B. W. Kelso.

A summary of aquatic
environmental information
relating to Western Mines Ltd.
Myra Falls Campbell River, B.C.

A SUMMARY OF
AQUATIC ENVIRONMENTAL INFORMATION
RELATING TO
WESTERN MINES LTD.
Myra Falls
CAMPBELL RIVER, B.C.

by

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June, 1980

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1 WESTERN MINES LTD. (N.P.L.)

Western Mines Ltd. (N.P.L.) has operated a 1000 ton per day copper-lead-zinc concentrator within the boundaries of Strathcona Provincial Park near the south end of Buttle Lake since December of 1966. Ore production is obtained from the underground and open pit Lynx Mine, located near the concentrator and the Myra Mine, located across the Myra Creek valley and downstream from the Lynx Mine (Figure 1). In the year ending December 31, 1979, the two mines produced 294 181 s tons of ore (Mining Journal, 1980). A third mine, the Price Mine, located on Thelwood Creek (Figure 1) is inactive at this time. Proven ore reserves as of January 1, 1980 stood at 1.14 million s tons, grading 8.0% zinc, 1.1% copper, 1.0% lead, 3.4 oz/s ton silver, and 0.08 oz/s ton gold and are sufficient to maintain three more years of production at the present milling rate (Mining Journal, 1980). Recently discovered additional reserves from the Upper Price zone and from a zone lying between the Myra and Lynx Mines are scheduled to be ready for production by 1984 (Mining Journal, 1980).

The mill produces separate lead, zinc and copper concentrates. Values of silver, gold and cadmium report to all three base-metal sulphides. For the year ending December 1, 1979, concentrate production totalled 11 525 s tons copper, 40 307 s tons zinc and 7 462 s tons lead, containing 19 922 oz gold and 791 222 oz silver (Mining Journal, 1980).

A simplified flowsheet showing the milling and tailings disposal circuits is given in Figure 2 (Eccles, 1977). The zinc circuit tails, which represents 70% of the total mill effluent and contains all the solid wastes, is gravity fed to a tailings raft located 5 km distant on Buttle Lake. Thickner effluents, which contain dissolved copper and cyanide, report to the alkaline chlorination plant for cyanide destruction and metal precipitation. The alkaline chlorination plant effluent is combined with zinc circuit tails and discharged together with a flocculant solution 30 meters below Buttle Lake's surface.

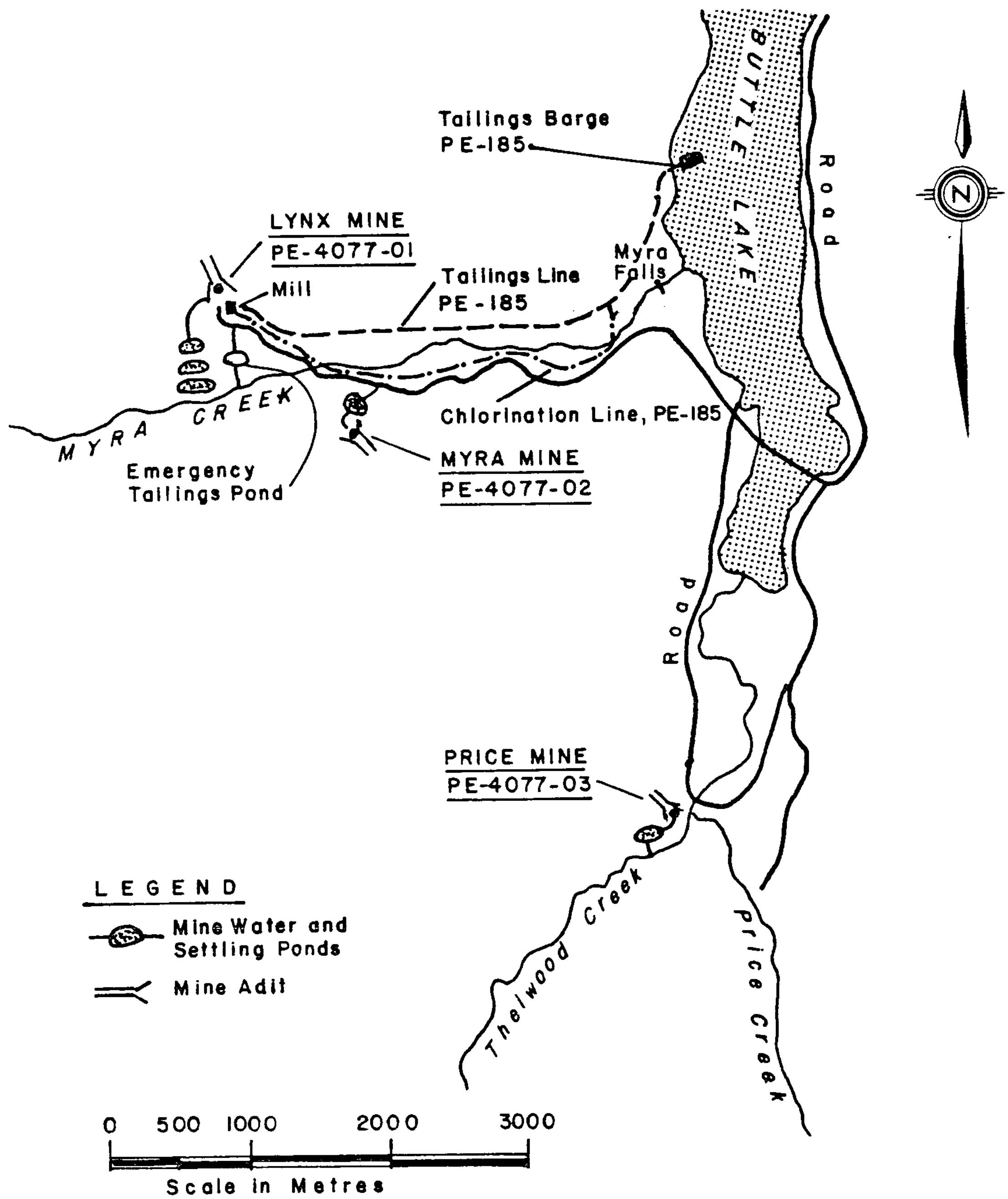


FIGURE 1 LOCATION MAP OF WESTERN MINES LTD. PRICE, MYRA AND LYNX MINE SITES

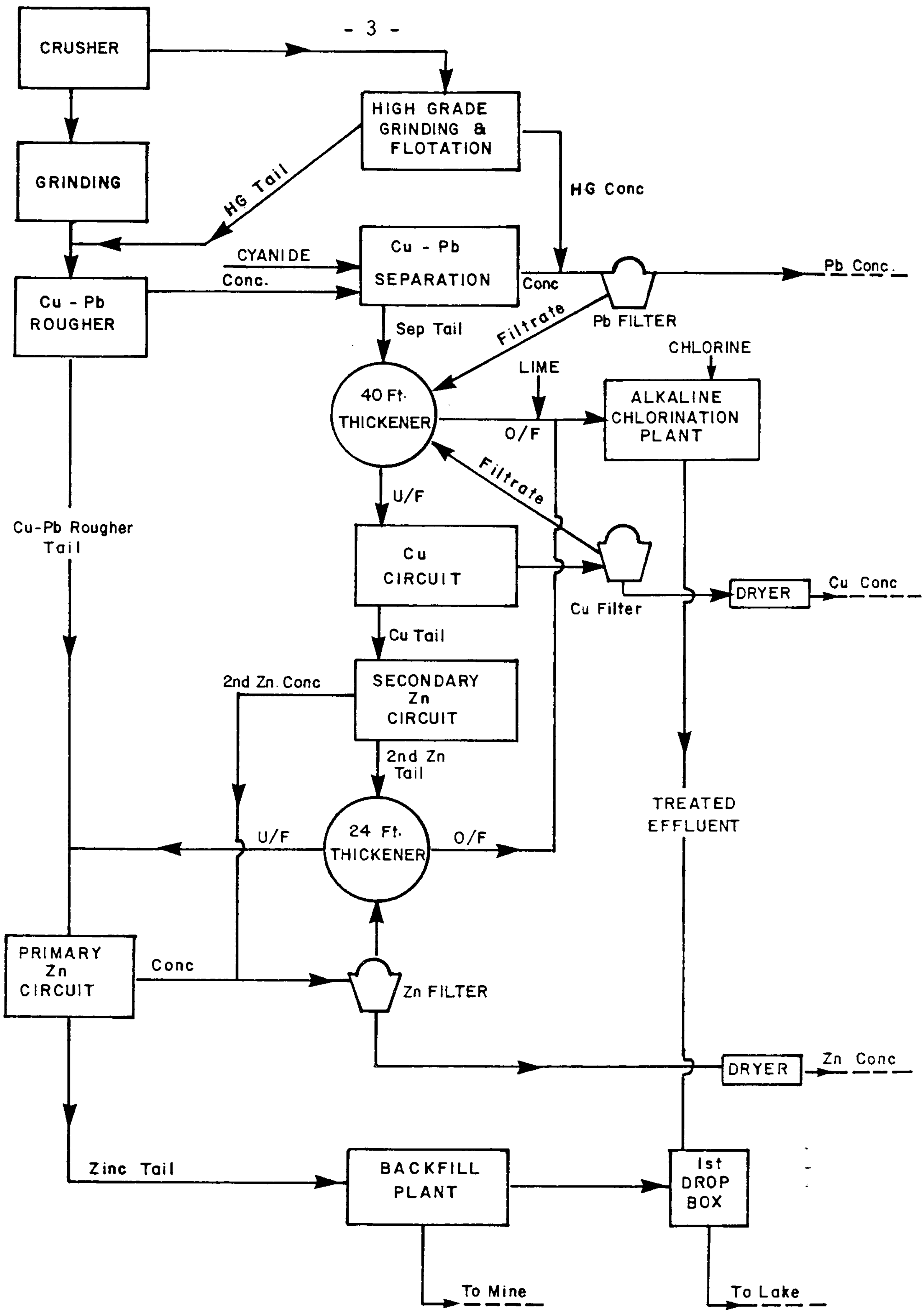


FIGURE 2 MILLING AND TAILING DISPOSAL FLOWSHEET AT WESTERN MINES LIMITED

A full detailed description of the milling methods used at Western Mines Ltd. are presented in the Canadian Institute of Mining and Metallurgy (1978).

Lynx Mine water seepage and plant site runoff enter Myra Creek from a series of three settling ponds. Seepage from Myra Mine and Price Mine is directed to a single settling pond at each location and discharged by exfiltration or decant to Myra and Thelwood Creeks respectively (Figure 1).

2 DESCRIPTION OF POLLUTION CONTROL AND EFFLUENT QUALITY

2.1 Historical Summary of Waste Dispoasl from 1966 to 1975

For the first eight years of operation, direct discharge of mill effluent to Buttle Lake was authorized under Pollution Control Permit PE-185 issued in May of 1967. Although the then Department of Fisheries did not comment on the above permit application because no anadromous species of fish were present in the upper Campbell River watershed, the fact that substantial discussion of joint monitoring occurred implies that, historically, the Department of Fisheries accepted in principle the proposed (and currently existing) effluent disposal scheme (Villamere, 1977).

Permit PE-185 stated that an average of 720 000 gpd of effluent could be discharged to the bottom of Buttle Lake approximately 1 km north of the mouth of Myra Creek. The effluent was to have been at a pH of 6.5 - 8.5 and contain less than: 10 mg/l dissolved copper; 10 mg/l dissolved hexavalent chromium; 5 mg/l dissolved zinc; 5 mg/l dissolved cyanide. The total solids content were not to exceed 134 800 mg/l. The permit required that the effluent be sampled and analyzed once each month to ascertain the levels of pertinent dissolved substances present. In addition, the permit required that a survey of the method of disposal of the tailings be undertaken by an independent party.

At that time (1967) heavy metals were not considered a problem, due to the pH of the circuit. Lead production commenced in June of 1970 but was limited for the following 2-1/2 years, at which time the Myra Mine high lead grade ore was brought on line. Consequently, the plant circuit was modified and cyanide was increased substantially to provide copper-lead separation. However, the essential use of cyanide greatly increased the levels of cyanide and dissolved copper in the effluent.

B.C. Research (1974), in summary analyses of all data obtained by five different agencies between April, 1966, and September, 1973, concerning Buttle Lake and the effluent discharge, concluded the following:

1. The mean values for dissolved copper, chromium and zinc in the tailings were within the permit limits but the individual samples assayed by Western Mines exceeded permissible zinc limits 14% of the time. The dissolved copper content of the tailings pond (used only for a short period of time) effluent was above the limit specified in Permit No. 185 70% of the time and the dissolved chromium levels 5% of the time, as reported by Western Mines.
2. Western Mines reported that the cyanide content of the tailings exceeded the permit limits up to 5% of the time. The values in the tailings pond effluent exceeded the Permit No. 185 limit in above 61% of the samples taken after 1970.
3. The Pollution Control Branch reported that the mean pH of both the tailings and the tailings pond effluent was above the permit limit. The individual samples were outside the limit 60 and 70% of the time respectively. Western Mines reported that the mean values were within the limits but that the individual samples were outside the limit up to 74% of the time for the tailings, and up to 63% of the time for the tailings pond overflow. Western Mines reported values which were much more acidic than those reported by the Pollution Control Branch, which may, in part, account for the higher mean values reported for heavy metals.
4. The Pollution Control Branch data indicated a mean total solids value for the tailings which was outside permit limits. The individual values exceeded 135 800 mg/l total solids 69% of the time. The Western Mines values were within the limits due to the procedures used to collect their composite tailings sample.

5. The mean dissolved copper content of the tailings themselves was 1.3 times the suggested level, whereas the dissolved lead values were within the suggested level. Bioassay data using rainbow trout indicated that the tailings were not toxic over 96 hours when flocculants were added.

However, with respect to the last statement, the Environmental Protection Service mine effluent chemistry and acute toxicity survey of 1973 (Hoos and Holman) observed that "Western Mines effluent, in particular, contained exceedingly high levels of total copper (230 mg/l), zinc (1300 mg/l), and lead (88 mg/l) and, although no dissolved measurements were conducted on this sample, it would appear that these metals, in conjunction with other effluent components, acted synergistically to produce the acutely toxic response reported in the bioassay results (LT_{50}-1.6 hour)."

2.2 Waste Disposal from 1975 to Present

As a result of the B.C. Research (1974) review, the British Columbia Pollution Control Branch, under Section 10(f) of the Pollution Control Act, on April 8, 1974, ordered Western Mines to increase the degree of treatment of their effluent covered by PE-185 (Western Mines Limited (N.P.L.), 1974) so that the effluent characteristics were equivalent to or better than: pH - 6 to 10, sulphates - 100 mg/l, dissolved copper - 0.30 mg/l, dissolved zinc - 5.0 mg/l, dissolved lead - 0.1 mg/l, total cyanide - 0.50 mg/l, suspended solids - 135 000 mg/l and the total average volume of 720 000 IGPD. An amended permit PE-185 with the following monitoring provisions was issued on June 6, 1975.

1. A monthly analysis of a 4-hour composite tailings sample for total and dissolved copper, lead and zinc; dissolved sulphates, pH, suspended solids, total cyanide, and free and total residual chlorine.

TABLE 1 A SUMMARY OF WESTERN MINES LTD. EFFLUENT QUALITY - 1978 AND 1979 - FROM B.C. MINISTRY OF ENVIRONMENT EQUIS DATA FILES

Parameter	Year	Max.	Min.	Average	Permit Requirements
pH	1978(14)	11.95	8.0	10.2	6-10
	1979(9)	11.40	8.9	10.2	6-10
Dissolved CN	1978(11)	2	L0.01	0.38	
	1979(7)	4	0.4	1.50	
Total CN	1978(11)	5	L0.01	1.6	0.50
	1979(7)	6	0.9	3.2	0.50
Suspended Solids	1978(11)	94,000	51,300	67,000	135,000
	1979(7)	136,000	49,400	82,000	135,000
Dissolved SO_4	1978(14)	586	372	475	1000
	1979(9)	810	362	522	1000
Total Cu	1978(11)	75	45.0	53.1	
	1979(8)	131	34.6	69.3	
Dissolved Cu	1978(14)	11	0.008	0.99	0.30
	1979(10)	6.93	0.006	1.41	0.30
Total Pb	1978(11)	94.80	31.9	56.3	
	1979(8)	150	29.6	67.7	
Dissolved Pb	1978(14)	0.63	0.005	0.085	0.1
	1979(10)	0.44	0.001	0.098	0.1
Total Zn	1978(11)	743	179	417	
	1979(8)	734	223	348	
Dissolved Zn	1978(14)	1.62	0.030	0.24	5.0
	1979(10)	16.8	0.029	1.79	5.0

L = Less than.
All values in mg/l unless otherwise stated.
() Indicates number of samples on which the average value given is based.

2. Twice annual "assessing toxicity type bioassay" on the composite tailings sample supernatant.
3. The copper, lead, zinc, and mercury content of the flesh and liver of a minimum of five fish, three times per year.

Subsequent to the Pollution Control Branch directive, investigations indicated that the most efficient and economical method of removing cyanide and copper contaminants from the effluent would be alkaline chlorination. Construction of a plant for this purpose commenced in August, 1973, and full operation was achieved in mid-1975 (Eccles, 1977).

A summary of 1978 and 1979 effluent quality as stored on the B.C. Ministry of Environment EQUIS data files, is provided in Table 1. Table 2 summarizes the relative frequency each of pH, total cyanide, dissolved copper, dissolved lead, and dissolved zinc exceeding the permitted values during each of 1978 and 1979. This summary also shows that effluent quality deteriorated in 1979 compared to 1978 in all parameters shown except pH.

During March of 1980, the Environmental Protection Service conducted a detailed study of Western Mines Limited's alkaline chlorination system (Ferguson, 1980). Both final effluent and combined effluent (at the second drop box) quality results were comparable to the above EQUIS data except for total cyanide (0.13 mg/l) and dissolved copper (0.377 mg/l) which were considerably lower during the study period. Only one out of five 5-hour daily composite total cyanide results exceeded the provincial requirements while four out of five 5-hour daily composite dissolved copper values exceeded the provincial requirements. The mean 96-hour LC_{50} on neutralized samples was 32% (Ferguson, 1980).

Final effluent total cyanide and dissolved copper concentrations were related in part to the alkaline chlorination plant performance. However, dissolved copper concentrations in the zinc circuit tails also exceeded the provincial requirements 80% of the time during the study. The alkaline chlorination plant performance was limited due to problems in the lime delivery system. Lime cakes form at the splitter box reducing the flow of lime to the system and resulting in a drop in pH and a degradation in effluent quality. The composition of possible metal-cyanide complexes could not be definitively determined from the data obtained but it is believed that both copper and iron cyanide complexes survive the alkaline chlorination system resulting in elevated total cyanide and dissolved copper levels (Ferguson, 1980).

TABLE 2 PERCENTAGE OF EFFLUENT SAMPLES EXCEEDING THE PERMITTED VALUES DURING 1978 and 1979

Parameter	1978	1979
pH	14%	11%
Total CN	54%	100%
Dissolved Cu	36%	50%
Dissolved Pb	18%	38%
Dissolved Zn	0%	12%

2.3 Mine Seepage and Plant Site Drainage

Mine seepage from the Lynx, Myra and Price main mine adits are authorized under Pollution Control Permit PE-4077 in average daily amounts of 720 000, 619 200 and 763 000 IGDP respectively. Except for the Lynx Mine and concentrator yard drainage, which is treated in a series of three settling ponds, all visible seepage exfiltrating from the mine water settling ponds must be equivalent to or better than:

total suspended solids - 75 mg/l, total solids - 1200 mg/l, pH - 6.5 to 8.5, dissolved arsenic - 0.05 mg/l, dissolved cadmium - 0.005 mg/l, dissolved copper - 0.30 mg/l, dissolved lead - 0.05 mg/l, dissolved zinc - 2.0 mg/l, total mercury - 0.001 mg/l, total cyanide - 0.10 mg/l, and dissolved sulphate - 200 mg/l.

A monthly receiving water monitoring program which includes the above parameters is also prescribed for upstream and downstream stations on Myra and Thelwood Creeks. Table 3 provides a summary of the limited available data on the three settling pond effluents as stored on the B.C. Ministry of Environment EQUIS data files.

All three mine water settling ponds appear adequate for solids removal and achieving mean values for heavy metals under permit however, individual analyses of various dissolved metals frequently exceeds the allowable levels in all three cases. The mean values of dissolved cadmium and zinc from the Lynx Mine, for example, are at or just above the permit requirements but were exceeded in 7 of the 14 and 6 of the 14 samples respectively. Although levels of dissolved metals in the mine water are lower, with the exception of zinc, than in the mill effluent, they pose a major concern because of the much larger combined volumes involved and thus the greater degree of loadings of metals discharged to Buttle Lake.

TABLE 3 SUMMARY OF LYNX, MYRA AND PRICE MINE WATER SETTLING POND EFFLUENTS, AS STORED ON THE B.C. MINISTRY OF ENVIRONMENT EQUIS DATA FILE - JANUARY 1975 TO NOVEMBER 1979

Parameter	Lynx Mine	Myra Mine	Price Mine	
	PE-407701	PE-407702	PE-407703	0100290
suspended solids	11.7 (14)	4.0 (12)	6.0 (2)*	14.0 (14)
total solids	308 (14)	157 (12)	162 (2)	248 (14)
pH	7.5 (14)	7.15 (12)	8.15 (2)	7.8 (14)
dissolved As	L0.004(12)	L0.003(10)	L0.005(2)	0.002(12)
dissolved Cd	0.009(14)	0.004(12)	L0.005(2)	L0.001(14)
dissolved Cu	0.026(14)	0.048(12)	L0.001(2)	0.002(14)
dissolved Pb	0.010(14)	0.016(12)	0.029(2)	0.027(14)
dissovled Zn	2.00 (14)	0.98 (12)	0.11 (2)	0.68 (14)
total Hg	L0.14 (11)	L0.13 (10)	0.08 (1)	L0.002(12)
total CN	0.01 (12)	L0.01 (11)	L0.01 (2)	L0.01 (13)
dissolved SO_4	97.5 (14)	44.9 (12)	37.45(2)	61.5 (14)

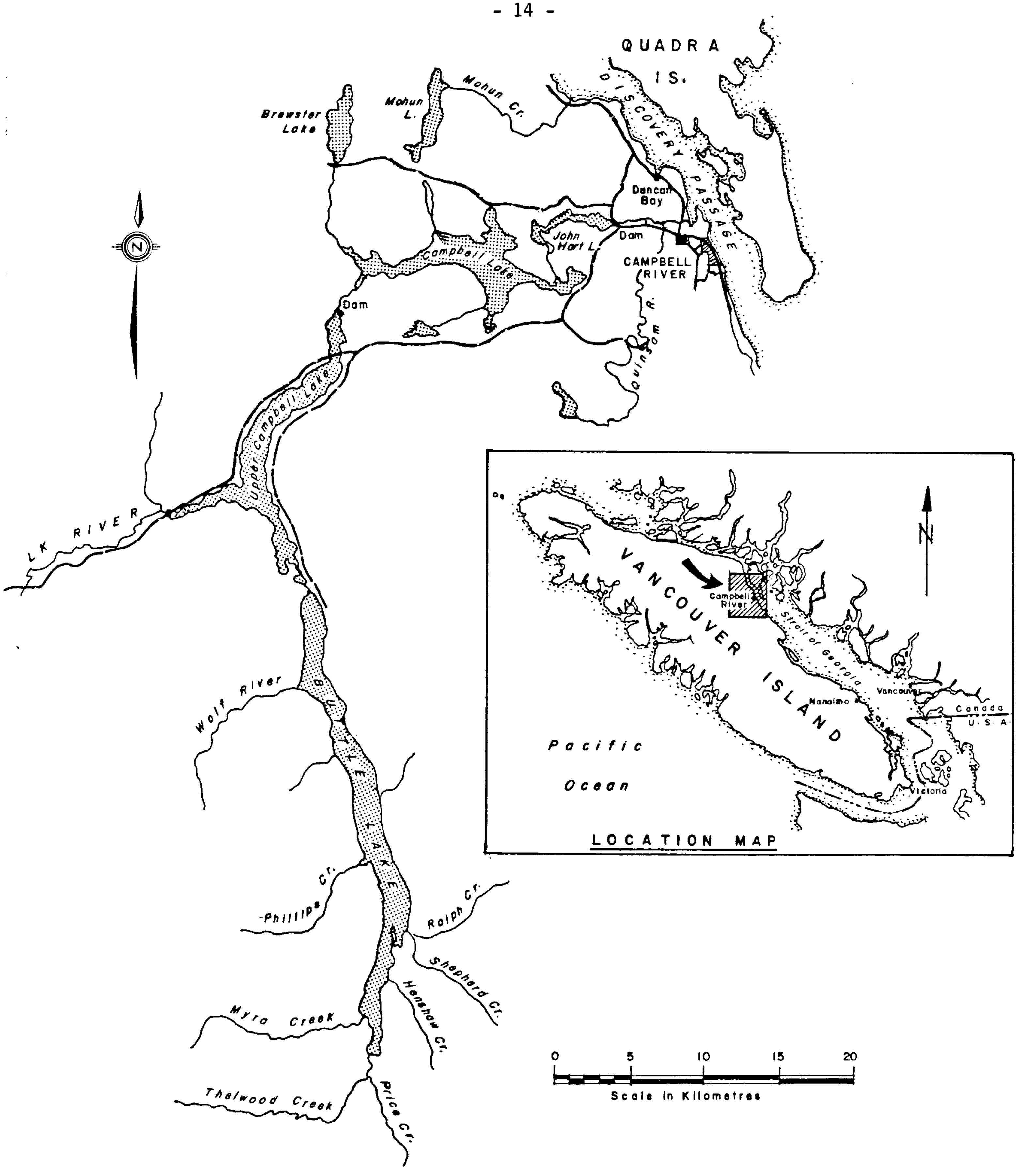
All values in mg/l unless otherwise stated.
L = Less than.
() Indicates the number of analyses on which the average value given was based.
* August, 1977, and July, 1978, only.

3 DESCRIPTION OF THE CAMPBELL RIVER DRAINAGE SYSTEM AND AQUATIC RESOURCES

The Campbell River chain of lakes and tributaries is situated in the central portion of Vancouver Island and drains an area of 542 square miles, Buttle Lake lies in a north-south valley at the head of the system. It drains northward into Upper Campbell Lake. The main tributary to the Upper Campbell River system is Elk River. The Campbell River drops rapidly from Lower Campbell Lake through several canyons and over Elk Falls and enters the sea at the town of Campbell River on the west side of Discovery Passage (Figure 3).

Upper Campbell Lake is contained behind Strathcona Dam on the Campbell River. This reservoir is the uppermost in a series of reservoirs beginning with the John Hart Dam and reservoir (Head Pond) situated downstream of Ladore Dam and reservoir (Lower Campbell). Upper Campbell Lake at full pool is joined with Buttle Lake, a former natural lake, located 11 km (7 mi) upstream of Strathcona Dam. The generation facility at Strathcona Dam is capable of producing 6.75×10^4 kilowatts of power. Mean discharge from the reservoir is 81 m^3/s (2850 cfs) and elevation at full pool is 225 m (737 feet). The reservoir first reached full pool in 1958 and can have a maximum level fluctuation of 25 m (82 feet).

Except for a report on Lower Campbell Lake, prepared by Dr. G.C. Carl (1937), little was known of the biology of the Campbell River system until it was examined in detail by the British Columbia Game Department in 1951. (McMynn and Larkin, 1953). Their report, which was performed in response to three proposed British Columbia Power Commission hydro-electric projects on the system, provides a cursory summary of morphometry, physical limnology and biology of Buttle, Upper Campbell and Lower Campbell Lakes, as well as Head Pond and Campbell River. In overall terms their findings with respect to the fishery potential were as follows:



GURE 3 LOCATION MAP OF THE CAMPBELL RIVER DRAINAGE SYSTEM

(a) Buttle Lake: Oligotrophic, poorly defined thermocline, soft (40 mg/l) and highly transparent (secchi disc 40-45 feet at both ends of the lake). Relatively high settled volumes of plankton and substantial productivity in profoundal fauna. Four species (*Salmo gairdneri*, *Salmo clarki clarki*, *Cottus* and *Salvelinus alpinus malma*) of fish were observed. Resource not heavily fished. Nine streams including Price, Myra and Thelwood were identified as providing exceptional trout spawning facilities. Apparent great recreational value.

(b) Upper Campbell Lake: Rapid flushing in part responsible for poor bottom fauna and poor plankton production. Available trout spawning potential approximately three-fold greater than Buttle Lake.

(c) Lower Campbell Lake: Created by the Ladore Dam. Well defined thermocline. Secchi disc of 25 feet in dull weather indicated moderately high transparency and total dissolved solids content moderate (40 ppm). Plankton hauls from 1937 and 1951 were similar. Phyto- plankton contained both eutrophic and oligotrophic types and the zooplankton were the abundant forms. Bottom fauna in both 1937 and 1951 were poorly developed. Fish populations in 1937 were principally *Salmo gairdneri* with some *Salmo clarki clarki*, *Salvelinus alpinus malma* and *Cottus*. Only rainbow and cutthroat trout were caught in 1951. From brief reconnaissance of tributary streams spawning potential was viewed as adequate to excellent.

(d) Head Pond: Created as a result of a power development completed in 1947. Efficiently mixed and rapid flush-out. Total dissolved solids slightly higher than other lakes in system (68 ppm). High volume of plankton may be result of drift down and lack of bottom fauna due to absence of a suitable substrate. Fish species included *Salmo gairdneri*, *Salmo clarki clarki*, *Salvelinus alpinus malma*, *Gasterosteous aculeatus* and *Cottus*. Limited spawning potential except in tributary streams entering north side of lake.

(e) Campbell River below the Head Pond: The Campbell River, below the Canyon, supports the following runs of migratory fish:

1. Spring salmon - August to November;
2. Humpback salmon, - July to October;
3. Coho salmon - September to December
4. Small numbers of dog salmon;
5. Occasional sockeye salmon;
6. Winter steelhead - November to April;
7. Summer steelhead - small fish spring run - May to June;
8. Summer steelhead - small fish fall run - August to September;
9. Cutthroat trout - spawning run - (winter months, peak probably February) and various feeding movements;
10. Rare Dolly Varden of small size;
11. Small number of lampreys;
12. Cottids and sticklebacks are present above tidal limits, as well as in the estuary;
13. Large runs of winter steelheads, coho and humpback salmon pass through the river to reach the Quinsam River. They are followed by cutthroat.

The Quinsam River Hatchery, which was opened in 1975, has been designed to enhance the Quathiaski Subdistrict escapements and commercial catches. Fish production figures from this important hatchery facility are as follows (Nassichuk, 1980) :

	Juvenile Production	Adult Production Catch & Escapement
Coho	1.9 million	275 000
Chinook	3.0 million	30 000
Chum	3.6 million (fed fry)	72 000
Pink	1.6 million (currently)	40 000
	3.2 million (max. production)	80 000
Steelhead	20 thousand	2 000
Cutthroat	(hatchery eexpansion to include cutthroat production under active consideration)	

The benefits of the program were first realized in 1977 with the return of adult coho. Tables 4 and 5 provide a summary of escapement data for both the Campbell and Quinsam Rivers (Fisheries and Marine Service, 1977).

TABLE 4 CAMPBELL RIVER MAINSTEM ESCAPEMENTS

Year	Sockeye	Coho	Pink	Chum	Chinook
1975	25	400	1500	3000	2500
1974	75	1500	4000	3500	2500
1973	150	1000	1000	4000	4300
1972	75	1500	3500	3500	7500
1971	75	1500	750	1500	7500
AVERAGE	80	1180	2150	3100	4860
AVERAGE 1966-70	80	1660	2400	1850	4000

TABLE 5 QUINSAM RIVER ESCAPEMENTS

Year	Sockeye	Coho	Pink	Chum	Chinook
1975	25	3500	30,000	400	200
1974	N.O.	3500	7500	400	75
1973	N.O.	4600	4000	1000	5
1972	N.O.	1500	3500	1500	75
1971	N.O.	1500	400	400	25
AVERAGE	5	2900	9100	750	75
AVERAGE 1966-70	0	2550	1350	500	N.O.

N.O. - Not Observed

4 SUMMARY OF RECEIVING WATER QUALITY MONITORING

The results of receiving water monitoring pursuant to Pollution Control Permits PE-4077 (as amended April 1977) and PE-185 (as amended June 1975) are recorded by Eccles (1976, 1977, 1978, 1979). Receiving water monitoring data obtained by the Waste Management Branch from 1971 to 1979 have been the subject of a separate B.C. Ministry of Environment Review (Clark, 1980) and are discussed in the following section under "Impact Assessments". Other receiving water data relevant to the Campbell River system are available (Inland Waters Directorate, 1979; McLean, 1979) but are not included in this summary.

Pollution Control Permit PE-4077 (as amended April 1977) requires the quarterly reporting of quarterly water analysis of Myra Creek and the monthly analysis of Thelwood Creeks, above and below the mine water settling pond discharges, for total and suspended solids; pH; dissolved arsenic, cadmium, copper, lead, zinc and sulphates; total mercury and total cyanide. These data show Thelwood Creek to be higher in dissolved sulphates, copper, lead and zinc downstream of the Price Mine that above and Myra Creek to be similarly affected by mine seepage and mill site runoff from the Myra and Lynx Mines.

Western Mines Ltd. annual reports (Eccles, 1976, 1977, 1978, 1979) provide much more extensive analysis for once only sampling per year for Myra Creek above and below the mine, Buttle Lake at the tailings raft, narrows, and Gold River Bridge, Thelwood Creek, Henshaw Creek and Ralph River. The data indicate that creek waters, with the exception of Myra and Thelwood, were unaffected by mining activity but Buttle Lake was somewhat harder; higher in alkalinity, dissolved sulphates, dissolved solids, dissolved copper and, particularly, dissolved and total zinc, as far downstream as Gold River Bridge.

Pollution Control Permit PE-185 (as amended June 1975) requires the annual reporting of heavy metal content of the flesh and liver of fish (copper, lead, zinc and mercury) collected three times per year. The data for 1976 and 1977 (Eccles, 1976, 1977) are presented in an unconventional manner and recalculation of the data do not give results that are suitable for comparison. However, data from Eccles (1979) can be compared (Table 6) to that reported by Baillie and Morrison (1977) who examined regional normals of heavy metal content in Vancouver Island lake fish as a means of comparing data collected from Buttle Lake fish. These data would indicate that levels of copper and zinc have increased since 1973 in both muscle and liver. Lead may also have increased since it was not detected in 1973 but is reported to be 0.55 ug/g and 1.04 ug/g in muscle and liver respectively in 1979. Further, Baillie and Morrison (1977) conclude that although fish muscle mercury, copper and zinc do not differ significantly from other Vancouver Island lakes, the liver of the same fish contains roughly six times the copper content. In liver tissue "background values [for copper] ranged from 1.98 ug/g to 1303 ug/g with an average of 103 ug/g." Copper content in liver tissue of "Buttle Lake fish ranged from 20.9 ug/g to 1980 ug/g with an average of 621 ug/g or roughly six times that found in background fish" from other Vancouver Island lakes.

TABLE 6 A COMPARISON OF METAL LEVELS IN BUTTLE LAKE FISH BETWEEN COLLECTIONS MADE IN 1973 AND 1978/79

	1973 (from Baillie & Morrison, 1977)		1978/79 (from Eccles, 1979)	
Metal ug/g dry wt.	dry muscle tissue % H_2O-73.9(26)	dry liver tissue % H_2O-76.4(26)	dry muscle tissue % H_2O-77.9(21)	wet liver tissue [% H_2O-75.0]
Copper	2.84(26)	621.00(26)	3.11(21)	163.10(21) [642.40]
Lead	ND(26)	ND(26)	0.55(21)	0.26(21) [1.04]
Zinc	18.30(26)	136.60(26)	41.50(21)	81.30(21) [405.20]
Mercury	0.36(26)	0.24(2)	0.19(21)	0.07(21) [0.28]

ND - Not Detected in sample

[] - Calculated on as assumed 75% moisture content

( ) - [illegible]

5 SUMMARY OF ENVIRONMENTAL IMPACT ASSESSMENTS

There have been four major review periods of the environmental impact of Western Mines Limited's discharge to Buttle Lake since 1966 which are summarized here sequentially:

(a) Pre-production environmental assessment
Wright Engineers (1966, 1966)

(b) Environmental impact review to 1968.
Langford (1968, 1969)

(c) Environmental impact review to 1973
B.C. Research (1974)

(d) Environmental impact review to 1979
B.C. Ministry of Environment (1980)

It must be noted that there has been relatviely little attempt by the authors of the above reviews to relate data to previous findings or to include all annual receiving water monitoring conducted by the company (Eccles, 1976, 1977, 1978, 1979) or the findings of related studies conducted between reviews (Department of Recreation and Conservation 1971; Baillie and Harrison, 1977; B.C. Research, 1977)

5.1 Pre-production Environmental Assessment

Two reports prepared by Wright Engineers Limited (1966, 1966) reported on a number of pre-production effluent assessments and on a literature search. The findings of the two reports are as follows:

(a) Bioassay examinations of three effluent types on a 3:1 dilution showed "the effluents to be remarkably lower in toxicity than one might have expected. Bioassays indicated a 10% mortality rate after four days exposure."

(b) With or without flocculation, mill effluent will settle to give a clean overflow and there was no tendency for settled pulp to disperse under the influence of strong convection currents.

(c) "It is felt that the above data and information (conclusion to the literature search) is sufficient evidence that the proposal of Western Mines Limited (N.P.L.) to discharge the mill tailings into the very large basin which constitutes Buttle Lake under controlled conditions will, in no way, have a deleterious effect."

5.2 Environmental Impact Review to 1968

The original Pollution Control Permit PE-185 required that a survey of the method of disposal of the tailings be undertaken by an independent party.

Dr. G.B. Langford (1968-69) carried out such a survey and issued an interim report in February, 1968, followed by a final report in January, 1969. He concluded that "the present methods of tailings disposal being practised by Western Mines Limited conformed to acceptable health and engineering standards."

Langford considered that the water in Buttle Lake continued to be of high quality. The aquatic life had not suffered and no irreparable damage had been done to aesthetic values. He also concluded that there were no alternative methods of tailings disposal that would offer any improvement over the methods being employed.

He recommended that the surveillance of Buttle Lake and its environs be maintained by the Pollution Control Branch and the Fish and Wildlife Branch of the Provincial Government to ensure that the discharge of tailings continue to be done in a satisfactory manner. He further recommended that the sampling procedures adopted in October, 1968, be continued.

5.3 Environmental Impact Review to 1973

The B.C. Research report (1974) prepared for the Pollution Control Branch in a summary of available lake water chemistry and biology data from April, 1966, to September, 1973, concluded that:

(1) Significant increases occurred in values for total copper, zinc and solids and turbidity at lower depths. Highest values were recorded at 250 feet of depth, two miles downstream.

(2) No significant difference occurred in surface waters at any sample site in Buttle Lake.

(3) No significant idfference occurred between feeder stream water quality and water leaving Buttle Lake (Excluding Myra Creek).

(4) Zinc concentrations in the fish liver had not changed significantly since 1966. Copper content had not changed since 1969; however, it was significantly higher that in 1966. Fish liver lead had increased significantly between 1969-1971 and 1971-1972.

(5) Disposal of tailings had no detrimental effect on water quality for domestic purposes; however, there was not enough available data to assess the impact on resident flora and fauna.

An interim report, (Department of Recreation and Conservation, 1971) reinforced the above findings, but noted differences between the north and south end of the lake with respect to fish tissue and bottom sediment metals. Also of significance at that time was the recording of a yearly decrease in Secchi disc readings from 1966 to 1969.

5.4 Environmental Impact Review to 1979

In 1979 the British Columbia Waste Management Branch (Clark, 1980) conducted a statistical review of all routine monitoring data stored on their EQUIS file. The terms of reference for the review excluded evaluation of tributary waters and effluent quality. Further, only Ministry of Environment data collected after January 1, 1972, were reviewed.

It was concluded from that review that "water leaving Buttle Lake is significantly different from surface water elsewhere in the lake for copper (total and dissolved), total residue, reactive silica, specific conductance, turbidity and zinc (total and dissolved), that there appear to be significant differences between lake sites for total copper, reactive silica and total zinc, and that a number of parameters appear to have concentrations significantly lower near the surface than deeper in the lake. Only zinc (both total and dissolved) was found significantly to have increased with time at all sites and depths examined. Reactive silica, total residue, copper (total and dissolved) and specific conductance showed increasing trends at some loations at 30 metre depths.

The water quality appears safe for drinking and bathing, but borderline with regard to protection of aquatic biota for copper, zinc and possibly cadmium. Copper and zinc appear to be increasing in the water column, both are predominantly in dissolved forms and hence both appear to pose a potential threat to aquatic life in Buttle Lake and portions of Upper Campbell Lake."

Clark (1980) recommended from his findings that a detailed multi-disciplinary investigation to include water, sediment and aquatic biota and covering Buttle Lake, tributary creeks, Upper Campbell Lake and possibly downstream waters, be conducted to delineate the environmental impact of Western Mines' discharge in detail, and to determine remedial actions.

During 1976, B.C. Hydro commissioned B.C. Research to characterize the limnological features of four large reservoirs under the managemnt of B.C. Hydro; one of which was Upper Campbell Lake. The study was envisaged as providing an information base for lake/reservoir comparisons and prediction base for future hydro-electric developments (B.C. Research, 1977)

Multi-depth sampling was conducted at one site on Lower Campbell Lake, two sites on Upper Campbell Lake and one site on Buttle Lake during late summer (maximum thermal stratification) and late fall turnover. The trophic status of each body was estimated from physical, chemical and biological measurements.

Data from the study suggests that the Campbell River system thermally gradiates with no definite thermocline. Considerable mixing and short water retention periods were felt responsible for this observation. Primary productivity was low despite relatively high light transmittance and abundance of all nutrients except nitrogen. The report concluded that:

> "Concern that primary productivity in Upper Campbell Lake was directly affected by tailings entering Buttle Lake from Western Mines Ltd.' copper-lead-zinc mine located near the south end of the lake is without basis, An assessment of heavy metals levels in Buttle Lake indicated little or no transport of tailings out of Buttle Lake (B.C. Research, 1974). Metals monitored in the Campbell River system for this study (Cu, Zn, Pb, Fe) were all below detection limits with the single exception of Zn in Buttle Lake which did not appear in Upper Campbell Lake."

An attempt to classify the trophic status of the system was somewhat confused because of its relatively high phosphorous levels (meso-eutrophic) and its relatively low primary productivity and nitrogen levels (ultra-oligotrophic). However, most characteristics placed the system in oligotrophic status (B.C. Research, 1977).

6 CONCLUSIONS AND RECOMMENDATIONS

Since production commenced in 1966, Westerm Mines Ltd., a relatively small, 1000 ton-per-day, copper-lead-zinc mine and mill located near the south end of Buttle Lake, Campbell River, B.C., has discharged tailings directly to Buttle Lake. Based on pre-production engineering assessements, which indicated that such a disposal practice would not have a deleterious effect, government agencies approved the scheme with the provision that it be monitored closely. Early post-startup engineering studies confirmed that the method of disposal was environmentally acceptable and did not indicate the development of an environmental problem. The first indications of lake degradation came in 1971 when differences were noted between the north and south end of the lake with respect to fish tissue and bottom sediment metals. Following a full evaluation of all available receiving enviroment monitoring data in 1973, which confirmed significant increases in copper, zinc, suspended solids and tubidity at lower depths of Buttle Lake and significant increases in fish liver lead levels, Western Mines Ltd. was ordered by B.C. Pollution Control Branch to increase the degree of treatment of their efluent. Alkaline-chlorination was employed in 1975 as being the most economical and efficient method of achieving the effluent treatment required.

A second review of selected data from 1972 to 1979 on the Campbell River system concluded that Buttle Lake was significantly degraded particularly with respect to zinc and at depth, and that overall water quality was borderline with regard to protection of aquatic biota. A review of effluent data for the last two years indicated that the quality has deteriorated and exceeds permit limits in pH, total cyanide and dissolved copper, lead and zinc. The effluent is also acutely toxic. This has been partly attributed to the problems in the lime delivery system of the alkaline chlorination plant resulting in poor performance in destroying copper and iron cyanide complexes. Additional loadings of metals to Buttle Lake from mine water have also been identified.

Despite the fact that a large number of agencies have examined the discharge of Western Mines Ltd., and its effects on the receiving environment, no study has been conducted which accurately delineates the environmental impact. Basically, the main shortcomings have been either the lack of adequate pre-production data from which to draw any valid comparison and insufficient volumes of reliable data which makes evaluation difficult or the omission of impact reviews to include all previous findings, all available receiving water monitoring data and all related studies on the Campbell River system. A comprehensive review of all presently available data is an essential first step.

There are enough data now available, without further study, which clearly indicate that metals in the effluent, which is acutely toxic, are contaminating the lake water quality several kilometers downstream and are accumulating in sediments and resident fish tissue to levels of immediate concern. A full definitive study of Buttle Lake and Campbell River system morphometry, physical limnology, chemistry, and biology would provide a more conclusive impact assessment of the Western Mines' discharge but would not provide the basis for developing alternate proposals for milling or waste disposal techniques which would provide relief to the present problem.

It is concluded that greater attention in the following areas of study are indicated:

(a) Efficiency of the alkaline chlorination plant to remove cyanides and dissolved metals;

(b) Efficiency of the mine seepage water settling ponds to control dissolved metal contaminants;

(c) Efficiency of the flocculation system to control the migration of suspended solids from the south end of Buttle Lake;

(d) Delineate the cause for greatly increased total and dissolved metals in the water column.

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