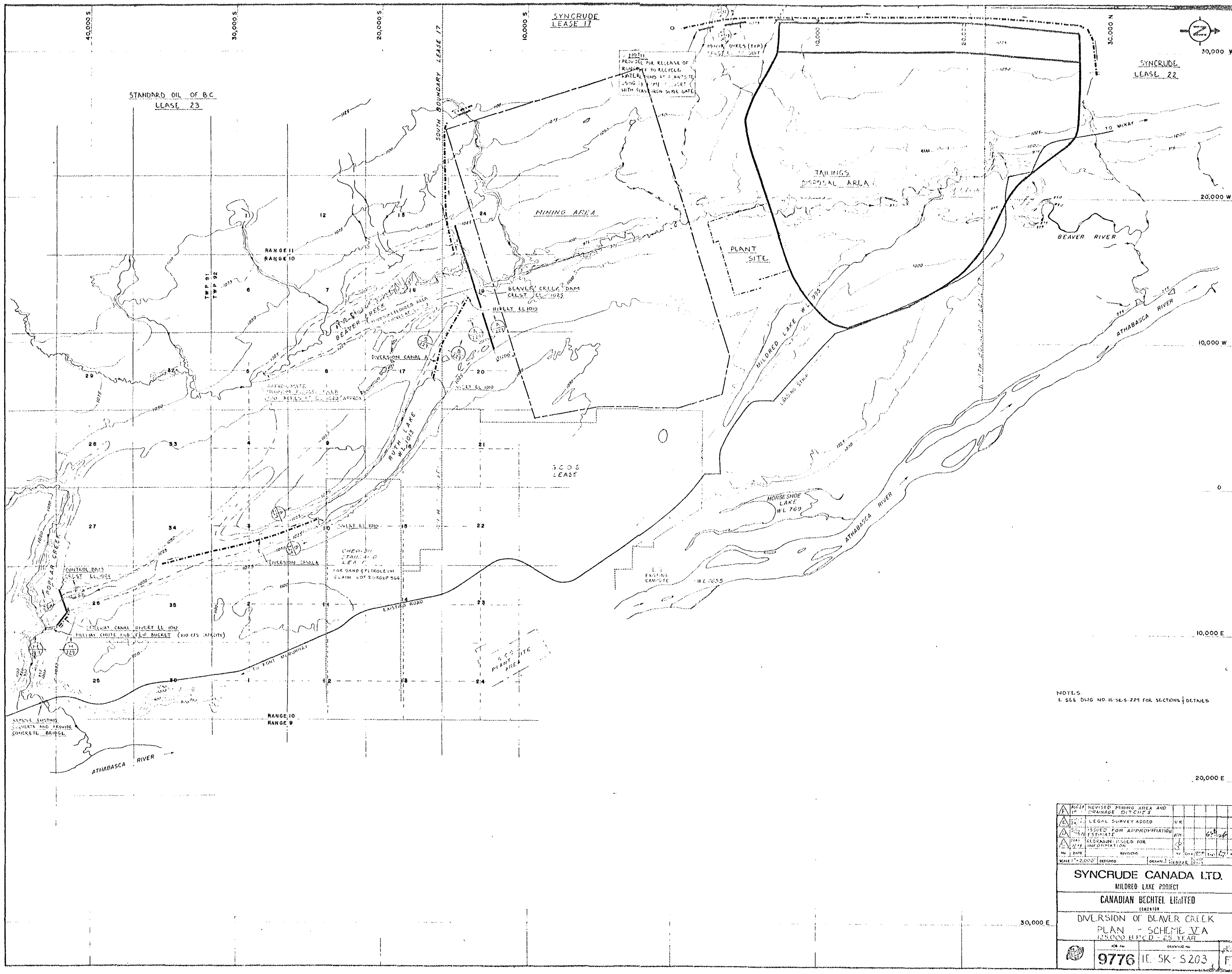
F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
SYNCRUDE LEASE 22
NORTH BOUNDARY LEASE 17
SOUTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
MINING AREA
TAILINGS CELL 2A
(SAND)
TAILINGS CELL 2B
(SAND)
MINING AREA
COKE
STORAGE
SULPHUR STORAGE
EFFLUENT POND
RECYCLE WATER POND
FROTH HEATING POND
EXTRACTION PLANT POND
SURGE PILE
POWER HS
DYKE (TYP)
RECLAIM WATER BARGE
SLUDGE RETURN BARGE 2 REQD
ALBERTA POWER SUB-STATION
RAW WATER INTAKE
RAW WATER POND
MILDRED LAKE W.L. 935
LANDING STRIP
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL 1014
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED RELOCATED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
DYKE
WATER SUPPLY LINE
HORSESHOE LAKE W.L 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
W.L 765.5
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 2001
PRODUCTION 92.8 MM TONS
9776 IR-SK-A-421


F/T TAILINGS POND (TAILINGS)
TAILINGS POND (SLUDGE & WATER)
SYNCRUDE LEASE 22
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
MINING AREA
TAILINGS CELL 2A (SAND)
TAILINGS CELL 2B (SAND)
MINING AREA
COKE STORAGE
SULPHUR STORAGE
FROTH TREATING POND
EFFLUENT POND
RECYCLE WATER POND
EXTRACTION PLANT POND
SURGE PILE
POWER HS.
DYKE (TYP.)
RECLAIM WATER BARGE
SLUDGE RETURN BARGE & REQD.
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L. 1013
ALBERTA POWER SUBSTATION
RAW WATER INTAKE
RAW WATER POND MAX. W.L. EL. 1015
MILDRED LAKE W.L. 995
DYKE
LANDING STRIP
PROPOSED RELOCATED PROVINCIAL HIGHWAY
WATER SUPPLY LINE
ACCESS ROAD TO PLANT
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
ATHABASCA RIVER
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING ROAD
TO FORT McMURRAY
EXISTING CAMPSITE
W.L. 765.5
LOW-LIFT PUMPING STATION
11,250 N 10,300 W
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
0
5,000 E
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
ISSUED FOR INFORMATION
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 2002
9776
R-SK-A-422

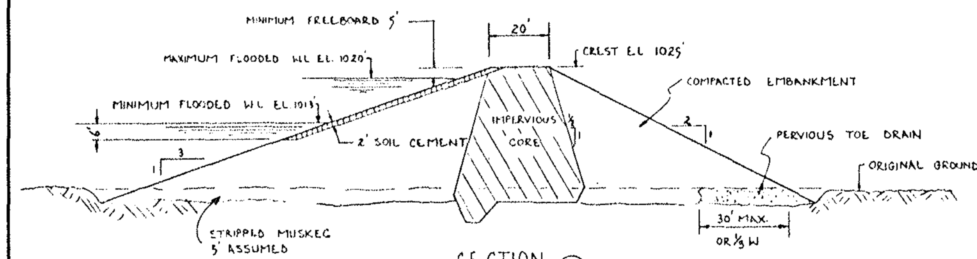

F/T TAILINGS POND
(TAILINGS)
TAILINGS POND
(SLUDGE & WATER)
SYNCRUDE
LEASE 22
OPEN CELL 3A
OPEN CELL 3B
COKE STORAGE
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
STANDARD OIL OF B.C.
LEASE 23
DRAINAGE DITCH
BEAVER CREEK
BEAVER CREEK DAM
NORMAL FLOODED AREA
EL. 1014
BASE LINE
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED RELOCATED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
CHEVRON STANDARD LEASE
DYKE (TYP)
SURGE PILE
FROTH TREATING POND
EFFLUENT POND
EXTRACTION PLANT POND
RECYCLE WATER POND
ALBERTA POWER SUB-STATION
RAW WATER INTAKE
DYKE
RAW WATER POND
MILDRED LAKE W.L. 995
LANDING STRIP
11,250 N
10,300 W
WATER SUPPLY LINE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
HORSESHOE LAKE
W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
W.L. 765.5
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
15,000 S
10,000 S
5,000 S
0
5,000 N
10,000 N
15,000 N
20,000 N
25,000 N
30,000 N
30,000 W
25,000 W
20,000 W
15,000 W
10,000 W
5,000 W
5,000 E
LEGEND
TAILINGS
VEGETATION
MINING PIT
STRIPPING & GRADING
OVERBURDEN REMOVAL
MUSKEG STORAGE
ISSUED FOR INFORMATION
1" = 1,000'
SYNCRUDE CANADA LTD
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE PLAN
YEAR 2004
PRODUCTION 92.8 MM TONS
9776
IR-SK-A-4234

8.0 BEAVER CREEK DIVERSION

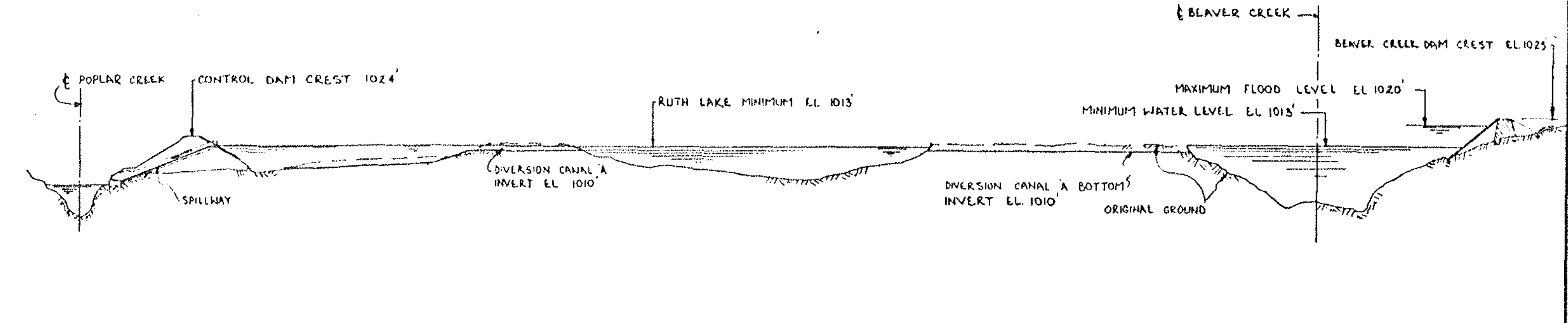
The scheme to direct Beaver Creek is covered in a separate source document. However, illustrative sketches IE-SK-S-203 and 229 are included as references.



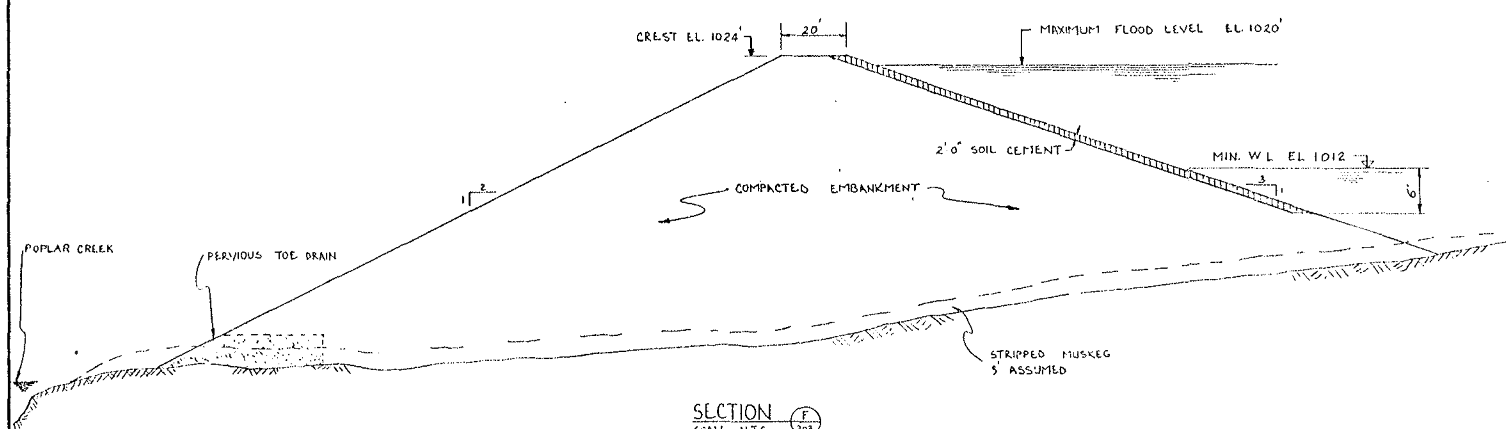
SYNCRUDE LEASE 17
SYNCRUDE LEASE 22
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
TAILINGS DISPOSAL AREA
MINING AREA
PLANT SITE
BEAVER RIVER
BEAVER CREEK
BEAVER CREEK DAM CREST EL 1025
DIVERSION CANAL
RUTH LAKE
MILDRED LAKE
HORSESHOE LAKE WL 769
ATHABASCA RIVER
POPLAR CREEK
CONTROL DAM CREST EL 1025
EXISTING ROAD
TO FORT McMURRAY
TO MCKAY
G.C.O.S. LEASE
RANGE 11
RANGE 10
RANGE 9
TWP 91
TWP 92
REMOVE EXISTING CULVERTS AND PROVIDE CONCRETE BRIDGE
NOTES
1. SEE DWG NO. IE-SK-S-229 FOR SECTIONS & DETAILS
40,000 S
30,000 S
20,000 S
10,000 S
10,000 N
20,000 N
30,000 N
30,000 W
20,000 W
10,000 W
10,000 E
20,000 E
30,000 E
F REVISED MINING AREA AND DRAINAGE DITCHES
E LEGAL SURVEY ADDED
D ISSUED FOR APPROPRIATION ESTIMATE
C REDRAWN - ISSUED FOR INFORMATION
No DATE REVISIONS
SCALE 1" = 2,000'
DESIGNED
DRAWN
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
EDMONTON
DIVERSION OF BEAVER CREEK
PLAN - SCHEME VI A
125000 B.P.C.D. - 25 YEAR
JOB No
9776
DRAWING No
IE-SK-S203
F



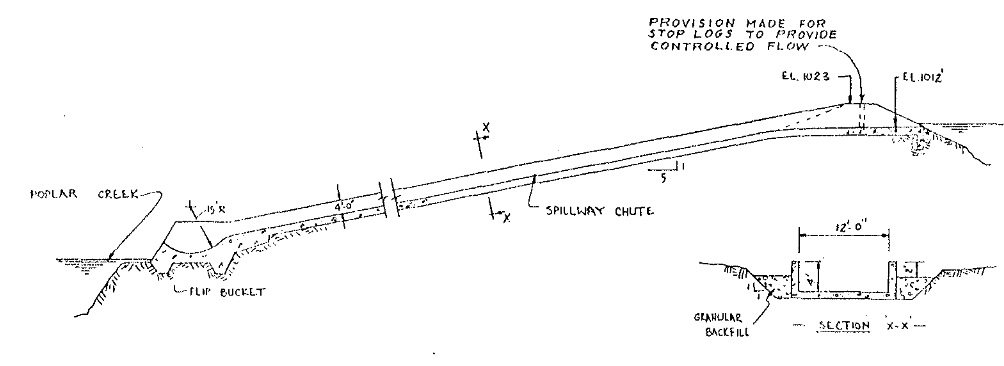
SECTION (A/203)
SCALE 1"=20'0"
— BEAVER CREEK DAM —



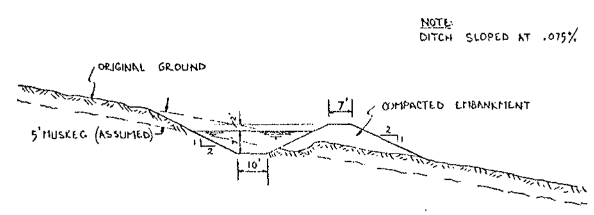
— BEAVER CREEK DIVERSION —
PROFILE
N.T.S.



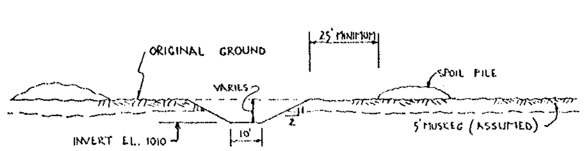
SECTION (F/203)
SCALE N.T.S.
— CONTROL DAM —



SECTION (H/203)
SCALE NIL
— SPILLWAY —



SECTION (D/203)
SCALE 1"=20'0"
— 500 CFS DRAINAGE DITCH —



SECTION (B/203)
SCALE 1"=20'0"
— DIVERSION CANAL 'A' —

NOTE:
SEE DWG. NO. IE-SK-S-201 FOR PLAN

No.	DATE	REVISIONS	BY
E	AUG 20 1973	REMOVED LOW LEVEL OUTLET & SECTION 'E'	W.N.
D	JULY 24/73	REMOVED CONTROL WEIR & DIVERSION CANAL 'B'	W.P.
C	5/7/73	ISSUED FOR APPROPRIATION ESTIMATE	W.Y.
B	MAY 7/73	REDRAWN AND ISSUED FOR INFORMATION	

SCALE AS NOTED

SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT

CANADIAN BECHTEL LIMITED
EDMONTON

DIVERSION OF BEAVER CREEK
SECTIONS & DETAILS - SCHEME VA
125,000 BPCD - 25 YEAR

JOB No.	DRAWING No.	REV
9776	IE-SK-S-229	E

9.0 MUSKEG HANDLING

9.1 General

The philosophy for muskeg storage and disposal is to keep just sufficient muskeg to meet the requirements for soil amendment of sand tailing dyke slopes.

Piled muskeg stored for long periods of time deteriorates and cannot be used for soil amendment purposes. In view of this the quantity of stock piled muskeg will correspond to the immediate needs of the site reclamation work.

Earthen dykes will be constructed to a height of approximately 10 ft around muskeg stockpiles.

Excess muskeg will be cast into mined out areas.

Muskeg removal from the plant site area will be placed in a waste pile within the bounds of the Tailings Pond as shown on the sketch 51B-SK-A-102.

Storage piles 1, 2 and 3, each containing approximately 100,000 cy of muskeg, will be established in locations about as shown on sketch 102. Muskeg from these piles will be used for soil amendment at the sand tailings dykes. Additional quantities will be borrowed locally.

9.2 Mine Area Muskeg

The quantity of muskeg, estimated from the topographical maps of the 7,000 acre mine area, is 40,000,000 cy.

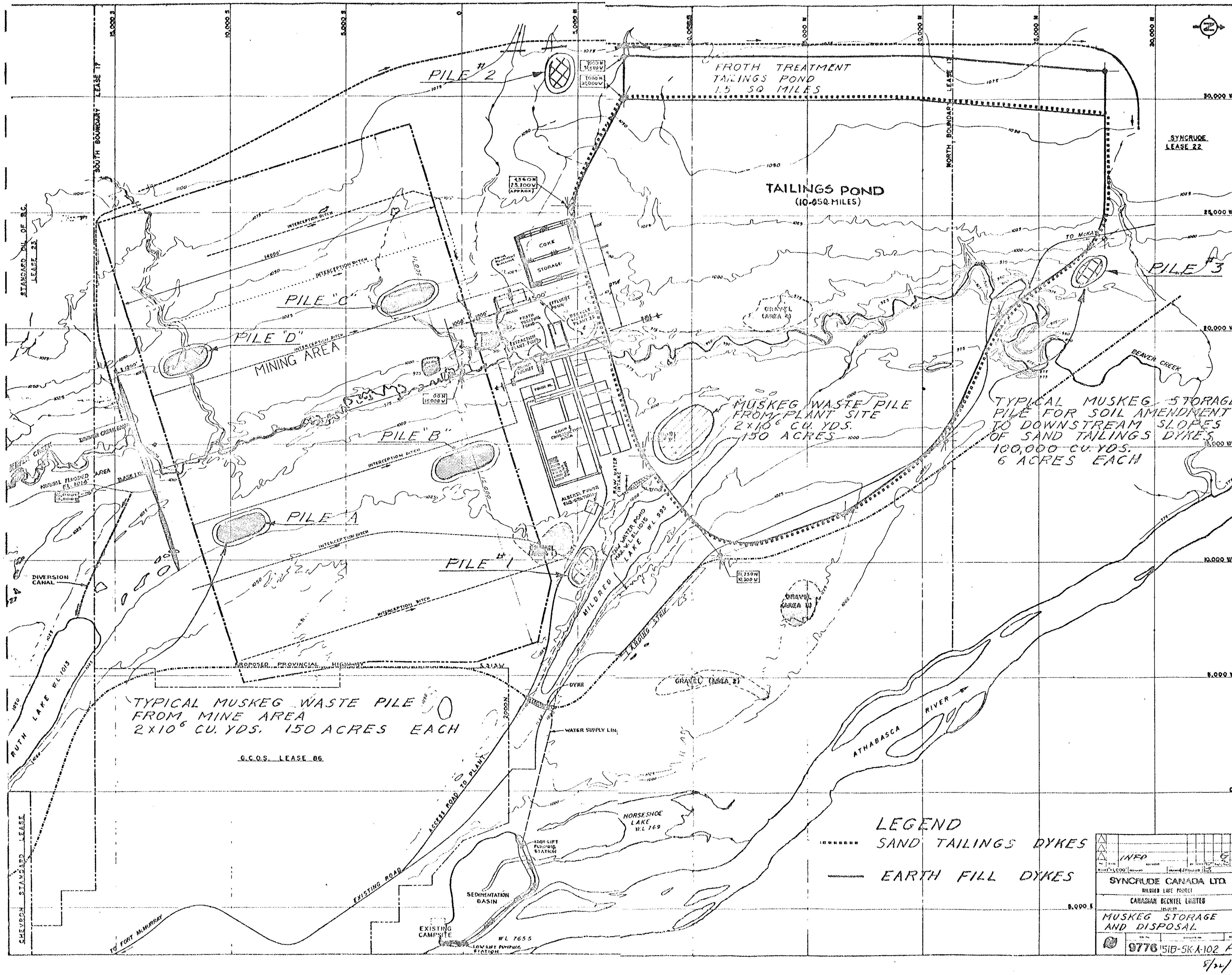
Initially, about 8,000,000 cy of muskeg will be removed from the area to be mined; approximately 1800 acres between the two interceptor ditches closest to the center line of the mine. These materials will be hauled to piles A through D as shown on sketch 51B-SK-A-102. This muskeg will subsequently be cast back into the pit along with overburden and rejects.

As the mine progresses, new piles of muskeg will be built-up, then cast into the pit.

Muskeg for revegetating the mine pit tailings cells will be borrowed from adjacent areas, as economical and convenient.

9.4 Haul Roads

Suitable haul roads will be constructed to each muskeg stock-pile.


PILE #2
FROTH TREATMENT TAILINGS POND 1.5 SQ MILES
TAILINGS POND (10-05 SQ MILES)
SYNCRUDE LEASE 22
NORTH BOUNDARY LEASE 17
SOUTH BOUNDARY LEASE 17
STANDARD OIL OF B.C. LEASE 23
PILE #3
PILE "C"
PILE "D"
MINING AREA
PILE "B"
PILE A
PILE #1
COKE STORAGE
BEAVER CREEK
MUSKEG WASTE PILE FROM PLANT SITE 2x10^6 CU. YDS. 150 ACRES
TYPICAL MUSKEG STORAGE PILE FOR SOIL AMENDMENT TO DOWNSTREAM SLOPES OF SAND TAILINGS DYKES 100,000 CU. YDS. 6 ACRES EACH
DIVERSION CANAL
MILDRED LAKE
GRAVEL (AREA 2)
ATHABASCA RIVER
RUTH LAKE
PROPOSED PROVINCIAL HIGHWAY
TYPICAL MUSKEG WASTE PILE FROM MINE AREA 2x10^6 CU. YDS. 150 ACRES EACH
G.C.O.S. LEASE 86
WATER SUPPLY LINE
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
HORSESHOE LAKE
SEDIMENTATION BASIN
EXISTING CAMPSITE
SHEVRON STANDARD LEASE
LEGEND
SAND TAILINGS DYKES
EARTH FILL DYKES
INFO
SYNCRUDE CANADA LTD.
CANADIAN BECHTEL LIMITED
MUSKEG STORAGE AND DISPOSAL
9776 51B-SK-A-102 A
8/24/73

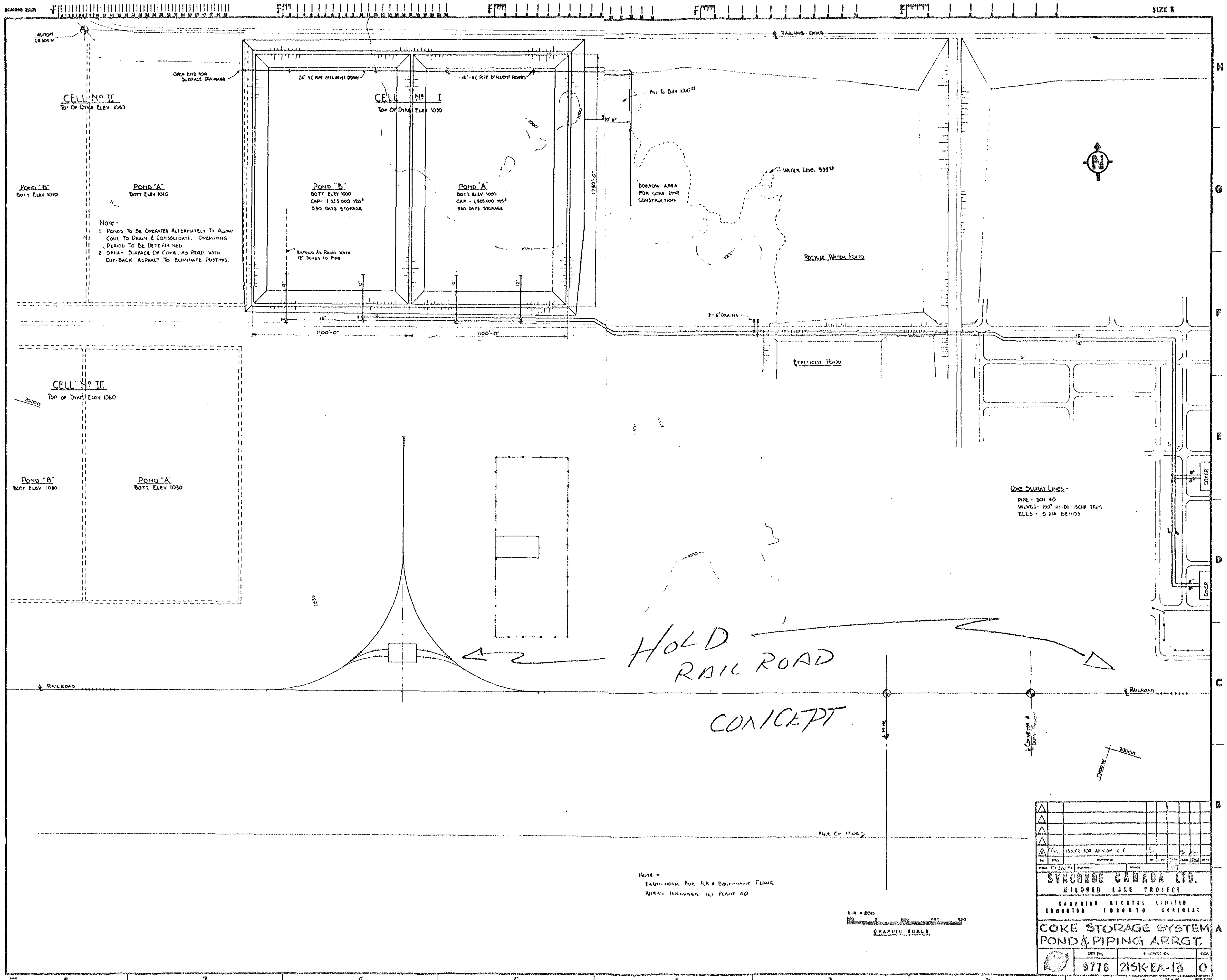
10.0 COKE STORAGE

Slurried coke will be pumped to storage cells near the operating complex. Motive water will drain, and return to the process water system. This circulating load of water is part of each water balance included in Section 5.0.

The storage details are illustrated by sketches 21-SK-EA-13. and 21.

The storage cells will occupy an area of about 640 acres, after the 25-year mining period has elapsed.

The storage area will not be vegetated with permanent cover as part of reclamation because coke represents an energy resource; which must be accessible in the future.



SIZE B
CELL No II
TOP OF DYKE ELEV 1040
POND "B"
BOTT ELEV 1010
POND "A"
BOTT ELEV 1010
OPEN END FOR SURFACE DRAINAGE
24" VC PIPE EFFLUENT DRAIN
18" VC PIPE EFFLUENT RISERS
CELL No I
TOP OF DYKE ELEV 1030
POND "B"
BOTT ELEV 1000
CAP - 1,525,000 YDS³
530 DAYS STORAGE
POND "A"
BOTT ELEV 1000
CAP - 1,525,000 YDS³
530 DAYS STORAGE
NOTE -
1. PONDS TO BE OPERATED ALTERNATELY TO ALLOW COKE TO DRAIN & CONSOLIDATE. OPERATING PERIOD TO BE DETERMINED.
2. SPRAY SURFACE OF COKE, AS REQD. WITH CUT-BACK ASPHALT TO ELIMINATE DUSTING.
EXTEND AS REQD. WITH 12" SCHED 10 PIPE
1100'-0"
1100'-0"
1730'-0"
TAILINGS DYKE
FILL TO ELEV 1000±
BORROW AREA FOR COKE DYKE CONSTRUCTION
WATER LEVEL 995±
RECYCLE WATER POND
2 - 6" DRAINS
EFFLUENT POND
CELL No III
TOP OF DYKE ELEV 1060
POND "B"
BOTT ELEV 1030
POND "A"
BOTT ELEV 1030
COKE SLURRY LINES -
PIPE - SCH 40
VALVES - 150#-RF-DI-13CHR TRIM
ELLS - 5 DIA BENDS
HOLD
RAIL ROAD
CONCEPT
RAILROAD
RAILROAD
FACE OF MINE
NOTE -
EARTHWORK FOR RR & DRAINAGE FEATURES
ALREADY INCLUDED IN PLANT 40
GRAPHIC SCALE
ISSUED FOR APPROVAL
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
EDMONTON TORONTO MONTREAL
COKE STORAGE SYSTEM
POND & PIPING ARRGT.
9776
21SK-EA-13
0

CELL Nº VI
TOP OF DYKE - EL 1055
BOTT OF POND - EL 1028
CELL Nº I
FOR DETAILS SEE DWG Nº 21SK-EA-
TOP OF DYKE - EL 1030
BOTT OF POND - EL 1000
CELL Nº II
TOP OF DYKE - EL 1040
BOTT OF POND - EL 1010
CELL Nº IV
TOP OF DYKE - EL 1075
BOTT OF POND - EL 1045
CELL Nº III
TOP OF DYKE - EL 1060
BOTT OF POND - EL 1030
CELL Nº V
TOP OF DYKE - EL 1095
BOTT OF POND - EL 1035
FACE OF MINE
COKE STORAGE
CELL Nº | STORAGE CAP. C.Y | DAYS STORAGE | YEARS * STORAGE
I | 3,050,000 | 1060 | 3.2
II | 3,050,000 | 1060 | 3.2
III | 3,050,000 | 1060 | 3.2
IV | 3,050,000 | 1060 | 3.2
V | 3,050,000 | 1060 | 3.2
VI | 3,725,000 | 300 | 4.0
TOTALS | | | 20
* BASED ON COKERS OPERATING 330 DAYS/YR
ISSUED FOR APPROVAL
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
EDMONTON TORONTO MONTREAL
COKE STORAGE SYSTEM
GENERAL ARRGT. PLAN.
9776
21SK-EA-21
0

11.0 FROTH TREATMENT TAILINGS STORAGE

Plant 6 tailings will be pumped to a 960 acre retention pond. The pond is located along the western perimeter of the main basin. Waters will flow out of the pond via API separators or similar, where an oily float will be recovered.

The residue forms a reserve deposit of heavy mineral values.

12.0 GRAVEL DEPOSITS

Site exploration to date has revealed the presence of four gravel areas. These are designated 1, 2, 3, and 4 and their locations are shown on site plan IR-SK-A-347.

The following tabulation gives the pertinent details of the gravel areas:

Gravel Area	Acres	Ov/B Thick' ft	Avg Thick' ft	Tot.Vol cy	Usable cy
1	56	2.	8.5	715,000	430,000
2	75	1.5	8.0	1,030,000	618,000
3	5	6.	5.0	37,100	22,200
4	46	2.	13.0	965,000	579,000

After the usable gravel is recovered from these areas, it is proposed to cast back the overburden and unused materials into the pits.

It is proposed to fill up area I with overburden from the mine and leave areas 2 and 3 with the original ground level depressed 3 to 5 feet. No reclamation action is necessary for gravel area 4 as it is within the pond area.

Any muskeg removed from the gravel areas 1, 2 and 3 will be stored and replaced on completion of each pit's operation.

S E C T I O N 3.

SITE RECLAMATION

C. REVEGETATION REPORT

August, 1973

TABLE OF CONTENTS

SUMMARY

Experiments with laboratory growth chambers have provided an insight into planning and implementing a revegetation program. Soil analysis done on tailings sand and overburden showed the soils to be infertile and that fertilization must be carried out. Even though the muskeg was low in nutrient content, addition of muskeg to the soil was most valuable as it increased soil moisture retention, thereby increasing productivity. Another important element is that of legume innoculation with nitrogen - fixing bacteria. This will eliminate legume wilt and provide good growth of legumes in the grass-legume mixtures. A good vegetative cover is possible without irrigation if a proper seeding (Brillon) and fertilization program is followed.

Plans have been made with Dr. Vaartenou to further our revegetation studies at the Provincial Government growth chambers. Following this, field work will begin as outlined by Dr. Vaartenou and Dames & Moore. A study on the effects of SO_2 on vegetation will also be initiated.

INTRODUCTION

In supplying one natural resource, (synthetic crude oil), the industry significantly affects another (land), often in an undesirable manner. Industry realizes that land can no longer be exploited as it has been in the past without concern for future consequences. It is the producer who must take the initiative in responsible land use practices.

A research and development program should analyze problems and develop solutions which assure public acceptance of the tar sands industry. By establishing vegetation on barren areas (tailings sand and dykes), Syncrude will minimize the loss of aesthetic and ecological qualities of the mining site.

Each industrial site presents a different set of conditions as a result of variations in climate, geography, and physiography. Local conditions must be identified before a revegetation program can be devised. As a step in this direction a program has been undertaken to assess the suitability of on-site soils, and to select a variety of plants that will establish a permanent, self-sustaining and maintenance-free vegetative cover.

GROWTH CHAMBER EXPERIMENTS

1. PLANTARIUMS

The first plantarium was custom-built and used in three of the six experiments. It was 48 inches long, 19 inches wide, and 22 inches high, and enclosed on all sides with glass (front sliding doors). Two 4-foot G.E. "plant-lite" fluorescent tubes were placed on top and were timer-controlled to be on for fourteen hours and off for ten hours. It was situated in the main laboratory.

The second plantarium was constructed at the Research laboratory. It was made of wood, with glass sliding doors and was 6 feet x 2½ feet. Attached to the ceiling were two 4 foot G.E. "plant lites" and two 2-foot fluorescent tubes. It was located in the bench unit "cooler" in order to simulate outdoor temperatures. To control the temperature, two in-car warmers and two thermostats were installed. A timer would turn the lights on and the heater on to a temperature of -- 75°F for 14 hours. When the lights and heater shut off the other heater-thermostat combination maintained the temperature at -- 55° - 60° F.

Both chambers were fitted with trays to hold gravel and or water and grids on which to place the plots.

2. SOIL PREPARATION

The tailings sand that was used in all experiments was obtained from the laboratory site. It was dried, the lumps crushed and the larger amounts of bitumen removed.

In the first experiment the clay that was used was centrifuged sludge and the peat was of a commercial compressed type. These were mixed in the various proportions on a volume-volume basis.

The remaining experiments used overburden and muskeg obtained from Tar Sands Lease 17. All mixtures were prepared on an equal volume basis after the overburden and muskeg were considered to be of fine enough texture to work with.

3. SOIL ANALYSIS

Soil analysis was not done on the soils used in the first experiment but for the remaining experiments all soils were sent to the Soils & Feed Testing Laboratory. The results follow:

SOIL ANALYSIS

	Available Plant Nutrients LB/ACRE			Sulphur	Soil Reactions	Soil Salinity Conductivity	Sulphates	Sodium	Organic Matter	Free Lime	Texture
	(N)	(P)	(K)	(S)	(pH)	(mmhos)	(SO_4)	(Na)			
<u>Exp #2</u>											
Overburden	0	07	105	3.1-5.0	6.3	.20		L	L		Sand
Overburden - Muskeg	0	15	165	3.1-5.0	7.2	.15		L	L		Sand
<u>Exp #3</u>											
Overburden	42	15	300	22.8	6.3	0.5		M	L^{+}		3
Overburden Muskeg	21	18	235	21.4	6.3	0.4		M	M^{+}		3
Sand	0	01	15	16.2	8.6	0.2		L	L		1
Sand - Muskeg	0	01	35	21.4	6.7	0.3		L	L		1
Muskeg	0	08	95	24.6	6.1	0.3		L^{+}	H		6
<u>Exp #4,5,6</u>											
Overburden	4	07	825	83.0	9.3	1.4	L^{+}	H^{+}	L^{+}	M	5
Overburden - Muskeg	7	07	410	784	7.6	1.1	L	H^{+}	L^{+}	M	10
Sand	0	01	15	16.2	8.6	0.2		L	L		1
Sand - Muskeg	0	06	25	26.1	7.3	0.5		L	L		7
Muskeg	0	02	60	8.8	4.9	0.2		L	H^{+}		6

As indicated by the table, all soils were low in nutrients with the exception of potassium in some overburden samples. Note that the overburden used in the last three experiments was higher in practically all analyses.

A description of the different soils will be discussed in the experimental results since all the soils varied in appearance from one experiment to another.

Refer to Appendix A for a guide to interpretation of soil test results as described by the Alberta Department of Agriculture Soils & Feed Testing Laboratory.

4. PLANT SPECIES

As suggested by Dames & Moore many varieties of plants were tested in the last four experiments. Of the nine species suggested, one (Arctic Sweet Clover) could not be obtained and was substituted by Polara Sweet Clover (on the suggestion of Maple Leaf Mills). The remaining were obtained from Mr. L. Gareau, Forage Corps Supervisor, Department of Agriculture along with his suggestion for four more varieties.

Experiment #3, therefore, used the following plants for screening purpose and remaining experiments.

SPECIES	VARIETY
Alfalfa	Beaver
Birds foot Trefoil	Leo
Sweet Clover	polara
Bromegrass	Manchor
Creeping Red Fescue	Boreal
Crested Wheatgrass	Fairway
Pubescent Wheatgrass	Greenleaf
Reed Canary Grass	Frontier
Tall Wheatgrass	Orbit
Russian Wildrye	Sawki
Streambank Wheatgrass	
Intermediate Wheatgrass	Chief
Bromegrass	Carlton

All varieties were selected for evaluation after reviewing the publication "Hay & Pasture Mixtures for Alberta". (1)

5. LEGUME INNOCULATION

Innoculation of the legumes was recommended because of the poor results that Mr. C. B. Berry of G.C.O.S. (2) found with the legumes wilting and disappearing within the first growing season. In the first two experiments legume wilting was noticed but with innoculation in the last four experiments this was no longer a problem.

"Probably one-half to two-thirds of the legumes possess the ability to form a symbiotic relationship with strains of bacterium found in the soil. The presence of roots of an appropriate host legume results in the multiplication of these bacteria in the soil and eventually some of them infect the roots through the very fine root hairs. This stimulates the production of a lump or nodule on the root. Nitrogen fixation occurs in these nodules, the plant supplying energy material to the bacteria, which, in turn, presumably possess ability to convert gaseous nitrogen to a combined form under these special circumstances". (3)

All the legumes were innoculated by placing a small amount of innoculant on top of each seed when seeding the pots.

6. FERTILIZATION

A fertilizer, 8-24-24, was added to all containers in the last four experiments at a rate of 300 lbs./acre. The actual amount of fertilizer applied to each pot was determined by relating the weight of the material in each pot to 2,000,000 lbs., the weight of an acre furrow slice of soil.

The fertilizer was made up from individual packages of N, P_2O_5, and K_2O. Solutions were made up so that each pot took about 25 mls. All fertilizer and water were applied through a syringe with a circular needle with holes in it to provide even coverage.

In experiment #4 micro-nutrients (called Fritted Trace Elements and obtainable from Robertson Seeds) were applied to some pots at a rate of 2 oz/cu. yd. This particular rate was suggested by Mr. Paul Kurelak because there were no application rates or elemental analysis supplied with the fertilizer. The weight of a cubic yard of each soil was determined and the fertilizer applied according to this weight. The micro-nutrients were dissolved in water and applied in the same way as the 8-24-24. Not all the fertilizer dissolved but was applied as such-partially dissolved.

7. EXPERIMENTAL RESULTS

(i) EXPERIMENT #1

In order to develop procedures and techniques for future greenhouse studies a simple experiment was set up to evaluate the problems one could encounter.

Three plants or plant mixtures were grown (a playground grass mixture, bromegrass, and White Dutch clover) in seven soil media, varying from sand with additions of centrifuged sludge (clay) and commercial peat to potting soil. The temperature was always between 75° F and 80° F and humidity close to 100%.

Of particular interest was the wilting of the cloves and tip burning of grasses toward the end of the first month. Excepting pure sand addition of clay in sand mixtures had the poorest growth rate.

It was decided that for future experiments muskeg and overburden would come from the Fort McMurray area to simulate more realistic growing conditions.

No problems were encountered.

(ii) EXPERIMENT #2

The object of this experiment was to compare plant species in two soils: overburden and an overburden-muskeg mixture. The overburden was very sandy, muck-like tar sand minus the bitumen. The muskeg was composed of rich black soil and decayed vegetative material.

The plants chosen were bromegrass, crested wheatgrass, alsike clover, and alfalfa and were duplicated in each soil type.

The legumes showed signs of wilt at two weeks and seemed to be necrotic but improved soon afterwards. Mold was noticed in some pots but was attributed to the high humidity in the plantarium. At the end of a month the plants in the muskeg mixture were much thicker than the ones in the overburden.

The grasses did equally well in both soils until the end of one month when tip burning was noticed, more so in the overburden than in the muskeg mixtures.

Even though the muskeg was low in nutrients, the use of it enhanced plant growth because of its water retention. This was particularly noticed towards the end of the experiment when they were seldom watered; the muskeg-grown plants stayed green for a longer time than plants grown in overburden.

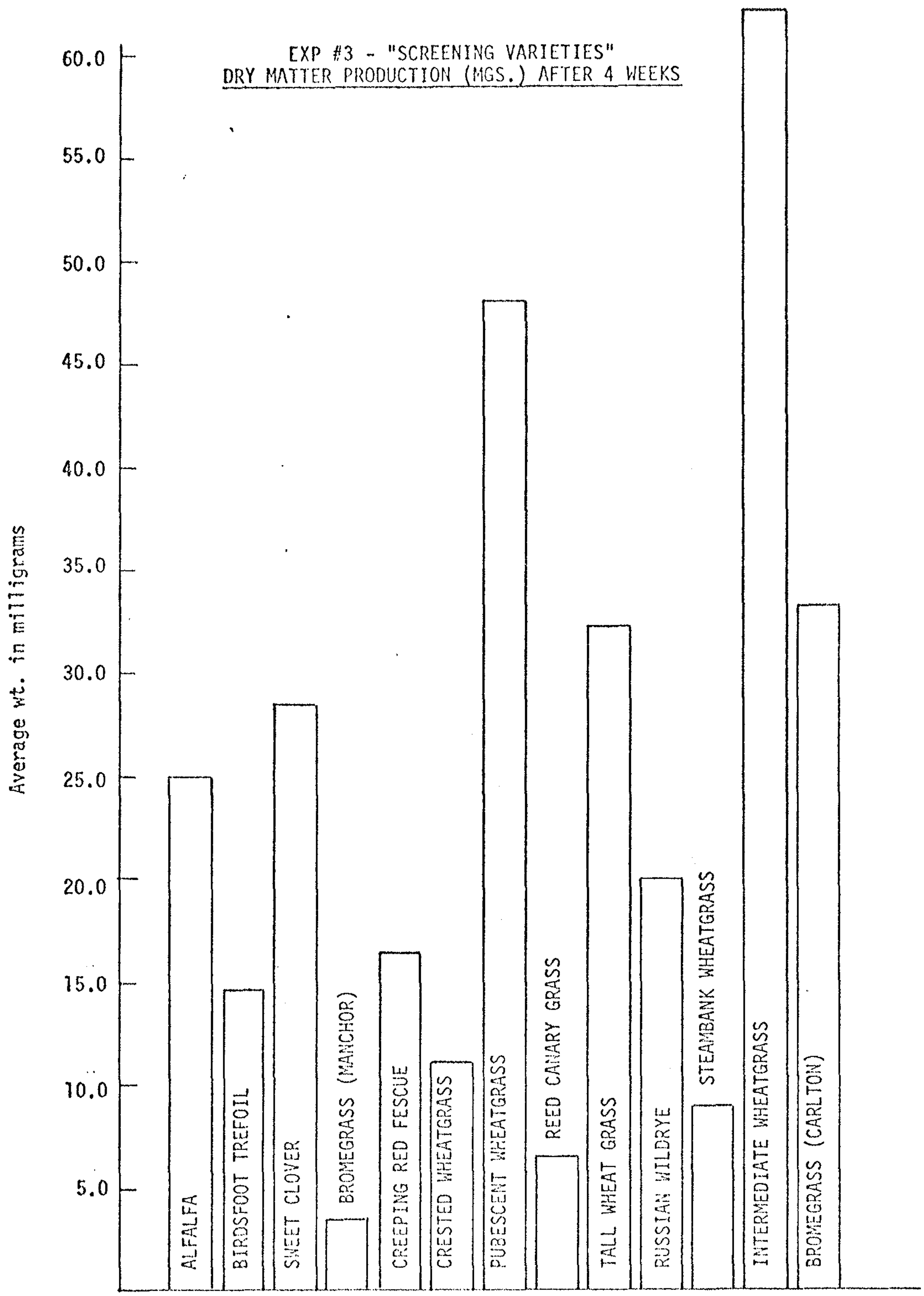
(iii) EXPERIMENT #3

This experiment and the three to follow were outlined by Dames & Moore in their report prepared for Syncrude. (4)

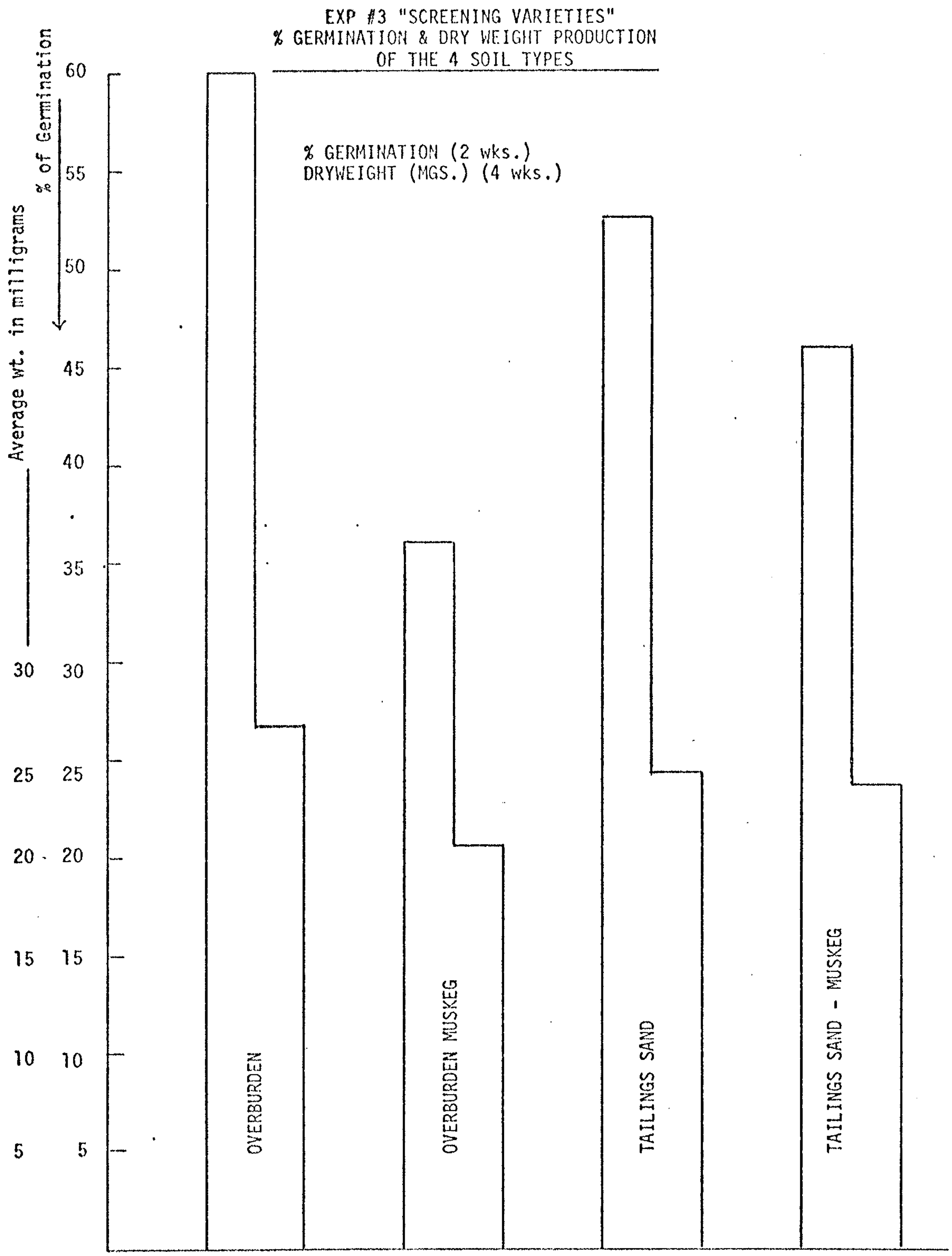
The principle objective of this experiment was a screening test to eliminate the poorer varieties of plants. Thirteen varieties are listed in Section 4. Plant species above were tested in four soil types and duplicated.

The four soil types were overburden, overburden-muskeg, tailings sand, and tailings sand-muskeg. The tailings sand was low or nil in major nutrients as was to be expected. The muskeg was of poor fertility, low in nitrogen and phosphorus, and only marginal in potassium. The overburden was "surface silt", similar to the muskeg in nutrient value, but very much like black topsoil in texture. (refer to Section 3, soils analysis)

Twenty-five seeds were placed in each pot, all legumes innoculated, some soil added to cover the seeds, and all fertilized with 8-24-24 at a rate of 300 lbs/acre.


EXP #3 - "SCREENING VARIETIES"
DRY MATTER PRODUCTION (MGS.) AFTER 4 WEEKS
Average wt. in milligrams
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
ALFALFA
BIRDSFOOT TREFOIL
SWEET CLOVER
BROMEGRASS (MANCHOR)
CREEPING RED FESCUE
CRESTED WHEATGRASS
PUBESCENT WHEATGRASS
REED CANARY GRASS
TALL WHEAT GRASS
RUSSIAN WILDRYE
STEAMBANK WHEATGRASS
INTERMEDIATE WHEATGRASS
BROMEGRASS (CARLTON)

Graph 1



EXP #3 "SCREENING VARIETIES"
% GERMINATION & DRY WEIGHT PRODUCTION
OF THE 4 SOIL TYPES
% GERMINATION (2 wks.)
DRYWEIGHT (MGS.) (4 wks.)
Average wt. in milligrams
% of Germination
60
55
50
45
40
35
30 30
25 25
20 20
15 15
10 10
5 5
OVERBURDEN
OVERBURDEN MUSKEG
TAILINGS SAND
TAILINGS SAND - MUSKEG

Graph 2

These samples were placed in the plantarium in the cooler in random order and watered every second day. The only problem encountered was the drying out of some plants at the end opposite to the 75°F. heater. The air flow was concentrated at the other end and was forced down over those plants.

After two weeks growth a germination count was taken and all pots photographed. Germination varied from 5.5% to 82%. This was considered to be a poor method of comparison because much of the germination occurred after two weeks.

After four weeks the plants were again photographed and cut down to soil level to be weighed. The clippings were placed in a filter paper and dried @ 77°C for 48 hours. After weighing, a graph was made to show the average dry matter production of each type of plant.

As indicated by this graph: of the ten grass species tested, four were considered to be inadequate for growth in these particular soils. They were bromegrass (Manchar), Reed canary grass and streambank wheatgrass because of their low dry weight productivity, and Russian wildrye because of its wiltiness. The remaining six grasses were considered worthwhile testing again.

All three legumes did very well, with only two pots of sweet clover showing wilt after four weeks. Innoculation of legumes proved to be worthwhile, the plants showing negligible wilt as compared to the first two experiments.

As shown in graph 2; on an average basis the pure soils produced better than the same soils mixed with muskeg, especially the overburden. The muskeg was very straw-like and seemed to be lacking in organic content. A better quality peat would have probably reversed the above situation. The only exception was that the legumes did better in the sand-muskeg than in the sand only.

The only alkaline soil was tailings sand (pH 8.6) and this was improved by adding the muskeg of a lower pH.

(iv) EXPERIMENT #4

To experiment with micro-nutrients only two soil types were used: tailings sand and overburden. This overburden was obtained from Rick Reinhart and was collected from samples taken from core holes at different depths - representing cross - sections of overburden. They are described as surface silts, sub-surface silts, shales, sands, gravel and lean tar sand.

Two legumes (alfalfa and sweet clover) and four grasses (creeping red fescue, pubescent wheatgrass, intermediate wheatgrass, and 'Carleton' bromegrass) were seeded and innoculated as in the previous experiment. Each plant was triplicated and fertilized at three different rates:

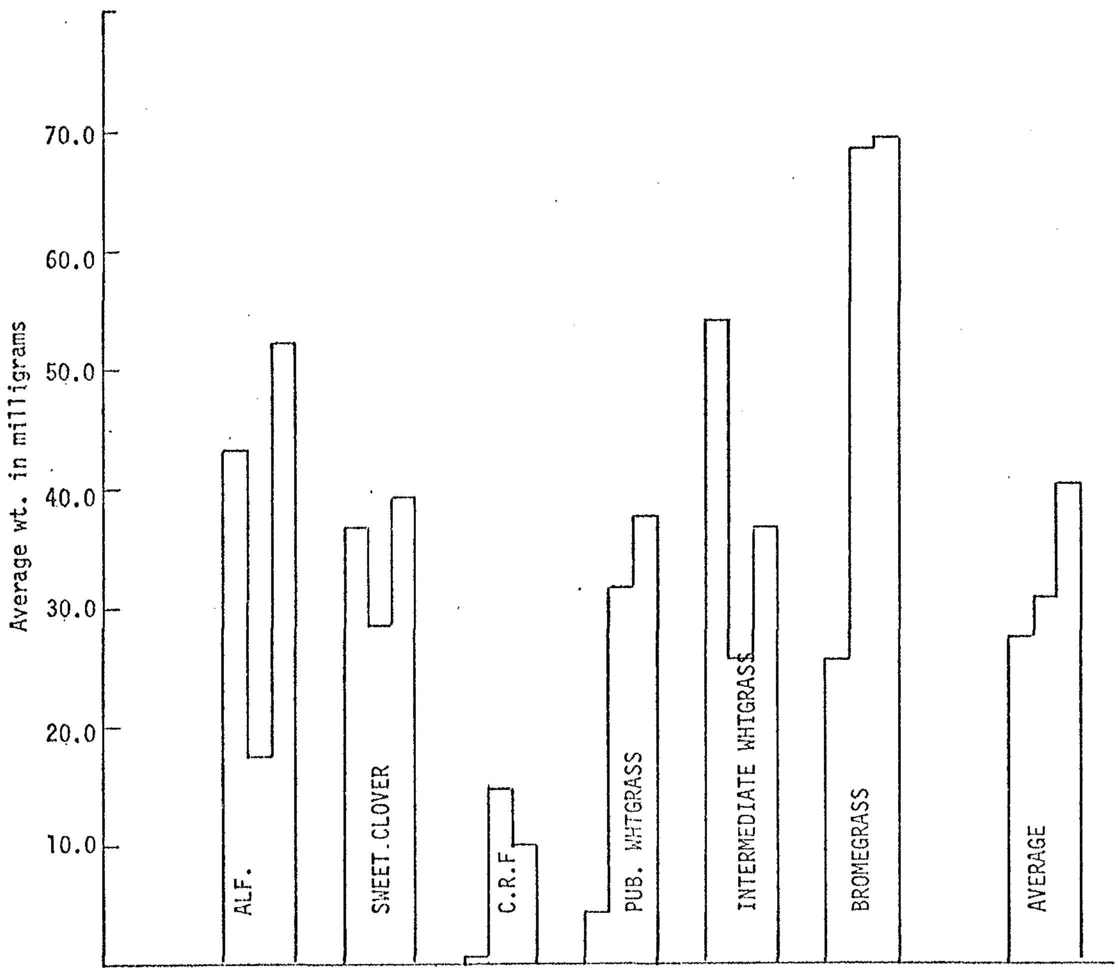
- 300 lbs/acre 8-24-24 only
- 300 lbs/acre 8-24-24 and fritted trace elements
- 300 lbs/acre 8-24-24 and 4x amount of fritted trace elements (refer to Section 6, Fertilization)

EXP #4 "MICRONUTRIENTS"

% DRY WEIGHT PRODUCTION
VS

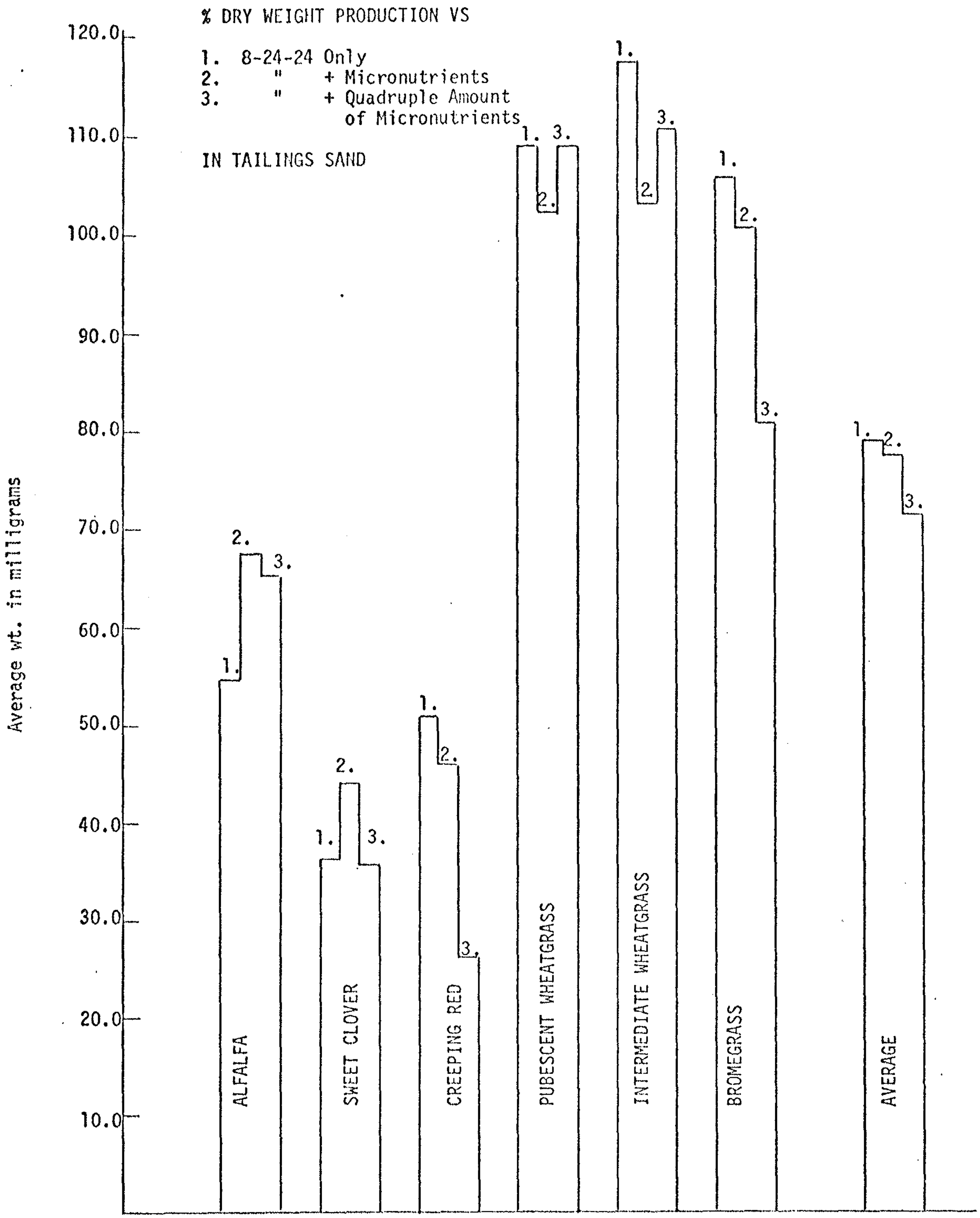
1. 8-24-24 Only
2. " + Micronutrients
3. " + Quadruple Amount of Micronutrients

IN OVERBURDEN



Graph 3

EXP #4 "MICRONUTRIENTS"



Graph 4

These plants were placed in the laboratory plantarium therefore the environment was not varied and averaged 75°F and 95% humidity.

All legumes emerged in sand within three days, regardless of fertilization; in overburden, a few days later. All grasses emerged in about a week, again regardless of fertilization rates used. All plants grew well and exhibited no wilting.

After four weeks growth the plants were weighed to determine dry weight production. Graph 3 (Appendix B) shows an average increase in weight as the fertilization rates were increased in the overburden, but graph 4 shows the opposite trend in tailings sand.

To take each individual variety and do a dry weight comparison of the different fertilizer rates will show erratic results and no correlation at all between growth in tailings sand and overburden. Only 50% of the samples showed an increase in weight from the lowest to the highest fertilizer rate.

By these results it cannot be said that the addition of micronutrients produced better or more plants.

By comparing graphs 3 and 4 it is obvious that the tailings sand had a much better productivity than the overburden. The overburden and tailings sand were strongly alkaline (pH9.3 and 8.6) the available potassium and sodium were very high causing a high conductivity (salt concentration) and pH in the overburden soil.

There may be three reasons for better productivity in the sand than in the overburden:

- higher pH of overburden
- higher salts concentration of overburden, causing "saline" soil and reduced crop growth.
- porosity of overburden causing moisture and fertilizer not to be retained as well as tailings sand.

In a case like this it would be more feasible to use sand as a growing media; at least, for a short period of time. The results may have been reversed over a longer period of time if grown in outside plots due to probable wind erosion of sand.

(v) EXPERIMENT #5

Six grasses and three legumes were combined together to determine the best of six mixtures. Alfalfa, birdsfoot trefoil, and sweet clover were combined with each of the two following grass groups:

1 - pubescent wheatgrass, creeping red fescue, tall wheatgrass

2 - intermediate wheatgrass, bromegrass, crested wheatgrass

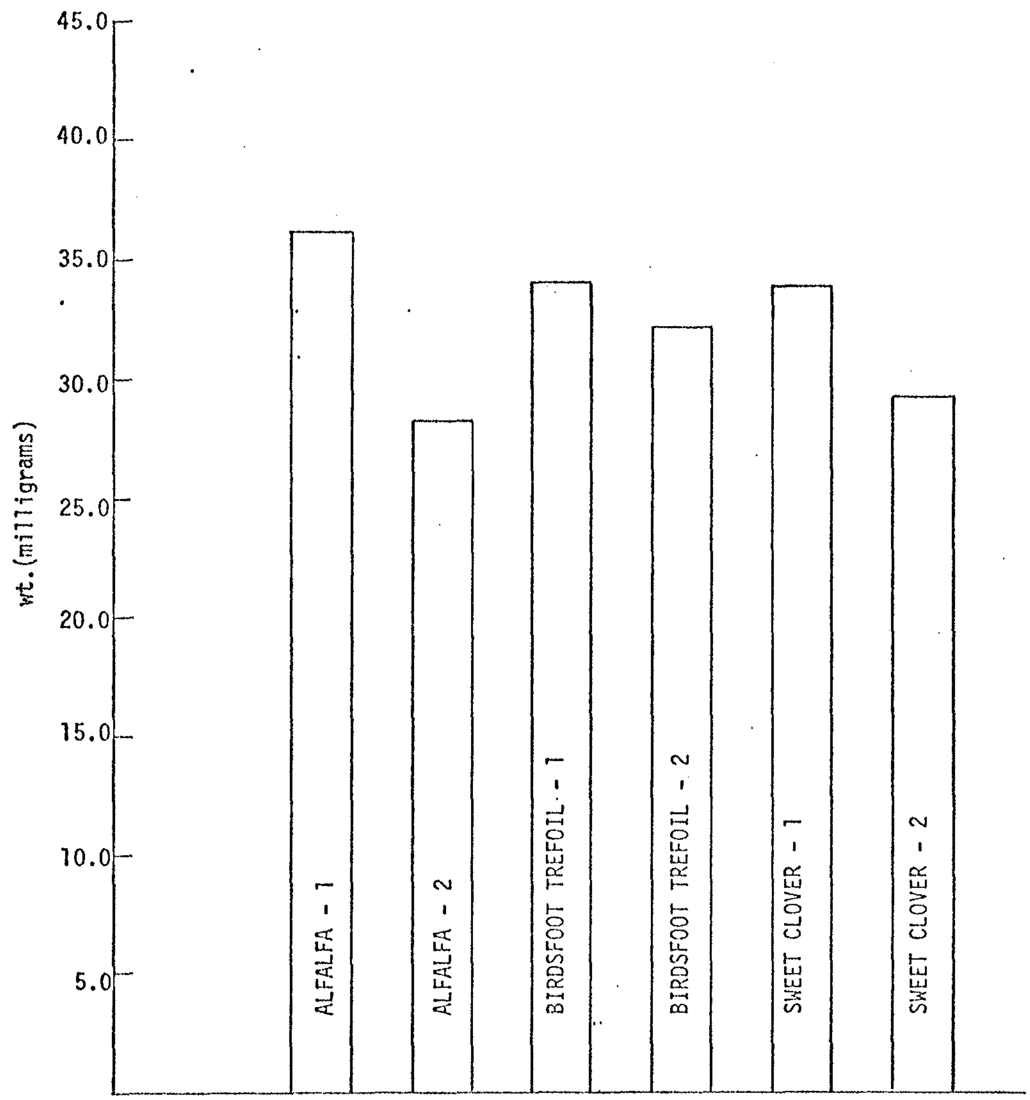
The combinations were chosen because of their dry matter production in experiment #3 and comparisons of plant types in "Hay and Pasture Varieties". Each mixture was duplicated in four soil types; tailings sand, overburden, and their mixtures with peat. The overburden was the same as that used in experiment #4. The peat was of good quality and seemed to be very rich.

Six seeds of each variety were placed at random in each pot and the legumes innoculated. All were fertilized with 8-24-24 at a rate of 300 lbs/acre. These were then placed in the plantarium in the cooler away from the drier side (refer to exp. #3).

All mixtures emerged at about the same time, legumes first.

At the end of four weeks the dry weight of the mixtures (Appendix B, graph 5) showed all mixtures to be close in production. The first grass grouping of pubescent wheatgrass, creeping red fescue, and tall wheatgrass did the best with all

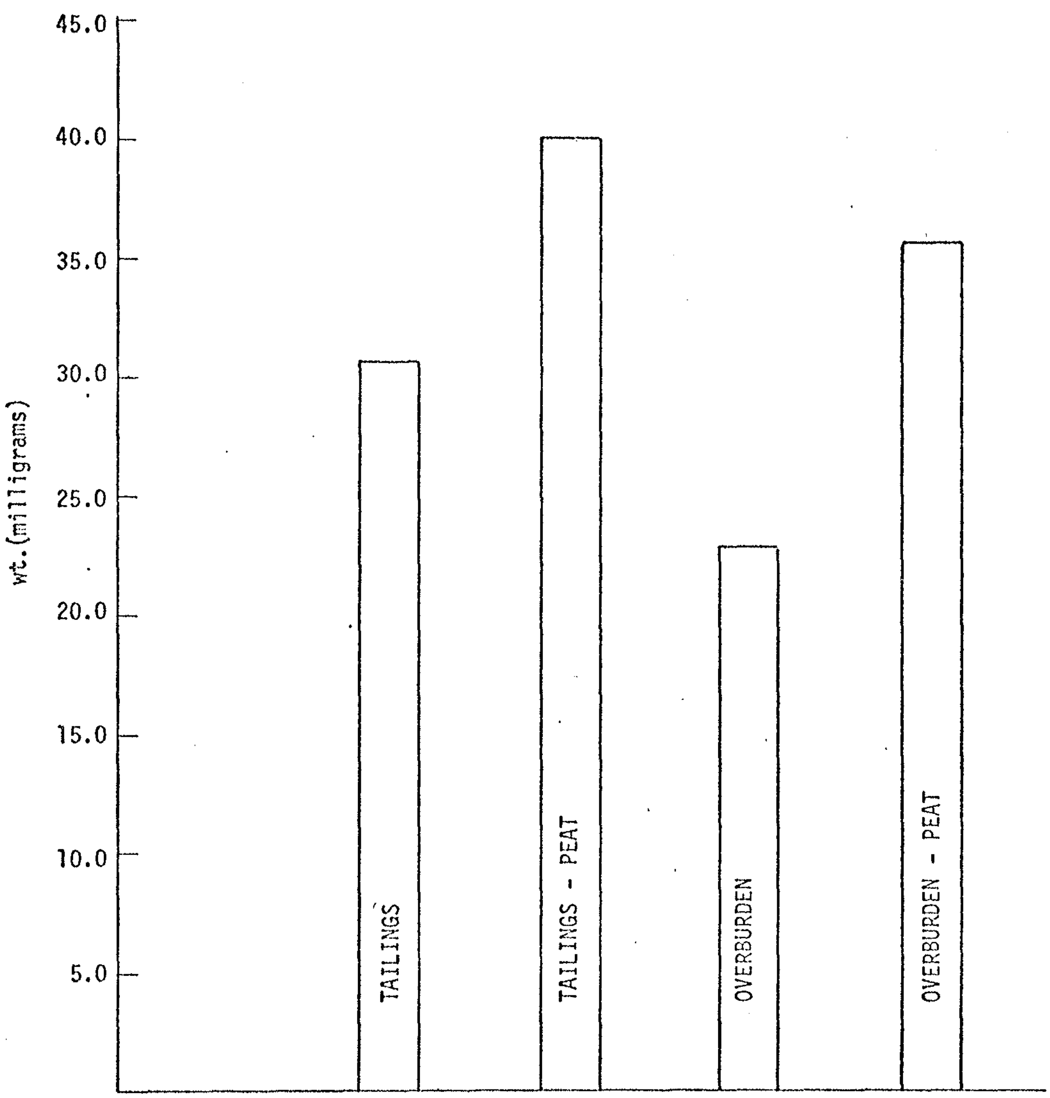
EXP #5 "MIXTURES"
AVERAGE DRY WEIGHT PRODUCTION
OF MIXTURES IN ALL SOILS



Graph 5

EXP #5 "MIXTURES"

DRY WEIGHT PRODUCTION OF THE 4 SOIL TYPES



Graph 6

legumes, and the alfalfa had a slightly higher weight product with these grasses.

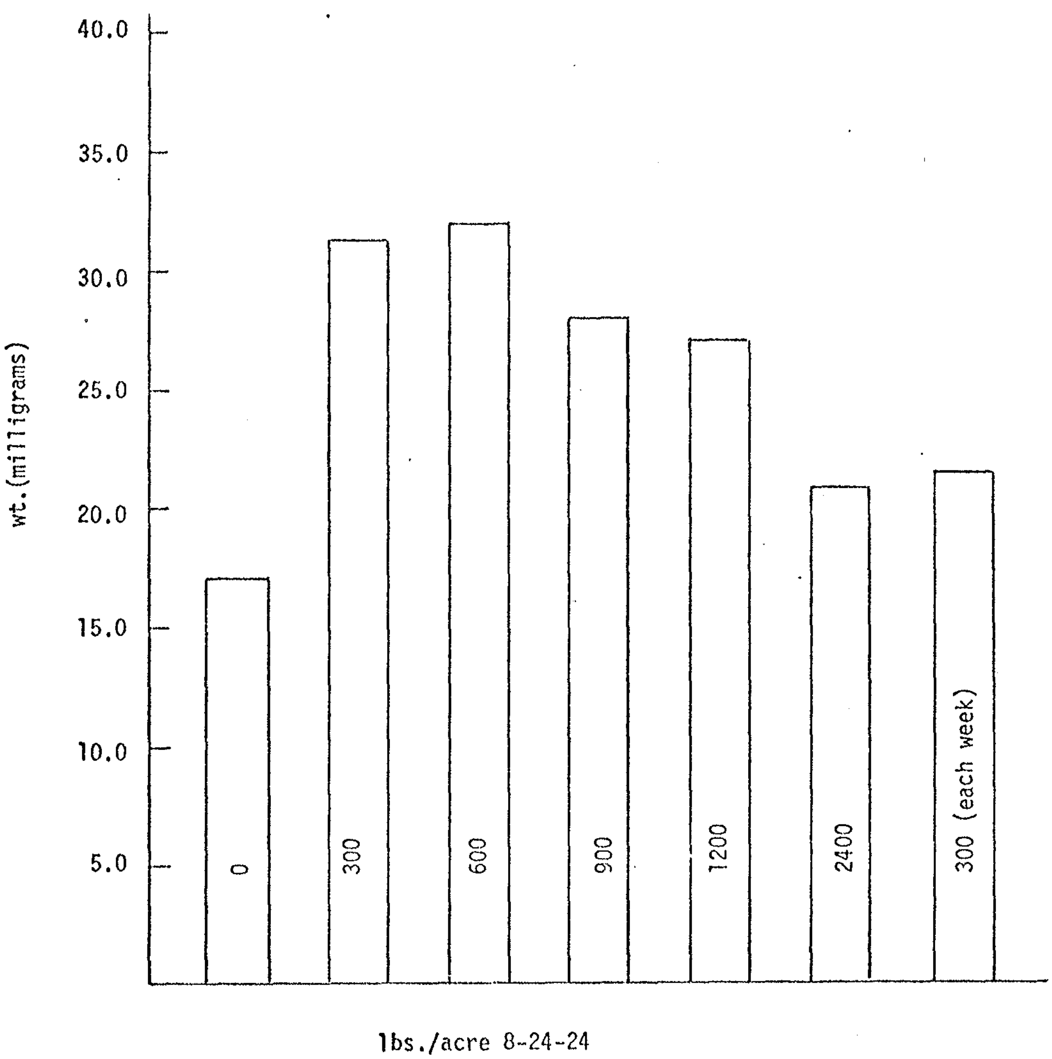
As shown in graph 6 the tailings sand had a better overall production than overburden for reasons explained in the previous experiment. Although the peat was again low in nutrients its water holding capacity greatly improved production of both soils.

It could be said that all the mixtures tried would do well in field plot studies but more work would have to be done on a long-term basis to determine if one species would dominate or completely overtake the others. A four-week experiment allows all plants to germinate but none to predominate or die-off.

(vi) EXPERIMENT #6

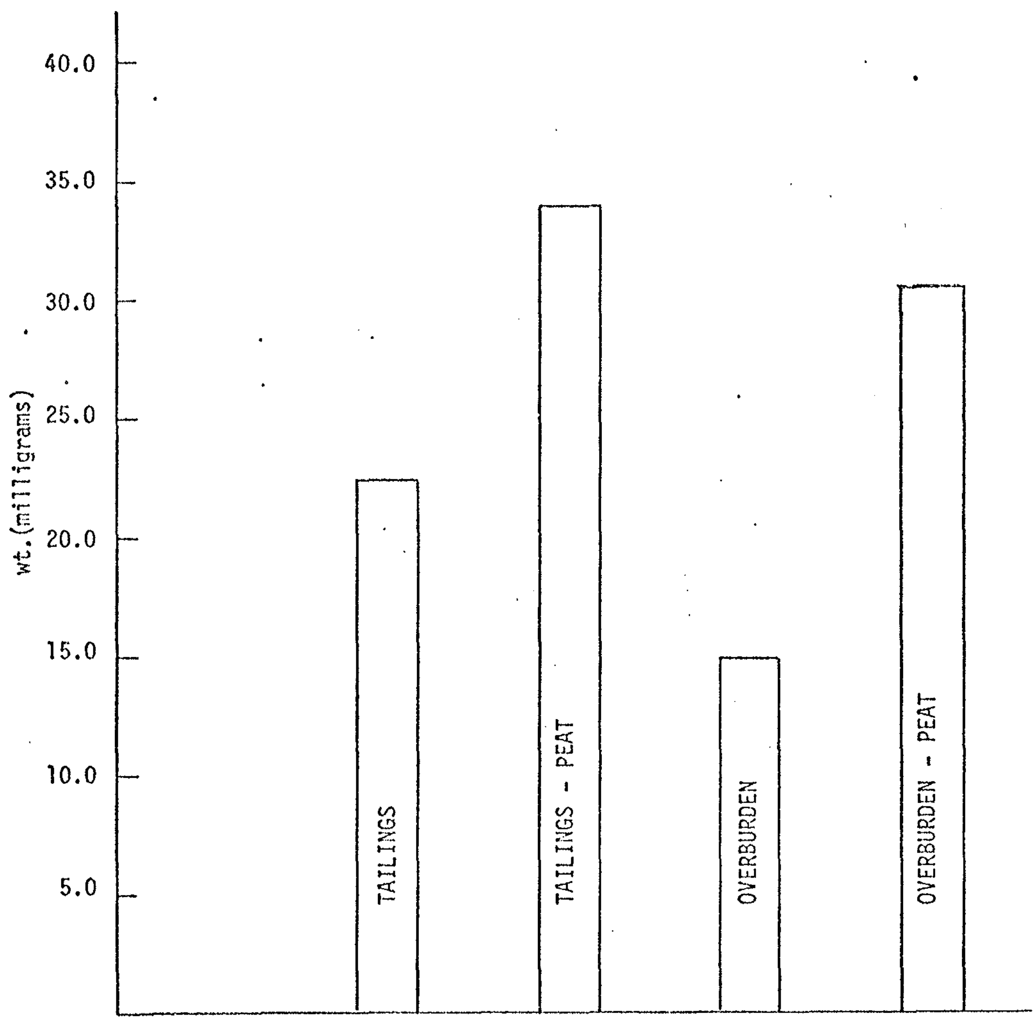
The best mixture from experiment #5 was chosen and used throughout this experiment to test varying fertilizer rates.

EXP #6 "FERTILIZER RATES"
AVERAGE DRY WEIGHT PRODUCTION OF ALL
SOILS VS FERTILIZER RATES



Graph 7

EXP #6 "FERTILIZER RATES"
DRY WEIGHT PRODUCTION OF THE 4 SOIL TYPES



Graph 8

The mixture was alfalfa, pubescent wheatgrass, creeping red fescue, and tall wheatgrass. The same four soils were used as in experiment #5.

Fertilizer was applied at varying rates to see if there was an optimum and if salt accumulation began. The fertilizer rates were: 0, 300, 600, 900, 1200, and 2400 lbs/acre of 8-24-24 and applied once at the time of seeding. One set of samples was fertilized with 300 lbs/acre each week (a total of 3 times). Each pot was duplicated.

The plants were watered every day and water kept in the tray to maintain a higher humidity. The average morning temperatures was 60^{o}F and 70% humidity; in the afternoon, temperature was 72^{o}F and 42% humidity.

At the end of 3½ weeks all plants were weighed and graphs charted. Graph 8 (Appendix B) is very similar to graph 6 (of experiment #5), showing the tailings sand to be more productive than overburden and the advantages of adding peat.

Graph 7 shows how production fell off after 600 lbs/acre were added. It would seem that addition of more than 300 to 600 lbs/acre for fertilizer would be wasted and of no value.

Although there was no noticeable salt accumulation in the pots of high fertilization, this many have contributed to the poor growth. It was surprising that the pots that were fertilized each week did so poorly as compared to the rates of 300, 600, and 900 lbs/acre. One explanation for this is that their location in the plantarium was slightly drier than the rest and it may have been enough to cause the lower productivity.

Fertilizer should definitely be applied but not at an excessive rate of over 600 lbs/acre. A longer term field plot study would check whether fertilizer is released to the plants over many weeks.

CONCLUSIONS

Experiments conducted in the growth chambers at the laboratory have given us some insight into future revegetation projects.

The stock-piling of muskeg to improve the soil in nutrient content would be a questionable practice as it was found to be low in nutrients. But, on the other hand, it has proved useful in improving water retention and lowering soil pH. This would be enough reason to have available good quality muskeg to later mix with sand and overburden. Good water retention is especially necessary for good germination.

As shown in the experiments, types and qualities of overburden are quite varied. In some cases overburden produced better plants than sand but the reverse was true in other cases. Since different areas exhibit different overburden, the steps to take in revegetation would be dependent on the area.

Good success was obtained with the utilization of legume innoculation. Plants that had been innoculated showed negligible wilt as compared to previous plants without innoculation. This step would be one of the most important in a revegetation program due to the importance of legumes in mixtures with grasses.

A variety of mixtures were tried and shown to be successful. As stated above, a long-term plot study will be the best way to determine which varieties would "co-operate" best with others. Seeding a mixture of varieties will be the best way to promote a permanent vegetative cover.

Tests to determine fertilizer rates were very difficult to simulate in growth chambers due to errors involved in applying fertilizer to very small amounts of soil. The experiments that were done showed no real advantage in micro-nutrient applications, at least at the rates used. Also, there seemed to be no advantage to fertilize at excessive rates and therefore risk salt accumulation. Fertilizer should be applied twice a year, rather than once and soils analysis done before and after to determine the effectiveness of doing this.

Some varieties of plants were found to be of low productivity in the growth chamber experiments and undoubtedly others will be eliminated in field plot studies. New varieties of plants are always being tested for hardiness in Northern Alberta zones and we should remain open to suggestions and possible improvements in our own revegetation program.

REVIEW OF DAMES & MOORE REPORT

The purpose of the Dames & Moore investigation was to: (1) assess the suitability of on-site soils as a growth medium, (2) identify vegetative types and the management practices that might be used to establish vegetation, and (3) recommend growth chamber and field plot investigations which would provide information that could be used to formulate revegetation programs.

Dr. Gerald Place, soil scientist with Dames & Moore, visited the plant site and collected tailings and overburden for chemical analysis by the Soils & Feed Testing Laboratory. In all samples nitrogen and phosphorous were low and potasium varied between low and medium. The pH of the abandoned tailings pond was mildly alkaline near the water's edge where grass was growing and medium to strongly acid in the areas devoid of grass. Overburden samples varied from being slightly acid to slightly alkaline (pH 6.0 to 7.5); salt level and sodium content were low in all samples.

He summarized that since there were no accumulations of salt or sodium, this would not limit plant growth because the alkalinity was not the result of sodium accumulations. Both materials, tailings and overburden, were infertile and would require large additions of nitrogen, phosphorous, and potasium to support plant growth.

Nine varieties of plants were outlined for us to use our growth chamber experiments as well as an outline for the four experiments discussed above. The experiments were followed through. A multi-year program for field plot experiments was also prepared.

Dr. Place also visited the plant site at G.C.O.S. to discuss their revegetation plots with Mr. C. B. Berry, Land Reclamation Supervisor. Two years of their program had been completed on seventy (70) acres. Mr. Berry found that it was too costly to irrigate on a large scale and that by using a Brillon seeder, which compacts the sand in conjunction with the seeding operation, a good stand of vegetation can be obtained without irrigation. He also found it best to fertilize twice during the growing season rather than only once and that aerial application would have to be used as the area increased. Ground driven equipment could not be used on slopes steeper than 3.5: 1 because the sand is not stable enough to support a vehicle when it travels down the slope and the traffic disturbs a great deal of vegetation.

Dr. Place made nine general recommendations for Syncrude to follow. They are:

(1) When the revegetation program is initiated at the site, an individual knowledgeable in seeding and growing plants should be assigned to the project on a full-time basis.

(2) It should not be necessary to stock-pile overburden for the purpose of incorporating it with tailings

sand to produce a good growth media. A proper seeding and fertilization program will be equally effective in providing a good vegetative cover.

(3) Reduce the dyke slope from 2:1 to at least 3.5:1. It will be difficult to establish vegetation on 2:1 slopes by means other than hydro-seeding. This method may not produce a satisfactory vegetative cover unless irrigation is used.

(4) Incorporation of clay and peat will improve the physical properties and increase the water-holding and nutrient retention capacities of the tailings sands. Even though these are desirable features they will not justify the additional expenses and time required for their implementation. This point, however, should be verified in the field plot research program.

(5) Plan to apply fertilization to the dykes by aerial applications. This method will not be necessary on the tailings sands, but it will be faster and easier.

(6) Use of irrigation should not be planned because it is too expensive to use on an area the size of Mining Area A, and vegetation can be established without it.

(7) Soil chemical stabilizers may be required to prevent wind erosion on the dykes and especially on the tailings during the first year when vegetation is being established.

(8) After vegetation has been established, the reclaimed areas should make a good habitat for game birds; hence, the feasibility of a stocking program should be investigated.

(9) A soil or plant scientist should be consulted at least once every year during the time the research program is being conducted. Assistance in interpreting the data and planning the following year's experiments will be required.

FUTURE RESEARCH PROGRAM

A responsible land use program will evolve over a period of many years and the research and development necessary for this should always be well-defined.

A summer employment program is now under way to collect native seeds and classify vegetation in many Alberta zones. Some students are stationed in the Fort McMurray area and through co-operation with Dr. Vaartnou, Head, Botany Section, Plant Industry Laboratory, Department of Agriculture, a program has been set up to provide Syncrude with valuable information on native plants. Under the direction of Dr. Vaartnou, the first year of a three-year program will involve testing these native seed types in overburden and sand. This will be done in cooperation with Syncrude personnel utilizing the growth chambers at the Alberta government's Longman Building.

Interpretation of these results will then lead to field plot work, preferably in Fort McMurray. Dames & Moore, in their report, outlined field plot experiments to investigate the following factors:

1. Seedbed mixture
    a. Tailings with and without muskeg
    b. Overburden with and without muskeg
2. Fertilization
    a. Optimum rate
    b. Application rate; single vs. split

3. Seeding method
    a. Brillon seeder
    b. Hydro-seeding
4. Seed mixtures
5. Fertility maintenance program

The experiments outlined by Dames & Moore should be carried out as well as any suggestions by Dr. Vaartnou.

Research into SO_2 effects on plant life can begin at any convenient time. Rather than transplant young trees or plants it would be best to build cabinets around established vegetation and then expose them to controlled amounts of SO_2-contaminated air. Temperature, humidity, and SO_2 levels should be continuously monitored. Free access of the plants to light would be provided by transparent plastic coverings. Of prime interest will be the identification of symptoms and diagnosis of injury to plants. After exposure to SO_2 the plants should be analyzed for sulfate content to determine their threshold limits.

Lichens are extremely sensitive to sulphurous pollution. They are most active under wet conditions, and since SO_2 is concentrated in rain water it can easily be accumulated in toxic amounts in the lichen. They are also, in contrast to higher plants, active during the winter when air pollution levels due to climatic conditions are high, and thus they can be used as indicators of air pollution during the whole year. At present, methods are being developed to measure the photosynthetic rates and changes in absorption and fluorescence spectra of lichens. The purpose is to be able to measure changes in lichens from polluted areas or in lichens transplanted to areas where air is suspended. Lichens can then be used for continuous, long-term registration of slight air pollution. (5.)

Research is always being done to develop better seeds and growing methods, and in the development and assessment of revegetation techniques to stabilize disturbed areas. Contact should frequently be made with these groups or government agencies so that we can remain open to their suggestions for improvements in our own revegetation program.

N.B. One of the last steps in the revegetation program will be one of reforestation. Once vegetation has been established to provide a good ground cover, trees and shrubs can then be planted. The potential of this altered landscape is then unlimited, providing numerous recreational uses, improving the physical appearance of the area, and maintaining our public responsibility by setting a good example that will be difficult to follow.

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APPENDIX A

Alberta Department of Agriculture

Soil & Feed Testing Laboratory

Guide to Interpretation of Soil Test Results

GUIDE TO INTERPRETATION OF SOIL TEST RESULTS

The following information on soil test levels should be used as a general guide and not for determining specific fertilizer rates. Other factors such as area (soil zone), crop to be grown, previous crops, soil texture, etc. are considered when making a recommendation. These soil tests and recommendations are based on a representative soil sample. Accurate crop and soil information and extensive field and laboratory investigations. The recommendations provide plant nutrient requirements and other cultural and management practices for efficient crop production. It should be realized by those using these recommendations that factors such as climate (amount and distribution of rainfall, temperature) soil management, variety, weed growth, insect damage, etc. can have a considerable bearing on the ultimate yield of crops. The nutrient recommendations given should provide near maximum returns per acre under favorable growing conditions. Nutrient recommendation for maximum yields would normally be higher than those given.

GENERAL RATINGS FOR MAJOR PLANT NUTRIENT TESTS (0-6" DEPTH)
(Range of Available Plant Nutrients in pounds per 2 million pounds)

RATING	NITROGEN	PHOSPHORUS	POTASSIUM	SULPHUR
Low	0-20	0-30	0-150	Deficient
Med	21-50	31-70	150-300	Marginal
High	51 or more	71 or more	301 or more	Adequate

NITROGEN

Soil nitrogen supply can be markedly affected by climatic conditions and past soil and crop management. Under favorable moisture and temperature conditions,

HIGH SOIL NITROGEN LEVELS WILL LIKELY OCCUR:

- on land that has been well fallowed
- where large quantities of manure or legume crops have been plowed down within two years of sampling

LOW SOIL NITROGEN LEVELS WILL LIKELY OCCUR:

- on poorly fallowed land supporting week and volunteer crops
- where previous crop growth was heavy
- on soils low in organic matter following recent breaking of sod and brush on soils that are cold or poorly drained

PHOSPHORUS (P)

Soil tests show that a majority of Alberta soils are low in available phosphorus. On deficient soils, crops respond profitably to phosphate fertilizer. A soil test for phosphorus is important in determining the most profitable rate of phosphate fertilizer to apply.

POTASSIUM (K)

Most Alberta soils contain adequate amounts of potassium. Soil tests for potassium show where this nutrient is required. Potassium deficiencies occur most frequently on peat soils or poorly drained (cold and wet) soils in the grey and black soil zones.

SULPHUR (S)

This test determines whether adequate amounts of sulphur are available for normal plant growth. Where the sulphur test is low a sulphur-containing fertilizer should be applied; where it is marginal, a field test using sulphur and nonsulphur fertilizer should be conducted. Crop response to sulphur can vary considerably, even within the same field.

SOIL REACTION (pH)

This test measures soil acidity or alkalinity. Most Alberta soils fall in the range of pH 5.5 to 7.5. The table below indicates ratings and the best pH levels for most crops.

pH VALUES

	50	55	60	65	70	75	80	85
very strongly acid	strongly acid	medium acid	slightly acid	neutral	neutral	mildly alkaline	moderately alkaline	strongly alkaline

Best range for most crops

SOIL SALINITY AND CONDUCTIVITY TEST

Conductivity is a measure of the total soluble salt concentration in a soil. Soluble salts are present in soils at all times however, when the concentration of salts is high, crop growth is reduced and the soil is considered "saline". Sulphates and sodium are determined to identify specific salts commonly causing salinity. The sulphate and sodium tests are rated in four categories: high (H), medium (M), low (L) and none (NIL). The degree within each category is indicated by a + or - sign. A high sodium test may indicate a solonetzic soil, which is characterized by poor physical structure which requires special management.

CONDUCTIVITY TEST

0-2 negligible salt effects
2-4 very sensitive crops affected
5-10 yield of most crops reduced
11-16 only tolerant crops satisfactory
16+ very high

ORGANIC MATTER & FREE LIME

These tests are estimates of the content in your soil. Results are rated into four categories: high (H), medium (M), low (L) or none (NIL). The degree within each category is indicated by a +or - sign. The organic matter test is an estimate of the humus content of the soil and does not include recent additions of straw, manure or sod.

Free lime is present in some soils and may reduce nutrient availability. Free lime cannot be readily removed from soil. The only practical way to counteract its effect is to increase soil organic matter content.

SOIL TEXTURE

This test is a manual estimate of texture which indicates the amount of sand, silt and clay in a soil. This is shown as six ratings: 1 - very coarse, 2 - coarse, 3 - medium, 4 - fine and 5 - very fine, 6 - organic (peaty). Texture affects moisture holding capacity of soil and therefore crop yield. Recommendations are adjusted to account for the effect of texture on crop production.

SECTION 4.

AIR QUALITY STUDIES

4. AIR QUALITY STUDIES

A. INTRODUCTION

The results of two studies are included in this section. They were made to determine the effect of plant variables and atmospheric conditions on sulphur dioxide ground level concentrations.

Included in the first study (Air Quality Study, March, 1973) are:

1. a brief analysis of meteorological data,
2. a number of matches of the plume survey conducted by the Department of Energy, Mines and Resources, Ottawa and others and
3. predictions of pollution levels attributed to the proposed Syncrude plant, the GCOS plant and five hypothetical plants in the general area.

In summary, neutral to slightly unstable conditions coincidental with a relatively high wind speed were observed to result in the highest pollution levels during the plume survey. Furthermore, these conditions were not an uncommon occurrence and when used in the prediction phase should give realistic sulphur dioxide ground level concentrations. Results from the first study also indicate that the proposed Syncrude plant will add less than 50% to the existing pollution level attributed to the GCOS plant and five plants of the Suncrude design could, on occasion, exceed the one hour ambient standard of 0.17 ppm.

Subsequent design optimization of the Suncrude facilities and utility plant provided additional input information. The second study (Air Quality Study, August, 1973) was made to reflect the updated emission information and, therefore, to confirm the adequacy of the design relative to air quality criteria.

Acquisition of baseline air quality information for the Lease 17 area is documented in Volume III, Baseline Information.

S E C T I O N 4.

AIR QUALITY STUDIES

B. AIR QUALITY STUDY, SYNCRUDE PLANT, FORT MCMURRAY AREA, MARCH, 1973

March, 1973

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Syncrude Canada Ltd. propose start-up of a 125,000 barrels per day synthetic crude oil plant in the general Fort McMurray area some time after 1976. Associated with the operations at this plant will be the emission of the combustion product sulphur dioxide adding to the current pollution level resulting from operations at the GCOS plant. Sulphur dioxide is a by-product of the sulphur recovery process, the steam generation process and the power plant if coke is utilized for fuel purposes.

Because of the potentially serious effects of a significant increase in the emission level, this air quality study was undertaken to evaluate the ground level concentrations of sulphur dioxide attributable to:

1. emissions from the Syncrude synthetic crude oil plant utilizing different fuel sources for the power plant,
2. the combined emissions from the Syncrude and GCOS plants, and
3. the combined emission of five synthetic crude oil plants of identical design as the Syncrude plant.

To properly access the pollution levels associated with each of the above cases, a model capable of representing the physics of the atmosphere and recognizing the influence of terrain should be utilized. A mathematical model, as opposed to a physical model, has the advantages of having no scaling problem and costing perhaps an order of magnitude less. Both types of models have the disadvantage that several assumptions must be made and certain atmospheric parameters must be estimated. Therefore, the models need to be calibrated by comparing predicted results with good quality measured data. Such measured data is presented in the plume survey conducted by the Department of Energy, Mines and Resources, Ottawa[1], et al.

Most mathematical models in use today stem from a point source solution to the classical dispersion equation, giving only approximate solutions to unusual atmospheric stability conditions and essentially ignoring the effects of uneven topography.

The model used for this study is a numerical solution of the three dimensional material balance for the entire air stream and for the pollutant flow within it. Wind flow over terrain is calculated by numerically solving a modified form of the three dimensional equation for velocity potential. The modification includes inviscid potential flow at high elevations and height dependent coefficients which account for surface friction in the boundary layer. The empirical modification allows the horizontal velocities to vary with height by the familiar logarithmic or power law formulations.

The pollutant material balance requires the solution of the three dimensional convection-diffusion partial differential equation. The eddy diffusivities can be space dependent. Experience with the model indicates variation of velocity and eddy diffusivity with height gives results in agreement with the Gaussian plume models of Sutton[2] and Pasquill[3] in the presence of flat terrain. However, applications involving terrain have indicated significantly different results from those obtained with plume models using the assumption of horizontal wind flow intersecting terrain.

The mathematical formulation and finite difference representations are developed in the Appendix.

METHOD OF APPROACH

The approach used in this study involved:

(1) analyzing meteorological data collected over a nine year period for the prevalence of various stability conditions with particular attention given to conditions existing during the period the Department of Energy, Mines and Resources were conducting the plume survey at the GCOS plant;

(2) analyzing and matching of measured plume profiles; and

(3) predicting pollution levels contributed by the Syncrude plant to the current level and by five plants having Syncrude's design.

Detailed discussions of each of these items are presented in this report.

For the sake of clarifying the calculation technique of the INTERCOMP environmental modelling system (EMS), the following qualitative description is presented. The study involved the use of three separate grid systems. These are schematically indicated in Figure 1. The first grid termed an "Elevation Grid" is prepared from a Department of Mines and Technical Survey contour map. An area surrounding the plant including all points of interest is digitized and then by interpolation the elevation at each intersection of a very fine two-dimensional grid is determined. This is pictorially indicated at the top left of Figure 1.

The second grid system termed the "Calculational Grid" represents the three-dimensional grid used for making the plume diffusion calculations. This is the step which represents the INTERCOMP modelling system. EMS calculates the concentrations for each block in the three-dimensional grid. Output from the diffusion model and the ground surface elevations are retained for each wind direction, wind speed and atmospheric stability for final processing.

This processing is done on the master grid illustrated at the bottom of Figure 1 where a two dimensional plot of ground level concentrations is prepared.

Each of the computations using the calculational grid and the master grid involve several steps which are described in the subsequent paragraphs:

(1) The user specifies the individual number of wind directions and wind speeds and atmospheric stabilities desired to be calculated,

(2) The diffusion model then utilizes the digitized contour elevations to determine for each wind direction the average terrain elevation for each downwind and crosswind grid block,

(3) The diffusion model, with the boundary conditions based on one of the specified wind directions and wind speeds, calculates the wind velocities for flow over or around the terrain for a selected atmospheric stability,

(4) The user specifies emission characteristics for each source and the model calculates plume rise by the Briggs[4] formula,

(5) The user specifies the diffusion coefficients consistent with the Pasquill-Gifford stability classes or based on history matching measured ground level concentrations.

(6) The diffusion model calculates concentrations in each of the three-dimensional grid blocks representing the plume dispersion due to the wind flow and turbulent diffusion, and

(7) The model plots the terrain description for a given wind direction, plots the ground concentrations for each wind speed and atmospheric stability and stores these for the later processing steps.

METEOROLOGY

At the time this study was undertaken only the results of the plume survey by the Department of Energy, Mines and Resources were available to validate the model for predicting ground level concentrations. The survey was conducted over a five day period October 4, 1971 to October 8, 1971, during which seven survey when measurements were taken. Of these, four were conducted while stable atmospheric conditions existed with the remainder of the observations taken during neutral stability.

Three plume measurements were selected to establish flow and eddy diffusivity coefficients for the Fort McMurray area. These measurements were conducted on the last two days of the survey period. On the morning of the first day, October 7, 1971, a radiative situation did not exist as the strong winds, which are associated with the backside of the low pressure area, would have dissipated any low level inversion prior to study time. The survey on October 8, 1971 from 0702 to 0845 MST was taken under moderately stable conditions consisting of an inversion in the boundary layer overlain by a neutral air layer. The fair skies throughout the night and the reduced wind speeds made for the radiative inversion observed. Similar conditions existed during the second survey taken on this day from 0941 to 1140 MST. However, some signs are evident that the inversion was breaking up as the temperature gradient was approaching an isothermal profile.

Reviewing the plume dispersion in light of the wind and temperature gradient, one can normally anticipate qualitatively the ground level concentrations. When neutral stratification exists with relatively high velocity winds as observed on October 7, 1971, the plume rise should be curtailed and convective currents should mix the pollutant to the ground yielding a high pollution level. Two possible explanations which could account for the exceptionally high plume rise coincidental with high ground level concentration is a lower wind velocity than measured, particularly at upper altitudes or errors in the measurement of the temperature gradient.

The plumes measured on October 8, 1971, were observed to rise through the stable boundary layer until buoyancy was lost at which point the plumes levelled off and blanketed most of the river valley. As expected the ground level concentrations measured were less than those of October 7, 1971.

From experience with meteorological conditions in other areas of Alberta and information presented in the literature, INTERCOMP is of the opinion fumigation would likely result in a higher instantaneous pollution level (i.e. less than 25%) than that recorded on October 7, 1971. Fumigation is of short duration and arises during the breakup of a temperature inversion. Inversions are recorded to occur in the Edmonton area 50 to 75 percent of the days and by inference occur in the Fort McMurray area with equal frequency. Unfortunately, none of the surveys were conducted during an inversion breakup. If a plume survey had been conducted shortly after 1200 MST on October 8, 1971, an excellent case of fumigation would probably have been recorded.

As mentioned earlier in this discussion, wind conditions influence atmospheric stability. Calm winds prevail near the surface during the inversion but after the inversion has broken they usually become stronger and the change with height is less pronounced. For a stable inversion, the wind varies as the 0.6 power of height and for neutral to unstable conditions the power dependence on height is 0.2 or less. Correlating wind speed with height in this manner has been utilized throughout the study.

MATCH OF MEASURED DATA

General Discussion

In order to validate the model in the area of interest under severe stability conditions, it would have been desirable to have had access to the continuous monitored ground level concentrations at the GCOS plant and the plume observations taken by the Department of Energy, Mines and Resources (EMR). These data would have complemented each other permitting the validation of the model during different seasons and stability conditions. Particularly of interest would have been those conditions observed to result in the highest level of pollution. Unfortunately only the plume survey was available at the time of this study, thus limiting the scope of the investigation to conditions coincidental with the plume survey.

Upon analyzing the surveys, it became evident that the meanderings of the plume as suggested by the measurements could not be matched exactly. These wanderings are believed to be attributable to slight variations in the wind direction or the drainage of upper cold air masses down adjoining river valleys into the Athabasca River valley. Without detailed meteorological data, the history matching of these peculiarities is not feasible. Instead, a decision was made to grossly match the plume surveys by attempting to approximate plume width, mid plume and ground level concentrations, and plume rise.

Before proceeding with the history match, a terrain map 36 miles by 36 miles was digitized and a data file prepared for input into the model. In this way various wind directions could be readily examined and any significant influence of the Athabasca River valley would be incorporated in the calculations.

Match of Conditions on October 8, 1971 - 0702 to 0845 MST

A moderately strong inversion existed at the time of the survey resulting in an extensive plume blanketing most of the river valley. The wind during the early morning hours of October 8, 1971 was from the south at speeds ranging from 3 to 20 mph in the boundary layer. This wind data was plotted against height on log - log paper, curve fitted with a straight line and utilized in the calculation to represent the wind distribution as a function of height. This same approach was employed in other matches.

During this particular survey SO_2 was being discharged from the 248 foot H_2S flare at a rate of 437 LTPD, and from the 348 foot power station flare at 82 LTPD. To encompass a sufficient area to accommodate the plume which had a maximum mid plume width of 11 miles and was sufficiently concentrated to give significant readings 24 miles downwind, a 15 x 17 areal grid was used. Grid blocks ranged from 2640 feet near the plant to 10,560 feet downwind from plant. The vertical grid system extended to a height of 3500 feet with the boundary layer in which the flow and eddy diffusivity constants were permitted to vary confined to the lower 1000 feet.

Figures 2 and 3 illustrate the history match obtained using a horizontal diffusivity of 10,000 feet^2/sec and a vertical diffusivity of 2.5 ft^2/sec. Concentrations in these figures are contoured for each concentration interval up to 1.0 ppm (see Table 1). As an example, the band of "threes" represent a range of concentrations from 0.25 to 0.30 ppm.

TABLE 1 - MAP LEGEND

Dependent Variable Range PPM of SO_2	Map Character
.0 - .05	
.05 - .10	1
.10 - .15	
.15 - .20	2
.20 - .25	
.25 - .30	3
.30 - .35	
.35 - .40	4
.40 - .45	
.45 - .50	5
.50 - .55	
.55 - .60	6
.60 - .65	
.65 - .70	7
.70 - .75	
.75 - .80	8
.80 - .85	
.85 - .90	9
.90 - .95	9
.95 -1.00	9

This legend applies to all history match calculations.

At the ground level the width of the plume was satisfactorily matched as indicated by the measured 0.1 ppm contour, but the 0.5 ppm contour was not. Only transverse B of the survey recorded a 0.5 ppm concentration at the ground level consequently the length of this contour is somewhat arbitrary and the departure is not considered critical to the uniqueness of the diffusivity coefficients. Generally the mid plume match is very good. However, some discrepancies were observed with the 0.5 ppm contour. As far as the plume rise is concerned, no calculated concentrations above 0.02 ppm were observed above 1100 feet which is generally in agreement with the observations of EMR.

Match of Conditions on October 8, 1971 - 0941 to 1140 MST

As indicated earlier, the 0941 to 1140 MST survey was taken during what appears to be initial stages of the inversion breakup. As in the earlier survey of this day, the plume blanketed most of the river valley and diffused to ground level within a mile downwind of the GCOS plant. The wind during the survey was from the south southeast at 8 to 20 mph in the boundary layer. The SO_2 emissions were 454 LTPD and 82 LTPD from the H_2S flare and the power station stacks, respectively. A grid system identical to that of the first history match was used.

The horizontal and vertical diffusivities eventually selected to provide the matches evident in Figures 4 and 5 were 20,000 ft^2/sec and 5 ft^2/sec, respectively. An increase in the horizontal diffusivity was necessary to help decrease the ground concentration to the level indicated by the plume survey. But generally the diffusivities are not significantly different from those used in the first history match. The significant difference of the two surveys is the temperature gradient effect on plume rise and its obvious influence on the ground level concentrations.

Match of Conditions on October 7, 1971 - 1102-1200 MST

An adiabatic temperature gradient existed while the October 7, 1971, survey was being conducted and the highest ground level concentrations measured during the survey period were recorded on this day. Unlike the previous surveys, the measured plume was comparatively narrow at slightly less than 2 miles wide and rose to a height approaching 4000 feet. No attempt was made to simulate the meandering noted in the horizontal and vertical directions.

The wind during the survey was recorded to blow out of the northwest at speeds ranging from 10 mph at ground level to over 40 mph at 2500 feet. The discharge of SO_2 during the survey was 509 LTPD from the H_2S flare and 82 LTPD from the power station flare stack. With the plume being narrower than previously observed, a 11 x 17 grid system was utilized. The vertical distance simulated in this case was 7000 feet.

In order to match the measured data as shown in Figures 6 and 7, the horizontal and vertical diffusivities chosen were 1000 and 500 sq.ft./sec. This narrowed the predicted plume considerably as desired and permitted the pollutants to distribute vertically as observed. Examining Figure 6 more closely, the 0.5 ppm ground level contour based solely on tranverse E was arbitrarily terminated. It may extend to the edge of the calculation grid as the predicted profile suggests giving a better match than indicated. Overall the areal distributions at mid plume and ground level appear satisfactory.

The predicted plume rose to 1400 feet in the vicinity of the stacks and levelled off at about 3300 feet some 11 miles downwind from the emission point upon losing its buoyancy effects. This performance is comparable to the sawtooth traverse measurements up the axis of the plume. The initial attempts to match the plume rise observed on October 7, 1971 were unsuccessful until the single wind profile measurement was adjusted. Without this alteration the diffusivity coefficients necessary to accommodate the plume rise gave ground level concentrations much too large.

Pasquill Calculations

A number of plume model calculations[5,6] utilizing the method of Pasquill were carried out for comparison purposes. The center-line ground level concentration results of these calculations are compared in Table 2 with those predicted by the numerical model and those inferred by the aerial plume surveys of October 7, 1971, and October 8, 1971. The plume model results for October 7, 1971, are within an order of magnitude of the observed pollution level suggesting the plume approaches a Gaussian distribution. However, this is not the case on October 8, 1971, when measurements were taken during a temperature inversion. For slightly stable conditions the plume model gives ground level concentrations 40 times too high some 3 miles downwind from the plant. Thus indicating the inadequacy of the plume model to handle atmospheric stabilities which can significantly influence the plume profile.

TABLE 2

Comparison of Numerical Model, Plume Model and Measured Plume Data

	Downwind Distance, ft. 100.	1320.	3960.	9240.	14520.	21120.	30360.	40920.
October 7, 1971 - Neutral Stability								
Elevation above stack base, ft.	0	-50.	-75	-75.	-50.	100.	250.	300.
	Concentrations, ppm							
Measured Plume Data	0.0	0.0	0.0	1.0	>1.0	1.0	>0.1	>0.1
Numerical Model	0.8	1.39	1.78	1.07	1.09	1.25	1.18	1.04
Pasquill Plume Model (horizontal wind)	0.0	0.01	2.85	2.10	1.18	.68	.36	.21
October 8, 1971 - Slightly stable (Inversion)								
Elevation above stack base, ft.	0.	-50.	-75.	-50	150.	190.	210.	240.
	Concentrations, ppm							
Measured Plume Data	0.0	0.0	0.0	>0.1	>0.1	>0.1	>0.1	>0.1
Numerical Model	0.08	0.09	0.10	0.09	0.09	0.09	0.10	0.12
Pasquill Plume Model (horizontal wind)	0.0	0.0	0.43	3.07	4.46	2.86	1.75	1.17

PREDICTIONS

General Discussion

Since it is desirable to calculate the highest ground level concentration to be expected when additional synthetic crude oil plants become operational, the flow and eddy diffusivity coefficients derived by history matching the plume survey of October 7, 1971, were selected for use in all predictions. A review of wind data collected at the Fort McMurray airport provided guidance as to the frequency of these conditions. Mean monthly wind speed frequency data for the period 1957 to 1966 shows 8 to 12 mph winds occur between 22 and 35 per cent of the time whereas winds in the 13 to 18 mph range occur between 6 and 10 per cent of the time. Unfortunately temperature gradient data associated with this wind data is not readily available. However, neutral to unstable conditions would be expected to coincide with the higher velocity wind range and for a significant part of the time that winds are recorded in the lower range. All predictions were made using an 8 mph wind.

Pollution Level due to Syncrude and GCOS Plants

Figure 8 indicates the maximum ground concentration due to SO_2 emissions of 280 LTPD from the Syncrude Plant will be 0.07 ppm some 9 miles downwind from the plant. This pollution level is approximately a 50 per cent increase over the levels caused by the GCOS plant during similar atmospheric stability conditions as illustrated on Figure 9. Emission levels from the GCOS plant for this prediction were 67.2 LTPD from the sulphur plant stack and 100 LTPD from the power station stack. This prediction assumes a northwest wind lines up the two plants giving a maximum ground level concentration some 3 miles downwind from the GCOS plant where the two plumes mix and diffuse to the ground. Concentrations in these figures and all others pertaining to the predictions unless indicated otherwise are normalized on 0.2 ppm instead of 1.0 ppm as before, so that the band of "threes" now represents 0.05 to 0.06 ppm.

Pollution Level due to Multiple Plants

The pollution level attributable to five hypothetical plants, each emitting 280 LTPD from a 600 foot stack is shown in Figure 10. A valley wind from the northwest is predicted to result in pollution level of 0.13 ppm. Figure 11 illustrates a more severe pollution level occurs when a northwest wind lines up the Syncrude, GCOS and Fina plants. Under these circumstances the maximum ground level concentration predicted is 0.21 ppm some 8 miles downwind from the Fina plant. The open 0.2 ppm contour suggests higher concentrations may occur further downwind and unfortunately the digitized topographical data does not permit validation or disapproval of this. However, in view of the limited plume width, the ground concentration would not be expected to exceed 0.2 ppm significantly.

Sensitivity to Operational Changes

Figure 12 is a prediction of the pollution level due to the Syncrude plant emitting 280 LTPD from a 825 foot stack during inversion conditions. Concentrations in this figure are normalized on 0.0003 ppm so that the band of "threes" now represents .00007 to .00009 ppm. Utilizing diffusivities found representative of neutral stability with moderately high wind speeds, a maximum ground level concentration of 0.04 ppm was predicted for the Syncrude plant emitting 280 LTPD SO_2 from a stack 825 feet high as shown in Figure 13. Substituting a stack 1100 feet high to accommodate coke fired boilers, which increased the emission level to 428 LTPD, a maximum ground level concentration of 0.06 ppm some 16 miles downwind from the plant was predicted. Figure 14 depicts the results of this latter prediction.

Monitor Locations

This study shows the maximum SO_2 ground level concentration due to the Syncrude plant occurs about 8 to 9 miles downwind of the plant with an 8 mph wind blowing. In contrast GCOS plant, being located in the valley and having lower stacks, its maximum contribution to the overall pollution level will occur 3-4 miles downwind. Consequently the ideal monitor locations considering the direction of the prevailing winds is about 9 to 10 miles WNW of the proposed Syncrude plant site and 3 to 4 miles SE of the GCOS plant. This latter location is across the Athabasca River from the GCOS plant and should not be considered because of its remoteness until access to the area is convenient.

If and when a calm condition develops, the maximum concentration of SO_2 is likely to occur near the plant site. Therefore, a third station in or near the Syncrude plant yard is recommended.

CONCLUSIONS

Our environmental impact study of the Syncrude plant on air quality has resulted in the following conclusions:

1. Relatively high wind conditions can cause high ground level concentrations which are only slightly less than those expected during fumigation conditions.

2. The additive effect once the Syncrude plant comes onstream will not double ambient concentrations. Depending on the stack specifications respecting emission level and height, the additional effect on maximum SO_2 concentrations appears to be less than 0.07 ppm.

3. To adequately assess the maximum concentrations during windy conditions monitors should be placed some 10 miles removed from the plant site in the west-northwest and southeast directions. Past experience suggests the ideal location to monitor pollution levels during calm conditions is near the plant site.

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F.I G U R E S

SCHEMATIC OF CALCULATIONAL APPROACH

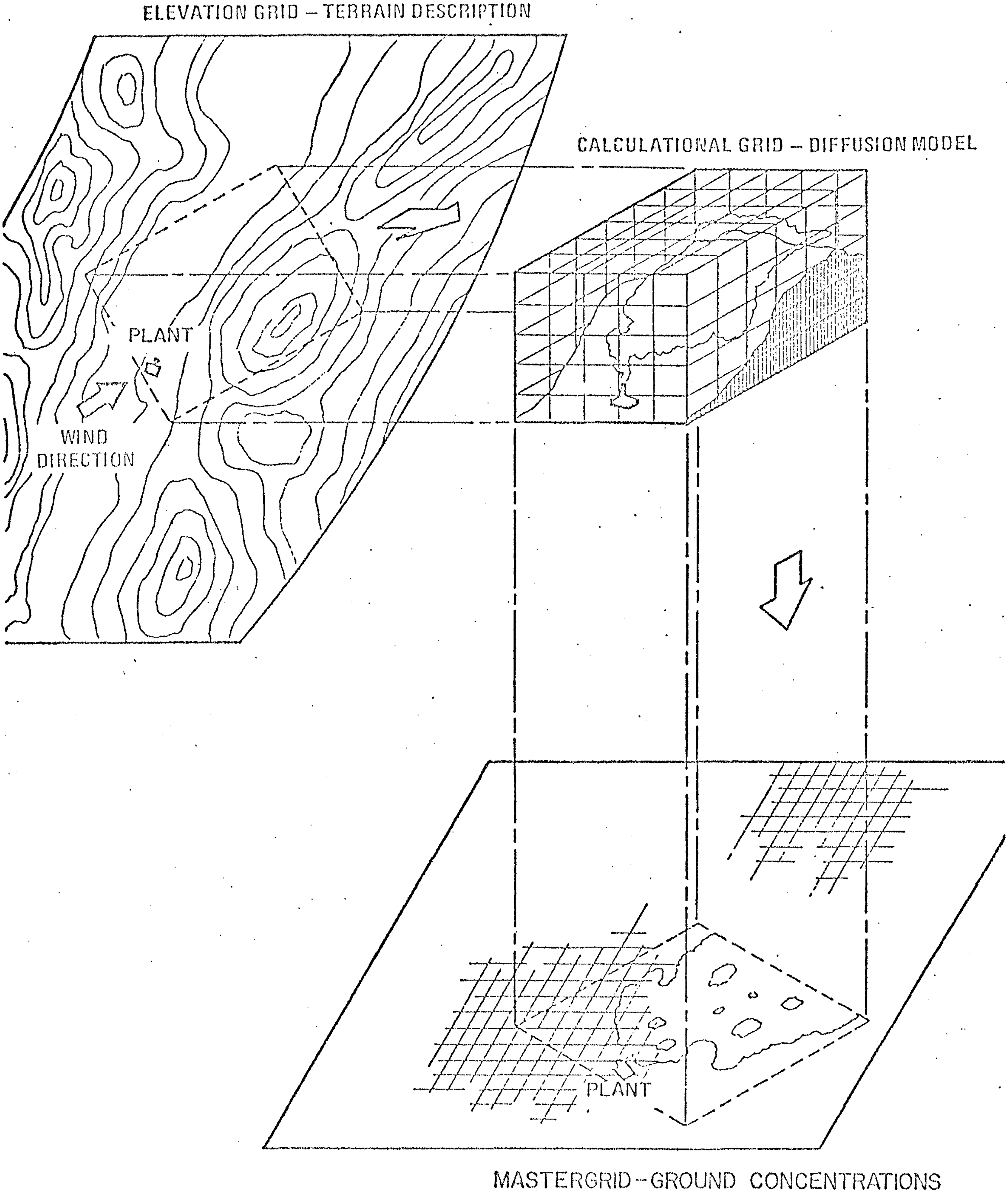

FIGURE 1

COMPARISON WITH EMR PLUME SURVEY

SO_2 GROUND LEVEL CONCENTRATION

OCTOBER 8, 1971

0702–0845 MST

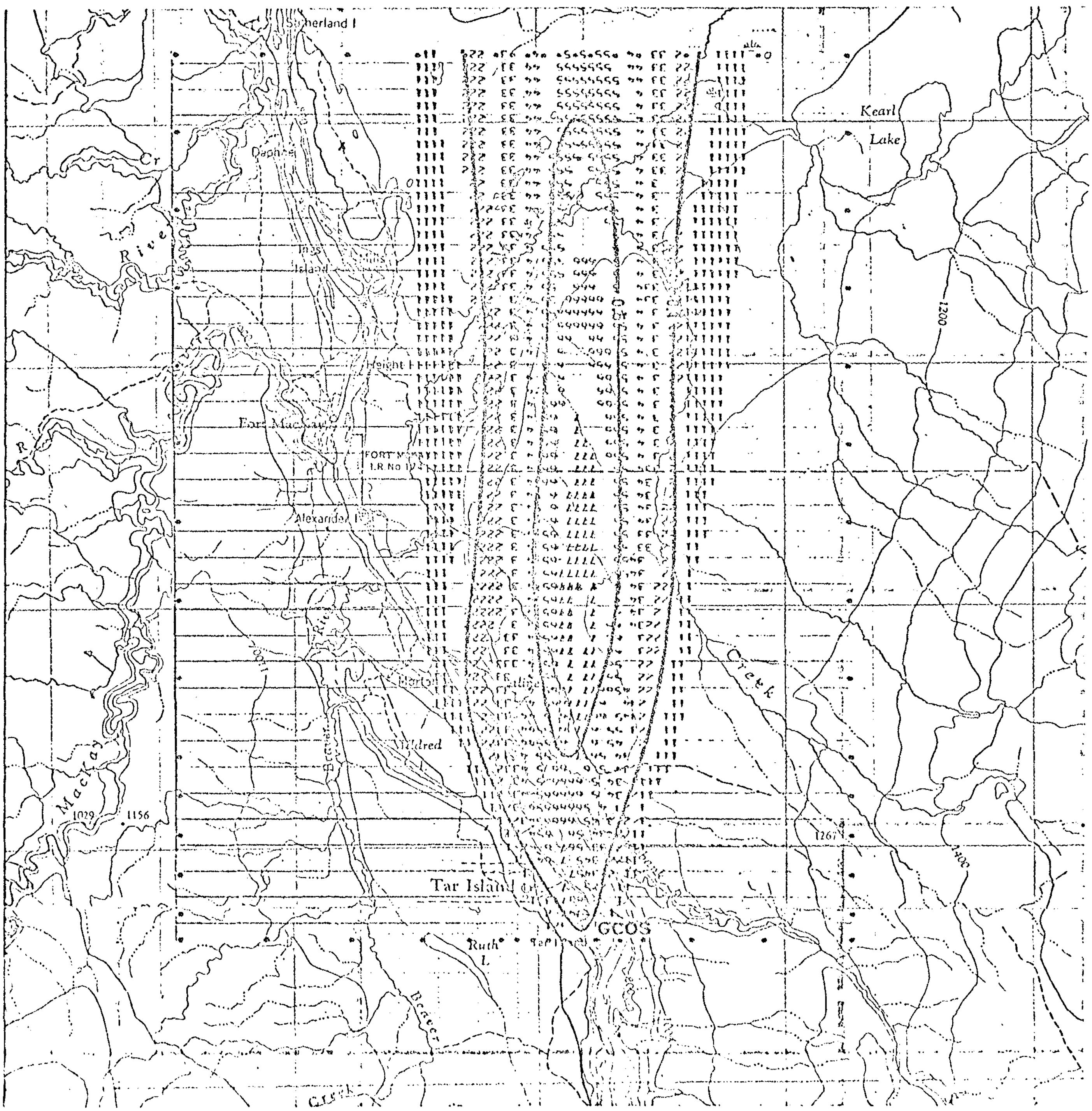

FIGURE 2

COMPARISON WITH EMR PLUME SURVEY

SO_2 MID PLUME CONCENTRATION

OCTOBER 8, 1971

0702–0845 MST

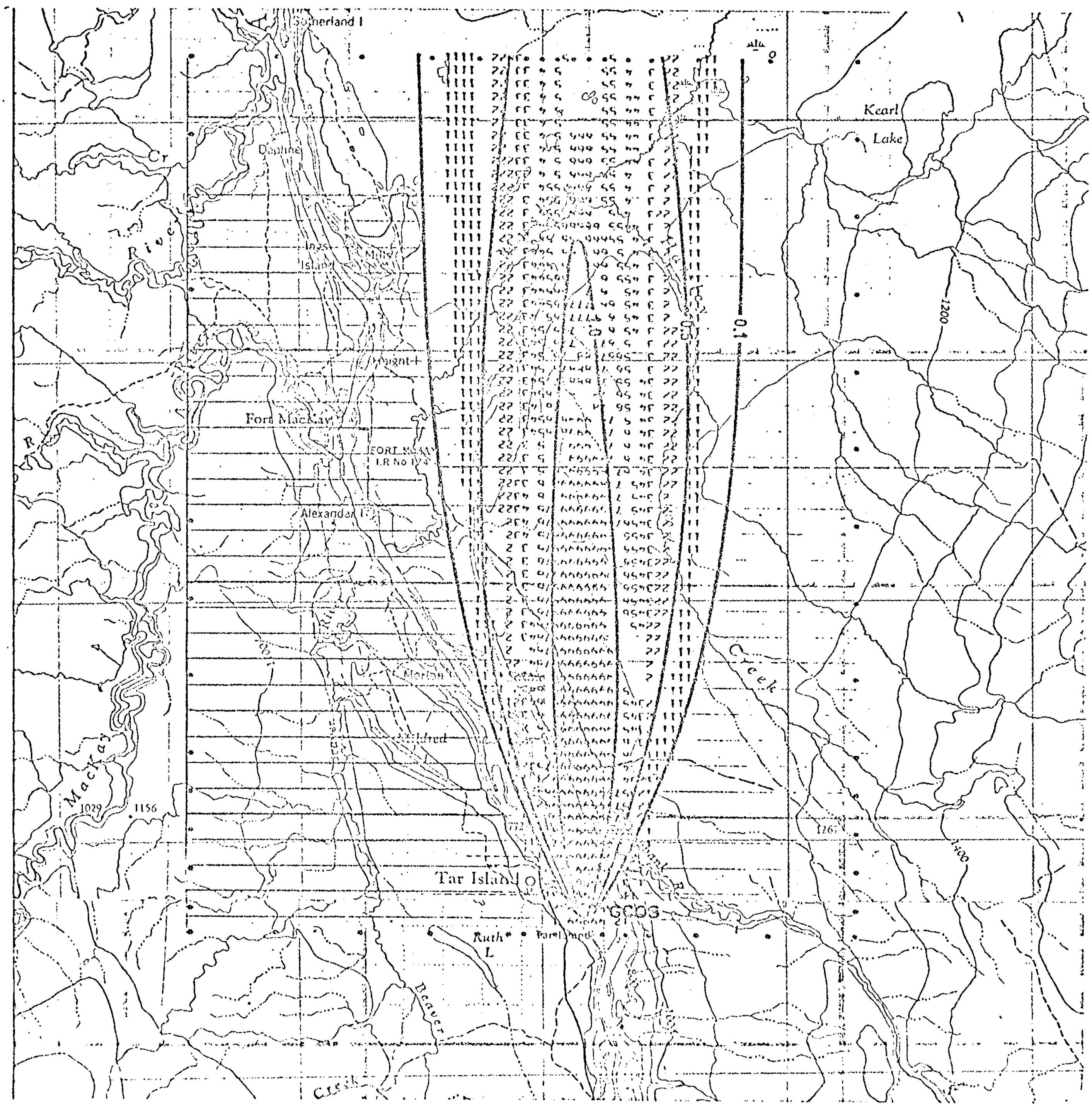

FIGURE 3

COMPARISON WITH EMR PLUME SURVEY

SO_2 GROUND LEVEL CONCENTRATION

OCTOBER 8, 1971

0941-1140 MST

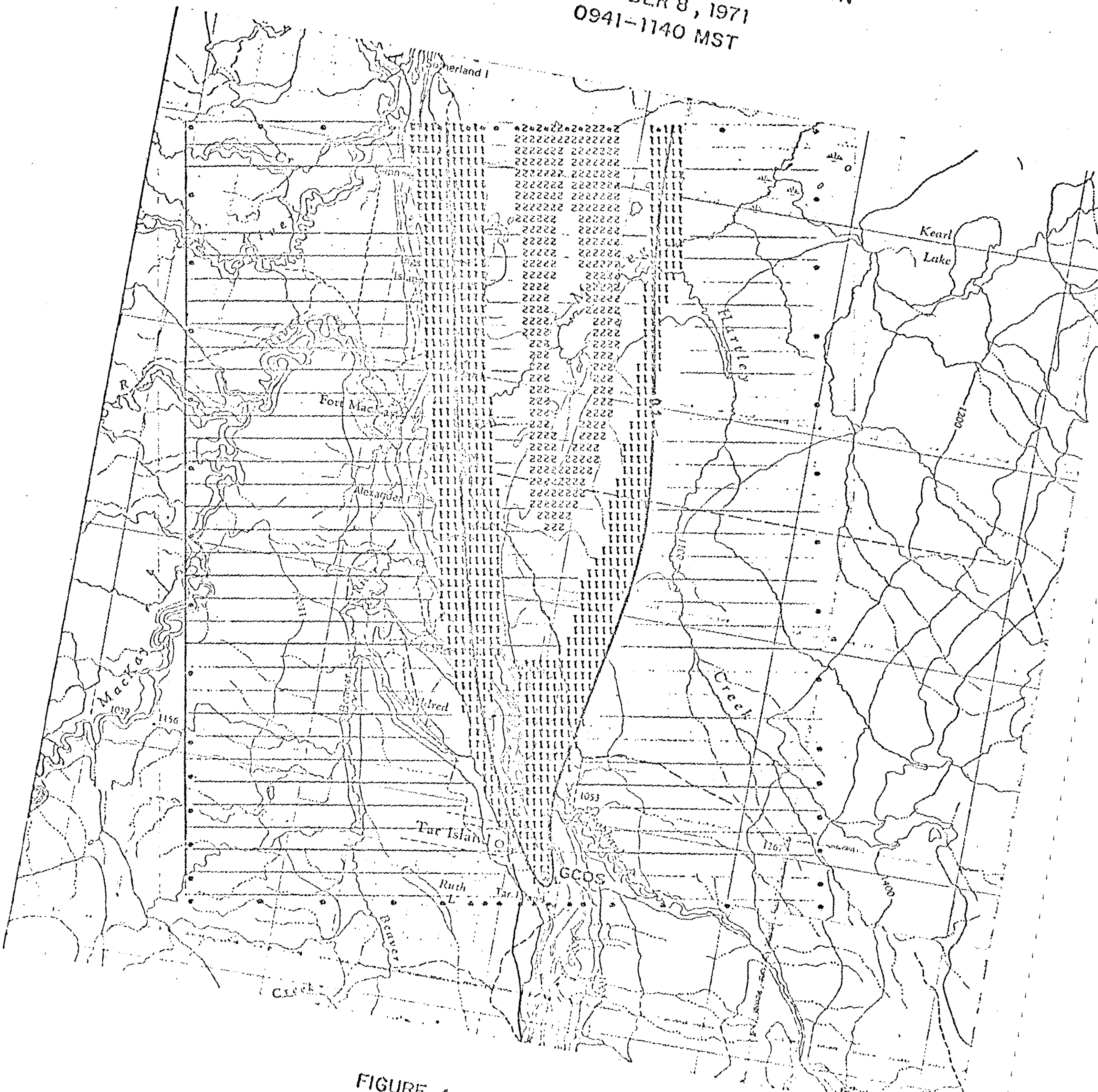

FIGURE 4

COMPARISON WITH EMR PLUME SURVEY

SO_2 MID PLUME CONCENTRATION

OOCTOBER 8, 1971
0941-0845 MST

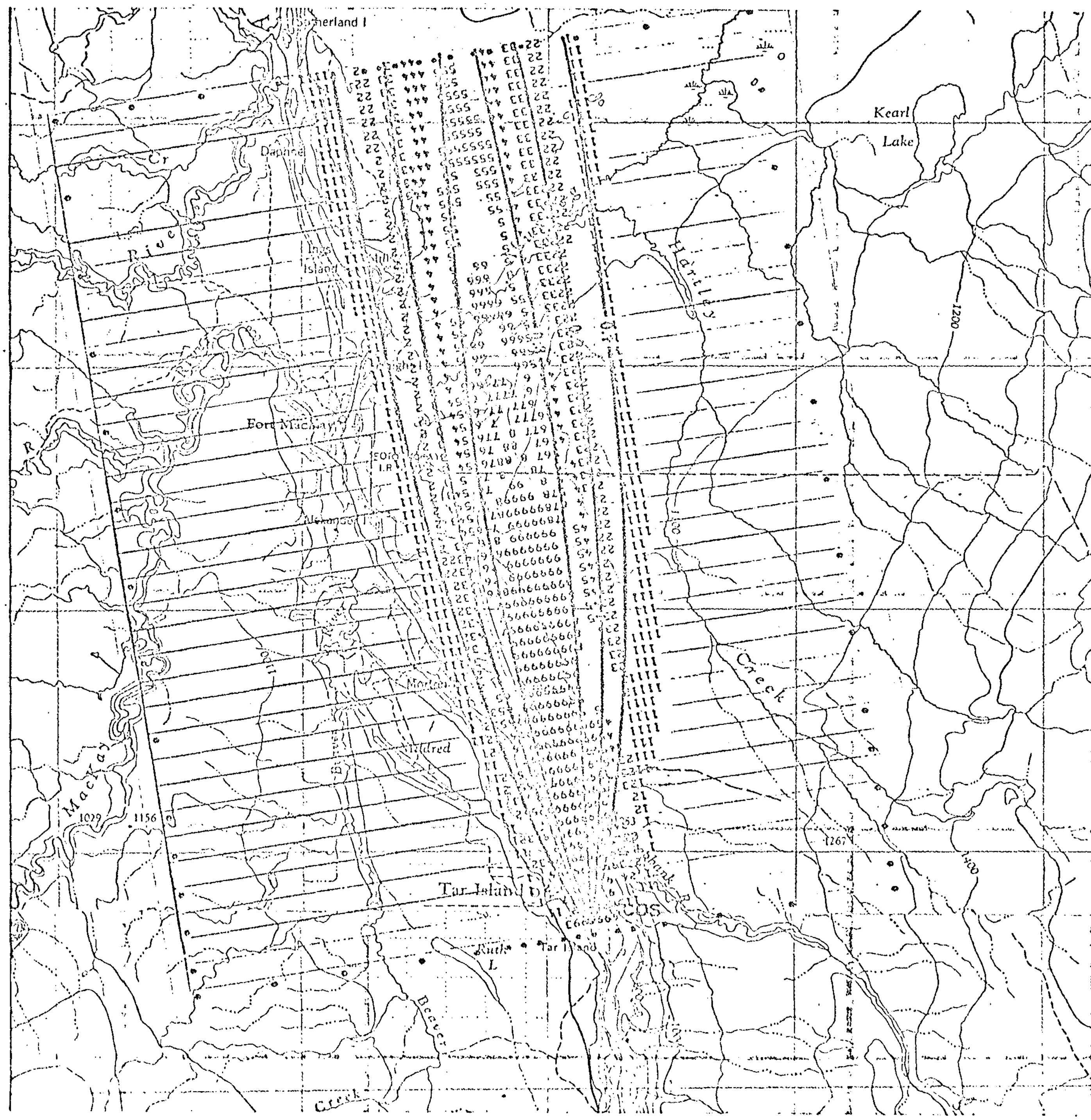

FIGURE 5

COMPARISON WITH EMR PLUME SURVEY

SO_2 GROUND LEVEL CONCENTRATION

OCTOBER 7, 1971
1102–1200 MST

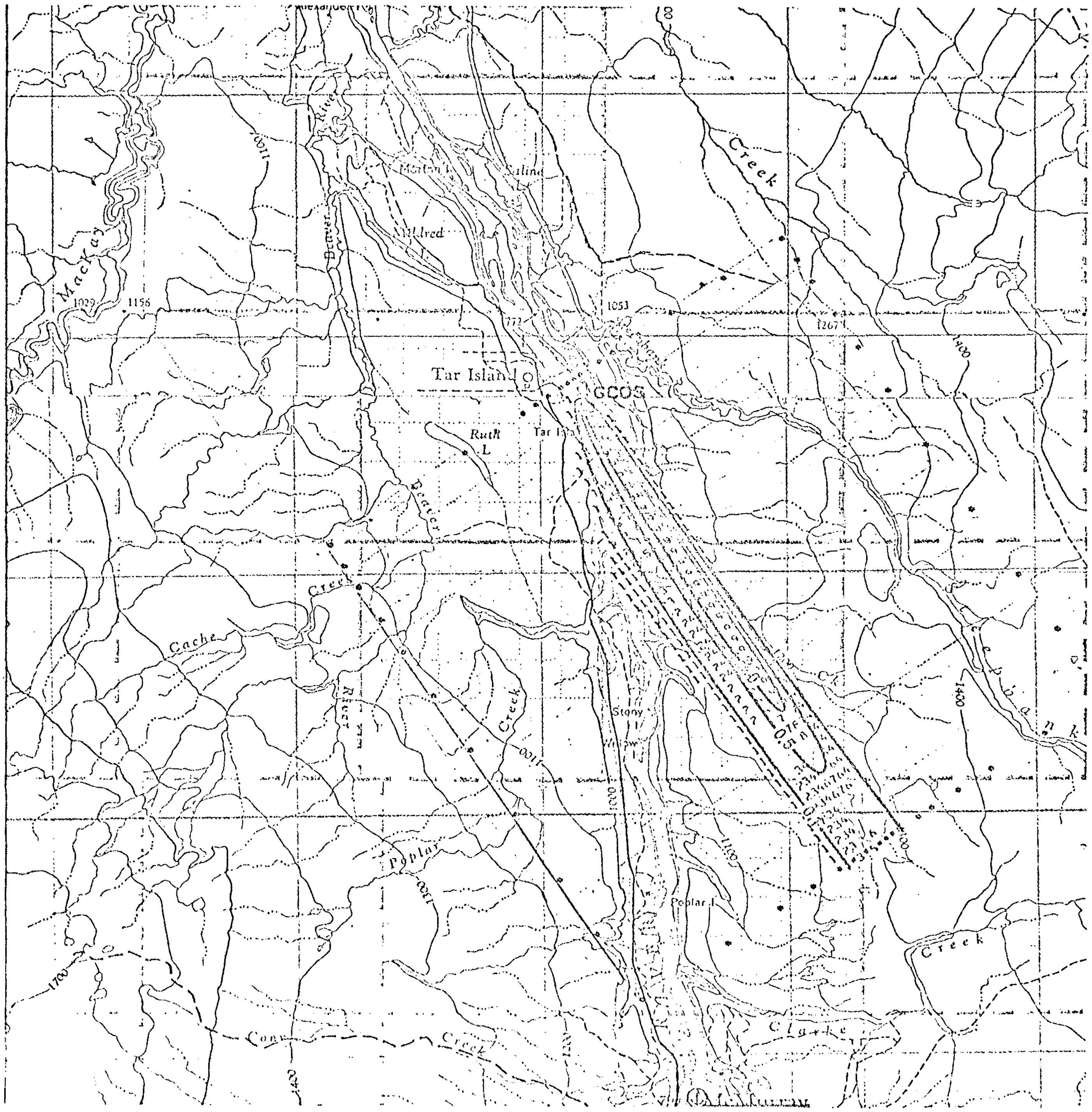

FIGURE 6

COMPARISON WITH EMR PLUME SURVEY

SO_2 MID PLUME CONCENTRATION

OCTOBER 7, 1971
1102-1200 MST

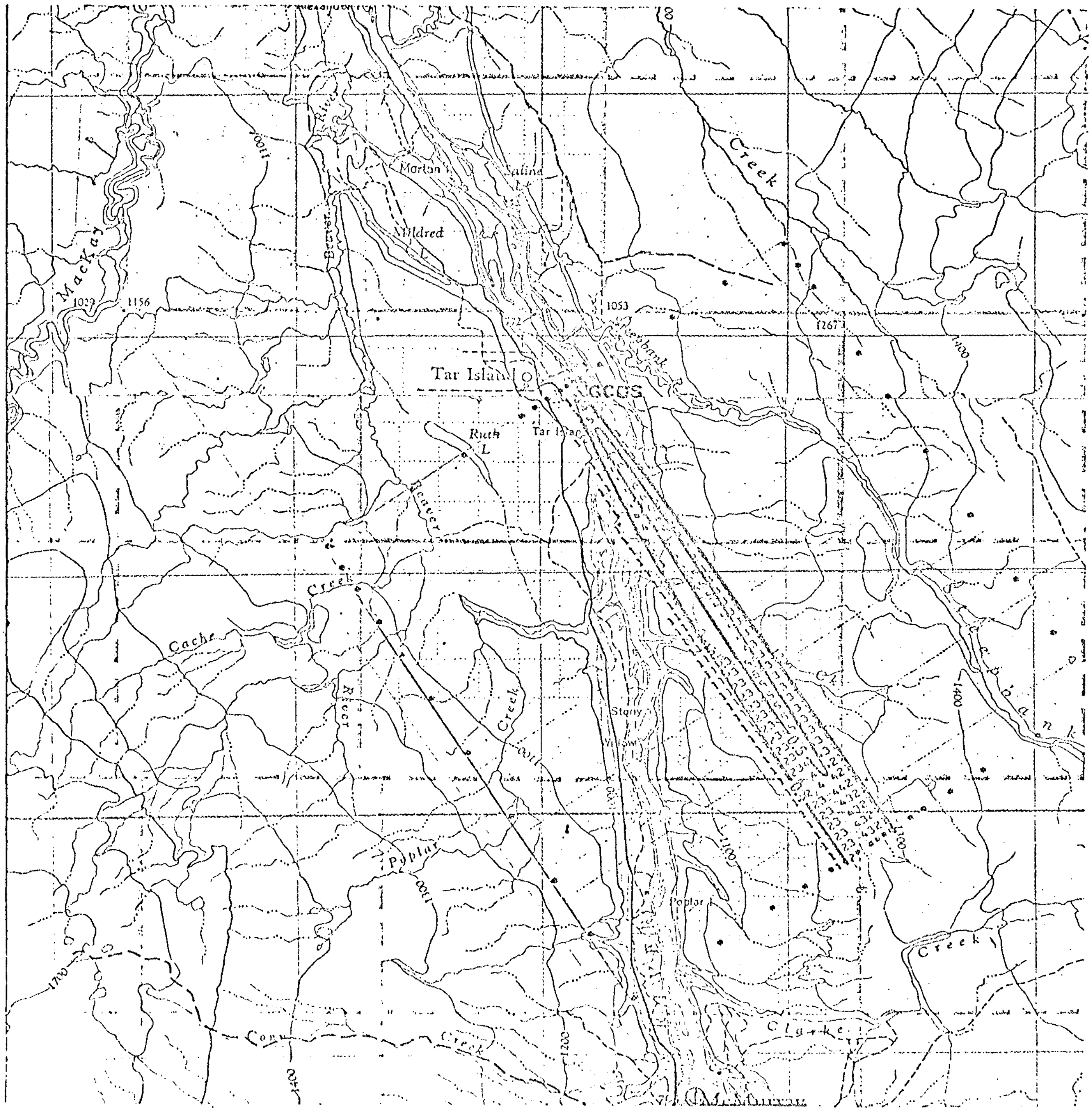

FIGURE 7

POLLUTION LEVEL DUE TO SYNCRUDE PLANT

WITH A 600 FT STACK

NEUTRAL CONDITIONS

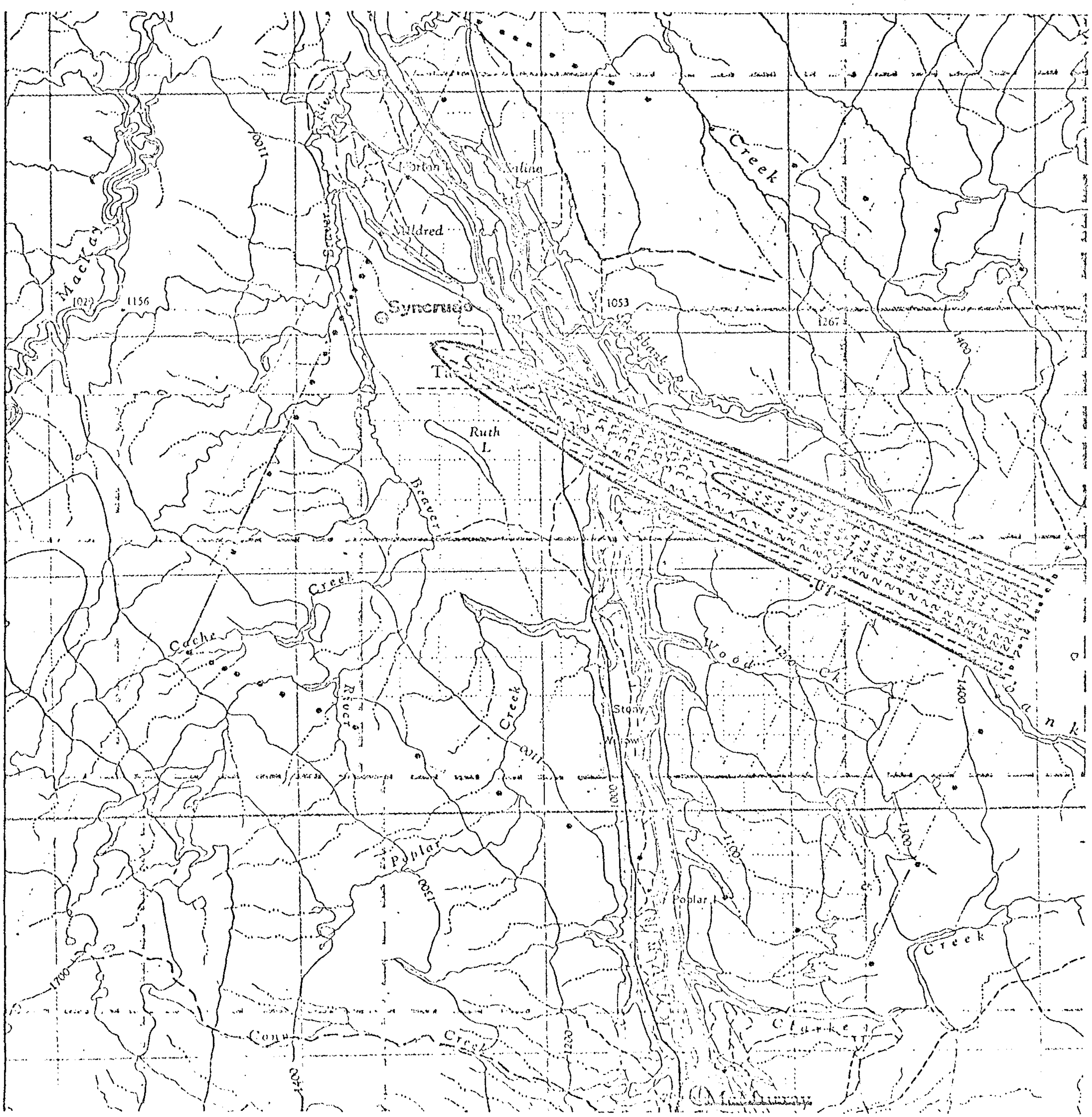

FIGURE 8

POLLUTION LEVEL DUE TO SYNCRUDE AND GCOS PLANTS

NEUTRAL CONDITIONS

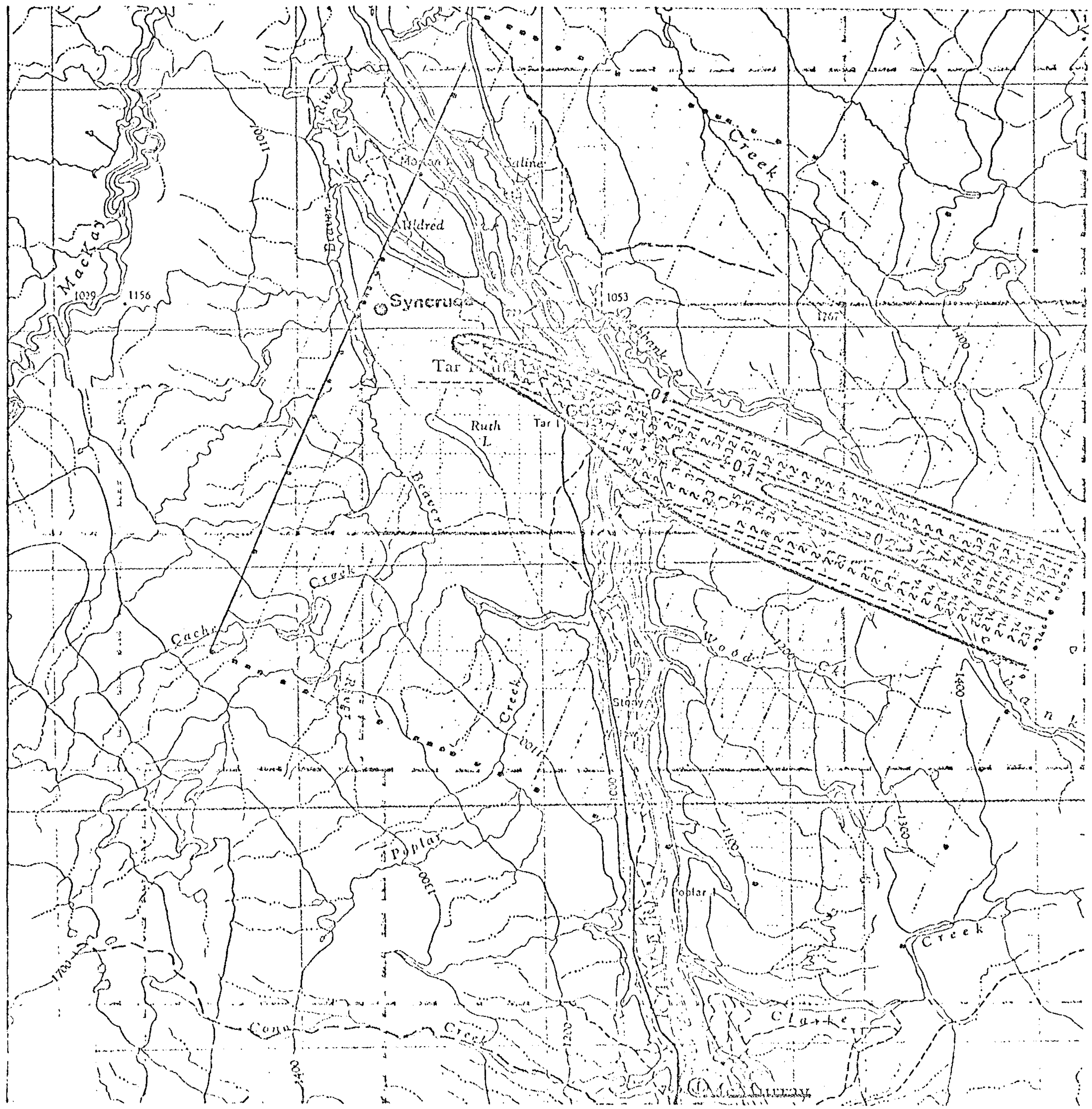

FIGURE 9

POLLUTION LEVEL DUE TO FIVE PLANTS

NEUTRAL CONDITIONS

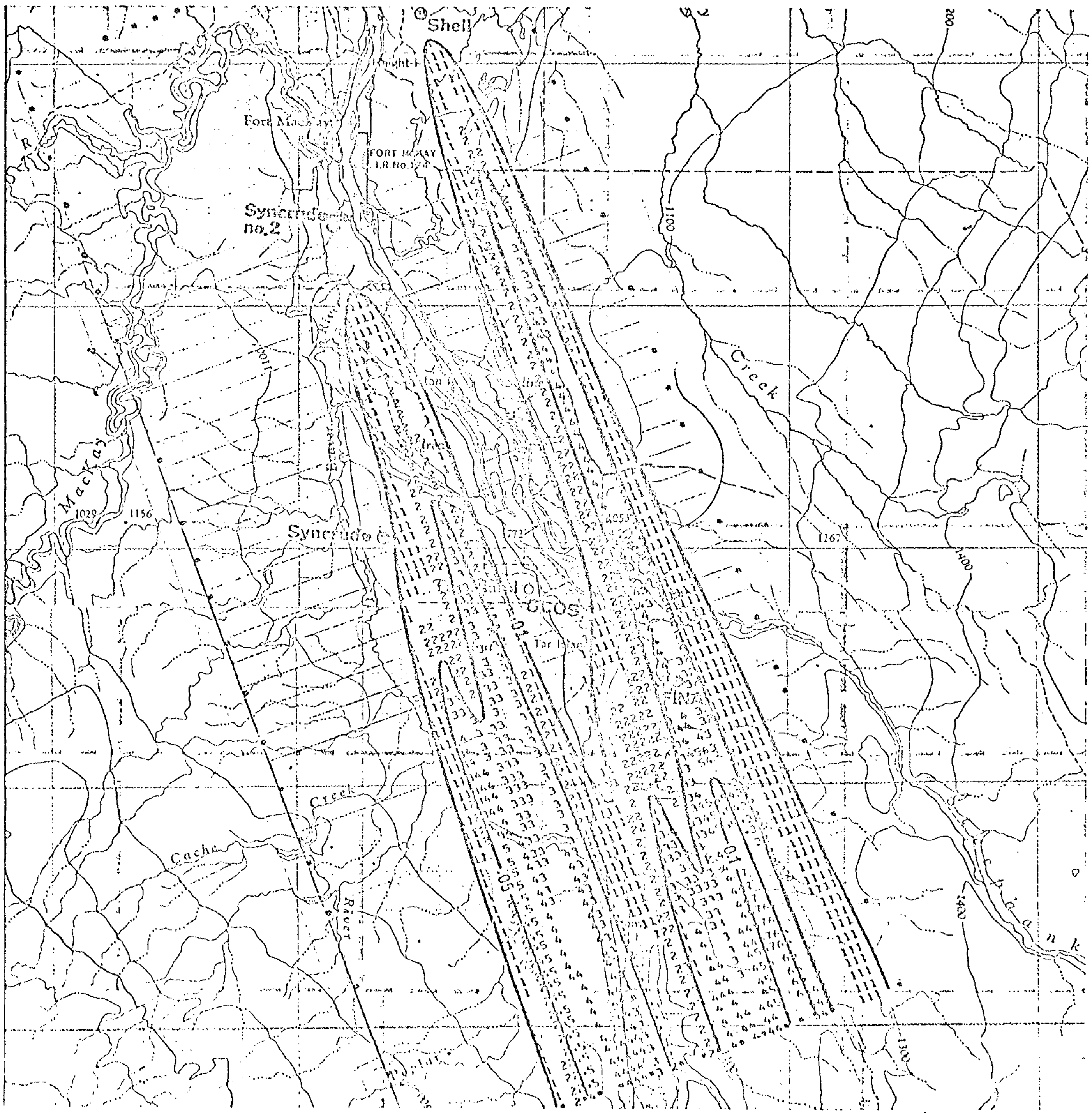

FIGURE 10

POLLUTION LEVEL DUE TO THREE PLANTS

ALIGNED BY A NW WIND

NEUTRAL CONDITIONS

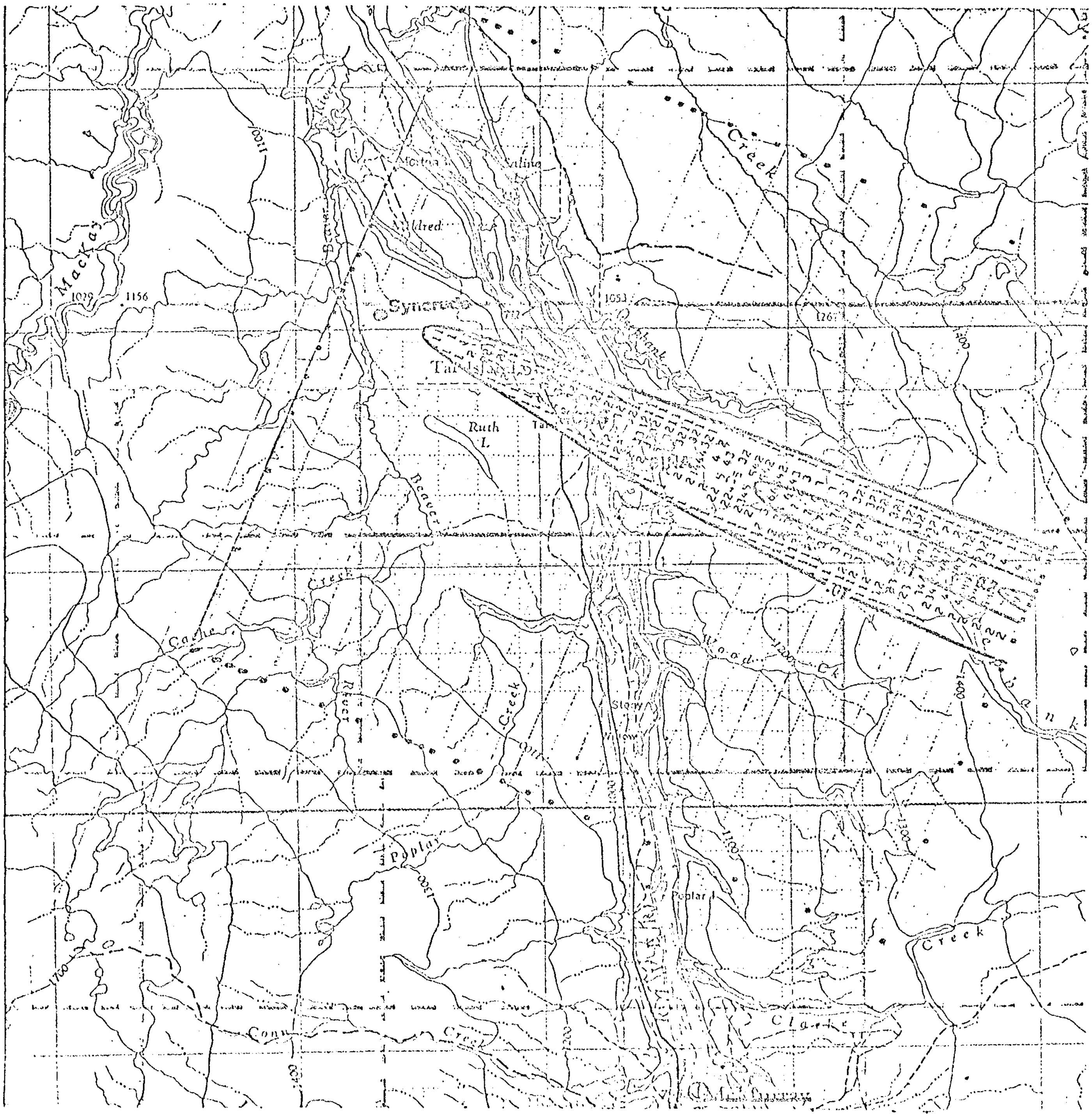

FIGURE 11

POLLUTION LEVEL DUE TO SYNCRUDE PLANT

WITH A 825 FT STACK

STABLE CONDITIONS

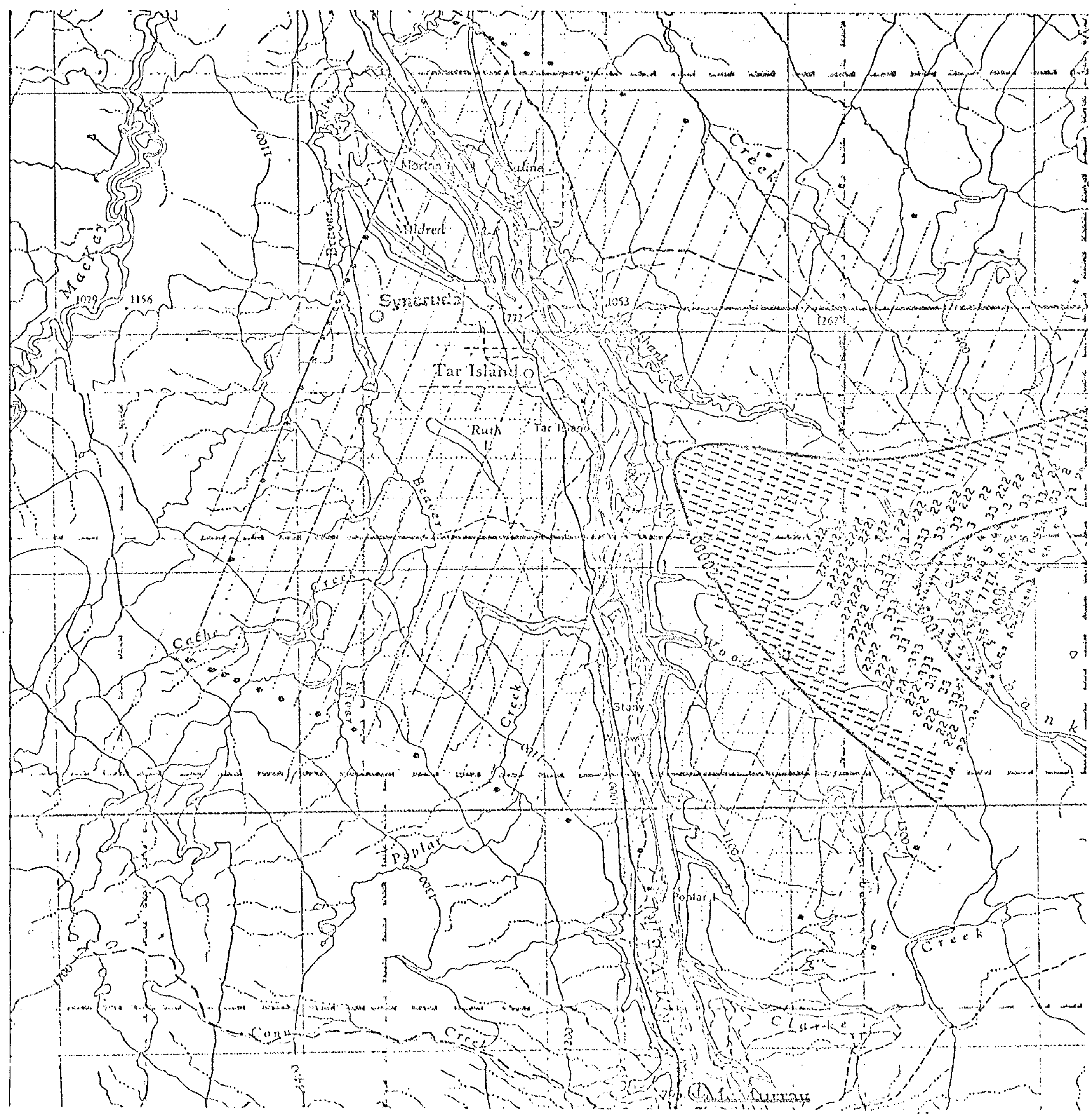

FIGURE 12

POLLUTION LEVEL DUE TO SYNCRUDE PLANT

WITH A 825 FT STACK

NEUTRAL CONDITIONS

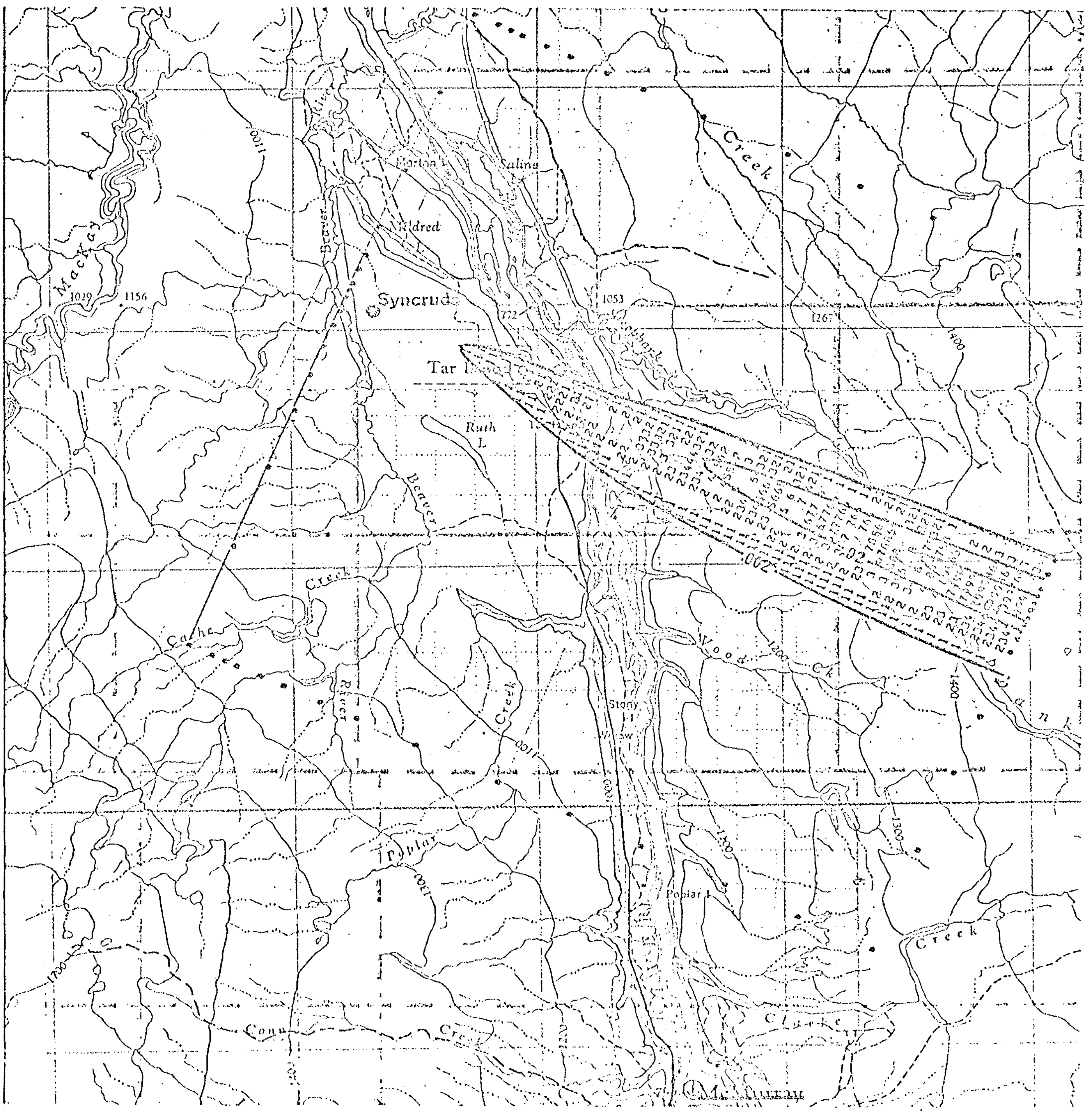

FIGURE 13

POLLUTION LEVEL DUE TO SYNCRUDE PLANT

WITH A 1100 FT STACK - COKE FIRED BOILER

NEUTRAL CONDITIONS

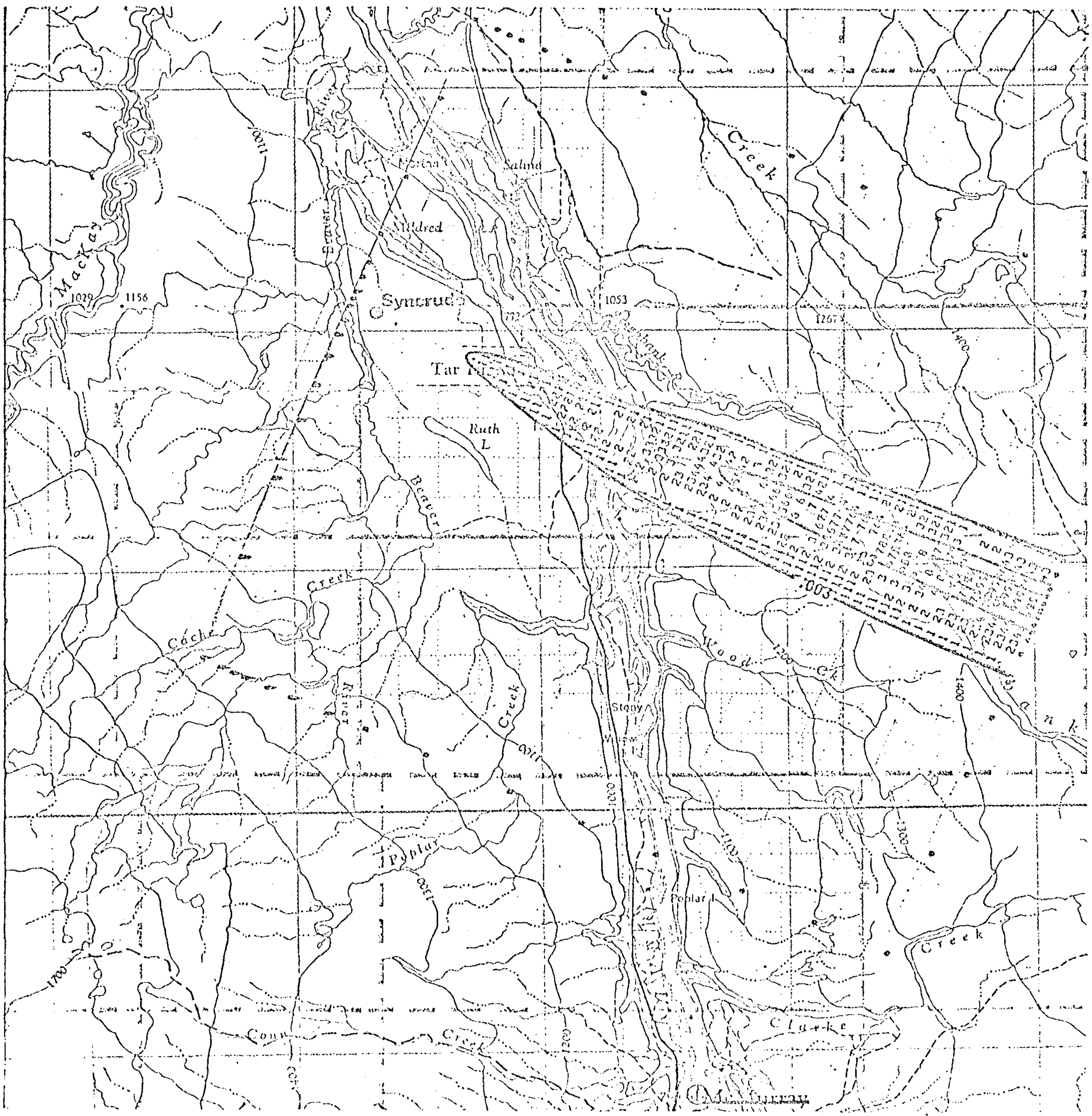

FIGURE 14

APPENDIX

APPENDIX

Wind Calculation Considering Topography

Material balance on the entire flowing air stream, assuming constant density, gives

$$\nabla \cdot \overline{U} = q \qquad (1)$$

where:

$\overline{U}$ = the time-averaged air velocity vector, consisting of components u, v and w in the x, y and z directions, respectively.

q = the source and sink volume rate per unit volume which will generate the desired wind distribution.

If a velocity potential defined by

$$\overline{U} = \nabla\phi \qquad (2)$$

is introduced into Equation (4), a form of Laplaces' equation is obtained:

$$\nabla^2\phi = q \qquad (3)$$

The assumption that the fluid motion is irrotational is contained in the definition of potential given by Equation (2). Solution of Equation (3) for boundary conditions of constant potential in the vertical direction and no terrain feature results in horizontal velocities which do not vary with height. However, near the surface, air viscosity becomes important and measurement of turbulence flow over a flat plate are found to give horizontal velocities which vary with height in a logarithmic or power law fashion. To account for this known behaviour, the definition of velocity potential in Equation (2) was modified to include a "flow coefficient", K, given by

$$\overline{U} = K\nabla\phi \qquad (4)$$

where K has components K_x, K_y and K_z.

As a consequence, over flat terrain, the horizontal velocities will have the same variation with height as do the corresponding flow coefficients in that direction. Over uneven terrain, vertical and crosswind flow will modify this power law or logarithmic variation. Additionally, these coefficients can be varied spatially to indicate different amounts of surface roughness. Substituting Equation (4) into Equation (1) gives

$$\nabla \cdot K\nabla\phi = q \qquad (5)$$

Solution of Equation (5) for the potential, ϕ, along with Equation (4) gives the three-dimensional velocity field $\overline{U}$. A variety of boundary conditions can be used for Equation (5). One possibility is that the wind is one-dimensional along the external boundaries. That is, u is specified and v and w are zero. The horizontal velocity at the boundary can, of course, be variable with height. Other boundary variations can be created with sources and sinks. No flow boundaries representing terrain are created by setting the appropriate flow coefficients to zero.

Formulation of the air flow in terms of a modified velocity potential represents a significant simplification of the real problem. Neglected in such an approach are such factors as (1) the change in wind direction with increasing elevation (Ekman spiral), (2) formation of eddies on the downwind side of obstacles to flow and (3) thermal or any density instability which can cause vortices in the flow.

The model for describing wind flow over irregular terrain features has been kept simple for two reasons. First, we did not want to consume a disproportionate share of computer time in solving the wind flow problem compared to that required for the turbulent diffusion solution. Second, the mathematical description of individual eddies downstream from obstacles in the flow is probably not essential to the pollutant dilution problem. In fact, refinement in the grid to adequately compute eddy formation will generally be impractical for realistic terrain problems. In a gross sense, the increased dispersion of pollutant due to eddy formation can be approximated by increasing the eddy diffusivity downstream of obstacles. In our model, we have made the diffusivities dependent on velocity, and thus an increase in diffusion occurs automatically as the flow progresses.

The finite difference representation used for Equation (5) was

$$\Delta(T\Delta\phi)_{ijk} = q_{ijk} \qquad (6)$$

where T is the transmissibility at any point, defined as follows:

$$\Delta(T\Delta\phi) = \Delta_x(T_x\Delta_x\phi) + \Delta_y(T_y\Delta_y\phi) + \Delta_z(T_z\Delta_z\phi)$$

$$\Delta_x(T_x\Delta_x\phi) = T_{i+\frac{1}{2}}(\phi_{i+1} - \phi_i)_{jk} - T_{i-\frac{1}{2}}(\phi_i - \phi_{i-1})_{jk}$$

$$T_{i+\frac{1}{2},\, jk} = (K_x\Delta y\Delta z/\Delta x)_{i+\frac{1}{2},\, jk}$$

Equation (6) is solved by one of two methods, depending on the boundary conditions. These methods are: (1) for constant potential in the vertical at the boundaries--line successive over-relaxation (LSOR) method; and (2) for no flow boundaries with internal sources and sinks--the strongly implicit procedure (SIP) of Stone[11].

Turbulent Diffusion

Material balance on the pollutant flowing in the air stream with velocity field, $\bar{U}$, defined in the previous section gives:

$$\nabla \cdot E\nabla C - \bar{U}\cdot\nabla C + r = \frac{\partial C}{\partial t} \quad q_s + q_a \tag{7}$$

where:

C = pollutant concentration, lbs pollutant/lb air

E = eddy diffusivity with components E_x, E_y and E_z in ft^2/sec.

r = rate of disappearance of pollutant due to reaction, lb pollutant/sec./lb air

q_s = pollutant source rate, lbs pollutant/sec./lbs air

q_a = pollutant ground adsorption rate, lbs pollutant/sec./lb air

t = time, sec.

The rate of disappearance of pollutant by chemical reaction, r, is assumed to be first-order and thus is proportional to the concentration. The pollutant source rate, q_s, is the pollutant mass source rate per unit volume of the total emission, divided by the air density. The ground adsorption rate, q_a, is the mass rate of pollutant absorbed (or adsorbed) at ground level per unit surface area multiplied by the specific surface of the ground and divided by the air density.

Equation (7) can be solved once the velocity field, $\bar{U}$, and the boundary conditions are specified. Calculation of the velocity profile is discussed in the previous section. Boundary conditions for diffusion are that the flux normal to the ground surface and at the upper boundary is zero. This upper boundary can represent a temperature inversion if desired.

The finite-difference approximation used for Equation (7) is of the form:

$$(\Delta T \Delta C)_{ijk,n+1} - \Delta_y(v\Delta_y C)_{ijk,n+1} -$$

$$\Delta_z(w\Delta_z C)_{ijk,n+1} + V_{ijk}(q_{s,ijk} - \frac{\ln_2}{\tau} C_{ijk,n+1}) =$$

$$\Delta_x(uA_xC)_{ijk,n+1} + \frac{1}{\Delta t}(V_{ijk} + \frac{A_z\Delta C_s}{\rho\Delta C})$$

$$(C_{ijk,n+1} - C_{ijk,n}) \quad (8)$$

where:

$\Delta(T\Delta C) = \Delta_x(T_x\Delta_xC) + \Delta_y(T_y\Delta_yC) + \Delta_z(T_z\Delta_zC)$

A = cross-sectional area, ft^2

$\Delta_y(T_y\Delta_yC) = T_{ij+\frac{1}{2},k}(C_{i+1} - C_j)_{ik} - T_{ij-\frac{1}{2},k}(C_j - C_{j-1})ik$

$T_{ij+\frac{1}{2},k} = (E_y\Delta x\Delta z/\Delta y)_{ij+\frac{1}{2},k}$

$\Delta_y(vA_yC) = (v\Delta x\Delta z)_{j+\frac{1}{2}}\{\alpha C_j + (1 - \alpha)C_{j+1}\}$

$(v\Delta x\Delta z)_{j-\frac{1}{2}}\{\alpha C_{j-1} + (1 - \alpha)C_j\}$

V_{ijk} = block volume $(\Delta x\Delta y\Delta z)_{ijk}$

$\frac{\Delta C_s}{\rho\Delta C}$ = slope of the adsorption isotherm, ft^3/ft^2

C_s = mass pollutant/unit area, lb/ft^2

ρ = air density, lb/ft^3

i, j, k = x, y, z indices

n = the time level index

$\Delta x, \Delta y, \Delta z, \Delta t$ = x, y, z and the time increments

τ = the reaction half-life

α = weighting parameter

The convection terms in each direction actually allow a variable space weighting scheme. The user can select among upstream weighting (if $v_{j+\frac{1}{2}}$ is negative, $\alpha = 0$), downstream weighting or equal weighting ($\alpha = 0.5$). The numerical procedure used to solve Equation (8) is the familiar alternating direction procedure (ADI) of Douglas-Rachford. If the primary wind direction is in the x-direction, the magnitude of the x-diffusion is unimportant. Note that, for these cases, a two-dimensional ADI procedure can be used because concentrations in each vertical plane are affected only by those upwind rather than by both upwind and downwind directions.

Because of the first-order derivatives in Equation (7), truncation error caused by the finite difference approximations both in space and time can be important. When the physical diffusion is small relative to convection, truncation error caused by the finite difference approximations both in space and time can be important. When the physical diffusion is small relative to convection, truncation error gives rise to a numerical diffusivity which can dominate the physical diffusivity. Generally, this happens in cases where the physical diffusion is molecular and consequently small rather than when turbulent diffusion is the predominant dispersive mechanism. Experience from comparison of the numerical model with analytical solutions indicates that truncation error will not be a significant limitation for the majority of the problems of interest.

SECTION 4.

AIR QUALITY STUDIES

C. AIR QUALITY STUDY, SYNCRUDE PLANT, AUGUST, 1973

August, 1973

AIR QUALITY STUDY - SYNCRUDE PLANT REVISED EMISSION LEVELS

INTRODUCTION

INTERCOMP was retained by Syncrude Canada Ltd. to predict SO_2 ground level concentrations attributable to operations at the Syncrude plant plus those due to combined emissions from plants in the area. These predictions, reflecting updated emission levels are supplementary to those provided Syncrude in March, 1973 in a report entitled "An Air Quality Study, Syncrude Plant". The updated data used in this investigation are summarized in Table 1.

POLLUTION LEVEL DUE TO SYNCRUDE PLANT

In making the prediction for the Syncrude plant, neutral stability with an 8 mph wind directed at the most significant terrain was used. Weather data recorded at the Fort McMurray airport suggest these conditions are observed 27 per cent of the days. In addition to their common occurrence, these conditions were noted to result in the highest ground level concentrations (GLC) recorded during the EMR plume survey. Higher velocity winds (i.e. 15 mph), which arise less than 1 per cent of the days, result in equivalent GLC.

Two other atmospheric stabilities having about equivalent prevalence as those used in this study are neutral and stable conditions at wind speeds less than 5 mph. However, past predictions using these conditions resulted in GLC at least an order of magnitude less than those predicted here.

Figure 1 is a contour plot of one half hour concentrations using the previously discussed atmospheric stability and emission levels. A peak concentration of 0.08 ppm, as denoted by the "fours", occurs 14 to 15 miles downwind from the plant, some 7 miles east of the river. Concentrations indicated in all figures of this study are normalized on 0.2 ppm and correspond to those map characters listed in Table 2. For example, the band of "fours" represents a range of concentrations from 0.07 to 0.08 ppm.

Comparing this prediction with that of our earlier prediction indicates the increased effluent flow rate results in the plume being transported further downwind accompanied by an additional dispersion of some 0.01 ppm. The 0.07 ppm quoted in our earlier report should have been rounded to 0.08 which would have approached 0.09 if an equivalent exit temperature of 475^{o}F had been used. Pasquill predictions for identical conditions give a maximum GLC of 0.05 ppm some 30 miles downwind of the plant.

From this prediction we have made a number of significant observations. Firstly, the terrain in the area has limited influence on GLC attributable to Syncrude's operation. Predicted plume rise calculations for an effluent flow rate of 21,400 cubic feet per second range from 2,100 to 2,500 feet whereas the most significant terrain rises some 800 feet above the base of the stack 20 miles east of the plant. The comparable GLC predicted by the Pasquill technique confirms this observation. Normally when calculating pollution levels in the presence of terrain, even though it may be limited, the intersecting plume assumption used in the Pasquill technique gives the higher GLC. The fact that the INTERCOMP model predicted higher levels suggests the conditions matched on October 7, 1971, in arriving at diffusion coefficients are severe and could conceivably represent a limiting case. INTERCOMP is of the opinion, however, that a fumigation situation might exceed the pollution levels predicted here. However, without additional meteorological data revealing the duration and strength of inversions in the area, such a case can not be investigated.

Further to this discussion, INTERCOMP believes no further predictions to accommodate effluent modifications should be made until additional meteorological and monitored data is obtained. The predicted GLC can not be refined to the nearest 0.01 ppm on the basis of only the EMR plume survey.

POLLUTION LEVEL DUE TO SYNCRUDE AND GCOS PLANTS

The GCOS data used in these predictions are based on submissions to the ERCB Hearing to consider a production increase. At a production level of 45,000 BOPD, coke to fire the steam boilers was being consumed at a rate of 2,100 LTPD. If 21% of the coke is stockpiled at the increased production rate of 65,000 BOPD, the coke consumption is estimated to be some 2,870 LTPD. At a sulphur content of 5.75%, boiler house emissions should be in the order of 300 LTPD. In estimating the SO_2 emissions from the H_2S flare at the increased production rate, a 94% sulphur recovery factor was used corresponding to the minimum sulphur recovery efficiency guidelines set by the ERCB. These emission rates are substantially greater than those used previously for GCOS and consequently the predicted pollution level is considerably greater.

Figure 2 depicts GLC of SO_2 for the case of an 8 mph wind aligning the two plants. A maximum GLC of 0.41 ppm occurs immediately downwind of the GCOS plant. Syncrude is contributing some 0.04 ppm to the overall level at this location. If Fina were to locate a third plant in the area having Syncrude's design, the location and value of peak GLC would not be altered.

TABLE 1

Basic Stack Data

	Height (feet)	Diameter (feet)	Exit Temp. (^{o}F)	Exit Velocity (Ft/Sec)	Emission (LTPD SO_2)
SYNCRUDE					
Incinerator Stack	600	17	475	90	280
GCOS					
Power Station Stack	348	19.3	500	50	300
H_2S Flare Stack	248	1.5	1100	50	50

TABLE 2

SO_2 Concentration Corresponding to Map Characters

SO_2 Concentration, ppm	Map Character
0 .01	
.01 - .02	1
.02 - .03	
.03 - .04	2
.04 - .05	
.05 - .06	3
.06 - .07	
.07 - .08	4
.08 - .09	
.09 - .10	5
.10 - .11	
.11 - .12	6
.12 - .13	
.13 - .14	7
.14 - .15	
.15 - .16	8
.16 - .17	
.17 - .18	9
.18 - .19	9
.19 - .20	9

POLLUTION LEVEL DUE TO SYNCRUDE PLANT WITH 600 FT STACK

NEUTRAL CONDITIONS

REVISED EMISSION RATES

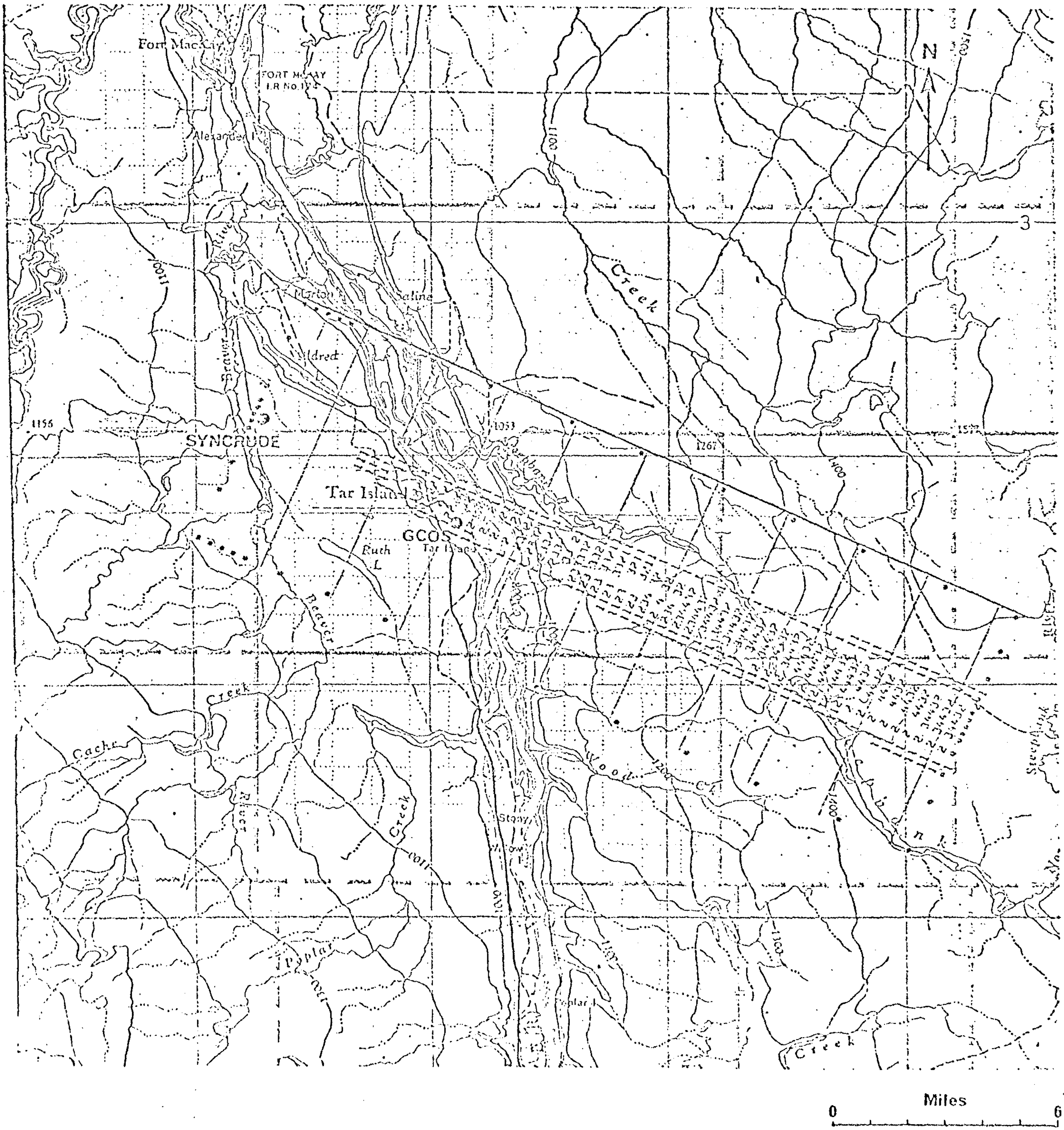

FIGURE 1

POLLUTION LEVEL DUE TO TWO PLANTS
ALIGNED BY A NW WIND

NEUTRAL CONDITIONS

REVISED EMISSION RATES

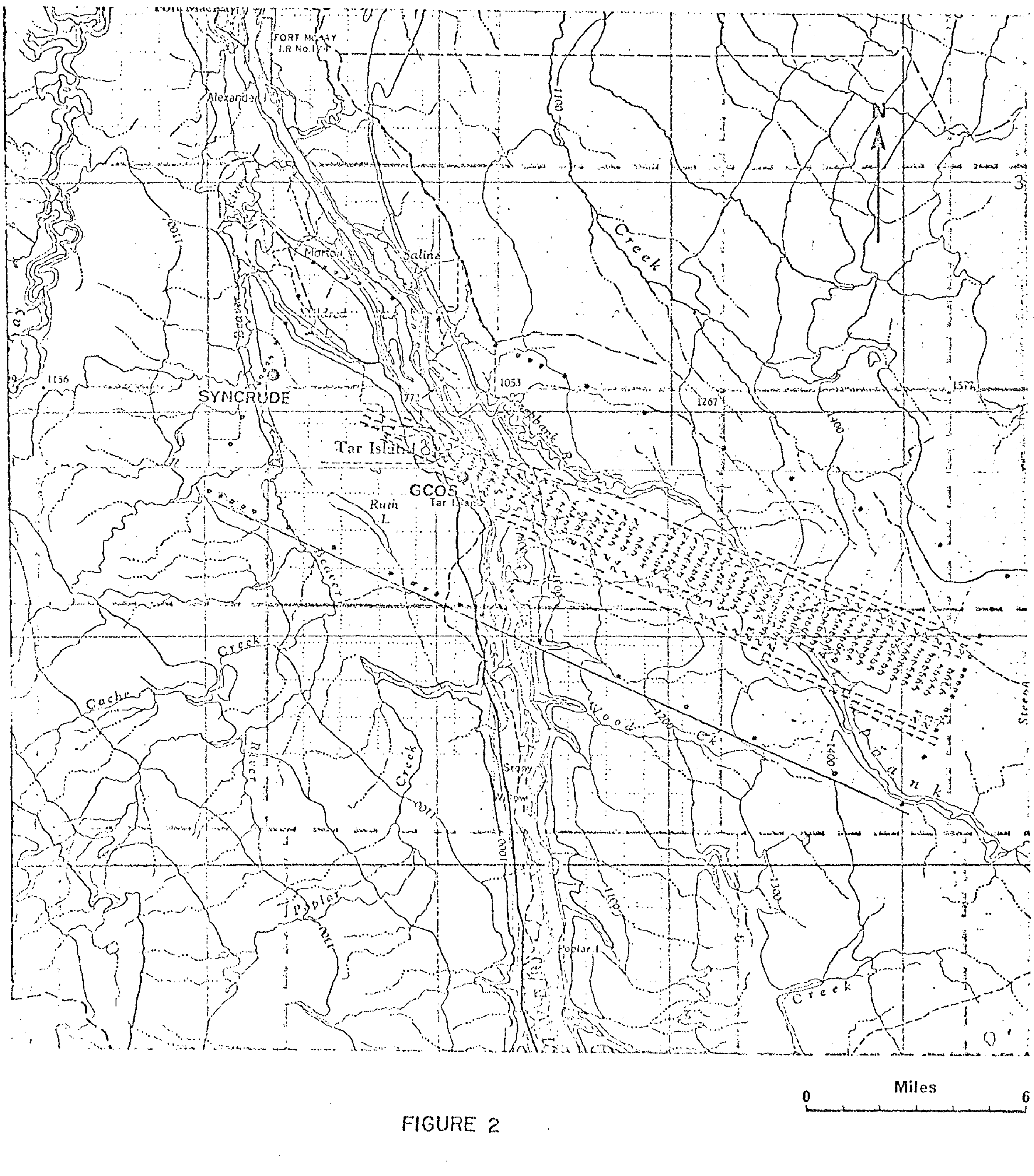

FIGURE 2