MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROVINCE OF BRITISH COLUMBIA

QUEEN CHARLOTTE ISLANDS
YAKOUN RIVER AND TRIBUTARIES
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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Environment Management Act, 1981

Approved: Feb 5/93 ______ J. O'Riordan ______
Date A/Deputy Minister

SUMMARY

THIS DOCUMENT is one in a series that presents ambient water quality objectives for British Columbia. It has two parts: an overview—which is available as a separate document—and a technical appendix. The overview provides general information about water quality in the Yakoun River and several tributary streams that would be affected by the Cinola Gold Project. The technical appendix presents the details of the water quality assessment for these waterbodies, and forms the basis of the recommendations and objectives presented in the overview. The overview is intended for both technical readers and for readers who may not be familiar with the process of setting water quality objectives. Water quality objectives tables are included for those readers requiring data about these waterbodies.

The Cinola Gold Project is an open-pit gold mine development proposed for Graham Island in the Queen Charlotte Islands of British Columbia. The Cinola Gold Project was under review by the B.C. Mine Development Review Process until all development-related activity was postponed indefinitely and the review was suspended.

This document sets water quality objectives to protect designated water uses in areas that will be affected by the mine development, should it proceed in the future. Designated water uses for all freshwater areas are aquatic life and wildlife--including their consumption by humans--plus drinking water and recreation, specifically in the Yakoun River. Some of the objectives set for freshwater are subject to confirmation by sensitive bioassays on salmonids and/or algal bioassays performed at the site (in-situ).

Designated water uses in the marine areas of Yakoun and Ferguson Bays are aquatic life and wildlife--including their consumption by humans--and recreation. Objectives set for Ferguson Bay, site of a proposed marine docking facility, are primarily designed to evaluate the impact of possible chemical spills on aquatic life.

Notable variables for which water quality objectives are set include pH, mercury and aluminum. Objectives have also been set for variables predicted by the mining company and its consultants to increase in receiving waters due to mining activities, and variables of environmental concern, not all of which have data collected before development occurs (background).

A monitoring program will be designed at a later date by regulatory agencies, should the Cinola Project proceed. Many details will depend on final project design. Special monitoring requirements and analyses are also detailed in the technical appendix.

PREFACE

Purpose of Water Quality Objectives

WATER QUALITY OBJECTIVES are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment, Lands and Parks' mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

How Objectives Are Determined

WATER QUALITY OBJECTIVES are based on scientific guidelines called water quality criteria.* Water quality criteria relate the physical, chemical or biological characteristics of water, biota (plant and animal life) or sediment to their effects on water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the criteria by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. A designated water use is one that is protected in a given location and is one of the following:

- raw drinking water, public water supply, and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

How Objectives Are Used

WATER QUALITY OBJECTIVES have no legal standing as yet and are not directly enforced. However, they do provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licenses and orders, and the management of fisheries and the province's land base. They also provide a reference

* The process for establishing water quality objectives is outlined more fully in *Preparing Water Quality Objectives in British Columbia*. Copies of this document are available from the Water Quality Branch, Environmental Protection Department.

against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated. Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses.

OBJECTIVES AND MONITORING

WATER QUALITY OBJECTIVES are established to protect all uses which may take place in a waterbody. Monitoring (sometimes called sampling) is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less. The monitoring usually takes place during a five week period, which allows the specialists to measure the worst, as well as the average condition in the water. For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (i.e., mean value, maximum value).

INTRODUCTION

THE CINOLA GOLD PROJECT is an open-pit gold mine development proposed by Barrick Mine Management Inc. and its subsidiary City Resources (Canada) Limited. The proposed mine site is on Graham Island in the Queen Charlotte Islands, British Columbia (Figure 1), about 18 km south from the village of Port Clements on Masset Inlet. Proposed facilities are all within the Yakoun River drainage basin. They include: the mine area with the open pit and waste rock stockpile within the Barbie Creek watershed, and the High West facilities with the plant site and tailings impoundments in the Florence Creek watershed. A marine docking facility is proposed at Ferguson Bay (Figure 2).

Most projected water quality impacts are confined to the Yakoun River and its tributaries, which flow to Yakoun Bay of Masset Inlet (Figure 2). Some tailings pond seepage could have an impact on the Mamin River drainage to the west, with its mouth at Juskatla Inlet. The baseline information used in this review relies largely on data collected by the Barrick Mine Management's consultants.

The Cinola Gold Project was under review by the B.C. Mine Development Review Process until all development-related activity was postponed by the company. Site-specific water quality objectives are needed to protect designated water uses in areas that will be impacted by the mine's development, should it proceed in the future. A federal-provincial advisory committee of regulatory agencies was established to assist in the development of provisional water quality objectives by the B.C. Ministry of Environment, Lands and Parks.

YAKOUN RIVER AND TRIBUTARIES PROFILE (QUEEN CHARLOTTE ISLANDS)

Hydrology

Study area streams are located on Figure 2. Their hydrology is described in detail in the technical appendix. Streamflows generally reflect rainfall patterns as rainfall is the only source of moisture. The exception is the Yakoun River, where rainfall-driven streamflows are moderated by the storage capacity in Yakoun Lake and snowpack in the headwaters. Following is a brief description of the nine study area streams.

Yakoun River
Yakoun River drains the largest area of old rivers on Graham Island, at 477 km2. It flows north from the Queen Charlotte Ranges to Yakoun Lake, then about 63 km to Masset Inlet at Yakoun Bay near Port Clements. All proposed Cinola mine construction is confined to the Yakoun River watershed, including the mine site, plant site and the High West tailings impoundments, and the water storage reservoir.

Barbie Creek
Barbie Creek drains the area around the proposed open pit, as well as higher ground to the west, and low swampy areas to the south and east. The catchment area is about 10.2 km2. It flows for about 9 km to its confluence with the Yakoun River, about 30 km upstream from the estuary. Barbie wetland is a flooded area where Barbie, Coreshack, and Adit Creeks converge, formed when a log sorting area and road construction modified the flow in Barbie Creek. The wetland makes low flow runoff during the summer more severe due to high transpiration by vegetation and evaporation from the relatively large area of low gradient.

Coreshack Creek
Coreshack Creek is about 1 km long, draining to Barbie wetland from an area including the proposed waste rock stockpile. The catchment area is 1.5 km2.

Adit Creek
Adit Creek originates in the proposed open pit and flows to Barbie wetland. The catchment area is about 0.3 km2. The flow is mainly groundwater from the exploration adit. During the operating life of the proposed mine, flows in Adit Creek would be reduced as some of its drainage area is in the open pit. Some flow would be diverted around the open pit, and water discharged from the test adit directed to the water treatment plant. Upon mine abandonment, the open pit is to be backfilled and flooded, with water overflowing to Adit Creek.

Florence Creek

Florence Creek is about 19 km long, flowing north to its confluence with the Yakoun River, just upstream from the estuary. The catchment area is about 28.3 km2. Florence Creek headwaters are in the proposed High West area which include the tailings and waste rock impoundments, the low-grade ore stockpile, the water storage reservoir, and the mill.

Canoe Creek

Canoe Creek is about 18 km long, flowing north to its confluence with the Yakoun River, about 5 km upstream from the estuary. Canoe Creek drains relatively high elevation terrain between the proposed mine site and plant site, with mostly low-lying and gently sloping terrain downstream in the Yakoun lowlands. Its catchment area is about 23.4 km2.

Sid Creek

Sid Creek is a small tributary to the Yakoun River, located about 2.5 km upstream from Barbie Creek and south of the proposed mine area. The creek drains part of a ridge near the proposed waste rock stockpile, as well as a second ridge to the southeast. The catchment area is 0.8 km2.

Clay Creek

Clay Creek is a small tributary to Yakoun River, about 4.5 km long, northeast of Barbie Creek. The catchment area is about 1.6 km2 of both forested and logged regions.

Boucher Creek

Boucher Creek flows to the Mamin River, draining a catchment of 9.5 km2. Its headwaters are near the headwaters of Florence Creek. There is the possibility of seepage of tailings pond water to Boucher Creek through the No. 2 saddle dam on Florence Creek upon mine abandonment. Any seepage across the dam during mine operation would also have an impact on Boucher Creek.

Water Uses

This section describes water uses in the Yakoun River, as well as in select streams in the Cinola project area. Water uses in Yakoun Bay and Ferguson Bay of Masset Inlet are included, the latter because construction in the eastern portion will provide facilities for off-loading equipment and consumable supplies for the proposed mine.

Fish Resources and Fisheries

Fish resources documented in the Yakoun and Mamin River systems include all five species of Pacific salmon (chinook, coho, chum, pink and sockeye), as well as rainbow trout, cutthroat trout and Dolly Varden char. Only the Yakoun River contributes all five species of salmon to Queen Charlotte Islands stocks. Yakoun River sockeye, pink, and chinook salmon contribute 45%, 70%, and 97%, respectively, to total Graham Island stocks.

The Mamin River system, in contrast, is a major producer of chum and pink salmon. The Yakoun River is also a major producer of steelhead in the Queen Charlotte Islands. All five species of salmon documented in the Yakoun River also use Yakoun Bay, with adults of all species, except coho staying in the estuary before migration up the river. Transient use of Ferguson Bay is expected by all five species of salmon and Dolly Varden char documented in the Yakoun estuary. Dense eelgrass communities in both Ferguson Bay and Yakoun Bay provide rearing opportunities for fish.

The only licence for water withdrawal within the Yakoun River watershed is for a salmon hatchery (chinook, coho, and sockeye) on Gold Creek held by the Masset Band Council.

Fish resource use includes:

- sport fishing in the Yakoun River for steelhead, cutthroat trout, coho salmon, and Dolly Varden char
- commercial fishing for shrimp by trawl at the mouth of the Yakoun River, crab in the deeper parts of the estuary, pink salmon by seine at the mouth of Masset Inlet and the channel to Dixon Entrance, and chum salmon by gillnetting in Dixon Entrance and Masset Inlet
- a native food fishery in the Yakoun River for sockeye, pink, and chum salmon by gillnetting

Wildlife Resources

Wildlife resources in the project area include black-tailed deer, possibly Rocky Mountain elk, black bear, and local fur-bearers including beaver, muskrat, river otter, racoon, and martin. Many upland bird species inhabit the Cinola project area. The Yakoun River estuary provides habitat for both migratory populations of aquatic birds and raptors, as well as feeding habitat for local breeding populations. The Yakoun River estuary received a maximum rating for coastal wetlands on the Queen Charlotte Islands for the waterfowl, wildlife, fisheries, and productivity contribution to its resource value. Area wildlife use includes both hunting and trapping.

Recreation

Recreational use of the mainstem Yakoun River is high. Users take advantage of angling, swimming, picnicking, camping, and hiking opportunities. Sport fishing on the Yakoun River occurs throughout the year, with steelhead fishing by residents and tourists being the most important. Yakoun Bay is used for recreation by waterfowl hunters and by people who come for scenic views of the tidal flats.

Mining

City Resources Canada (parent company Barrack Mine Management Inc.) has a water licence application for diversion, storage, and mining use of water from Barbie Creek, Florence Creek, Canoe Creek, and Clay Creek, all within the proposed mine project area and tributaries to the Yakoun River.

Waste Discharges

Wastewater management systems have been proposed for mine area waste discharge for the Cinola Gold Project.

Wastewater Management Systems

All water management systems would discharge to Barbie Creek or its tributaries. Treatment includes settling ponds to remove sediments and associated metals, a lime-water treatment plant to neutralize acid drainage and precipitate metals, and artificial (constructed) wetlands to attenuate nutrients and metals.

Wastewater treatment. The wastewater treatment plant is designed to treat all acid water during mine operation. It will be maintained as a contingency after mine abandonment should discharge from the backfilled pit be acidic. As mentioned previously, the water treatment plant is designed to neutralize all acid drainage and reduce the level of metals.

All facilities in the High West area would discharge to Florence Creek, except seepage to Boucher Creek through a tailings dam. The mine plan directs all potentially affected drainage from the High West area to three sequentially activated impoundments, all isolated from Florence Creek drainage by embankments. Diversion ditches are proposed to redirect unaffected surface water around the impoundments. A settling pond would be located immediately downstream from Impoundment No. 3. Due to the poor quality of the impoundment water and the limited dilution available in Florence Creek, the impoundment is designed for zero discharge to Florence Creek during the operating life of the mine. Process water from the active impoundment would be recycled back to the mill. However, the floating decant at the silt check facility downstream from Impoundment No. 3 would have a discharge and would likely contribute suspended matter to Florence Creek.

Artificial wetlands. The mining company predicts that the water qulaity in Florence Creek will be restricted to the period following the proposed "de-activation and reclamation" of impoundments in a wetland and pond system. Florence Creek would then be redirected through the reclaimed impoundments. Water quality would be affected by the interaction with tailings and waste rock in the reclaimed impoundments, and by groundwater seepage through the impoundments. Receiving water criteria and the site-specific objectives set in this document would be met by the company by controlling the discharge rates from the reclaimed impoundments after mine abandonment.

Transportation

Cargo would be transported to the Graham Island mine site by barge with docking facilities constructed at Ferguson Bay (Figure 2), inside the east breakwater of MacMillan Bloedel's log boom and dryland sort. A laydown area would provide for unloading, storage, reloading, and shipping of cargo, with a bulk explosives plant located about 360 m south. Limestone and diesel fuel would be stored on site. General cargo unloaded at Ferguson Bay and transported to the mine site include, but are not restricted to the following: limestone, fuel oil and diesel, explosives (such as ammonium nitrate), and reagents including quicklime, sulphuric acid, sodium cyanide, sodium hydroxide, sodium sulphide, copper sulphate, ammonia, and chlorine.

WATER QUALITY ASSESSMENT AND OBJECTIVES

Water Quality Assessment

The proposed Cinola project would directly affect the waters of Barbie Creek, its tributaties and Florence Creek during both the mine operation and after the mine had been abandoned. The company predicts that Florence Creek would not be affected by the tailings and waste rock impoundments in its headwaters during mine operation due to the "zero discharge" policy developed in the mine plan. Florence Creek would only be affected by tailings and waste rock during reclamation and mine abandonment as flow is redirected through the original watercourse. The water quality of the Yakoun River and its other tributaries are discussed in the technical appendix, followed by a discussion of water quality in Boucher Creek of the Mamin River drainage.

Metals

Some low detection limit data for mercury as well as some preliminary aluminum speciation data from Yakoun River tributaries are discussed in the Technical Appendix, and are the basis for objectives for these two variables. Finally, metals burden in fresh water fish tissue as well as marine biota are summarized and discussed in the Technical Appendix, and are the basis for objectives for tissue.

Mercury. Mercury levels are presently elevated in some fresh waters and fish, with levels projected to increase by the mining company in Barbie Creek. Most historical water sample analyses were at too high a detection limit to identify how frequently samples exceeded aquatic life criteria. Depending on the stability of the reclaimed impoundments, mercury levels would only have an impact on Florence Creek when it reverts to its former channel in the High West area.

Aluminum. Background levels of aluminum in the Yakoun River and its tributaries consistently exceeded aquatic life guidelines and the mining company projects increases above mean dissolved aluminum levels in Barbie and Florence Creeks. The main environmental concern is the precipitation of aluminum on fish gills as high pH discharges mix with high aluminum, low pH waters in natural streams.

Barbie Creek in particular may be sensitive to pH change if it is already outside the theoretical minimum aluminum solubility range of pH 5.6 to 6.2 when a change occurs. Any change in pH outside this range may increase aluminum toxicity by increasing the inorganic constituents which are available to biological organisms causing aquatic life guidelines to be exceeded without the addition of any aluminum due to waste discharges. Collection of samples from Cinola streams and the Yakoun River on a routine basis for aluminum speciation is recommended in the Technical Appendix, to form the basis for water quality objectives.

pH

Tributary streams to the Yakoun River have naturally occurring pH levels frequently lower than guidelines to protect aquatic life. With low pH and low buffering capacity to acidic inputs due to low alkalinities, aquatic life in these streams could be at risk from inputs of untreated acid mine drainage. On the other hand, the level of pH in streams could also increase with the Cinola project from the addition of limestone or lime-neutralized effluents.

Other Variables

Other variables are predicted by the mining company to increase in receiving waters due to mining activities: cyanide, nitrate-nitrogen, periphyton, sulphate, arsenic, cadmium, chromium, copper, iron, lead, nickel, silver, and zinc.

Additionally, the following variables have been identified and discussed in the technical appendix as being of environmental concern, not all of which have data collected before development occurs (background): dissolved oxygen, suspended solids, turbidity, bottom sedimentation (in salmonid spawning areas), nitrite-nitrogen, ammonia-nitrogen, and selenium.

Water Quality Objectives

Designated Water Uses

Water uses designated for protection by water quality objectives for waterbodies potentially affected by the Cinola project were determined by the Federal-Provincial Cinola water quality objectives committee. This committee included representatives from the B.C. Ministry of Environment, Lands and Parks (Water Quality Branch and Environmental Protection Division), the Department of Fisheries and Oceans, Environment Canada (Environmental Protection), and Island Waters Directorate (Water Quality Branch).

Water uses designated for protection for freshwater are aquatic life and wildlife—including their consumption by humans—drinking water, and recreation, specifically in the Yakoun River. Some objectives set for freshwater are subject to confirmation.

Designated water uses in the marine areas of Yakoun and Ferguson bays are aquatic life and wildlife, including their consumption by humans, and recreation. Objectives set for Ferguson Bay, site of a proposed marine docking facility, are primarily designed to evaluate the impact of possible chemical spills on aquatic life.

The technical appendix details where objectives apply in specific waterbodies. This varies from the entire waterbody to specific reaches, and often excludes small initial dilution zones downstream from waste discharges.

Monitoring

A monitoring program will be designed at a later date by regulatory agencies, should the Cinola Project proceed. Many details will depend on final project design. Special monitoring requirements and analyses are detailed in the technical appendix.

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LOCATION AND SAMPLING SITES MAPS

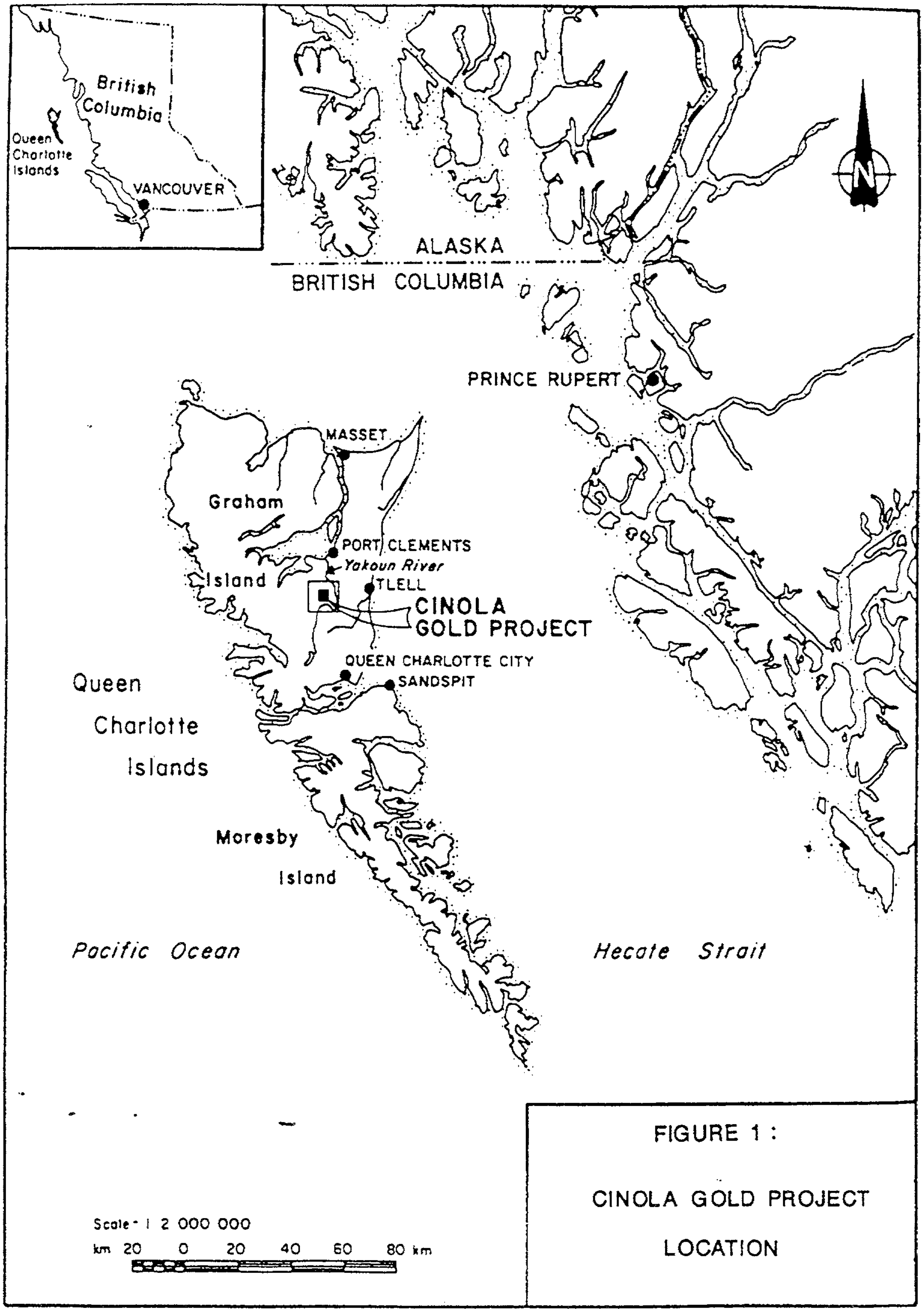

FIGURE 1 :

CINOLA GOLD PROJECT LOCATION

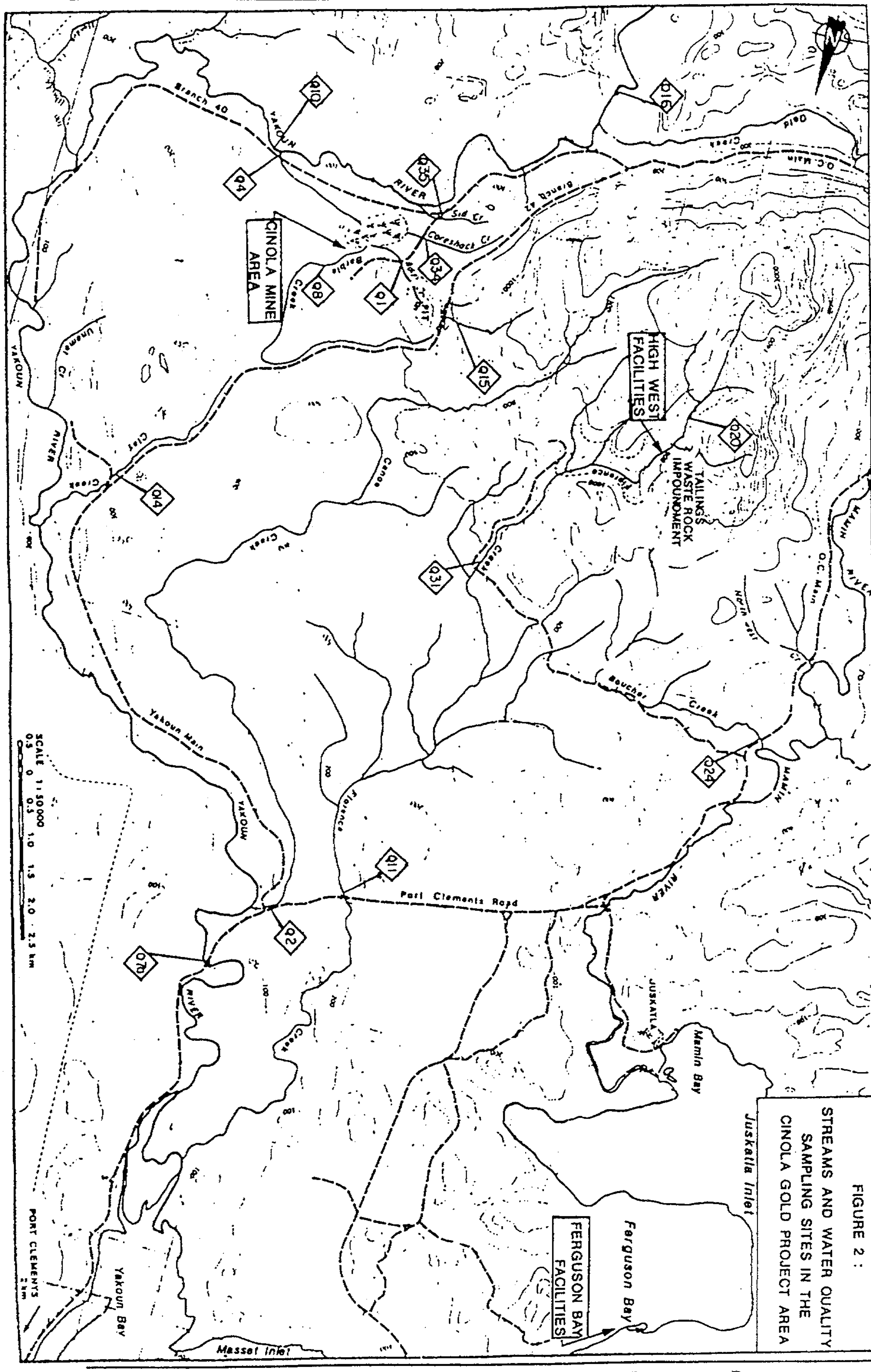

FIGURE 2 : STREAMS AND WATER QUALITY SAMPLING SITES IN THE CINOLA GOLD PROJECT AREA

WATER QUALITY OBJECTIVES AND MONITORING TABLES

THE FOLLOWING TABLES provide a summary of the objectives data. Provincial water quality objectives for freshwater streams within the Cinola project area are summarized in Table 1. Those for marine areas of the Yakoun River estuary and bay, as well as Ferguson Bay, are summarized in Table 6. Objectives for Ferguson Bay are primarily designed to evaluate the impact of a spill on marine aquatic life. Of the objectives proposed for freshwater, some are subject to confirmation by sensitive bioassays on salmonids and/or in-situ algal bioassays.

To protect water uses in a waterbody, objectives specify a range of values for characteristics (variables) that may affect these uses. These values are maximum and/or minimum values that are not to be exceeded.

Some readers may be unfamiliar with terms such as maximum concentration, 30-day average concentration, and not applicable (NA). Maximum concentration means that a value for a specific variable generally should not be exceeded; 30-day average concentration means that a value should not be exceeded during a period of 30 days, when five or more samples are collected at approximately equal time intervals. Not applicable (NA) means that water uses are not threatened for that particular variable.

TABLE 1: PROVISIONAL WATER QUALITY OBJECTIVES FOR STREAMS IMPACTED BY THE PROPOSED CINOLA PROJECT

Water Bodies	Boucher Ck.	Coreshack Ck.	Florence Ck.	Barbie Ck.	Adit Ck.	Sid Ck.	Yakoun R.	Canoe Ck. and Clay Ck.
Designated Uses	Aquatic Life and Wildlife (including consumption by humans)						Aquatic Life & Wildlife (incl. consumption by humans), Recreation, Drinking Water	Aquatic Life & Wildlife (incl. consumption by humans)
Variables								
cyanide (WAD)[5]	<5 ug/L 30 - day average; 10 ug/L maximum							NA
inorganic nitrogen: (i) ammonia - N (ii) nitrite - N (iii) nitrate - N	30 - day average from <0.131 to <2.08 mg/L, maximum from 0.682 to 27.7 mg/L; both dependent on pH and temperature (objectives detailed in Tables 2 & 3) 30 - day average from <0.02 to <0.20 mg/L; maximum from 0.06 to 0.60 mg/L; both dependent on chloride concentration (objectives detailed in Table 4) 10 mg/L maximum							NA
oxygen, dissolved	(i) where salmoid embryo and larval stages are present, 11 mg/L dissolved oxygen (in water)/8 mg/L interstitial (intergravel) dissolved oxygen; (ii) where other salmonid life stages are present, 8 mg/L dissolved oxygen (in water); and (iii) when background levels are less than these objectives, then there should be no significant decrease over background (95% confidence level) due to anthropogenic activities[2]							NA
particulate matter [1]: (i) non-filterable residue (ii) turbidity (iii) Sedimentation	≤ background + 10 mg/L where background ≤ 100 mg/L; or ≤ background + 10% where background is > 100 mg/L ≤ background + 5 NTU where background is ≤ 50 NTU; or ≤ background + 10% where background is > 50 NTU in all salmonid spawning areas: the benthic accumulation of fines (<3 mm diameter) should not be significantly increased (95% confidence level) by weight over background[2]							
periphyton[6]	<100 mg/m^2 chlorophyll a						<50 mg/m^2 chlorophyll a	NA
pH	NA		see Table 5		NA		see Table 5	NA
sulphate	100 mg/L maximum							NA
dissolved aluminum	NA	no significant increase in dissolved aluminum due to waste discharges[2,3]						NA
total arsenic	0.050 mg/L maximum total arsenic							NA
total cadmium	objectives in water are based on hardness: (i) 0.2 ug/L maximum total cadmium for hardness 0-60 mg/L (ii) 0.8 ug/L maximum total cadmium for hardness > 60 mg/L (iii) should background levels exceed these objectives, then there should be no significant increase (95% confidence level)[2]							NA

...continued

TABLE 1 (cont)

Variable	Boucher	Coreshack	Florence	Barbie	Adit	Sid	Yakoun R	Canoe Ck.
total chromium	2 ug/L maximum; or no significant increase (95% confidence level) should background exceed the objective[2]							NA
total copper[5]	(i) 30 - day average of from <2 ug/L (for hardness $\le$ 50 mg/L) to <12 ug/L (hardness of 300 mg/L); (ii) maximum of from 2 ug/L (0 mg/L hardness) to 30 ug/L (300 mg/L hardness); or (iii) no significant increase (95% confidence level) when background exceeds the objective[2].							NA
total iron	0.3 mg/L maximum; or no significant increase in total iron (95% confidence level) when background exceeds the objective							NA
total lead	3 ug/L maximum in <u>water</u>; 0.8 ug/g (wet weight) maximum in fish tissue, or no significant increase (95% confidence limit) over background if background is >0.8 ug/g[2]							NA
total mercury[5]	NA		<u>in water</u>: <10 ng/L 30 - day average, 20 ng/L maximum <u>in fish</u>: 0.5 ug/g wet weight maximum in cutthroat, rainbow trout, & Dolly Varden[4]	<u>in water</u>: <20 ng/L 30 - day average, 50 ng/L maximum	NA		<u>in water</u>: <20 ng/L 30 - day average, 50 ng/L maximum <u>in fish</u>: 30 - day average for cutthroat, rainbow trout, Dolly Varden of <0.20 / 0.15 / 0.15 ug/g wet weight, respectively; and 0.5 ug/g wet weight maximum (all species)[4]	NA
total nickel	25 ug/L maximum							NA
total selenium	1 ug/L maximum <u>in water</u>; 3 ug/g wet weight maximum <u>in biota</u>; and 5 ug/g dry weight maximum <u>in sediment</u>							NA
total silver	0.1 ug/L maximum							NA
dissolved zinc	10 ug/L maximum; or + 20% of background if background exceeds the objective							NA

Footnotes:

1 Increases in non-filterable residue and turbidity are not to be cumulative from upstream to downstream, and thus apply to groups of discharges.
2 This is to be interpreted as meaning that if monitoring shows an increase of more than 20% over background, then an increase in monitoring would be required to show whether the change is in fact significant at the 95% confidence level.
3 Provisional objective until inorganic monomeric aluminum data are available for all streams with potential pH shifts from mining activity.
4 Recommended minimum sample size of 10, each species.
5 The 30-day average is based on a minimum of 5 sample collected at equal intervals over 30 days.
6 The periphyton objective is an average based on at least 5 randomly located samples from natural substrates at each site.
NA not applicable

TABLE 2

AVERAGE 30 - DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FROM NITROGEN CRITERIA DOCUMENT (AND TABLE 6.1.2 OF THIS REPORT'S TA) FOR PROTECTION OF FRESHWATER AQUATIC LIFE (mg/L-N)

pH	Temp 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.0906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured valuse must be less than the average of the corresponding individual valuesd in Table 3.
- each measured value is compared to the corresponding indivdual values in Table 3. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding objectives values in Table 3.

TABLE 3

MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF FRESHWATER AQUATIC LIFE

(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

TABLE 4
APPROVED B.C. CRITERIA FOR NITRITE–N TO PROTECT AQUATIC LIFE

30-Day Average	NO2–N Concentration (mg/L) Maximum	Chloride (mg/L)
0.02	0.06	<2
0.04	0.12	2–4
0.06	0.18	4–6
0.08	0.24	6–8
0.10	0.30	8–10
0.20	0.60	>10

TABLE 5
pH OBJECTIVES FOR YAKOUN RIVER AND TRIBUTARIES

Waterbody/Qualifications	pH Objectives
Barbie Creek in areas with: (i) no substantial increases in hardness (≤50 mg/L) and sulphate (≤30 mg/L)	no restriction on change over background within pH range 5.5 to 6.2 pH <5.5: no decrease, +0.5 increase over background pH >6.2: no increase, -0.5 decrease over background
(ii) substantial increase in hardness (>50 mg/L) and sulphate (>30 mg/L) such as below the water treatment plant	±0.5 units change over background
Florence Creek in areas with no significant change in hardness (<50 mg/L) or sulphte (<30 mg/L)	no restriction on change over background within pH range of 5.5 to 6.2 pH <5.5: -0.2 units decrease, +0.5 units increase over background pH >6.2: ±0.5 unit change over background
Yakoun River	±0.5 unit change over background (interim objective until aluminum speciation data collected)

TABLE 6

PROVISIONAL WATER QUALITY OBJECTIVES FOR YAKOUN RIVER ESTUARY AND YAKOUN BAY, AND FERGUSON BAY

Water Bodies	Yakoun River Estuary & Bay	Ferguson Bay[1]
Designated Water Uses	Aquatic Life & Wildlife (Including Consumption By Humans) & Recreation	
Variables: Ammonia - N	NA	in terms of 30 - day average and maximum concentrations, as detailed in Tables 7 & 8
Chlorine	NA	in terms of chlorine - produced oxidants: 40 ug/L maximum during the 2 hour period following a spill
Cyanide	1 ug/L maximum weak - acid dissociable cyanide	
Particulate matter: (a) non-filterable residue (NFR) (b) turbidity	NA	induced NFR ≤ 10 mg/L (for background ≤ 100 mg/L) induced turbidity ≤ 5 NTU when background ≤ 50 NTU, or ≤ 10 % when background is > 50 NTU
pH	NA	7.0 - 8.7
sulphide	NA	2ug/L maximum undissociated H_2S
total copper		30 - day average of ≤ 2 ug/L total copper, and a maximum of 3 ug/L total copper
total lead	in biota[2]: 0.8 ug/g wet weight maximum for Dungeness crab, mussels and clams; or no significant increase (95% confidence level) should background levels exceed this objective[3].	NA

...continued

TABLE 6 (cont)

Water Bodies	Yakoun River Estuary & Bay	Ferguson Bay[1]
Variables: total mercury	in biota[2]: (i) mussels and clams, 0.1 ug/g maximum (wet weight) (ii) Dungeness crab, 0.10 ug/g average, 0.20 ug/g maximum (wet weight) (iii) shrimp, 0.18 ug/g average, 0.50 ug/g maximum (wet weight)	NA
PAHs in Sediments (includes both low molecular weight & high molecular weight PAHs)	NA	in sediments: — ug/g dry-weight maximum Total LPAH 0.5 naphthalene 0.2 acenaphthylene 0.06 acenaphthene 0.05 fluorene 0.05 phenanthrene 0.15 anthracene 0.1 Total HPAH 1.2 fluoranthene 0.17 pyrene 0.26 benzo (a) anthracene 0.13 chrysene 0.14 benzo-fluoranthenes 0.32 benzo (a) pyrene 0.16 indeno (1,2,3-c,d) pyrene 0.06 debenzo (a,h) anthracene 0.06 benzo (g,h,i) perylene 0.07

[1]Ferguson Bay objectives are primarily designed to evaluate the impact of a spill with regards to aquatic life. Routine monitoring would be for PAHs in sediments and particulate matter variables (non-filterable residue and turbidity), with the other objectives monitored only should a spill occur.

[2]The objectives should be based on a minimum of 10 samples of each species.

[3]This is to be interpreted as meaning that if monitoring shows an increase of more than 20% over background, then an increase in monitoring frequency would be required to show whether the change is in fact significant at the 95% confidence level.

NA not applicable

TABLE 7
AVERAGE 5 TO 30 - DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN
FOR PROTECTION OF SALTWATER AQUATIC LIFE
(mg/L-N)

pH	Temperature (°C) 0	5	10	15	20	25
	Salinity = 10 g/kg					
7.0	41.	29.	20.	14.	9.4	6.6
7.2	26.	18.	12.	8.7	5.9	4.1
7.4	17.	12.	7.8	5.3	3.7	2.6
7.6	10.	7.2	5.0	3.4	2.4	1.7
7.8	6.6	4.7	3.1	2.2	1.5	1.1
8.0	4.1	2.9	2.0	1.40	0.97	0.69
8.2	2.7	1.8	1.3	0.87	0.62	0.44
8.4	1.7	1.2	0.81	0.56	0.41	0.29
8.6	1.1	0.75	0.53	0.37	0.27	0.20
8.8	0.69	0.50	0.34	0.25	0.18	0.14
9.0	0.44	0.31	0.23	0.17	0.13	0.10
	Salinity = 20 g/kg					
7.0	44.	30.	21.	14.	9.7	6.6
7.2	27.	19.	13.	9.0	6.2	4.4
7.4	18.	12.	8.1	5.6	4.1	2.7
7.6	11.	7.5	5.3	3.4	2.5	1.7
7.8	6.9	4.7	3.4	2.3	1.6	1.1
8.0	4.4	3.0	2.1	1.5	1.0	0.72
8.2	2.8	1.9	1.3	0.94	0.66	0.47
8.4	1.8	1.2	0.84	0.59	0.44	0.30
8.6	1.1	0.78	0.56	0.41	0.28	0.20
8.8	0.72	0.50	0.37	0.26	0.19	0.14
9.0	0.47	0.34	0.24	0.18	0.13	0.10
	Salinity = 30 g/kg					
7.0	47.	31.	22.	15.	11.	7.2
7.2	29.	20.	14.	9.7	6.6	4.7
7.4	19.	13.	8.7	5.9	4.1	2.9
7.6	12.	8.1	5.6	3.7	3.1	1.8
7.8	7.5	5.0	3.4	2.4	1.7	1.2
8.0	4.7	3.1	2.2	1.6	1.1	0.75
8.2	3.0	2.1	1.4	1.0	0.69	0.50
8.4	1.9	1.3	0.90	0.62	0.44	0.31
8.6	1.2	0.84	0.59	0.41	0.30	0.22
8.8	0.78	0.53	0.37	0.27	0.20	0.15
9.0	0.50	0.34	0.26	0.19	0.14	0.11

The criterion value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations Intermediate values of pH, temperature or salinity should be interpolated linearly. The freshwater criteria apply at salinities <10 g/Kg (see Tables 3 and 4).

TABLE 8
MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF SALTWATER AQUATIC LIFE (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	270	191	131	92	62	44
7.2	175	121	83	58	40	27
7.4	110	77	52	35	25	17
7.6	69	48	33	23	16	11
7.8	44	31	21	15	10	7.1
8.0	27	19	13	9.4	6.4	4.6
8.2	18	12	8.5	5.8	4.2	2.9
8.4	11	7.9	5.4	3.7	2.7	1.9
8.6	7.3	5.0	3.5	2.5	1.8	1.3
8.8	4.6	3.3	2.3	1.7	1.2	0.92
9.0	2.9	2.1	1.5	1.1	0.85	0.67
	Salinity = 20 g/kg					
7.0	291	200	137	96	64	44
7.2	183	125	87	60	42	29
7.4	116	79	54	37	27	18
7.6	73	50	35	23	17	11
7.8	46	31	23	15	11	7.5
8.0	29	20	14	9.8	6.7	4.8
8.2	19	13	8.9	6.2	4.4	3.1
8.4	12	8.1	5.6	4.0	2.9	2.0
8.6	7.5	5.2	3.7	2.7	1.9	1.4
8.8	4.8	3.3	2.5	1.7	1.3	0.94
9.0	3.1	2.3	1.6	1.2	0.87	0.69
	Salinity = 30 g/kg					
7.0	312	208	148	102	71	48
7.2	196	135	94	64	44	31
7.4	125	85	58	40	27	19
7.6	79	54	27	25	21	12
7.8	50	33	23	16	11	7.9
8.0	31	21	15	10	7.3	5.0
8.2	20	14	9.6	6.7	4.6	3.3
8.4	12.7	8.7	6.0	4.2	2.9	2.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4
8.8	5.2	3.5	2.5	1.8	1.3	0.94
9.0	3.3	2.3	1.7	1.2	0.94	0.71

g/kg salinity is equivalent to parts per thousand (ppt or $^{0}/_{00}$)

Intermediate values of pH, temperature or salinity should be interpolated linearly. The freshwater criteria apply at salinities <10 g/kg (see Tables 2 and 3).

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1. INTRODUCTION

The Cinola Gold Project is a proposed open-pit gold mine development by Barrick Mine Management Inc. and its subsidiary City Resources (Canada) Limited, on Graham Island in the Queen Charlotte Islands of British Columbia (Figure 1). The proposed mine site is about 18 km south of the Village of Port Clements on Masset Inlet. Proposed facilities are all within the Yakoun River drainage, including: (i) the mine area with the open-pit and waste rock stockpile within the Barbie Creek watershed; and (ii) the High West facilities with the plant site and tailings impoundments in the Florence Creek watershed. A marine docking facility is proposed at Ferguson Bay (Figure 2).

Most projected water quality impacts are confined to the Yakoun River and its tributaries which flow to Yakoun Bay of Masset Inlet (Figure 3). Some tailings pond seepage could impact the Mamin River drainage to the west, with its mouth at Juskatla Inlet. The baseline data used in this review relies largely on data collected by the proponent's consultants during the Cinola Project's environmental impact assessment.

The Cinola Gold Project was under review by the B.C. Mine Development Review Process until all development-related activity was postponed by the company. There is a need to develop site specific water quality objectives to protect designated water uses in areas that will be impacted by the mine development, should it proceed in the future. A federal-provincial advisory committee of regulatory agencies was established to assist in the development of water quality objectives by the British Columbia Ministry of Environment, Lands and Parks.

2. HYDROLOGY OF STUDY AREA STREAMS

The following description of streams within the proposed Cinola project area is taken from the Cinola Gold Project Stage II Report (Volume III Baseline Environmental Description)[(36)]. Streamflows generally reflect rainfall patterns as this is the only source of moisture[(36)]. The exception is the Yakoun River, where rainfall-driven streamflows are moderated by the storage capacity in Yakoun Lake and snowpack in the headwaters. Some flow data are given to put the hydrologic characteristics of the streams into perspective. All streams described below are located on Figure 3.

The Yakoun River is the largest drainage on Graham Island, at 477 km^2. It flows north from the Queen Charlotte Ranges to Yakoun Lake, and then about 63 km to Masset Inlet at Yakoun Bay near Port Clements. All proposed Cinola mine construction is confined to the Yakoun River watershed including the mine site, plant site, and High West tailings impoundments and the water storage reservoir. It is the only stream in the project area with long-term flow data available. Mean monthly flows range from 7.5 m^3/s in August to 58.7 m^3/s in November with an annual mean flow of 32.4 m^3/s. The 200-year flood estimate is 1097 m^3/s; the 20-year drought 0.49 m^3/s.

Barbie Creek drains the area around the proposed open-pit as well as higher ground to the west and low swampy areas to the south and east. The catchment area is about 10.2 km^2. It flows for about 9 km to its confluence with the Yakoun River about 30 km upstream of the estuary. Barbie wetland is a flooded area of about 9 ha where Barbie, Coreshack, and Adit Creeks converge. The wetland was formed when a log sorting area as well as road construction modified the flow in Barbie Creek. The wetland exacerbates low flow runoff during the summer due to high transpiration by vegetation, and evaporation from the relatively large area of low gradient. Mean annual runoff is estimated at 0.31 m^3/s, the 200-year flood peak at 13.6 m^3/s, and the 20-year drought flow at 0.003 m^3/s.

Coreshack Creek is about 1 km long, draining to Barbie wetland from an area including the proposed waste rock stockpile. The catchment area is about 1.5 km^2. The

200-year peak flow is estimated at 2.4 m^3/s, with the 20-year drought estimated at 0.0008 m^3/s.

Adit Creek originates in the proposed open pit and flows to Barbie wetland. The catchment area is about 0.27 km^2. The mean annual discharge is 0.012 m^3/s, mainly due to groundwater flow from the exploration adit. The 200-year flood peak is estimated at 0.9 m^3/s and the 20-year drought at 0.0005 m^3/s. During the operating life of the proposed mine, flows in Adit Creek would be reduced as (i) some of its drainage area is in the open-pit, and (ii) some flow would be diverted around the open-pit and water discharged from the test adit directed to the water treatment plant. Upon mine abandonment, the open pit is to be backfilled and flooded, with water overflowing to Adit Creek.

Florence Creek is about 19 km long, flowing north to its confluence with the Yakoun River just upstream from the estuary. The catchment area is about 28.3 km^2. Florence Creek headwaters have the highest average elevations of creeks in the Cinola project area and the steepest slopes. These headwaters are in the proposed High West area which include the tailings/waste rock impoundments, the low-grade ore stockpile, the water storage reservoir, and the mill. Downstream from the proposed impoundments Florence Creek is not well channelled (diffuse). Estimated flows are the following: mean annual 1.27 m^3/s, the 200-year peak flood 60.4 m^3/s, and the 20-year drought 0.05 m^3/s.

Canoe Creek is about 18 km long, flowing north to its confluence with the Yakoun River about 5 km upstream from the estuary. Canoe Creek drains relatively high elevation terrain between the proposed mine site and plant site, with mostly low-lying and gently sloping terrain downstream in the Yakoun lowlands. Its catchment area is about 23.4 km^2. Estimated discharge flows are the following: mean annual 0.69 m^3/s, the 200-year flood peak 14.5 m^3/s, and the 20-year drought 0.014 m^3/s.

Sid Creek is a small tributary to the Yakoun River, located about 2.5 km upstream from Barbie Creek and south of the proposed mine area. Two reaches are separated by the Branch 45 road crossing, and vary in gradient. The reach near the Yakoun River has many beaver dams although beaver ponds are located on or adjacent to both reaches. The creek drains part of a ridge on or near the proposed waste rock stockpile as well as a second ridge to the southeast. The catchment area is 0.8 km^2. The 200-year estimated flood peak is 2.1 m^3/s, the 20-year drought 0.0004 m^3/s.

Clay Creek is a small tributary to the Yakoun River, about 4.5 km long, northeast of Barbie Creek. The catchment area is about 1.6 km^2 of both forested and logged regions. The 200-year flood is estimated at 2.9 m^3/s, the 20-year drought 0.0035 m^3/s.

Boucher Creek flows to the Mamin River, draining a catchment of 9.5 km^2. Most of the watershed is low-lying, hilly terrain. The 200-year flood is estimated at 29.0 m^3/s, the 20-year drought 0.005 m^3/s. Its headwaters are near the headwaters of Florence Creek, with the Stage II report predicting seepage of tailings pond water to Boucher Creek through the No. 2 saddle dam upon mine abandonment. Any seepage across the dam during mine operation would also impact Boucher Creek.

3. WATER USES

This section describes water uses in the Yakoun River and in select streams in the Cinola Project area. Water uses in Yakoun Bay and Ferguson Bay of Masset Inlet are included, the latter because construction in the eastern portion would provide facilities for off-loading equipment and consumable supplies for the proposed mine. Water use information is from the Cinola Gold Project Stage II Report (Volume III)[36].

3.1 Water Licenses

The only license for water withdrawal within the Yakoun River watershed is held by the Masset Band Council. It is for a fish hatchery (chinook, coho, sockeye) on Gold Creek which flows into the Yakoun River above the proposed Cinola project area. The hatchery is part of the Department of Fisheries and Oceans Salmon Enhancement Program.

City Resources (Canada) Limited has a water license application for diversion, storage, and mining-use of water from Barbie Creek, Florence Creek, Canoe Creek, and Clay Creek, all within the mine project area and tributaries to the Yakoun River.

3.2 Fisheries Resources

3.2.1 Introduction: Yakoun And Mamin River Systems

The following table documents the fish species found in the Yakoun and Mamin River systems.

Fish Species Documented in the Yakoun and Mamin River Systems

SPECIES	SCIENTIFIC NAME
Chinook Salmon	*Oncorhynchus tshawytscha*
Coho Salmon	*Oncorhynchus kisutch*
Chum Salmon	*Oncorhynchus keta*
Pink Salmon	*Oncorhynchus gorbuscha*
Sockeye Salmon	*Oncorhynchus nerka*
Rainbow Trout	*Oncorhynchus mykiss*
Steelhead Trout	*Oncorhynchus gairdneri (sea-run)*
Coastal Cutthroat Trout	*Oncorhynchus clarki*
Dolly Varden Char	*Salvelinus malma*
Aleutian Sculpin	*Cottus aleutius*
Prickly Sculpin	*Cottus asper*
Threespine Stickleback	*Gasterosteus aculeatus*
River Lamprey	*Lampetra ayresi*
Western Brook Lamprey	*Lampetra richardsoni*

Salmonids include all five species of Pacific salmon (chinook, coho, chum, pink, sockeye) as well as rainbow, steelhead, and coastal cutthroat trout. From the list above, only Dolly Varden char is of recreational importance and is found throughout the two drainages. There are resident populations in the upper reaches of most creeks and often above barriers impassable to salmonids.

Escapements of salmon species to the Yakoun and Mamin River systems are shown in the following table, together with total escapements for Graham Island (the north island) for perspective. Only the Yakoun River system contributes all five salmon species to Queen Charlotte Island stocks. Calculated from the table, Yakoun River sockeye, pink, and chinook salmon contribute 45%, 70%, and 97%, respectively, to total Graham Island stocks. Even year runs of Pink salmon to the Yakoun River are 50% of the total Queen Charlotte Islands escapement, and are one of the largest in British Columbia. The Mamin River system, in contrast, is a major producer of coho and pinks, but a small sockeye producer.

Average Annual Escapement Estimates and Standard Deviation for Salmon Species in the Yakoun and Mamin Drainage Systems (1976 to 1986)

		SOCKEYE	CHINOOK	COHO	CHUM	PINK[1]
Total Graham Island[2]	n	25 727	757	42 808	49 938	511 266
	SD	9 048	358	37 735	19 147	385 265
Yakoun River	n	11 591	741	8 527	186	360 000
	SD	4 305	362	2 862	62	366 515
Mamin River	n	100	-	2 818	-	22 133
	SD	35	-	924	-	11 726

[1]Based on even-year averages, the dominant runs in the northern Queen Charlotte Islands. Pink salmon estimates for the Yakoun River have incorporated accurate fence counts.

[2]Includes all 15 documented watercourses on Graham Island.

Sockeye and chinook salmon are an especially important native food fishery at the mouth of the Yakoun river. Sockeye enhancement efforts have included both fertilization of Yakoun Lake and periodic hatchery production at the Gold River/Marie Lake hatchery. Chinook have been a traditional native food due to their large size. The Yakoun River supports the only significant size run of chinook in the Queen Charlotte Islands.

Cutthroat trout are present in both the Yakoun and Mamin River mainstems as well as many tributary streams. There are anadromous and resident forms, both utilized in a sport fishery. Similarly, rainbow trout and (anadromous) steelhead are present in the Yakoun and Mamin river systems. The Yakoun River is the major steelhead trout producing river in the Queen Charlottes. Together, these rivers produce from 1000 to 3000 of the total Queen Charlotte steelhead population of 10 000 to 20 000 fish.

3.2.2 Coreshack Creek

IEC Beak (1982)[36] and Norecol (1988)[36] identified coho and Dolly Varden in Coreshack Creek. Coho spawning is restricted to the lower reach because of available gravel substrate and low grades. Upper Coreshack Creek has resident Dolly Varden, but because of steep grades and limited spawning gravels has only low spawning and moderate rearing potential for coho. Department of Fisheries and Oceans has also identified cutthroat trout in Coreshack Creek (Wayne Knapp, personal communication)[37].

3.2.3 Adit Creek

There is little fisheries information on Adit Creek. Gradients in the lower reach (below the Branch 45 road crossing) are low at about 4%, increasing to over 10% in the upper reaches. Substrates are fines and gravels. IEC Beak (1982)[36] observed coho at the Branch 45 road crossing although no fish were captured then or later by Norecol (1988)[36]. Norecol suggests the possibility of coho spawning in the lower reaches as well as rearing there by both coho and Dolly Varden.

3.2.4 Barbie Creek

Documented fish species include primarily coho and Dolly Varden as well as smaller populations of cutthroat and rainbow trout. IEC Beak surveys identified rearing throughout Barbie Creek although juvenile coho were identified mainly in Barbie wetland and the reach downstream to the Yakoun River. Suitable coho spawning gravels identified by IEC Beak surveys were in the area adjacent to the Yakoun River as well as a drainage ditch adjacent to the Branch 42 road, but most coho spawning was predicted to be above Barbie wetland. Fisheries refuge habitat from high winter flows is available in the pools and areas sheltered by log debris in lower Barbie Creek and Barbie wetland.

3.2.5 Florence Creek

The upper reach of Florence Creek begins at the falls located about 500 m above the Branch 4 road crossing. This presents an impassable barrier to anadromous species, and only Dolly Varden are present in the upper reach. Below the falls are Dolly Varden, coho and pink salmon, cutthroat trout and possibly rainbow trout and steelhead. Spawning areas have been documented by IEC Beak for coho and pink salmon as well as cutthroat trout.

3.2.6 Canoe Creek

IEC Beak surveys (1980 - 1982)[36] identified coho and pink salmon, cutthroat and rainbow trout, steelhead, and Dolly Varden in Canoe Creek. IEC Beak believes anadromous species are restricted to the lower 7.5 km by impassable falls. Spawning of steelhead trout and pink salmon have been documented in the lower reach.

3.2.7 Sid Creek

Coho salmon, rainbow trout, and Dolly Varden have been identified in Sid Creek. Gravels suitable for coho spawning appeared restricted to a small area in the lower reach, although coho rearing could occur throughout Sid Creek if movement of juveniles upstream is not restricted by beaver dams. Spawning in the upper reach appears limited to resident Dolly Varden due to the small size of the gravels.

3.2.8 Clay Creek

The IEC Beak survey (1980)[36] identified coho salmon and Dolly Varden. Extensive pool habitat provides coho rearing-use but generally limited spawning habitat.

3.2.9 Yakoun River

As mentioned previously, the Yakoun River is unique to the Queen Charlotte Islands in that all five species of salmon are found there (chum, coho, chinook, sockeye, and pink). Steelhead and cutthroat trout are also present.

Salmon spawning areas depend on the species, and are as follows:

(i) Sockeye spawn in the river upstream from Gold Creek as well as in Yakoun Lake tributaries. Sockeye rearing occurs in Yakoun Lake and in the upper reach of the river.

(ii) Pink spawn throughout the Yakoun River mainstem, but mostly above the Port Clements bridge and mostly during even-year runs. Pink salmon also spawn in tributaries of Yakoun Lake.

(iii) Chum, least abundant of the species in the Yakoun River, spawn in the lower reach, including the Yakoun River estuary.

(iv) Coho spawning is widespread throughout the Yakoun River and Yakoun Lake and their tributary streams. Coho have been documented as spawning in Yakoun River tributaries within the Cinola project area. Juvenile coho were the most abundant fish species documented by IEC Beak and Norecol surveys (1980 - 1987)[36] in the Cinola project area.

(v) Chinook spawning in the Yakoun River occurs primarily above Gold Creek, but with some spawning in tributary streams outside of the Cinola project area. Rearing occurs in both the Yakoun River mainstem and the lower reaches of some tributary streams.

As mentioned previously, the Yakoun River is the major producer of steelhead in the Queen Charlotte Islands. Rearing lasts for three years in the Yakoun River mainstem as well as tributary streams outside of the Cinola project area.

Cutthroat trout spawn in both the mainstem Yakoun River and most tributary streams. Evidence suggests that rearing cutthroat are mostly present in the tributaries.

Dolly Varden char are common throughout the mainstem Yakoun River and tributary streams. Specific spawning and rearing areas have not been identified.

3.2.10 Boucher Creek

IEC Beak (1982)[36] and Norecol (1987)[36] surveys documented coho salmon, Dolly Varden char, and a few rainbow and cutthroat trout in the lower reaches of Boucher Creek, with Dolly Varden and cutthroat trout in the headwaters.

Boucher Creek is tributary to the Mamin River which supports coho and pink salmon, steelhead and coastal cutthroat trout, and Dolly Varden. Sockeye and chinook salmon have also been reported, but in low numbers. Average annual escapements of coho and pink salmon to the Mamin River are 33% and 6%, respectively, of the average annual escapement to the Yakoun River. These escapements are about 7% and 4% of the total Graham Island escapements of coho and pink salmon, respectively.

3.2.11 Yakoun Bay

Yakoun Bay of Masset Inlet has an area of from 4 - 5 km^2 at the mouth of the Yakoun River. The Yakoun River divides into two channels before entering the bay, with Florence Creek entering the west channel just upstream from Yakoun Bay.

There are large communities of vegetation dominated by eelgrass (*Zostera marina*) both intertidally and offshore. Other areas have *Carex* sp. or Fucus sp. as the dominant vegetation. All of these habitats provide rearing areas for fish.

Resident fish documented in the Yakoun estuary include the following: staghorn sculpin (*Leptocottus armatus*), starry flounder (*Platichthys stellatus*), shiner perch (*Cymatogaster aggregata*), threespine stickleback (*Gasterosteus aculeatus*), bay pipefish (*Syngnathus griseolineatus*), and crescent gunnel (*Pholis laeta*).

All five species of salmon documented in the Yakoun River system utilize Yakoun Bay both as adults returning to spawn as well as out-migrating juveniles. The time of year as well as the amount of time juvenile salmon spend in the estuary depend on species. Apparently sockeye fry rear in the tidal channel rather than in the estuary. Steelhead trout and Dolly Varden char juveniles were documented in the estuary by Beak (1980)[36], as were out-migrating adult steelhead trout and Dolly Varden. The timing of adult salmon returning to the Yakoun River to spawn is species dependent, but generally occurs from May through late summer for salmon, July to November for cutthroat, and September to June for steelhead. All species, except coho, hold in the estuary before migration up the Yakoun River; coho apparently hold in the Kumdis estuary east of Port Clements.

3.2.12 Ferguson Bay

Ferguson Bay, about 5 km east of Yakoun Bay, is the site of the proposed service dock for the delivery of supplies and equipment to the proposed Cinola mine site.

Transient use of Ferguson Bay is expected by all five species of salmon as well as by Dolly Varden char documented in the Yakoun River estuary. Dense beds of eelgrass and kelp provide rearing opportunities. Adult salmon returning to spawn in the Yakoun River could pass through Ferguson Bay. There are spawning salmonids in an unnamed creek that enters Ferguson Bay, with juveniles likely in the bay from spring to early summer. Other fish species documented in or near Ferguson Bay include shiner surf perch (*Cymatogaster aggregata*), rockfish juveniles (family Hexagrammidae), bay pipefish (*Syngnathus griseolineatus*), and sandlance (*Ammodytes hexapterus*).

3.3 Wildlife Resources

The most common ungulate in the Cinola project area is the Sitka black-tailed deer (*Odocoileus hemionus*). A small population of about 100 Rocky Mountain elk (*Cervus elaphus*) is present on Graham Island. Although most are found in the Tlell Valley, elk use of the Cinola project area is possible.

Furbearers, either documented or assumed to be around creeks or wetlands in the Cinola project area, include beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), river otter (*Lontra canadensis*), and raccoon (*Procyon lotor*). Other species include red squirrel (*Tamia sciurus*), martin (*Martes americana*), and ermine (*Mustela erminea*). Of these species, martin, river otter, and raccoon are trapped in the project area.

With regard to predators, the black bear (*Ursus americanus*) is the only large carnivore on the Queen Charlotte Islands. Bear signs in the Cinola project area indicate habitat suitability and use.

Upland bird species seen in the Cinola project area include the following: Blue Grouse, a game bird; raptors including Bald Eagle, Red-Tailed Hawk, Osprey, and Sharp-Shinned Hawk; among other species, the most numerous include Belted Kingfisher, Western Flycatcher, Tree Swallow, Winter Wren, American Robin, Varied Thrush, Orange-Crowned Warbler, Dark-Eyed Junco, Fox Sparrow, and Song Sparrow.

Yakoun River estuary use by birds is high. The estuary received the only maximum rating for coastal wetlands on the Queen Charlotte Islands by Hunter et. al. (1985)[3] for its waterfowl, wildlife, and fisheries productivity. The Yakoun River estuary provides habitat for both migratory populations of aquatic birds and raptors as well as feeding habitat for local breeding populations.

3.4 Resource Utilization

3.4.1 Recreation

The mainstem Yakoun River has high recreational value, with angling, swimming, and the associated streamside activities of picnicking, camping, and hiking. Sport fishing on the Yakoun River occurs throughout the year by local residents, with steelhead fishing by residents and tourists being the most important. The reach of the Yakoun River adjacent to the Branch 40 access road is the most heavily used for recreation due to the large number of access points. There are four popular swimming and angling pools from about the Barbie Creek mouth to the end of the Branch 40 access road near the confluence with Unamet Creek.

Yakoun Bay is used for recreation by waterfowl hunters and people viewing the Yakoun Bay tidal flats. There is a small recreation reserve (2.3 ha in area) at the mouth of the Yakoun River.

3.4.2 Fisheries Utilization

Sport Fishing. Steelhead fishing is the most important angling activity on the Yakoun River, it being the primary steelhead producer in the Queen Charlotte Islands. Resident and non-resident anglers also take cutthroat trout, coho salmon, and Dolly Varden char. Several licensed guides service this activity. The number of steelhead anglers estimated by IEC Beak (1982)[36] is from 10 to 20 during the week and from 50 to 60 on weekends. Steelhead fishing occurs from October to March on the reach of the Yakoun River below Ghost Creek (a tributary about 10 km upstream from the mine site). Cutthroat trout and coho salmon are fished mainly from June through September during the steelhead closure. Although some fishing for coho occurs in the Yakoun River during the fall, most occurs in the Yakoun Bay and the Kumdis estuary to the northeast (not mapped). Dolly Varden char are usually incidental catches to trout and salmon.

Commercial Fishing. There is a shrimp fishery with trawlers at the mouth of the Yakoun River as well as a crab fishery in the deeper portions of the estuary. A pink salmon seine fishery occurs from August to September of even-year runs, and is located at the mouth of Masset Inlet and the channel to Dixon Entrance. A gillnet fishery for chum salmon occurs from mid to late September in Dixon Entrance, sometimes extending into Masset Inlet.

The Department of Fisheries and Oceans prohibits bivalve-shellfish harvesting in marine North Coast areas (except for razor and geoduck clams) due to concern regarding paralytic shellfish poisoning. Crustacean-shellfish harvesting (crab and shrimp mentioned above) is permitted.

Native Food Fishery. The Masset Indian Band takes sockeye salmon from the Yakoun River with gillnets, primarily from May 1 to June 15. A native food fishery for pink salmon occurs in the Yakoun River as well, but during August of even-year runs. Some gill netting for chum salmon and chinook also occurs.

3.4.3 Wildlife Utilization

Hunting. The Cinola project area is within provincial Wildlife Unit 6-13. IEC Beak (1982)[36] determined that deer are the main wildlife taken by hunters within the project area, although black bear and grouse are also taken. Although elk may be present in the project area, most hunting is done in the Tlell Valley. The Cinola project lies within a large guiding territory, although coastal areas are where most guiding activity is concentrated. Waterfowl hunting for geese and ducks occurs in the Yakoun River estuary in the fall.

Trapping. One registered trapline includes the Cinola project mine site, High West area, and the main access roads. A second registered trapline includes the proposed Ferguson Bay dock area. Although native trappers do not have to report trapping activities, it is known that major species taken include squirrel, beaver, muskrat, and otter.

4. DESCRIPTION OF THE MINING PROCESS AND WASTE MANAGEMENT

The following is summarized from the Cinola Gold Project, Stage II Report (Volume II and Addendum Report)[36].

4.1 Mine Site

The Cinola Gold Project would be an open-pit mine producing about 24.7 t of ore over a 12-year mine life with additional mineable reserves. The mine site would include the following (see Figure 4): (i) the mine site with service buildings, offices, warehouses, and explosives storage area; (ii) an open pit; (iii) a waste rock stockpile for potential acid generating waste rock storage; (iv) a mudstone dump for storage of Haida formation mudstones from the west wall of the open- pit; (v) an overburden stockpile of material stripped from the pre-production development of the open-pit; and (vi) a low-grade ore stockpile (in the High West area) from ore mined that would exceed milling requirements from years one to three of the 12-year operational phase. This stockpile would be reclaimed (by milling with high grade ore) from years three through six.

4.2 Plant / Mill Site

The plant site would be located in the High West area southeast of the tailings/waste rock impoundments (Figure 4). It would include the ore processing mill, power plant, sewage treatment plant, coarse ore stockpile, primary crusher area, and a complex including the office, warehouse, and service area.

The nitrate oxidation-cyanidation gold milling process includes the following: crushing; grinding; oxidation of sulphides using nitric acid leaching; neutralization with limestone and lime; cyanide leaching of residues using a hybrid carbon-in-pulp/carbon-in-leach process; gold adsorption on to carbon and carbon regeneration; gold elution; electrowinning; and smelting.

4.3 Treatment Of Mine Wastes

All acid releasing waste rock (the argillically altered rock) as well as one quarter of the potential acid generating waste rock (Skonum sediments and hydrothermal breccias) would be permanently submerged in the tailings impoundments. The remaining three-quarters of the potential acid generating rock would be stored in the waste rock stockpile, to be backfilled to the open-pit and permanently flooded with water to prevent acid generation when mining is completed (years 13 and 14, the reclamation phase).

Several features have been designed into the waste rock stockpile to prevent and control acid generation during the operating life of the mine. These include: addition of crushed limestone to the waste rock (for neutralization); placement of a low permeability cover over the surface to minimize oxidation as well as precipitation inflows; providing a base drainage layer to prevent groundwater entry to the stockpile; and diverting runoff from the stockpile through collection ditches to the water treatment plant.

4.4 TREATMENT OF PLANT SITE AND MILL WASTES

Three sequentially activated impoundments would be used for permanent storage of all acid consuming tailings (neutralized with lime) as well as all of the acid-releasing waste rock, some of the potential acid generating waste rock, and minor quantities of other wastes including runoff from the low-grade ore stockpile and precipitate from the water treatment plant (described in detail in Section 5.3).

The tailings slurry will be treated to reduce cyanide and mercury, the two constituents of major concern before discharge to the active impoundment. Cyanide destruction would be accomplished through sulphur dioxide/air cyanide oxidation, and mercury levels reduced through precipitation with sodium sulphide.

Nitrate from nitric acid leaching (and explosives use in mining) is reduced in tailings water by nitrogen recycling in the mill circuit.

A plant for the internal treatment of part of the circulating process water would remove soluble salts using reverse osmosis. This water would then be used as make-up water for the cyanide circuit with the concentrated salt solution returned to the oxidation process. This internal treatment of part of the process water would achieve a low demand for fresh water to the mill. Additional demands would be met with recycling from the tailings impoundment. Overall, the volume of poor quality water to the active impoundment would be minimized.

5. WASTE DISCHARGES AND WATER MANAGEMENT

The following is summarized from the Cinola Gold Project Stage II Report (Volume 4)[36].

5.1 Introduction

To protect high fisheries values of receiving waters and to address environmental concerns related to acid generation, the proponent's water management/waste discharge plan has the following objectives:

(i) to minimize changes in creek flows,
(ii) to remove sediments from disturbed areas with settling ponds,
(iii) to minimize flows of potentially acid water or poor quality water,
(iv) to collect and contain poor quality water (including acid drainage), and
(v) to provide treatment. Treatment systems include settling ponds, the water treatment plant, and natural and constructed wetlands.

Water management/waste discharge systems in the Mine area and High West area are briefly described below.

5.2 Mine Area

Eight water management systems have been designed by the proponent in the Mine area. All systems would discharge to Barbie Creek or its tributaries. The following table summarizes the water management systems, discharge locations, and types of discharges according to the level of treatment predicted by the proponent as necessary to meet environmental (aquatic life) criteria. Although not predicted by the proponent as being impacted by mine operation, Sid Creek has been included in the table as it would receive a "clean" water diversion from around a constructed wetland and will have water quality objectives set for it. Treatments include settling ponds to remove sediments and associated metals, a lime water treatment plant to neutralize acid drainage and precipitate metals followed by discharge to artificial (constructed) wetlands to attenuate nutrients and metals.

The water treatment plant is designed to treat all acid water during mine operation and will be maintained as a contingency after mine abandonment should discharge from the backfilled pit be acidic. Acid water flows in excess of the 3500 m^3/d design capacity would be stored in two settling ponds for later treatment. During low rainfall periods when discharge of treatment plant water to Barbie Creek could cause aquatic life criteria to be exceeded, treated water would be discharged to the active High West impoundment. As mentioned previously, the water treatment plant is designed to neutralize all acid drainage and reduce the level of metals. Its design includes the following:

(i) lime addition and aeration to adjust pH and precipitate metals;

(ii) sodium sulphide, calcium sulphide, or TMT (a sulphide substitute) to reduce levels of mercury and other metals;

(iii) coagulation and precipitation of colloidal particles through conditioning; and

(iv) clarification/thickening to separate the precipitate from the solution. The clarified solution is pumped to a monitoring pond (for problem detection/correction or treatment) and then to an equalization pond to minimize effluent quality fluctuations.

WATER MANAGEMENT FOR THE MINE AREA

Cinola Water Management System No.	Discharge Location(s)	Type of Discharge
		No Treatment Required:
- -	Sid Creek	clean water diversion around constructed wetland
1	Coreshack Creek	runoff from undisturbed area above the Waste Rock Stock-pile; discharged <u>south</u> to Coreshack Creek
1	Upper Barbie Creek	runoff from undisturbed area above the Waste Rock Stock-pile, discharged <u>north</u> to Upper Barbie Creek
		Settling Pond only:
2	Coreshack Creek	Waste Rock Stockpile cover runoff
5	Coreshack Creek	mudstone runoff and clean groundwater from Open-Pit
7	Upper BarbieCreek	runoff from the north slope of the Waste Rock Stockpile
8	Upper Barbie Creek	runoff from the Mine Plant
		Settling Pond(s) & Wetland:
6	Middle Barbie Creek	runoff from Mudstone Dump, Overburden Stockpile, haul road, and undisturbed catchment
		Settling Pond, Wetland & Water Treatment:
3	Lower Barbie Creek (below natural wetland)	groundwater and infiltration from the Waste Rock Stockpile
4	Lower Barbie Creek (below wetland)	acidic groundwater and acidic runoff from the Open-Pit

5.3 High West Area

5.3.1 Introduction

All facilities in the High West area would discharge to Florence Creek, except seepage to Boucher Creek (see Figure 4).

The proponent's objectives in the High West area for flow management include minimizing the changes to the flow regime in Florence Creek, to keep tailings/waste rock impoundments flooded, and to have the capability of augmenting low flows in Florence Creek with water from the storage reservoir constructed in the headwaters. The mine plan directs all potentially affected drainage from the High West area to three sequentially activated impoundments, all isolated from Florence Creek drainage by embankments. Diversion ditches are to redirect unaffected surface water around the impoundments. A settling pond would be located just downstream from Impoundment No. 3.

Due to the poor quality of the impoundment water and the limited dilution available in Florence Creek, the impoundment design is for zero discharge to Florence Creek during the operating life of the mine. This would be achieved with the recycling of process water from the active impoundment back to the mill. However, the floating decant at the settling pond downstream from Impoundment No. 3 would have a discharge and likely contribute suspended matter to Florence Creek.

Water quality impacts on Florence Creek are predicted by the proponent to be restricted to the period following impoundment "de-activation and reclamation". Florence Creek would then be redirected through the impoundments which are proposed to be reclaimed in a wetland/pond system. Florence Creek water quality would be impacted from interaction with tailings and waste rock in the reclaimed impoundments as well as groundwater seepage through the reclaimed impoundments. Site specific water quality objectives (set in this document) would be met by the proponent by controlling the discharge rates from the reclaimed impoundments after mine abandonment.

Four water management systems for the High West area are discussed separately in the following.

5.3.2 The Water Storage Reservoir Diversion System

The Cinola development should not (according to the proponent) drastically change flows in Florence Creek as only the area of the active impoundment(s) would be removed from the drainage. Flow reductions due to the water storage reservoir upstream would be primarily during the October and November high runoff period when the reservoir would be filled or recharged. Runoff is to be directed around the reservoir for the rest of the year.

The reservoir is designed to meet all the freshwater needs of the project as well as to have the capability of augmenting drought flows to protect fish habitat.

5.3.3 Tailings / Waste Rock Impoundment And Settling Pond System

There is concern that mercury methylation rates would be enhanced in the flooded soils of both Impoundment No. 3 (used as a settling pond for the clean water diversion to Florence Creek in years 1 to 8) and the water storage reservoir. Organic soils would be removed from these reservoirs prior to flooding to minimize this problem. Mercury released from the ore during the milling process would be precipitated as cinnabar (HgS) by the addition of sodium sulphide.

When tailings/waste rock Impoundment No.'s 1 & 2 are full, water would be transferred to the last operational impoundment so they can be reclaimed. On mine closure, water from Impoundment No. 3 would be pumped to the Pit while it is being backfilled. Once reclaimed, an impoundment is expected to take about two years to fill with water (precipitation and groundwater) to the height of an emergency spillway. When Impoundment No. 1 is reclaimed and filled, it would discharge via the freshwater diversion to Florence Creek except during July and August low flows. Once Impoundment No. 2 is reclaimed and full, there would be a discharge to the fresh water diversion system and ultimately to Florence Creek in all months. These discharges would have had their water quality affected by tailings water. Should discharges from the reclaimed impoundments be of unacceptable quality, proponent contingencies include the following:

(i) controlled discharge to the active impoundment,
(ii) storage for longer than the one year predicted by the proponent to have

discharge quality meet Florence Creek environmental criteria, and

(iii) release of freshwater from the water storage reservoir to increase the dilution available in Florence Creek.

On mine closure, Florence Creek would be returned to its pre-diversion channel which includes the reservoir and the three impoundments. The settling pond downstream from Impoundment No.3 is to be removed. Spillways in the impoundments are to be maintained with a minimum of 2 m of water and neutralized tailings over the waste rock to inhibit acid generation. Cyanide (from the ore extraction process) and copper, two particular concerns in the submerged tailings, are predicted by the proponent to decrease in concentration from degradation (to cyanate) and precipitation, respectively. This is predicted to improve the quality of groundwater seepage to Florence Creek. The proponent's best estimated mean groundwater flow upwards through the reclaimed impoundments to Florence Creek is 151 m^3/d (45 to 305 m^3/d range).

The proponent also predicts impacts on Boucher Creek (of the Mamin River drainage) when the Florence Creek flow course is re-established; a range from 1 to 25 m^3/d (best estimated mean flow of 9 m^3/d) of groundwater seepage through the saddle embankment of Impoundment No. 2.

5.3.4 Low-Grade Ore Stockpile

The potentially poor quality runoff from the acid-generating Skonun sediments will be directed to the mill and neutralized prior to discharge to the active impoundment with the tailings slurry. Drainage is expected to contain elevated metals from acid leaching as well as nitrates from explosives use. Surface runoff from the mudstone cap is predicted by the proponents to be of good quality and directed around the stockpile with a diversion ditch with discharge to (ultimately) Impoundment No. 3 for settling.

5.3.5 Mill Area And Power Plant System

All potentially acid-generating drainage from the coarse ore stockpile would either be utilized in the milling process or pumped into the tailings line. All other good quality drainage would be directed to Impoundment No. 3 through the low-grade ore stockpile diversion ditch. All effluents from the process plant, chemical neutralization tank, and the sewage treatment plant would either be recycled through the mill circuit or discharged to the active impoundment. Waste water from the diesel generators at the power plant would also be directed to the active impoundment. The cyanide-destruction plant in the mill area would treat mill effluent before discharge to the active tailings impoundment.

5.4 Ferguson Bay Facilities

Cargo transported to the Graham Island mine site would be by barge with docking facilities constructed at Ferguson Bay (Figure 2), inside the east breakwater of MacMillan Bloedel's log boom and dryland sort. A laydown area would provide for unloading, storage, reloading, and shipping of cargo, with a bulk explosives plant located about 360 m south. Limestone and diesel fuel would be stored on site. General cargo unloaded at Ferguson Bay and transported to the mine site include, but would not be restricted to the following: limestone, fuel oil and diesel, explosives (e.g., ammonium nitrate), and reagents including quicklime, sulphuric acid, sodium cyanide, sodium hydroxide, sodium sulphide, copper sulphate, ammonia, and chlorine.

6. WATER QUALITY

Barbie Creek (and its tributaries) and Florence Creek are discussed first as the proposed Cinola project would impact their waters directly. Barbie Creek would be impacted both during the mine operation as well as after mine abandonment. The proponent predicts that Florence Creek should not be impacted from the tailings/waste rock impoundments in its headwaters during mine operation due to the 'zero discharge' developed into the mine plan; only upon tailings pond reclamation and mine abandonment would Florence Creek be impacted as flow is redirected through the original watercourse. Water quality of the Yakoun River and its other tributaries are then discussed, followed by a discussion of the water quality in Boucher Creek of the Mamin River drainage. Finally, metals levels in both fresh water and marine biota are discussed. All sites or areas are on Figure 3. Generally, only those characteristics are discussed that exceed water use criteria, or that may be affected by the Cinola development and that have water quality objectives set for them. Ministry of Environment, Lands and Parks approved criteria and CCREM (Canadian Council of Resource and Environment Ministers) water quality guidelines(10) are frequently referred to. The CCREM is currently known as CCME (Canadian Council of Ministers of Environment).

6.1 CORESHACK CREEK (Tributary To Barbie Creek)

Water quality data for Site Q34 collected by Norecol, the proponent's consultants, from December 1987 to August 1988 (n = 9) are summarized in Table 6.1.1. Site Q34 is located at the Branch 42 access road crossing upstream from the mouth at Barbie wetland.

The pH ranged from 6.0 to 6.6 (mean of 6.3), usually less than the British Columbia criteria and CCREM guidelines of 6.5 to 9.0 to protect aquatic life and wildlife(40,10). Total alkalinity ranged from 2 - 8 mg/L, indicating that Coreshack Creek is highly sensitive to acidic inputs (low buffering capacity) in terms of aquatic life protection(14).

Turbidity and suspended solids were generally low, less than 1.7 NTU and 3 mg/L, respectively. The exception was likely a rainfall event on July 20, 1988, where levels of turbidity and suspended solids were elevated at 9.5 NTU and 32 mg/L, respectively.

Coreshack Creek water was soft, ranging from 6.0 to 12.0 mg/L hardness (as $CaCO_3$).

The water was highly coloured, ranging from 37 to 170 true colour units (mean of 74 colour units). Highly coloured water indicates the presence of complex organic compounds originating from the decomposition of organic matter.

Sulphate levels were low, ranging from 1 to 5 mg/L. The drinking water criterion is 150 mg/L for aesthetics[27]. The suggested level to protect aquatic life is 100 mg/L, the rationale discussed in Section 7.4.

Ammonia-nitrogen levels were generally low, ranging from <0.005 to 0.012 mg/L (mean of 0.006 mg/L). Levels were less than the 30-day average and maximum British Columbia aquatic life criteria levels[9] given in Tables 6.1.2 and 6.1.3, respectively. Nitrate-nitrogen levels were low, ranging from <0.005 to 0.025 mg/L (mean of 0.008 mg/L), and less than the British Columbia aquatic life criteria 30-day average and maximum of 40 and 200 mg/L, respectively[9]. Similarly, nitrite-nitrogen levels were low at <0.002 mg/L in all samples. British Columbia nitrite criteria are dependent on chloride concentration, and are presented in Table 6.1.4[9].

Periphyton data from Coreshack Creek are not yet available, but are understood to be normally low. British Columbia criteria for streams are maximums of 50 mg/m^2 chlorophyll a to protect aesthetics, and 100 mg/m^2 chlorophyll a to protect salmonids[13].

Levels of dissolved aluminum were high, exceeding the British Columbia aquatic life aluminum criteria maximum for pH both above and below 6.5 in all but one sample. The criteria levels for the range of pH found in Coreshack Creek (6.0 - 6.6) are from 0.047 to 0.1 mg/L maximum dissolved aluminum[1], while those ambient levels of pH measured in Coreshack Creek

have ranged from 0.1 to 0.32 mg/L dissolved aluminum (mean of 0.19 mg/L). Aluminum speciation data from other streams in the Cinola project are summarized in Table 6.1.5.

Total arsenic levels ranged from <1 to 15 μg/L (mean of 2.6 μg/L) with corresponding dissolved arsenic from <1 to 3 μg/L (mean of 1.2 μg/L). These levels are less than the CCREM aquatic life guideline of 50 µg/L total arsenic maximum(10), indicating suitability of Coreshack Creek water for aquatic life with respect to arsenic.

Cadmium levels were below the detection limit (0.2 µg/L) in all samples for both dissolved and total cadmium. The detection limit is the same as the CCREM aquatic life guideline for a hardness of 0-60 mg/L (as $CaC0_3$)(10) as found in Coreshack Creek.

CCREM aquatic life guidelines for total chromium are 2 µg/L for phytoplankton and zooplankton and 20 µg/L for fish(10). Coreshack Creek levels were at or below the detection limit (1 µg/L) for all samples, both dissolved and total, indicating the suitability of Coreshack Creek water for aquatic life with respect to chromium on the dates sampled.

Copper levels in Coreshack Creek ranged from <0.5 µg/L (the detection limit) to 0.9 µg/L for total copper (mean of 0.5 µg/L) and were below the detection limit for dissolved copper. These levels were below both the 30-day average and maximum British Columbia aquatic life criteria, which are based on hardness(5). These criteria are in terms of µg/L total copper, and are as follows: (i) a 30-day average of <2 µg/L when average hardness is <50 mg/L, or (<0.04 x average hardness) when the average hardness is >50 mg/L; and (ii) a maximum of (0.094 x hardness + 2).

Iron levels in Coreshack Creek were high, exceeding the 0.3 mg/L maximum total iron CCREM aquatic life criterion(10) in all but one sample for total iron and in all but two samples for dissolved iron, with maximums of 8.1 and 1.16 mg/L, respectively.

Total mercury levels in Coreshack Creek were below the detection limit of 0.05 µg/L in all samples. British Columbia aquatic life criteria are 0.02 µg/L 30-day average and 0.1 µg/L maximum total mercury(4). The high detection limit may have masked samples that exceeded the average criterion. Available low level mercury data for Cinola project area streams are discussed in section 6.3 (Barbie Creek) and 6.4 (Florence Creek).

Total manganese levels in Coreshack Creek ranged from 0.03 to 0.51 mg/L (mean of 0.11 mg/L), in two of nine samples exceeding the 0.1 mg/L aquatic life criterion of Dawson(45), but less than the 1.0 mg/L guideline of Davies and Goettl(43). Dissolved manganese levels were less than these criteria, except one sample at 0.16 mg/L.

Levels of lead in Coreshack Creek, both dissolved and total, were below the detection limit of 1 μg/L. These levels were less than the British Columbia criteria which are given in terms of total lead[12]. These criteria are as follows: (i) 30-day average for hardness > 8 mg/L should be less than or equal to 3.31 + exp(1.273 ln (average hardness) - 4.705); none proposed for hardness < 8 mg/L; and (ii) maximum = 3 μg/L when hardness <8 mg/L, and maximum = exp (1.273 ln (hardness) - 1.460) when hardness > 8 mg/L.

Nickel levels were all <2 μg/L for both dissolved and total nickel. These levels are less than the CCREM aquatic life guideline, which is 25 μg/L maximum for total nickel at a hardness of from 0-60 mg/L $CaC0_3$[10].

Selenium levels were all less than the 1 μg/L detection limit in all samples for both dissolved and total selenium. These levels were less than the CCREM aquatic life guideline of 1 μg/L maximum total selenium[10].

Silver levels were all less than the 0.2 μg/L detection limit for both dissolved and total silver. The detection limit is too high for comparison with the 0.1 μg/L total silver maximum CCREM aquatic life criterion[10].

Levels of zinc in Coreshack Creek, both dissolved and total, were less than the CCREM tentative aquatic life guideline of 0.030 mg/L maximum total zinc[10]. These levels ranged from 0.0014 to 0.0036 mg/L for dissolved zinc (mean of 0.0024 mg/L), and from 0.0014 to 0.0065 mg/L for total zinc (mean of 0.0032 mg/L). These levels are also lower than the 0.015 mg/L total zinc reported by the IJC (1987) as toxic to phytoplankton[11].

6.2 ADIT CREEK (Tributary To Barbie Creek)

Water quality data for Adit Creek Site Q1 sampled by Norecol from November 1986 to August 1988 (n = 20) are summarized in Table 6.2. Site Q1 is located at the Branch 42 road crossing above Barbie wetland. Adit Creek has been impacted since a test adit was drilled and began discharging groundwater to the creek. The water samples collected to date reflect this contamination, with levels of arsenic, cadmium, chromium, copper, mercury, and zinc greater than found in adjacent small streams. As mentioned previously, flows in Adit Creek would be reduced during mine operation as some drainage area is lost to the open pit. Total flows from the pit would go into Adit Creek upon mine abandonment. Whether or not the Cinola mine development proceeds, remedial work should be considered for Adit Creek to reduce the impact of the test adit.

The pH in Adit Creek varied from 4.2 - 6.6 (mean of 5.6), with all samples but one less than the British Columbia criteria and CCREM guidelines to protect aquatic life of from 6.5 to 9.0[40,10]. These data may reflect the acid drainage from the test adit, but are similar to other small creeks in the area. Total alkalinity ranged from 1 to 8 mg/L (as $CaC0_3$), indicating that Adit Creek has little buffering capacity to acidic inputs[14].

Turbidity ranged from 1.5 to 23 NTU, higher than both Coreshack Creek previously discussed as well as Barbie Creek to which it drains (maximum of 18 NTU at Upper Barbie Creek Site Q15). Suspended solids ranged from 1 to 16 mg/L, similar to those levels found in Coreshack and Barbie Creeks.

Adit Creek water was soft, ranging from 10 to 50 mg/L hardness, but averaging about twice as hard as in Coreshack Creek previously discussed.

Colour ranged from 13 to 85 true colour units (mean of 53.2), not as dark stained as Coreshack Creek (maximum of 170 true colour units), but still highly coloured.

Sulphate levels ranged from 1 to 53 mg/L, an indication of neutralized acid drainage. Drinking water criteria are 150 mg/L for aesthetics[27]. The suggested level to protect aquatic life is 100 mg/L, with its rationale discussed in Section 7.4.

Ammonia-nitrogen levels ranged from <0.005 to 0.087 mg/L (mean of 0.026 mg/L), less than both the 30-day average and maximum British Columbia aquatic life criteria (detailed in Tables 6.1.2 and 6.1.3)[9].

Nitrate-nitrogen levels ranged from <0.005 to 0.126 mg/L (mean of 0.019 mg/L), less than the 30-day average and maximum British Columbia criteria of 40 mg/L and 200 mg/L, respectively[9].

Nitrite-nitrogen levels were below the 0.002 mg/L detection limit in all samples. This level is below the British Columbia aquatic life criteria levels, presented in Table 6.1.4[9].

Periphyton data are not yet available, but are understood to be low. British Columbia criteria are maximums of 50 mg/m^2 chlorophyll a to protect aesthetics and 100 mg/m^2 chlorophyll a to protect salmonids[13].

Total cyanide levels were less than the 0.001 mg/L detection limit in all samples. These levels were less than the British Columbia aquatic life criteria which, in terms of weak-acid dissociable cyanide, are 0.005 mg/L 30-day average and 0.010 mg/L maximum[6].

Levels of dissolved aluminum were high, ranging from 0.19 to 1.3 mg/L (mean of 0.49 mg/L). All sample concentrations exceeded both the 30-day average and maximum levels specified by the British Columbia criteria regression equations for aluminum[1]. Maximum dissolved aluminum allowed by the criteria are 0.1 and 0.020 mg/L pH of 6.6 and 4.2, respectively. The 1.3 mg/L dissolved aluminum level on March 22, 1988, corresponded to a pH of 4.7. Aluminum speciation of Adit Creek samples collected on February 27, 1989 (Table 6.1.5), however, showed that the level of biologically available inorganic monomeric aluminum was less than the criteria level and not a problem to aquatic life. Most of the aluminum was in the unreactive forms (particulate, colloidal, polymeric, and resistant organic). The level of reactive inorganic monomeric aluminum was 17 and 18 µg/L (replicates), lower than the 50 µg/L British Columbia average criterion for pH of 6.75 (see Table 6.1.5). The levels of inorganic monomeric aluminum at the lower pH (5.6 to 5.7) found in Barbie Creek on the same date were at or above the British Columbia average criteria, suggesting that Adit Creek would not tolerate significant changes in pH from mining activity. This would be especially true if the pH was shifted much outside the theoretical aluminum solubility minimum of pH 5.6 to 6.2[15].

Total arsenic levels in Adit Creek ranged from 0.001 to 0.076 mg/L (mean of 0.009 mg/L) with dissolved arsenic ranging from 0.001 to 0.008 mg/L (mean of 0.004 mg/L). Levels exceeded the CCREM aquatic life guideline of 0.050 mg/L total arsenic[10] in only one of twenty samples at 0.076 mg/L total arsenic (July 22, 1987).

Cadmium levels ranged from <0.2 to 0.6 µg/L for total cadmium (mean of 0.2 µg/L), and all samples were below the detection limit for dissolved cadmium. Only one sample exceeded the CCREM aquatic life criterion of 0.2 µg/L maximum total cadmium (for hardness <60 mg/L)[10]; this was 0.6 µg/L total cadmium (October 14, 1987).

Total chromium levels ranged from below the 0.001 mg/L detection limit to 0.012 mg/L (mean of 0.002 mg/L), with all dissolved chromium levels below this detection limit. Only one sample at 0.012 mg/L exceeded the CCREM aquatic life guideline of 0.002 mg/L to protect phytoplankton and zooplankton, but was less than the 0.020 mg/L maximum level guideline to protect fish[10].

Copper levels in Adit Creek ranged from <0.5 to 2.7 µg/L for total copper (mean of 1.1 µg/L) and <0.5 to 1.7 µg/L for dissolved copper (mean of 0.8 µg/L). The 30-day average British Columbia aquatic life criterion of 2 µg/L[5] was exceeded for total copper in 2 of 20 samples. Sample concentrations were less than the maximum British Columbia criteria levels. These are based on the calculation: 0.094 (hardness) + 2 µg/L[5].

Iron levels exceeded the CCREM aquatic life guideline of 0.3 mg/L maximum total iron[10] in all samples, ranging from 0.91 to 41 mg/L total iron (mean of 3.5 mg/L) and from 0.32 to 2.1 mg/L for dissolved iron (mean of 0.9 mg/L). These high levels might, in part, explain the high colour in the water.

British Columbia aquatic life criteria for mercury are a 30-day average of 0.02 µg/L and a maximum of 0.1 µg/L total mercury[4]. Adit Creek water samples ranged in concentration from below the detection limit (0.05 µg/L) to 0.06 µg/L for total mercury (mean of 0.05 µg/L), exceeding the average criterion on at least one occasion, but with the high detection limit possibly masking other high values. All sample concentrations were less than the maximum criterion of 0.1 µg/L, however. No analyses were made for dissolved mercury.

Total manganese levels ranged from 0.005 to 1.18 mg/L (mean of 0.44 mg/L), with 18 of 20 samples exceeding the 0.1 mg/L aquatic life criterion of Dawson[45] and one of twenty samples exceeding the 1 mg/L criterion of Davies and Goettl[43]. Dissolved manganese levels were similar, ranging from 0.19 to 1.18 mg/L (mean of 0.46 mg/L). The 0.005 mg/L total manganese compared with 0.54 mg/L dissolved manganese on June 24, 1988, as well as 0.032 mg/L total manganese compared with 0.32 mg/L dissolved manganese on August 18, 1988, suggest sample contamination, errors in analyses or in data transcription.

Lead levels, both dissolved and total, were less than the 1µg/L detection limit. These levels were less than both the 30-day average and maximum British Columbia criteria, which are based on hardness[12].

Zinc levels ranged from 2.6 to 50 µg/L for total zinc (mean of 11.4 µg/L) and from 0.5 to 8.1 µg/L for dissolved zinc (mean of 2 µg/L). Two samples for total zinc exceeded the CCREM tentative aquatic life guideline of 30 µg/L maximum total zinc[10], whereas all levels of dissolved zinc were less than this criterion.

Nickel levels ranged from below the detection limit (2 µg/L) to 7 µg/L and 3 µg/L for total and dissolved nickel, respectively. These levels are less than the CCREM aquatic life guideline of 25 µg/L for a hardness of 0-60 mg/L $CaC0_3$[10].

Selenium levels were less than the 1 µg/L detection limit in all samples, for both dissolved and total selenium. These levels are less than the CCREM aquatic life guideline of 1 µg/L maximum total selenium[10].

Silver levels were less than the detection limit of 0.2 µg/L in all samples for both dissolved and total silver. This detection limit is too high to properly evaluate these Adit Creek samples as the CCREM aquatic life criterion is 0.1 µg/L maximum total silver[10].

6.3 BARBIE CREEK (Tributary To Yakoun River)

Water quality data for Sites Q15 (Upper Barbie Creek), Q8 (Middle Barbie Creek), and Q4 (Lower Barbie Creek) are summarized in Table 6.3. Barbie Creek sites were each sampled by Norecol over different periods from November 1986 to August 1988 (n from 17-20 depending on the variable) and are the basis for the majority of the discussion below. Background data collected by Environment Canada from 1983 to 1988[16,17,18](but not tabulated in this report) are discussed where deemed appropriate, generally when these data extend the range of values of variables of concern.

The pH of Barbie Creek ranged from a low of 4.6 (upper Barbie Site Q15) to 6.6 (lower Barbie Site Q4), with mean values from upper to lower Barbie Creek of 4.9, 5.5, and 5.9, respectively. Most samples were more acidic than the British Columbia criteria and CCREM guidelines to protect aquatic life of 6.5 to 9.0[40,10]. Similarly, Environment

Canada pH data was as low as 4.8 with mean values for middle to lower Barbie Creek of 6.5 (n = 4) and 5.7 (n = 13), respectively.

Alkalinities generally increased from upper to lower Barbie Creek with maximum alkalinities of 5.0, 8.0, and 10.0 mg/L, respectively, as determined by Norecol. Data showed alkalinities to be highest during the summer low rainfall period and lowest during the fall and winter high rainfall/high dilution period. Alkalinities as low as those found in Barbie Creek (<10 mg/L) give a low buffering capacity and the water is therefore highly sensitive to acidic inputs[14]. Environment Canada alkalinity data were similarly low for Barbie Creek, ranging from <1 to 8 mg/L.

Turbidity in Barbie Creek was low, ranging from 0.5 to 18 NTU for all sites. If the maximum level is excluded, the next highest turbidity was 8.6 NTU. Similarly, suspended solids in Barbie Creek were low, ranging from <1 to 16 mg/L. High suspended solids levels were quite rare, however, with the following average suspended solids levels for the 3 sites a better indication of average conditions: 3.0 mg/L Site Q15, 3.8 mg/L Site Q8, and 2.9 mg/L Site Q4.

Barbie Creek water was soft, with hardness ranging from 7 to 31 mg/L, both extreme levels from upper Barbie Creek. Hardness is due to polyvalent metallic ions dissolved in water, primarily calcium and magnesium. Hardness was lowest in Barbie Creek during the summer (June to August) when groundwater flow predominates.

Barbie Creek water was highly coloured, ranging from 84 to 453 true colour units (mean of 214 colour units, all sites), with both extreme levels from upper Barbie Creek Site Q15. The strong brown colour of these waters is due to the high content of humic substances (organics) leached from decomposing vegetation.

Sulphate levels in Barbie Creek were low, ranging from <1 to 13 mg/L as determined by Norecol and up to 16 mg/L as determined by Environment Canada. The drinking water criterion is 150 mg/L for aesthetics[27]. The suggested level for protection of aquatic life is 100 mg/L (rationale discussed in section 7.4).

Ammonia-nitrogen levels in Barbie Creek ranged from <0.005 to 0.057 mg/L (mean of about 0.010 mg/L, all sites), which were less than both the 30-day average and maximum British Columbia aquatic life criteria presented in Tables 6.1.2 and 6.1.3[19]. The

30-day average ammonia criteria range from 0.1 to 2 mg/L, and maximum criteria range from 0.7 to 28 mg/L, both dependent on pH and temperature.

Nitrate-nitrogen levels in Barbie Creek ranged from <0.005 to 0.112 mg/L (mean of 0.014 mg/L, all sites), the maximum value recorded at lower Barbie Creek Site Q4. These levels are much lower than both the 30-day average and maximum British Columbia aquatic life criteria of 40 mg/L and 200 mg/L, respectively(9).

Nitrite-nitrogen levels in Barbie Creek were low, ranging from <0.002 to 0.004 mg/L. Most samples from all three sites were below the detection limit. British Columbia aquatic life criteria are dependent on chloride concentration, and vary from 0.06 to 0.60 mg/L maximum nitrite concentration, and from 0.02 to 0.20 mg/L 30-day average concentration(9).

Periphyton data are not yet available from the study area, including Barbie Creek. Levels are understood to be normally low. British Columbia periphyton criteria are maximums of 50 mg/m^2 chlorophyll a to protect aesthetics, and 100 mg/m^2 chlorophyll a to protect salmonids(13).

Total cyanide levels in Barbie Creek were less than the detection limit (1 µg/L) in all samples from all three sites. These levels are less than British Columbia aquatic life criteria which, in terms of weak-acid dissociable cyanide, are 5 µg/L 30-day average and 10 µg/L maximum(6).

Total aluminum levels ranged from 0.2 to 2.2 mg/L (mean of 0.60 mg/L, n = 83), with dissolved levels of from 0.20 to 0.70 mg/L (mean of 0.45 mg/L, n = 83) for all sites sampled by both Norecol and Environment Canada. Levels of dissolved aluminum frequently exceeded the maximum British Columbia aquatic life criteria, which decreases with decreasing pH(1). For example, the lowest pH of 5.1 which occurred on two occasions at lower Barbie Creek Site Q4, corresponds with a maximum criterion level of 0.024 mg/L dissolved aluminum relative to the ambient levels of 0.50 mg/L (April 11, 1987) and 0.34 mg/L (December 14, 1987). Aluminum speciation data from samples taken February 27, 1989 from Sites Q8 Middle and Q4 Lower Barbie Creek (Table 6.1.5) show that the proportion of reactive aluminum (organic plus inorganic monomeric) was greater than in the sample from Florence Creek. Inorganic monomeric aluminum levels in middle Barbie Creek were lower than in Adit Creek, with levels in lower Barbie Creek similar to those levels in Adit Creek. Table 6.1.5 also shows that the level of inorganic monomeric aluminum, the biologically available fraction, equalled the 30-day average British Columbia criterion at Middle Barbie Creek Site Q8 and exceeded it at Lower Barbie Creek Site Q4. Barbie Creek pH was within the theoretical minimum aluminum solubility range of pH 5.6 to 6.2 when the sampling for speciation occurred. The pH data collected by Norecol presented in Table 6.3 were within this pH range about 50% of the time with samples above and below the minimum solubility about 25% of the time each. These few aluminum speciation data suggest that aluminum that is naturally present and biologically available frequently exceed British Columbia aquatic life criteria.

Total arsenic levels as measured by Norecol ranged from below the detection limit (1 µg/L) at all sites to maximums of 47 µg/L, 8 µg/L, and 14 µg/L at sites from upstream to downstream, respectively (mean of 5 µg/L, all sites). Dissolved arsenic levels similarly ranged from below the detection limit to maximums of 17 µg/L, 4 µg/L, and 7 µg/L at sites from upstream to downstream, respectively (mean of 3 µg/L, all sites, n = 50). Similarly, samples collected by Environment Canada had total arsenic levels from 1 to 9.1 µg/L (mean of 4.4 µg/L), and dissolved arsenic from 0.6 to 3.9 µg/L (mean of 2.4 µg/L), from both their sites (n = 27). All these sample levels from Barbie Creek were less than the CCREM aquatic life guideline of 50 µg/L total arsenic maximum[(10)].

All samples from Barbie Creek sites collected by Norecol had concentrations less than the 0.2 µg/L cadmium detection limit, for both dissolved and total cadmium. This detection limit is the CCREM aquatic life guideline (0.2 µg/L) for total cadmium[(10)], indicating suitability of Barbie Creek for aquatic life with respect to this characteristic. Similarly, all Environment Canada data were at or below the 0.2 µg/L detection limit, for both total and dissolved cadmium (n < 15).

Chromium levels as determined by Norecol were generally less than or equal to the detection limit (0.001 mg/L) at all sites; exceptions were 2 anomalous dissolved chromium values of 0.002 mg/L at Sites Q15 and Q4 while the corresponding total chromium values were < 0.001 mg/L. These levels were less than the CCREM aquatic life guidelines of 0.002 mg/L maximum total chromium to protect phytoplankton and zooplankton and 0.020 mg/L maximum total chromium to protect fish[(10)].

Levels of total copper in Barbie Creek as determined by Norecol ranged from less than the detection limit (0.5 µg/L) to maximums of 1.1 µg/L, 1.9 µg/L, and 1.8 µg/L at sites from upstream to downstream, respectively (n = 50). Levels of dissolved copper were lower, ranging to maximums of 1.0 µg/L, 1.7 µg/L, and 0.9 µg/L at sites from upstream to downstream (n = 49). All these levels were less than the British Columbia aquatic life criterion 30-day average of 2 µg/L total copper(5). The British Columbia maximum criteria for Barbie Creek range from 2.7 µg/L (for hardness of 7 mg/L) to 4.9 µg/L total copper (for hardness of 31 mg/L) based on the following calculation for the criteria: 0.094 (hardness) + 2 µg/L(5). Environment Canada data were similarly less than both average and maximum aquatic life criteria, with maximums of 1.7 and 0.8 µg/l for total and dissolved copper, respectively (n = 27 and 30).

Iron levels in Barbie Creek ranged from 0.5 to 11.3 mg/L for total iron (mean of 2.6 mg/L) and from 0.5 to 4.3 mg/L for dissolved iron (mean of 1.2 mg/L, n = 83), all sites. These levels exceeded the CCREM aquatic life guideline of 0.3 mg/L maximum total iron(10) on all occasions, and could partly account for the high water colour.

Total mercury levels at all sites were below the 0.05 µg/L detection limit except for the first sample taken from upper Barbie Creek Site Q15 on November 26, 1986, at 0.15 µg/L. No analyses have been made for dissolved mercury. British Columbia aquatic life criteria, in terms of total mercury, are 0.02 µg/L 30-day average and 0.1 µg/L maximum(4). The one sample from upper Barbie Creek at 0.15 µg/L total mercury exceeded both these criteria. The high detection limit (0.05 µg/L) may have masked additional results from all three sites that exceeded the 0.02 µg/L average criterion. A few low level mercury data were collected in 1988, including the following: (i) samples from lower and middle Barbie Creek, with total mercury levels ranging from <5 to 31 ng/L (n = 8)(18), and (ii) samples from lower Barbie Creek ranging from 6.6 to 9.5 ng/L total mercury (n = 4), and all samples of ionic mercury <0.4 ng/L (n = 3)(28). Only one sample at 31 ng/L total mercury exceeded the 30-day average British Columbia aquatic life criterion (0.02 µg/L or 20 ng/L)(4).

Levels of lead in samples collected by Norecol and Environment Canada were below the detection limit of 1 µg/L, for both dissolved and total lead, at all Barbie Creek sites. These ambient levels in Barbie Creek were less than both the 30-day average and maximum British Columbia aquatic life criteria, which are based on hardness(12).

Manganese levels in samples collected by both Norecol and Environment Canada were variable, ranging from a minimum of 0.090 to 0.100 mg/L dissolved and total at all sites to a maximum of 0.72 mg/L dissolved manganese (n = 83) and 0.930 mg/L total manganese. Guidelines to protect aquatic life range from 0.1 to 1 mg/L[45,43], and ambient levels have fallen within this range.

Nickel levels in samples collected by Norecol were at or less than the 2 µg/L detection limit for all samples of both dissolved and total nickel. These levels in Barbie Creek were less than the CCREM aquatic life guideline of 25 µg/L total nickel, based on hardness of 0-60 mg/L $CaC0_3$[10].

Levels of both total and dissolved selenium in samples collected by Norecol were below the detection limit of 1 µg/L in all samples from all sites. These levels are less than the CCREM aquatic life guideline of 1 µg/L maximum total selenium[10].

Silver was less than the 0.2 µg/L detection limit for both dissolved and total silver in all samples collected by Norecol at all sites on Barbie Creek. The detection limit is too high, and may have masked results that exceeded the 0.1 µg/L maximum total silver CCREM aquatic life criterion[10].

Levels of zinc in Barbie Creek were low. Total zinc levels ranged from less than the detection limit (0.5 µg/L) to 12 µg/L from Norecol data, and to 15 µg/L from Environment Canada data, from all sites. Dissolved zinc levels were up to 10 µg/L from Norecol data and to 16 µg/L from Environment Canada data, from all sites. All these levels were less than the CCREM tentative aquatic life guideline of 30 µg/L maximum total zinc[10]. Two of 27 Environment Canada samples equalled or exceeded the minimum concentration causing toxicity to phytoplankton of 15 µg/L total zinc reported by the IJC for the Great Lakes[11]. The IJC's recommended maximum total zinc concentration objective of 10 µg/L for the Great Lakes was exceeded in 2 of 50 samples from Barbie Creek (all sites) that were collected by Norecol and in 5 of 20 samples collected by Environment Canada.

Limited dissolved oxygen data from Barbie Creek have been collected by Environment Canada (see Derksen)[17,18,19] at sites similar in location to Norecol's Q4 and Q8, and Barbie wetland. Levels in water ranged from 2.6 mg/L (on Aug.31, 1989) to 10.2 mg/L (Feb.29,1984; n = 25), presumably a function of flow as very low flows were observed during the 2.6 mg/L sampling. Comparison of these ambient levels to the U.S. EPA (1986) salmonid criteria[8] require additional information as to which stage of the salmonid life cycle was present, if any, during the time of sampling. While 11 mg/L is considered the level of no production impairment for embryo and larval stages, 8 mg/L is considered the level of no production impairment for other life stages.

6.4 FLORENCE CREEK (Tributary To Yakoun River)

Data from three sites are discussed, including Upper Florence Creek Q20 (headwaters), Middle Florence Creek Q31 (below the falls), and Lower Florence Creek Q11 (at the Port Clements road crossing). The data are summarized in Table 6.4 and were collected by Norecol over different periods from February 1987 to August 1988 (n varies from 11 to 18 depending on the site). Background data collected by Environment Canada at a site in Lower Florence Creek from 1983 to 1988[16,17,18] are discussed where deemed appropriate, generally when these data extend the range of values of variables of concern.

The pH in Florence Creek as determined by Norecol ranged from 5.2 to 7.1 for all sites. Mean pH levels were 6.7, 6.6, and 6.0 at sites from upstream to downstream, respectively. Similarly, Environment Canada pH data from Lower Florence Creek ranged from 5.0 to 7.2, with a same mean pH of 6.0 (n = 13) as identified by Norecol at Site Q11 (Lower Florence Creek). These pH levels were frequently lower than British Columbia criteria and CCREM guidelines to protect aquatic life of 6.5 to 9.0[40,10], in particular at the downstream Site Q11.

The alkalinity in Florence Creek as determined by Norecol ranged from a low of 0.7 mg/L at lower Florence Creek Site Q11 to 21 mg/L at upper Florence Creek Site Q20 (n = 46). Alkalinity of <10 mg/L indicates fresh water highly sensitive to acidic inputs (low buffering capacity)[14]. As this was the case for sites from upstream to downstream in 36%, 76%, and 89% of samples, respectively, it is evident that Florence Creek has low buffering capacity. Similarly, Environment Canada alkalinity data were low, ranging from nil to 13.0 mg/L (n = 13).

Turbidity in Florence Creek was low, ranging from 0.3 to 8.5 NTU for all sites. Suspended solids were also low, ranging from at or near the detection limit (1 mg/L) to 12 mg/L for all sites.

Similar to other creeks in the Yakoun River drainage previously discussed, Florence Creek water was soft, with hardness ranging from 1.2 to 20 mg/L (n = 67, all sites, both agencies). Similar as well, colour in Florence Creek was high, up to 922 true colour units, averaging 175 (n = 46, Norecol data).

Sulphate levels as determined by Norecol ranged from below the 1 mg/L detection limit to 6 mg/L. Environment Canada determined sulphate levels from 3.7 to 13 mg/L (n = 13). The drinking water criterion is 150 mg/L for aesthetics[27]. The suggested level to protect aquatic life is 100 mg/L (rationale discussed in Section 7.4).

Ammonia-nitrogen levels ranged from below the 0.005 mg/L detection limit to 0.026 mg/L. These levels were below both the 30-day average and maximum British Columbia aquatic life criteria, which are dependent on pH and temperature[9].

Nitrite-nitrogen levels were less than the 0.002 mg/L detection limit in all samples at all sites. These levels were less than British Columbia aquatic life criteria, which are dependent on chloride concentration[9].

Nitrate-nitrogen levels ranged from below the 0.005 mg/L detection limit to a maximum of 0.063 mg/L, all sites. These levels were lower than the British Columbia aquatic life criteria of 40 mg/L 30-day average and 200 mg/L maximum[9].

Baseline periphyton data from Florence Creek are not available, but are expected to be low. Perrin[31] identified low levels in Florence Creek using 19-day flow-through algal bioassays on artificial substrates, with a maximum of 5.4 mg/m^2 chlorophyll a. Post mine development levels were predicted not to exceed 20 mg chlorophyll a/m^2[36]. British Columbia periphyton criteria are 50 mg/m^2 chlorophyll a to protect aesthetics and 100 mg/m^2 chlorophyll a to protect salmonids[13].

Total cyanide levels in all samples from all three sites as determined by Norecol were less than the 1 μg/L detection limit. These low levels were less than the British Columbia aquatic life criteria of 5 μg/L and 10 μg/L for the 30-day average and maximum, respectively[6].

Aluminum levels as determined by Norecol and Environment Canada ranged from 0.15 to 1.60 mg/L (mean of 0.44 mg/L, n = 67) and from 0.04 to 0.91 mg/L (mean of 0.34 mg/L, n = 67) for total and dissolved aluminum, respectively, from all sites. British Columbia aquatic life criteria are a 30-day average of 0.05 mg/L and a maximum of

0.1 mg/L dissolved aluminum (for pH >6.5)[1], and both criteria were exceeded in Florence Creek for most samples. Aluminum speciation of a sample from Site Q31 on February 27, 1989 showed a total aluminum level of 0.219 and 0.210 mg/L (split sample), but only 0.007 and 0.008 mg/L of the biologically available inorganic monomeric aluminum (see Table 6.1.5). This fraction was less than both the 30-day average and maximum criteria (0.050 and 0.10 mg/L for pH >6.5).

Total arsenic levels in Florence Creek as determined by Norecol were at or below the 1 µg/L detection limit in all samples, with the exception of the maximum levels of 2 µg/L on two occasions at Middle Barbie Creek Site Q31. Similarly, Environment Canada data were below the 0.5 µg/L detection limit except two samples at 0.6 µg/L (n = 18). These levels are less than the CCREM guideline of 50 µg/L maximum total arsenic to protect aquatic life[10].

Cadmium levels, both dissolved and total, were below the 0.2 µg/L detection limit in all samples collected by Norecol, at all sites. Similarly, Environmental Canada cadmium data (dissolved and total) were at or below their detection limit of 0.1 µg/L in all samples (n = 11). These levels were less than the CCREM aquatic life guideline of 0.2 µg/L maximum total cadmium for hardness <60 mg/L[10].

Total chromium levels in samples collected by Norecol ranged from below the 1 µg/L detection limit for most samples from all sites to a maximum of 3 µg/L at upstream Site Q20. Only this one sample exceeded the CCREM guideline of 2 µg/L to protect phytoplankton and zooplankton, but was less than the 20 µg/L level to protect fish[10]. Levels of dissolved chromium were from less than the detection limit to 2µg/L in all samples from all sites.

Total copper levels in samples collected by Norecol (n = 46) ranged from below the 0.5 µg/L detection limit at all sites to a maximum of 1.8 µg/L at Upper Florence Creek Site Q20. Similarly, all Environment Canada's samples were less than the detection limit, except one sample at 1.2 µg/L (n = 18). All these sample concentrations were less than the 2 µg/L 30-day average British Columbia aquatic life criterion as well as the maximum criterion (based on the calculation: 0.094 x hardness + 2 µg/L for hardness <50 mg/L)[5]. Dissolved copper levels in both Norecol's and Environment Canada's samples ranged from below the detection limit to 0.9 µg/L for all sites.

Iron levels in Florence Creek were high, with a range of from 0.30 to 2.39 mg/L for total iron (mean of 0.98 mg/L, n = 67, all sites) and from 0.11 to 1.2 mg/L for dissolved iron (mean of 0.66 mg/L, n = 66), as determined by both Norecol's and Environment Canada's sampling. Most sample concentrations have exceeded the CCREM aquatic life guideline of 0.3 mg/L maximum total iron[10].

Total mercury levels at all Florence Creek sites as determined by Norecol were less than the detection limit (0.05 µg/L). These levels were less than the British Columbia aquatic life criterion maximum of 0.1 µg/L[4]. The detection limit was higher than the British Columbia 30-day average criterion of 0.02 µg/L, however, and may have masked sample levels that exceeded that criterion. A few low level mercury data were collected in 1988, including the following: (i) total mercury levels in lower Florence Creek from August 3 to September 15 ranged from <5 to 9 ng/L (n = 4)[18], and (ii) samples from middle Florence Creek collected in September ranged in concentration from 2.6 to 4.6 ng/L total mercury (n = 5) and from 0.4 to 1.4 ng/L ionic mercury (n = 3)[28]. None of these low level mercury data exceeded British Columbia aquatic life criteria.

Total manganese levels in Florence Creek ranged from 0.01 to 0.28 mg/L, all sites, as determined by both Norecol and Environment Canada (n = 57). Only 3 exceeded the 0.1 mg/L aquatic life criterion of Dawson[45], but all were less than the 1.0 mg/L criterion of Davies and Goettl[43]. Levels of dissolved manganese were similar, from 0.010 to 0.25 mg/L. Two of 66 samples, both from Upper Florence Creek Site Q20, exceeded the 0.1 mg/L criterion, but all samples were less than the 1.0 mg/L criterion.

Levels of lead in all Florence Creek samples were below the 1 µg/L and 0.5 µg/L detection limits for both dissolved and total lead in samples collected both by Norecol and Environment Canada. These levels were less than both the British Columbia 30-day average and maximum aquatic life criteria which are based on hardness[12].

Nickel levels, both dissolved and total, were less than the 2 µg/L detection limit at all sites as determined by Norecol. These levels are less than the CCREM aquatic life criteria which are based on hardness and vary from 25 - 150 µg/L[10].

Selenium levels, both dissolved and total, were less than the 1 µg/L detection limit for all samples from the three sites. These levels were less than the 1 µg/L maximum total selenium CCREM aquatic life criterion[10].

Silver levels, both dissolved and total, were less than the 0.2 µg/L detection limit. This detection limit was too high to compare against the CCREM aquatic life guideline of 0.1 µg/L maximum total silver[10].

Total zinc levels as determined by Norecol ranged from below the 0.5 µg/L detection limit at all sites to a maximum of 40 µg/L at Lower Florence Creek Site Q11 (mean of 2.7 µg/L, all sites). Similarly, dissolved zinc ranged from <0.5 µg/L to 5.1 µg/L, all sites (mean of 0.8 µg/L). Only the maximum total zinc level of 40 µg/L exceeded the following guidelines: (i) CCREM tentative aquatic life guideline of 30 µg/L maximum total zinc[10]; (ii) the level reported by the IJC (1987) as toxic to phytoplankton: 15 µg/L[11]; and (iii) the IJC (1987) recommended objective level for the Great Lakes of 10 µg/L maximum total zinc[11]. Environment Canada data for total zinc were all less than the 2 µg/L detection limit (n = 18). Dissolved zinc ranged from <2 to 4 µg/L (mean of <2 µg/L, n = 18), similarly below the above criteria.

Limited Dissolved oxygen data from Florence Creek have been collected by Environment Canada (see Derksen)[17,18,19]. Levels in water ranged from 8.4 mg/L (Aug.23, 1988) to 12.0 mg/L (Sept.14, 1988). Comparison of there ambient data to the U.S. EPA (1986) salmonid criteria[8] require additional information as to which stage of the salmonid life cycle was present during the time of sampling. The level of no production impairment for embryo and larval stages is considered to be 11 mg/L, with 8 mg/L considered the level of no production impairment for other life stages.

6.5 CANOE CREEK (Tributary To Yakoun River)

Water quality data collected by Norecol for Canoe Creek Site Q2, located about 1 km upstream from the confluence with the Yakoun River, are summarized in Table 6.5. Data were collected from November 1986 to January 1988 (n = 13). Background data collected by Environment Canada from the same location in 1983 and 1984[16] are discussed when deemed appropriate, but are not tabulated in this report.

The pH in Canoe Creek ranged from 4.7 to 6.7 (mean of 5.3), and was less than the lower limit of the British Columbia criteria and CCREM guidelines to protect aquatic life of 6.5 to 9.0[40,10] in most samples. Similarly, Environment Canada pH data ranged from 4.5 to 4.9 (mean of 4.7, n = 6). These relatively low pH levels are similar to those found in other Cinola project area streams.

Alkalinity in Canoe Creek ranged for <1 to 6 mg/L. Levels of less than 10 mg/L indicate low buffering capacity and high sensitivity to acidic inputs in terms of aquatic life protection[14]. Environment Canada reported alkalinity as nil on their sample dates (n = 6).

Turbidity and suspended solids levels were similarly as low as other Cinola study area streams, ranging from 0.7 to 2.1 NTU and from <1 to 3 mg/L, respectively.

Canoe Creek water was soft, ranging from 5 to 13 mg/L hardness (as $CaC0_3$) in data from both Norecol and Environment Canada (n = 19).

Similar to the streams previously discussed, Canoe Creek was highly coloured, ranging from 156 to 360 true colour units (mean of 245 colour units). As mentioned previously, highly coloured water is partly due to dissolved organics.

Sulphate levels as determined by Norecol were below the 1 mg/L detection limit in all samples (n = 46). Environment Canada data for sulphate were from 3.7 to 8.0 mg/L (n = 6). These levels are among the lowest found in Cinola study area streams. The suggested level to protect aquatic life is 100 mg/L, with its rationale discussed in Section 7.4.

Ammonia-nitrogen levels were low, ranging from below the 0.005 mg/L detection limit to 0.016 mg/L. These levels were less than both the 30-day average and maximum British Columbia aquatic life criteria which are based on pH and temperature[9]. Nitrite-nitrogen levels were below the 0.002 mg/L detection limit in all samples, and less than British Columbia aquatic life 30-day average and maximum criteria, both dependent on chloride concentration[9]. Similarly, nitrate- nitrogen levels were low, ranging from below the 0.005 mg/L detection limit to 0.034 mg/L. These ambient levels were less than British Columbia aquatic life criteria of 40 mg/L 30-day average and 200 mg/L maximum[9].

Levels of total cyanide as determined by Norecol were all below the 0.001 mg/L detection limit. British Columbia aquatic life criteria are 0.005 mg/L 30-day average and 0.010 mg/L maximum[6], which are higher than levels found in Canoe Creek indicating suitability of these waters for aquatic life with respect to this characteristic.

Levels of dissolved aluminum as determined by both Norecol and Environment Canada ranged from 0.23 to 0.64 mg/L (mean of 0.42 mg/L, n = 19). For the pH range found in Canoe Creek (4.5 to 6.7), British Columbia aquatic life maximum criteria ranged from 0.021 to 0.1 mg/L dissolved aluminum, with the 30-day average criteria ranging from 0.006 to 0.05 mg/L dissolved aluminum[1]. Both criteria are less than ambient levels. No aluminum speciation data are available for Canoe Creek to compare bioavailable forms of aluminum to these criteria.

Arsenic levels were at or below the detection limits in all Norecol (1 μg/L) and Environment Canada samples (0.5 μg/L) for both dissolved and total arsenic. These ambient levels are much lower than the CCREM guideline of 50 μg/L maximum total arsenic to protect aquatic life[10].

Total cadmium levels at Canoe Creek Site Q2 were less than the 0.2 μg/L and 0.5 μg/L detection limits of both Norecol and Environment Canada, respectively, in all samples except one, 0.3 μg/L on December 14, 1987 (n = 19). Levels of dissolved cadmium were all less than the detection limits. Only the one sample at 0.3 μg/L total cadmium exceeded the CCREM aquatic life guideline of 0.2 μg/L maximum total cadmium (for hardness 0-60 mg/L as found in Canoe Creek)[10].

Chromium levels, as determined by Norecol, were below the 1 μg/L detection limit for both dissolved and total chromium, and were lower than the CCREM guidelines of 2 μg/L maximum total chromium to protect phytoplankton and zooplankton and 20 μg/L maximum to protect fish[10]. Environment Canada data were all below the 5 μg/L detection limit for both dissolved and total chromium (n = 6).

Maximum copper levels for both total and dissolved copper were 1.4 μg/L in Norecol's samples. Environment Canada's sample concentrations were all less than the 1 μg/L detection limit for both dissolved and total copper. All samples concentrations were less than the British Columbia aquatic life criteria 30-day average (2 μg/L) and maximum criteria (in μg/L: 0.094 x hardness + 2) for hardness ≤50 mg/L as $CaC0_3$[5].

Similar to other Cinola project area streams, Canoe Creek water was high in iron in data collected both by Norecol and Environment Canada, from 0.61 to 2.00 mg/L (mean of 1.07 mg/L) and from 0.58 to 1.50 mg/L (mean of 0.83 mg/L) for total and dissolved iron, respectively. The CCREM aquatic life guideline of 0.3 mg/L maximum total iron[10] was exceeded in all samples.

All samples from Canoe Creek Site Q2 had total mercury levels below the 0.05 µg/L detection limit, with the exception of one Environment Canada sample at 0.06 µg/L total mercury (n = 19). The detection limit was too high, however, to identify whether samples exceeded the British Columbia aquatic life 30-day average criterion of 0.02 mg/L maximum total mercury[4]. All Canoe Creek sample concentrations were less than the criterion maximum of 0.1 µg/L total mercury[4].

Levels of both dissolved and total lead were less than the 1 µg/L detection limit, and less than both the British Columbia 30-day average and maximum criteria (based on hardness)[12] in all samples from both sampling agencies.

Levels of nickel and selenium were below their respective detection limits of 2 and 1 µg/L in all samples collected by Norecol, and less than their respective CCREM aquatic life guideline (from 25-150 µg/L maximum total nickel, based on hardness; 1 µg/L maximum total selenium). All silver levels were less than the 0.2 µg/L detection limit, possibly masking results exceeding the CCREM aquatic life criterion of 0.1 µg/L[10].

Levels of zinc in Norecol's Canoe Creek data from Site Q2 ranged from below the 0.5 µg/L detection limit to 1.8 µg/L for total zinc and from 0.7 µg/L to 1.7 µg/L for dissolved zinc. Environment Canada's data were <2 µg/L for total zinc and to 3 µg/L for dissolved zinc (n = 6). Higher dissolved than total values were present because coincident samples were not collected. These levels are lower than the CCREM tentative aquatic life guideline of 30 µg/L maximum total zinc[10] as well as the toxicity level to phytoplankton of 15 µg/L reported by the IJC[11].

Limited dissolved oxygen data were collected from Canoe Creek by Environment Canada (Derksen, 1985)[17]. Levels in water were from 10.1 to 11.1 mg/L (n = 2). Comparison of these ambient levels to the U.S. EPA (1986) salmonid criteria[8] require additional information as to which stage of the salmonid life cycle was present during the time of sampling. The level of no production impairment for embryo and larval stages is considered to be 11 mg/L, with 8 mg/L the level for other life stages.

6.6 SID CREEK (Tributary To Yakoun River)

Norecol's sampling of Sid Creek Site Q35 began on January 18, 1988. Only data for that date are available (Table 6.6). Data reported are within the range of values discussed for other Cinola study area streams including the Yakoun River (Section 6.8), and will not be discussed further.

6.7 CLAY CREEK (Tributary To Yakoun River)

Water quality data for Clay Creek Site Q14 are summarized in Table 6.7. Data were collected by Norecol from November 1986 to January 1989 (n = 12 or 13, dependent on the variables). This site is located about 1.5 km upstream from the Yakoun River confluence.

The pH in Clay Creek at the times of sampling ranged from 4.2 to 5.8 (mean of 4.7), with all samples less than the 6.5 to 9.0 British Columbia criteria and the CCREM guidelines to protect aquatic life[40,10].

Alkalinity ranged from <1 to 2 mg/L (as $CaC0_3$), indicating that Clay Creek is highly sensitive to acidic inputs (low buffering capacity) with regards to aquatic life protection[14].

Hardness levels were very soft, ranging from 5 to 12 mg/L as $CaC0_3$.

Turbidity and suspended solids were both low, ranging from 0.6 to 2.5 NTU and from <1to 2 mg/L, respectively.

Clay Creek water was highly coloured, ranging from 188 to 483 colour units (mean of 307 colour units). Strong water colour (brown) is consistent with other Cinola project area streams due to the high concentration of dissolved organics.

Ammonia-nitrogen levels were low, ranging from below the 0.005 mg/L detection limit to 0.031 mg/L. These levels were less than British Columbia aquatic life criteria which range from 0.1 to 2 mg/L 30-day average and from 0.7 to 28 mg/L maximum, both dependent on pH and temperature[9].

Nitrate-nitrogen levels ranged from less than the 0.005 mg/L detection limit to 0.044 mg/L, levels much lower than the 30-day average and maximum British Columbia aquatic life criteria of 40 and 200 mg/L, respectively[9].

Nitrite-nitrogen levels were less than the detection limit of 0.002 mg/L in all samples. These low levels are much less than either the 30-day average or maximum British Columbia aquatic life criteria which are dependent on chloride concentration[9].

Periphyton data are not yet available but are expected to be low. British Columbia periphyton criteria are 50 and 100 mg/m^2 chlorophyll a to protect aesthetics and salmonids, respectively[13].

Total cyanide levels were less than the 1 µg/L detection limit for all samples. These levels were less than the aquatic life criteria of 5 µg/L 30-day average and 10 µg/L maximum weak-acid dissociable cyanide[6].

Aluminum levels were relatively high, ranging from 0.36 to 0.90 mg/L (mean of 0.59 mg/L) and from 0.46 to 1.00 mg/L (mean of 0.70 mg/L) for dissolved and total aluminum, respectively. British Columbia aquatic life criteria are in terms of dissolved aluminum and are dependent on pH. They range from 0.020 to 0.039 mg/L and from 0.005 to 0.015 mg/L for maximum and 30-day average criteria, respectively, for the pH range in Clay Creek[1]. Ambient levels in Clay Creek exceeded both these criteria, as have levels in the other Cinola project streams previously discussed. No aluminum speciation of Clay Creek water samples has been done, so no specific data on the bioavailable forms of aluminum are available to compare more accurately to the provincial criteria.

Arsenic levels were low, ranging from below the 0.001 mg/L detection limit to maximum for total arsenic of 0.002 mg/L. These levels are much lower than the CCREM aquatic life guideline of 0.050 µg/L maximum total arsenic[10].

Cadmium levels were below the 0.2 µg/L detection limit in all samples for both dissolved and total cadmium. These levels are lower than the CCREM aquatic life criterion of 0.2 µg/L maximum total cadmium for hardness of 0-60 mg/L[10], as was the case in Clay Creek.

Chromium levels were below the 0.001 mg/L detection limit in all samples except the one taken on July 22, 1987 which was 0.003 and 0.004 mg/L for dissolved and total cadmium, respectively. This one sample had levels exceeding the CCREM guideline of 0.002 mg/L maximum total chromium to protect phytoplankton and zooplankton, but was less than the 0.020 mg/L criterion for fish[10].

Copper levels ranged from below the detection limit of 0.5 µg/L to maximums of 1.4 and 1.9 µg/L for dissolved and total copper, respectively. These ambient levels in Clay Creek were less than both the 30-day average (2 µg/L) and maximum British Columbia criteria (for hardness less than 50 mg/L as $CaC0_3$)[5].

Iron levels were relatively high, ranging from 0.44 to 1.26 mg/L dissolved iron (mean of 0.75 mg/L) and from 0.45 to 1.43 mg/L total iron (mean of 0.80 mg/L). These naturally occurring high levels exceed the CCREM aquatic life guideline which is 0.3 mg/L maximum total iron[10].

All samples had total mercury levels less than the 0.05 µg/L detection limit; however, this high detection limit may have masked results that exceeded the British Columbia 30-day average aquatic life criterion of 0.02 µg/L[4]. All samples had concentrations less than the British Columbia criterion maximum of 0.1 µg/L total mercury.

Lead levels were below the 1 µg/L detection limit in all samples for both dissolved and total lead. These levels in Clay Creek were less than the 30-day average and the maximum British Columbia aquatic life criteria which are based on hardness[12].

Clay Creek nickel levels were less than the 2 µg/L detection limit in all samples for both dissolved and total nickel. These levels are less than the CCREM aquatic life criterion of 25 µg/L maximum total nickel for hardness of less than 60 mg/L (as $CaC0_3$)[10] as found in Clay Creek.

Selenium levels were below the 1 µg/L detection limit in all samples, for both dissolved and total selenium. Levels were lower than the CCREM aquatic life guideline of 1 µg/L maximum total selenium[10].

Silver levels were less than the 0.2 μg/L detection limit in all samples, for both dissolved and total silver. The detection limit was too high to compare these levels to the CCREM aquatic life guideline of 0.1 μg/L maximum total silver[10].

Zinc levels in Clay Creek ranged from less than the 0.5 μg/L detection limit to maximums of 2.5 μg/L and 7.9 μg/L for dissolved and total zinc, respectively. These levels were below the CCREM tentative aquatic life guideline of 30 μg/L[10] as well as below the 15 μg/L concentration reported as toxic to phytoplankton by the IJC[11].

6.8 YAKOUN RIVER

Water quality data for Upper Yakoun River Site Q16 (upstream from Gold Creek), Middle Yakoun River Site Q10 (downstream from Barbie Creek until April 11, 1987, when the sampling location was changed to upstream from Barbie Creek), and Lower Yakoun River site Q7a (at the Port Clements Road crossing) are summarized in Table 6.8. Samples were collected by Norecol over different periods from November 1986 to August 1988 (n from 8 to 20 dependent on the site). Environment Canada collected data from 1983 to 1987 from a site about 1 km below Gold Creek as well as from another site at the same location downstream from Barbie Creek as Norecol[16,17].

Drinking water is a designated use of the Yakoun River. Water quality parameters have met drinking water guidelines unless specifically discussed in the following section.

The pH at Yakoun River sites, as determined by Norecol and Environment Canada, was from 5.9 to 7.5, with a mean pH of 6.7 for all sites (n = 62). British Columbia criteria and Health and Welfare Canada guidelines to protect drinking water are from 6.5 - 8.5[40,27]. Ten of 62 samples were less than these minimum criteria.

Alkalinity data from the three sites ranged from 1 to 19 mg/L (mean of 9.3). Levels were frequently less than 10 mg/L, indicating that the Yakoun River is sensitive to acidic inputs during much of the year[14].

Turbidity and suspended solids in the Yakoun River were generally low, ranging from 0.4 to 4.9 NTU and from 1 to 17 mg/L, respectively.

Similar to creeks in this drainage previously discussed, the Yakoun River had soft water, ranging in hardness from 5 to 20 mg/L (all sites). Colour was also similar to that found in the other creeks, ranging from 16 to 183 true colour units with the most coloured water occurring at the most downstream Site Q7a.

Sulphate levels were low in the Yakoun River, ranging from below the detection limit of 1.0 mg/L to maximums of 3.0, 2.0, and 5.0 mg/L at sites from upstream to downstream, respectively. The drinking water criterion is 150 mg/L for aesthetics(27). The suggested level to protect aquatic life is 100 mg/L, with its rationale discussed in Section 7.4.

Ammonia-nitrogen levels in the Yakoun River were low, ranging from below the 0.005 mg/L detection limit to a maximum of 0.032 mg/L (all sites). These levels were less than both the British Columbia 30-day average and maximum aquatic life criteria which are dependent on pH and temperature, and range from 0.1 to 2.0 mg/L and from 0.7 to 28.0 mg/L, respectively (see Tables 6.1.2 and 6.1.3)(9).

Nitrate-nitrogen levels were similarly low, ranging from below the 0.005 mg/L detection limit to a maximum of 0.057 mg/L (all sites). These ambient levels were much lower than the British Columbia aquatic life criteria of 40 mg/L 30-day average and 200 mg/L maximum nitrate-nitrogen, respectively (see Table 6.1.4).

Nitrite-nitrogen levels were low, all below the 0.002 mg/L detection limit. These levels were below the British Columbia aquatic life criteria which are dependent on chloride concentration and vary from 0.06 to 0.60 mg/L 30-day average and from 0.02 to 0.20 mg/L maximum nitrite(9).

Periphyton data are not yet available but are understood to be low. British Columbia criteria are 50 mg/m^2 chlorophyll a to protect aesthetics and 100 mg/m^2 chlorophyll a to protect salmonids(13).

Total cyanide levels in the Yakoun River as determined by Norecol were below the 0.001 mg/L detection limit in all samples from all sites. These levels were less than the British Columbia aquatic life criteria 30-day average and maximum of 0.005 mg/L and 0.010 mg/L, respectively(6).

Aluminum levels in the Yakoun River were similar at all three sites, ranging from 0.007 to 0.41 mg/L dissolved aluminum (mean of 0.13 mg/L, n = 63; Norecol and Environment Canada samples) and from 0.039 to 0.85 mg/L for total aluminum (mean of 0.30 mg/L, n = 64; both agencies). The British Columbia drinking water criterion of 0.2 mg/L dissolved aluminum(1) was exceeded in 6 of 65 samples. The British Columbia aquatic life criteria for the pH levels found in the Yakoun River (5.9 - 7.5) are a 30-day average of from 0.018 to 0.05 mg/L and a maximum of from 0.043 to 0.1 mg/L dissolved aluminum(1). These criteria were exceeded on a regular basis in Yakoun River water samples. Although aluminum speciation of samples has not been done, La Zerte(2) has predicted that the majority of the aluminum at the higher pH levels (as found in the Yakoun River) should be in the unreactive forms including particulate, colloidal, polymeric, and resistant organic. If this is the case, the level of biologically available aluminum (inorganic monomeric) could be lower than the British Columbia criteria. The aluminum speciation data in Table 6.1.5 show that inorganic monomeric aluminum was below criteria for Adit and Florence Creeks, but at or above criteria for Barbie Creek.

Arsenic levels in the Yakoun River were at or below the 1 μg/L and 0.5 μg/L detection limits of Norecol and Environment Canada, respectively, in all samples from all sites. These ambient levels were much less than the aquatic life and drinking water guidelines of 0.050 mg/L total arsenic maximum(10,1).

Dissolved and total cadmium levels in the Yakoun River as determined by Norecol were mostly below the 0.2 μg/L detection limit except for one sample each at Upper Yakoun River Site Q16 and Middle Yakoun River Site Q10 at 0.4 μg/L and 0.5 μg/L total cadmium, respectively (n = 52). Only these two samples exceeded the CCREM aquatic life guideline of 0.2 μg/L maximum total cadmium (for hardness of <60 mg/L as $CaCO_3$)(10). All Environment Canada samples from their two sites were at or below this aquatic life guideline, ranging from below the detection limit of 0.1 μg/L to 0.2 μg/L total cadmium (n = 12).

Chromium levels at all Yakoun River sites were below the detection limits of both sampling agencies for both dissolved and total chromium. These levels were lower than the CCREM aquatic life guidelines of 0.002 mg/L and 0.020 mg/L to protect phytoplankton/zooplankton and fish, respectively(10).

Copper levels at the Yakoun River sites as determined by Norecol varied from below the detection limit of 0.5 µg/L to maximums of 0.8 µg/L and 1.4 µg/L for dissolved and total copper, respectively. These levels were less than both the 30-day average and maximum British Columbia aquatic life criteria, which are dependent on hardness[5]. Only 1 of 12 samples collected by Environment Canada exceeded their detection limits (0.5 and 1 µg/L), and at 10 µg/L exceeded both the 30-day average aquatic life criterion (2 µg/L total copper) and maximum criterion (3.2 µg/L total copper at 12.7 mg/L hardness).

Iron levels at all sites were relatively high, ranging from 0.09 to 0.56 mg/L for dissolved iron (mean of 0.21 mg/L, n = 64) and from 0.11 to 1.03 mg/L for total iron (mean of 0.38 mg/L, n = 64; both agencies). These levels are similar to those at other creeks in this drainage previously discussed, and similarly often exceeded the CCREM aquatic life guideline and the Health and Welfare drinking water (aesthetic) guideline of 0.3 mg/L maximum total iron[10,1].

All samples for mercury taken by Norecol from the Yakoun River sites (n = 52) had levels of total mercury below the 0.05 µg/L detection limit. One of 12 samples taken by Environment Canada exceeded the 0.05 µg/L detection limit, at 0.12 µg/L. British Columbia aquatic life criteria are 0.02 µg/L 30-day average and 0.1 µg/L maximum total mercury[4]. Although all Yakoun River samples but one had levels less than the criteria maximum (0.1 µg/L), the high detection limit (0.05 µg/L) may have masked results that exceeded the 0.02 µg/L average criterion.

Nickel levels at all Yakoun River sites sampled by Norecol were at or below the 0.002 mg/L detection limit in all samples for both dissolved and total nickel. These ambient levels were less than the CCREM aquatic life guideline of 0.025 mg/L maximum total nickel (for hardness of <60 mg/L as found in the Yakoun River)[10].

Lead levels in all samples collected by Norecol from Yakoun River sites (n = 52) were less than the 0.001 mg/L detection limit. This is less than both the 30-day average and maximum British Columbia aquatic life criteria which are in terms of total lead[12]. Samples collected by Environment Canada were all less than the detection limits (1 µg/L in 1983 - 1984, 0.5 µg/L in 1987) except one sample at 0.9 µg/L total lead (n = 12). All these sample concentrations were similarly less than both the average and maximum aquatic life criteria.

Selenium levels were less than the 1 µg/L detection limit in all samples collected by Norecol from all sites, for both dissolved and total selenium. These levels in the Yakoun River were less than the CCREM aquatic life guideline of 1 µg/L maximum total selenium[10].

Silver levels at all Yakoun River sites as determined by Norecol were below the 0.2 µg/L detection limit for both dissolved and total silver. This detection limit was too high and may have masked sample levels that have exceeded the CCREM aquatic life guideline of 0.1 µg/L maximum total silver[10].

Zinc levels in the Yakoun River at sites sampled by Norecol ranged from below the 0.5 µg/L detection limit to maximums of 2.8 µg/L dissolved zinc and 4.0 µg/L total zinc (n = 52). These levels are less than the 30 µg/L maximum total zinc CCREM tentative aquatic life criterion[10] and the 15 µg/L toxicity levels for phytoplankton reported by the IJC[11]. Similarly, Environment Canada sampling showed zinc levels from <2 to 6 µg/L for total lead, and from <2 to 3 µg/L for dissolved lead (n=12), all less than the above criteria to protect aquatic life.

Limited dissolved oxygen data were collected from the Yakoun River by Environment Canada (Derksen, 1985)[17], from a site similar in location to Norecol's Q10. Levels in water were from 10.4 to 11.4 mg/L (n = 2). Comparison of these ambient levels to the U.S. EPA (1986) salmonid criteria[8] require additional information as to which stage of the salmonid life cycle was present at the time of sampling. The level of no production impairment for embryo and larval stages is considered to be 11 mg/L, with 8 mg/L the level for other life stages.

6.9 BOUCHER CREEK (Tributary To Mamin River)

Boucher Creek Site Q24 is located just above the confluence with the Mamin River, at the Port Clements Road crossing. The water quality data are summarized in Table 6.9. Samples were collected by Norecol from February 1987 to January 1988 (n=6). Boucher Creek could be impacted by the Cinola mine development should there be seepage through the No. 2 saddle dam in the High West tailings/waste rock area.

The pH of Boucher Creek at site Q24 varied from 5.8 to 6.6 (mean of 6.0). Ambient pH was less than the lower limit of the 6.5 - 9.0 British Columbia criteria and CCREM guidelines to protect aquatic life[40,10] in 3 of 6 samples.

Boucher Creek water was soft, ranging from 6 to 8 mg/L hardness (as $CaCO_3$). The alkalinity ranged from 1 to 6 mg/L indicating that Boucher Creek is poorly buffered and therefore sensitive to acid inputs[14].

Turbidity and suspended solids were both low, ranging from 0.7 to 2.3 NTU and from less than the 1 mg/L detection limit to 2 mg/L, respectively.

Similar to creeks in the Yakoun River drainage previously discussed, Boucher Creek water was highly coloured, ranging from 141 to 200 true colour units (mean of 188 true colour units).

Sulphate levels were low, all less than the 1 mg/L detection limit. The drinking water criterion is 150 mg/L for aesthetics[27]. The suggested level to protect aquatic life is 100 mg/L (rationale discussed in Section 7.4).

Ammonia-nitrogen levels were low, ranging from below the 0.005 mg/L detection limit to 0.022 mg/L. These levels are lower than both the British Columbia aquatic life criteria 30-day average and maximum, which are dependent on pH and temperature[9]. Average criteria range from 0.1 to 2.0 mg/L with the maximum criteria ranging from 0.7 to 28 mg/L (see Tables 6.1.2 and 6.1.3 for the detailed criteria).

Nitrate-nitrogen levels were low, ranging from below the 0.005 mg/L detection limit to 0.014 mg/L. These ambient levels were much lower than the British Columbia aquatic life criteria of 40 mg/L 30-day average and 200 mg/L maximum[9].

Nitrite-nitrogen levels were below the 0.002 mg/L detection limit in all samples. Ambient levels in Boucher Creek were less than British Columbia aquatic life criteria which, dependent on chloride concentration, range from 0.02 to 0.20 mg/L 30-day average and from 0.06 to 0.60 mg/L maximum nitrite-nitrogen[9] (see Table 6.1.4).

Periphyton data are not available for Boucher Creek. British Columbia criteria are in terms of mg/m^2 chlorophyll a and are 50 and 100 to protect aesthetics and salmonids, respectively[13].

Total cyanide levels were below the 0.001 mg/L detection limit in all Boucher Creek samples. These levels are less than the British Columbia aquatic life criteria of 0.005 mg/L 30-day average and 0.010 mg/L maximum weak-acid dissociable cyanide[6].

Aluminum levels ranged from 0.23 to 0.50 mg/L (mean of 0.31 mg/L) and from 0.29 to 0.76 mg/L (mean of 0.41 mg/L) for dissolved and total aluminum, respectively. British Columbia aquatic life criteria for aluminum are dependent on pH; they range from 0.015 to 0.05 mg/L dissolved aluminum 30-day average and from 0.039 to 0.1 mg/L maximum dissolved aluminum for the pH range in Boucher Creek[1]. Both these average and maximum criteria were exceeded in all Boucher Creek samples. Although there are no aluminum speciation data from Boucher Creek, La Zerte[2] predicts that because the biologically available inorganic monomeric species decreases as pH increases, at some point in the pH range found in Boucher Creek of 5.8 to 6.6 the level of inorganic monomeric aluminum could be less than the British Columbia criteria. Aluminum speciation of Boucher Creek water needs to be done to confirm this prediction. Aluminum speciation data from Adit, Barbie, and Florence Creeks are presented in Table 6.1.5.

Arsenic levels were at or below the detection limit (0.001 mg/L) in all samples, for both dissolved and total arsenic. These ambient levels were less than the CCREM aquatic life criterion of 0.050 mg/L total arsenic maximum[10].

Levels of both dissolved and total cadmium were less than the 0.2 µg/L detection limit in all samples. These levels were less than the CCREM aquatic life guideline of 0.2 µg/L maximum total cadmium (for hardness <60 mg/L)[10].

Chromium levels, both dissolved and total, were below the 0.001 mg/L detection limit in all samples. These low levels suggest suitability of Boucher Creek water for aquatic life when compared with the CCREM aquatic life guideline of 0.002 mg/L maximum total chromium for phytoplankton and zooplankton and 0.020 mg/L maximum total chromium for fish[10].

Copper levels ranged from the 0.5 µg/L detection limit to maximums of 1.2 and

3.0 µg/L for dissolved and total copper, respectively. Only the one sample with the 3.0 µg/L maximum total copper concentration exceeded the 30-day average British Columbia aquatic life criterion of 2 µg/L. All samples had copper concentrations less than the British Columbia criteria maximum values, which are based on hardness[5].

Iron levels in Boucher Creek were relatively high, ranging from 0.39 to 0.92 mg/L (mean of 0.58 mg/L) and from 0.43 to 1.44 mg/L (mean of 0.70 mg/L) for dissolved and total iron, respectively. All samples had levels that exceeded the CCREM aquatic life guideline of 0.3 mg/L maximum total iron[10].

Total mercury levels in water were less than the 0.05 µg/L detection limit in all samples. This detection limit, however, is higher than the 0.02 µg/L 30-day average British Columbia aquatic life criterion[4], possibly masking actual results which exceeded this criterion. All sample concentrations were less than the British Columbia criteria maximum of 0.1 µg/L total mercury[4].

Manganese levels ranged from 0.027 to 0.13 mg/L and from 0.033 to 0.17 mg/L for dissolved and total manganese, respectively. The 0.1 mg/L maximum total manganese aquatic life criterion proposed by Dawson[45] was exceeded in only one sample at 0.13 and 0.17 mg/L dissolved and total manganese, respectively. All sample concentrations were less than the 1.0 mg/L total manganese aquatic life criterion proposed by Davies and Goettl[43].

Nickel levels in Boucher Creek were below the 0.002 mg/L detection limit in all samples, for both dissolved and total nickel. These ambient levels are less than the CCREM aquatic life guideline of 0.025 mg/L maximum total nickel (for hardness <60 mg/L)[10].

Levels of lead were low, below the 0.001 mg/L detection limit in all samples. These levels were less than both the 30-day average and maximum British Columbia aquatic life criteria[12].

Selenium levels were less than the 1 µg/L detection limit in all samples for both dissolved and total selenium. These levels were less than the CCREM aquatic life guideline of 1 µg/L maximum total selenium[10].

Silver levels were less than the 0.2 µg/L detection limit in all samples, for both dissolved and total silver. The detection limit is too high for comparison of these data to the CCREM aquatic life guideline of 0.1 µg/L maximum total silver(10).

Zinc levels ranged from 0.6 to 1.6 µg/L and from 0.8 to 4.2 µg/L for dissolved and total zinc, respectively. These levels are lower than the CCREM aquatic life guideline of 30 µg/L maximum total zinc(10) as well as the level of 15 µg/L reported by the IJC as toxic to phytoplankton(11).

6.10 Marine Water Quality Data

Some marine water quality data have been collected from Yakoun Bay (several depths). Available data from June through December 1987 are found in Appendix 5.5.5-1 of Volume III (Baseline Environmental Description) of the Cinola Gold Project Stage II Report(36). Of particular relevance are the metals data, with the number of samples ranging from 13 to 23, depending on the variable. Metals levels were generally below their respective detection limits for both dissolved and total metals, including arsenic, cadmium, copper, cyanide, lead (all <1 µg/L), and mercury (<0.05 µg/L). Only some sample levels of total zinc were detectable, and ranged from <1 to 5 µg/L (mean of <3 µg/L, n = 13). These zinc levels were less than both the 4-day and 1-hour marine aquatic life criteria of 86 and 95 µg/L, respectively, and less than the lowest level known to affect marine aquatic life (saltwater plants) of 19 µg/L(8).

6.11 Metals In Biota

6.11.1 General

Fish and shellfish tissue metal analyses have been conducted over several years during the Cinola Project environmental impact assessment, on samples from streams potentially impacted by the Cinola project as well as from marine environments. Sampling agencies, type, and location of these data are as listed in the following table:

Title of Data Table/Sampling Agency	Location
A **Fresh Water**	
- Levels of Metals in Fish from the Yakoun River and Florence Creek, Collected by Ministry of Environment, 1987 - 1988	Table 6.10.1
- Levels of Metals in Fish from the Yakoun and Mamin River Drainages, Collected by Norecol 1986-1987	Table 6.10.1
- Levels of Metals from the Yakoun River Drainage, Collected by IEC Beak 1980 - 1982 (includes some Yakoun River estuary data)	Table 6.10.1
- Muscle Mercury Levels in Juvenile Coho Salmon from Caged Hatchery Stock (Environment Canada) Compared to Feral Fish (Norecol), 1988	Table 6.10.2 (both Tables 6.10.1 and 6.10.2 from the Cinola Gold Project Stage II Report, Volume III, Appendix 5.9.3-4)[36]
B **Marine**	
- Mercury Concentrations in Marine Biota from the Cinola Gold Project Study Area, Collected by Norecol During 1986 and 1987 (includes Yakoun and Mamin River estuaries, Masset Inlet)	Cinola Gold Project Stage II Report, Volume III, Appendix 5.9.4-1[36]
- Concentration of Other Metals in Marine Biota from the Yakoun River Estuary, Collected by Norecol During 1986 and 1987	Cinola Gold Project Stage II Report, Volume III Appendix 5.9.4-2[36]
- Concentration of Metals in Marine Biota from the Cinola Gold Project Area, Collected by Department of Fisheries and Oceans and by Waste Management Branch (Ministry of Environment) in 1979, 1982, and 1984 (includes Yakoun River estuary and Savory Beach)	Cinola Gold Project Stage II Report, Volume III, Appendix 5.9.4-3[36]

6.11.2 Fresh Water Fish Tissue

6.11.2.1 Mercury

Monitoring for mercury in fish within the Cinola project impact areas has been a priority of both the proponent and regulatory agencies due to the following: (i) the project area is within a geologic mercuriferous zone (with high mercury levels), (ii) mercury levels are presently elevated in some waters and fish tissue, and (iii) the proponent has projected increases of mercury to Barbie Creek with the Cinola Gold Project[36].

The 1987 to 1988 Ministry of Environment data from Table 6.10.1 show maximum mercury concentrations in the muscle of fish from the Yakoun River of 0.28 µg/g (n = 26), 0.39 µg/g (n= 5), and 0.45 µg/g (n = 35) wet weight for Dolly Varden char, rainbow trout, and cutthroat trout, respectively. These levels exceed the British Columbia criterion of 0.1 µg/g wet weight maximum for heavy consumption of fish (over 1 kg per week on a regular basis) and approach the 0.5 µg/g criterion for average consumption of fish (about 0.2 kg per week on a regular basis)[4]. Mean tissue mercury levels of 0.11, 0.23, and 0.28 µg/g wet weights for Dolly Varden char, rainbow, and cutthroat, respectively, also exceeded the 0.1 µg/g criterion for heavy consumption.

Data collected by Norecol from 1986 to 1987 in Table 6.10.1 showed similar maximum levels of 0.16 µg/g for Dolly Varden (n = 15) and 0.36 µg/g for rainbow trout (n = 35) from the Yakoun River. Similar mercury levels in fish from the Mamin River drainage (Mamin River and Boucher Creek) were identified, with maximum levels of 0.33 µg/g for coho (n = 45), 0.11 µg/g for rainbow (n = 11), 0.34 µg/g for Dolly Varden char (n = 23), and 0.14 µg/g for cutthroat (n = 2). Many of these sample concentrations exceeded the British Columbia heavy consumption criterion of 0.1 µg/g mercury (wet weight), but all were less than the 0.5 µg/g average consumption criterion[4] with the exception of one coho sample from the Yakoun River at 0.58 µg/g.

IEC Beak's monitoring from 1980 - 1982 showed similar fish muscle tissue mercury levels in the Yakoun River drainage (four creeks plus the Yakoun River; Table 6.10.1). Levels ranged from 0.02 µg/g (wet weight, various salmonid species) to a maximum of 0.34 µg/g wet weight in Dolly Varden char from Barbie Creek (Cinola Gold Project Stage II Report). These data show 80 of 122 samples or 66% of samples from the Yakoun River drainage to exceed the 0.1 µg/g human consumption criterion (for heavy consumption)[4]. All sample levels were less than the 0.5 µg/g wet weight criterion for average consumption of fish, however. It is notable that the highest level of tissue mercury identified during this study by IEC Beak was in sculpins from Florence Creek. Levels ranged from 0.15 to 2.20 µg/g wet weight (n = 19), frequently exceeding both the 0.1 and 0.5 µg/g consumption criteria[4]. These high levels could be of significance to non-human consumers of this species.

Muscle mercury levels of juvenile coho salmon reared in the Pallant Creek Hatchery (on Moresby Island) and caged at sites in Barbie and Gold Creeks for six weeks are summarized in Table 6.10.2. The mean muscle mercury concentrations for the fish caged in both lower Barbie and Gold Creeks were significantly different than the control fish (hatchery Day-0, $p = 0.05$). There was no significant difference in muscle mercury concentrations between middle Barbie Creek fish and the controls. Environment Canada believes the results indicate that caged hatchery stock can be used as an in situ monitoring tool to demonstrate small differences in bioavailable mercury through bioaccumulation (Derksen, 1989)[(18)].

Muscle mercury levels in feral juvenile coho salmon from the same creeks above are included in Table 6.10.2 for comparison. The levels in 31 of 32 samples (all creeks), up to 0.260 µg/g Hg, exceed the 0.1 µg/g (wet weight) criterion for heavy consumption[(4)] and could be of concern for non-human consumers of fish. In addition to mercury concentrations in feral fish being higher than the caged hatchery stock, Environment Canada concluded the following: (i) there were no significant differences between fish collected from lower Barbie Creek in August compared to September; (ii) there were no significant differences between fish from lower Barbie Creek and middle Barbie Creek in August; and (iii) the relatively larger standard deviation for Gold Creek fish may have been partly due to sampling fish with different exposure backgrounds (both truly feral fish as well as fish introduced from the Marie Lake hatchery). Environment Canada estimated a 90% chance of detecting a mean mercury concentration significantly different from the Barbie Creek mean (0.183 µg/g, $n = 24$) by one standard deviation (0.034 µg Hg/g) to require a sample size of $n = 13$. Similarly, detecting a mean mercury concentration significantly different than the Barbie Creek mean by one-half a standard deviation (0.017 µg Hg/g) would require a sample size of $n = 46$[(18)].

The concentration of mercury in fish liver from the Yakoun River was as elevated as in muscle tissue. Ministry of Environment data had higher mercury levels in liver than Norecol 1986/1987 data (Table 6.10.1) for comparable species: maximum levels of 0.67 µg/g (mean of 0.36 µg/g, $n = 5$) compared with 0.18 µg/g (mean of 0.08 µg/g, $n = 8$) for rainbow trout; and maximum levels of 0.56 µg/g (mean of 0.14 µg/g, $n = 25$) compared with 0.23 µg/g (mean of 0.16 µg/g, $n = 6$) for Dolly Varden char. Cutthroat had the highest maximum level, 0.79 µg/g (mean of 0.39 µg/g) in the Ministry of Environment data (no comparable data from Norecol). Liver mercury levels in fresh water fish from the Mamin River drainage collected by Norecol ranged from 0.02 to 0.44 µg/g (all species; mean of 0.07 µg/g, n = 13). This was similar to levels in fish liver from the Yakoun River drainage of from 0.03 to 0.45 µg/g (mean of 0.15 µg/g, all species) identified by Norecol and from <0.05 to 0.79 µg/g (mean of 0.30 µg/g, all species) identified by the Ministry of Environment.

Fish from Yakoun Lake were sampled once by Ministry of Environment in 1984[42]. Although sample sizes were small, mercury levels in cutthroat and Dolly Varden char were similar to levels in fish from the lower parts of the Yakoun River drainage discussed previously. Mercury in muscle ranged from 0.29 to 0.41 µg/g (wet weight) in cutthroat (mean of 0.35 µg/g, SD = 0.06, n = 2), and from 0.08 to 1.50 µg/g in Dolly varden char (mean of 0.56 µg/g, SD = 0.66, n = 3). Further sampling of Dolly Varden char is needed to confirm the anomalously high value (1.50 µg/g) which exceeds the 0.5 µg/g criterion for average consumption[4]. Mercury levels in liver from cutthroat trout ranged from 0.27 to 0.57 µg/g (mean of 0.42 µg/g, SD = 0.06, n = 4).

6.11.2.2 Other Metals

Ministry of Environment 1987-1988 data for lead in Yakoun River fish were all below the detection limit of 10 µg/g dry weight (Table 6.10.1). Conversion of these dry weight lead levels to wet weight was done assuming an 80% moisture content of fish, resulting in all sample levels of <2 µg/g wet weight lead. This detection limit (2 µg/g wet weight) was too high and may have masked results that exceeded the 0.8 µg/g wet weight lead alert level in British Columbia for heavy consumption of the edible tissue of fish (and shellfish)[12]. Norecol's 1986 data for lead in fish tissue sampled from the Yakoun River drainage (only mercury was sampled in both 1986 and 1987; Table 6.10.1) ranged from less than the detection limit (1 µg/g dry weight) to a maximum of 2.28 µg/g dry weight/0.5 µg/g wet weight (converted) from one cutthroat sample, and to a maximum of 6.27 µg/g dry weight/1.3 µg/g wet weight from rainbow trout (mean of <1.38 µg/g dry weight/<0.28 µg/g wet weight; n = 13). Mean tissue lead levels, all species, was <1.42 µg/g dry weight/0.28 µg/g wet weight. Only this maximum level in rainbow trout exceeded the 0.8 µg/g lead wet weight alert level for heavy fish consumption in British Columbia[12]. Limited sampling of the Yakoun River drainage by IEC Beak in 1980 (Table 6.10.1) showed lead levels in fish muscle to frequently exceed the 0.8 µg/g wet weight alert level for fish consumption. Maximum species wet weight levels of lead (converted from dry weights in Table 6.10.1) identified in their sampling from various streams were the following: 2.5 μg/g in Dolly Varden char from Barbie Creek (mean of 0.5 μg/g, n = 23, all streams), 4.3 μg/g in cutthroat from the Yakoun River (mean of 2.0 μg/g, n = 11, all streams), and 4.3 μg/g in rainbow from Canoe Creek (mean of 1.8 μg/g, n = 5, all streams). These levels of lead are higher than data collected by both the Ministry of Environment and Norecol.

Fish tissue copper levels were similar between species as well as sampling location in the Yakoun River drainage, as evident in the most current Ministry of Environment data (1987) and the Norecol data (1986; Table 6.10.1). The highest levels were in cutthroat from the Yakoun River, which ranged from 1 to 11 μg/g dry weight (mean of 2.5 μg/g, n = 35). IEC Beak recorded a maximum of 17.8 μg/g, in Dolly Varden char from Barbie Creek (mean of 4.8 μg/g, n = 17).

Fish tissue zinc levels were similar between species and sampling agencies in the Yakoun River drainage (Table 6.10.1). Mean dry weight zinc levels for the various species (all streams) were as follows: (i) coho 32.5 μg/g (n = 29, Norecol) to 76 μg/g (n = 3, Ministry of Environment); (ii) cutthroat 35.8 μg/g (n = 13, IEC Beak) to 50 μg/g (n = 39, Ministry of Environment); (iii) rainbow 26.0 μg/g (n = 13, Norecol), 34 μg/g (n = 5, Ministry of Environment), 49.8 μg/g (n = 5, IEC Beak); (iv) Dolly Varden char 28.7 μg/g (n = 12, Norecol), 61 μg/g (n = 42, Ministry of Environment), 69.2 μg/g (n = 23, IEC Beak).

Dry weight fish tissue selenium levels in 1988 Ministry of Environment data (for coho salmon, cutthroat trout, and Dolly Varden char; Table 6.10.1) were from below the 10 μg/g detection limit to 47 μg/g. Converted to wet weights, the selenium levels ranged from <2 to 9.4 μg/g, with 5 of 23 samples exceeding the 3 μg/g (wet weight) aquatic life criterion set by the International Joint Commission[11].

Fish tissue arsenic, chromium, and cadmium were at or near their respective detection limits in both Ministry of Environment 1987 data and Norecol's 1986 data (Table 6.10.1) for samples from the Yakoun River and its tributaries.

6.11.3 Marine Biota

Baseline metal levels in marine biota from the Yakoun River estuary have been determined by Norecol (for Barrick Mine Management), the Department of Fisheries and

Oceans, and the Ministry of Environment (Waste Management Branch) from 1979 to 1987. Norecol has also collected baseline metals data from marine biota in both the Mamin River estuary and Masset Inlet. Of particular concern are baseline levels of lead and mercury in marine areas to be potentially impacted by fresh waters draining the Cinola project area. Elevated levels of these metals have been identified in fish sampled from fresh water streams within the Cinola project area. Metals data in marine biota have not been tabulated in this report, but can be found in Appendices 5.9.4-1 to 5.9.4-3 of the Cinola Gold Project Stage II Report, Volume III[36].

Similar wet weight mercury levels have been identified in Dungeness crab (leg muscle) in the Yakoun River estuary by the various sampling agencies, including: 0.025 to 0.157 µg/g (mean of 0.075 µg/g, n = 27) by the Department of Fisheries and Oceans (1979 - 1982); <0.05 to 0.16 µg/g (mean of 0.09 µg/g, n = 5) by the Ministry of Environment (1984); and 0.04 to 0.16 µg/g (mean of 0.09 µg/g, n = 20) by Norecol (1986 - 1987). These levels in crab were less than the 0.5 µg/g (wet weight) British Columbia mercury criterion for the average consumption of fish, but were frequently higher than the 0.1 µg/g criterion for heavy consumption[4]. Should mercury levels in crab increase in the future, levels could be of concern to human consumers. It should be noted that crab are just one indicator organism used to monitor increased metals levels over background in marine biota. An increase of mercury in crab should the Cinola mine proceed, would indicate an impact on marine benthic resources in general with regard to this characteristic.

Soft tissue from shrimp (tails) sampled from the Yakoun River estuary by Norecol (1986-1987) had wet weight mercury levels ranging from 0.03 to 0.49 µg/g (mean of 0.13 µg/g, n = 15), often exceeding the 0.1 µg/g British Columbia criterion for heavy consumption of fish/shellfish by humans and in two samples (0.45/0.49 µg/g) approaching the 0.5 µg/g moderate consumption criterion[4]. Mussel and clam tissue mercury levels were lower, with maximums of 0.04 µg/g (mean of 0.03 µg/g, n = 8) and 0.05 µg/g (mean of 0.03 µg/g, n = 8), respectively.

Lead levels in marine fish and shellfish sampled by the Department of Fisheries and Oceans (1979, 1982) and by Norecol (1986 - 1987) from the Yakoun River estuary were all less than the British Columbia alert level for human consumption of 0.8 µg/g wet weight[12]. One sample of sculpins (Department of Fisheries and Oceans data) had too high a detection limit (2 µg/g wet weight, converted from dry weight) to compare to the 0.8 µg/g consumption criterion, as did the 1984 Ministry of Environment data for crabs (2 - 2.2 µg/g wet weight detection limit, converted from dry weight).

Arsenic levels in Dungeness crab leg muscle from the Yakoun River estuary have been sampled the most extensively by various agencies. The dry weight levels found are as follows:

DFO(1979): range 12.2 - 51.1 µg/g, mean = 30.4 µg/g, SD = 12.3 µg/g, n = 14
(1982): range 10 - 44 µg/g, mean = 25 µg/g, SD = 9 µg/g, n = 13
Ministry of Environment (1984): range 22 - 60 µg/g, mean = 32 µg/g, SD = 16 µg/g, n = 5
Norecol (1986-1987): range 11.0 - 37.4 µg/g, mean = 21.5 µg/g, SD = 7.6 µg/g, n = 19

There are no arsenic tissue criteria for marine biota. There is a fresh water aquatic life guideline of 3.5 µg/g (wet weight) in processed fish protein used by Health and Welfare Canada to protect human consumers[29]. When the dry weight tissue data for Dungeness crab listed above are converted to wet weight and compared to this guideline for perspective, 34 of 51 samples exceeded the guideline. Caution should be used in comparing levels in Dungeness crab, however, as the guidelines is based on a consumer whose diet consists primarily of fish.

Cadmium levels in marine biota were generally low. Some data from the Yakoun River estuary, however, showed detectable levels. Mean levels in Dungeness crab hepatopancreas were 2.36 µg/g dry weight (<0.5 to 9.05 µg/g, n = 20), and in blue mussel (all soft tissue) 2.78 µg/g (1.26 to 4.26 µg/g, n =8), both sampled by Norecol (1986 - 1987). Although the Department of Fisheries and Oceans (1982) showed low cadmium levels in staghorn sculpin (mean of 0.053 µg/g, n = 10 for muscle; mean of 0.242 µg/g, n = 10 for liver) and Dungeness crab (below detection limits), a mean level of 1.66 µg/g dry weight (0.3 to 3.67 µg/g range, n = 3) was identified in pink shrimp. There are no tissue criteria for cadmium

7. WATER QUALITY OBJECTIVES

7.1 Philosophy

Water quality objectives are set by the Ministry of Environment, Lands and Parks to protect the designated water uses of waterbodies that would be potentially impacted by anthropogenic activity. Objectives are based upon approved water quality criteria for British Columbia or upon working (temporary) criteria from the literature or other jurisdictions to protect the most sensitive water uses. Should a waterbody have exceptionally valuable resources of provincial significance and good existing water quality, the water quality objectives are set to avoid degradation.

Water quality objectives are to be met 100% of the time between the streamflow extremes for which the water and waste management measures are designed with regards to effluent discharges and water quality, in this case the 1-in-10 year high and low flows. A water quality objective that is exceeded would indicate that a potential problem has occurred that needs correcting. Objectives based on water use protection criteria are designed to be a conservative estimate of the water quality conditions needed to protect the environment (i.e., a conservative estimate of the threshold of some detrimental effect to the environment and its uses).

Water quality objectives are site-specific and based on the best available information. As such, objectives are provisional and will be reviewed as more monitoring information becomes available and the Ministry of Environment, Lands and Parks establishes more approved water quality criteria for British Columbia.

Water quality objectives apply immediately outside of initial dilution zones of either entire water bodies or designated reaches. Initial dilution zones are usually small areas where initial mixing occurs between the waste discharge and the receiving waters. Although initial dilution zones are site specific, they are typically less than 100 m long, and occupying less than 25 to 50% of the width of the waterbody. They are located, sized, and shaped to minimize the impact of waste discharges on aquatic populations. Although water quality objectives do not apply in initial dilution zones, objectives for contaminants in biological tissue apply throughout the waterbody. No acutely toxic or nuisance conditions are allowed inside initial dilution zones (for more details see "Principles" document[35]).

Processes such as chemical changes, precipitation, adsorption, and microbiological action, as well as dilution, take place in these zones to ensure that water quality objectives are met at their border.

Objectives in terms of 30-day average and maximum concentrations are calculated from a minimum of 5 samples in 30 days.

7.2 Designated Uses Of Waterbodies For Objectives

The following table lists the water uses designated for protection by water quality objectives for waterbodies potentially impacted by the Cinola project, as determined by the Federal-Provincial Cinola water quality objectives committee. This committee had representatives from the British Columbia Ministry of Environment, Lands and Parks (Water Quality Branch and Environmental Protection Division), the Department of Fisheries and Oceans, Environment Canada (Environmental Protection), and the Inland Waters Directorate (Water Quality Branch). Water quality objectives are designed to protect the most sensitive water use.

WATERBODY	DESIGNATED USES
1. Fresh Water	
Florence Creek	aquatic life (below the falls, with salmonid spawning and rearing) and wildlife, including their consumption by humans. Note that the habitat of resident fish (and other aquatic life) above the falls is lost to tailings pond development in the High West area
Barbie Creek	aquatic life (includes fish spawning and rearing) and wildlife, including their consumption by humans
Coreshack Creek	aquatic life (includes fish spawning and rearing) and wildlife, including their consumption by humans
Adit Creek	aquatic life (fish-use at least in the lower reach adjacent to Barbie Wetlands) and wildlife, including their consumption by humans
Sid Creek	aquatic life (includes fish spawning and rearing) and wildlife, including their consumption by humans
Canoe Creek	aquatic life (includes fish spawning) and wildlife, including their consumption by humans
Clay Creek	aquatic life (includes fish rearing) and wildlife, including their consumption by humans
Yakoun River	aquatic life (includes fish spawning and rearing) and wildlife, including their consumption by humans (e.g., native food fishery), recreation/aesthetics, drinking water
Boucher Creek	aquatic life (includes salmonid rearing) and wildlife, including their consumption by humans
2. Marine Water	
Yakoun Bay	aquatic life (includes salmonid rearing, important eelgrass communities) and wildlife (includes migratory birds), as well as their consumption by humans (includes crustacean-shellfish harvesting), recreation
Ferguson Bay	aquatic life (includes fish-rearing, shellfish, eelgrass communities) and wildlife, recreational/food fisheries

7.3 Where Objectives Apply In Waterbodies

7.3.1 Florence Creek

Mine plans eliminate Upper Florence Creek with a water storage reservoir in the headwaters, three tailings impoundments and a settling pond downstream. Headwater flow would be diverted around the impoundments and Florence Creek would originate at the outlet of the settling pond, continuing 400 m downstream to a canyon with a 5 m falls impassable to fish. Water quality objectives would apply to Florence Creek below these falls. Protection above the falls is not necessary as the falls are impassable to anadromous fish and headwater habitat is essentially lost to mine development. Water quality Site Q31 is located at the Branch 4 Road crossing just below the falls, and would continue to be the sampling location for objectives monitoring.

7.3.2 Barbie Creek

Upper Barbie Creek would receive discharges from two small settling ponds plus "clean" water diversions. Middle Barbie Creek would receive settling pond/ artificial wetland effluent and a "clean" water diversion that discharges above Barbie wetlands. Lower Barbie Creek would receive effluent from the lime water treatment plant/artificial wetland that discharges below Barbie wetlands. Water quality objectives would apply everywhere in Barbie Creek except for small initial dilution zones (IDZs) downstream from waste discharges (to be determined by regulatory agencies). Waste discharge points must be located to avoid IDZs conflicting with significant fish spawning and rearing habitat. Zones of passage for fish (where objectives would apply) are probably impractical in a stream this small.

7.3.3 Coreshack Creek

Upper Coreshack Creek would be lost to settling ponds, with the creek originating downstream from the last one. Water quality objectives would apply from the last settling pond to the mouth of Coreshack Creek at Barbie wetland.

7.3.4 Adit Creek

During operations, upper Adit Creek would be lost to the open-pit, and flow in Adit Creek would be reduced accordingly. The creek would originate at the pit boundary during mining and at the pit outlet after abandonment as total flow from the pit will be discharged to Adit Creek after pit reclamation. There is no significant dilution available in Adit Creek or change in dilution along its length. Water quality objectives are to apply to the entire creek, from the pit to the mouth, with no initial dilution zone. Although the majority of the creek is currently impacted and unused, the lower reach adjacent to Barbie wetland is utilized by fish. Water quality objectives should be met throughout Adit Creek to protect fish use both in Adit Creek and Barbie wetland.

7.3.5 Sid Creek

Sid Creek flows to the Yakoun River. It would receive a "clean" water diversion. It could also potentially be impacted from the water treatment plant/artificial wetland in its drainage although this effluent is to be piped to a discharge location in Barbie Creek below the wetland. Objectives apply to the entire creek.

7.3.6 Canoe Creek

This creek flows to the Yakoun River. Impacts from the Cinola project would be restricted to the lower priority concerns of sedimentation from road use and possibly overflows from sedimentation ponds. Objectives will apply to the entire creek and be restricted to sedimentation characteristics including turbidity and suspended solids, based on a comparison of upstream/background to downstream levels.

7.3.7 Clay Creek

This creek flows to the Yakoun River. Similar to Canoe Creek, impacts are restricted to the lower priority concern of sedimentation from road use along the Yakoun Main that parallels Clay Creek for most of its length. Sedimentation objectives (turbidity and suspended solids) apply to the entire creek.

7.3.8 Yakoun River

The mine project design plan is for discharge to both Florence and Barbie Creeks and substantial change in water quality of these drainages would be difficult to avoid. Proponent projections suggest difficulty in meeting objectives in Barbie Creek for some variables at low flows, unless water treatment plant effluent is pumped to the active tailings impoundment in the Florence Creek drainage during these low flow periods of potentially high impact. Water quality objectives for the Yakoun River should be met outside of a mixing zone downstream from Barbie Creek. This will allow dilution and assimilation of Barbie Creek water by water in the Yakoun River to protect water uses of the river. Site Q10, until May of 1987 established downstream from Barbie Creek, should be re-established at the downstream end of this Barbie Creek initial dilution zone for the monitoring of objectives, with the site location to be approved by regulatory staff.

The proponent may not be permitted to discharge water treatment plant/artificial wetland effluent to lower Barbie Creek but may obtain a Provincial permit to discharge directly to the Yakoun River. In this case, water quality objectives would have to be met in the river at the end and on the side(s) of an initial dilution zone to be designed for the discharge by regulatory staff.

7.3.9 Yakoun River Estuary and Bay and Ferguson Bay

Water quality objectives apply in all areas and out to deep water (20 fathoms).

7.3.10 Boucher Creek

Part of the Mamin River drainage, Boucher Creek could be impacted from tailings pond seepage in the proposed mine High West area. Water quality objectives are to apply everywhere in Boucher Creek.

7.4 Variables For Objectives In Fresh Water

Variables selected for water quality objectives are based on the proponent's Stage II projections of contaminants to be discharged. Present levels of most water quality variables are based on Norecol/British Columbia Research data available to date (1988). Fish tissue data used were mostly collected by the Ministry of Environment, Environment Canada, and Norecol. Objectives for both water and biota (tissue) are subject to revision as more data becomes available, including data from sensitive, chronic, in-situ bioassays on salmonids and algae. Water quality objectives are set to protect the designated uses as outlined for waterbodies summarized in Section 7.2. Objectives for variables described below apply to all these waterbodies, with the exception of Canoe and Clay Creeks where only sedimentation objectives (turbidity/suspended solids) apply.

Many of the objectives are expressed in terms of no significant increase at the 95% confidence level. Because the variability in environmental constituents would normally mean that excessive sampling (e.g., daily samples for 30 days) would need to be done to prove a significant increase at the 95% confidence level, an increase of +20% will be taken to be a conservative estimate of a significant increase when using normal sampling effort (e.g., 5 weekly samples in 30 days). (For a more detailed explanation see Reference 46.) Increases of more than 20% will be considered to have not met the objective, subject to confirmation by increased monitoring and an impact assessment. The latter could range from an assessment of whether the waste discharge(s) involved could have caused the increase to studies on the aquatic biota.

7.4.1 Mercury

7.4.1.1 Rationale

Levels are presently elevated in some waters and fish, with levels projected by the proponent to increase in Barbie Creek. As the tailings impoundments in the High West area are designed as zero discharge systems during the operating life of the mine, only when Florence Creek flows through the reclaimed impoundments upon mine closure should mercury levels impact Florence Creek (and possibly Boucher Creek). This would depend on the stability of the reclaimed impoundments.

7.4.1.2 Present Levels

Most samples have been analysed at a high detection limit of 0.05 μg/L. Levels in fresh water have been less than this 0.05 μg/L detection limit except for two samples of total mercury from Adit Creek (both 0.06 μg/L), one sample from Canoe Creek (0.06

µg/L), and one sample from upper Barbie Creek (0.15 µg/L). This detection limit is too high and may have masked other results from project area streams that exceeded British Columbia aquatic life criteria. More recent sampling at lower detection limits has identified the following: (i) total mercury levels in Barbie Creek ranging from <5 - 31 ng/L (mean of <14 ng/L, n = 8), and in Florence Creek of <2.6 - 9 ng/L (mean of <5 ng/L, n = 9); and (ii) ionic mercury in Barbie Creek of <0.4 ng/L (n = 3), and in Florence Creek of 0.4 - 1.4 ng/L (mean of 0.9 ng/L, n = 3). Some low detection limit analyses by Norecol are not yet available. Mercury in fish muscle reached highest mean levels of 0.63 µg/g wet weight in Florence Creek sculpins, with a maximum level of 2.20 µg/g. The highest mean level on record for a sport fish species was 0.21 µg/g for Barbie Creek cutthroat trout (n = 35). Mercury levels in water (low detection limit) and fish are summarized below.

Mercury in Water and Fish in Barbie and Florence Creeks
and the Yakoun River

	Water (Total Low Level Hg) Mean/Range (ng/L)	**Fish** Mean/Range (µg/g Hg wet weight)
Barbie Cr	<14/<5 - 31 (n = 8)	Coho 0.17/0.07 - 0.38 (n = 42)
		Cutthroat 0.21/0.08 - 0.34 (n = 10)
		Rainbow 0.09/0.04 - 0.14 (n = 2)
		Dolly Varden 0.14/0.02 - 0.27 (n = 52)
Florence Cr.	<5/2.6 - 9 (n = 9)	Coho 0.12/0.08 - 0.24 (n = 9)
		Cutthroat 0.14/0.08 - 0.23 (n = 14)
		Dolly Varden 0.16/0.02 - 0.48 (n = 27)
		Sculpin 0.63/0.15 - 2.2 (n = 19)
Yakoun R.	no data at low levels (all <50 MDC)	Coho 0.07/0.02 - 0.58 (n = 57)
		Cutthroat 0.17/0.07 - 0.45 (n = 38)
		Rainbow 0.13/0.02 - 0.39 (n = 49)
		Dolly Varden 0.12/0.02 - 0.28 (n = 45)

7.4.1.3 Ministry of Environment Lands and Parks Objectives

For Water: British Columbia aquatic life criteria are 0.02 μg/L 30-day average (calculated from at least 5 weekly samples in 30 days) and 0.1 μg/L maximum total mercury in water[4]. These levels are too high considering the low levels found in the ambient data as well as the relatively high mercury levels in fish tissue. Allowing mercury in water to rise to criteria could lead to unacceptable levels in fish tissue. Objectives for water are proposed for Barbie and Florence Creeks and the Yakoun River, and are as follows:

(i) Barbie and Florence Creeks. Average mercury levels in water are from <1.4ng/L in Florence Creek to <5 ng/L in Barbie Creek, with sport fish tissue levels for both creeks averaging 0.21 μg/g (wet weight) and with maximum levels to 0.48 μg/g (wet weight). The concern is that maximum levels in fish tissue before mine development already approach the 0.5 μg/g criterion for the average consumption of fish[4]. With mercury levels in water predicted by the proponent to double in Barbie Creek and quadruple in Florence Creek, levels could rise in fish tissue to exceed criteria for safe consumption. The proposed objectives are based on the present (limited) data for low level mercury in these creeks, and are the following:

Barbie Creek:	20 ng/L 30-day average, 50 ng/L maximum
Florence Creek:	10 ng/L 30-day average, 20 ng/L maximum

The objectives are tentative, subject to additional low level data collection.

(ii) Yakoun River. In order to limit mercury in fish tissue to safe consumption levels, it is important to maintain mercury levels in water as close to pre-mine development levels as possible. Until low level mercury data are collected for the Yakoun River, tentative objectives are recommended at 20 ng/L 30-day average and 50 ng/L maximum.

For Tissue: British Columbia tissue criteria are 0.5 μg/g wet weight total mercury for the average consumption of fish and 0.1 μg/g total mercury for heavy consumption[4]. The proposed tissue objectives for mercury for creeks and the Yakoun River are the following:

(i) Barbie and Florence Creeks. The fish populations in these creeks are relatively small and not fished significantly by either native Indians or sport fisherman. The proposed provisional objective for mercury in fish tissue is a maximum of 0.5 µg/g wet weight, based on a minimum sample of 10 fish for each of the three sport fish species including cutthroat trout, rainbow trout, and Dolly Varden char.

(ii) Yakoun River. Fish populations are relatively large. With both sport fisherman and native Indians fishing these water, it is probable that there are some heavy fish consumers (i.e., 1 kg/week for extended periods). Because of the need to keep mercury levels in fish as close to present levels as possible, the proposed provisional objectives are small increases above the pre-mine development levels for each of the three sport fish species. These objectives are the following (wet weights):

cutthroat trout:	0.20 µg/g wet weight average, 0.5 µg/g maximum
rainbow trout:	0.15 µg/g wet weight average, 0.5 µg/g maximum
Dolly Varden char:	0.15 µg/g wet weight average, 0.5 µg/g maximum

The objectives should be based on a minimum sample of 10 of each species.

7.4.2 Copper

7.4.2.1 Rationale

Proponent projected increases for copper are up to 2 µg/L in Florence Creek, to 10 µg/L in lower Barbie Creek, and to 11 µg/L in Adit Creek at low flows.

7.4.2.2 Present Levels

The levels of total copper in Cinola project area streams were generally less than 2 µg/L, but approached this level with maximums of 1.9 and 1.8 µg/L in middle and lower Barbie Creek sites, respectively, 1.8 µg/L in upper Florence Creek, and 1.9 µg/L in Clay Creek. The highest concentrations on record are from single samples from Adit and Boucher Creeks of 2.7 and 3.0 µg/L total copper, respectively. All sample levels of dissolved copper from all streams were less than 2 µg/L.

7.4.2.3 Ministry of Environment, Lands and Parks Objectives

British Columbia aquatic life criteria for copper are a 30-day average (calculated from a minimum of 5 weekly samples) of ≤2 µg/L when average hardness is ≤50 mg/L (as $CaCO_3$), or ≤ 0.04 x (average hardness) when the average hardness is >50 mg/L, and a maximum of 0.094 x hardness + 2 µg/L. Receiving water hardness will increase with the mine development due to lime addition in the water treatment plant and limestone addition to the waste rock stockpile. The British Columbia criteria allow for increased copper levels with increasing hardness to reflect aquatic life protection offered by the copper/hardness relationship. The proposed objectives for streams and the Yakoun River restricts the maximum allowed increase in copper to protect aquatic life: (i) a 30-day average of 2 µg/L total copper (hardness ≤50 mg/L) to a maximum of 12 µg/L total copper (at hardness of 300 mg/L); (ii) a maximum of from 2 µg/L (0 hardness) to 30 µg/L (300 mg/L hardness); and (iii) no significant increase (at the 95% confidence level) when background exceeds the objective. Both the average and maximum objectives increase to a limit of 300 mg/L hardness as few data are available to extrapolate the copper toxicity versus hardness relationship beyond 300 mg/L hardness. These objectives are subject to the results of chronic bioassays on salmonids should lime treatment plant effluent be discharged to Barbie Creek, primarily to confirm the effectiveness of hardness in ameliorating the toxicity of copper.

7.4.3 Cyanide

7.4.3.1 Rationale

Proponent projections are that levels in Florence Creek would be low

(1 µg/L), but are dependent on the level of cyanide degradation in the tailings impoundments. The proponent has no expectations or projections of cyanide additions to Barbie Creek.

7.4.3.2 Present Levels

All Cinola project area streams (Yakoun and Mamin River drainages) had total cyanide levels below the 1 µg/L detection limit.

7.4.3.3 Ministry of Environment, Lands and Parks Objectives

British Columbia criteria and the proposed objectives for streams and the Yakoun River are 5 µg/L 30-day average and 10 µg/L maximum weak-acid dissociable cyanide to protect aquatic life[(6)]. Strong-acid dissociable cyanide should also be monitored because of the potential for the production of toxic cyanide species by sunlight.

7.4.4 pH

7.4.4.1 Rationale

pH levels in streams within the Cinola project area are currently very low (<6.5) and could increase or decrease due to the Cinola gold project; decrease from acid generation or increase from limestone or lime-neutralized effluents.

7.4.4.2 Present Levels

Many pH values in project area streams are <6.5. Minimum pH levels are: 4.2 in Adit and Clay Creeks, 4.6 in Barbie Creek, 4.7 in Canoe Creek, 5.2 in Florence Creek, 5.8 in Boucher Creek, 5.9 in the Yakoun River, and 6.0 in Coreshack Creek.

7.4.4.3 Ministry of Environment, Lands and Parks Objectives

The British Columbia freshwater aquatic life criteria allow unrestricted change within the range 6.5 to 9.0[(40)], which is in agreement with the CCREM aquatic life guidelines[(10)]. Above or below these limits, however, the British Columbia criteria have more specific requirements detailed in the criteria document. In addition to meeting these criteria, there is need to restrict pH changes around the minimum theoretical aluminum solubility range of pH 5.6 to 6.2 to protect aquatic life from precipitation of aluminum (e.g., on the gills of fish). This minimum solubility range of 5.6 to 6.2 occurred in Barbie Creek during sampling for the preliminary aluminum speciation[2]. Based on these incomplete data, objectives for Barbie and Florence Creeks as well as the Yakoun River are proposed as follows:

(i) Barbie Creek (in areas where there is no substantial increase in background hardness and SO_4, i.e., for hardness ≤50 mg/L, sulphate ≤30 mg/L):
-no restriction on change over background within pH range 5.5 to 6.2 (slightly more symmetrical solubility minimum range)
- pH <5.5, no decrease, +0.5 units increase over background
- pH >6.2, no increase, -0.5 units decrease over background

(ii) Barbie Creek (in areas where there is substantial increase in background hardness and SO_4, as would occur below the water treatment plant, i.e., hardness >50 mg/L, sulphate >30 mg/L):
-+0.5 units change over background (on the premise that hardness and sulphate would reduce aluminum toxicity by an order of magnitude, offsetting solubility increases of 0.5 to 1 orders of magnitude implied by an 0.5 unit change)

(iii) Florence Creek (in areas where there is no significant change in background hardness or SO_4, i.e., hardness <50 mg/L, sulphate <30 mg/L):
-no restriction on change over background within pH range of 5.5 to 6.2
-pH >6.2, +0.5 units change over background
-pH <5.5, -0.2 units decrease, +0.5 units increase over background (solubilityincreases faster with decreasing pH than increasing pH)

These pH objectives for (i), (ii), and (iii) need to be confirmed by more aluminum speciation work as well as sensitive, chronic bioassays on salmonids using Barbie and Florence Creek water.

(iv) Yakoun River:
-aluminum speciation data from the Yakoun River are required to design pH objectives. In the interim,however, a change of ±0.5 units over backgroundwill be considered acceptable to minimize solubility concerns with regards to aluminum.

7.4.5 Particulate Matter Variables

Non-filterable Residue (Suspended Solids), Turbidity, and Bottom Sedimentation.

7.4.5.1 Rationale

Levels of these variables would increase due to land disturbances (e.g., mining, road building and road use) and effluent discharges. All are of concern in protection of aquatic life, in particular the effects of increased bottom sedimentation on salmonid spawning gravels.

7.4.5.2 Present Levels

Non-filterable residue ≤32 mg/L
Turbidity ≤23 NTU
Bottom Sedimentation: not measured

Present levels of non-filterable residue and turbidity are generally low although more sampling during high flow events is expected to extend the range of values.

7.4.5.3 Ministry of Environment, Lands and Parks Objectives (as maximums)

(i) Non-Filterable Residue (mg/L). British Columbia aquatic life criteria and the proposed provisional objectives for the streams and the Yakoun River are that induced non-filterable residue should not exceed 10 mg/L when background levels are ≤100 mg/L, nor should induced non-filterable residue be more than 10% of background when background is >100 mg/L[7].

(ii) Turbidity (NTU). British Columbia aquatic life criteria and the proposed provisional objectives for streams and the Yakoun River are that induced turbidity should not exceed 5 NTU when background turbidity is ≤50 NTU, nor should induced turbidity be more than 10% of background when background is >50 NTU[7].

The applicability of provincial particulate matter criteria (suspended solids and turbidity) to the Yakoun River and its tributaries has been confirmed by Singleton[30].

These increases in suspended solids and turbidity are not cumulative from upstream to downstream, and therefore apply to groups of discharges to be determined by regulatory staff when mine planning is finalized. Because many project streams originate in settling ponds (Barbie, Florence, Coreshack, and Adit), have low available dilution and multiple sediment discharges, these objectives could be difficult for the proponent to meet. More stringent objective levels would be necessary in spawning areas if the sedimentation objectives below are not achieved.

(iii) Sedimentation. The proposed objective for salmonid spawning areas is that the benthic accumulation of particulate matter less than 3 mm in diameter (fines) should not be significantly (95% confidence level) increased (by weight) over natural background levels. We recommend a minimum of 3 sediment traps at each site both to establish background levels (pre-mine development) and to check this objective. The objective should be achieved in addition to the other objectives for non-filterable residue and turbidity.

7.4.6 Dissolved Oxygen

7.4.6.1 Rationale

There is the potential for reduced flows, elevated water temperatures, discharge of oxygen-consuming materials, and increased sedimentation which is of concern for aquatic resources in fresh waters impacted by the mine development.

7.4.6.2 Present Levels

There are only a few dissolved oxygen data from Cinola streams, and none collected by the proponent. These data range from a minimum of 2.6 mg/L (Barbie Creek wetland, summer low-flow conditions) to maximums of 12.0 mg/L (Florence Creek).

7.4.6.3 Ministry of Environment, Lands and Parks Objectives

The US EPA(1986)[8] salmonid criteria are recommended as objective levels for the streams and the Yakoun River. These objectives are proposed pending results of measuring existing (natural) dissolved oxygen in these streams, and apply where habitat and stream flows are suitable. Levels are dependent on salmonid life stages, and include the following:

(i) Embryo and larval stages present: 11 mg/L dissolved oxygen <u>in the overlying</u> water which represents a level of no production impairment, and assumes 8 mg/L <u>interstitial</u> (intergravel) dissolved oxygen concentration[8]. In addition, an interstitial dissolved oxygen objective is set at the EPA level of 8 mg/L and should be measured directly in spawning gravels with the technique favoured (and used) at the Quinsam Hatchery. This is a standpipe pounded 20 - 25 cm into the gravel, followed by disposal of the initial surface water, with dissolved oxygen measurement of the interstitial water refill using a Leeds and Northup non-consumptive dissolved oxygen probe (Bill McLean, Quinsam Hatchery, personal communication).

(ii) Other salmonid life stages present: 8 mg/L dissolved oxygen <u>in water</u>, which represents a level of no production impairment[8].

(iii) When background levels are less than these objectives, then there should be no significant decrease over background (95% confidence level) due to anthropogenic activities.

7.4.7 Periphyton

7.4.7.1 Rationale

The proponent's Stage II report predicts periphyton growth to increase by five to ten times in Florence and Barbie Creeks due to nitrogen and phosphorus discharged from the mine.

7.4.7.2 Present Levels

Background data are not yet available but are understood to be normally low. Flow-through algal bioassays of Florence Creek water produced a maximum periphyton level (background, with no nutrient addition) of 5.4 mg/m^2 chlorophyll a on artificial substrates (styrofoam). A five to ten fold increase in levels like these would still result in relatively low levels.

7.4.7.3 Ministry of Environment, Lands and Parks Objectives

British Columbia criteria for periphyton are maximums of 50 mg/m^2 chlorophyll a to protect aesthetics and 100 mg/m^2 chlorophyll a to protect salmonids(13). The aesthetics criterion (50 mg/m^2 chlorophyll a) is the recommended objective for the Yakoun River, with the salmonid criterion (100 mg/m^2) the recommended objective for all the other streams in the Cinola project area. These objectives are subject to confirmation of present natural levels in streams.

The Salmonid Enhancement Program's experimental enrichment of the upper Keogh River in British Columbia set no periphyton target levels to protect salmonids, but has recorded levels of up to 100 to 200 mg/m^2 chlorophyll a with no apparent adverse affects (Chris Perrin, Limnotek Research and Development, personal communication). Pre-fertilization levels of chlorophyll a standing crop never exceeded 10 mg/m^2.

7.4.8 Nitrate

7.4.8.1 Rationale

The proponent's Stage II projections include: (i) an increase to 7 mg/L nitrate-N in Florence Creek at Q_2 low flow (average 7-day low flow with a 2 year return period), implying an increase to 2.8 mg/L with additional dilution at the mouth at Yakoun Bay; and (ii) an increase to 2 mg/L nitrate-N in Barbie Creek in an average June, to 6 mg/L at Q_{10} low flow (ten year return period, by extrapolation). These levels suggest increases in the Yakoun River with complete mixing of from 0.10 to 0.15 mg/L nitrate-N.

7.4.8.2 Present Levels

Maximum nitrate-N levels are the following: 0.025 mg/L in Coreshack Creek, 0.126 mg/L in Adit Creek, 0.112 mg/L in Barbie Creek, 0.063 mg/L in Florence Creek, 0.034 mg/L in Canoe Creek, 0.044 mg/L in Clay Creek, 0.014 mg/L in Boucher Creek, and 0.057 mg/L in the Yakoun River.

7.4.8.3 Ministry of Environment, Lands and Parks Objective

British Columbia fresh water aquatic life criteria for nitrate-N are a 30-day average of ≤40 mg/L and a maximum of 200 mg/L[(9)]. The British Columbia wildlife criterion is 100 mg/L maximum nitrate-N[(9)]. The proposed objective for Cinola project streams and the Yakoun River is 10 mg/L maximum nitrate-N, which is the British Columbia drinking water and recreation criterion (re drinking or ingesting water while recreating)[(9)]. This level is well below the B.C. average criterion of 40 mg/L nitrate-N to protect salmonids from nitrate toxicity[(9)]. The objective assumes that nitrate-N is not the limiting factor in periphyton growth (as suggested by the Florence Creek algal bioassays) and is subject to confirmation by algal bioassays using Barbie Creek and Yakoun River water.

7.4.9 Nitrite and Ammonia

7.4.9.1 Rationale

Besides nitrate, nitrogen moves between the other inorganic forms of nitrite and ammonia as a consequence of environmental conditions and microbial activity. Although no projections by the proponent have been made, there is the potential for increases in nitrite and ammonia in surface waters due to residues from ammonium nitrate explosives and the nitric acid reagent used in the milling, together with accompanying nitrification/ denitrification. Pilot mill effluent contained 295 mg/L nitrate-N and 2.8 mg/L nitrite-nitrogen. If the ratio of nitrate-N to nitrite-N from the pilot mill was constant, there would be 0.065 mg/L nitrite-nitrogen in Florence Creek based on the proponent's projected 6.9 mg/L nitrate-N in Florence Creek at Q_2 low flow. (This nitrite-nitrogen level is equal to the British Columbia criterion at a chloride concentration of 7 mg/L. There could be more or less nitrite-nitrogen depending on whether nitrifying or denitrifying conditions prevail.)

7.4.9.2 Present Levels

Whereas nitrite-nitrogen levels have been below the 0.002 mg/L detection limit in all streams and the Yakoun River, ammonia-N levels have been variable with the maximum recorded as follows: 0.012 mg/L Coreshack Creek, 0.016 mg/L Canoe Creek, 0.022 mg/L Boucher Creek, 0.026 mg/L Florence Creek, 0.031 Clay Creek, 0.032 mg/L Yakoun River, 0.057 mg/L Barbie Creek, and 0.087 mg/L Adit Creek.

7.4.9.3 Ministry of Environment, Lands and Parks Objectives

The proposed provisional objectives for both Cinola streams and the Yakoun River are the British Columbia aquatic life criteria which are as follows:

(i) ammonia: 30-day average criteria of from 0.131 to 2.08 mg/L, and maximum criteria of from 0.682 to 27.7 mg/L, both dependent on pH and temperature (see Tables 6.1.2 and 6.1.3 for detailed criteria)[9].

(ii) nitrite: 30-day average criterion of from 0.02 to 0.20 mg/L, and maximum criterion of from 0.06 to 0.60 mg/L, both dependent on chloride concentration[9]. Specifically, these criteria are detailed in Table 6.1.4.

7.4.10 Zinc

7.4.10.1 Rationale

The proponent has projected increases in zinc in streams with the Cinola development, due to present mineralization in the area.

7.4.10.2 Present Levels

Barbie Creek ≤15 μg/L Zn-Total, ≤10 μg/L Zn-Dissolved
Coreshack Creek ≤6.5 μg/L Zn-Total, ≤3.6 μg/L Zn-Dissolved
Adit Creek ≤50 μg/L Zn-Total, ≤8.0 μg/L Zn-Dissolved
Florence Creek ≤40 μg/L Zn-Total, ≤5.1 μg/L Zn-Dissolved
Yakoun River ≤4.0 μg/L Zn-Total, ≤2.8 μg/L Zn-Dissolved
Other Streams ≤7.9 μg/L Zn-Total, ≤2.5 μg/L Zn-Dissolved

7.4.10.3 Ministry of Environment, Lands and Parks Objectives

The CCREM tentative aquatic life guideline is 30 μg/L total zinc maximum[10], a level already exceeded in Adit and Florence Creeks on rare occasions. CCREM noted that recent studies have suggested that phytoplankton are more sensitive to zinc, and that these studies should be considered before applying the tentative guideline to a waterbody where most of the zinc would be bioavailable. Although 30 μg/L appears to be a no-effect level for salmonids and invertebrates, one study (Affleck, 1952)[19] found effects on rainbow trout ova and alevins at 10 μg/L total zinc in very soft (8 mg/L), low alkalinity (8 mg/L) water, similar to that in the Yakoun River and its tributaries. The IJC (1987)[11] reported toxicity to phytoplankton as low as 15 μg/L and recommended an objective for the Great Lakes of 10 μg/L maximum total zinc.

The proposed objective for Cinola project streams and the Yakoun River is 10 μg/L maximum dissolved zinc, or plus 20% of background dissolved zinc if background exceeds the objective. Dissolved zinc was chosen because it is believed that it more accurately reflects the bioavailable zinc than total zinc when zinc may be bound to suspended particulate matter. This objective is subject to sensitive, chronic algal and salmonid bioassays.

7.4.11 Selenium

7.4.11.1 Rationale

Selenium occurs in the environment associated with sulphur. Sulphate in the environment is projected by the proponent to increase, and selenium could increase as well. Projected increases are to 3 µg/L in Adit Creek at Q_{10} low flow after pit reclamation, and to 1 µg/L (0.5 µg/L increase) in Florence Creek at Q_2 low flow. Although no projections are made for Barbie Creek, there is some evidence from the proponent of high selenium from a test using an unlimed waste rock column (220 µg/L) but no evaluation of selenium removal in the water treatment plant.

7.4.11.2 Present Levels

<1 µg/L dissolved and total selenium, all sites in all streams.

7.4.11.3 Ministry of Environment, Lands and Parks Objectives

The CCREM aquatic life guideline is 1 µg/L maximum total selenium[10]. The IJC (1981)[20] also recommended 3 µg/g wet weight maximum in aquatic biota and 5 µg/g dry weight maximum in sediments. The following are the recommended objectives for Cinola project streams and the Yakoun River: 1 µg/L maximum total selenium in water, 3 µg/g wet weight maximum in biota, and 5 µg/g dry weight maximum in sediments. Some Ministry of Environment fish tissue levels exceeded the selenium objective for biota. Baseline data on selenium in the sediments need to be collected. Environment Canada had implemented sediment baseline monitoring but analysis for selenium was not included. The potential for selenium discharge to the aquatic environment needs to be further evaluated.

7.4.12 Cadmium

7.4.12.1 Rationale

Cadmium is both persistent and bioaccumulative. Levels are projected by the proponent to increase to (i) 0.2 µg/L (0.1 µg/L increase) in Barbie Creek at Q_{10} low flow (hardness of 626 to 868 mg/L), and (ii) 0.3 µg/L in Adit Creek at Q_{10} low flow after pit reclamation (hardness was not projected but is expected to be high). The proponent does not expect cadmium to increase in Florence Creek and has made no projections for Coreshack Creek.

7.4.12.2 Present Levels

All creeks in the Cinola project area (including Boucher Creek) had levels of both dissolved and total cadmium at or below the 0.2 µg/L detection limit with the following exceptions: (i) Adit Creek with 1 of 20 samples at 0.6 µg/L total cadmium and <0.2 µg/L dissolved cadmium (hardness 50 mg/L); (ii) Canoe Creek with 1 of 13 samples at 0.3 µg/L total cadmium and <0.2 µg/L dissolved cadmium (hardness not available); (iii) 2 of 13 samples from the upper Yakoun River and 1 of 20 samples from middle Yakoun River at from 0.4 to 0.5 µg/L total cadmium, and all samples <0.2 µg/L dissolved cadmium (hardness from 14 to 15 mg/L).

7.4.12.3 Ministry of Environment, Lands and Parks Objectives

CCREM aquatic life guidelines, based on hardness, are the following[10]:

- 0.2 µg/L maximum total cadmium for hardness 0 - 60 mg/L
- 0.8 µg/L maximum total cadmium for hardness 60 - 120 mg/L
- 1.3 µg/L maximum total cadmium for hardness 120 - 180 mg/L
- 1.8 µg/L maximum total cadmium for hardness >180 mg/L

The proposed objectives to protect aquatic life in both Cinola streams and the Yakoun River are a modification of these guidelines due to the persistent and bioaccumulative nature of cadmium. The objectives are:

(i) 0.2 µg/L maximum total cadmium for hardness 0 - 60 mg/L

(ii) 0.8 µg/L maximum total cadmium for hardness >60 mg/L

(iii) Should background levels exceed these objectives, then there should be no significant increase in cadmium. If monitoring shows an increase of more than 20% over background, then an increase in monitoring frequency would be required to show whether the change is statistically significant.

7.4.13 Lead

7.4.13.1 Rationale

Lead is both persistent and bioaccumulative. Lead levels are projected by the proponent to increase to 1 µg/L (0.5 µg/L increase) in Florence Creek at Q_2 low flow, and 1 µg/L in Adit Creek at Q_{10} after pit reclamation. The proponent does not expect lead to increase in Barbie Creek and has made no projections for Coreshack Creek.

7.4.13.2 Present Levels

All samples for both dissolved and total lead in streams and the Yakoun River have been less than the 1 µg/L detection limit, with one exception: one sample from Florence Creek had a concentration of 1 µg/L for both dissolved and total lead (corresponding hardness of 20 mg/L). Ministry of Environment 1987-1988 fish tissues were analysed at too high a detection limit for comparison with the human consumption alert level of 0.8 µg/g wet weight. Of Norecol's 1986-1987 data, only one rainbow trout sample at 1.3 µg/g exceeded this alert level. Mean tissue lead levels in fish collected by IEC Beak in 1980 consistently exceeded the 0.8 µg/g alert level in all species.

7.4.13.3 Ministry of Environment, Lands and Parks Objectives

British Columbia aquatic life criteria are based on hardness, and are as follows:

(i) when hardness is $\leq$8 mg/L, the maximum total lead is 3 µg/L;

(ii) when hardness is >8 mg/L:
the 30-day average is $\leq 3.31 + \exp(1.273 \ln(\text{average hardness}) - 4.705)$;

the maximum equals exp(1.273 ln(hardness) - 1.460) in µg/L total lead[12].

The British Columbia tissue alert level is 0.8 µg/g (wet weight) for the edible tissue of fish/shellfish for human consumption[12].

The proposed objectives for fresh waters in streams and the Yakoun River are a modification of these criteria: (i) 3 µg/L total lead maximum in water at any hardness due to the persistent and bioaccumulative nature of lead and elevated background fish tissue levels; and (ii) 0.8 µg/g (wet weight) maximum in fish tissue, or no significant increase (95% confidence level) over background if background is >0.8 µg/g. More monitoring of lead in fish tissue is needed to further define background levels before the Cinola project proceeds.

7.4.14 Nickel

7.4.14.1 Rationale

Levels are projected to increase to 13 µg/L (12 µg/L increase) in Barbie Creek at Q_{10} low flow after reclamation, and to 3 µg/L in Florence Creek at Q_2 low flow.

7.4.14.2 Present Levels

All sample concentrations from streams and the Yakoun River were less than the 2 µg/L detection limit for both dissolved and total nickel, except Adit Creek which had maximum levels of 7 and 3 µg/L, respectively.

7.4.14.3 Ministry of Environment, Lands and Parks Objectives

CCREM aquatic life guidelines are based on hardness as follows[10]:

25 µg/L nickel total maximum for hardness <60 mg/L
65 µg/L nickel total maximum for hardness 60 - 120 mg/L
110 µg/L nickel total maximum for hardness 120 - 180 mg/L
150 µg/L nickel total maximum for hardness >180 mg/L

The proposed provisional objective for both Cinola project streams and the Yakoun River is 25 μg/L maximum total nickel at any hardness. It is not expected that this objective concentration would ever be exceeded.

7.4.15 Chromium

7.4.15.1 Rationale

Chromium levels are projected by the proponent to increase to 1.5 μg/L (0.5 μg/L increase) in Barbie Creek at Q_{10} low flow, 1 μg/L (0.5 μg/L increase) in Florence Creek at Q_2 low flow, and 1 μg/L in Adit Creek at Q_{10} low flow after reclamation.

7.4.15.2 Present Levels

The proponent determined that all Cinola streams and the Yakoun River had levels ≤1 μg/L for both dissolved and total chromium except the following: (i) Adit Creek with one sample (n = 20) at 12.0 μg/L total and <1 μg/L dissolved chromium, (ii) upper Florence Creek to 3 μg/L total and 2 μg/L dissolved chromium, and (iii) Clay Creek with one sample (n = 13) at 4 and 3 μg/L total and dissolved chromium, respectively. Environment Canada used a high detection limit of 5 μg/L.

7.4.15.3 Ministry of Environment, Lands and Parks Objectives

CCREM aquatic life guidelines are 2 μg/L maximum total chromium for phytoplankton and zooplankton and 20 μg/L maximum for fish[(10)]. The proposed objectives for Cinola streams and the Yakoun River include: (i) a maximum of 2 μg/L total chromium, and (ii) if background exceeds this objective, then no significant increase (95% confidence level), with a 20% increase over background serving as an alert level.

7.4.16 Silver

7.4.16.1 Rationale

Silver levels are projected by the proponent to be at 0.1 µg/L (no increase on the assumed background of <0.2 ÷ 2 = 0.1 µg/L) in Barbie Creek at Q_{10} low flow after reclamation, and 0.3 µg/L (0.2 µg/L increase) in Florence Creek at Q_{10} low flow at closure.

7.4.16.2 Present Levels

Levels of both dissolved and total silver were less than the 0.2 µg/L detection limit at all sites (streams and the Yakoun River).

7.4.16.3 Ministry of Environment, Lands and Parks Objectives

The proposed objective for silver to protect aquatic life in Cinola streams and the Yakoun River is the CCREM aquatic life guideline of 0.1 µg/L maximum total silver[10]. The present minimum detectable concentration for silver of <0.2 µg/L would be acceptable in the monitoring data until the detection limit can be lowered, but the objective of 0.1 µg/L should be used for design and calculated concentrations.

7.4.17 Aluminum

7.4.17.1 Rationale

Background levels consistently exceed British Columbia dissolved aluminum criteria and the proponent projects increases above mean dissolved aluminum levels of the following: (i) Florence Creek at Q_2 low flow, from 0.27 to 0.30 mg/L; (ii) Barbie Creek at Q_{10} low flow, from 0.36 to 0.39 mg/L; and (iii) a reduction in Adit Creek, from 0.5 mg/L to between 0.3 and 0.43 mg/L. The major concern is the precipitation of aluminum hydroxide on fish gills as high pH discharges mix with high aluminum, low pH waters in natural streams.

7.4.17.2 Present Levels

Background levels in Cinola project area streams are summarized in the following table :

	n	Dissolved Aluminum	pH	Inorganic Monomeric Aluminum	pH
Coreshack Creek	9	0.1 - 0.32 mg/L	6.0-6.6	-	-
Adit Creek	20	0.19 - 1.30 mg/L	4.2-6.6	17.5 µg/L	6.75
Barbie Creek	50	0.20 - 0.70 mg/L	4.6-6.6	16.3 µg/L	5.70
Florence Creek	46	0.04 - 0.91 mg/L	5.2-7.2	7.5 µg/L	6.68
Canoe Creek	13	0.14 - 0.56 mg/L	4.7-6.7	-	-
Sid Creek	1	0.11 mg/L	6.4	-	-
Clay Creek	13	0.36 - 0.90 mg/L	4.2-5.8	-	-
Yakoun River	50	0.007 - 0.41 mg/L	5.9-7.5	-	-
Boucher Creek	6	0.23 - 0.50 mg/L	5.8-6.6	-	-

7.4.17.3 Ministry of Environment, Lands and Parks Objective

British Columbia aluminum criteria are in terms of dissolved aluminum and are the following (in mg/L):

(i) maximum: $pH \geq 6.5 = 0.1$

$pH < 6.5 = \exp[1.209 - 2.426(pH) + 0.286(pH)^2]$

(ii) 30-day average: $pH \geq 6.5 = 0.05$

$pH < 6.5 = \exp[1.6 - 3.327(\text{median pH}) + 0.402(\text{median pH})^2]$

These criteria are modified with detailed knowledge of the bioavailable forms of aluminum. Aluminum speciation is needed for all streams and the Yakoun River on a routine basis for baseline and operational monitoring.

Objectives for streams with potential pH shifts from mining activity (creeks including Barbie, Adit, Sid, Florence and the Yakoun River) should be the British

Columbia aluminum criteria in terms of biologically available aluminum, mostly inorganic monomeric aluminum. Until inorganic monomeric aluminum data are available on a routine basis, however, the proposed objective is that there be no significant increase in dissolved aluminum due to the waste discharges (as well as strict pH limitation; see pH objective). A 20% increase over background dissolved aluminum would serve as an alert level, with increased sampling to see whether the increase is significant at the 95% confidence level.

This no change objective level is due primarily to the preliminary aluminum speciation data. Justification is based on Pommen[15] and is as follows:

(i) The inorganic monomeric Al values in Barbie Creek were at (middle Barbie) or above (lower Barbie) British Columbia 30-day average criteria, and just under Ontario maximum criteria.

(ii) Barbie Creek pH was within the theoretical minimum Al solubility range of pH 5.6 to 6.2 at the time of Al speciation sampling. Stage II data show that lower Barbie was within this range about 50% of the time with 25% of samples both above and below this range. Upper Barbie Creek was almost always less than pH 5.6; middle Barbie pH should be somewhere between upper and lower Barbie values. The point to note is that Barbie Creek may be sensitive to pH change if it is already outside of the theoretical minimum aluminum solubility range of pH 5.6 to 6.2 when a change occurs.

(iii) Any pH change in Barbie Creek outside of the theoretical minimum solubility range of pH 5.6 to 6.2 may increase aluminum toxicity by increasing the inorganic monomeric component and cause British Columbia criteria to be exceeded without the addition of any additional aluminum from waste discharges.

(iv) Adit Creek and Florence Creek, the two other streams with Al speciation data, have lower inorganic monomeric levels with respect to the applicable criteria and are not as sensitive to pH change as Barbie Creek. However, they still could not tolerate pH changes of more than about ±0.5 units at any pH (and maybe less if pH change puts pH much outside of the 5.6 to 6.2

solubility minimum) without possibly increasing the levels of bioavailable aluminum with regards to the British Columbia criteria.

This aluminum objective needs to be confirmed by additional aluminum speciation data and sensitive, chronic salmonid bioassays.

7.4.18 Iron

7.4.18.1 Rationale

Background total and dissolved levels frequently exceeded the aquatic life and drinking water guideline (0.3 mg/L) and are projected by the proponent to increase in Barbie Creek by 0.1 to 0.46 mg/L on a mean background of 1.65 mg/L total iron. No increases are projected for Florence Creek, and a decline is projected in Adit Creek.

7.4.18.2 Present Levels:

Coreshack Creek	0.058 - 8.10 mg/L total iron
	0.25 - 1.16 mg/L dissolved iron
Adit Creek	0.91 - 41.0 mg/L total iron
	0.32 - 2.10 mg/L dissolved iron
Barbie Creek	0.53 - 11.3 mg/L total iron
	0.49 - 4.28 mg/L dissolved iron
Florence Creek	0.30 - 2.39 mg/L total iron
	0.11 - 1.18 mg/L dissolved iron
Canoe Creek	0.61 - 2.00 mg/L total iron
	0.58 - 1.50 mg/L dissolved iron
Sid Creek	0.28 mg/L total iron
	0.25 mg/L dissolved iron (n = 1)
Clay Creek	0.28 - 0.80 mg/L total iron
	0.25 - 0.75 mg/L dissolved iron
Yakoun River	0.11 - 1.03 mg/L total iron
	0.09 - 0.56 mg/L dissolved iron
Boucher Creek	0.38 - 0.70 mg/L total iron
	0.19 - 0.58 mg/L dissolved iron

7.4.18.3 Ministry of Environment, Lands and Parks Objectives

The CCREM aquatic life guideline and drinking water guideline are 0.3 mg/L maximum total iron(10,27). This is the proposed objective for Cinola streams and the Yakoun River, but with no significant increase in total iron at the 95% confidence level should background exceed the objective. A 20% increase over background would signal an alert level with more frequent sampling implemented to determine if the increase was in fact significant.

7.4.19 Sulphate

7.4.19.1 Rationale

Maximum levels projected by the proponent are 868 mg/L in lower Barbie Creek at Q_{10} low flow, and 280 mg/L in Florence Creek at Q_{10} low flow.

7.4.19.2 Present Levels

Sulphate levels for Florence and Barbie Creeks ranged from below the 1 mg/L detection limit to maximums of 6 and 13 mg/L, respectively. Adit Creek has the highest recorded level of sulphate, up to 53 mg/L (impacted by mine adit drainage). Sulphate levels in other areas were either below the detection limit or had maximum levels of the following: 5 mg/L Coreshack Creek, 1 mg/L Clay Creek, and 5 mg/L Yakoun River.

7.4.19.3 Ministry of Environment, Lands and Parks Objective

A provisional objective for sulphate of 100 mg/L maximum is proposed for Barbie Creek and its tributaries, Florence Creek, and the Yakoun River to protect aquatic life. The objective would be subject to the results of in situ algal bioassays and sensitive chronic bioassays with salmonids.

Although the toxicity data base for sulphate is weak, some studies indicate environmental impacts at fairly low levels and justify the objective. These studies include:

(i) Lethal/sublethal effects on eels and bass. While sulphate is generally considered innocuous to fish at concentrations above 1000 mg/L by a number of researchers, there are some studies which indicate that sulphate concentrations below 100 mg/L may be harmful to fish. For example, Boge et al.[21,22] showed changes in enzyme activity in the gills and digestive system of eels (*Anguilla anguilla*) exposed to 71 mg/L $S0_4$. Also, Hughes[23] determined 24-, 48-, 72-, and 96-h LC0's (no effect) of 500, 100, 100, and 100 mg/L $S0_4$, respectively, and 24-, 48-, 72- and 96-h LC50's of 2000, 1000, 500, and 250 mg/L, respectively, for striped bass (*Morone saxatilis*) larvae. Fingerlings were more tolerant with a 24-h LC0 of 2500 mg/L and a 24-h LC50 of 3500 mg/L $S0_4$.

Boge et al[24,25] performed similar enzyme activity tests on rainbow trout (*Oncorhynchus mykiss*) exposed to the same sulphate concentration (71 mg/L) as the eels, but no changes were noted at constant temperature or when combined with thermalshock.

It is also noted that neither of these species of eel or bass are found in the fresh or marine waters of the Queen Charlotte Islands. However, the existence of these data justify considering sulphate as toxic given the lethal and sublethal concentrations reported here.

(ii) Impact on macroinvertebrate communities. From the work on the Northair Gold Mine (Whistler), it was believed that sulphate levels of about 71 mg/L (average, range of 27.7 to 189 mg/L) caused prolific sulphur bacterial growth in Anomaly Creek resulting in significant changes to the macroinvertebrate community[26].

7.4.20 Arsenic

7.4.20.1 Rationale

The proponent projects a maximum increase of 0.010 mg/L total arsenic in Barbie Creek and 0.011 mg/L in Florence Creek at Q_{10} low flow.

7.4.20.2 Present Levels

Levels of arsenic in Barbie Creek have ranged from below the 0.001 mg/L detection limit to 0.047 and 0.017 mg/L for total and dissolved arsenic, respectively. Maximum total arsenic levels in other Cinola streams include 0.015 mg/L Coreshack Creek, 0.076 mg/L Adit Creek, 0.002 mg/L Florence Creek, 0.001 mg/L Canoe Creek, 0.002 mg/L Clay Creek, 0.001 mg/L Boucher Creek, and 0.003 mg/L Yakoun River.

7.4.20.3 Ministry of Environment, Lands and Parks Objective

The proposed objective for Cinola streams and the Yakoun River is the CCREM aquatic life guideline of 0.050 mg/L maximum total arsenic[10].

7.5 Variables For Objectives In Marine Waters

7.5.1 Yakoun River Estuary And Bay

7.5.1.1 Cyanide in Water

(a) Rationale

Levels of cyanide are projected by the proponent to increase to 1 µg/L in Florence Creek and therefore may increase in the Yakoun River estuary and bay.

(b) Present Levels

Norecol's 1987 water quality data from Yakoun Bay indicate total cyanide levels below the 1 µg/L detection limit in all samples from all depths.

(c) Ministry of Environment, Lands and Parks Objective

The proposed objective for the Yakoun River estuary and bay is the British Columbia marine aquatic life criterion of 1 µg/L maximum weak-acid dissociable cyanide to protect marine and estuarine aquatic life[6]. Strong-acid dissociable cyanide should also be monitored because of the potential for the production of toxic cyanide species by sunlight.

7.5.1.2 Mercury in Marine Biota

(a) Rationale

Mercury levels are projected by the proponent to increase in Barbie Creek with mining activities, and therefore may ultimately increase in the Yakoun River estuary and Yakoun Bay.

(b) Present Levels

Although Norecol's 1987 water quality data from Yakoun Bay had mercury levels below the 0.05 μg/L detection limit, levels are elevated in some fresh water creeks draining to the Bay as well as in some fish in fresh water. Some tissue in marine biota also had elevated levels, in particular the Dungeness crab and shrimp in the following summary of mercury in marine biota from Yakoun Bay (wet weights in μg/g):

	mean	range	SD	N
Dungeness crab (leg muscle)	0.08	0.026 - 0.16	0.03	52
shrimp (tail tissue)	0.14	0.03 - 0.49	0.15	15
mussels	0.03	0.01 - 0.04	0.01	8
clams	0.03	0.02 - 0.05	0.01	8

(c) Ministry of Environment, Lands and Parks Objectives

British Columbia tissue criteria are from 0.1 to 0.5 μg/g wet weight total mercury in the edible portion of fish and shellfish, to protect consumers whose diets are based primarily on fish and shellfish or who are average consumers, respectively[4]. The proposed provisional objectives for marine biota in the Yakoun River estuary and bay are the following:

(i) for mussels and clams, the criterion for heavy consumption of 0.1 µg/g maximum (wet weight). Although the data base is weak, levels have been less than this objective. Should further sampling to increase the data base reveal higher levels, the objective should be modified according to the baseline with the rationale as for Dungeness crab and shrimp as described in (ii);

(ii) for Dungeness crab and shrimp, small increases (25%) above the pre-mine development levels which already exceed the 0.1 µg/g criterion for heavy consumption. The proposed objectives are as follows:

Dungeness crab	0.10 µg/g average	0.20 µg/g maximum
shrimp	0.18 µg/g average	0.50 µg/g maximum

The objectives (i) and (ii) should be based on a minimum of 10 samples of each species. Monitoring of biota to increase the baseline should continue.

7.5.1.3 Lead in Marine Biota

(a) Rationale

Proponent projections are for increased lead in Florence and Adit Creeks, and therefore lead may ultimately increase in the Yakoun River estuary and bay.

(b) Background Level

The lead levels in marine biota from limited sampling of the Yakoun River estuary from 1979-1987 were below the British Columbia edible tissue alert level. Further baseline monitoring of lead in marine biota is needed.

(c) Ministry of Environment, Lands and Parks Objective

The British Columbia alert level for total lead in the edible portion of fish and shellfish for human consumption is 0.8 µg/g (wet weight)[12]. This is the proposed objective for the Yakoun River estuary and bay, sampled in Dungeness crab, mussels, and clams. Should further sampling for the purpose of establishing an adequate baseline determine levels exceeding this objective, then the objective is that there should be no significant increase in marine benthic tissue of Dungeness crab, mussels, and clams at the 95% confidence level.

7.5.1.4 Arsenic in Marine Biota

(a) Rationale

The proponent has projected increases of arsenic to Barbie Creek, and thus ultimately increases to the marine environments in the Yakoun River estuary and bay could occur. Arsenic tends to precipitate with iron at the freshwater-marine water interface, and thus estuarine sediments tend to be sinks for arsenic where it may be available for uptake by biota[32].

(b) Present Levels

The arsenic concentration in the leg muscle of Dungeness crab from the Yakoun River estuary has varied from 10 - 60 μg/g dry weight (mean of 27 μg/g, SD = 11 μg/g, n = 51). Dungeness crab has the best data base of the marine invertebrates sampled.

(c) Ministry of Environment, Lands and Parks Objective

Although there are no approved marine tissue criteria for arsenic in British Columbia to protect human consumers, arsenic levels in Dungeness crab from Yakoun Bay have frequently exceeded the Health and Welfare Canada guideline of 3.5 μg/g (wet weight) for processed fish used as a diet staple[29]. No objective is proposed for arsenic in marine tissue at this time, however, monitoring of Dungeness crab should continue to increase the baseline.

7.5.1.5 Cadmium in Marine Biota

Although tissue cadmium data from the Yakoun River estuary/Masset Inlet were generally at low levels, maximums of up to 4.26 μg/g dry weight were recorded in tissue from blue mussel (*Mytilus californianus*). Although there are no cadmium tissue criteria to put these levels into perspective, continued monitoring of blue mussel is recommended to further establish a baseline. Cadmium and other metals in the discharges from the Cinola mine would be expected to be reduced with the strict permit limits on mercury and lead.

7.5.2 Ferguson Bay

The following objectives are primarily designed to evaluate the impact of a spill with regards to marine aquatic life. Routine monitoring would be for PAHs in sediments and particulate matter variables (non-filterable residue and turbidity), with the other objectives monitored only should a spill occur.

7.5.2.1 Ammonia

(a) Rationale

Both ammonia and ammonium nitrate are unloaded at Ferguson Bay. Spills would result in impacts to aquatic life from ammonia, which is toxic.

(b) Ministry of Environment, Lands and Parks Objectives

British Columbia criteria for total ammonia-nitrogen to protect marine aquatic life are in terms of maximum and average concentrations as given in Tables 7.1 and 7.2, respectively[38]. Criteria limits are dependent on pH, temperature, and salinity. These criteria are the proposed objectives for Ferguson Bay.

7.5.2.2 pH

(a) Rationale

Changes in pH to the marine environment would occur with spills of reagents/bulk supplies including limestone, quicklime, sulphuric acid, and sodium hydroxide.

(b) Ministry of Environment, Lands and Parks Objective

British Columbia marine aquatic life criteria and the proposed provisional objective for Ferguson Bay is that pH stay within the range of 7.0 to 8.7[40].

7.5.2.3 Cyanide

(a) Rationale

Cyanide would be released to the marine environment with a spill of sodium cyanide.

(b) Ministry of Environment, Lands and Parks Objective

The British Columbia criterion to protect marine (and estuarine) aquatic life and the proposed provisional objective for Ferguson Bay is a maximum of 1 µg/L weak-acid dissociable cyanide (as CN)[6].

7.5.2.4 Sulphide

(a) Rationale

Sulphide would be released to the environment with a spill of sodium sulphide.

(b) Ministry of Environment, Lands and Parks Objective

The proposed sulphide objective for Ferguson Bay is the British Columbia working aquatic life criterion which is in terms of undissociated H_2S. The objective is that the maximum undissociated H_2S should not exceed 2 µg/L[33].

There are problems at this time with measurements to check this objective. The lab (Zenon) MDC is 500 µg/L (0.5 mg/L) due to the unstable nature of sulphide in solution. Once total sulphide is accurately determined, possibly best done with a field probe, the proportion of undissociated H2S is a function of ionic strength/conductivity, pH, and temperature (all need to be measured in the field) as detailed in Standard Methods[39]. For example, at the provincial average marine pH of 7.8 (n = 434, SD = 0.2, range 7.1 to 8.6)[40], temperature of 15° C, and full seawater conductivity (50 000 µmhos/cm), 13% of the total dissolved H_2S is undissociated. The resulting calculated concentrations of undissociated H_2S is compared to the 2 µg/L objective.

7.5.2.5 Copper

(a) Rationale

Copper to the marine environment would result from a spill of copper sulphate.

(b) Ministry of Environment, Lands and Parks Objectives

British Columbia marine aquatic life criteria for copper and the proposed objectives for Ferguson Bay are a 30-day average of ≤2 µg/L total copper and a maximum of 3 µg/L total copper(5).

7.5.2.6 Chlorine

(a) Rationale

Increased levels in the marine environment could result from a chlorine spill.

(b) Ministry of Environment, Lands and Parks Objective

British Columbia marine and estuarine aquatic life criteria are in terms of chlorine-produced oxidants, and include the following: (i) a 30-day average for continuous exposure of 3 µg/L. This is based on 5 samples in not less than 2 hours nor more than 30 days, and is the threshold of chronic toxicity; and (ii) a maximum for controlled intermittent exposure of 40 µg/L, not to exceed 2 hours in a 24 hour period, the threshold of acute toxicity(34). The proposed objective for Ferguson Bay is 40 µg/L maximum for chlorine-produced oxidants during the 2 hour period following a spill.

7.5.2.7 PAHs in Sediments

(a) Rationale

Fuel oil and diesel fuel unloaded at the Ferguson Bay docking facility could result in spills and an increase in hydrocarbons to the marine environment.

(b) Ministry of Environment, Lands and Parks Objectives

The objectives for PAHs (polycyclic aromatic hydrocarbons) developed for Burrard Inlet sediments are proposed for Ferguson Bay. The objectives are 0.1 of the apparent effects threshold for infauna (a 10:1 safety factor) as detailed in Reference 47. Sediment objectives are included for both low molecular weight and high molecular weight PAHs (LPAH/HPAH). They are as follows:

PAH	µg/g dry-weight maximum in sediment	
Total LPAH	**0.5**	
nahpthalene		0.2
acenaphthylene		0.06
acenaphthene		0.05
fluorene		0.05
phenanthrene		0.15
anthracene		0.1
Total HPAH	**1.2**	
fluoranthene		0.17
pyrene		0.26
benzo(a)anthracene		0.13
chrysene		0.14
benzo-fluoranthenes		0.32
benzo(a)pyrene		0.16
indeno (1,2,3-c,d) pyrene		0.06
debenzo (a,h) anthracene		0.06
benzo (g,h,i) perylene		0.07

7.5.2.8 Objectives for Particulate Matter

(a) Rationale

Levels of non-filterable residue and turbidity would increase due to land disturbances and effluent discharges.

(b) Ministry of Environment, Lands and Parks Objectives (as maximums)

(i) Non-filterable residue. British Columbia aquatic life criteria and the proposed provisional objectives for Ferguson Bay are that induced non-filterable residue should not exceed 10 mg/L (for background levels ≤100 mg/L).

(ii) Turbidity. British Columbia aquatic life criteria and the proposed provisional objectives for Ferguson Bay are that induced turbidity should not exceed 5 NTU when background turbidity is ≤50 NTU, nor should induced turbidity be more than 10% of background when background is >50 NTU[(7)].

8. MONITORING

A monitoring program will be designed at a later date by regulatory agencies. Many details will depend on final project design.

The baseline monitoring in place for freshwater, marine waters, and biological tissue should be continued. In addition, the following should occur:

(i) Yakoun River Site Q10 should be relocated upstream from Barbie Creek, rather than its current downstream location. Alternately, an additional site could be established upstream, with site Q10 remaining downstream.

(ii) Aluminum speciation should be included in routine sampling/analyses of both the Yakoun River and streams.

(iii) Mercury analyses for water should be routinely analysed at the 5 ng/L detection limit.

(iv) Cyanide analysis should be for both weak-acid dissociable and strong-acid dissociable forms.

(v) Oxygen should be included in the routine monitoring, both in water and intragravel.(the latter in salmonid spawning areas during spawning periods). Oxygen monitoring techniques should be standardized.

(vi) Techniques should also be standardized to monitor for the sedimentation objective in salmonid spawning areas. A suitable sampler is detailed in McNeil and Ahnell[41].

(vii) Periphyton sampling is required on a routine basis during the peak growing season.

(viii) Baseline data on selenium in biota and sediments need to be collected, and the potential for selenium discharge to the aquatic environment needs to be further evaluated.

(ix) A background data base should be established for variables specified for objectives in Ferguson Bay, including PAHs in sediments.

REFERENCES

1. Butcher, G.A. 1988. Water Quality Criteria for Aluminum. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

2. La Zerte, B. Ontario Ministry of the Environment. Memorandum to B. Nijman Re: Aluminum Speciation of Cinola Samples, March 10, 1989.

3. Hunter, R.A., K.R. Summers, and R.G. Davies. 1985. A Rating Scheme for British Columbia's Major Coastal Wetlands (Unpublished Report). Ministry of Environment, Victoria, B.C.

4. Nagpal, N.K. 1989. Water Quality Criteria for Mercury. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

5. Singleton, H.J. 1987. Water Quality Criteria for Copper. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

6. Singleton, H.J. 1986. Water Quality Criteria for Cyanide. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

7. Singleton, H.J. 1985. Water Quality Criteria for Particulate Matter. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

8. U.S. Environmental Protection Agency. 1986. Water Quality Criteria for Water 1986. Office of Water Regulations and Standards. Washington, D.C. 20460 EPA 440/5-86-001.

9. Nordin, R.N. and L.W. Pommen. 1986. Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia). Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

10. Canadian Council of Resource and Environment Ministers. Canadian Water Quality Guidelines. March 1987.

11. International Joint Commission, Great Lakes Science Advisory Board. 1987 Report of the Aquatics Ecosystem Objectives Committee.

12. Nagpal, N.K. 1987. Water Quality Criteria for Lead. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

13. Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

14. Swain, L.G. 1985. Personal Communication, Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

15. Pommen, L. Memorandum to B. Nijman Re: pH and Aluminum Objectives for Yakoun River Tributaries. Water Management Branch, Ministry of Environment, May 26, 1989. File WQU 64.150214.

16. Derksen, G. 1985. Yakoun River, Tributary Streams and Mamin River Data Report on Water Quality Samples Collected by the Environmental Protection Service November 1983 and February 1984. Regional Program Report No. 85-13. Department of the Environment, Environmental Protection Service.

17. Derksen, G. 1990. 1987 Cinola Project Baseline Studies. Regional Program Report No. 90-01. Environment Canada, Environment Protection.

18. Derksen, G. 1989. 1988 Cinola Project Baseline Studies. Regional Program Report No. 89-06. Environment Canada, Environmental Protection.

19. Derksen, G. 1989. Cinola Project Baseline Studies. (Draft). Environment Canada, Environmental Protection.

20. International Joint Commission. Report to the Great Lakes Science Advisory Board, Report of the Aquatic Ecosystem Objectives Committee, November 1981.

21. Boge, G., A. Rigal, and G. Peres. 1982a. Effects of the Sulphate Ions on some Enzymatic Activities in the Gut and the Gill of the Eel (Anguilla anguilla) During Thermal Stresses. Ann. Inst. Michel Pacha, Lab. Marit. Physiol., Vol. 13, pp. 12-19.

22. Boge, G., A. Rigal, and G. Peres. 1982b. Effects of the Sulphate Ion on some Enzymatic Activities in the Gut and the Gill of the Eel (Anguilla anguilla) in a Constant Temperature Culture. Inst. Michel Pacha, Lab. Marit. Physiol., Vol. 13, pp. 1-11.

23. Huges, J.S. 1973. Acute Toxicity of Thirty Chemicals to Striped Bass (Morone saxatilis). Western Proceedings, 53rd Annual Conference of the Western Assoc. of State Game and Fish Commissioners. Salt Lake City, Utah. July 10 - 13.

24. Boge, G., A. Rigal, and G. Peres. 1982c. Effects of Calcium Sulphate and Potassium Sulphate on Different Enzymatic Activities of Trout (Salmo gairdneri R.) after the Production of Thermal Shocks. CAH. LAB. HYDROBIOL. MONTEREAU., No. 14, pp. 13-16.

25. Boge, G., A. Rigal, and G. Peres. 1982d. Effect of Calcium Sulphate and Potassium Sulphate Upon Different Enzyme Activities in the Intestine of Trout (Salmo gairdneri R.) Maintained at Constant Temperature. CAH. LAB. HYDROBIOL. Montereau. No. 14, pp. 7.-11.

26. Spence, J.M.B. Waste Management Branch, Smithers. Personal Communication to B. Nijman, Water Management Branch, Victoria, British Columbia. December 12, 1989.

27. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality 1987. Supply and Services Canada, Ottawa, Ontario. 1987.

28. Cinola Gold Project, Studies of Mercury and Mercury Methylation. Agassiz North Associates, December 1988. In: Appendix I-5-1, Stage II Review Response to Government Comments, March 1989.

29. Canadian Food and Drug Directorate, Health Protection Branch. 1979. Food and Drug Regulations.

30. Singleton, H.J. British Columbia Ministry of the Environment. Memorandum to L.W. Pommen Re: Particulate Matter Objectives for the Yakoun River and Its Tributaries. March 17, 1989. Water Management Branch File WQU 64.040412.

31. Perrin, C.J. A Test of Nutrient Limitation in Streams Draining the Cinola Development, Queen Charlotte Islands. Limnotek Research and Development. December 1988 (Draft).

32. Langston, W.J. 1983. The Behaviour of Arsenic in Selected United Kingdom Estuaries. Can. J. Fish. Aquat. Sci. 40 (Suppl. 2): 143-150.

33. U.S. Environmental Protection Agency. 1976. Quality Criteria for Water July 1976. Washington, D.C.

34. Singleton, H.J. 1989. Ambient Water Quality Criteria for Chlorine. Resource Quality Section, Water Management Branch, Ministry of Environment.

35. Water Management Branch, Ministry of Environment, 1986. Principles for Preparing Water Quality Objectives in British Columbia.

36. City Resources (Canada) Limited, 1988. Cinola Gold Project Stage II Reports (Volumes I-VI).

37. Wayne Knapp, Department of Fisheries and Oceans, Personal Communication. January 17, 1989.

38. Nordin, R.N. 1990. Ambient Water Quality Criteria for Ammonia to Protect Marine Aquatic Life. Water Management Branch, Ministry of Environment.

39. Anon. 1985. Standard Methods for the Examination of Water and Wastewater. Prepared by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation. Sixteenth Edition.

40. McKean, C.J. and N.K. Nagpal. 1990. Water Quality Criteria For pH. Technical Appendix. Ministry of Environment, Water Quality Branch, Victoria B.C.

41. McNeil, W.J. and W.H. Ahnell. 1964. Success of Pink Salmon Spawning Relative to Size of Spawning Bed Materials. United States Fish and Wildlife Service. Special Scientific Report Fisheries No. 469. Washington, District. of Columbia. 15 pp.

42. McKean, C.J. 1984. Yakoun Lake fish tissue data, July 18, 1984 (unpublished). Ministry of Environment, Water Management Branch.

43. Davies, P.H. and J.P. Goettl Jr. 1977. Aquatic Life - Water Quality Recommendations for Heavy Metals and Other Inorganic Toxicants in Fresh Waters. Pages 8-36 In: Water pollution studies. Job Prog. Rep., Fed. Aid Proj. F-33-R-12, Colorado Division of Wildlife, Fort Collins, CO: 68 p.

44. Affleck, R.J. 1952. Zinc Poisoning in a Trout Hatchery. Australian Jour. of Marine and Freshwater Res. 3:142.

45. Dawson, G.W. 1974. The Chemical Toxicity of Elements. BNWL-1815. Battelle Northwest Laboratory, Richland, WA: 25 p.

46. Swain, L.G. 1990. Okanagan Area, Similkameen River SubBasin, Water Quality Assessment and Objectives. Technical Appendix, First Update. Resource Quality Section, Water Management Branch, British columbia Ministry of Environment.

47. Nijman, R. and L.G. Swain. 1990. Coquitlam-Pitt River Area, Burrard Inlet Water Quality Assessment and Objectives. Technical Appendix. Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment.

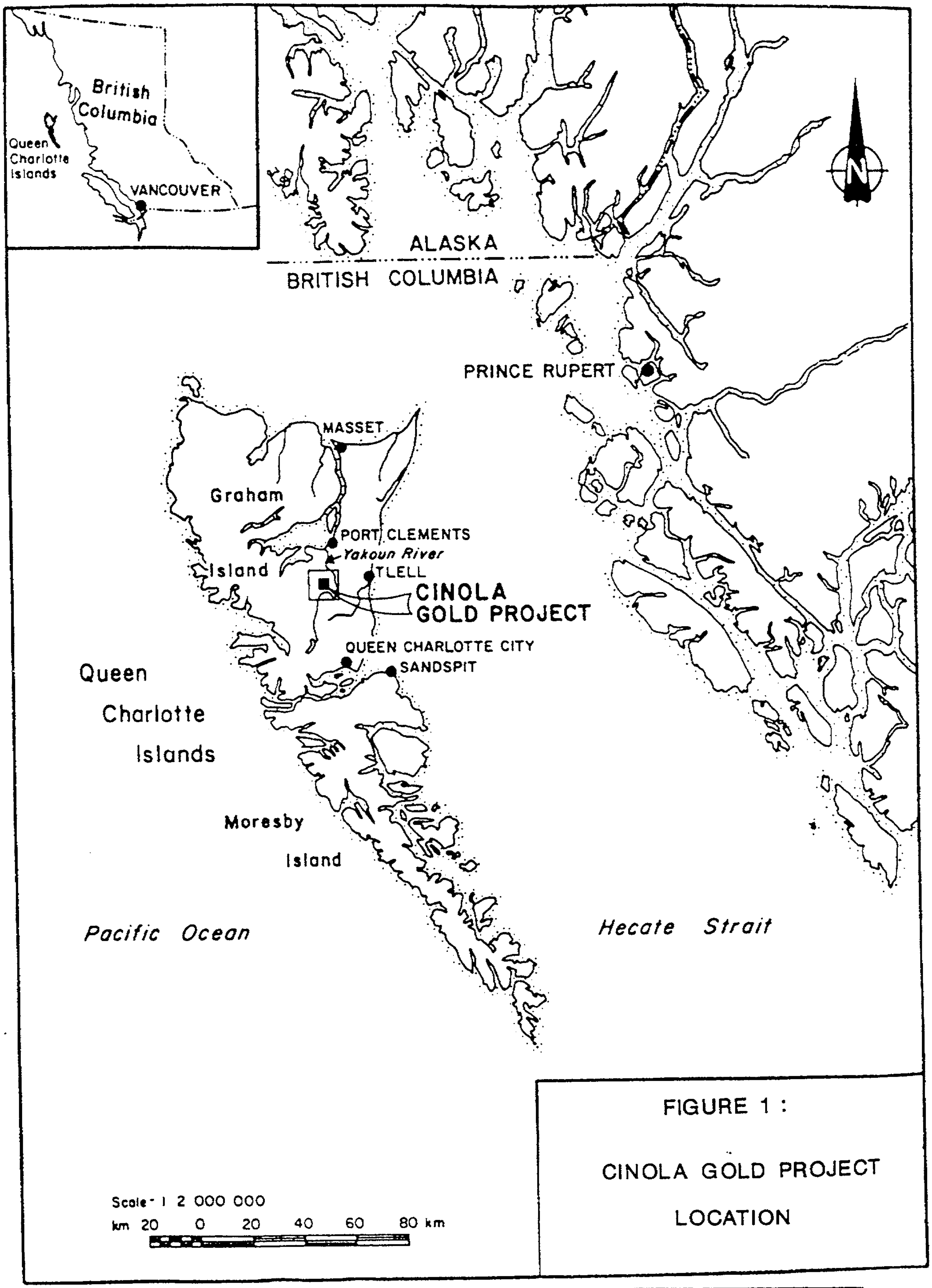


FIGURE 1 :

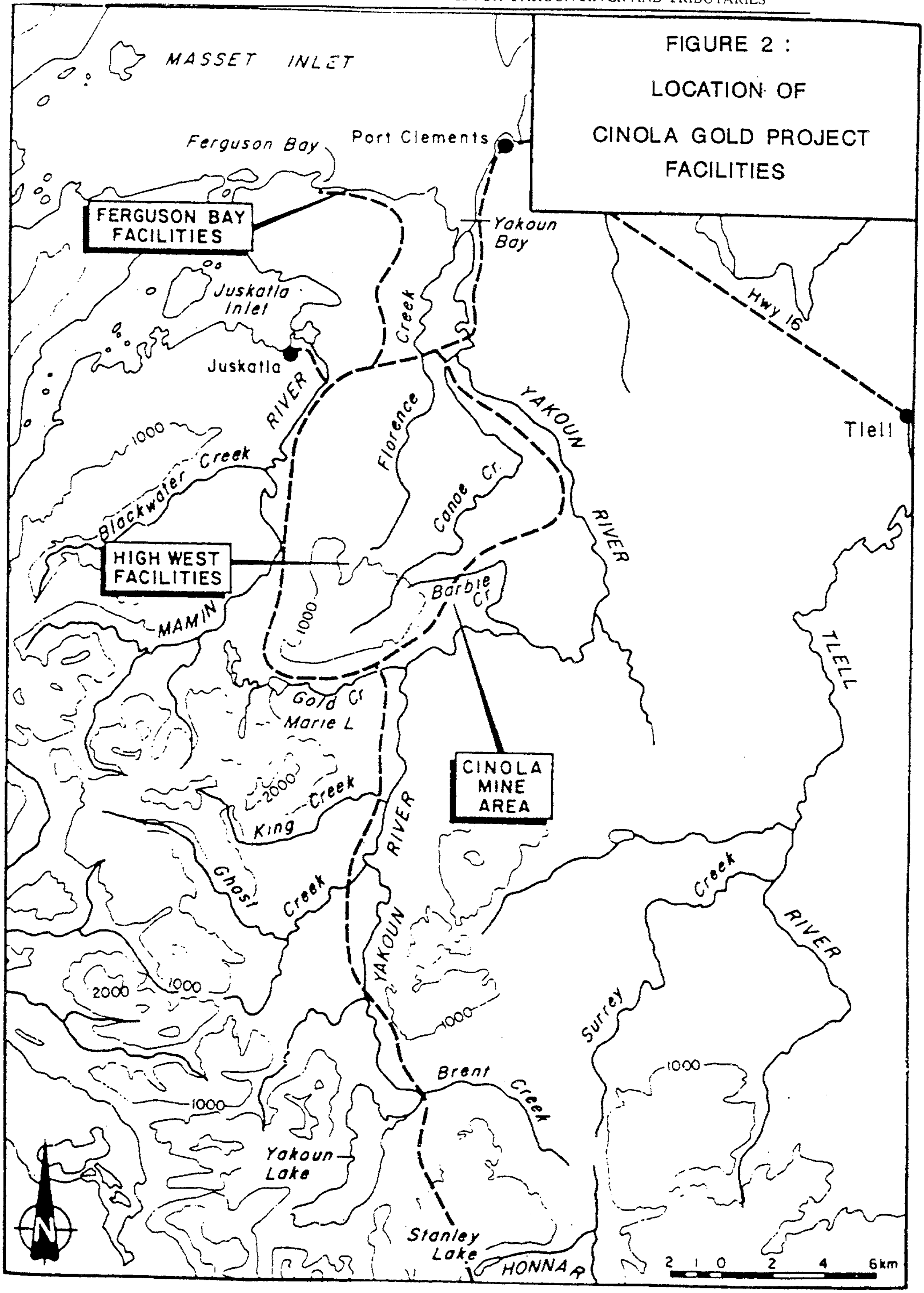
CINOLA GOLD PROJECT LOCATION

FIGURE 2 :

LOCATION OF

CINOLA GOLD PROJECT

FACILITIES



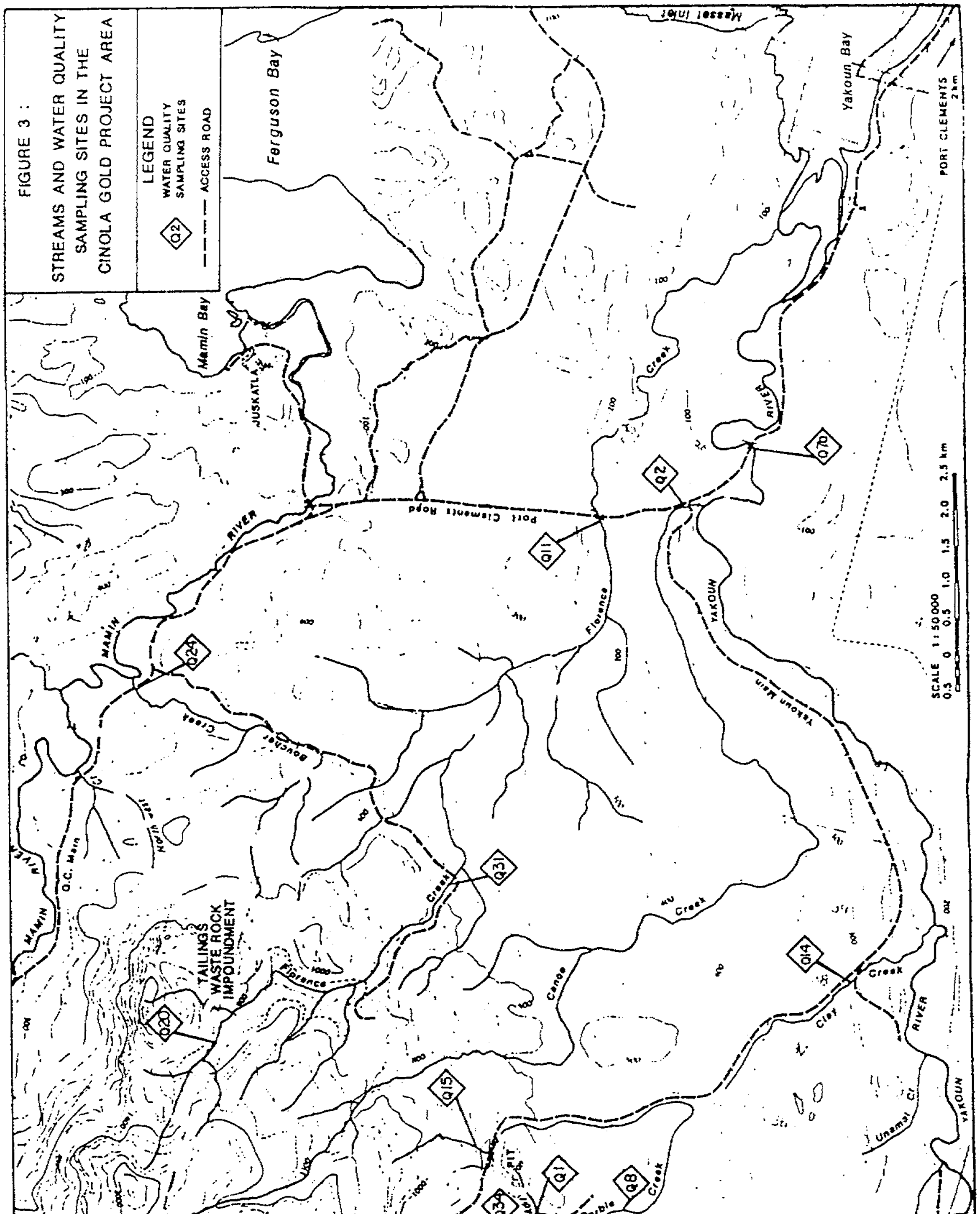


FIGURE 3: STREAMS AND WATER QUALITY SAMPLING SITES IN THE CINOLA GOLD PROJECT AREA

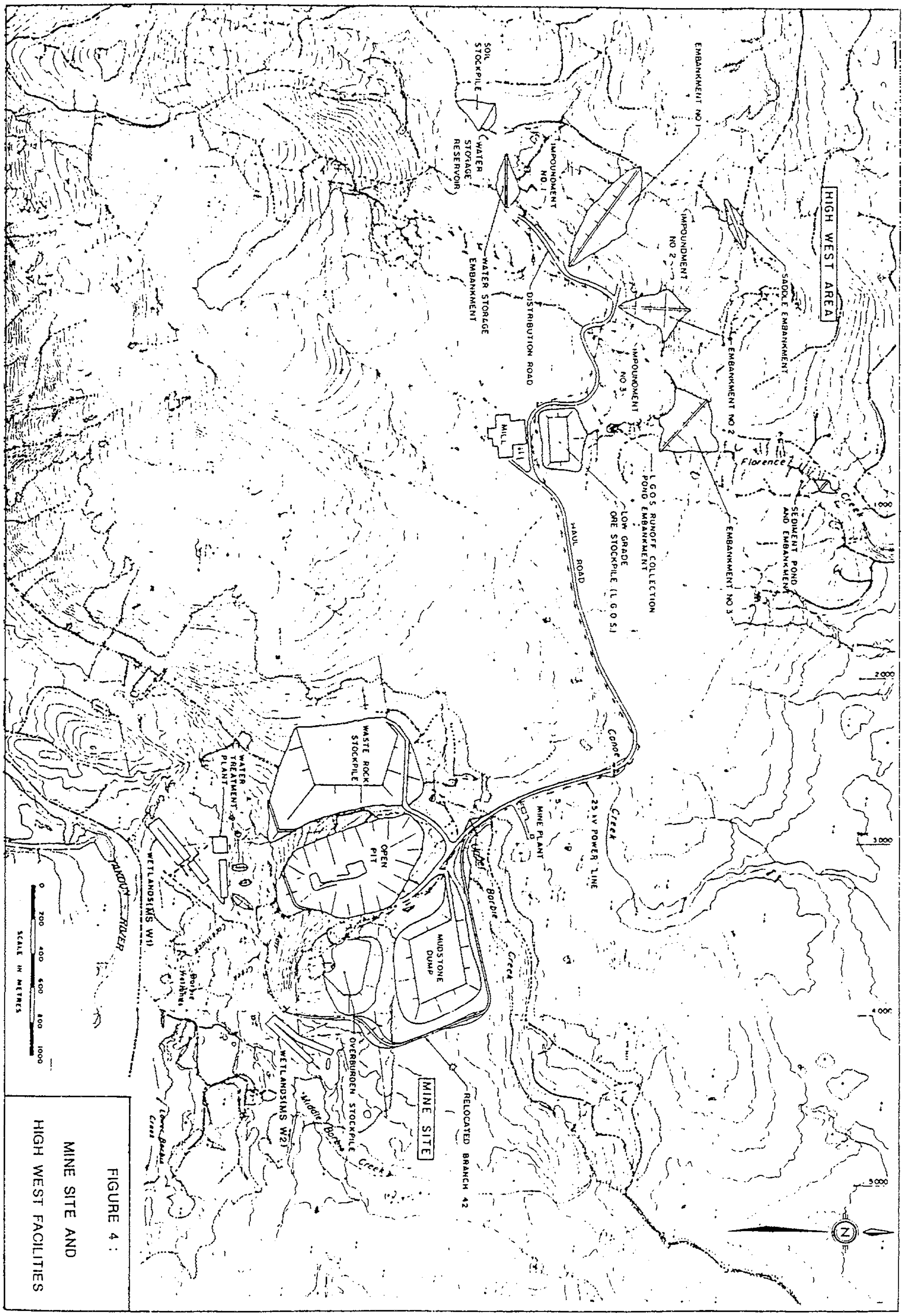


FIGURE 4 :
MINE SITE AND
HIGH WEST FACILITIES

Table 6.1.1
Water Quality Data, Coreshack Creek Site Q34
December 1987 - August 1988

Variable	n	Max	Min	Mean	SD
pH	9	6.6	6.0	6.3	0.2
Alkalinity, Total (mg $CaCO_3$/L)	9	8.0	2.0	4.2	2.1
Turbidity (NTU)	9	9.5	0.5	1.8	3.1
Conductance (umhos/cm)	9	47.0	35.0	41.7	4.2
Suspended Solids (mg/L)	9	32.0	<1.0	4.9	10.8
Hardness (mg $CaCO_3$/L)	9	12.0	6.0	9.3	2.1
Color, True (TCU)	9	170.0	37.0	74.1	41.5
Fluoride (mg/L)	9	<0.1	<0.1	0.1	0.0
Sulphate (mg/L)	9	5.0	1.0	3.7	1.4
Ammonia (mg N/L)	9	0.012	<0.005	0.006	0.003
Nitrate (mg N/L)	9	0.025	<0.005	0.008	0.007
Nitrite (mg N/L)	9	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	9	0.057	0.003	0.020	0.018
Dissolved (mg/L)	9	0.017	0.003	0.008	0.005
Cyanide, Total (mg/L)	9	<0.001	<0.001	0.001	0
Metals, Total (mg/L)					
Ag	9	<0.0002	<0.0002	0.0002	0
Al	9	0.78	0.13	0.29	0.21
As	9	0.015	<0.001	0.003	0.005
Cd	9	<0.0002	<0.0002	0.0002	0
Cr	9	<0.001	<0.001	0.001	0
Cu	9	0.0009	<0.0005	0.0005	0.0001
Fe	9	8.1	0.06	1.35	2.70
Hg (ug/L)	9	<0.05	<0.05	0.05	0
Mn	9	0.51	0.03	0.11	0.16
Ni	9	<0.002	<0.002	0.002	0
Pb	9	<0.001	<0.001	0.001	0
Se	9	<0.001	<0.001	0.001	0
Zn	9	0.0065	0.0014	0.0032	0.0019
Metals, Dissolved (mg/L)					
Ag	9	<0.0002	<0.0002	0.0002	0
Al	9	0.32	0.10	0.19	0.06
As	9	0.003	<0.001	0.001	0.001
Cd	9	<0.0002	<0.0002	0.0002	0
Cr	9	<0.001	<0.001	0.001	0
Cu	9	<0.0005	<0.0005	0.0005	0
Fe	9	1.16	0.25	0.45	0.30
Mn	9	0.16	0.03	0.06	0.04
Ni	9	<0.002	<0.002	0.002	0
Pb	9	<0.001	<0.001	0.001	0
Se	9	<0.001	<0.001	0.001	0
Zn	9	0.0036	0.0014	0.0024	0.0010

Sampled by Norecol

TABLE 6. 1. 2

AVERAGE 30-DAY CONCENTRATION OF AMMONIA FOR PROTECTION OF FRESHWATER AQUATIC LIFE (mg/L-N)

pH	Temperature (°C) 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.85
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in this Table.
- each measured value is compared to the corresponding individual values in this Table.
No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in this Table.

Table 6. 1. 3.

MAXIMUM CONCENTRATION OF AMMONIA NITROGEN FOR PROTECTION OF FRESHWATER AQUATIC LIFE (mg/L-N)

pH	Temperature (°C) 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

Table 6.1.4
CRITERIA FOR NITRITE-NITROGEN FOR PROTECTION OF FRESHWATER AQUATIC LIFE

Chloride Concentration (mg/L)	Maximum Nitrite Concentration (mg/L as N)	Average Nitrite Concentration* (mg/L as N)
less than 10	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
greater than 10	0.60	0.20

* the 30-d average chloride concentration should be used to determine the appropriate 30-d average nitrite criterion.

TABLE 6.1.5

Preliminary Aluminum Speciation Data, Cinola

				Aluminum Species (ug/L)					
Site	Rep.	pH	F-	Total	Reactive [1]	Unreactive [2]	Reactive Organic	Inorganic Monomeric [3]	30-Day Average B.C. Criterion [4]
Q1 Adit Ck.	1	6.74	69	257	54	203	36	18	50
	2	6.76	70	231	54	177	37	17	50
Q8 Middle Barbie Ck.	1	5.63	17	237	145	92	132	13	12
	2	5.64	16	251	145	106	134	11	12
Q4 Lower Barbie Ck.	1	5.75	17	234	121	113	99	22	14
	2	5.77	17	243	121	122	102	19	15
Q31 Middle Florence Ck.	1	6.67	14	219	67	152	60	7	50
	2	6.68	16	210	66	144	58	8	50

Sampled February 27, 1989; analyzed by Ontario Ministry of the Environment

1 reactive aluminum = organic + inorganic monomeric
2 total aluminum - reactive aluminum = unreactive aluminum (particulate, colloidal, polymeric + very resistent organic). A high percentage of unreactive aluminum is expected at these pH levels (majority of the aluminum in these samples).
3 inorganic monomeric aluminum is mostly aluminum hydroxide = reactive - reactive organic
4 B.C. criteria are in terms of dissolved aluminum

Table 6.2
Water Quality Data, Adit Creek Site Q1
November 1986 - August 1988

Variable	n	Max	Min	Mean	SD
pH	20	6.6	4.2	5.6	0.7
Alkalinity, Total (mg $CaCO_3$/L)	20	8.0	1.0	2.5	1.9
Turbidity (NTU)	20	23.0	1.5	7.3	6.0
Conductance (umhos/cm)	20	162.0	42.0	69.9	27.8
Suspended Solids (mg/L)	20	16.0	<1.0	4.6	4.7
Hardness (mg $CaCO_3$/L)	20	50.0	10.0	18.1	9.6
Color, True (TCU)	20	85.0	13.0	53.2	19.8
Fluoride (mg/L)	20	<0.10	<0.10	0.10	0
Sulphate (mg/L)	20	53.0	<1.0	14.8	11.6
Ammonia (mg N/L)	20	0.087	<0.005	0.026	0.021
Nitrate (mg N/L)	20	0.126	<0.005	0.019	0.031
Nitrite (mg N/L)	20	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	20	0.107	0.003	0.028	0.023
Dissolved (mg/L)	20	0.032	0.003	0.016	0.010
Cyanide, Total (mg/L)	20	<0.001	<0.001	0.001	0
Metals, Total (mg/L)					
Ag	20	<0.0002	<0.0002	0.0002	0
Al	20	1.70	0.29	0.74	0.44
As	20	0.076	0.001	0.009	0.017
Cd	20	0.0006	<0.0002	0.0002	0.0001
Cr	20	0.012	<0.001	0.002	0.003
Cu	20	0.0027	<0.0005	0.0011	0.0007
Fe	20	41.1	0.9	3.5	9.1
Hg (ug/L)	20	0.060	<0.050	0.051	0.003
Mn	20	1.180	0.005	0.442	0.279
Ni	20	0.007	<0.002	0.002	0.001
Pb	20	<0.001	<0.001	0.001	0
Se	20	<0.001	<0.001	0.001	0
Zn	20	0.050	0.003	0.011	0.012
Metals, Dissolved (mg/L)					
Ag	20	<0.0002	<0.0002	0.0002	0
Al	20	1.30	0.19	0.49	0.29
As	19	0.008	0.001	0.004	0.003
Cd	20	<0.0002	<0.0002	0.0002	0
Cr	20	<0.001	<0.001	0.001	0
Cu	20	0.0017	<0.0005	0.0008	0.0004
Fe	19	2.10	0.32	0.92	0.49
Mn	20	1.18	0.19	0.46	0.2
Ni	20	0.003	<0.002	0.002	0.001
Pb	20	<0.001	<0.001	0.001	0
Se	20	<0.001	<0.001	0.001	0
Zn	20	0.008	0.001	0.002	0.002

Sampled by Norecol

Table 6.3
Water Quality Data for Barbie Creek Sites Q15 (Upper), Q8 (Middle), and Q4 (Lower)

	Q15 Upper Barbie Ck.					Q8 Middle Barbie Ck.					Q4 Lower Barbie Ck.				
Variable	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD
pH	20	6.2	4.6	4.9	0.4	12	6.4	4.7	5.5	0.6	18	6.6	5.1	5.9	0.5
Alkalinity, Total (mg $CaCO_3$/L)	20	5.0	<1.0	1.3	0.9	12	8.0	<1.0	2.9	2.6	18	10.0	<1.0	3.9	2.7
Turbidity (NTU)	20	18.0	0.5	2.8	4.1	12	5.1	0.8	2.3	1.6	18	7.0	1.1	2.5	1.5
Conductance (umhos/cm)	20	70.0	35.0	48.8	8.1	12	69.0	44.0	55.2	7.9	18	67.0	40.0	49.6	7.0
Suspended Solids (mg/L)	20	16.0	<1.0	3.0	4.3	12	16.0	<1.0	3.8	4.9	18	8.0	<1.0	2.9	1.9
Hardness (mg $CaCO_3$/L)	20	31.0	7.0	11.9	6.0	12	18.0	8.0	12.8	3.0	18	21.0	8.0	12.0	3.5
Color, True (TCU)	20	453	84	194	92	12	354	140	231	62	18	395	114	219	83
Fluoride (mg/L)	20	<0.1	<0.1	0.1	0	7	<0.1	<0.1	0.1	0	18	<0.1	<0.1	0.1	0.1
Sulphate (mg/L)	20	13.0	<1.0	7.0	2.5	12	13.0	<1.0	4.4	4.3	18	7.0	<1.0	3.2	2.1
Ammonia (mg N/L)	20	0.057	<0.005	0.013	0.016	12	0.014	<0.005	0.007	0.002	18	0.042	<0.005	0.011	0.010
Nitrate (mg N/L)	20	0.042	<0.005	0.013	0.012	12	0.061	<0.005	0.015	0.019	18	0.112	<0.005	0.014	0.025
Nitrite (mg N/L)	20	0.004	<0.002	0.002	0.001	12	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	20	0.077	0.003	0.025	0.018	12	0.071	0.011	0.041	0.020	18	0.092	0.012	0.035	0.021
Dissolved (mg/L)	20	0.053	0.003	0.019	0.012	11	0.044	0.010	0.028	0.010	18	0.082	0.007	0.027	0.018
Cyanide, Total (mg/L)	20	<0.001	<0.001	0.001	0	12	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Metals, Total (mg/L)															
Ag	20	<0.0002	<0.0002	0.0002	0	12	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Al	20	0.89	0.20	0.56	0.20	12	2.2	0.4	0.7	0.6	18	0.70	0.3	0.5	0.1
As	20	0.047	<0.001	0.009	0.013	12	0.008	<0.001	0.003	0.003	18	0.014	<0.001	0.004	0.004
Cd	20	<0.0002	<0.0002	0.0002	0	12	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Cr	20	<0.001	<0.001	0.001	0	12	0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Cu	20	0.0011	<0.0005	0.0007	0.0002	12	0.0019	<0.0005	0.0009	0.0005	18	0.0018	<0.0005	0.0007	0.0004
Fe	20	11.3	0.5	2.3	2.8	12	4.0	0.7	1.7	1.2	18	5.8	0.6	2.4	1.4
Hg (ug/L)	20	0.15	<0.05	0.05	0.03	12	<0.05	<0.05	0.05	0	17	<0.05	<0.05	0.05	0
Mn	20	0.44	0.10	0.16	0.08	12	0.35	0.09	0.16	0.08	18	0.93	0.10	0.19	0.19
Ni	20	0.002	<0.002	0.002	0	12	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Pb	20	<0.001	<0.001	0.001	0	12	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Se	20	<0.001	<0.001	0.001	0	12	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Zn	20	0.0120	<0.0005	0.0055	0.0024	12	0.0110	<0.0005	0.0039	0.0029	18	0.0063	<0.0005	0.0031	0.0014
Metals, Dissolved (mg/L)															
Ag	20	<0.0002	<0.0002	0.0002	0	12	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Al	20	0.64	0.20	0.45	0.12	12	0.7	0.3	0.5	0.2	18	0.6	0.2	0.4	0.1
As	20	0.017	<0.001	0.005	0.005	12	0.004	<0.001	0.002	0.001	18	0.007	<0.001	0.002	0.002
Cd	20	<0.0002	<0.0002	0.0002	0	12	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Cr	20	<0.001	<0.001	0.001	0	12	0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Cu	20	0.0010	<0.0005	0.0006	0.0002	11	0.0017	<0.0005	0.0009	0.0004	18	0.0009	<0.0005	0.0006	0.0001
Fe	20	4.3	0.5	1.5	1.0	12	1.4	0.7	1.0	0.3	18	2.7	0.5	1.1	0.6
Mn	20	0.41	0.09	0.15	0.07	12	0.32	0.09	0.15	0.07	18	0.72	0.01	0.16	0.15
Ni	20	0.002	<0.002	0.002	0	12	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Pb	20	<0.001	<0.001	0.001	0	12	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Se	20	<0.001	<0.001	0.001	0	12	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Zn	20	0.0100	0.0005	0.0051	0.0023	11	0.0081	0.0019	0.0037	0.0020	17	0.0065	0.0005	0.0027	0.0014
Sampling dates:	November 1986 - August 1988					November 1986 - January 1988					March 1987 - August 1988				

Sampled by Norecol

Table 6.4
Water Quality Data for Florence Creek Sites Q20 (Upper), Q31 (Middle), and Q11 (Lower)

Variable	Q20 Upper Florence Ck.					Q31 Middle Florence Ck.					Q11 Lower Florence Ck.				
	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD
pH	11	7.1	6.2	6.7	0.3	17	7.2	5.6	6.6	0.2	18	6.6	5.2	6.0	0.4
Alkalinity, Total (mg $CaCO_3$/L)	11	21.0	5.0	11.5	5.2	17	14.0	2.0	7.5	3.6	18	10.0	0.7	3.7	2.7
Turbidity (NTU)	11	2.9	0.5	1.3	0.8	17	8.5	0.4	1.5	2.2	18	2.1	0.3	1.1	0.5
Conductance (umhos/cm)	11	62.0	35.0	45.7	8.9	17	50.0	31.0	38.5	5.4	18	50.0	4.4	30.5	14.0
Suspended Solids (mg/L)	11	1.0	<1.0	1.0	0	17	12.0	<1.0	2.1	3.2	18	2.0	<1.0	1.0	0.6
Hardness (mg $CaCO_3$/L)	11	20.0	10.0	14.5	3.7	17	14.0	4.0	9.8	2.5	18	12.0	1.2	6.7	3.4
Color, True (TCU)	11	922	74	191	255	17	248	78	141	54	18	335	44	196	92
Fluoride (mg/L)	11	<0.1	<0.1	0.1	0	15	<0.1	<0.1	0.1	0	18	0.1	<0.1	<0.1	0
Sulphate (mg/L)	11	<0.1	<1.0	1.0	0	17	<1.0	<1.0	1.0	0	18	6.0	<1.0	1.3	1.6
Ammonia (mg N/L)	11	0.026	<0.005	0.008	0.008	17	0.012	<0.005	0.007	0.003	18	0.019	<0.005	0.008	0.003
Nitrate (mg N/L)	11	0.020	<0.005	0.007	0.004	17	0.063	<0.005	0.011	0.015	18	0.035	<0.005	0.008	0.004
Nitrite (mg N/L)	11	<0.002	<0.002	0.002	0	17	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	11	0.053	0.009	0.027	0.013	17	0.053	0.005	0.027	0.012	18	0.037	0.005	0.021	0.011
Dissolved (mg/L)	11	0.033	0.006	0.020	0.009	17	0.035	0.005	0.019	0.009	18	0.032	0.003	0.017	0.010
Cyanide, Total (mg/L)	11	<0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Metals, Total (mg/L)															
Ag	11	<0.0002	<0.0002	0.0002	0	17	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Al	11	0.32	0.15	0.25	0.07	17	1.60	0.19	0.42	0.33	18	0.72	0.27	0.46	0.11
As	11	0.001	<0.001	0.001	0	17	0.002	<0.001	0.001	>0	18	0.001	<0.001	0.001	0
Cd	11	<0.0002	<0.0002	0.0002	0	17	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Cr	11	0.003	<0.001	0.001	0.001	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Cu	11	0.0018	<0.0005	0.0007	0.0004	17	0.0009	<0.0005	0.0006	0.0002	18	0.0010	<0.0005	0.0006	0.0002
Fe	11	1.50	0.33	0.66	0.44	17	1.12	0.30	0.58	0.29	18	1.61	0.54	1.02	0.50
Hg (ug/L)	11	<0.05	<0.05	0.05	0	17	<0.05	<0.05	0.05	0	18	<0.05	<0.05	0.05	0
Mn	11	0.28	0.04	0.08	0.08	17	0.04	0.01	0.02	0.01	18	0.110	0.017	0.041	0.014
Ni	11	<0.002	<0.002	0.002	0	17	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Pb	11	<0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Se	11	<0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Zn	11	0.0041	<0.0005	0.0010	0.0011	17	0.0039	0.0005	0.0010	0.0008	18	0.0400	<0.0005	0.0062	0.0124
Metals, Dissolved (mg/L)															
Ag	11	<0.0002	<0.0002	0.0002	0	17	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Al	11	0.32	0.13	0.21	0.07	17	0.91	0.16	0.33	0.18	18	0.49	0.04	0.31	0.16
As	11	<0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Cd	11	<0.0002	<0.0002	0.0002	0	17	<0.0002	<0.0002	0.0002	0	18	<0.0002	<0.0002	0.0002	0
Cr	11	0.002	<0.001	0.001	>0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Cu	11	0.0009	<0.0005	0.0006	0.0002	17	0.0008	<0.0005	0.0006	0.0001	17	0.0007	<0.0005	0.0004	0.0002
Fe	11	1.10	0.29	0.49	0.25	17	0.81	0.28	0.47	0.18	17	1.11	0.11	0.61	0.36
Mn	11	0.25	0.01	0.07	0.07	17	0.027	0.010	0.017	0.005	17	0.080	0.012	0.035	0.014
Ni	11	<0.002	<0.002	0.002	0	17	<0.002	<0.002	0.002	0	18	<0.002	<0.002	0.002	0
Pb	11	0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Se	11	<0.001	<0.001	0.001	0	17	<0.001	<0.001	0.001	0	18	<0.001	<0.001	0.001	0
Zn	10	0.0009	<0.0005	0.0006	0.0002	15	0.0011	<0.0005	0.0007	0.0002	17	0.0051	<0.0005	0.0012	0.0014
Sampling dates:	March 1987 - January 1988					February 1987 - August 1988					March 1987 - August 1988				

Sampled by Norecol

Table 6.5
Water Quality Data, Canoe Creek Site Q2
November 1986 - January 1988

Variable	n	Max	Min	Mean	SD
pH	13	6.7	4.7	5.3	0.7
Alkalinity, Total (mg $CaCO_3$/L)	13	6	<1	2	1.9
Turbidity (NTU)	13	2.1	0.7	1.4	0.5
Conductance (umhos/cm)	13	56	32	42	7
Suspended Solids (mg/L)	13	3	<1	1	1
Hardness (mg $CaCO_3$/L)	13	13	5	8	2
Color, True (TCU)	13	360	156	245	63
Fluoride (mg/L)	8	<0.1	<0.1	0.1	0
Sulphate (mg/L)	13	<1	<1	1	0
Ammonia (mg N/L)	13	0.016	<0.005	0.008	0.003
Nitrate (mg N/L)	13	0.034	<0.005	0.010	0.011
Nitrite (mg N/L)	13	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	13	0.064	0.007	0.030	0.016
Dissolved (mg/L)	13	0.042	0.010	0.026	0.011
Cyanide, Total (mg/L)	13	<0.001	<0.001	0.001	0
Metals, Total (mg/L)					
Ag	13	<0.0002	<0.0002	0.0002	0
Al	13	0.87	0.36	0.56	0.14
As	13	0.001	<0.001	0.001	0
Cd	13	0.0003	<0.0002	0.0002	>0
Cr	13	<0.001	<0.001	0.001	0
Cu	13	0.0014	<0.0005	0.0007	0.0003
Fe	13	2.00	0.61	1.13	0.47
Hg (ug/L)	13	<0.05	<0.05	0.05	0
Mn	13	0.07	0.03	0.05	0.01
Ni	13	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0
Zn	13	0.0018	<0.0005	0.0012	0.0004
Metals, Dissolved (mg/L)					
Ag	13	<0.0002	<0.0002	0.0002	0
Al	13	0.64	0.23	0.42	0.14
As	13	0.001	<0.001	0.001	0
Cd	13	<0.0002	<0.0002	0.0002	0
Cr	13	<0.001	<0.001	0.001	0
Cu	13	0.0014	<0.0005	0.0006	0.0002
Fe	13	1.50	0.58	0.85	0.28
Mn	13	0.06	0.021	0.05	0.01
Ni	13	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0
Zn	11	0.0017	0.0007	0.0012	0.0004

Sampled by Norecol

Table 6.6
Water Quality Data, Sid Creek Site Q35
January 1988

Variable	n	Max	Min	Mean	SD
pH	1	6.4			
Alkalinity, Total (mg $CaCO_3$/L)	1	3			
Turbidity (NTU)	1	0.5			
Conductance (umhos/cm)	1	45			
Suspended Solids (mg/L)	1	1			
Hardness (mg $CaCO_3$/L)	1	10			
Color, True (TCU)	1	52			
Fluoride (mg/L)	1	0.1			
Sulphate (mg/L)	1	1			
Ammonia (mg N/L)	1	0.005			
Nitrate (mg N/L)	1	0.012			
Nitrite (mg N/L)	1	0.002			
Phosphorus, Total (mg/L)	1	0.003			
Dissolved (mg/L)	1	0.003			
Cyanide, Total (mg/L)	1	0.001			
Metals, Total (mg/L)					
Ag	1	0.0002			
Al	1	0.13			
As	1	0.001			
Cd	1	0.0002			
Cr	1	0.001			
Cu	1	0.0005			
Fe	1	0.28			
Hg (ug/L)	1	0.05			
Mn	1	0.016			
Ni	1	0.002			
Pb	1	0.001			
Se	1	0.001			
Zn	1	0.0014			
Metals, Dissolved (mg/L)					
Ag	1	0.0002			
Al	1	0.11			
As	1	0.001			
Cd	1	0.0002			
Cr	1	0.001			
Cu	1	0.0005			
Fe	1	0.25			
Mn	1	0.012			
Ni	1	0.002			
Pb	1	0.001			
Se	1	0.001			
Zn	1	0.0007			

Sampled by Norecol

Table 6.7
Water Quality Data, Clay Creek Site Q14
November 1986 - January 1989

Variable	n	Max	Min	Mean	SD
pH	13	5.8	4.2	4.7	0.5
Alkalinity, Total (mg $CaCO_3$/L)	12	2	<1	1	0.3
Turbidity (NTU)	13	2.5	0.6	1.2	0.5
Conductance (umhos/cm)	13	74	46	56	7
Suspended Solids (mg/L)	13	2	<1	1	0
Hardness (mg $CaCO_3$/L)	13	5	12	8	2
Color, True (TCU)	13	483	188	307	94
Fluoride (mg/L)	13	<0.1	<0.1	0.1	0
Sulphate (mg/L)	13	<1	<1	1	0
Ammonia (mg N/L)	13	0.031	<0.005	0.011	0.007
Nitrate (mg N/L)	13	0.044	<0.005	0.013	0.012
Nitrite (mg N/L)	13	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	13	0.097	0.032	0.055	0.019
Dissolved (mg/L)	12	0.088	0.031	0.052	0.017
Cyanide, Total (mg/L)	13	<0.001	<0.001	0.001	0
Metals, Total (mg/L)					
Ag	13	<0.0002	<0.0002	0.0002	0
Al	13	1.00	0.46	0.70	0.18
As	13	0.002	<0.001	0.001	0
Cd	13	<0.0002	<0.0002	0.0002	0
Cr	13	0.004	<0.001	0.001	0
Cu	13	0.0019	<0.0005	0.0008	0.0005
Fe	13	1.43	0.45	0.80	0.28
Hg (ug/L)	13	<0.05	<0.05	0.05	0
Mn	13	0.06	0.024	0.04	0.01
Ni	13	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0
Zn	13	0.0079	<0.0005	0.0021	0.0019
Metals, Dissolved (mg/L)					
Ag	13	<0.0002	<0.0002	0.0002	0
Al	13	0.90	0.36	0.59	0.16
As	13	<0.001	<0.001	0.001	0
Cd	13	<0.0002	<0.0002	0.0002	0
Cr	13	0.003	<0.001	0.001	0
Cu	13	0.0014	<0.0005	0.0007	0.0003
Fe	13	1.26	0.44	0.75	0.25
Mn	13	0.06	0.021	0.04	0.01
Ni	13	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0
Zn	13	0.0025	<0.0005	0.0014	0.0006

Sampled by Norecol

Table 6.8
Water Quality Data for Yakoun River Sites Q16 (Upper), Q10 (Middle), and Q7A (Lower)

Variable	Q16 Upper Yakoun R.					Q10 Middle Yakoun R.					Q7A Lower Yakoun R.				
	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD	n	Max	Min	Mean	SD
pH	13	7.4	6.1	6.7	0.4	20	7.4	6.0	6.8	0.3	17	7.5	5.9	6.7	0.4
Alkalinity, Total (mg $CaCO_3$/L)	13	16.0	5.0	9.3	3.3	20	16.0	1.0	9.2	3.6	19	19.0	1.0	9.3	4.3
Turbidity (NTU)	13	4.9	0.5	1.6	1.5	20	3.6	0.4	1.4	1.0	19	3.2	0.4	1.3	0.7
Conductance (umhos/cm)	13	53.0	33.0	41.9	6.5	20	53.0	33.0	41.5	5.1	19	63.0	36.0	45.4	7.4
Suspended Solids (mg/L)	13	17.0	<1.0	3.1	5.2	20	9.0	<1.0	2.1	2.1	19	6.0	<1.0	1.9	1.6
Hardness (mg $CaCO_3$/L)	13	17.0	10.0	12.8	2.2	20	18.0	5.0	12.5	2.9	19	20.0	9.0	12.9	3.2
Color, True (TCU)	13	100	16	55	28	20	93	16	52	22	19	183	34	91	37
Fluoride (mg/L)	8	<0.1	<0.1	0.1	0	15	<0.1	<0.1	0.1	0	15	<0.1	<0.1	0.1	0
Sulphate (mg/L)	13	3.0	<1.0	1.4	0.7	20	2.0	<1.0	1.2	0.4	19	5.0	<1.0	1.4	1.1
Ammonia (mg N/L)	13	0.024	<0.005	0.008	0.006	20	0.032	<0.005	0.009	0.008	19	0.027	<0.005	0.008	0.005
Nitrate (mg N/L)	13	0.043	<0.005	0.021	0.013	20	0.057	<0.005	0.021	0.018	19	0.035	<0.005	0.014	0.010
Nitrite (mg N/L)	13	<0.002	<0.002	0.002	0	20	<0.002	<0.002	0.002	0	19	<0.002	<0.002	0.002	0
Phosphorus, Total (mg/L)	13	0.035	0.007	0.019	0.011	20	0.055	0.003	0.016	0.011	19	0.055	0.003	0.019	0.012
Dissolved (mg/L)	12	0.026	0.005	0.012	0.007	19	0.023	<0.003	0.009	0.006	19	0.035	0.003	0.012	0.009
Cyanide, Total (mg/L)	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Metals, Total (mg/L)															
Ag	13	<0.0002	<0.0002	0.0002	0	20	<0.0002	<0.0002	0.0002	0	19	<0.0002	<0.0002	0.0002	0
Al	13	0.85	0.04	0.30	0.26	20	0.80	0.04	0.22	0.20	19	0.60	0.07	0.30	0.18
As	13	0.001	<0.001	0.001	0	20	0.001	<0.001	0.001	0	19	0.003	<0.001	0.001	0.001
Cd	13	0.0004	<0.0002	0.0002	0.0001	20	0.0005	<0.0002	0.0002	0.0001	19	<0.0002	<0.0002	0.0002	0
Cr	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Cu	13	0.0014	<0.0005	0.0008	0.0003	20	0.0008	<0.0005	0.0006	0.0001	19	0.0010	<0.0005	0.0006	0.0001
Fe	13	1.03	0.11	0.33	0.29	20	0.67	0.11	0.29	0.15	19	0.94	0.27	0.46	0.16
Hg (ug/L)	13	<0.05	<0.05	0.05	0	20	<0.05	<0.05	0.05	0	19	<0.05	<0.05	0.05	0
Mn	13	0.210	0.017	0.054	0.060	20	0.050	0.010	0.026	0.011	19	0.070	0.017	0.033	0.013
Ni	13	0.002	<0.002	0.002	0	20	<0.002	<0.002	0.002	0	19	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Zn	13	0.0030	<0.0005	0.0010	0.0008	20	0.0040	0.0005	0.0012	0.0009	19	0.0018	<0.0005	0.0009	0.0004
Metals, Dissolved (mg/L)															
Ag	13	<0.0002	<0.0002	0.0002	0	20	<0.0002	<0.0002	0.0002	0	19	<0.0002	<0.0002	0.0002	0
Al	13	0.41	0.04	0.14	0.13	20	0.19	0.01	0.09	0.05	17	0.32	0.06	0.16	0.07
As	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	0.002	<0.001	0.001	0.00
Cd	13	<0.0002	<0.0002	0.0002	0	20	<0.0002	<0.0002	0.0002	0	19	<0.0002	<0.0002	0.0002	0
Cr	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Cu	13	0.0007	<0.0005	0.0006	0.0001	20	0.0008	<0.0005	0.0005	0.0001	19	0.0008	<0.0005	0.0005	0.0001
Fe	13	0.29	0.09	0.17	0.07	20	0.36	0.09	0.16	0.07	19	0.56	0.19	0.30	0.10
Mn	13	0.040	<0.001	0.015	0.010	20	0.040	0.008	0.018	0.010	19	0.040	0.013	0.026	0.008
Ni	13	<0.002	<0.002	0.002	0	20	<0.002	<0.002	0.002	0	19	<0.002	<0.002	0.002	0
Pb	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Se	13	<0.001	<0.001	0.001	0	20	<0.001	<0.001	0.001	0	19	<0.001	<0.001	0.001	0
Zn	12	0.0028	<0.0005	0.0008	0.0008	19	0.0018	<0.0005	0.0007	0.0003	17	0.0014	<0.0005	0.0007	0.0003
Sampling dates:	November 1986 - January 1988					November 1986 - August 1988					February 1987 - August 1988				

Sampled by Norecol

Table 6.9
Water Quality Data, Boucher Creek Site Q24
February 1987 - January 1988

Variable	n	Max	Min	Mean	SD
pH	6	6.6	5.8	6.0	0.3
Alkalinity, Total (mg $CaCO_3$/L)	6	6	1	3.2	2.1
Turbidity (NTU)	6	2.3	0.7	1.7	0.6
Conductance (umhos/cm)	6	36	32	34.9	2.0
Suspended Solids (mg/L)	6	2	<1	1.3	>0
Hardness (mg $CaCO_3$/L)	6	8	6	7.8	1
Color, True (TCU)	6	200	141	188	24
Fluoride (mg/L)	6	<0.1	<0.1	0.1	0
Sulphate (mg/L)	6	<1	<1	1	0
Ammonia (mg N/L)	6	0.022	<0.005	0.009	0.007
Nitrate (mg N/L)	6	0.014	<0.005	0.012	0.004
Nitrite (mg N/L)	6	0.002	0.002	0.002	0
Phosphorus, Total (mg/L)	6	0.048	0.015	0.034	0.014
Dissolved (mg/L)	6	0.032	0.012	0.024	0.009
Cyanide, Total (mg/L)	6	<0.001	<0.001	0.001	0
Metals, Total (mg/L)					
Ag	6	<0.0002	<0.0002	0.0002	0
Al	6	0.76	0.29	0.41	0.17
As	6	0.001	<0.001	0.001	0
Cd	6	<0.0002	<0.0002	0.0002	0
Cr	6	<0.001	<0.001	0.001	0
Cu	6	0.0030	<0.0005	0.0011	0.0010
Fe	6	1.44	0.43	0.70	0.38
Hg (ug/L)	6	<0.05	<0.05	0.05	0
Mn	6	0.17	0.033	0.056	0.05
Ni	6	<0.002	<0.002	0.002	0
Pb	6	<0.001	<0.001	0.001	0
Se	6	<0.001	<0.001	0.001	0
Zn	6	0.0042	0.0008	0.0016	0.0013
Metals, Dissolved (mg/L)					
Ag	6	<0.0002	<0.0002	0.0002	0
Al	6	0.50	0.23	0.31	0.10
As	6	<0.001	<0.001	0.001	0
Cd	6	<0.0002	<0.0002	0.0002	0
Cr	6	<0.001	<0.001	0.001	0
Cu	6	0.0012	<0.0005	0.0006	0.0003
Fe	6	0.92	0.39	0.58	0.19
Mn	6	0.13	0.027	0.052	0.04
Ni	6	<0.002	<0.002	0.002	0
Pb	6	<0.001	<0.001	0.001	0
Se	6	<0.001	<0.001	0.001	0
Zn	6	0.0016	0.0006	0.0010	0.0004

Sampled by Norecol

TABLE 6.10.1 Levels of Metals in Fish in the Yakoun and Mamin River Systems

Metal	Location	Agency/ Species	Ministry of Environment 1987-88 n	range	mean	Norecol 1986-87 n	range	mean	IEC BEAK 1980-82 n	range	mean
1. Muscle (i) Mercury (ug/g wet weight)	Yakoun R.	Coho				45	0.02 - 0.58	0.09	12	0.02 - 0.05	0.04
		Cutthroat	35	0.11 - 0.45	0.28	1	0.07		2	0.07 - 0.23	0.15
		Rainbow	5	0.11 - 0.39	0.23	35	0.02 - 0.36	0.07	9	0.06 - 0.13	0.10
		Dolly Varden	26	<0.05 - 0.28	0.11	15	0.02 - 0.16	0.13	4	0.03 - 0.22	0.11
	Barbie Ck.	Coho				18	0.07 - 0.38	0.16			
		Cutthroat							10	0.08 - 0.34	0.21
		Rainbow							2	0.04 - 0.14	0.09
		Dolly Varden				18	0.03 - 0.23	0.14	34	0.02 - 0.27	0.14
	Florence Ck.	Coho	3	0.08 - 0.10	0.09				16	0.10 - 0.24	0.15
		Cutthroat	4	0.08 - 0.12	0.10				10	0.11 - 0.23	0.17
		Dolly Varden	16	0.05 - 0.24	0.12				11	0.02 - 0.48	0.19
		Sculpin							19	0.15 - 2.20	0.63
	Canoe Ck.	Cutthroat							2	0.12 - 0.14	0.13
		Rainbow							1	0.08	
		Dolly Varden							3	0.11 - 0.23	0.16
	Gold Ck.	Rainbow							3	0.02 - 0.04	0.03
		Dolly Varden							3	0.02 - 0.30	0.13
	Mamin R.	Coho				30	0.03 - 0.33	0.09			
		Rainbow				10	0.02 - 0.11	0.07			
		Dolly Varden				10	0.02 - 0.15	0.05			
	Boucher Ck.	Coho				15	0.05 - 0.23	0.14			
		Cutthroat				2	0.14	0.14			
		Rainbow				1	0.07				
		Dolly Varden				13	0.09 - 0.34	0.05			
(ii) Copper (ug/g dry weight)	Yakoun R.	Coho				18	1.83 - 3.54	2.3			
		Cutthroat	35	1 - 11	2.5	1	3.94		2	3.22 - 3.74	3.48
		Rainbow	5	2 - 4	2.4	13	1.99 - 8.45	4.0			
		Dolly Varden	26	2 - 6	2.9	5	2.28 - 4.4	3.6			
	Barbie Ck.	Coho				3	2.57 - 3.11	2.76			
		Cutthroat							7	2.42 - 4.32	3.54
		Rainbow							1	3.85	
		Dolly Varden				3	1.99 - 3.21	2.62	17	2.19 - 17.82	4.81

...continued

Table 6.10.1 (continued)

Metal	Location	Agency/ Species	Ministry of Environment 1987-88 n	range	mean	Norecol 1986-87 n	range	mean	IEC BEAK 1980-82 n	range	mean
1. Muscle (ii) Copper (con't) (ug/g dry weight)	Florence Ck.	Coho	3	2 - 3	2.3						
		Cutthroat	4	2 - 3	2.5						
		Dolly Varden	16	2 - 4	3.3						
	Canoe Ck.	Cutthroat							2	3.86 - 5.47	4.66
		Rainbow							1	4.69	
		Dolly Varden							3	3.09 - 5.41	4.58
	Gold Ck.	Rainbow							3	2.22 - 7.46	4.08
		Dolly Varden							3	2.41 - 6.70	4.33
(iii)Lead (ug/g dry weight)	Yakoun R.	Coho				18	<1	<1			
		Cutthroat	35	<10	<10	1	2.28		2	7.15 - 21.51	14.33
		Rainbow	5	<10	<10	13	<1 - 6.27	1.38			
		Dolly Varden	26	<10	<10	5	<1	<1			
	Barbie Ck.	Coho				3	<1	<1			
		Cutthroat							7	<0.10 - 11.92	6.26
		Rainbow							1	0.77	
		Dolly Varden				3	<1	<1	17	0.10 - 12.63	2.90
	Florence Ck.	Coho	3	<10	<10	8	<1	<1			
		Cutthroat	4	<10	<10						
		Dolly Varden	16	<10	<10	4	<1	<1			
	Canoe Ck.	Cutthroat							2	8.31 - 10.61	9.40
		Rainbow							1	21.31	
		Dolly Varden							3	<0.22 - 0.50	0.35
	Gold Ck.	Rainbow							3	0.08 - 15.36	5.25
		Dolly Varden							3	0.25 - 7.84	4.26
(iv) Zinc (ug/g dry weight)	Yakoun R.	Coho				18	22.1 - 45.9	32.1			
		Cutthroat	35	18 - 54	30	1	24.9		2	28.5 - 34.9	31.7
		Rainbow	5	31 - 42	34	13	22.3 - 33.9	26.0			
		Dolly Varden	26	29 - 66	40	5	24.6 - 36.0	27.6			
	Barbie Ck.	Coho				3	28.6 - 39.0	34.2			
		Cutthroat							9	28.5 - 81.2	42.1
		Rainbow							1	45.6	
		Dolly Varden				3	27.3 - 28.8	28.2	17	26.0 - 284	83.2

Table 6.10.1 (continued)

Metal	Location	Agency/ Species	Ministry of Environment 1987-88 n	range	mean	Norecol 1986-87 n	range	mean	IEC BEAK 1980-82 n	range	mean
(iv) Zinc (con't) (ug/g dry weight)	Florence Ck.	Coho	3	66 - 84	76	8	23.1 - 43.3	30.7			
		Cutthroat	4	59 - 88	70						
		Dolly Varden	16	48 - 117	82	4	27.7 - 34.8	30.3			
	Canoe Ck.	Cutthroat							2	25.4 - 41.6	33.5
		Rainbow							1	57.1	
		Dolly Varden							3	60.5 - 81.0	67.7
	Gold Ck.	Rainbow							3	33.7 - 56.8	46.8
		Dolly Varden							3	35.9 - 94.6	56.7
2. Liver Mercury (ug/g wet weight)	Yakoun R.	Cutthroat	35	0.08 - 0.79	0.39						
		Rainbow	5	0.11 - 0.67	0.36						
		Dolly Varden	25	<0.05 - 0.56	0.14						
	Barbie Ck.	Dolly Varden							8	0.01 - 0.91	0.34
	Florence Ck.	Coho	1	0.18							
		Cutthroat	3	0.10 - 0.12	0.11						
		Dolly Varden	11	0.05 - 0.59	0.29				2	0.04 - 0.56	0.30
	Yakoun R. Drainage	Coho				14	0.05 - 0.45	0.20			
		Rainbow				8	0.03 - 0.18	0.08			
		Dolly Varden				6	0.10 - 0.23	0.16			
	Mamin R. Drainage	Coho				7	0.02 - 0.22	0.10			
		Rainbow				1	0.03				
		Dolly Varden				5	0.03 - 0.44	0.09			

Notes on additional muscle metals data (all dry weights):

1. Aluminum. There are Ministry of Environment data which were <5.0 ug/g for the Yakoun River (n=17, all species) but ranged from <5-9.1 ug/g in Florence Creek (n=23, all species).
2. Arsenic. Ministry of Environment data were mostly <0.1 ug/g (n=83, all species) except some Dolly Varden samples which were from 0.1 - 0.2 ug/g (n=6). Norecol data were all <0.1 ug/g (n=55, all species). IEC Beak data were generally below (various) detection limits (0.1 - 0.47 ug/g, all species) but up to 1.88 ug/g in Dolly Varden.
3. Cadmium. Ministry of Environment data were all <1 ug/g (n=89, all species). Norecol data were all <0.5 ug/g (n=55, all species). IEC Beak data were all near or below various detection limits (0.08 - 0.94 ug/g, all species).
4. Chromium. There are Ministry of Environment data <1 ug/g for the Yakoun River (n=66, all species), but from 2-4 ug/g for Florence Creek (n=23, all species).
5. Selenium. There are Ministry of Environment data for the Yakoun River that were at or below the 10 ug/L detection limit (n=66, all species), and for Florence Creek that ranged from <10 - 47 ug/g (n=23, all species, mean of 16.9 ug/g).

TABLE 6.10.2

Muscle Mercurey Levels in Junvenile Coho Salmon from Caged Hatchery Stock Compared to Feral Fish, 1988

Sampling Agency/ Sample Location	Mercury Concentration, Wet Weight, ug/g				
	n	Min.	Max.	Mean	SD
1. Environment Canada, Hatchery stock					
Pallant Hatchery Day O	8	0.052	0.065	0.057	0.004
Mid Barbie Creek Day 42	8	0.056	0.070	0.060	0.004
Lower Barbie Creek Day 42	8	0.053	0.071	0.066	0.005
Gold Creek Day 42	8	0.059	0.076	0.066	0.005
2. Norecol, Feral Fish					
Mid Barbie Creek: August, 1988	8	0.146	0.238	0.184	0.025
Lower Barbie Creek:					
August, 1988	8	0.145	0.260	0.193	0.036
September, 1988	8	0.123	0.241	0.171	0.034
Gold Creek: September, 1988	8	0.074	0.256	0.134	0.060

from Derksen (1990)[18]

TABLE 7.1
MAXIMUM CONCENTRATION OF TOTAL AMMONIA-NITROGEN FOR PROTECTION OF SALTWATER AQUATIC LIFE (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	270	191	131	92	62	44
7.2	175	121	83	58	40	27
7.4	110	77	52	35	25	17
7.6	69	48	33	23	16	11
7.8	44	31	21	15	10	7.1
8.0	27	19	13	9.4	6.4	4.6
8.2	18	12	8.5	5.8	4.2	2.9
8.4	11	7.9	5.4	3.7	2.7	1.9
8.6	7.3	5.0	3.5	2.5	1.8	1.3
8.8	4.6	3.3	2.3	1.7	1.2	0.92
9.0	2.9	2.1	1.5	1.1	0.85	0.67
	Salinity = 20 g/kg					
7.0	291	200	137	96	64	44
7.2	183	125	87	60	42	29
7.4	116	79	54	37	27	18
7.6	73	50	35	23	17	11
7.8	46	31	23	15	11	7.5
8.0	29	20	14	9.8	6.7	4.8
8.2	19	13	8.9	6.2	4.4	3.1
8.4	12	8.1	5.6	4.0	2.9	2.0
8.6	7.5	5.2	3.7	2.7	1.9	1.4
8.8	4.8	3.3	2.5	1.7	1.3	0.94
9.0	3.1	2.3	1.6	1.2	0.87	0.69
	Salinity = 30 g/kg					
7.0	312	208	148	102	71	48
7.2	196	135	94	64	44	31
7.4	125	85	58	40	27	19
7.6	79	54	27	25	21	12
7.8	50	33	23	16	11	7.9
8.0	31	21	15	10	7.3	5.0
8.2	20	14	9.6	6.7	4.6	3.3
8.4	12.7	8.7	6.0	4.2	2.9	2.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4
8.8	5.2	3.5	2.5	1.8	1.3	0.94
9.0	3.3	2.3	1.7	1.2	0.94	0.71

g/kg salinity is equivalent to parts per thousand (ppt or $^{0}/_{00}$)

Intermediate values of pH, temperature or salinity should be interpolated linearly. The freshwater criteria apply at salinities <10 g/kg (see Tables 6.1.2 and 6.1.3).

TABLE 7.2
AVERAGE 5 TO 30 DAY CONCENTRATION OF TOTAL AMMONIA-NITROGEN
FOR PROTECTION OF SALTWATER AQUATIC LIFE
(mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	41.	29.	20.	14.	9.4	6.6
7.2	26.	18.	12.	8.7	5.9	4.1
7.4	17.	12.	7.8	5.3	3.7	2.6
7.6	10.	7.2	5.0	3.4	2.4	1.7
7.8	6.6	4.7	3.1	2.2	1.5	1.1
8.0	4.1	2.9	2.0	1.40	0.97	0.69
8.2	2.7	1.8	1.3	0.87	0.62	0.44
8.4	1.7	1.2	0.81	0.56	0.41	0.29
8.6	1.1	0.75	0.53	0.37	0.27	0.20
8.8	0.69	0.50	0.34	0.25	0.18	0.14
9.0	0.44	0.31	0.23	0.17	0.13	0.10
	Salinity = 20 g/kg					
7.0	44.	30.	21.	14.	9.7	6.6
7.2	27.	19.	13.	9.0	6.2	4.4
7.4	18.	12.	8.1	5.6	4.1	2.7
7.6	11.	7.5	5.3	3.4	2.5	1.7
7.8	6.9	4.7	3.4	2.3	1.6	1.1
8.0	4.4	3.0	2.1	1.5	1.0	0.72
8.2	2.8	1.9	1.3	0.94	0.66	0.47
8.4	1.8	1.2	0.84	0.59	0.44	0.30
8.6	1.1	0.78	0.56	0.41	0.28	0.20
8.8	0.72	0.50	0.37	0.26	0.19	0.14
9.0	0.47	0.34	0.24	0.18	0.13	0.10
	Salinity = 30 g/kg					
7.0	47.	31.	22.	15.	11.	7.2
7.2	29.	20.	14.	9.7	6.6	4.7
7.4	19.	13.	8.7	5.9	4.1	2.9
7.6	12.	8.1	5.6	3.7	3.1	1.8
7.8	7.5	5.0	3.4	2.4	1.7	1.2
8.0	4.7	3.1	2.2	1.6	1.1	0.75
8.2	3.0	2.1	1.4	1.0	0.69	0.50
8.4	1.9	1.3	0.90	0.62	0.44	0.31
8.6	1.2	0.84	0.59	0.41	0.30	0.22
8.8	0.78	0.53	0.37	0.27	0.20	0.15
9.0	0.50	0.34	0.26	0.19	0.14	0.11

The criterion value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations. Intermediate values of pH, temperature or salinity should be interpolated linearly. The freshwater criteria apply at salinities <10 g/Kg (see Tables 6.1.2 and 6.1.3).