ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Acute Lethality of Mine Depressurization Water to Trout-Perch and Rainbow Trout Volume I

AF I.I.2

March 1979

Sponsored jointly by

Alberta Environment

Environment Canada

Environnement Canada

15th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta, Canada
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975 (amended September 1977). This 10-year program is designed to direct and co-ordinate research projects concerned with the environmental effects of development of the Athabasca Oil Sands in Alberta.

A list of research reports published to date is included at the end of this report.

Enquiries pertaining to the Canada-Alberta Agreement or other reports in the series should be directed to:

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Acute Lethality of Mine Depressurization Water
to Trout-Perch and Rainbow Trout
Volume I
Project AF 1.1.2
AOSERP Report 23

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The Hon. John W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. L. Marchand
Minister of the Environment
Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "Acute Lethality of Mine Depressurization Water to Trout-Perch and Rainbow Trout, Volume I".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Hydrology Research Committee (now the Water System), under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

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ACUTE LETHALITY OF MINE DEPRESSURIZATION WATER TO TROUT-PERCH (*Percopsis omiscomaycus*) AND RAINBOW TROUT (*Salmo gairdneri*), VOLUME I

DESCRIPTIVE SUMMARY

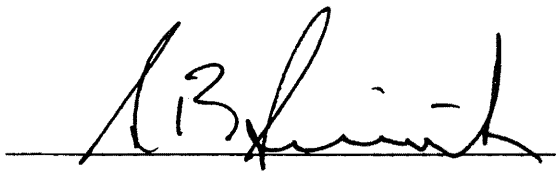
BACKGROUND

In order to conduct oil sands mining operations in the surface mining region of the Athabasca oil sands deposits, most regions require depressurization of the basal sandstone formations. The groundwater produced by depressurization operations is of poor enough quality to be toxic to fish. The purpose of this project is to provide information regarding the acute lethality of oil sands mining and extraction plant wastewaters to fish. Specific objectives were to provide toxicity information on a specific wastewater using Athabasca River water as the diluent and to compare the value of field toxicity studies and the predictive accuracy of laboratory bioassays using treated waters rather than natural waters.

ASSESSMENT

This report is presented in two volumes: Volume I contains discussion and summary of results whereas Volume II provides backup data. The report has been reviewed by various AOSERP researchers, representatives of the oil sands industry, Alberta Environment, Fisheries and Environment Canada, and the University of Alberta. Although the conclusions of the report do not necessarily reflect the views of Alberta Environment or Fisheries and Environment Canada it is the impression of AOSERP management that the researchers have addressed and defined acute toxicity of mine depressurization water to two species of fish. The mention of trade names for commercial products does not constitute an endorsement or recommendation for use. The Alberta Oil Sands Environmental Research Program is satisfied with the efforts put forth by the researchers in this project and accepts this report,

"Acute Lethality of Mine Depressurization Water to Trout-Perch and Rainbow Trout" as important and valid work. Volume I is recommended for wide distribution and Volume II is recommended for placement in the Alberta Environment Library.



S.B. Smith
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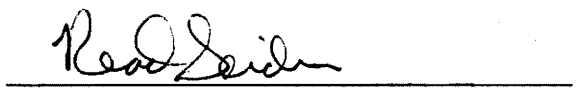

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ACUTE LETHALITY OF MINE DEPRESSURIZATION WATER TO TROUT-PERCH (*Percopsis omiscomaycus*) AND RAINBOW TROUT (*Salmo gairdneri*)

VOLUME I

by

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Alberta Environment
Water Quality Control Branch

for

ALBERTA OIL SANDS
ENVIRONMENTAL RESEARCH PROGRAM

AF 1.1.2

March 1979

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ABSTRACT

Mine depressurization water obtained from five wells on Lease 17 held by Syncrude Canada Limited, was examined for chemical composition and acute toxicity to two species of fish.

In the first series of experiments, mine depressurization water was diluted with various proportions of water obtained from the Athabasca River, and trout-perch (*Percopsis omiscomaycus*) were exposed to these mixtures for up to 10 days. These experiments were performed in a mobile laboratory located in Fort McMurray. The 96-hour lethal concentrations (LC_{50}'s) ranged from 20% by volume (Well No. 5) to 48% by volume (Well No. 1). The 96-hour LC_{50}'s for the composite samples ranged from 35% by volume to 45% by volume.

Similar studies were undertaken in the second series of experiments in Edmonton, using rainbow trout (*Salmo gairdneri*) with Edmonton City water as the diluent. Four of the five wells previously tested were studied, with resulting 96 hour LC_{50}'s of between 20% and 40% by volume for Well No. 2, and 60% and 80% by volume for the other three wells. In addition, a study was performed on a composite of these four wells to determine the effect of storage time on toxicity. It was observed that toxicity decreased after 10 days storage (96-hour LC_{50}'s of between 40% and 60% volume to between 60% and 80% by volume) but then increased (96-hour LC_{50} of 15.2% by volume) after 20 days storage.

Considerable variations in toxicity were found between wells and even water from a single well varied in toxicity depending on the time the sample was obtained and how long it had been stored. Variations in the chemical composition of the mine depressurization water were observed for such components as zinc, nickel, and iron between sample periods, as well as for concentrations of sodium, chloride, and other components from well to well.

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We are grateful to Mr. D. Berry and his crew for their assistance in seining trout-perch from the Athabasca River and to D. Hadler and C. Boyle for their help and patience while we were in Fort McMurray.

We would like to acknowledge the assistance of R. Wilson and M. Falk for their advice throughout the project and for their critical comments regarding our report and L. Mackay for obtaining some of the maps used in this report.

We must also express our gratitude to Syncrude Canada Limited for their co-operation by providing samples, access to the site, and providing data regarding the sample sites.

Finally, we would like to express our gratitude to G. Andriatz and G. de Castro for their typing which extended over several drafts.

This report project, AF 1.1.2, was funded by the Alberta Oil Sands Environmental Research Program, a joint Alberta-Canada research program, established to fund, direct and co-ordinate research into the effects of oil sands developments on renewable resources of the Athabasca Oil Sands.

1. INTRODUCTION

1.1 INTRODUCTION

The Alberta Oil Sands constitute the largest known reserves of petroleum in the world, containing approximately 900 billion barrels of heavy oil. (Department of Mines and Minerals 1974). The largest deposits of oil sands in Alberta are the Athabasca deposits (approximately 600 billion barrels) in Fort McMurray area which are currently being commercially exploited. (Figure 1).

As the Athabasca Oil Sands are developed, a number of crude oil refineries will operate in the area. The operation of these refineries will cause a number of wastewaters to be discharged into the surrounding streams and rivers. The chemical characteristics of these wastes will depend on the mine location and the process being used to remove oil from the sand. Specifically, mine depressurization water, a wastewater associated with mining preparations, will be generated by such refineries and in order to estimate the effects of such effluents on the environment, it is necessary to conduct studies on the toxicities of this material.

1.2 OBJECTIVE

The objective of this study was to determine the acute lethality of mine depressurization water associated with a surface mining operation and to provide a chemical data base for the waste. Acute lethality bioassays were to be conducted by using Athabasca River water for dilution of the samples of wastewater and holding water for the test organism; trout-perch (*Percopsis omiscomaycus*). This species of fish is indigenous to the Athabasca River. The bioassays were to be conducted in a mobile laboratory located in the Fort McMurray area.

As a follow-up, acute lethality bioassays were to be conducted in Edmonton on the mine depressurization water using treated City of Edmonton water as the diluent and rainbow trout (*Salmo gairdneri*) as the test organism.

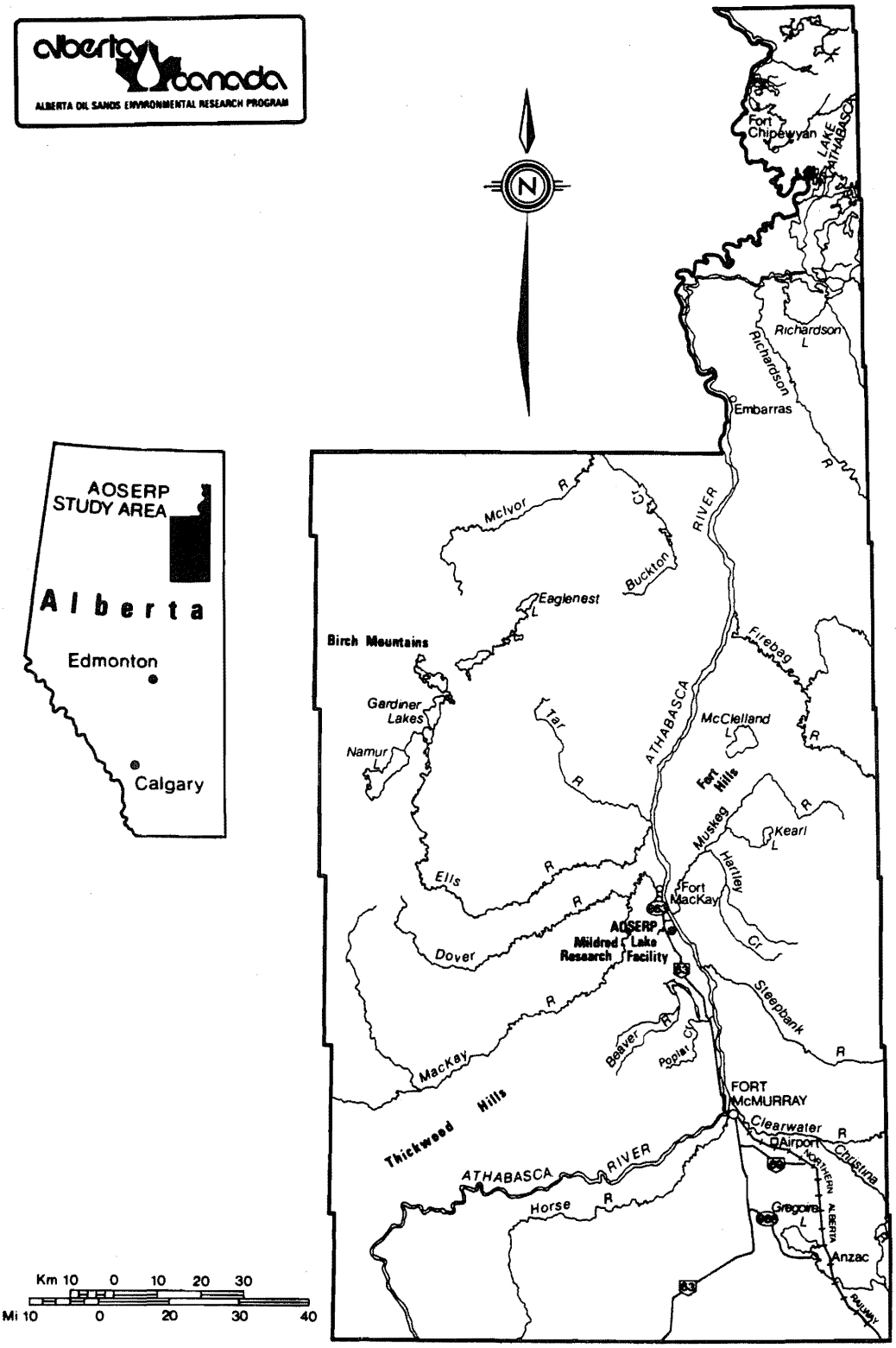

Figure 1. The Alberta Oil Sands Environmental Research Program study area.

The results of these bioassays were to indicate whether or not mine depressurization water is toxic to fish and if further, more sophisticated sub-lethal tests should be performed. The chemical analysis may identify chemical components which may be studied individually or in combination with other chemicals. The field program will be useful in determining the value of acute lethality studies being conducted in the study area using a mobile laboratory.

1.3 MINE DEPRESSURIZATION WATER

Syncrude Canada Limited, located on Lease 17, is one development in the Fort McMurray area (Figure 2). This refinery is expected to start production in 1978. The only liquid effluent from this operation, at the present time, is the mine depressurization water which is a result of the mining operation.

The most important and unique groundwater conditions in the oil sands occur in the basal water sands, which occur beneath the tar sands and are under artesian pressure. The water level in wells penetrating the basal sands generally rises almost to ground level. Under natural conditions, this pressure is more than counter-balanced by the resistance provided by the overlying strata. As the over-burden is removed, there is less material over the aquifer creating an unbalanced uplift. This unbalanced uplift could give rise to heaving problems in the pit floor and instability in the pit walls. Excess hydrostatic pressure can also result in piping old bore holes and fractures. This would cause undermining and cause water to collect on the pit floor, hampering mining operation. As a result the basal water sands have to be depressurized (Hall and Kiss 1975).

Basal water sands present unique problems to mine depressurization schemes. The sands are generally unconsolidated or semi-consolidated and require screening to prevent collapse and undermining. The sands are fine-grained and very uniform, requiring very careful selection of well screens and gravel packs. The formation water (mine depressurization water) is generally brackish, which gives rise to corrosion and disposal problems. Dissolved gases are present in the water and the gases tend

to come out of solution as depressurization proceeds (Hall and Kiss, 1975).

Mine depressurization water results from the commercial activities of Syncrude Canada Limited and most certainly will continue to be produced by other future developments. Great Canadian Oil Sands is the only other crude oil refinery presently operating in the area. It does not produce mine depressurization water as a result of its operations.

Beaver Creek runs north through Syncrude's Lease 17. To conduct a successful mining operation, it was necessary to dam the creek bed and to divert Beaver Creek into Poplar Creek via Ruth Lake and the Beaver Creek reservoir (Stone 1976); (Figures 2 & 3). Over one hundred and forty wells have been sunk in the mine field on Lease 17. From these wells, the mine depressurization water is pumped into various ditches and eventually discharges into the reservoir. There, Beaver Creek water mixes with the depressurized water and then flows through Ruth Lake to empty into Poplar Creek and finally into the Athabasca River (Stone 1976).

1.4 CHEMICAL CHARACTERIZATION OF MINE DEPRESSURIZATION WATER

With the assistance of personnel from Syncrude Canada and chemistry data provided by the company, five wells were selected for this study as being representative of the ground water quality found in the mining area. Wells were selected on the basis of salinity and accessibility. The well locations have been identified by Syncrude's grid system as follows: (Figure 4).

Site 1:	1000S	-	2900E
Site 2:	1400S	-	5300E
Site 3:	14,600S	-	4800E
Site 4:	15,700S	-	4900E
Site 5:	14,600S	-	5300E

Chemical parameters that characterize mine depressurization water vary from well to well and also from day to day. A profile of the mine depressurization water chemical composition expressed as the means and range of all the parameters analyzed during the five month study, are given in Table 1. Organic profiles of mine depressurization water and Athabasca River water are given in Tables 2 and 3.

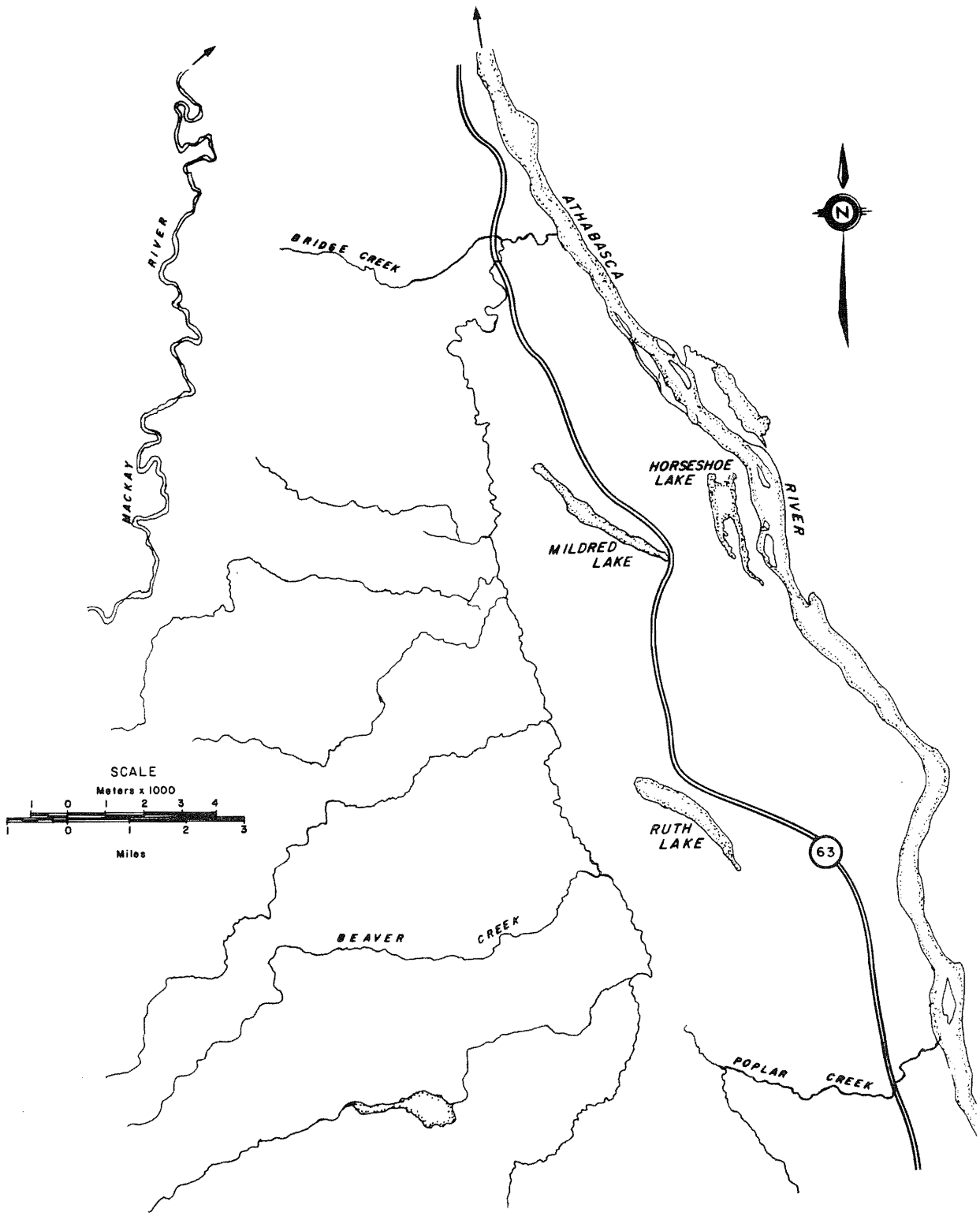

Figure 2. Syncrude of Canada Limited Lease 17 prior to development. Base map courtesy of Syncrude Environmental Affairs Edmonton.

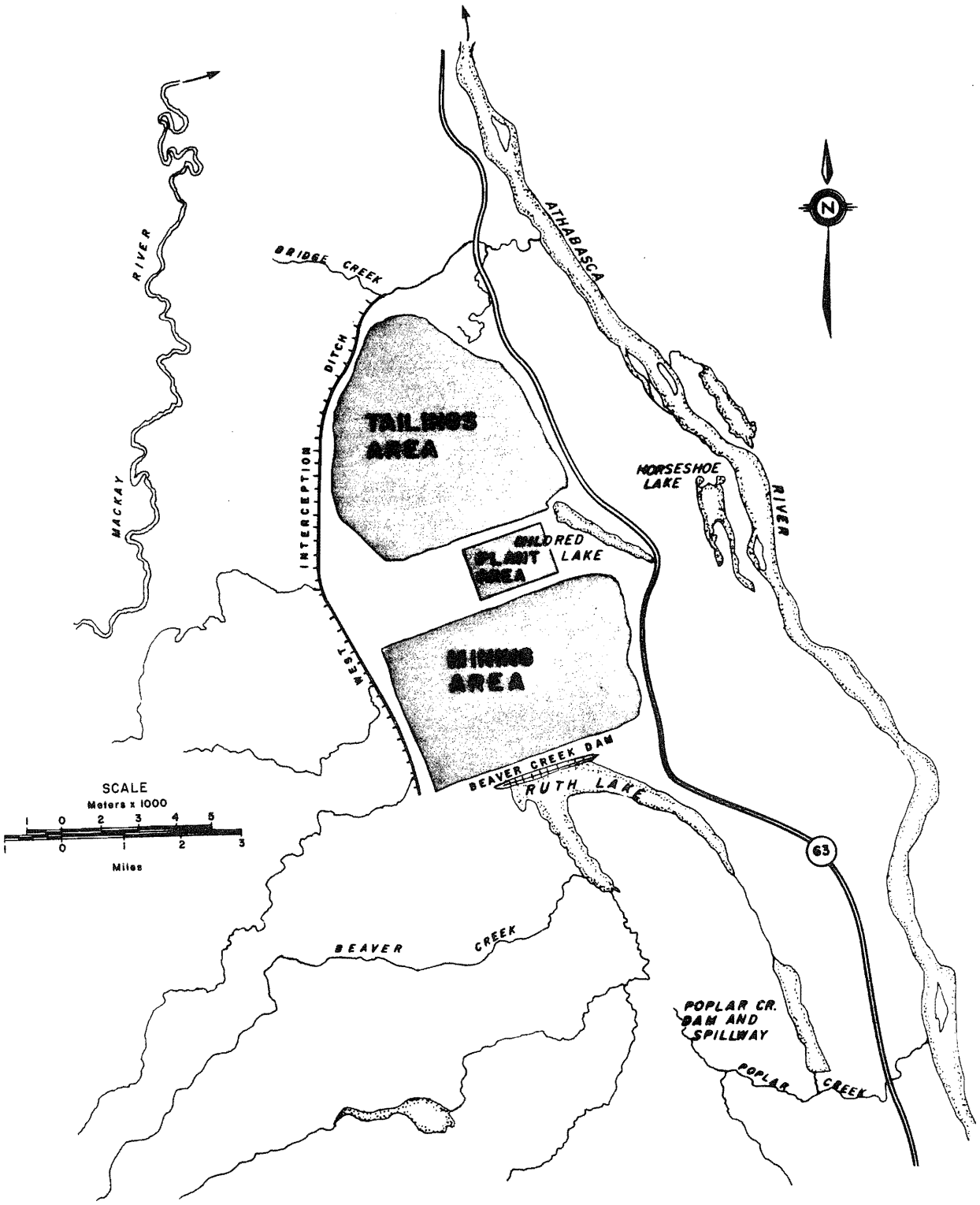

Figure 3. Syncrude of Canada Limited Lease 17 after development. Base map courtesy Syncrude Environmental Affairs Edmonton.

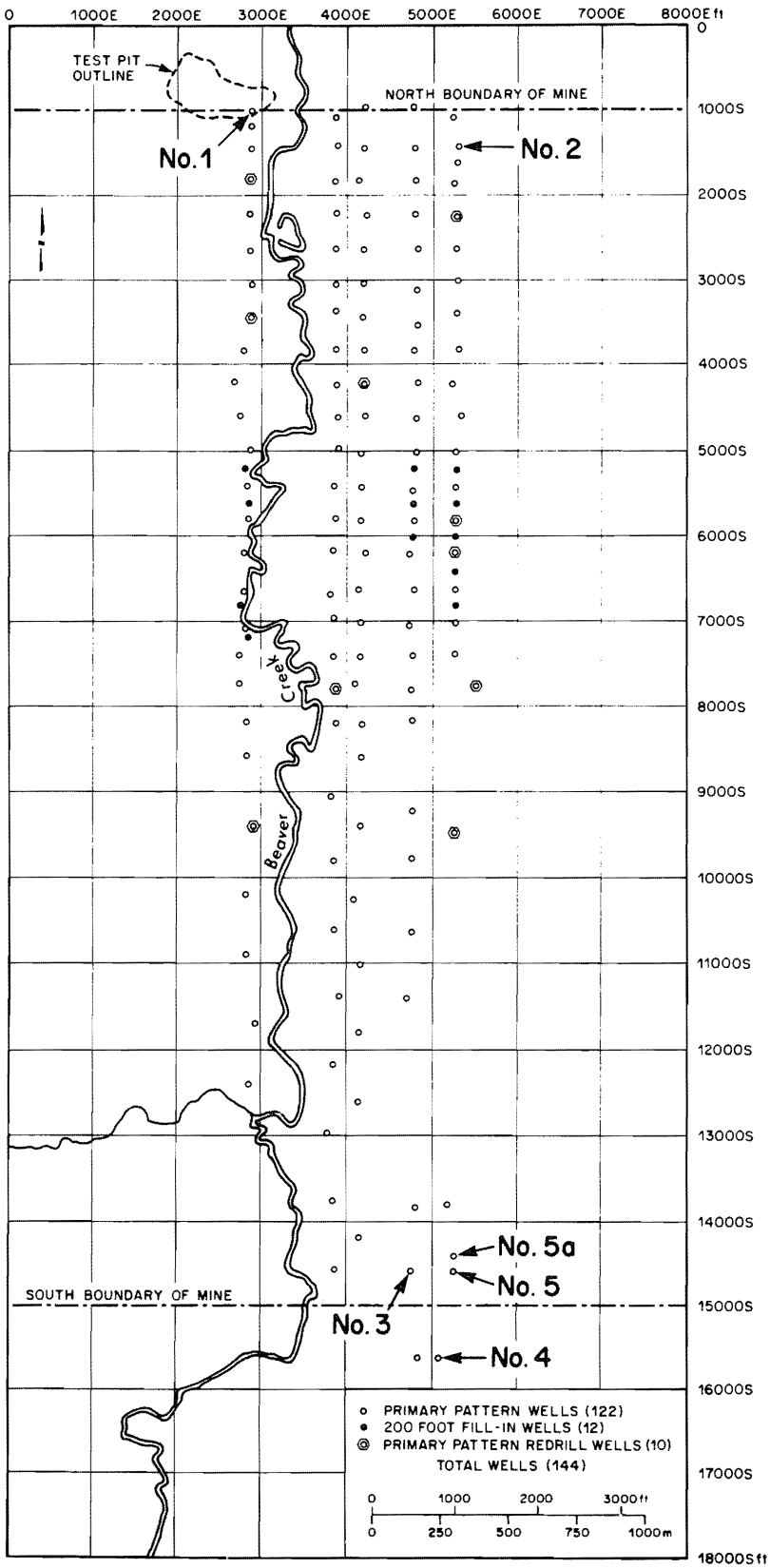

Figure 4. Syncrude of Canada Limited Lease 17 Mine Site showing well locations. Map courtesy of Syncrude Operations Fort McMurray.

Table 1. A profile of the chemical composition of mine depressurization water from Syncrude of Canada Limited, Lease 17.

Parameter	Mean	Range L - H
Inorganics		
Ammonia	7.65	2.2 - 13.65
Bicarbonate	3150.29	1828.5 - 5427
Calcium	71.86	1.0[a] - 318
Carbonate	27.18	0.0 - 396
Chloride	7615.47	2250 - 10500
Conductivity	25658.5	9400 - 48000
Fluroide	0.71	0.48 - 1.25
Hardness, Total	741.58	295 - 1377
Magnesium	133.89	47 - 253
Nitrite	0.1[a]	0.1[a] - ND
Nitrite	0.037	0.1[a] - 0.061
pH	7.55	6.9 - 9.1
Phosphorus, Ortho	0.06	0.005[a] - 0.242
Phosphorus, Total	0.17	0.0005[a] - 1.74
Potassium	45.44	19 - 65
Silica	4.39	2.0 - 18.0
Sodium	5622.63	2150 - 7900
Sulphate	10.22	0.5[a] - 78
Sulphide	0.051	0.02[a] - 0.11
Total Inorganic Carbon	579.19	250 - 820
Organics		
Alkalinity, Total	2628.78	1524 - 4452
Biochemical Oxygen Demand	3.67	2.0 - 8.0
Carbon, Total	757.31	474 - 1130
Chemical Oxygen Demand	231.4	10 - 1282
Humic Acid	1.17	1.08[a] - 1.36

Continued ...

Table 1. Continued.

Parameter	Mean	Range L - H
Hydrocarbon, Total	15.01	0.001[a] - 324
Nitrogen, Total Kjeldahl	11.37	4.8 - 22.9
Oil and Grease	2.43	0.1[a] - 36.3
Phenol	0.0055	0.0001[a] - 0.029
Polychlorinated Biphenyls	0.00015	0.0001[a] - 0.0006
Surfactants	0.32	1.02[a] - 188
Tannin and Lignin	0.62	0.1[a] - 2.0
Total Organic Carbon	189.42	1.0[a] - 9319
Physical		
Color	25.31	5 - 98
Color T_2	98.62	98 - 99
Color T_3	96.62	96 - 97
Odor	17.31	2 - 100
Total Dissolved Solids	15561.16	9319 -19245
Total Residue	15479.32	8810 -19330
Total Filterable Residue	14688.68	5768 -19240
Total Filterable Residue Fixed	16268.39	5376 -19140
Total Non-Filterable Residue	55.84	0.4[a] - 436
Total Non-Filterable Residue Fixed	47.33	0.4[a] - 394
Turbidity	32.16	0.01[a] - 298
Metals		
Aluminum	0.16	0.005[a] - 2.3
Arsenic	0.004	0.0002 - 0.02
Boron	2.60	0.48 - 7.08
Cadmium	0.013	0.001[a] - 0.053
Chronium	0.008	0.002[a] - 0.036
Cobalt	0.05	0.002[a] - 0.165

Continued ...

Table 1. Concluded.

Parameter	Mean	Range L - H
Copper	0.015	0.001[a] - 0.032
Iron	1.51	0.04[a] - 7.45
Lead	0.028	0.002[a] - 0.142
Manganese	0.194	0.65 - 1.2
Mercury	0.0034	0.0001[a] - 0.07
Nickel	0.059	0.002[a] - 0.32
Selenium	0.0014	0.005[a] - 0.0037
Silver	0.011	0.001[a] - 0.05
Vanadium	0.004	0.001[a] - 0.02
Zinc	0.024	0.001[a] - 0.2

Alkalinity and Hardness expressed as Calcium Carbonate

Conductivity in microsiemens/cm

Metals as Totals mg/ℓ

Nitrite, Nitrite & Nitrate, Ammonia expressed as N

pH in pH units

Phosphorus, Ortho expressed as P

Phosphorus, Total expressed as P_4

Turbidity in J.T.U.

[a]Less than

Table 2. Organic Analysis of Mine Depressurization Water from Five Wells from Syncrude of Canada Limited Lease 17[a].

Parameters (All values as mg/ℓ)	Sample Dates Sept.14/76	Nov.30/76
Original Carbon	35	24
Extractable Carbon	21	16
Residual Carbon	14	8
Percentage of Carbon Extracted	60.	64.
Asphaltenes	3.41	1.80
Alkanes & Alkenes	0.11	0.01
Aromatics	0.60	0.02
Polar Compounds	0.03	0.02
Sulphur Compounds	2.7	3.3
Elemental Sulphur	0.001	0.001
Phosphorous Compounds	0.0001	0.0001
Chlorinated Hydrocarbons	0.01	0.006
Organic Nitrogen Compound	0.014	0.029
Aldehydes	0.48	0.54
Amides	0.36	0.27
Ketones	0.01	0.01
Quinones	0.45	0.55
Esters	1.15	1.34
Phenols Colorimetric	0.003	0.001
Phenols by GC	0.19	0.19
Organic Acids	1.1	2.6

[a] Adapted from original tables in Strosher (1976).

Table 3. Organic analysis of Athabasca River water: upstream sample.[a]

Parameters (All values as mg/ℓ)	Sample Dates Sept.15/76	Dec.15/76	Feb.17/77
Original Carbon	15	15	9
Extractable Carbon	3	3	3
Residual Carbon	12	12	6
Percentage of Carbon Extracted	20	20	33
Asphaltenes	ND	ND	ND
Alkanes and Alkenes	0.004	0.001	0.001
Aromatics	0.009	0.002	0.001
Polar Compounds	0.030	0.010	0.002
Sulphur Compounds	0.06	0.04	0.01
Elemental Sulphur	0.003	0.001	0.001
Phosphorous Compounds	0.00001	0.00002	0.00006
Chlorinated Hydrocarbons	0.001	0.001	0.001
Organic Nitrogen Compounds	0.001	0.001	0.001
Aldehydes	0.19	0.26	0.48
Amides	0.50	0.42	0.22
Ketones	0.01	0.01	0.01
Quinones	0.10	0.12	0.10
Esters	0.001	0.029	0.027
Phenols Colorimetric	0.001	0.001	0.001
Phenols by GC	0.01	0.01	0.01
Organic Acids	0.01	0.01	0.01

[a] Adapted from original tables in Strosher (1976).

2. MATERIALS AND METHODS

2.1 FIELD BIOASSAYS USING TROUT-PERCH (*Percopsis omiscomaycus*)

2.1.1 Mobile Laboratory and Operation

The mobile laboratory used for this project was provided by Alberta Environment, Pollution Control Division, Water Quality Control Branch. The laboratory consisted of a 4.4 m x 2.1 m (14.5 ft. x 7 ft.) laboratory unit built onto a one-ton four-wheel drive truck. The laboratory unit was of a tubular steel construction with aluminum sheeting on the outer shell and insuluted with 63.5 mm (2.5 in.) polyurethane. The unit was equipped with an outer storage compartment, a propane heater and a 6.5 KVA gasoline generator. Inside the laboratory was equipped with a 180 ℓ (40 gal.) stainless steel holding tank, a 180 ℓ (40 gal.) plexiglass holding tank, and a 1.8 m x 1.8 m (6 ft. x 6 ft.) diluter board for a Michigan type diluter. Lighting was provided by two sets of 0.9 m (3 ft.) fluorescent lights as well as a small incandescent bulb (Figure 5).

For this study, a 0.55 kW (3/4 horsepower) refrigeration unit with a condensing unit mounted inside the laboratory was installed to maintain a temperature of 15 $\pm$ 1°C. The 12 hour day-night photoperiod was regulated by a timer.

The holding water and diluent for the laboratory was Athabasca River water taken directly from the river by a 0.55 kw (3/4 horsepower) centrifugal pump. To prevent the pump from sucking up mud from the bottom of the river, a 25.4 mm (1 in.) polyethylene intake line with a foot valve attached, was floated approximately 0.6 to 0.9 m (2 to 3 ft.) above the river bottom. A 115 ℓ (25 gal.) insulated plastic tank was mounted on the laboratory roof to serve as a water reservoir. A plastic ball-cock valve was used to maintain the water level in the reservoir. The temperature in the reservoir was controlled at 15 $\pm$ 1°C by a 0.24 kW (1/3 horsepower) refrigeration unit. A 0.55 kW (3/4 horsepower) oil-less compressor with a 46 ℓ (10 gal) tank was used for aeration. Figures 6 & 7 show the mobile laboratory set up and on location on MacDonald Island.

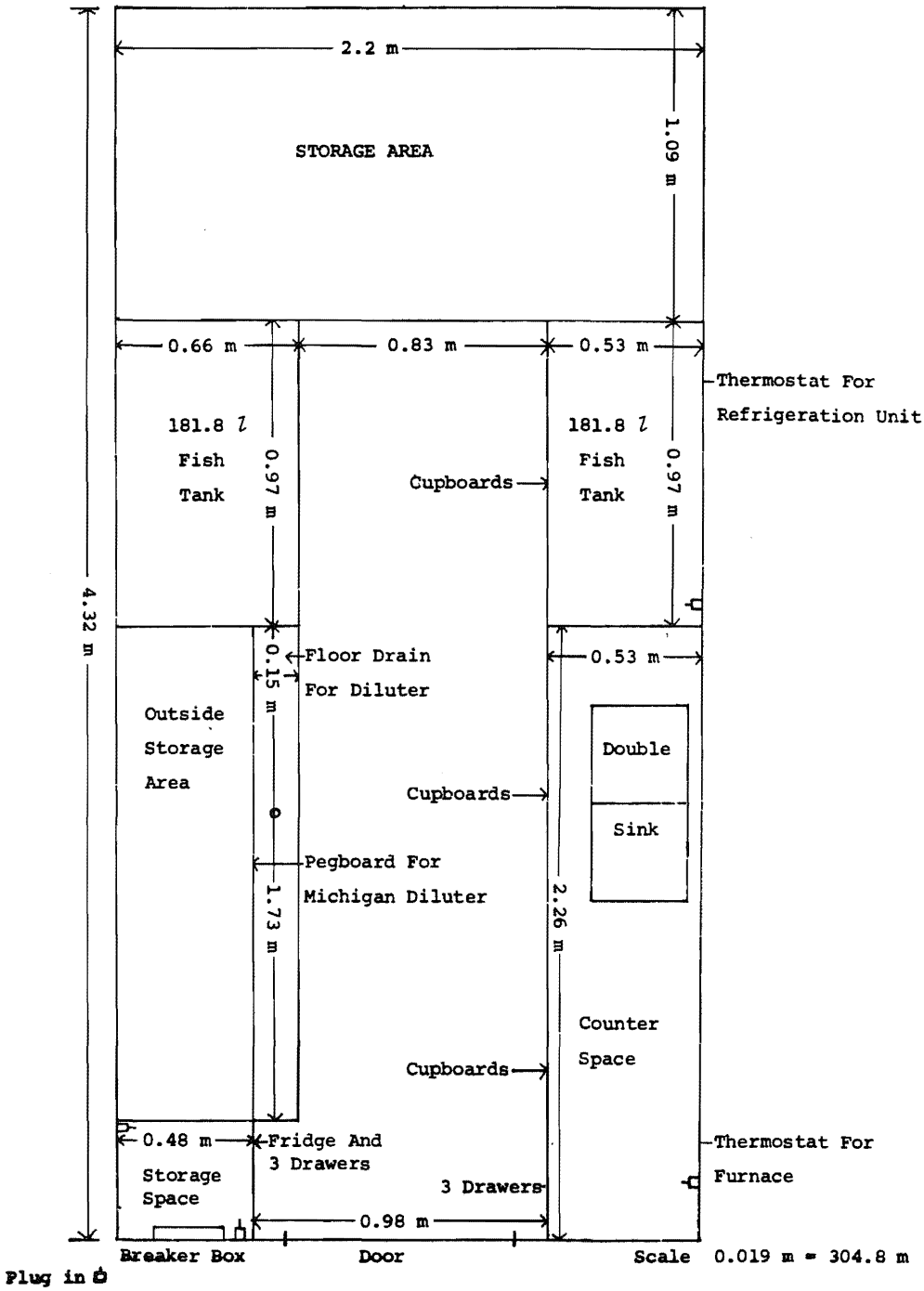

Figure 5. Schematic of floor plan of Water Quality Control Branch Mobile Bioassay Laboratory .

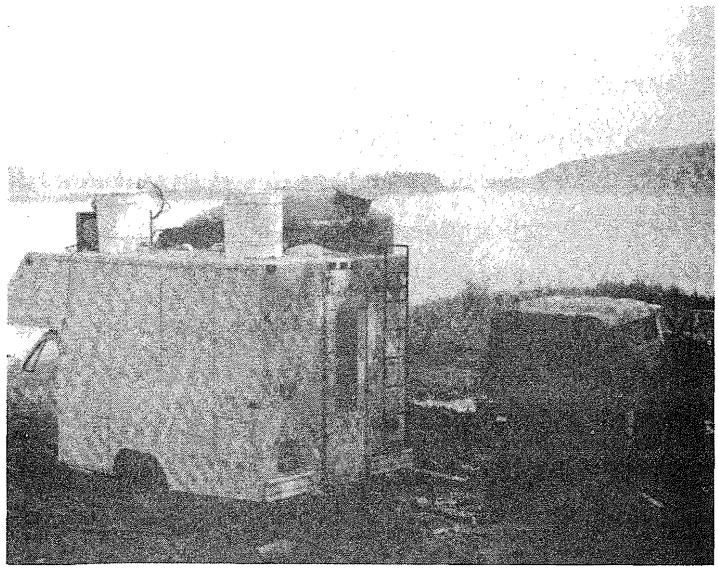

Figure 6. Mobile Bioassay Laboratory on location by the Athabasca River on MacDonald Island in Fort McMurray. Photo facing North.

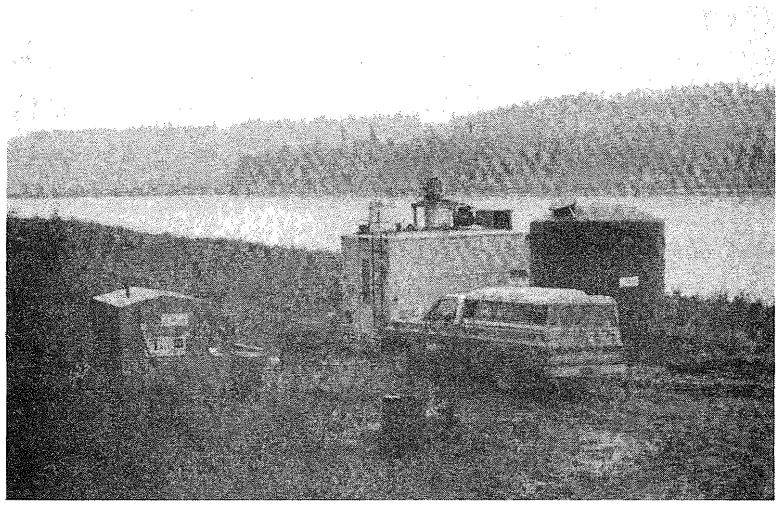

Figure 7. Mobile Bioassay Laboratory on location by the Athabasca River on MacDonald Island in Fort McMurray. Photo facing South.

2.1.2 Fish Care and Handling

With the assistance of AOSERP, Aquatic Fauna Sector personnel, trout-perch (*Percopsis omiscomaycus*) were seined from the Athabasca River directly across from the mobile laboratory (Figure 8). Trout-perch are described by Scott and Crossman (1973), as possessing characteristics exhibited by both salmonids and perches. They are small, dark spotted silvery fishes, essentially bottom feeders, living in quiet backwaters of large muddy rivers and along sandy beaches in lakes. There appears to be a marked inshore movement after dark for the purpose of feeding; this species feeds mainly on aquatic insects, small crustaceans and mollusks. According to Paetz and Nelson (1970), trout-perch are common to the Hay, Slave, Peace, Athabasca, Beaver, Battle, Red Deer, Bow,Oldman, and North and South Saskatchewan drainages in Alberta. They provide an important forage fish for walleye (*Stizostedion vitreum vitreum*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), and burbot (*Lota lota*), which are all indigenous to the Athabasca River in the Fort McMurray area.

The captured fish were transported immediately to the laboratory and placed in a 180 ℓ (40 gal) holding tank. They were held at ambient temperature until there was no mortality in the tanks, a minimum of four days. During temperature acclimation, which did not begin until the mortality ceased, the temperature was adjusted upward or downward 1°C per day until the desired temperature was reached. Once the desired temperature was reached, the fish were held for two weeks prior to being used in the experiments. Fish were also regulated to a 12 hour day-night photoperiod.

Twice daily, mortality, dissolved oxygen, pH conductivity, temperature and flow rate were recorded (See Table 4). In the fish tanks, dissolved oxygen was maintained at 80% saturation or better, temperature was held at 15 $\pm$ 1°C and the flow rate was sufficient to keep the tanks free from fecal matter. The fish were fed a dry commercial fish food at a rate of 1.5% of their body weight daily.

Temperature fluctuations were caused by refrigeration unit malfunctions and electrical problems encountered with the generators.

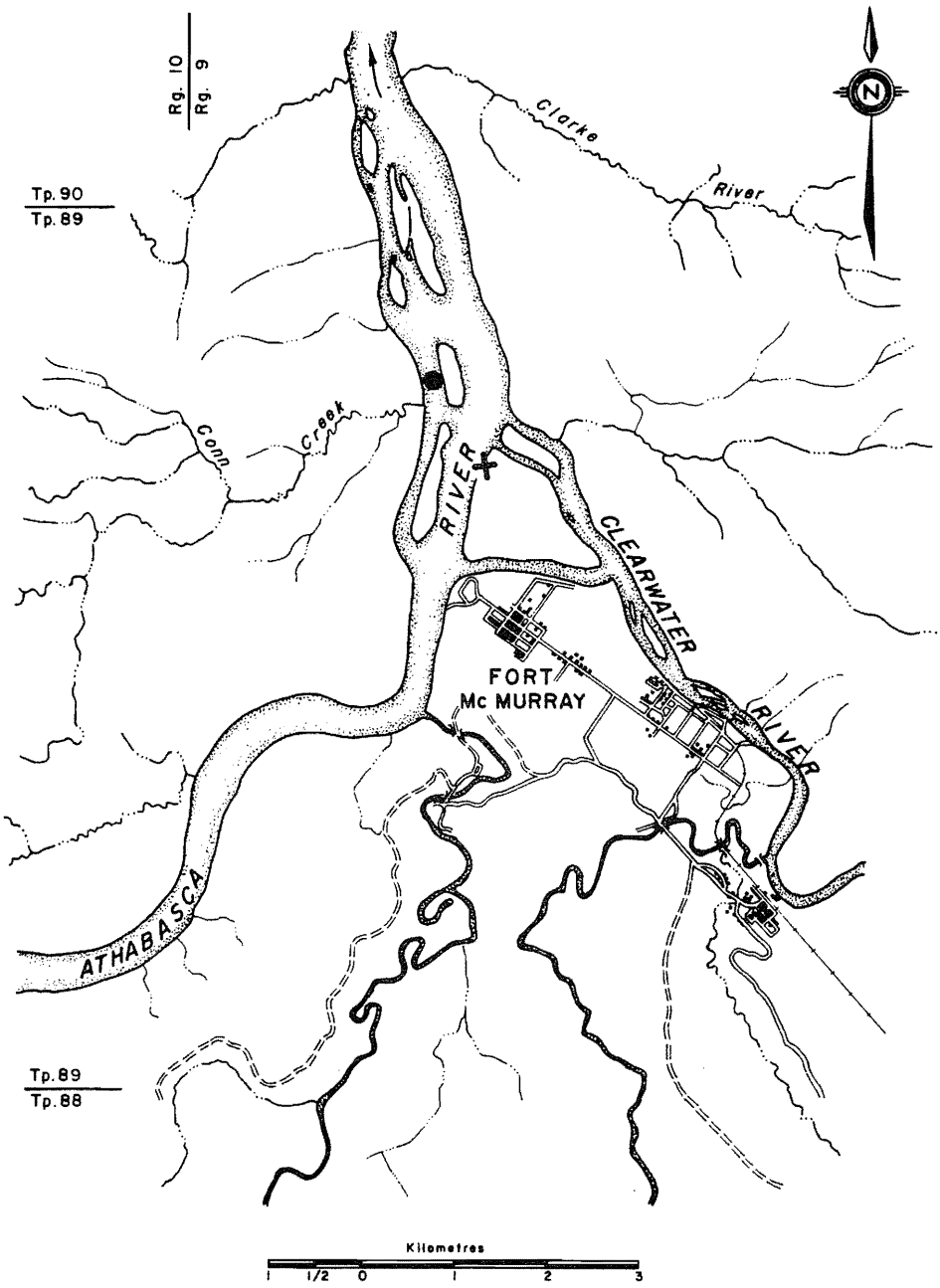

Figure 8. Topographic map showing fish seining and Mobile Laboratory locations. Map courtesy Surveys and Mapping Branch, Department of Energy Mines and Resources.

= Fish seining location on Athabasca River.
= Mobile Laboratory location on MacDonald Island.

Table 4. Summary of fish holding data for trout-perch (*Percopsis omiscomaycus*) seined from the Athabasca River

Parameters	Mean and Standard Deviation
Temperature (^{o}C)	14.4 ± 1.95
pH (pH units)	8.07 ± 0.86
Dissolved Oxygen (ppm)	9.3 ± 1.2
Conductivity (microsiemens/cm)	225 ± 33.0

2.1.3 Dilution Water

Untreated Athabasca River water was used for holding the fish and for the dilution of the mine depressurization water. The river water was not recycled. Samples of the Athabasca River water were collected and preserved weekly for detailed chemical analyses. During weeks that experiments were being conducted, river water samples were sent via air to Alberta Environment, Pollution Control Division Laboratory in Edmonton (June and July) and later to Chemex Labs (Alberta) Limited in Calgary (August, September, October). The results are given in Volume II of this report.

2.1.4 Mine Depressurization Water Handling and Storage

Toxicity studies were carried out on water obtained from each of five wells and from three composites of five wells. For the individual well bioassays, samples were collected in four 115 ℓ (25 gal) polyethylene lined steel drums. The drums had been thoroughly washed prior to being used. Polyethylene liners were filled with sample, the air at the top was forced out and the liners were sealed. Samples were transported to the mobile laboratory and stored outside until the evening prior to being used for the test. At the time the bioassay sample was being collected, samples were collected and preserved from all five wells for chemical analysis.

Composite samples were collected and transported back to the laboratory site in a 14,000 ℓ (3000 gal) steel tank which had been thoroughly cleaned. Approximately 4500 ℓ (1000 gal) was collected from each of the five selected wells for the composite. Flexible rubber hosing was used to transfer the sample from the well to the tank. Flow rates were calculated by means of a stop-watch and a 23 ℓ (5 gal) plastic pail to estimate when the 4500 ℓ (1000 gal) of sample had been collected. At the time of collection, samples were taken and preserved for chemical analysis from each of the five wells.

The composite sample was transported to Fort McMurray and transferred to a 23,000 ℓ (5000 gal) fibreglass storage tank located beside the mobile laboratory. A 0.24 kW (1/3 horsepower) submersible pump was

used to mix the sample for 24 hours. The sample was stored at ambient air temperature. After mixing, samples were collected and preserved for chemical analysis.

After collection of the first composite (6 and 7 July 1976) and thorough mixing of the sample, 18,000 ℓ (4000 gal) were sent in a refrigerated truck to the Freshwater Institute in Winnipeg for use in acute and sublethal studies. The remaining 4600 ℓ (1000 gal) were used for acute lethality bioassays in the mobile laboratory.

A composite sample collected 15 September 1976 was also tested in Edmonton, using rainbow trout, (*Salmo gairdneri*) as the test organism and treated City of Edmonton water as the diluent. This test was conducted by Environment Canada, Environmental Protection Service, Bioassay Laboratory (Volume II).

2.1.5 Bioassay Procedures

Lethal concentration (LC_{50}) values were obtained by exposure of fish to different concentrations of mine depressurization water for 96 hours. A semi-static procedure with 90% replacement every 24 hours was performed on the five wells and one composite sample. Two, ten day static bioassays were performed in the initial composite samples.

The bioassay vessels were 23 ℓ (5 gal) polyethylene pails lined with clean polyethylene bags. The bags were first rinsed with copious amounts of Athabasca River water to ensure that no contaminants were present. After the initial series of concentrations had been prepared, the temperature was brought to 15°C before the fish were introduced. Replacement samples were poured in 23 ℓ (5 gal) pails and stored overnight in the laboratory in order to bring them to 15 ± 1°C. Gentle aeration maintained the dissolved oxygen concentration between 80 and 100% saturation.

With the exception of the undiluted effluent sample and the river water control, all concentrations were mixed as percent by 20 ℓ (4.35 gal) volume. Each sample was duplicated and five fish were used in each vessel for a total of 10 fish per 40 ℓ (8.70 gal) concentration. Fish were not fed for two days prior to an experiment and during

the experiment. If the mortality in the holding rank exceeded 1% before the experiment started, the experiment was postponed.

Mortality checks for an experiment were performed at: 0, ¼, ½, 1, 2, 4, 8, 12, 18, 24 and every 12 hours after the completion of the first day until the end of the experiment. Checks of pH, dissolved oxygen, temperature and conductivity were performed every 12 hours. Samples of mine depressurization water and the dilution water were collected and preserved for chemical analysis at the commencement of the experiment (Volume II).

2.2 LABORATORY BIOASSAYS AND STORAGE TIME TEST USING RAINBOW TROUT (*Salmo gairdneri*)

2.2.1 Laboratory

Acute lethality bioassays were conducted in Edmonton on four of the five wells studied in Fort McMurray. These bioassays were performed in the Alberta Environment, Pollution Control Division, Water Quality Control Branch, Bioassay Laboratory. Hatchery-reared rainbow trout were the test species for these tests.

2.2.2 Fish Care and Handling

One to five gram rainbow trout (*Salmo gairdneri*) were obtained from a certified disease free hatchery located in Tacoma, Washington, and were held in a 2300 ℓ (500 gal) tank for two weeks. The fish were then transferred to 800 ℓ (175 gal) living stream units for temperature acclimation. Acclimation was achieved by adjusting the temperature 1°C per day to 15°C. The fish were held at this temperature for a further two weeks prior to use in experiments. A 12 hour day-night photoperiod was maintained in the laboratory. The fish were fed a dry commercial trout food at a rate of 1.5% of their body weight daily.

Twice daily, mortality, dissolved oxygen, pH, temperature and flow rates were recorded (Table 5).

2.2.3 Dilution Water

Treated City of Edmonton water was used as the dilution water. The water was passed through a 46 ℓ/min (10 gal/min) anthrofilt filter for suspended solid removal; a 46 ℓ/min (10 gal/min) activated charcoal filter for chlorine removal and an ultra-violet dechlorinator-sterilizer. The water then passed into a 800 ℓ (175 gal) reservoir. This tank was the site of temperature and pH control. The pH was adjusted by finally regulating CO_2 into the reservoir. A 1.2×10^{-3} M sodium thiosulphate solution was introduced into the reservoir at a rate of 1 ml/min for additional chlorine removal.

Twice daily, pH, temperature, conductivity, free chlorine and total residual chlorine was measured (Table 6).

Table 5. Summary of fish holding data for rainbow trout (*Salmo gairdneri*)

Parameters	Mean and Standard Deviation
Temperature (^{o}C)	14.4 ± 0.4
pH (pH units)	7.46 ± 0.59
Dissolved Oxygen (ppm)	9.7 ± 0.79
Conductivity (microsiemens/cm)	193 ± 62.0

Table 6. Summary of daily water chemistry data for Bioassay Laboratory treated water

Parameters	Mean and Standard Deviation	
Temperature (^{o}C)	14.4	0.5
pH (pH units)	7.64	0.22
Conductivity (microsiemens/cm)	209	22.0
Free Chlorine (ppm)	0.01[a]	0.00
Total Residual Chlorine (ppm)	0.01[a]	0.00

[a] Less than

2.2.4 Mine Depressurization Water Handling and Storage

Four of the five wells studied in Fort McMurray were sampled for additional study in Edmonton (Figure 4). Well No. 3 was not flowing when these samples were collected. Samples were collected in 115 ℓ (25 gal) polyethylene lined drums which had been thoroughly washed to prevent contamination. A total of 6000 ℓ (1300 gal) of mine depressurization water were collected in February, 1977; 450 ℓ (100 gal) for a composite and 3600 ℓ (800 gal) for a composite storage test. At the time of collection, samples were collected and preserved for chemical analysis. The samples were sealed and transported to Edmonton in an unrefrigerated truck.

Samples for the individual wells and composite were stored outside at ambient temperature. As the samples were collected in February, they were frozen during storage. Before an experiment, the sample was brought into the laboratory and thawed out. After the sample was brought into the laboratory and thawed, it was agitated to ensure that no settling of material had occurred and to prevent a concentration gradient being formed.

Samples collected for the storage study were pumped into a 3700 ℓ (800 gal) insulated fibreglass tank. This tank had previously been cleaned and rinsed with treated water to prevent contamination of the sample. A floating top minimized evaporation. Temperature of the wastewater was maintained at 4°C and a submersible pump was used to prevent settling of suspended solids and the formation of a concentration gradient.

2.2.5 Bioassay Procedure

Lethal concentration (LC_{50}) values were obtained by exposure of fish to different concentrations of mine depressurization water for 96 hours. A semi-static procedure with 90% replacement every 24 hours was performed on four of five wells previously studied and a composite from Syncrude Canada Limited, Lease 17. The bioassay vessels were 68 ℓ (18 gal) polyethylene pails lined with polyethylene bags. The bags had been previously rinsed with treated water. Each bioassay

vessel contained 40 ℓ of test solution and 10 fish. A waterbath controlled temperature to 15 $\pm$ 1°C.

For the storage study, lethal concentration (LC_{50}) values were determined by exposure of fish to different concentrations of mine depressurization water for 96 hours. Continuous flow experiments with 90% replacement in 10 hours were conducted on the 3700 ℓ (800 gal) composite sample. Experiments were performed on a fresh sample, after ten days of storage and after four weeks of storage. A swing arm diluter was used as the dosing apparatus. The bioassay vessels in this series of experiments were 23 ℓ (5 gal) pails lined with rinsed polyethylene bags. Each bioassay vessel contained 20 ℓ of test solution and 10 fish. The temperature was controlled at 15 $\pm$ 1°C and dissolved oxygen was maintained between 80 and 100% saturation. If mortality in the holding tanks exceeded 1%, experiments were not conducted.

Mortality checks were performed at: 0, ¼, ½, 1, 2, 4, 8, 12, 18, 24, and every 12 hours after the first day until the end of the experiment. Every 12 hours, pH, dissolved oxygen, temperature, and conductivity were measured and in the continuous flow experiments flow rates were measured. Samples of the mine depressurization water and dilution water were collected and preserved at the start of each experiment for more comprehensive chemical analysis (Volume II).

2.3 DATA ANALYSIS AND REPORTING

For each experiment, mean survival times (MST's) were calculated (% by volume) using the method of Litchfield (1949). Ninety-six hour lethal concentrations (LC_{50}'s) were calculated by one of three methods: by Sprague (1969) when only mean survival times could be calculated; by Litchfield and Wilcoxon (1949) when a partial response was observed after 96 hours and by Muench and Reed (Woolf 1968) (Tables 7, 8 and 9).

Chemistry results for the samples collected at the start of the experiments and the diluent were reported in table form. The mean

Table 7. Summary of results of bioassays conducted on mine depressurization water from Syncrude's Lease 17, using Athabasca River water as the diluent and trout-perch (*Percopsis omiscomaycus*) as the test species.

Exp. No.	Storage Time (Days)	Sample	Diluent	Test Mode	Test Species	Fish Length (cm)	Fish Weight (gm)	Conditioning Factor $gm/cm^3 \times 100$	Loading Density gm/l	96 hr. LC_{50} (%) Sprague (1969)	96 hr. LC_{50} (%) Reed & Muench [Woolf (1968)]
1	12	Composite	Athabasca River	Static	Trout perch	5.75 ± 0.23	2.15 ± 0.32	1.13	0.54/l/ experiment	20 - 40	45.0 (30.8 - 59.2)
2	18	Composite	Athabasca River	Static	Trout Perch	6.0 ± 0.30	2.5 ± 0.44	1.15	0.63/l/ experiment	40.0	
3	1	Well #2	Athabasca River	S.S.R.[b]	Trout Perch	5.95 ± 0.39	2.13 ± 0.90	1.01	0.53/d	23.6	28.3 (24.1 - 32.5)
4	1	Well #2	Athabasca River	S.S.R.[b]	Trout Perch	5.97 ± 0.49	2.61 ± 0.66	1.23	0.65/d	30.9	
5	1	Well #2	Athabasca River	S.S.R.[b]	Trout Perch	5.79 ± 0.59	2.44 ± 0.75	1.26	0.61/d	T[c]	31.3 (23.0 - 39.6)
6	1	Well #3	Athabasca River	S.S.R.[b]	Trout Perch	5.9 ± 0.32	2.0 ± 0.39	0.97	0.50/d	40.0	
7	5	Composite	Athabasca River	S.S.R.[b]	Trout Perch	4.37 ± 0.23	0.8 ± 0.10	0.96	0.20/d	35.0	32.0 (28.1 - 35.9)
8	10	Composite	Athabasca River	S.S.R.[b]	Trout Perch	4.3 ± 1.3	0.68 ± 0.07	0.86	0.17/d	30 - 35	
9	2	Well #1	Athabasca River	S.S.R.[b]	Trout Perch	4.2 ± 0.15	0.6 ± 0.04	0.81	0.15/d	48.0	50.1 (42.2 - 58.0)
10	1	Well #4	Athabasca River	S.S.R.[b]	Trout Perch	4.86 ± 0.93	1.22 ± 0.55	1.06	0.49/d	T[c]	
11	1	Well #5	Athabasca River	S.S.R.[b]	Trout Perch	4.4 ± 0.72	0.95 ± 0.33	1.12	0.33/d	21.0	24.4 (16.8 - 32.0)
12	1	Well #4	Athabasca River	S.S.R.[b]	Trout Perch	5.3 ± 1.12	1.58 ± 0.94	1.06	0.63/d	41.0	37.4 (24.5 - 50.3)

S.S.R.[b] - Semi-Static 90% molecular replacement every 24 hrs. T[c] - Terminated

Table 8. Summary of results of bioassays conducted on mine depressurization water from Syncrude's Lease 17, using Edmonton treated water as the diluent and rainbow trout (*Salmo gairdneri*) as the test species.

Exp. No.	Storage Time (Days)	Sample	Diluent	Test Mode	Test Species	Fish Length (cm)	Fish Weight (gm)	Conditioning Factor $gm/cm^3 \times 100$	Loading Density gm/l	96 hr LC_{50} (% by volume)			
										Sprague		Litchfield	Reed & Muench
14	1	Well #4	E.T.W.[d]	S.S.R.[b]	Rainbow Trout	5.18 ± 0.69	1.66 ± 1.67	1.19	0.42/day	# 4	60 - 80	N.C.	64.3 (59.2-69.4)
16	1	Composite	E.T.W.[d]	S.S.R.[b]	Rainbow Trout	5.49 ± 0.37	1.68 ± 0.37	1.02	0.67/day	Comp.	60 - 80	N.C.	68.6 (64.2-73.0)
18	10	Well #2	E.T.W.[d]	S.S.R.[b]	Rainbow Trout	6.12 ± 0.50	2.46 ± 0.77	1.07	0.62/day	#2	20 - 40	37.5 (25.9-54.4)	38.4 (32.7-44.1)
19	10	Well #1	E.T.W.[d]	S.S.R.[b]	Rainbow Trout	5.94 ± 0.55	2.19 ± 0.73	1.04	0.55/day	#1	64.0	58.5 (47.9-71.4)	64.8 (59.3-70.3)
21	17	Well #5	E.T.W.[d]	S.S.R.[b]	Rainbow Trout	6.56 ± 1.04	3.02 ± 1.04	1.07	0.76/day	#5	60.0	61.9 (51.8-73.9)	65.6 (54.9-76.3)

S.S.R.[b] - Semi-Static 90% Molecular Replacement every 24 hours.
E.T.W.[d] - Edmonton Treated Water

Table 9. Summary of results of storage bioassays conducted on mine depressurization water from Syncrude's Lease 17, using Edmonton treated water as the diluent and rainbow trout (*Salmo gairdneri*) as the test species.

Exp. No.	Storage Time (Days)	Sample	Diluent	Test Mode	Test Species	Fish Length (cm)	Fish Weight (gm)	Conditioning Factor $gm/cm^3 \times 100$	Loading Density gm/ℓ	96 hr LC_{50} (%) Sprague (1969)	96 hr LC_{50} (%) Reed & Muench [Woolf (1968)]
15	1	Composite	E.T.W.[d]	Continuous Flow	Rainbow Trout	5.39 ± 0.47	1.57 ± 0.34	1.00	0.79/day	52.5	55.2 (50.1 - 60.6)
17	10	Composite	E.T.W.[d]	Continuous Flow	Rainbow Trout	6.11 ± 0.49	2.27 ± 0.77	1.00	1.135/day	80 - 100	80 (74.9 - 85.1)
22	29	Composite	E.T.W.[d]	Continuous Flow	Rainbow Trout	5.58 ± 0.25	0.82 ± 0.12	0.91	0.33/day	15.2	11.1 (3.7 - 18.5)

E.T.W.[d] - Edmonton Treated Water.

and range for each well parameter of the field samples and the diluent were also reported in table form (Volume II).

For each experiment, mean fish length with variance , mean fish weight with variance, conditioning factor, loading density, storage time and 96-hour lethal concentrations (LC_{50}'s) were in table form (Tables 7, 8 and 9).

3. RESULTS

3.1 FIELD ACUTE LETHALITY STUDIES OF MINE DEPRESSURIZATION WATER USING TROUT-PERCH (*Percopsis omiscomaycus*).

Mine depressurization water from all five wells and the composite produced significant mortality in trout-perch.

Ninety-six hour lethal concentrations (LC_{50}'s) ranged from 21% by volume (Sprague 1969) for Well No. 5 to 48% by volume (Sprague 1969) for Well No. 1. The ninety-six hour lethal concentrations (LC_{50}'s) for the composite samples ranged from 35% by volume (Sprague 1969) to 45% by volume (Sprague 1969) (See Table 7).

In all of the samples tested, the greatest mortality occurred within the first 24 hours. In the highest concentrations, the fish becan to show signs of stress immediately. Symptoms observed were: rapid opercular movements, loss of equilibrium, darkening of color and gasping at the surface. Shortly before death, the fish sank down to the bottom of the container and lay on the bottom with very slow movements. In the experiment conducted on Well No. 2, two of the fish in the highest concentration (100%) exhibited some signs of hemorrhaging from the gill area. The pH's of the various concentrations increased with time. The increase was approximately 1 pH unit from 7.5 to 8.5.

The results of the analysis of the wells and the composite samples indicated that the composition of the samples varied from week to week. The concentrations of components such as zinc, nickel and iron varied between sample periods. The concentrations of sodium, chloride and other toxicants were also found to vary from well to well.

The Athabasca River water composition also varied due to heavy rains experienced during portions of the field project. Sodium and chloride concentrations ranged from 5.9 - 36.0 ppm and 1.0 - 51.0 ppm respectively.

3.2 ACUTE LETHALITY STUDY OF THE MINE DEPRESSURIZATION WATER USING RAINBOW TROUT (*Salmo gairdneri*).

Water from four of the five wells previously tested and the composite sample were all found to produce significant mortality in

rainbow trout. The most toxic well was found to be Well No. 2 with a 96 hour lethal concentration (LC_{50}) between 20% and 40% by volume. The 96 hour lethal concentrations (LC_{50}'s) for the remaining three wells and the composite samples were all determined to be 60% and 80% by volume (Table 8).

As in the trout-perch studies, the greatest mortality occurred within the first 24 hours. In the highest concentrations, the rainbow trout began to show signs of stress immediately and the symptoms were similar to those exhibited by trout-perch.

The pH's of the various concentrations were observed to increase with time as in the trout-perch experiments.

Examination of the chemical components for Well No. 2, collected on 24 August and on 22 February 1977, indicated some differences. In February, Well No. 2 was higher in calcium, 72 ppm; bicarbonate, 3841 ppm; fluoride, 0.77 ppm; silica, 5.3 ppm; phenol, 0.064 ppm and chemical oxygen demand (COD), 232 ppm. The values for the August 1976 sample were; calcium, 60 ppm; bicarbonate, 3686 ppm; fluoride, 0.52 ppm; silica, 2.6 ppm; phenol, 0.024 ppm and chemical oxygen demand, 30 ppm. Well No. 2 was the most toxic well to rainbow trout (20% < 96 hr LC_{50} < 40%) (Sprague 1969) and the second most toxic well to trout-perch (96 hr LC_{50} 23.0%) (Sprague 1969).

Examination of the chemistry data does not indicate to us that one individual component could be identified as the primary toxicant.

3.3 EFFECTS OF STORAGE ON THE ACUTE LETHALITY OF MINE DEPRESSURIZATION WATER ON RAINBOW TROUT (*Salmo gairdneri*).

These lethal concentration experiments using a continuous flow procedure indicated that the mine depressurization water was acutely lethal to rainbow trout. These experiments were conducted on a composite sample of mine depressurization water. The 96 hr. lethal concentration for the semi-static and continuous flow bioassay were between 40% and 60% by volume.

After ten days storage, the 96 hour lethal concentration increased, ie., the sample was less toxic. The ninety-six hour lethal concentration was between 60% and 80% by volume.

A third test of the sample after 29 days storage, showed it to be extremely toxic. The 96 hour lethal concentration was 15.2% by volume (Sprague 1969) (See Table 9).

The symptoms exhibited by the rainbow trout in this series of experiments were identical to those exhibited by trout-perch and rainbow trout in the previous series of experiments. In the continuous flow experiments, there were no signs of hemorrhaging from the gill area.

One trend observed in the continuous flow experiments was a continual increase in the pH of the composite sample. The initial pH was 7.47; after ten days of storage, the pH increased to 8.21 and after 29 days of storage, the pH increased to 9.04.

Storage, with the exception of the pH change and the corresponding carbonate-bicarbonate shift did not significantly alter the composition of the mine depressurization water when the chemical components were examined. There was no appearance of a precipitate during the bioassays which would indicate the loss of some anions and cations due to the formation of insoluble compounds.

4. DISCUSSION

4.1 ACUTE LETHALITY STUDY

The mine depressurization water was found to be toxic to trout-perch (*Percopsis omiscomaycus*) and rainbow trout (*Salmo gairdneri*).

The results obtained in this study support the findings of McMahon (1976). Lethal concentration values for mine depressurization water from a well identified as (2600S - 4800E) on Syncrude Canada Limited's Lease 17, were 34.7% (13.7 - 89.7) for trout-perch at 15°C and 37.2% (29.4 - 75.5) for rainbow trout at 15°C. Athabasca River water was used to dilute the mine depressurization water. McMahon (1976) concluded that mine depressurization water was slightly more toxic when Athabasca River water was used as the diluent rather than dechlorinated Calgary City water.

A lethal concentration value was obtained by exposure of rainbow trout, acclimated to treated Edmonton City water to different concentrations of a composite mine depressurization water sample. This experiment was conducted by the Environment Canada, Environmental Protection Service, Aquatic Toxicology Laboratory. A static procedure yielded a 96 hour lethal concentration of 54.6 % by volume.

In all of the experiments conducted, the majority of deaths occurred within the first 48 hours. In the two ten-day static experiments, there was no significant mortality after four days of exposure. Fish went into stress immediately after being introduced into the mine depressurization water concentrations. Some hemorrhaging from the gill area was observed in the 100% concentrations.

Chemical components whose toxic action would affect the gills may also be influencing the toxicity. The hemorrhaging may be due to the osmotic effect of high salinity. In the mine depressurization water, significant traces of copper, zinc, nickel and ammonia were detected. The concentrations of copper, zinc and nickel ions by themselves were certainly below lethal levels as determined by McKee and Wolfe (1963). Wilber (1971) indicates that zinc salts cause direct damage to the gill epithelium preventing adequate respiratory exchange. He also adds that

zinc reacts synergistically with copper and nickel. A zinc-nickel combination is stated to be five times more toxic than either chemical individually (Wilber 1971).

Salinity may have been a contributing factor to the toxicity of the mine depressurization water although it is probably not a major toxic component. Although the sensitivity of trout-perch to saline water is not well documented, rainbow trout are known to have a high tolerance to salinity (Conte and Wagner 1965). McMahon (1976), in studies on mine depressurization water concluded that rainbow trout and trout-perch were very sensitive fish species and their sensitivities were similar to Arctic grayling (*Thymallus arcticus*), walleye (*Stizostedion vitreum vitreum*) and mountain whitefish (*Prosopium willaimsoni*).

The mine depressurization water storage test indicated that between 10 days storage and 29 days storage the toxicity to rainbow trout increased. The effluent storage tanks were equipped with floating lids and the temperature of the effluents was maintained at 4°C to minimize evaporation. Examination of the chemical data for the stored sample did not indicate any significant change in the sample with the exception of pH.

The pH of the sample changed from 7.5 to 9.0. The change in pH may be due to the removal of dissolved gases which come out of solution with depressurization (Hall and Kiss 1975) or the breakdown of organic compounds. As the pH became more basic, the amount of un-ionized ammonia would increase. Examination of the chemical data for the storage sample indicated that the un-ionized concentration went from 0.08 to 1.77 mg/ℓ. The un-ionized ammonia concentration of 1.77 mg/ℓ was above the lethal concentration of 0.41 mg/ℓ for rainbow trout (E.P.A. 1972). Ammonia was probably responsible for the increase in toxicity of the mine depressurization.

Trace organic compounds may also have contributed to the toxicity of the mine depressurization water. Analysis for trace organic constituents for a third composite sample and two well samples was conducted by Strosher (1976) (Tables 2 & 3). Further analysis to identify

predominant organic compounds may indicate toxic compounds.

4.2 FIELD TOXICITY LABORATORY

One of the objectives of the project was to determine how a mobile laboratory would function in the study area.

The mobile laboratory functioned adequately when it was located in the Fort McMurray area. The major problem in operating a mobile laboratory was the continual maintenance. The time required to maintain the laboratory operational was double the time required for a normal bioassay facility. The staff were required to drive 30 miles from the campsite to the laboratory over very rough roads. This travel was required twice a day, seven days a week.

In addition to normal laboratory maintenance, the field laboratory required the filling of fuel tanks daily. A security check was required in the evenings in case vandals had shut off the generator. During heavy rains, it was necessary to check the water pump frequently to insure the river had not carried it away.

A laboratory operation in the Fort McMurray area would function more efficiently if the laboratory personnel were lodged in Fort McMurray and the laboratory were tied into the town's water and power supply. For short term studies, a self-sufficient mobile laboratory is ideal. Studies of long term duration require an uninterrupted power supply and a water supply of a relatively constant quality.

During the study period, the water quality of the Athabasca River varied greatly due to some heavy rain storms. The pump for the water intake was located on the river bank; debris carried down the river became entangled with the intake water line and carried the pump along the river bank. The silt load clogged the water reservoir and diluter and made frequent cleaning of the fish holding facilities necessary. After two of the heavier storms, oil droplets appeared in the river water, and at this time, fish mortalities increased. Presumably, the use of treated town water would have reduced or eliminated this problem.

Because storage affected the toxicity of the mine depressurization, the lethal concentration determinations must be conducted as rapidly as possible. Whether the sample is transported to a central laboratory or tested in the field depends on logistic considerations.

5. CONCLUSIONS

1. Lethal concentration studies after 96 hours of exposure show a wide variation in toxicity of mine depressurization water, although all samples produced some mortality at 100% effluent.

2. The chemical composition of the effluent differs widely between wells, and also differs if water from the same well is sampled at different times.

3. Storage of mine depressurization water results in changes which are manifest as changes in the lethal concentration.

4. On-site studies are possible but present considerable practical difficulties.

5. There is no obvious correlation between toxicity and the levels of any constituent of mine depressurization water.

6. SUMMARY

1. Ninety-six hour lethal concentration values of from 21% by volume to 48% by volume were obtained by exposure to trout-perch (*Percopsis omiscomaycus*) seined from the Athabasca River, to different concentrations of mine depressurization water from five wells located on Syncrude Canada Limited, Lease 17. The 96-hour LC_{50}'s for composite samples of these five wells ranged from 35% by volume to 45% by volume. Semi-static and static procedures were used in a mobile laboratory located in Fort McMurray.

2. Ninety-six hour tethal concentrations values of from 20% by volume to 80% by volume were obtained by exposure of rainbow trout (*Salmo gairdneri*) to different concentrations of mine depressurization water from four of the above five wells located on Syncrude Canada Limited, Lease 17. Semi-static procedures were used in the bioassay laboratory in Edmonton. Edmonton City water was used as the diluent.

3. A study using rainbow trout (*Salmo gairdneri*) was performed on a composite site to determine the effect of storage on the toxicity of mine depressurization water. The 96-hour lethal concentrations values ranged from 15.2% by volume to 80% by volume. It was observed that the toxicity of the mine depressurization water decreased for the first 10 days of storage and then increased. Testing was conducted under the continuous flow mode using a modification of a swing-arm diluter.

4. Variations in the chemical composition and toxicity of the mine depressurization atom-water were observed between sample periods and from well to well. It was concluded that toxicity is not due to any one constituent of the mine depressurization atom-water, but a combination of constituents.

7. RECOMMENDATIONS FOR FURTHER WORK

1. Due to changes in the chemical composition and the toxicity of the mine depressurization water, further acute, chronic and sub-lethal studies should be conducted to determine the possible toxic and long-term effects of the mine depressurization water on all life stages of plants, micro-organisms, invertebrates and fish indigenous to this area and, thus, provide information in terms of potential environmental impacts.

2. The chemical composition and toxic effects, acute, chronic and sub-lethal, of the liquid effluents associated with other refinery operations should be documented. Again, these studies should involve all life stages of the indigenous plants, micro-organisms, invertebrates and fish and should utilize the receiving water as the diluent.

3. If any toxic constituents of the mine depressurization water or the whole liquid effluent of other refinery operations in the area, can be identified, further chronic and sub-lethal tests should be conducted to determine the long-term effectson the aquatic biota of the oil sands region.

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