PROGRESS REPORT
75

EXPLOITS RIVER INVESTIGATIONS - 1962

POLLUTION SURVEYS

L. J. Cowley

July, 1963

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RED INDIAN LAKE AND EXPLOITS RIVER

by

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PART ONE

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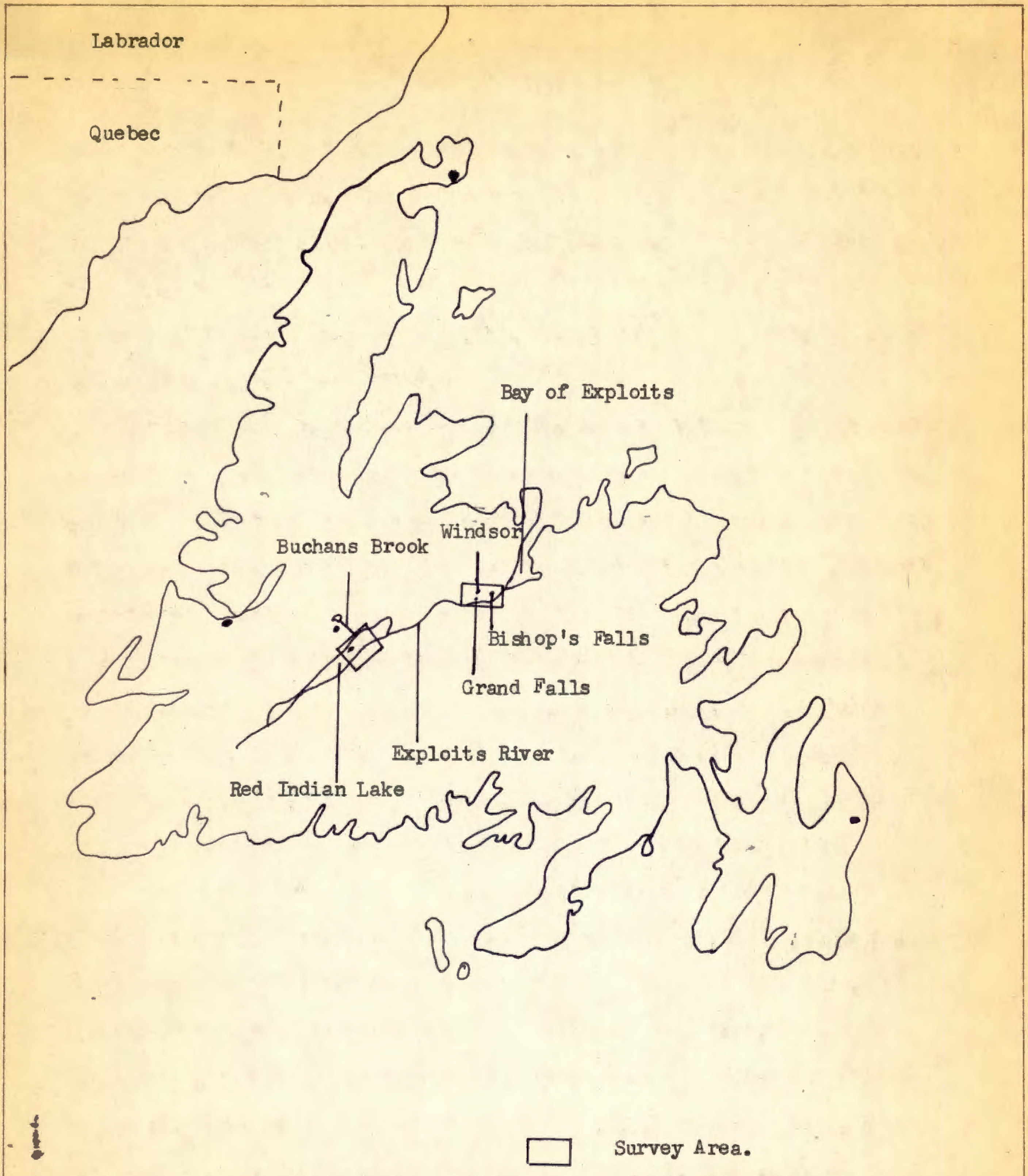
Introduction

During 1962, pollution surveys were carried out on Red Indian Lake and the Exploits River. Red Indian Lake has an area of 73 square miles and is situated on the main stem of the Exploits River. The Exploits is the largest on the Island of Newfoundland and flows in a northeasterly direction into Notre Dame Bay (Fig. 1). Total area of the Exploits River Watershed is 4,300 square miles.

In 1958 a biological survey of approximately 1,300 square miles of the Exploits River Watershed (Red Indian Lake to the Bay of Exploits) was conducted to evaluate the salmon populations frequenting the river and its tributaries; to determine the artificial and natural obstructions, as well as industrial activities which may affect the Atlantic salmon; and finally, to calculate the potential salmon population of the area. The potential population was estimated to be between 25,000 to 50,000. The Exploits presently supports a salmon population of 1,500 - 3,000.

As a result of the 1958 survey, recommendations were made as to further investigation necessary for proper evaluation of the salmon potential of the Exploits. One recommendation was that the effect of industrial and domestic wastes discharged into the Exploits River be investigated as a possible hazard to existing and potential fish life. The results of this investigation form the basis of this report.

The chief source of industrial pollution on the Exploits River is the Anglo-Newfoundland Development Company (A.N.D.) at Grand Falls, a pulp and paper company operating since 1909 (Fig. 2). The company produces both groundwood and sulphite pulp. Untreated domestic sewage is also discharged into the river from the towns of Grand Falls, Windsor and Bishop's Falls. In 1961 a pollution survey was conducted on the



DRAWN:	DEPARTMENT OF FISHERIES, CANADA	DATE:
CHECK:	Fig. 1. Pollution Survey Areas - Red Indian Lake and Exploits River.	SCALE: 1" = 48 mi.
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river below the Grand Falls area. During a limnological survey of Red Indian Lake in 1961 it was discovered that heavy metal wastes discharged into Red Indian Lake might constitute a source of pollution in that body of water, and which might extend to the main river itself. In 1961 a brief survey of this possible pollution problem was conducted. The results of this survey were inconclusive, and further investigation was deemed necessary in 1962. In addition to the mining waste survey in 1962, it was also necessary to collect further data on the effects of pulp mill wastes to the main river.

Mine wastes are discharged into Red Indian Lake by the American Smelting and Refining Company (ASARCO) at Buchans, operators of a lead, copper and zinc concentrating mill. The Company discharges its tailings and mill effluent into Red Indian Lake via Buchans Brook (Fig. 1 and 3).

Detrimental effects of mine waste, pulp mill waste, and domestic sewage on fish life could nullify any development the Department of Fisheries may undertake on the Exploits River, and Red Indian Lake. Thus it is necessary that the degree of pollution be established.

This pollution survey report will be divided into two parts. The first part deals with the effects of mine waste on Red Indian Lake, while the second is concerned with the effects on the river of pulp mill waste, domestic wastes, and mine wastes from Red Indian Lake.

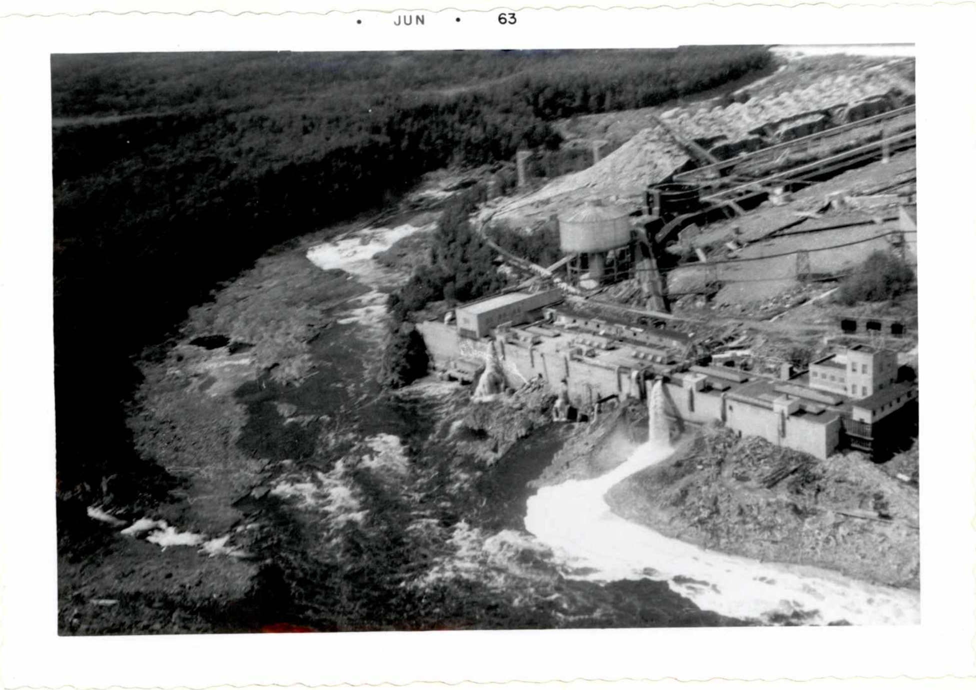

Fig. 2. Partial View of A.N.D. Company Pulp and Paper Mill on the Exploits River. In foreground waste material can be seen entering the river.

Fig. 3. Mine Waste in Red Indian Lake. "X" marks the mouth of Buchans Brook. Summer homes and swimming beach can be seen in the photo.

PART ONE

RED INDIAN LAKE

Materials and Methods

Location of Sampling Stations

Eight sampling stations were established in Red Indian Lake. These were located as follows (Fig. 4):

Station #1 was located at the mouth of Buchans Brook. The waste underwent partial dilution here, but at this Station the waste would have its greatest concentration, excluding the river.

Station #2 was approximately 1.3 miles East southeast of the mouth of Buchans Brook and approximately 300 yards from shore.

Station #3 was approximately 500 yards South of the mouth of Buchans Brook.

Station #4 was approximately 3.0 miles southwest of Buchans Brook and 200 yards East of Buchans Island.

Station #5 was 5.4 miles southwest of the mouth of Buchans Brook and approximately midway between the two shores.

Station #6 was 2.5 miles South from the mouth of Buchans Brook.

Station #7 was located in Buchans Brook, about 1 mile from the mouth. Samples collected in vicinity of bridge on main road into Buchans.

Station #8 was approximately 1.0 miles South of Buchans Brook.

Sampling depths at each Station were as follows:

Station #1 Surface, 5 ft., 7 ft., 10 ft.

Station #2 Surface, 10 ft., 15 ft., 20 ft., 60 ft., 90 ft.

Station #3 Surface, 5 ft., 10 ft., 30 ft., 60 ft.

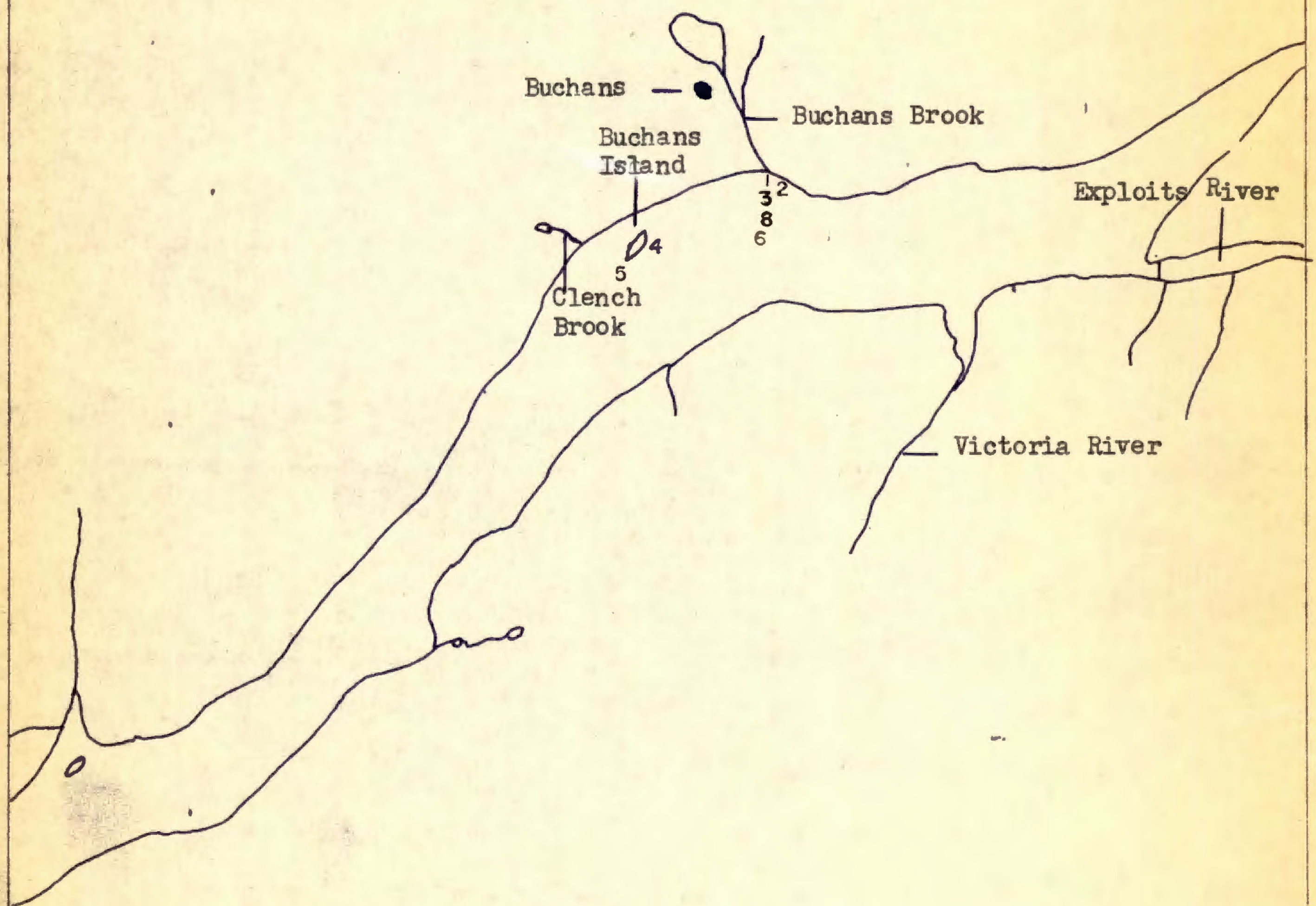

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Fig. 4. Sampling Stations - Red Indian Lake.

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Station #4 Surface, 5 ft., 20 ft., 30 ft., 35 ft., 40 ft., 45 ft., 60 ft.

Station #5 Surface, 20 ft., 30 ft., 60 ft.

Station #6 20 ft.

Station #7 Surface.

Station #8 10 ft.

Sampling depths of 10 ft., 90 ft., and 60 ft. for Stations #1, #2, and #3 respectively were near the bottom.

Surface sampling was anywhere from 1 - 3 ft.

Chemical and Physical Analyses (App. Tables 1, 2 & 3)

The following chemical and physical analyses were carried out:

Dissolved Oxygen - Determinations were carried out according to Miller's Method (Thomas, J.F.J., 1953, Industrial Water Resources of Canada, Water Survey Report No. 1, Canada Department of Mines and Technical Surveys).

Free Carbon Dioxide - Determinations and "Phenolphthalein Alkalinity"were performed as described in Lagler, K.F., 1956.

Temperatures - Were determined using a submergible type electronic thermometer by Applied Research Associates of Texas. A pocket thermometer was also used. Temperatures were primarily taken at the surface since it was found that no noticeable temperature change occurred up to 60 ft.

Copper, Iron, Sulphate, Turbidity, pH - Were determined using Hellige Aqua Analyzer (photoelectric colorimeter) and Hellige Test Procedures.

Total Alkalinity - Was determined using either methyl orange or bromo phenol blue as indicators and 0.02N H_2SO_4 (Lagler, K.F., 1956).

Lead - Was determined using Hellige Lead Testing Outfit, No. 351-DO.

Copper, Zinc, Lead, Iron, $KMnO_4$, Total Hardness, and pH - Determinations were also performed by Mines and Technical Surveys, Ottawa.

Copper, Lead, Zinc - Determinations on Red Indian Lake bottom deposits only were carried out by the provincial Department of Mines and Resources, Newfoundland. All other chemical determinations, except these, are on water samples.

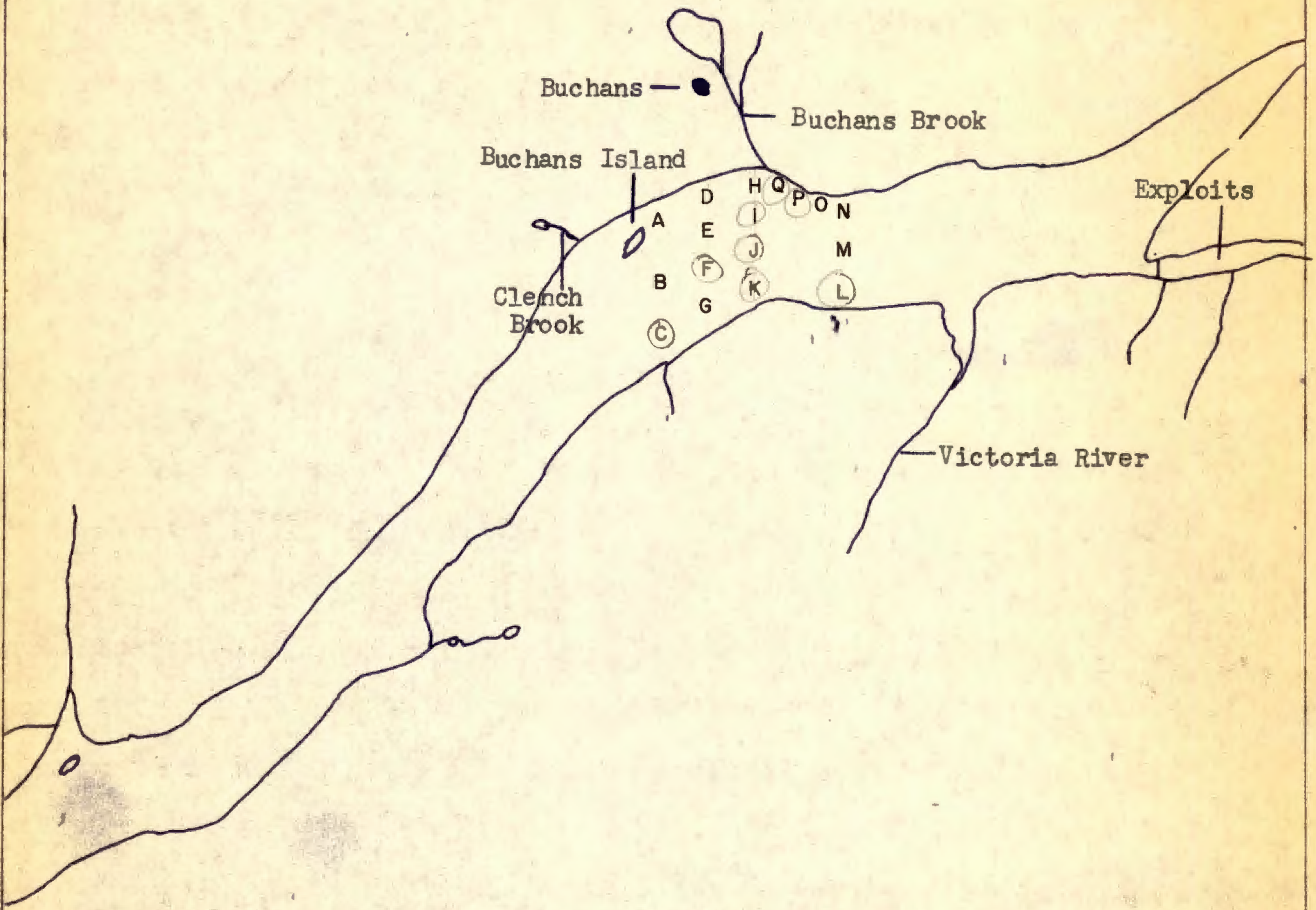
Dredging - Was carried out in seventeen locations in the lake using a Petersen Dredge. These locations are designated alphabetically A-Q (Fig. 5). These dredged samples were examined for macroscopic life as well as chemically for copper, zinc and lead content.

Live Fish Experiment

In addition to regular chemical and physical determinations, live fish were held in cages at three locations to determine the effects of mine waste on two species indigenous to the area, landlocked salmon (*Salmo salar*) and mud trout (*Salvelinus fontinalis*). Fish for the experiment were captured at the mouth of Clench Brook, 4.8 miles southwest of Buchans Brook (Fig. 4). Traps were located at Stations #1, #3, and #4 (Fig. 4). Traps were designated by the Station at which they were located. The trap at Station #1 was guarded by and fastened to the stumps of two trees. At Station #3 the trap was anchored ten to fifteen feet below the water surface. At Station #4 the trap was situated approximately six feet below the surface and guarded by Buchans Island. All traps were so anchored that wave action on the lake could be ruled out as a cause of mortality. Trap sizes were roughly 4' x 3' x 3'.

There were two live fish experiments during the period August 1 - 13. During the first live fish experiment from August 1 - 7:

Trap #1 had one landlocked salmon and four mud trout. Extended from August 1 - August 5.



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CHECK:	Fig. 5. Dredging Locations - Red Indian Lake.	SCALE: 1" = 4 mi.
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Trap #3 had four landlocked salmon. Extended from August 3 - August 7.

Trap #4 had four landlocked salmon. Extended from August 1 - August 5.

During the second live fish experiment from August 7 - August 13:

Trap #1 had five fish - two landlocked salmon and three mud trout. Two mud trout were put in August 7, one mud trout and two landlocked salmon were put in August 9.

Trap #3 had four mud trout from August 9 - August 13.

Trap #4 had four mud trout from August 9 - August 13.

Fish used in both live fish experiments ranged in length from 6 inches to 12 inches.

Fish mortality and survival were calculated on a 96 hour basis.

Traps were visited three times daily, during daylight hours only about four hours apart, except Trap #4 on August 11 and 12, when the lake was too rough.

Netting - Limited netting of the lake in the pollution area was conducted by both the lake survey team and the pollution survey team.

Results and Discussions

Pollution may be defined as the introduction of anything which adversely impairs the use of water for human consumption, commercial or recreational use, or anything deleterious to fish, bird, animal or plant life. There are varying degrees of pollution. What may be harmful for human consumption is not necessarily harmful to fish or plant life. Pollution may be natural or induced. Only the latter is of concern in this report.

Domestic or industrial wastes may be solid, liquid, or gaseous and when discharged to rivers and lakes may exert some or all the following effects:

1. Destroy spawning beds, smother bottom growth, increase turbidity, and reduce light penetration.
2. Deplete oxygen and increase carbon dioxide or other gases to toxic levels.
3. Alter pH.
4. Impair or destroy the gills of fishes: e.g. acids, salts of the heavy metals such as Cu, Zn, Pb, etc.
5. Upset the physiological function of internal organs when absorbed through gills, stomach or body tissues: e.g. hydrogen sulphide, cyanide, ammonia, chlorine, chloramines, etc.

These effects can be either immediate (e.g. destroying the gills of fishes by heavy metals, poisoning with cyanide, etc.), or long term (e.g. the gradual destruction of spawning beds, smothering of bottom growth, decay of bark and fiber, thus affecting dissolved oxygen, etc.).

Mining - Ore mined at Buchans amounts to about 360,000 tons/year and tailings to approximately 260,000 tons/year. The mill normally operates a total of 306 days per year. Appendix 1, Table 4, gives the composition of the ore mined at Buchans.

Ore mined is concentrated by flotation, the useful concentrate being the marketable product, the remainder, "tailings", is disposed of to Red Indian Lake via Buchans Brook. There are no settling basins.

Chemicals used in the flotation process are listed in Appendix 1, Table 5. Of these, analysis was carried out only for copper and zinc sulphate. However, certain qualifications can be made regarding the chemicals and these will be discussed under the heading "Flotation Chemicals".

Chemical Determinations

Copper - Dissolved copper concentrations during the 1962 survey ranged from 0.02 - 0.60 ppm, and total copper from 0.01 - 0.49 ppm. Highest dissolved copper concentrations were recorded at Station #1, up to 0.60 ppm. Beyond Station #1 the highest recorded was 0.16 ppm. Only three dissolved copper determinations were made on Buchans Brook (Station #7) water, the readings were 0.14, 0.40 and 0.04 ppm.

During the 1961 pollution survey on Red Indian Lake, dissolved copper concentrations ranged from 0.02 - 0.05 ppm and total from 0.02 - 0.07 ppm. Sample collection in 1961 was not as extensive as for 1962. Thus a more complete picture is obtained from 1962 sampling.

Analysis of bottom samples (silt) at locations "C", "F","I", "J", "K", "L", "P", "Q", showed (total) copper concentrations of 300 ppm, 1,000 ppm, 350 ppm, 300 ppm, 400 ppm,0.00, 250 ppm, 700 ppm respectively (Fig. 5). Bottom deposits on this range would definitely help to maintain a certain amount of dissolved copper in solution.

Location "L", where no copper or any of the other heavy metals was present, was close to the shore opposite Buchans Brook. Sand was predominent in this location and no silt was evident as at the other locations.

Powers (1917) and Jones (1938) (1939) indicate that cupric chloride and nitrate can be toxic (as Cu) between 0.01 and .02 ppm in soft water. Copper sulphate between 0.1 - 0.8 ppm (probably .025 - 0.2 ppm as Cu) has been reported tolerable or harmful in different waters to the following fish: trout, perch, goldfish, etc., while in concentrations of 1.0 - 4.0 ppm

(0.25 - 1.0 ppm as Cu) has been reported lethal or the maximum safe concentrations for the following: brook and rainbow trout, mummichags (in fresh-water), pike, perch, etc. Copper nitrate in concentrations of 0.18 ppm has been reported lethal to salmon. Sprague and Carson (1963) found that young salmon are killed by .04 ppm of copper and that an avoidance reaction was induced at approximately 0.01 ppm for water of total hardness of 20 ppm. Total hardness of Red Indian Lake waters in pollution areas, except Station #1, in 1961 and 1962 ranged from 8.6 - 9.1 ppm. Station #1 from 22.4 - 39.7 ppm. Red Indian Lake water may be classed as very soft. Hard water reduces the toxicity of heavy metals considerably.

In the River Dove, England, with a copper concentration of 0.12 ppm, animals were severely reduced in number compared to areas above the zone of pollution. It was found that a copper concentration between 0.6 ppm and 1.0 ppm obliterated all animals and had serious effects on the flora.

It can be concluded, therefore, that copper is entering the lake at too high a concentration both in solution and in the silt.

Zinc - Concentrations of dissolved zinc ranged from 0.20 - 0.39 ppm, and total zinc from 0.15 - 5.9 ppm in 1962. In 1961, dissolved concentrations ranged from 0.26 - 0.51 ppm with total zinc between 0.27 - 0.59 ppm. Station #1 had the highest concentrations of dissolved and total zinc, 0.51 ppm and 5.9 ppm respectively. Outside Station #1 the highest amounts were 0.36 ppm dissolved, and 0.36 ppm total. Zinc analysis was not as extensive as that for copper and lead as analysis could not be done in the field.

Analysis of bottom samples at locations "C", "F", "I", "J", "K", "L", "P", "Q", showed zinc at concentrations of 1,200, 2,000, 2,100, 5,000, 2,220, 0.00, 10,000 and 2,100 ppm respectively.

Lloyd (1960) found that in soft water zinc at 0.5 ppm was lethal to rainbow trout, while Goodman (1951) found that 1.0 ppm of zinc was not fatal to 10 - 14 day old rainbow fingerlings. The tests were on a 48 hour basis. He found that 2.4 week old rainbow fingerlings could not tolerate 4 ppm but showed a tendency to develop resistance with age.

Sprague and Carson (1963) found that 0.6 ppm of zinc was fatal to young salmon and that an avoidance reaction was initiated at approximately 0.12 ppm for water of total hardness of 20 ppm.

It can be concluded, therefore, that zinc is in too high a concentration in the area of the lake surveyed.

<u>Lead</u> - Dissolved lead concentrations in 1962 ranged from 0.00 - 1.0 ppm. A plausible explanation for dissolved lead reduced to zero is that it reacts with the sulphate and chloride ions, etc., to form insoluble compounds. Total lead concentrations in 1962 ranged from 0.0 - 3.6 ppm. In 1961 total lead ranged from 0.00 - 0.11 ppm, dissolved lead not determined.

Analysis of bottom samples at "C", "F", "I", "J", "K", "L", "P", "Q", showed lead to be present in concentrations of 3,000, 4,700, 5,000, 2,000, 4,000, 0.00, 5,000, 4,500 respectively.

Carpenter (1926), working on lead polluted rivers, found that fish (fish not specified) held in cages died when lead reached 0.30 - 0.40 ppm at flood times. It is highly probable that zinc shared in the mortalities but methods of detection were not known at that time. In one particular instance it was found that with lead between 0.20 - 0.50 ppm, the river contained only 14 species of animals but, as lead concentrations dropped to 0.10 ppm, species increased to 29. With a further drop in lead concentrations to around 0.02 ppm, at least 103 species of animals were present.

Jones (1938), using sticklebacks (Gasterosteus aculeatus) showed that lead can be decidedly toxic at 0.1 ppm and upwards.

Rainbow trout have been killed in concentrations of 1.0 ppm of lead after 100 hours exposure.

Lead is the least toxic of the three metals, copper, zinc and lead, and its lethal level is probably around 1.0 ppm or higher in Red Indian Lake.

It can be said then that dissolved lead reaches undesirable concentrations in the area surveyed in Red Indian Lake.

From the results of the 1961 and 1962 chemical analyses of Red Indian Lake water, it is apparent that the heavy metal concentrations in solution fluctuate. This is due to variations in mill production, rainfall and wind. Wind is the most important factor; it agitates bottom deposits, bringing metals into solution and suspension.

Heavy metal deposits in the bottom silt in the lake are also extremely high. The possibility exists that the metals at these concentrations, and if in sufficient quantity, could be reclaimed by the mill. It is possible that some of the lake bottom deposits of copper, zinc, and lead are natural deposits.

Iron - Dissolved iron at Station #1 ranged from 0.18 - 0.80 ppm, total iron from 16.9 - .18 ppm. At Stations #2, #3, #4 and #5 dissolved iron range from 0.17 - 0.59 ppm and total iron from 0.04 - 3.94 ppm. Stations #6 and #8 had total determinations only and these were .02 ppm and 0.06 ppm respectively. Station #7, Buchans Brook, had dissolved iron concentrations from 0.25 - 1.95 ppm and total iron readings of 0.60 and 0.62. Total iron for Station #7 of 0.62 ppm and at Station #1, 0.18 and 0.39 ppm, are probably errors. The dissolved iron is most likely correct. The total iron determinations is time consuming and more open to error. A check was not deemed worthwhile.

Doudoroff and Katz (1953) report that some investigations found iron harmful to fish at concentrations of 1.0 ppm and lower. However, sufficient evidence is lacking and it appears that if the pH of the water is tolerable, iron in such quantities just stated is not toxic. In general, the toxicity of iron is little known but in concentrations as has been found in Red Indian Lake it quite possibly has helped to compound the toxic effects of copper, zinc and lead.

Dissolved Oxygen - Dissolved oxygen at Station #1 had a mean saturation value of 85.4% (75-98). The mean dissolved oxygen saturation value at Station #2 was 85.0% (75-91). Only two dissolved oxygen determinations were made at Station #3 and the values were 88 and 89 per cent saturation. Mean saturation values for Station #4 was 89.8% (76-103). At Station #5 only one determination 98%.

Dissolved oxygen value of 60% saturation and above is considered necessary during summer months while 75% saturation is ideal, particularly for game fish.

Thus dissolved oxygen in Red Indian Lake was at satisfactory levels during the survey and mine waste does not appear to affect it to any great degree, if at all.

pH - The initial pH of the mine waste is about 10.5. In Buchans Brook it decreases to a range of 6.6 - 7.5. pH at Station #1 ranged from 6.3 - 7.2, at Station #2: 6.3 - 6.7, Station #3: 6.3 - 6.8, Station #4: 6.3 - 6.9, Station #5: 6.4 - 6.9, and Stations #6 and #8: 6.7 and 6.8 respectively.

These wastes have no effect on the pH of the lake, but do affect Buchans Brook. Fish can tolerate a wide variation in pH from 5.0 - 9.5 (Tarzwell, 1957). The waters of Red Indian Lake during the survey ranged between 6.3 - 7.2, with the majority of the pH readings between 6.4 - 6.8 and rarely above 7.0. Thus this acid nature of Red Indian Lake waters will tend to keep the heavy metals in solution. This acidity is general for Newfoundland surface waters.

Free Carbon Dioxide - Free carbon dioxide concentrations at Stations #1 to #5 ranged from 1.00 - 2.80. These concentrations are within acceptable limits. Free carbon dioxide in excess of 6.0 ppm is usually indicative of organic pollution. Most fish can withstand 30 ppm of this gas, barring other factors (Tarzwell, 1957).

The free carbon dioxide content in Red Indian Lake is most likely the result of natural processes and, even if not, does not create any problems.

Sulphate - Mill wastes are high in sulphate. This, however, appears to rapidly decrease with dilution. Sulphate concentrations in the lake were not recorded above 12.0 ppm, with the majority of readings being between 2.0 - 5.0 ppm. No sulphate readings exceeding 5.5 ppm were recorded beyond 200 yards off the mouth of Buchans Brook.

Sulphate determinations recorded in Red Indian Lake would not be injurious to fish life. In small quantities sulphates are harmless to fish life.

Chemical Reagents - Table 1 lists the chemicals used in the flotation process. No chemical analyses (except for copper, zinc and sulphate) was conducted for these chemicals but certain qualifications can be made concerning them.

Table 1. Chemicals Used in Flotation Process at Buchans

Chemical	Lbs/Ton of Ore	Lbs/Milling Day	Lbs/Milling Year
Sulphur	1.2	1,490	456,000
Sodium Cyanide	.20	248	76,000
Zinc Sulphate	1.6	1,987	608,000
Reagent 301	.13	161.0	49,400
Thiocarbonalid	.06	74.0	22,800
Hydrated Lime	1.76	2,185	668,800
Dow Froth	.014	17.0	5,320
Crycellic Acid	.044	55.0	16,720
Copper Sulphate	.91	1,130	345,800
Isoprapyl Zanthate	.17	211	64,600
Sodium Bichromate	.76	943	288,800
Total		8,501	2,602,240

The chemicals zinc sulphate and copper sulphate would be measured as zinc, copper and sulphate. Sulphate is high in the initial waste discharge, 158 ppm, but is considerably diluted before reaching the lake. Sulphur used in the flotation process is converted primarily to sulphide, however the formation of hydrogen sulphide in any large quantities is unlikely because of the alkalinity of the waste material before it enters the lake, and the formation of insoluble sulphides is sufficient to eliminate any adverse conditions.

Sodium cyanide as cyanide is in too small a quantity to create any problems, however cyanide readily forms complex ions with copper and iron and this greatly reduces its toxicity. Not only is the cyanide toxicity greatly reduced by copper and iron in such a complex but copper and iron toxicity is also substantially reduced (Brown, 1957).

Hydrated lime primarily affects pH. This, if anything, is beneficial as an alkaline medium reduces the toxicity of the heavy metals.

Sodium bichromate as bichromate is toxic in concentrations of 20 ppm or greater (Klein, 1962). It is very unlikely that bichromate in the quantities used in the mill would even be measurable at Station #1.

The remaining chemicals, Reagent 301, Thiocarbanalid, Dow Froth, Crycellic Acid, Isoprapyl Zanthate, are probably not in sufficient quantities to create any significant problems.

These chemicals combined may at times create a hazard to fish life, but their effect would be confined to a very limited area and almost definitely not beyond Station #1. These are not, therefore, a source of serious concern.

Live Fish Experiment

The live fish experiment was designed to show if any substances from mine wastes were present in lethal quantities and the short term effect on fish, even if not present at toxic levels. Fish were held in cages at Stations #1, #3 and #4 from August 1 - 13.

At Station #4 in the first experiment, two fish developed a fungus growth (Saprolegnia parasitica) and died. This was attributed to the handling of the fish which led to the removal of the mucus. No fungus developed on the fish at Stations #1 and #3. This could be due to the heavy metals and suspended silt. During the second live fish experiment, extreme care was used in handling the fish. This time one fish developed fungus at Station #4.

The results of the live fish experiments are given in Table 2. Mortalities were lowest from August 1 - 7 and highest from August 7 - 13. The heavy metals reached their highest concentrations during the period August 7 - 13. Turbidity was also highest during this period.

Out of a total of 10 fish held in live traps at Station #1 from August 1 - 13, five died due to mine waste pollution; out of 8 fish held at Station #3, one died. Mortalities at Station #4 were attributed to fungus growth.

Table 2. Results of Live Fish Experiment from August 1 - 13, 1962. Experiments were for 96 hours.

Stations with Traps	Total No. Fish in Live Traps		Mortalities		Survival Time in Hours	
	Aug. 1-7	Aug. 7-13	Aug. 1-7	Aug. 7-13	Aug. 1-7	Aug. 7-13
Station #1	5	5	1	4	70	7 20 43 90
Station #3	4	4	1	0	43	No Mortalities
Station #4	4	4	2(1)	1(1)	76(1) 91	49-90(2)
Sub-total	13	13	4	5		
Total	26		9			

(1) Mortalities at Station #4 are attributed to fungus growth (Saprelegnia parasiticia).

(2) Accurate survival time not possible as lake too rough to visit trap regularly.

Table 3 shows the concentration of heavy metals, dissolved oxygen and turbidity at various stages during the live fish experiment.

Many more chemical determinations for heavy metals and more live fish experiments would be desirable than was performed to establish exact lethal concentrations and "safe levels", etc. Particularly "safe level" concentration of the heavy metals since this is one of the prime purposes of a survey. However, much more time would be necessary. Sufficient information was obtained to deduce valuable information with the use of the available literature on metal pollution. Lethal concentrations of the metals occur apparently only within the area of

Table 3. Concentrations in ppm of Heavy Metals, Dissolved Oxygen and Turbidity at Various Periods from August 1 - 13, 1962.

Stations	Date	Copper	Zinc	Lead	D.O.	Turbidity
1	Aug. 1	0.05	-	.05	9.4	24.0
	" 2	-	-	-	9.2	-
		.02	-	.05		5.0
		.05		.05	9.3	7.0
	Aug. 3	0.50		0.80	8.3	305
				0.30	9.0	40.0
	" 4			0.60	8.7	145.0
					9.6	12.0
	" 5					33.0
					9.3	15.0
3	Aug. 2	.02		Trace		8.0
	" 3	0.1		0.15		3.0
	" 4			0.20	9.0	7.0
	" 5					16.0
	" 6					3.0
						10.0
					9.4	17.0
						15.0
4	Aug. 1	.05		0.10		5.0
	" 2	.05		0.05		4.5
		.02		0.10		8.0
	" 3			0.15		3.0
				0.10	9.0	3.0
	" 4					5.0
	" 5					2.0
						12.0
1	Aug. 9	0.6		1.0	9.4	500.0
		.07		0.45		174.0
		.02	.1	0.30		500
		.02	.39			175.0
	Aug. 10			0.70		170.0
						105.0
						55.0
3	Aug. 9					8.0
						4.0
		.02(Total)	0.15(Total)	0		8.0
		.01(Total)	0.21(Total)	0		4.0
	Aug. 10					13.0
	" 13	.02(Total)	0.28(Total)	0		5.0
4	Aug. 13	.01(Total)	0.26(Total)	0		5.0

Station #1 and #3, or within a radius of 500 yards of the waste discharge into the lake. Within this area during the live fish experiments, concentrations of copper, zinc and lead as high as 0.6, 0.39 and 1.0 ppm respectively were obtained and turbidity as high as 500 ppm. Outside Station #1 and #3 the highest recorded concentrations of copper, zinc and lead were 0.16, 0.20 and 0.60 respectively. Concentrations of the metals and turbidity could have reached higher concentrations than recorded. Sampling would have to be more frequent to determine this. It is apparent that high concentrations of the metals is correlated with high turbidity. This would be expected.

In the Northwest Miramichi it was found that low concentrations of zinc and copper produced mortality for salmon parr held in cages (Sprague - unpublished data F.R.B.C.). Table 4 outlines their results and a comparison of the range concentrations of the heavy metals in Red Indian Lake.

Table 4. Times to 50% Mortality of Salmon Parr Held in Cages in Northwest Miramichi River and a Comparison of the Results of the Range of Concentration of Heavy Metals Found in Red Indian Lake.

Northwest Miramichi River			Red Indian Lake		
Heavy Metals ppm Averages		ET 50(with 90% confidence limits) in days	Heavy Metal Range ppm in 1962 During Live Fish Experiment		
Zn	Cu		Zn	Cu	Pb
.005	Trace	No death in 4 days	0.10-0.39	0.02-0.60	0.00-1.0
1.3	0.10	50 min. (Approx. est.)			
0.008	0.02	No death in 11 days			
0.89	0.15	2.6 (2.0 - 3.6)			
0.67	0.15	6.5 (Approx. est.)			
0.44	0.09	7.6 (6.0 - 9.6)			

Comparing the metal concentrations and mortalities in the Northwest Miramichi and the heavy metal concentrations in Red Indian Lake, it is most likely that high metal concentrations in Red Indian Lake do not persist very long or mortalities would be expected to be much higher and more rapid, unless there has been a certain acclimitization of the resident fish to the metal pollution. Unfortunately we do not have results as to how long various concentrations of the heavy metals persist in Red Indian Lake, which is an important factor. However, mortalities in the area of Station #1 and #3 are probably insignificant when one considers that the lake covers an area of approximately 73 square miles.

More important than the lethal effects of the metals is probably the sub-lethal effects. On the Northwest Miramichi River, it was observed that adult salmon (Salmo salar) migrated downstream at various heavy metal (copper and zinc) concentrations. These observations resulted in laboratory experiments to determine if this downstream migration was an avoidance reaction to the heavy metals. The experiments revealed that when zinc reached 0.12 ppm it induced avoidance reactions in salmon parr (Salmo salar) and that copper at 0.01 ppm initiated similar reactions. The two metals together caused the same effects but at lower concentrations. Thus on the basis of these experiments and with the observations and water quality data from the Northwest Miramichi, it seemed certain that the heavy metals were impeding migration. Concentrations of the heavy metals that induced downstream migration were generally close to these concentrations that caused avoidance reactions in the laboratory experiments.

A "safe level" or "toxicity index", because of these experiments, has since been established for the Northwest Miramichi. The "safe level" is about 15% of the lethal concentration of the heavy metals. This "safe level" takes into account the change in water quality throughout the year (Sprague - Unpublished data, F.R.B.C.). If, because of metal pollution, salmon migration is impeded to the extent that they do not reach their spawning grounds or spawn successfully elsewhere, this then becomes as serious as direct mortalities from metal pollution.

Indications are that in the Northwest Miramichi unusually large numbers of salmon migrated downstream during 1960, 1961, and 1962, because of the heavy metal pollution and failed to return. These salmon were thus presumed lost from the spawning stock of the river (Saunders - Unpublished data, F.R.B.C.).

It was also found that in the Northwest Miramichi fish food was reduced for about fifteen miles in the river and that fish were scarce in the polluted area.

Thus, knowing the range of heavy metal concentrations in Red Indian Lake and the results of the Northwest Miramichi experiments, it is quite possible that heavy metal concentration in northeast area of the lake are at "unsafe levels". Thus if Atlantic salmon could enter Red Indian Lake they probebly would not because of the mine pollution. More investigation, though, would be necessary before this latter statement could be accepted with any certainty.

Physical Tests

Dredging - Dredging was confined to a small area of the lake. There was a total of seventeen dredgings (Fig. 5). These indicated that the tailings settle out, to a large extent, within a radius of 200 yards of the mouth of Buchans Brook. However, significant quantities have spread over a large area of lake bottom.

Chemical analysis of the bottom deposits of the lake, already discussed, shows a high concentration of copper, zinc and lead. It is not known what the natural concentrations of these minerals in bottom materials might be.

Gross examination of the silt also indicated that no macroscopic life was present.

Netting - Brief netting was carried out by the lake survey team and the pollution survey team during 1961 and 1962 in the pollution survey area. Two landlocked salmon smolts were netted about 700 yards off Buchans Brook. Indications are that fish are not generally found in the pollution area. More netting would be necessary to establish this point definitely. The southwest end regions of Red Indian Lake were shown to support a good fish population.

Turbidity - Turbidity was high in Buchans Brook (Station #7) ranging from 27 - 700 ppm. Readings at Station #1, near the entrance of mine wastes into the lake, ranged from 1 - 500 ppm. Fluctuations in mill production greatly affects turbidity in Buchans Brook, while variations in mill production, run-off, and wind action, increases or decreases turbidity at Station #1. Strong winds agitate mine waste deposits in shallow water. Turbidity at Station #2 ranged from 5 - 60 ppm. At Stations #3, #4, #5, #6 and #8 readings were from 1 - 17 ppm. High turbidity thus seems to be confined to Buchans Brook and Station #1, and was variable at all Stations examined.

The degree of turbidity in the waters outside Station #1 and #3 is not serious to fish life. Brown, 1957, says that "Interference with gill functions ascribable to chemically inert suspended matter as the primary cause or factor apparently can only occur when the concentrations are exceedingly high." Turbidity in the pollution survey area, however, is definitely a detriment to any tourist development or attraction to fishermen. The turbid area is located within the region of the most accessible, and possibly the best, beach on the lake (Fig. 3).

Temperature - Summer temperatures of Red Indian Lake are moderate. Station #1 had an average temperature of 55.6°F (45° - 66°), Station #3 55.8°F (50° - 59°), and Station #4 54.1°F (50° - 59°). At Stations #2, #5, #6, and #8, temperatures were taken irregularly.

These relatively cool temperatures would help to reduce the effects of the heavy metals.

Summary and Conclusions

Dissolved copper, lead, and zinc in Red Indian Lake exist at undesirably high levels in local areas. Bottom deposits of copper, zinc, and lead, are extremely high, and would now most likely maintain dissolved concentrations of the metal at various levels for many years. Within 400 - 500 yards off the mouth of Buchans Brook these dissolved metals may reach lethal concentrations to fish. Beyond this area, it is doubtful if such is ever the case. The literature dealing with toxicity of heavy metals suggests that pollution would be more serious over a wider range. Explanations for this not being so may be (1) high dissolved oxygen content of the water, (2) cool temperatures, and (3) moderate acclimitization of resident fish to the metals. Results for fish not so acclimitized, such as anadromous species, may be different.

Iron concentrations are high, but in themselves most likely not serious. Iron may help to increase the toxicity of the heavy metals. Dissolved oxygen concentrations were adequate. pH fluctuated slightly in the lake but was no cause for concern. The lake is acidic and this would help to bring heavy deposits into solution. The lake's water is very soft. Free carbon dioxide was within acceptable limits, as were the sulphates. Dredgings revealed that bottom deposits of mine tailings are largely confined within 200 yards radius of the mouth of Buchans Brook.

Turbidity, while rarely high beyond Station #1 (and in itself not likely be toxic to fish life), has a detrimental effect on the recreational possibilities of the area.

Temperatures on Red Indian Lake were never high. The waters of the lake may be described as cool.

PART TWO

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PART TWO

EXPLOITS RIVER

Materials and Methods

Location of Sampling Stations

Five sampling stations were established in the Exploits River. These were located as follows (Fig. 1):

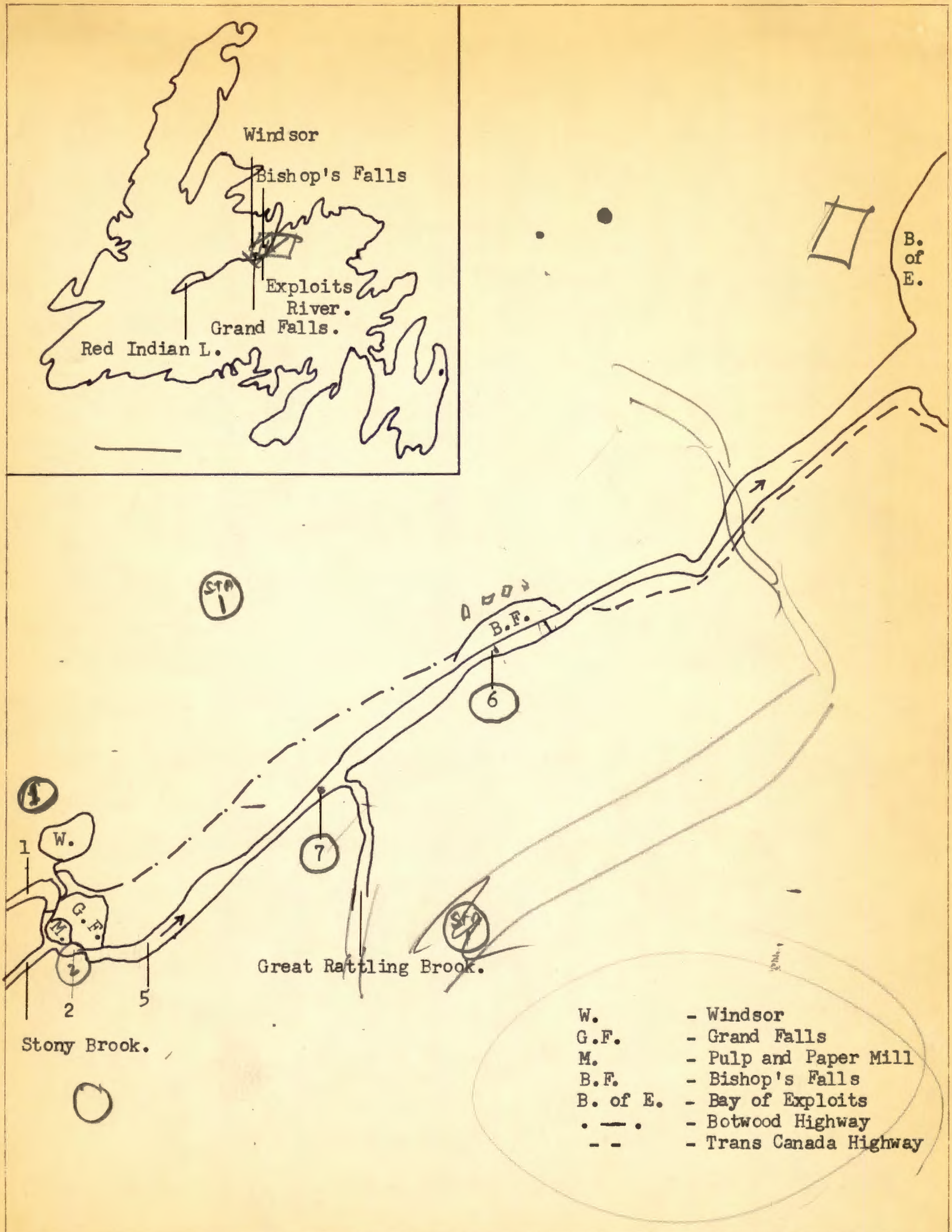
Station #1 was located above the Grand Falls dam and approximately 1.6 miles upstream from the paper mill's waste discharge pipes (North and South sewers), and 2 and 2½ miles upstream from Grand Falls and Windsor domestic sewer outlets respectively. This was the "control" station. Station #1 in 1962 was the same as Station #1 in 1961.

Station #2 was approximately 200 yards downstream from North sewer and approximately 50 yards downstream from South sewer. This Station had the greatest concentration of pulp mill wastes and was the same location as Station #2 in 1961.

Stations #3 and #4 of the 1961 survey were not included in the 1962 survey.

Station #5 was approximately 1,600 yards downstream from the North sewer and approximately 1,425 yards downstream from the South sewer. Grand Falls and Windsor sewage enters the Exploits River approximately 475 and 175 yards respectively upstream from this Station. Shallow rapids existed between Stations #2 and #5. Station #5 was located so as to measure cumulative effect of pulp mill waste and domestic sewage from Grand Falls and Windsor. Station #5 in 1962 was the same as Station #5 in 1961.

Station #6 was approximately ten miles downstream from both the North and South sewers and about one-half mile above the dam at Bishop's Falls. It was expected to indicate the extent pollution extended downstream and



DRAWN:	DEPARTMENT OF FISHERIES, CANADA
CHECK:	
APPROVED:	Fig. 1. Sampling Stations - Exploits River.

DATE:

SCALE: 1" = 2 mi.

DWG. NO.

whether or not any "recovery" was occurring. Station #6 in 1962 was the same as Station #6 in 1961.

Station #7 was approximately 5 miles downstream from both the North and South sewers. This Station was not represented in the 1961 survey, and in 1962 was between Station #5 and #6.

Sampling depths at each Station were as follows:

Station #1	Surface, five feet.
Station #2	Surface, five feet.
Station #5	Surface, five feet.
Station #6	Surface, five, ten feet.
Station #7	Surface, five, ten feet.

Live Fish Experiment

In addition to regular chemical and physical determinations, live fish were held in cages at three locations to determine the gross effects of waste at these sites on adult Atlantic salmon (Salmo salar). Traps to hold the fish were set up at Stations #1, near and downstream from #2, and #5. Station #1 was the control station. Traps measured 4' x 3' x 3' and were anchored about 3 feet below the water surface. The trap at Station #1 had two Atlantic salmon. The trap below Station #2 had two Atlantic salmon. The trap at Station #5 had three Atlantic salmon.

The live fish experiment was conducted for 96 hours. Traps were checked twice daily - morning and afternoon.

Chemical and Physical Analyses (App. Tables 6 & 7)

The following chemical and physical analyses were carried out:

Dissolved Oxygen - Determinations were carried out according to Miller's Method (Thomas, J.F.J., 1953, Industrial Water Resources of

Canada, Water Survey Report No. 1, Canada Department of Mines and Technical Surveys).

Free Carbon Dioxide - Determinations and "Phenolphthalein Alkalinity" were performed as described in Lagler, K.F., 1956, Freshwater Fishery Biology (pp. 254-257).

Temperatures - Were determined when water samples were taken, using an electronic thermometer (Applied Research Associates, Texas) and a pocket thermometer. Temperatures were primarily surface temperatures, as no noticeable difference existed when taken at various depths.

Chlorine - Was determined using Hellige Aqua Analyzer and Testing Outfit No. 955-1.

Copper, Sulphate, Turbidity, pH - Were determined using Hellige Aqua Analyzer (photoelectric colorimeter) and Hellige Test Procedures.

Total Hardness - Was determined by Mines and Technical Surveys, Ottawa.

Total Alkalinity - Was determined by Mines and Technical Surveys, Ottawa.

Lead - Was determined using Hellige Lead Testing Outfit, No. 351-DO.

Copper, Zinc, Lead, Iron, $KMnO_4$, and pH - Determinations were also performed by Mines and Technical Surveys, Ottawa.

Results and Discussions

Production of Pulp

Pulp is produced by two methods at the Anglo-Newfoundland Development Company in Grand Falls. Each method, together with amounts produced, is described below. Sulphite pulp was not produced during the greater part of this survey. Sulphite waste was discharged to the river during another part of this survey in November. This survey in November was primarily for heavy metal determinations.

Groundwood Pulp is manufactured by pressing debarked specified lengths of wood against a showered grooved grindstone, separating the wood fibers into individual fibers or bundles. Thereafter, the stock goes through various screening processes to remove wood and reject unwanted material. There are eighteen grinders and each capable of producing roughly 33 tons of groundwood pulp/day. The Company produces approximately 525 tons of groundwood pulp/day.

Sulphite Pulp is produced by cooking wood chips with sulphuric acid and steam. This separates the cellulose fibers from the lignin. Cooking time is six hours, after which the stock is washed for four or five hours to remove the acids and lignin. Most of the acid is recovered.

There are five digestors, each holding thirty tons of chips and 30,000 gallons of acid. The mill produces approximately 270 tons of sulphite pulp/day.

The total pulp mill waste entering the Exploits River at present is approximately 60,000 u.s.g.p.m. or 3,600,000 u.s.g.p.h. or 86,400,000 u.s.g.p.d. The wastes enter the river through two sewers - the North and South sewers. The North sewer (Fig. 2) has the largest flow, over 50,000 u.s.g.p.m., of which 300 - 400 gallons is sulphite waste liquor; the remaining waste is wash water, water spillage from the wood handling system, and water used to convey bark to the dewatering screens. The South sewer (Fig. 2) discharges small wood fiber, large quantities of service water, and white water spillage. Waste discharge to the river is continuous, twenty-four hours a day, seven days a week.

Total fiber losses at present to the river through the two sewers

Fig. 2. North and South Sewers.

amounts to 15 B.D. tons/day.

Little bark is discharged to the river, 95-98% is burned for steam. However, large quantities are lost from the wood during storage in the river. The A.N.D. Company cuts approximately 325,000 cords annually at present and most is stored in the river at some time before being debarked for use in the mill.

Sulphite waste liquor contains 11-14% solids and this solid material consists of 65-70% calcium lignosulphonate, 20-30% pentoses, and hexose, 6-10% ash chiefly as calcium sulphite and sulphate, as well as polysaccharide, resin and unconsumed calcium bisulphite. Small quantities of formic and acetic acid, methyl and ethyl alcohol, acetone and furfural are present.

Other constituents of waste discharge to the river are minute quantities of thiosulphates, sulphites, free sulphur from the groundwood bleaching process, and sodium hydroxide used in pH control.

The temperature of these waters at time of discharge is approximately 80°F. in summer and 40° in winter.

Mining Wastes

Mining waste is discharged in Red Indian Lake by the American Smelting and Refining Company (Part One pp. 11). Quantities of this waste enters the Exploits River and alters its water quality.

Domestic Sewage

Grand Falls, Windsor (Fig. 1) and the pulp mill, discharge approximately 1,500,000 - 2,000,000 gals/day of domestic sewage to the Exploits River. These are the only sources which discharge any significant quantity of sewage to the river. Accumulation of sewage on the river bed is confined to a very small area in the vicinity of the outfalls.

River Flows and Waste Dilution

Table 1 gives the average recorded monthly outflow in cfs at Grand Falls from October, 1958 - October, 1962. The lowest monthly recorded outflow is rarely below 4550 cfs. In the winter months it may be less than 4550 cfs, down to 3000 cfs. Water levels during the summer months are maintained at a fairly constant level due to regulation with dams by the A.N.D. Company. Thus using 4500 cfs as the lowest recorded average monthly outflow at Grand Falls during the summer months, and the daily discharge of industrial waste (approximately 86,400,000 u.s.g.p.d.) the dilution is approximately 1:34. The dilution factor for sulphite waste liquor when being discharged and for domestic sewage is approximately 1:5900 and 1:1700 respectively.

Table 1. Water Discharge in cfs at Grand Falls on the Exploits River.

Month	1958-59	1959-60	1960-61	1961-62
October	8,650	5,200	6,000	4,840
November	11,100	6,010	5,450	5,260
December	9,320	9,560	4,420	4,150
January	5,200	6,500	4,500	4,110
February	3,180	6,400	3,380	5,230
March	3,670	6,290	2,920	5,040
April	8,700	6,760	5,010	16,000
May	7,100	10,800	12,500	16,700
June	5,730	5,360	8,130	11,100
July	5,360	5,180	4,590	5,430
August	5,400	5,100	4,670	5,300
September	6,010	4,860	4,550	4,540

The foregoing outlines, in general, pulp and paper operations at the Anglo-Newfoundland Development Company, together with a general description of mining and domestic waste discharges which also alter the water quality of the Exploits River.

Live Fish Experiment

The live fish experiment was designed to show if any substances from pulp mill waste, mining waste and domestic waste, or any other wastes, were present in lethal quantities, and the effect of pollution on a short term basis for fish even if not present at toxic levels. The fish were held for 96 hours. More experiments were not considered necessary on the basis of the results, plus the results of the 1961 live fish experiment on the Exploits and the 1962 experiments at Red Indian Lake.

Fish held at Station #1 acted as the "control". Mine waste contamination from Red Indian Lake existed at this Station. Fish held below Station #2 were subject to pulp mill waste (excluding sulphite waste liquor), mine waste, and sewage from the mill. Fish held at Station #5 were subjected to pulp mill waste (excluding sulphite waste liquor), mine waste and domestic sewage from Grand Falls, Windsor and the mill.

General observations indicated that live fish below Station #2 would encounter the greatest concentration of pulp mill waste in their upstream migration, assuming fish avoid the pulp mill waste near the outflow. The river width in the region of the outflow is 300 - 350 feet, the waste is confined to 60 - 70 feet for 300 yards downstream by the flow pattern of the river. It then undergoes rapid mixing and dilution. Since sulphite waste liquor was not being discharged at the time of the survey or fish experiment, it will not be a factor. Sulphite waste liquor primarily effects dissolved oxygen. Itrarely has any direct effect on fish.

The fish held at Station #5 would receive the effect of pulp mill waste, domestic waste from Grand Falls and Windsor, as well as mine pollution.

Dissolved oxygen, pH, total hardness, and heavy metal concentrations at time of experiment are shown in Table 2. Unfortunately, most determinations were for total concentrations of the heavy metals. This was an error and was discovered too late to rectify. Indications are, however, that most of the copper exists in the dissolved state. In 1961 analysis of the river water showed dissolved copper at .02 - .03 ppm. Dissolved zinc from the 1961 survey ranged from 0.14 - 0.22 ppm. Lead in 1961 was not determined.

Table 2. Concentrations in ppm of Dissolved Oxygen, Total Hardness and the Heavy Metals (Total) and pH from August 24 - 26, 1962

Station	Date	D.O.	Total Hardness	Copper	Zinc	Lead	pH
1	Aug. 24	8.9	8.9	0.02	0.18	0.04	6.8
	Aug. 26	9.2	9.4	0.02	0.07	0.09	6.7
			9.4	0.02	0.05	0.16	6.8
				0.01 (Dissolved)	0.10 (Dissolved)	0.03 (Dissolved)	
2	Aug. 25	8.9	10.0	0.01	0.29	0.09	6.7
	Aug. 25		9.9	0.02	0.17	0.09	6.7
5	Aug. 24	8.7	10.4	0.02	0.13	0.02	6.7
	Aug. 26	8.6	11.6	0.03	0.11	0.04	6.5
6	Aug. 25	8.3	11.3	0.02	0.36	0.08	6.5
7	Aug. 25	8.4	11.4	0.04	0.16	0.05	6.6

Fish held in the live traps were evidently unaffected by pulp mill, mine wastes and domestic sewage. Fish appeared lively and showed no ill effects during the experiment. No signs of distress were observable.

Salmon are known, from past and present data, to migrate past Bishop's Falls (between 1,500 - 3,000 fish) to Great Rattling Brook (at least 1200) which is approximately 4 miles above Bishop's Falls and 6 miles below the entrance of the pulp mill waste and domestic waste into the river, and to Stoney Brook which is above the entrance of the pulp mill waste and domestic waste into the river. Thus it appears that pulp mill waste, domestic waste, and mine wastes, have little affect on salmon migration. It is known, however, that young Atlantic salmon have an avoidance reaction for the heavy metals at sub-lethal concentrations (Sprague and Carson, 1963). It was found in laboratory experiments that when zinc or copper alone reached approximately .12 ppm or .01 ppm respectively, an avoidance reaction was initiated in young salmon and the two metals together caused similar effects but at lower concentrations (ibid).

These laboratory results on avoidance reactions were generally in agreement with results in the field, where it was observed that at approximately the same concentrations salmon migrations in Northwest Miramichi, N.B., were upset (Sprague, Unpublished data, F.R.B.C.). This affect on salmon migration could be as serious as mortalities. If salmon fail to reach the spawning grounds or spawn successfully, it has the same effect as a direct kill. Whether the heavy metal pollution from Red Indian Lake effects migratory fish at any time is hard to establish but observations seem to indicate that it does not.

From the 1961 and 1962 live fish experiments, it can be ascertained with certainty that the pulp mill waste and domestic waste in the Exploits River are not lethal to salmon (except,perhaps, in the vicinity of the waste outlets) and do not appear to deter migration. Mining waste also do not reach lethal quantities in the Exploits River in the lower regions and most unlikely in the upper regions (near Red Indian Lake). However, in the upper regions salmon migration could be affected by heavy metal pollution. This, at present, would be hard to ascertain.

Chemical Determinations

Dissolved Oxygen - The dissolved oxygen content of unpolluted streams varies with a number of factors. The more important ones are:

(a) Stream flow, stream fall, and temperature.

(b) O_2 produced by aquatic plants.

(c) O_2 demand of aquatic organisms and organic debris in the stream.

Sulphite waste liquor was not being discharged to the river during the survey, except during a minor survey in November. Thus, only the effects of groundwood pulp mill waste, domestic waste, decaying bark, and debris, etc. on dissolved oxygen could be measured. Determination of the effects of sulphite waste liquor on dissolved oxygen will be possible when the 1961 and 1962 data are compared (Fig. 3).

Dissolved oxygen at Station #1 had a mean saturation value of 90% (87 - 90) or 9.2 ppm (8.9 - 9.6). Only four samples were collected at Station #1 because knowing the dissolved oxygen results for 1961 at this Station, plus the trend indicated by these four samples, it was thought that time could be more usefully spent analyzing the river water in the lower regions of the river. During 1961 at Station #1 the dissolved oxygen mean saturation value was 80% (70 - 90%) or 7.7 ppm (6.5 - 8.7). There is a difference in the mean saturation values. This is probably due to the difference in the size of the samples. More samples were collected during 1961 and over a greater span of time and at a greater variety of water temperatures.

At Station #2 the mean per cent saturation was 89.2% (86 - 97) or 9.1 ppm (8.6 - 10.3). Station #2 location in 1962 was approximately the same as Station #2 in 1961. During 1961, the mean per cent saturation value at Station #2 was 65% (39 - 85) or 6.2 ppm (3.4 - 7.9). Here can be seen the effects of sulphite waste liquor. From these results it can be seen that the other pulp mill wastes, groundwood, wash water, etc., have very little effect on the dissolved oxygen.

The dissolved oxygen at Station #5 had a mean per cent saturation value of 87.7% (84 - 97) or 9.2 ppm (8.6 - 10.3). Station #5 in 1961 had a mean per cent saturation value of 56% (18 - 92) or 5.6 ppm (1.7 - 9.7). Station #5 was the region most affected by pollutants in 1961. The data collected in 1962 indicates that the primary cause of oxygen reduction is the sulphite waste liquor.

Station #6 had a mean saturation value of 83.9% (76 - 94) or 8.5 ppm (7.4 - 9.4). Station #6 in 1961 had a mean saturation value of 72% (45 - 92) or 6.9 ppm (4.2 - 9.0).

Station #7 had a mean saturation value of 87.0% (81 - 90) or 8.8 ppm (8.4 - 9.2). Station #7 does not correspond to any Station in 1961.

On November 28, 29, 30, water samples were collected at Stations #2 and #5. During this period sulphite waste liquor was being discharged to the river. Station #2, during this period, had a dissolved oxygen mean per cent saturation value of 76.7% (75 - 79) or 9.2 ppm (9 - 9.5) and Station #5 had a mean per cent saturation value of 77.0% (75 - 79) or 9.3 ppm (9 - 9.5).

Figure 3 demonstrates the effects of the pulp mill waste and domestic sewage on the D.O. of the river in 1961 compared to the effects of mill waste (excluding sulphite waste liquor) and domestic sewage in 1962. In addition, the effects of pulp mill waste (includes sulphite liquor) and domestic sewage for three days in November of 1962 are indicated. In November samples were not collected from Station #1, the control. It can be seen that in November the sulphite waste liquor does have a depressing

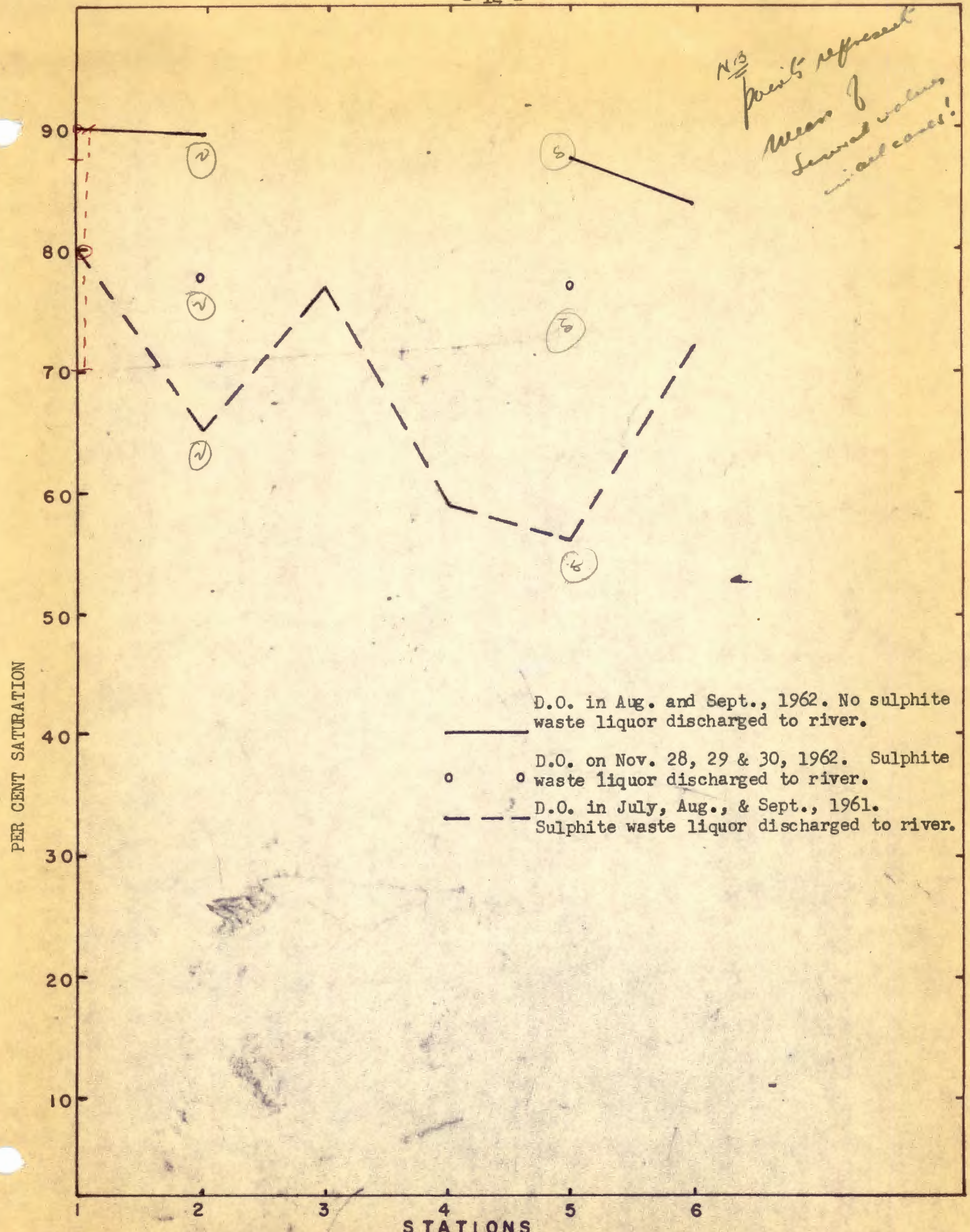


Fig. 3. The Effects of Sulphite Waste Liquor on the Dissolved Oxygen of the Exploits River.

effect on the dissolved oxygen. Figure 3 indicates that in 1962 the dissolved oxygen was slightly depressed from Stations #2 to #6 when compared to Station #1. This is undoubtedly due to the effects of decaying bark, fiber, mill waste water, and domestic sewage. The effect is not serious or of any real concern. However, 1961 values demonstrate that when sulphite waste liquor is discharged to the river it obliterates any other depressing effects on the dissolved oxygen and it becomes the prime factor. Since sulphite liquor waste discharged to the river was only a temporary interruption, conditions approximating those in 1961 will still be the normal occurrence. We know now, however, that sulphite waste liquor is the biggest oxygen depressant and that the other wastes have a very minor effect.

In the 1961 survey, dissolved oxygen of the Exploits River was rarely below 5.0 ppm and never in the 1962 survey. Tarzwell and Gaufin (1953) contend that when a stream D.O. is usually above 5.0 ppm but not below 3.0 ppm for more than a few hours, adverse effects on fish will not occur. The authors further state that, on the basis of their studies and other data, it is believed that for warm water fish population the dissolved oxygen must not fall below 5.0 ppm for more than 8 hours in a 24 hour period, and never below 3.0 ppm.

The Natural Resources Committee (1939) reports that "Lethal levels of dissolved oxygen vary from 0.56 ppm for goldfish to 3.4 ppm at 25°C. for trout. Since respiratory and circulatory compensation, which are distinctly undesirable in fish, begin long before these low levels are reached, the limit given 5.0 ppm seems to be the lowest value which may be reasonably expected to maintain a varied fish fauna". The Washington State Pollution

Control Committee accepts 5.0 ppm as a minimum allowable limit.

On the basis of the 1961 pollution survey, it was concluded that the pulp mill waste and domestic sewage from Grand Falls and Windsor does not have any prolonged serious effect on the D.O. of the river. (Exploits River Investigations - Pollution Survey, 1961 MS Rept.). There are no reasons for changing this conclusion now. It would, however, be desirable to maintain a monitoring program for one or two years when water samples would be collected during summer hot periods and analyzed for dissolved oxygen.

<u>$KMnO_4$ or Oxygen Consumed</u> - This is a test to determine the quantity of oxygen required to oxidize impurities (organic or inorganic) in domestic or industrial wastes. $KMnO_4$ values were determined on nine samples. The values at Station #1 were between 6.3 - 7.0 ppm, during the 1961 pollution survey the values for Station #1 and above Grand Falls were between 4.4 - 5.0 ppm. For Stations #2, #5, #6, #7 the $KMnO_4$ values ranged between 9.1 - 18.4 ppm. For Station #2 and below during the 1961 pollution survey the values were between 11.0 ppm and 14.0 ppm.

$KMnO_4$ value for the pulp mill waste itself is high, up to 570 ppm, which is indicative of a very high organic content. The $KMnO_4$ values for Stations #2 and below indicates that a fair amount of this organic matter is still present in the river but also that there is a good assimilation of the waste with the river water below the plant. As a rule, $KMnO_4$ values for a river should not exceed 3 - 5 ppm. However, the $KMnO_4$ values determined indicate that the organic matter in itself would not have any serious adverse effects on the D.O. of the river. This is substantiated by the dissolved oxygen values obtained during the 1962 pollution survey.

Sulphide (Hydrogen Sulphide) - In the 1961 pollution survey the validity of sulphide concentrations were open to doubt. In 1962 only a few sulphide determinations were carried out because dissolved oxygen was consistently satisfactory and, with a fast flowing river, it is unlikely that sulphide would be produced in detectable quantities.

Analysis of mill waste showed sulphide in concentrations between 0.5 - 1.0 ppm. The mill waste undoubtedly would produce some sulphide but not much. In very small concentrations sulphide odour is easily detected, it was never detected either from mill waste or river during our survey. The small quantities measured in the waste would have no effect on the river, but would undergo substantial dilution or be readily lost in the atmosphere. Analysis of the river water showed no sulphide present. Minute quantities of sulphide may be formed by the decaying organic material but detrimental quantities are formed mostly under anaerobic conditions. The Exploits River is fast flowing with sufficient dissolved oxygen. Both of these factors prevent the accumulation of any significant quantities of sulphide. Therefore, it can be concluded that sulphide is no problem.

Total Hardness - Exploits River water may be described as very soft. Analysis of the water in the summer of 1961 and 1962 showed total hardness ranging between 8.9 - 12.1 ppm. Hard water can considerably reduce the toxicity of the heavy metals. Unfortunately, the total hardness of the water of the Exploits River or Red Indian Lake have little effect on reducing the toxicity of heavy metals.

Copper - Analysis for heavy metals was carried out during two periods in 1962 - August 24 to August 26, and November 29 and 30.

During the period August 24 - 26, the analysis for copper, except for one dissolved determination, was for total copper. Total copper ranged from

.01 ppm to .04 ppm and dissolved copper was .01 ppm. In 1961 dissolved copper was from .02 - .03 ppm. Heavy metal determinations in 1961 were in September.

On November 29 and 30 dissolved copper determinations showed a range from 0.16 ppm to 0.40 ppm. We do not know, but it appears that a heavy discharge of water was occurring from Red Indian Lake. These concentrations are high.

Sprague and Carson (1963) found that dissolved copper at .01 ppm caused an avoidance reaction in young salmon while the lethal concentrations of dissolved copper was estimated at .04 ppm.

The effects of copper at sub-lethal levels in the Exploits River on fish is difficult to ascertain since adequate observations of migrating fish were not possible.

Comparing results of copper concentrations and live experiments in the Exploits River with copper concentrations and live fish experiments in Red Indian Lake, there is little doubt that lethal concentrations of copper do not occur in the Exploits River. It is quite possible, however, that on occasions they reach levels that may initiate a temporary avoidance reaction.

Zinc - Total concentrations of zinc in the Exploits River in 1962 ranged from .05 to 0.36 ppm and a dissolved determination showed 0.1 ppm. In 1961 total zinc ranged from 0.14 ppm - 0.29 ppm, while dissolved zinc ranged from 0.14 ppm to 0.22 ppm.

Experiments with zinc by Sprague and Carson (ibid) has shown that young salmon are killed by zinc at 0.6 ppm and an avoidance reaction is initiated at 0.12 ppm.

Finn (1940) reported mortality of brook trout in contaminated aquarium water with a zinc concentration of 1.0 ppm. Goodman (1951) found that 1.0 ppm of zinc was not fatal to 10 - 14 day old rainbow fingerlings. It thus appears that anywhere from 0.6 - 1.0 ppm of dissolved zinc is lethal to fish. It is very unlikely that concentrations as high as 0.6 ppm of dissolved zinc is ever experienced in the Exploits River. Unfortunately, we know little about the sub-lethal effects of zinc. While the zinc in the Exploits is not lethal, the work of Sprague and Carson (ibid) would indicate possibly adverse effects from zinc on fish.

Lead - Total lead concentrations in the Exploits River from August 24 - 25 ranged from 0.0 - .16 ppm and dissolved lead one determination - .03. On November 29 and 30 dissolved lead ranged from 0.05 - 0.3 ppm.

Lead is the least toxic of the three metals copper, zinc and lead. It is highly unlikely that lead itself in the Exploits River ever reaches toxic levels. This fact is based on the results of Red Indian Lake survey and more particular on the fact that Sprague and Carson (ibid) found that zinc was fatal at 0.6 ppm and thus zinc, being more toxic than lead, lead is probably not toxic before 1.0 ppm if not higher.

Copper, zinc and lead are strongly synergistic. These three metals are found in concentrations in the Exploits River that not only should produce, on times, an avoidance reaction by fish but possibly mortalities. Why abnormal reactions have not been observed in salmon is difficult to explain. A plausible reason might be that there is a strain of salmon in the river resistant to heavy metal pollution. The reaction of hatchery fish (used in live fish experiments in the Northwest Miramichi) to heavy metal pollution could be much more sensitive than that of wild fish or, dissolved metals could exist in a form that is not detrimental. In the lower stretches of the Exploits River heavy metals have undergone substantial dilution. This raises the question as to the effect heavy metal pollution may have on salmon in the upper regions where dilution is much less. The answer to these questions, it would seem, is best answered by bio-assay experiments.

Sulphite - Sulphite determinations were carried out on mill waste when the mill was not producing sulphite pulp merely as a check. During this period sulphite ranged from 0.0 - 8.0 ppm. The majority of readings were zero. Since sulphite affects primarily dissolved oxygen, this amount of sulphite is negligible.

On November 28, 29 and 30, when sulphite pulp was being produced, sulphite ranged from 0.0 - 54.0 ppm. Since this testing was only for a short period and at various intervals during the day, sulphite could have been much higher, undoubtedly it fluctuates between high and low concentrations.

Physical Tests

Turbidity - Turbidity readings of the river water ranged from 3.0 - 11.0 ppm while turbidity of mill waste ranged from 5.0 ppm to 375 ppm. Most of the turbidity is the result of fine fiber.

Irwin, Stevenson and Wallen (1951) have shown that turbidity must be very high to directly harm fish life. In experiments with 16 species of fish they usually observed no behavioural reactions of fish until turbidity reached 20,000 ppm (S_1O_2). "Interference with gill functions ascribable to chemically inert suspended matter as the primary cause or factor, apparently can occur only when the concentrations of suspended matter are exceeding high"..... states Brown (1957). Turbidity, therefore, presents no problems.

Temperature - The water temperature of the river ranged from 46°F - 64°F during the survey.

The temperature of the pulp mill waste ranges from 40°F in winter to 80°F in summer.

Any effects on the temperature of the river water from mill waste is not discernible, except in the immediate area of the waste entrance.

Summary and Conclusions

Live fish held at Stations #1, #2 and #5 demonstrated no ill effects from waste materials.

Dissolved oxygen concentrations during the survey in August and September were not affected to any degree from Stations #2 to #7. This was so because sulphite waste liquor was not being discharged to the river. However, its effect is seen in November when it is again discharged to the river. From the 1961 survey and the November results, it can be concluded that the D.O. of the river is not seriously affected by pulp mill wastes and domestic wastes.

$KMnO_4$ values were within normal limits at Station #1, but were a bit high from Stations #2 to #7. Values for the mill effluent were extremely high, but river values indicate good assimilation of the wastes with the river water.

Sulphide creates no problems in the river.

The heavy metals zinc, copper and lead are probably never at lethal levels but could have sub-lethal effects.

Waste materials do not affect the pH of the river to any great degree.

Turbidity is very low and is unlikely to present problems now or in the future.

Temperature of the water was not altered to any noticeable degree by the various wastes.

In conclusion, it can be said that pulp mill waste, domestic wastes, and mine wastes are never at lethal levels (for fish life) in the Exploits River. There is the possibility of sub-lethal effects for mine waste.

Recommendations

1. It is recommended that bio-assay experiment be carried out to estimate the lethal levels of copper, zinc and lead to fish in the Exploits system, and the concentrations at which avoidance reactions are initiated.

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Appendix

TABLE 1

Chemical and Physical Tests, Red Indian Lake - 1962

Date	Stn.	Depth FT.	Temp.	D.O.	D.O. % Saturation	Free CO_2	SO_4	Turb.	Alk. ph-th	Total Alk.	pH	Copper	Total Iron	Diss. Iron	Lead
July 20	2	S	-	-	-	-	3.9	24.0	0	-	6.6	.12	-	0.30	-
" 20	5	S	-	-	-	-	1.8	3.5	0	-	6.5	.06	-	0.32	-
" 20	1	S	-	-	-	-	4.2	47	0	-	6.5	.06	2.4	0.40	-
" 20	4		-	-	-	-	2.1	1.0	0	-	6.4	.07	-	0.35	-
" 20	1	S	45	-	-	-	-	-	-	-	-	.05	-	-	-
" 20	1	S	50	10.73	94.0	2.5	2.25	6.0	0	-	6.3	.05	-	0.35	-
" 20	1	10	50	9.30	82.0	2.8	5.5	43.0	0	-	6.6	.04	2.33	0.18	-
" 20	2	S	52	10.01	90.0	1.0	5.25	45.0	0	-	6.5	.04	1.95	0.17	-
" 20	2	60	52	9.58	86.0	1.75	4.0	60.0	0	-	6.5	.05	-	0.21	-
" 20	3	S	50	-	-	-	2.5	5.0	0	-	6.4	.04	-	0.12	-
" 20	3	60	-	-	-	-	2.3	96.5	0	-	6.4	0.13	-	0.52	-
" 20	4	S	50.6	10.72	96.0	1.50	2.9	5.0	0	-	6.5	0.16	3.49	0.35	-
" 20	4	60	50.6	11.58	103.0	2.00	3.0	73.0	0	-	6.4	0.10	-	0.26	-
" 20	5	S	49.5	-	-	-	2.2	3.0	0	-	6.4	.05	-	0.28	-
" 20	5	60	-	-	-	-	2.0	4.0	0	-	6.4	.06	1.95	0.23	-
" 21	1	S	51.0	9.58	84.0	2.50	3.0	4.0	0	-	6.4	.07	2.87	0.30	-
" 21	1	7	51.0	8.58	77.0	2.25	2.0	7.0	0	-	6.3	0.14	-	0.28	-
" 21	2	S	51.0	10.15	91.0	1.60	3.8	10.0	0	-	6.3	.06	-	0.30	-
" 21	2	20	51.0	9.30	83.0	2.00	3.3	11.0	0	-	6.5	.06	-	0.30	-
" 21	3	S	52.0	-	-	-	2.2	3.5	0	-	6.4	.07	3.94	0.35	-
" 21	3	S	-	-	-	-	3.4	10.0	0	-	6.3	0.12	-	0.30	-
" 21	4	S	52.5	9.73	88.0	2.00	3.8	5.0	0	-	6.6	.05	-	0.40	-
" 21	4	35	52.5	8.44	76.0	1.70	4.6	13.0	0	-	6.5	.06	-	0.40	-
" 21	5	S	52.0	-	-	-	4.3	5.0	0	-	6.4	.06	-	0.37	-
" 21	5	60	-	-	-	-	3.0	5.0	0	-	6.4	.15	-	0.28	-
" 22	7	S	-	-	-	-	5.3	-	-	-	6.6	.14	-	-	-
" 23	1	S	50.0	-	-	-	-	23.0	-	-	6.5	-	-	-	-
" 23	2	S	-	-	-	-	3.0	50.0	-	-	6.5	.10	0.55	0.37	-
" 23	3	S	-	-	-	-	-	7.0	-	-	6.4	-	-	-	-
" 23	7	S	-	-	-	-	-	27.0	-	-	6.9	-	0.60	0.40	-
" 24	1	10	51.0	-	-	-	-	6.0	-	-	6.7	.02	-	0.40	-
" 24	2	90	52.0	-	-	-	-	6.0	-	-	6.4	.05	-	0.35	-
" 24	3	60	51.0	-	-	-	2.6	6.0	-	-	6.5	.02	-	0.35	-
" 24	4	30	50.0	-	-	-	-	5.0	-	-	6.3	-	0.47	-	-

All concentrations are in p.p.m. unless otherwise specified.

Date	Stn.	Depth Ft.	Temp.	D.O.	D.O. % Saturation	Free CO_2	SO_4	Turb.	Alk. ph-th	Total Alk.	pH	Copper	Total Iron	Diss. Iron	Lead
July 24	5	30	50.0	-	-	-	-	5.0	-	-	6.4	0.02	-	0.30	-
" 24	Millertown Area	S	-	-	-	-	-	-	-	-	6.7	-	0.25	0.19	-
" 25	1	S	55.0	-	-	-	-	16.0	0	-	6.7	-	-	-	-
" 25	2	S	56.0	-	-	-	-	5.0	0	-	6.7	0.02	0.72	0.59	-
" 25	3	S	55.0	-	-	-	-	4.0	0	-	6.6	0.02	-	-	-
" 25	5	S	54.0	-	-	-	-	3.0	0	-	6.9	0.02	0.58	0.48	-
" 25	7	S	-	-	-	-	2.0	700	0	-	7.3	0.40	0.62	1.95	-
" 25	7	S	-	-	-	-	-	112.0	-	-	7.0	0.04	-	0.90	-
" 25	1	5	59.3	-	-	-	-	9.0	-	-	6.7	-	-	0.72	-
" 25	3	30	59.3	-	-	-	-	2.5	-	-	6.7	-	-	-	-
" 25	4	45	59.0	-	-	-	-	3.5	-	-	6.7	-	-	-	-
July 26	1	S	57.0	7.87	75.0	-	-	-	-	-	-	-	-	-	-
" 26	2	15	54.0	8.15	75.0	1.5	-	-	-	-	6.6	-	-	-	-
" 26	3	10	54.0	9.58	88.0	1.3	-	-	-	-	6.6	-	-	-	-
" 26	4	40	53.0	9.44	86.0	1.4	-	-	-	-	6.5	-	-	-	-
" 26	5	60	52.0	10.73	98.0	1.4	-	-	-	-	6.6	-	-	-	-
" 26	1	S	56.0	8.58	82.0	1.6	-	-	-	-	6.6	-	-	-	-
" 26	7	S	-	-	-	-	-	484	-	-	7.5	-	-	0.25	-
Aug. 1	4	30	54.0	-	-	-	-	5.0	-	-	6.6	0.05	-	0.28	0.10
" 1	1	5	54.0	9.4	86.0	-	-	24.0			6.8	0.05	-	-	.05
" 2	1	S	54.0	9.2	85.0	-	-	-	-	-	-	.05	-	-	-
" 2	1	S	54.0	-	-	-	-	5.0	-	10.0	6.6	.02	0.39	0.35	.05
" 2	4	5	54.0	-	-	-	-	4.5	-	-	6.6	.05	-	0.33	.05
" 2	1	S	55.0	9.3	87.0	-	-	7.0	-	-	6.7	.05	-	0.23	.05
" 2	3	S	55.0	-	-	-	-	8.0	-	-	6.7	.02	-	0.23	0
" 2	4	S	54.0	-	-	-	-	8.0	-	-	6.7	.02	-	0.20	0.10
" 3	1	S	55.0	8.3	78.0	-	-	305	-	7.0	6.7	0.50	-	-	0.80
" 3	3	5	55.0	-	-	-	-	3	-	-	6.5	0.10	-	-	0.15
" 3	4	5	54.0	-	-	-	-	3	-	-	6.6	0.10	-	-	0.15
" 3	1	S	57.0	9.0	86.0	-	-	40.0	-	9.0	6.9	-	-	-	0.30
" 3	3	5	58.0	9.0	86.0	-	-	7.0	-	-	6.6	-	-	-	0.20
" 3	4	5	59.0	9.0	85.0	-	-	3.0	-	-	6.6	-	-	-	0.10
" 4	1	S	62.0	8.72	88.0	-	-	145.0	-	-	6.9	-	-	-	0.60

Date	Stn.	Depth Ft.	Temp.	D.O.	D.O. % Saturation	Free CO_2	SO_4	Turb.	Alk. ph-th	Total Alk.	pH	Copper	Total Iron	Diss. Iron	Lead
Aug. 4	3	5	58.0	-	-	-	-	16.0	-	-	6.8	-	-	-	-
" 4	4	5	57.0	-	-	-	-	5.0	-	7.0	6.6	-	-	-	-
" 4	1	S	62.0	9.6	98.0	-	-	12.0	-	-	6.9	-	-	-	-
" 5	1	S	-	-	-	-	-	33.0	-	-	6.8	-	-	-	-
" 5	3	5	-	-	-	-	-	5.0	-	-	6.8	-	-	-	-
" 5	4	5	-	-	-	-	-	2.0	-	7.5	6.7	-	-	-	-
" 5	1	S	58.0	9.3	90.0	-	-	150	-	10.0	6.8	-	-	-	-
" 5	3	5	57.0	-	-	-	-	10.0	-	-	6.8	-	-	-	-
" 5	4	5	56.0	-	-	-	-	12.0	-	-	6.8	-	-	-	-
" 6	3	S	58.0	9.2	89.0	-	-	17.0	-	-	6.8	-	-	-	-
" 6	3	5	58.0	-	-	-	-	15.0	-	9.0	6.7	-	-	-	-
" 6	3	5	58.0	-	-	-	-	-	-	-	6.7	-	-	-	-
" 7	1	S	62.0	8.6	87.0	-	-	580	-	-	7.3	-	-	-	-
" 8	7	S	-	-	-	-	-	105	-	-	7.1	-	-	-	-
" 8	7	S	-	-	-	-	-	97.0	-	-	7.2	-	-	-	-
" 9	1	S	57.0	9.4	90.0	-	-	500	-	-	7.4	0.6	-	0.35	1.0
" 9	3	5	58.0	-	-	-	-	8.0	-	-	6.7	-	-	-	-
" 9	1	S	57.0	-	-	-	-	174.0	-	-	6.9	.07	-	.80	0.45
" 9	3	10	58.0	-	-	-	-	4	-	8.0	6.7	-	-	-	-
" 10	1	S	57.0	-	-	-	-	170	-	-	7.2	-	-	-	0.7
" 10	3	10	59.0	-	-	-	-	13.0	-	8.0	6.8	-	-	-	-
" 10	1	S	66.0	-	-	-	-	105	-	10.5	7.0	-	-	-	-
" 10	1	S	-	-	-	-	-	55	-	15.0	-	-	-	-	-

TABLE 2

ANALYSIS OF WATER SAMPLE(S)
(In parts per million)

Location	near Buchans, Newfoundland		
Source of Water	Red Indian Lake		
Fisheries Station No.	1	1	2
Sampling point	At surface at 1200 hrs.	At surface at 1500 hrs.	At 10' depth at 0845 hrs.
Reference	Dept. of Fisheries, Newfoundland Area.		
Laboratory number	8970	8971	8972
Date of sampling	Aug. 9/62	Aug. 9/62	Aug. 13/62
Storage period (days)	42:43	42:43	38:39
Temp. at sampling (°C)	13.9	13.9	14.4
Temp. at testing (°C)	25.6	25.7	25.7
Oxygen consumed ($KMnO_4$)	4.0	6.6	6.2
pH	7.1(7.1)	7.0(6.9)	6.5(6.7)
Turbidity (Units)	500.	175.	5
Alkalinity as $CaCO_3$ (-Phenolphthalein	0.0	0.0	0.0
(-Total	21.9	16.5	4.5
Conductance, micromhos at 25°C.	98.5	54.8	28.2
Hardness as $CaCO_3$ (Total	39.7	22.6	9.3
(Non-carbonate	17.8	6.1	4.8
Iron (Fe) Total	16.9	3.7	0.04
	Total / Diss.	Total / Diss.	Total
Copper (Cu)	0.49 / 0.02	0.10 / 0.02	0.02
Zinc (Zn)	5.9 / 0.1	1.1 / 0.39	0.24
Lead (Pb)	3.6 / 0.3	0.82 / -	< 0.01

Source of Water	Red Indian Lake		
Fisheries Station No.	3	3	3
Sampling point	At 5' depth at 0845 hrs.	At 5' depth at 1200 hrs.	At 30' depth at 1500 hrs.
Laboratory number	8973	8974	8975
Date of sampling	Aug. 13/62	Aug. 9/62	Aug. 9/62
Storage period (days)	38:39	42:43	42:43
Temp. at sampling (°C)	14.4	14.4	14.4
Temp. at testing (°C)	25.6	25.6	25.7
Oxygen consumed ($KMnO_4$)	5.9	5.9	6.1
pH	6.4(6.8)	6.6(6.7)	6.5(6.7)
Turbidity (Units)	5	8	4
Alkalinity as $CaCO_3$ (-Phenolphthalein	0.0	0.0	0.0
(-Total	4.4	4.6	4.2
Conductance, micromhos at 25°C.	28.2	28.4	27.3
Hardness as $CaCO_3$ (Total)	8.9	9.2	8.9
(non-carbonate	4.5	4.6	4.7
Iron (Fe) Total	0.05	0.05	0.05
	Total	Total	Total
Copper (Cu)	0.02	0.02	<0.01
Zinc (Zn)	0.28	0.15	0.21
Lead (Pb)	0.0	0.0	0.0

Source of water		Red Indian Lake				
Fisheries Station No.		4	5	6		8
Sampling point		At 20' depth at 0800 hrs.	At 20' depth at 0815 hrs.	At 20' depth at 0830 hrs.		1 mile from mouth of Buchans Brook at 10' depth
Laboratory number		8976	8977	8978		8979
Date of sampling		Aug. 13/62	Aug. 13/62	Aug. 13/62		Aug. 10/62
Storage period (days)		38:39	38:39	38:39		41:42
Temp. at sampling (^{o}C)		14.4	14.4	14.4		15.0
Temp. at testing (^{o}C)		25.7	25.6	25.5		25.6
Oxygen consumed ($KMnO_4$)		6.0	6.0	6.1		7.0
pH		6.4(6.7)	6.6(6.6)	6.4(6.7)		6.5(6.8)
Turbidity (Units)		5	4	5		5
Alkalinity as $CaCO_3$	(-Phenolphthalein	0.0	0.0	0.0		0.0
	(-Total	4.4	4.0	4.1		4.1
Conductance, micromhos at 25^{o}C.		26.6	27.0	26.8		25.3
Hardness as $CaCO_3$	(Total	8.8	8.6	9.1		9.0
	(Non-carbonate	4.4	4.6	5.0		4.9
Iron (Fe)	Total	0.05	0.05	0.02		0.06
		Total	Total	Total	Diss.	Total
Copper	(Cu)	0.01	0.02	0.02		0.01
Zinc	(Zn)	0.26	0.37	0.26	0.20	0.30
Lead		0.0	0.0	0.08	0.02	0.0

DEPARTMENT OF MINES, AGRICULTURE AND RESOURCES

MINES BRANCH - ASSAY LABORATORY

TABLE 3

Assay Laboratory Report on Bottom Deposits - Red Indian Lake.

Results of Analyses:	Concentration in parts per million			
Sample No.	Location	Copper	Zinc	Lead
3	C	300	1,200	3,000
6	F	1,000	4,700	2,000
9	I	350	2,100	5,000
10	J	300	5,000	2,000
11	K	400	2,200	4,000
12	L	0.00	0.00	0.00
16	P	250	10,000	5,000
17	Q	700	2,100	4,500

TABLE 4.

Composition of Ore Mined at Buchans

Suspected pollution Red Indian Lake
From ASARCO, Buchans.

Sewage Disposal - Into Brook about 3½ to 5 miles from lake. This flows through one 12" sewer, never more than 1/3 full at peak hour (5:00 p.m.). No treatment.

Water requirements

Townsite	250,000 gal/day.
Mill	1,500,000 gal/day.

Tailings 260,884 short dry tons/year.

Ore		Used
$BaSO_4$	-	45.9%
SiO_2	-	23.8%
Al_2O_3	-	5.1%
CaO	-	1.8%
Gold	-	.010
Silver	-	.87 oz.
Copper	-	.09%
Lead	-	.42%
Zinc	-	1.23%
Iron	-	3.5%

TABLE 5

Flotation Chemicals

Flotation Chemicals in lbs/ton of original ore
Sulphur - 1.2 lb.
Sodium Cyanide - .2 lb.
Zinc Sulphate - 1.6 lb.
Reagent 301 - Butylalcohol, Carbon bisulphide, sodium hydroxide - .13 lbs.
Thiocarbanalid - .06 lb.
Hydrated lime - 1.76 lb.
Dowfroth - .014
Crycillic Acid - .044 lb.
Copper Sulphate - .91 lb.
Isopropyl Zanthate - .17 lb.
Sodium Bechromate - .76

pH of tailings - 10.5 pH water used 7

There is a duty rebate received on Reagents as they are considered to be going out of the country on the ore.

There are no settling basins.

No milling on Sunday, therefore no tailings after 8:00 a.m. Sunday.

Milling days, 1960 - 306.

TABLE 6

Chemical and Physical Tests, Exploits River - 1962

Date		Stn.	Depth	Temp.	D.O.	D.O. % of Saturation	Free CO_2	Chlor-inity	S	SO_3	SO_4	Turb.	Total Alkalinity	pH	Cu	Pb
Aug.	22	2	S	59	8.9	87.0	2.5	-	0	0	0.9	5	-	6.7	-	-
"	22	2	5	59	-	-	-	-	0	0	0.9	-	-	-	-	-
"	22	2	S	59	-	-	-	-	-	-	-	-	-	6.8	-	-
"	23	2	S	59	9.2	91.0	2.0	-	-	-	-	-	-	6.7	-	-
"	23	2	5	58	8.9	86.0	2.0	-	-	-	-	-	-	6.7	-	-
"	23	5	S	58	8.9	86.0	2.0	-	-	-	-	-	-	6.7	-	-
"	23	5	5	58	8.8	84.0	1.6	-	-	-	0.9	-	-	6.7	-	-
"	23	NS		60	-	-	-	-	-	22.0	8	55	-	5.0	-	-
"	23	SS		72	-	-	-	-	-	0	4.8	60	12.0	6.8	-	-
"	23	7	S	59	9.0	88.0	2.0	-	-	-	-	-	-	6.6	-	-
"	23	7	10	59	9.2	90.0	2.2	-	-	-	-	-	-	-	-	-
"	23	6	S	59	9.2	90.0	2.0	-	-	-	-	-	-	6.5	-	-
"	23	6	10	59	8.9	87.0	2.0	-	-	-	-	-	-	-	-	-
"	24	1	5	57	9.2	88.0	-	-	-	-	2.0	-	-	-	-	-
"	24	5	5	58	9.6	93.0	1.7	-	-	-	-	7.0	-	6.6	-	-
"	24	NS	S	60	-	-	-		0.5 to 1.0	8.0		68	2.0	5.1	-	-
"	24	SS	S	70	-	-	-	-	0.5	-	-	47	10.0	6.6	-	-
"	24	NS	S	64					0.5 to 1.0	0	-	68	7.5	5.0	-	-
"	24	SS	S	74	-	-	-	-	0.5 to 1.0	0	-	105	8.0	6.6	-	-
"	24	7	S	60	9.0	90.0	1.8	-	-	-	-	-	-	6.6	-	-
"	24	7	5	60	8.9	89.0	1.8	-	-	-	-	-	-	6.6	-	-
"	24	6	S	59	8.6	85.0	3.2	-	-	-	-	-	-	6.5	-	-
"	24	6	5	59	8.7	85.0	3.0	-	-	-	-	-	-	6.6	-	-
"	24	NS		-	-	-	-	-	-	0		60.0	-	4.1	-	-
"	24	1	S	-	8.9	87.0	-	-	-	-	-	-	-	-	-	-
"	24	5	S	-	8.7	85.0	-	-	-	-	-	-	-	-	-	-
"	24	SS		-	-	-	-	-	-	0	-	55.0	-	6.3	-	-
"	25	NS		65	-	-	-	-	-	5.5	-	43.0	-	4.1	-	-
"	25	SS		74	-	-	-	-	-	0	-	90.0	-	6.8	-	-
"	25	7	S	58	8.7	84.0	2.0	-	-	-	-	-	-	6.7	-	-

All concentrations in p.p.m. unless otherwise specified.

Date	Stn.	Depth	Temp.	D.O.	D.O. % of Saturation	Free CO_2	Chlor-inity	S	SO_3	SO_4	Turb.	Total Alkalinity	pH	Cu	Pb
Aug. 25	7	5	58	8.4	81.0	1.2	-	-	-	-	-	-	-	-	-
" 25	6	S	58	8.3	80.0	2.5	-	-	-	-	-	-	6.5	-	-
" 25	6	5	58	8.3	80.0	2.8	-	-	-	-	-	-	-	-	-
" 25	NS		64	-	-	-	-	-	0	-	60	-	4.7	-	-
" 25	SS		74	-	-	-	-	-	0	-	115	-	6.3	-	-
" 25	6	5	61	9.3	94.0	3.0	-	-	-	-	7.0	7.0	6.5	-	-
" 25	7	5	61	8.7	87.0	1.9	-	-	-	-	7.0	7.0	6.6	-	-
" 25	2	S	62	8.9	91.0	1.4	-	-	-	-	3.0	-	-	-	-
" 25	2	5	62	-	-	-	-	-	-	-	5.0	8.0	6.7	-	-
" 25	2	S	62	-	-	-	-	-	-	-	3.0	-	6.7	-	-
" 25	NS		64	-	-	-	-	-	-	-	52	-	4.2	-	-
" 25	SS		76	-	-	-	-	-	-	-	75	-	6.5	-	-
" 26	2	S	61	8.6	86.0	2.7	-	-	-	-	7.0	-	6.6	-	-
" 26	5	5	61	8.6	86.0	3.0	-	-	-	-	11.0	9.0	6.5	-	-
" 26	NS		-	-	-	-	-	-	-	-	58.0	-	4.3	-	-
" 26	SS		-	-	-	-	-	-	-	-	50.0	-	6.5	-	-
" 26	1	S	62	9.2	95.0	1.8	-	-	-	-	5.0	-	6.7	-	-
" 26	1	5	62	-	-	-	-	-	-	-	5.0	-	6.8	-	-
Aug. 27	2	S	63	8.6	87.0	1.2	-	-	-	-	-	-	6.5	-	-
" 27	2	S	63	8.6	87.0	1.3	-	-	-	-	-	-	6.5	-	-
" 27	2	S	63	8.6	88.0	1.2	-	-	0	1.0	8	8.0	6.5	-	-
" 27	2	S	63	-	-	-	-	-	0	1.0	10	-	6.5	-	-
" 27	NS		64	-	-	-	-	-	3.0	-	320	-	4.6	-	-
" 27	NS		64	-	-	-	-	-	4.2	22.0	-	-	4.5	-	-
" 27	NS		64	-	-	-	-	-	5.5	-	72.0	-	4.7	-	-
" 27	NS		64	-	-	-	-	-	3.0		375	2.0	3.8	-	-
" 27	NS		64	-	-	-	-	-	5.5	23.5	-	-	2.5	-	-
" 27	NS		64	-	-	-	-	-	8.0	19.0	-	-	1.0	-	-
" 27	SS		75	-	-	-	-	-	0	19.0	84.0	-	6.5	-	-
" 27	SS		75	-	-	-	-	-	0	19.0	115?	4.0	-	-	-
" 27	6	5	63	7.6	78.0	3.2	-	-	0	19.0	6	-	6.4	-	-
" 27	6	S	63	7.4	76.0	3.1	-	-	0	19.0	7	9.0	6.2	-	-
" 28	NS		-	-	-	-	-	-	-	-	5	-	6.6	-	-
" 28	SS		-	-	-	-	-	-	-	-	5	-	7.0	-	-

Date	Stn.	Depth	Temp.	D.O.	D.O. % of Saturation	Free CO_2	Chlor-inity	S	SO_3	SO_4	Turb.	Total Alkalinity	pH	Cu	Pb
Aug. 28	1	S	-	-	-	1.8	-	-	0	-	4	-	6.8	-	-
" 28	2	S	63	8.6	88.0	1.8	-	-	0	-	5	10.0	6.8	-	-
" 28	5	S	63	8.6	88.0	1.4	-	-	0	-	4	-	6.9	-	-
" 30	7	S	-	-	-	-	-	-	-	21	5	-	6.6	-	-
" 30	6	S	-	-	-	-	-	-	-	22	4	-	6.6	-	-
" 30	NS		-	-	-	-	-	-	-	20	5	-	6.7	-	-
" 30	SS		-	-	-	-	-	-	-	20	6	-	6.8	-	-
Sept. 5	2	5	-	10.3	-	1.5	-	-	-	-	-	-	6.8	-	-
" 5	5	5	-	10.3	-	1.3	-	-	-	-	-	-	6.8	-	-
" 7	1	5	55	9.6	90.0	1.0	-	-	-	5	-	-	6.8	-	-
" 7	2	5	55	10.3	97.0	1.1	-	-	-	0	-	-	6.8	-	-
" 7	5	5	55	10.3	97.0	0.9	-	-	-	0	-	-	6.6	-	-
Nov. 27	SS	S	62	-	-	-	0	-	0	-	-	-	6.5	0	0.1
" 27	NS	S	47	-	-	-	.03	-	33	-	-	-	-	-	-
" 27	SS	S	60	-	-	-	0	-	0	-	-	-	6.2	0	.05
" 27	NS	S	46	-	-	-	.03	-	34.5	-	-	-	1.9	0.1	0.3
" 27	SS		-	-	-	-	-	-	-	-	-	-	6.3	0	-
" 27	NS		-	-	-	-	-	-	-	-	-	-	1.9	0	0.4
" 28	SS	S	60	-	-	-	0	-	0	-	-	-	-	-	-
" 28	NS	S	46	-	-	-	0	-	10	-	-	-	2.1	0.15	0.1
" 28	2	S	46	9.0	75.0	-	-	-	-	-	-	-	-	-	-
" 29	NS	S	46	-	-	-	.02	-	19	-	-	-	-	.1	.2
" 29	2	S	46	9.0	75.0	-	0	-	0.5	-	-	-	-	.33	.15
" 29	5	S	46	9.0	75.0	-	0	-	0.5	-	-	-	-	.24	.05
" 29	NS	S	45	-	-	-	.02	-	21	-	-	-	2.1	0.1	.05
" 29	2	S	46	9.0	75.0	-	0	-	0.5	-	-	-	-	.40	.30
" 29	5	S	46	9.0	75.0	-	0	-	0.5	-	-	-	-	.33	.075
Nov. 30	NS	S	46	-	-	-	0	-	54	-	-	-	-	-	-
" 30	2	S	46	9.5	79.0	-	-	-	6.0	-	-	-	-	.33	.10
" 30	5	S	46	9.5	79.0	-	-	-	-	-	-	-	-	.16	.10
" 30	NS	S	46	-	-	-	0	-	48.5	-	-	-	-	-	-
" 30	2	S	46	9.5	79.0	-	0	-	5	-	-	-	-	.16	.10
" 30	5	S	46	9.5	79.0	-	0	-	0	-	-	-	-	.38	.20

NS - North Sewer
SS - South Sewer.

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

TABLE 7

ANALYSIS OF WATER SAMPLE(S)
(In parts per million)

Location		Near Grand Falls, Newfoundland		
Source of water		Exploits River		
Fisheries Station No.		1	1	1
Sampling point		At surface	At surface at 1900 hrs.	At 5' depth at 1900 hrs.
Reference		Dept. of Fisheries, Newfoundland Area		
Laboratory number		8988	8991	8992
Date of sampling		Aug. 24/62	Aug. 26/62	Aug. 26/62
Storage period (days)		27:28	25:26	25:26
Temp. at sampling (°C)		16.1	16.7	16.7
Temp. at testing (°C)		25.3	25.3	25.4
Oxygen consumed ($KMnO_4$)		6.6	6.3	7.0
pH		6.5(6.8)	6.7(6.7)	6.8(6.8)
Turbidity (Units)		7	5	5
Alkalinity as $CaCO_3$	(-Phenolphthalein	0.0	0.0	0.0
	(-Total	5.2	5.3	4.9
Conductance, micromhos at 25°C.		27.8	26.3	26.0
Hardness as $CaCO_3$	(Total	8.9	9.4	9.4
	(Non-carbonate	3.7	4.1	4.5
Iron (Fe)	Total	0.08	0.08	0.07
		Total	Total	Total / Diss.
Copper	(Cu)	0.02	0.02	0.02 / 0.01
Zinc	(Zn)	0.18	0.07	0.05 / 0.1
Lead	(Pb)	0.04	0.09	0.16 / 0.03

Source of water Fisheries Station No.		Exploits River 2	2	5	5
Sampling point		At surface 1930 hrs.	At 5' depth at 1900 hrs.	At surface at 2000 hrs.	At 5' depth at 1130 hrs.
Laboratory number		8990	8989	8993	8994
Date of sampling		Aug. 25/62	Aug. 25/62	Aug. 24/62	Aug. 26/62
Storage period (days)		26:27	26:27	27:28	25:26
Temp. at sampling (°C)		16.7	16.7	16.1	16.1
Temp. at testing (°C)		25.6	25.4	25.5	25.5
Oxygen consumed ($KMnO_4$)		10.3	9.1	11.8	17.4
pH		6.5(6.7)	6.5(6.7)	6.6(6.7)	6.1(6.5)
Turbidity (Units)		3	5	6	11
Alkalinity as	(-Phenolphthalein	0.0	0.0	0.0	0.0
$CaCO_3$	(-Total	4.5	5.0	4.4	3.5
Conductance, micromhos at 25°C.		28.7	28.0	29.4	32.6
Hardness as	(Total	10.0	9.9	10.4	11.6
$CaCO_3$	(Non-carbonate	5.5	4.9	6.0	6.1
Iron (Fe)	Total	0.15	0.07	0.11	0.11
		Total	Total	Total	Total
Copper	(Cu)	0.01	0.02	0.02	0.03
Zinc	(Zn)	0.29	0.17	0.13	0.11
Lead	(Pb)	0.09	0.09	0.02	0.04

Source of water		Exploits River						
Fisheries Station No.		6	7					
Sampling point		At 5' depth at 1730 hrs.	At 5' depth at 1700 hrs.	At North sewer at 0735 hrs.		at 1930 hrs.	At South sewer at 1930 hrs.	
Laboratory number		8995	8996	8997		8998	8999	
Date of sampling		Aug. 25/62	Aug. 25/62	Aug. 27/62		Aug. 24/62	Aug. 24/62	
Storage period (days)		26:27	26:27	24:25		27:28	27:28	
Temp. at sampling (°C)		16.1	16.1	17.8		17.2	23.9	
Temp. at testing (°C)		25.6	25.7	25.6		25.7	25.8	
Oxygen consumed ($KMnO_4$)		14.3	18.4	84.0		Very high	28.5	
pH		6.4(6.5)	6.4(6.6)	3.9(4.7)		3.7(4.1)	6.0(6.3)	
Turbidity (Units)		7	7	75		60	55	
Alkalinity as $CaCO_3$	(-Phenolphthalein	0.0	0.0	0.0		0.0	0.0	
	(-Total	4.8	4.5	0.0		0.0	5.4	
Conductance, micromhos at 25°C.		31.2	31.1	139.2		251.2	38.7	
Hardness as $CaCO_3$	(Total	11.3	11.4	36.5		91.6	13.2	
	(Non-carbonate	6.5	6.9	36.5		91.6	7.8	
Iron (Fe)	Total	0.25	0.07	0.44		0.41	0.12	
		Total	Total	Total	Diss.	Total	Total	Diss.
Copper	(Cu)	0.02	0.04	0.23	0.08	0.29	0.13	0.05
Zinc	(Zn)	0.36	0.16	0.42	0.45	0.10	0.71	0.45
Lead	(Pb)	0.08	0.05	0.32	0.13	0.0	0.0	