MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

OKANAGAN AREA
SIMILKAMEEN RIVER SUB-BASIN
WATER QUALITY ASSESSMENT
AND OBJECTIVES
TECHNICAL APPENDIX
FIRST UPDATE

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1.0 INTRODUCTION

1.1 BACKGROUND

The Ministry of Environment is preparing water quality assessments and objectives for priority waterbodies. This report provides an update of the water quality in the Similkameen River between Stemwinder Park and the International Boundary as well as an analysis of water quality in Hedley Creek (Figure 1). The main purpose of this review was to develop new provisional water quality objectives for the Similkameen River between Princeton and the International Boundary and Hedley Creek, due to considerable interest in several mining properties containing gold and silver downstream from Stemwinder Park. Objectives have existed for the Similkameen River since November 1985[(1)]; however, many of the characteristics which could be impacted by metal mining operations were not considered for inclusion at that time. Objectives were approved in February 1987[(5)] for Cahill and Red Top Gulch Creeks, tributaries to the Similkameen River just south from Hedley. A mine/mill complex has recently been constructed in the headwaters of these creeks.

The Ministry of Environment is developing criteria for water quality characteristics of concern in British Columbia. Until criteria for a characteristic have been approved by the Ministry, working criteria will be used. The criteria mentioned in this report are working criteria, unless noted as being provincial criteria.

The data reported in this report have been collected to about May 1988. Some of these are reported with mean values, but often as median values. The reason for this apparent inconsistency is that many data were collected over long time periods during which many detection limits may have existed. The author has used whichever statistic has more meaning. Median values are always reported for coliforms and pH.

1.2 PROVISIONAL WATER QUALITY OBJECTIVES - BASIC PHILOSOPHY

Water quality objectives are established in British Columbia for waterbodies on a site-specific basis. An objective can be a physical, chemical or biological characteristic for water, biota or sediment, which will protect the most sensitive designated water use at a specific location with an adequate degree of safety. The objectives are aimed at protecting the most sensitive designated water use with due regard to ambient water quality, aquatic life, waste discharges, and socio-economic factors(2).

Water quality objectives are based upon working water quality criteria which are characteristics of water, biota, or sediment that must not be exceeded to prevent specified detrimental effects from occurring to a water use(2). The working criteria upon which the proposed objectives are based come from the literature, and are referenced in the following chapters. The B.C. Ministry of Environment is in the process of developing official criteria for water quality characteristics throughout British Columbia, to form part of the basis for permanent objectives.

As a general rule, objectives are only set in water bodies where man-made influences threaten a designated water use, either now or in the future. Provisional objectives are proposed in this report, and are to be reviewed as more monitoring information becomes available and as the Ministry of Environment establishes water quality criteria.

The provisional objectives take into account the use of the water to be protected and the existing water quality. They allow for changes from background which the Ministry of Environment feels can be tolerated, or for upgrading which may be required. Any change from background which is allowed indicates that some waste assimilative capacity can be used while still maintaining a good margin of safety to protect designated water uses. In cases of water quality degradation, objectives will set a goal for corrective measures.

The objectives do not apply to initial dilution zones of effluents. These zones in rivers are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50 percent of the width of the river, from its bed to the surface.

In cases where there are many effluents discharged to the river, there could be some concern about the additive effect of initial dilution zones in which water quality objectives may be exceeded. Permits issued pursuant to the Waste Management Act control effluent quality which in turn determines the extent of initial dilution zones and the severity of conditions within them. In practice, small volume discharges or discharges with low levels of contaminants will require initial dilution zones much smaller than the maximum allowed. The concentrations of contaminants permitted in effluents are such that levels in the initial dilution zones will not be acutely toxic to aquatic life or create objectionable or nuisance conditions. 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 will be met at their border.

When dealing with limited data bases, natural variability can be noted, and comments made on whether extremes exceed published working water quality criteria. This doesn't necessarily mean that there is a problem since these extremes may occur naturally in the drainage in question or the material may not be bio-available. These are factors which must be understood before specific objectives can be finalized.

1.3 DESCRIPTION OF WATER BODIES

1.3.1 SIMILKAMEEN RIVER, STEMWINDER PARK TO INTERNATIONAL BOUNDARY

This section of the Similkameen River passes by the town of Hedley, Keremeos, and Cawston before crossing the International Boundary near Nighthawk (Figure 1). The main highway to the Okanagan Valley follows the river from Stemwinder Park to about Keremeos. The river within this section is generally surrounded by grassland, pasture, and woodlands, although a large number of orchards exist near Keremeos.

"A characteristic of all the tributaries to the Similkameen River, in the neighbourhood of Hedley, is the sudden steepening of the grades, shortly before entering the main valley"[(4)].

1.3.2 HEDLEY CREEK

Hedley Creek is a relatively undeveloped watershed. The Creek flows in a south-westerly direction, joining the Similkameen River at Hedley.

2.0 HYDROLOGY

Flow measurements have been made at Station 08NL038 on the Similkameen River near Stemwinder Park and Station 08NL050 on Hedley Creek at the mouth (Figure 2). Freshet on both water bodies occurs from April through September with peak flows in June[1]. Drainage areas at those two stations are 389 km^2 on Hedley Creek and 5 590 km^2 on the Similkameen River.

Seven-day average low flows from the Similkameen River at Stemwinder Park for individual years ranged from 3.11 m^3/s to 8.34 m^3/s for the period 1966 to 1985. From 1974 to 1985, seven-day low flows in Hedley Creek were from 0.076 m^3/s to 0.359 m^3/s. For two-and ten-year return periods, seven-day low flows were 0.176 m^3/s and 0.078 m^3/s respectively in Hedley Creek and 5.7 m^3/s and 3.16 m^3/s respectively in the Similkameen River.

3.0 WATER USES

Licenced water withdrawals along the Similkameen River and Hedley Creek are shown on Figure 14 of Reference 1, reproduced here as Figure 3. These figures have not been updated for this review since it is unlikely that significant changes have occurred which would influence designated water uses in either waterbody.

To summarize[1], there are 56 licenced withdrawals on the Similkameen from Stemwinder Park to the International Boundary, amounting to 12 052 dam^3 per year for irrigation, 36 m^3/d for domestic water, 341 m^3/d for industrial use, and 909 m^3/d for mining. On Hedley Creek there are three water licences with total use of 682 m^3/d for domestic water, 796 m^3/d for waterworks, 222 dam^3 per year for irrigation, and 4214 m^3/d for mining.

Fish species which occur in this section of the Similkameen River include rainbow trout, whitefish, prickly sculpin, longnose dace, bridgelip sucker, northern mountain sucker, peamouth chub, northern squawfish, crappie, and redside shiner[3]. Rainbow trout use the river section from Hedley to the International Boundary and the mouths of creeks as spawning areas[1]. In Hedley Creek, the greatest density of rainbow trout was found within 250 m of the mouth[3]. The greatest density of northern squawfish in the Similkameen River was found at the mouth of Hedley Creek[3].

Fishing for rainbow trout occurs throughout the Similkameen River, while fishing for whitefish occurs mainly during the winter from Stemwinder Park to the International Boundary[1].

Hedley Creek is not used for recreation, but the Similkameen River is used for swimming, canoeing, rafting, and kayaking[1].

Approved designated water uses for the Similkameen River are for drinking water, aquatic life, wildlife, recreation, livestock, and irrigation. Proposed designated water uses for Hedley Creek are for drinking water, aquatic life, wildlife, livestock and irrigation.

4.0 NON-POINT SOURCE DISCHARGES

4.1 AGRICULTURAL SOURCES

The 1981 Canada Census indicated that 90% of the livestock in the Similkameen sub-basin were cattle(1). The earlier assessment(1) of the impact of cattle on water quality had used information from the Ministry of Agriculture Beef Assurance Program. The estimates provided were considered to be low since not all cattle were listed with the Ministry in this voluntary program(1). As well, some ranchers from outside the sub-basin drive their cattle to within the sub-basin, and vice-versa.

The earlier estimated number of cattle was 3 250(1). This estimate has not been revised for this assessment since a significant difference in numbers is not expected over the short time difference. It had been estimated that these cattle would generate 14 300 kg of phosphorus and 142 300 kg of nitrogen(1). Based on a seven-day average low flow with a two-year return period of 5.7 m^3/s in the Similkameen River, these yearly contributions if released over varying time periods could increase concentrations in the river as follows:

Period of Release	Increase in Concentration (mg/L)	
	Phosphorus	Nitrogen
1 week	4.15	41.3
2 weeks	2.07	20.6
4 weeks	1.04	10.3

Such increases are unlikely since these estimates assume:

(1) That all wastes generated by the cattle enter the water through direct transport rather than partly through the groundwater system,

(2) That all wastes enter the river at one time as opposed to varying periods throughout the year, and

(3) That seven-day low flows would last for periods up to one month in duration.

No cattle were indicated as being in the Hedley Creek watershed.

No attempt was made earlier[(1)] to determine the influence of fertilizers on nutrient levels since sufficient detail did not exist to provide estimates. The only information available was that for the entire Similkameen sub-basin: 234 farms applied 1000 tonnes of fertilizer to 3 175 ha, of which 63% was cropland, 30% was tame hay, and 7% was improved pasture[(1)]. Any increase in concentrations in the Similkameen River due to fertilizer application would likely be generated through groundwater contributions rather than by overland flow.

Thirty-nine percent of the Similkameen sub-basin lies between Hedley and the International Boundary. However, this author estimates from visual observation that at least 50% of the sub-basin used for agriculture lies downstream from Hedley. If it is assumed that 50% of the 1000 tonnes of fertilizer applied to the entire Similkameen sub-basin is applied to that area downstream from Hedley, then 500 tonnes of fertilizer would be applied. Assuming a 20% content of both nitrogen and phosphorus, and a 25% over-application rate which enters the river through groundwater during the entire year, the contribution of nitrogen and phosphorus would be 68.5 kg/d of each from fertilizer. During low flow periods, this would amount to increases of 0.14 mg/L each of nitrogen and phosphorus. This is insignificant relative to the potential increases from cattle wastes.

4.2 FORESTRY

The most recent logging activity in the study area has occurred at two locations. At one location approximately three kilometres west from the confluence of McNulty Creek and Hedley Creek (Figure 2), limited selected logging has occurred.

The most significant logging has been associated with the re-development of the Nickel Plate Mine. It would influence Cahill Creek (Figure 2) and its tributaries to a greater degree than Hedley Creek although there likely has been some impact on Hedley Creek.

5.0 PERMITTED WASTE DISCHARGES

A number of operations discharging effluents under Waste Management permit have been discontinued since the earlier assessment[1]. These include: Hedley Improvement District landfill (PR-3000) located on an abandoned tailings pile (currently proposed for re-processing by Sumac Ventures) on the west side of Hedley Creek; a car wash (PE-5507) and laundromat (PE-352) operated by K and V Schevchenko in Keremeos; a fruit packing warehouse operated by the Okanagan-Similkameen Cooperative Growers Association (PE-2211) in Keremeos; and a fruit cold storage plant operated by Similkameen United Growers Cooperative Association (PE-4395) in Cawston. These operations and those which follow are indicated on Figure 3 by their waste management permit number.

5.1 BANBURY GOLD MINES (PE-6872)

This operation has a permit related to effluent generated from a heap leaching metal extraction process. The operation is located on the west side of the Similkameen River just north from Hedley. The operation was described in the earlier assessment[1]. Permit PE-6872 allows the discharge of an average 0.8 m^3/d (maximum of 150 m^3/d) to an impermeable evaporation basin about 200 m from the Similkameen River. There is to be no positive discharge to the environment.

The heap leaching process uses sodium hydroxide to control the alkalinity of the liquor and sodium cyanide to dissolve gold and silver. Small quantities of leachate liquor are discharged due to a build-up of contaminants, while the remaining discharge consists of rainfall washing through depleted ore reserves. This process has not operated except at pilot-scale capacity.

5.2 APEX-ALPINE RECREATIONS LTD. - APEX MOUNTAIN (PE-6017)

This ski resort, located about 35 km west from Penticton in the headwaters of Keremeos Creek, was described in the earlier assessment[1]. Aerated lagoons are used to treat domestic wastewater. Waste Management Permit PE-6017 allows the discharge of an average of 427 m^3/d (maximum of 636 m^3/d) of wastewater with maximum concentration of 65 mg/L BOD_5 and 60 mg/L suspended solids.

Recent monitoring results for this operation were as follows:

Date	Concentration (mg/L)	
	SS	BOD_5
87/01/21	26	14
87/04/02	25	25
88/02/17	13	< 10

These data indicate that the wastewater is receiving a high level of treatment. This fact, as well as the fact that the wastewater is discharged to an infiltration basin 245 m from Keremeos Creek, should result in no impact on Keremeos Creek or the Similkameen River.

5.3 CORPORATION OF THE VILLAGE OF KEREMEOS (PE-5928)

Keremeos has operated a tertiary treatment plant 300 m from the Similkameen River since late 1982. The plant is an activated sludge plant with effluent discharged to ground through a sand filter about 300 m from the river. Alum can be added to the effluent and contact time provided in tanks so that nutrient levels are reduced.

Waste Management Permit PE-5928 restricts the effluent to a maximum discharge of 270 m^3/d with maximum concentrations upstream from the sand filter of 45 mg/L BOD_5, 60 mg/L suspended solids, and 1.5 mg/L total phosphorus. Data collected between February 1985 and July 1988 indicate that the BOD_5 (90th percentile - 21 mg/L:n = 13) and suspended solids (90th percentile - 36 mg/L: n = 26) generally met the limit, but that total phosphorus values were greater than 1.5 mg/L on 19 of 27 occasions.

The maximum permitted discharge rate of 270 m^3/d would be diluted by a factor of 1824:1 at 7-day low flows of 5.7 m^3/s. If the maximum total phosphorus concentration recorded in the effluent (11.4 mg/L - July 1986) were discharged under these conditions, an increase of 0.006 mg/L could be expected. Coincident upstream (Site 0500692) and downstream (Site 0500693) measurements (n=13) of total phosphorus between March 1985 and March 1988 were as follows:

Total Phosphorus (mg/L-P)

Date	Upstream	Downstream	Date	Upstream	Downstream
85 03 21	0.006	0.005	87 05 13	0.13	0.105
86 03 11	0.016	0.017	87 06 17	0.006	0.007
86 07 29	0.006	0.006	87 07 22	<0.003	0.004
86 09 23	0.003	<0.003	87 09 22	0.004	0.004
86 11 12	<0.003	0.003	87 11 17	<0.003	<0.003
87 01 14	<0.003	<0.003	88 03 16	0.003	0.003
87 03 11	0.004	0.005			

Increased concentrations were measured on five occasions (86 03 11, 87 03 11, 86 11 12, 87 06 17, and 87 07 22) while decreases were measured on three occasions (85 03 21, 86 09 23, and 87 05 13). Using the total phosphorus values measured in the effluent and the "worst-case" dilution of 1824:1, the calculated increases in river concentrations compare to measured increases as follows:

Total Phosphorus (mg/L-P) Concentrations

Date	Effluent	Increase in River	
		Calculated	Measured
86 03 11	2.48	0.0014	0.001
86 11 12	3.28	0.0018	-
87 03 11	0.90	0.0005	0.001
87 06 17	No Value	-	0.001
87 07 22	0.819	0.0004	-

These data do not show conclusively that this facility is impacting the Similkameen River. It must be noted that only a small percentage of the total phosphorus in the effluent would be biologically available, and a large percentage would likely be removed by the sand filter and by movement of effluent through the ground.

Recent data for ammonia-nitrogen (n = 7 : Range - 0.016 to 0.081 mg/L) indicate that there would not be too much concern about its impact on the Similkameen River. Nitrate/nitrite values (n=9) ranged from 7.3 to 24.4 mg/L, and even with direct transport (no attenuation on soil) would increase by only 0.013 mg/L in the river.

The Corporation of the District of Keremeos has recognized that the plant is not operating as designed due to maintenance problems. These problems are to be corrected in the next few years.

5.4 BLUE HAVEN TENT AND TRAILER PARK (PE-6079)

This store/campground complex located eight kilometres north from Keremeos has been described earlier[1]. The wastewater discharge from the laundromat to a septic tank and seepage pit was not expected to affect water quality in Keremeos Creek. Permit PE-6079 was reviewed by Waste Management in September 1985, and no changes were deemed to be required. No recent monitoring data have been collected.

5.5 DANKOE MINES LTD. (PE-202)

This company operates a metal concentrator on an intermittent basis. The historical operation was described in the earlier assessment[1]. The capacity of the operation has been reduced from 40 t/d to 9 t/d.

High maximum values reported earlier[1] in the groundwater adjacent to this operation were 0.3 mg/L of dissolved lead, 0.22 mg/L of dissolved manganese, 0.28 mg/L of dissolved silver, and 213 mg/L of sulphate. In historical discharges to the tailings pond[1], maximum values of total arsenic (8.6 mg/L), cadmium (0.71 mg/L), chromium (2.62 mg/L), iron (11 000 mg/L), and molybdenum (11.8 mg/L) were at levels which would adversely affect groundwater and surface water quality.

5.6 CORONA CORPORATION NICKEL PLATE MINE PROJECT (PE-7613)

This project, located about 19 kilometres by road east from Hedley, has been described in detail in reference 5. The site has been mined extensively in the past, with tailings from previous operations being deposited near the Similkameen River and Hedley Creek (see Section 5.7). The present mill operation began in 1987. Seepage from the tailings pond and surface drainage water are the only discharges to the creeks tributary to the Similkameen River.

Provisional water quality objectives were established for nearby waterbodies as follows: for arsenic, cadmium, mercury, selenium, zinc, and sulphate since these could be released through oxidation of the orebody; aluminum, nitrate, nitrite, and ammonia which can be released from blasting compounds; cyanide and lead nitrate which are used in the mill; thiocyanate and cyanate which can be generated in the tailings impoundment or the treatment of mill effluents; molybdenum, copper, iron, and silver which can be released through the milling of the ore; and turbidity and suspended solids which can be increased due to activities associated with the mine.

Releases of compounds which might reach the Similkameen River are only expected to occur in the Spring of the year, otherwise most liquid effluents are to be recycled within the operation. The impact that these compounds will have will depend upon the success that the company has in capturing seepage flows from the tailings impoundment and minimizing runoff from the waste rock pile. The success of recycling supernatant, and the possibility of settling pond overflow entering Cahill or Red Top Gulch creeks, are also important factors.

5.7 CANDORADO MINES LTD. (AE-7894)

This company is proposing to re-process two tailings piles left by former gold operations near Hedley (Nickel Plate workings). One pile is located on the east bank of Hedley Creek at its confluence with the Similkameen River and the other about 500 m downstream on the north bank of the Similkameen River (Figure 4). In total, there are approximately 1 200 000 tonnes of tailings which are to be treated by use of a cyanide heap leach system[3]. "The "old" tailings pile, adjacent to Hedley Creek was deposited between 1904 and 1931 while the "new" tailings pile was deposited between 1935 and 1961"[3] (Figure 4).

The tailings from the old mining operations consist mainly of pyrite (FeS_2) and arsenopyrite (FeAsS) as well as lesser quantities of copper, cobalt, nickel, molybdenum, zinc, cadmium, and antimony[3]. Other metals at high concentrations in the tailings include aluminum, chromium, iron, and lead.

The leaching process (see Figure 4) will be carried out on tailings which have been processed using portland cement and water to create porous, spherical (6 to 50 mm) agglomerates. The leach area is as close as 100 m to the river at some spots. A cyanide solution will be sprayed over the agglomerates which will be piled on a double-lined leach pad. The cyanide solution will dissolve gold from the agglomerates and then be passed through activated coconut carbon from which the gold will be recovered. The cyanide solution will then be recycled.The gold will be eluted from the carbon by hot solutions of alcohol and sodium hydroxide with some cyanide. The metals will then be recovered electrolytically.

The company has indicated that there will be no positive discharge to the environment.

5.8 SUMAC VENTURES INC.

Sumac Ventures has proposed to re-process two tailings piles left by a former gold operation near Hedley[6]. The two piles are located on the east and west banks of Hedley Creek just north from Hedley (Figure 4). In total, about 621 400 tonnes of tailings mined by Hedley-Mascot Gold Mines Ltd. between 1936 and 1949 are to be treated by use of a cyanide heap leach system. The project is not expected to generate an effluent for discharge.

The operation is to be located on the west bank of Hedley Creek, occupying an area of about 19 000 m^2. Seven heaps are envisioned, each of three or four tiers between six to eight metres per tier, yielding a heap that might reach close to 20 m high eventually.

The proposal indicates that the heap leaching will occur over four or five years, for a period of seven to nine months per year. It is likely that the leaching operation will be similar to that described for the Candorado operation (Section 5.7). Gold and silver will be removed from the pregnant solution, this process to be carried out in two portable trailers.A bridge may be constructed across Hedley Creek to reduce the hauling distance between the two piles.

An initial analysis of the tailings indicated the presence of high concentrations of aluminum, arsenic, boron, barium, chromium, copper, iron, manganese, molybdenum, nickel, phosphorus, lead, strontium, titanium, vanadium, and zinc.

6.0 AMBIENT WATER QUALITY AND PROPOSED PROVISIONAL WATER QUALITY OBJECTIVES

6.1 HEDLEY CREEK

Proposed designated water uses for Hedley Creek are for aquatic life, wildlife, irrigation, livestock, and drinking water supplies.

Data have been collected on Hedley Creek at two sites (see Figure 2 or 4). The Ministry of Environment has collected data at Site 0500032 at the highway bridge between 1972 and 1982. These data were summarized earlier(1) and are reproduced here from that document as Table 1. Data have been collected approximately at this same location from 1986 to 1988 by Candorado Mines Ltd. The site was referenced as W-1, and was identified as being located just upstream from the highway bridge. These data are summarized in Table 2.

There are three tailings piles, runoff from which could affect the water quality of Hedley Creek. Water quality objectives which may be proposed related to these tailings piles would only apply if anthropogenic activity should disturb any of these piles in any manner. These piles were deposited decades ago, therefore those persons responsible for the deposition no longer hold rights to the piles. Erosion of the tailings by extreme flow events likely still occur, and it is likely that the proposed objectives may be exceeded on such occasions. Other objectives may be proposed which should apply immediately, since there are some activities (e.g., limited logging) where the proposed objectives would be pertinent.

6.1.1 pH AND ALKALINITY

Ministry of Environment measurements of pH at Site 0500032 ranged from 7.0 to 7.9 from 1973 to 1982 (Table 1). Data obtained by Candorado Mines in the period 1986 to 1988 had a wider range, from 5.96 to 8.17 (Table 2). Median values were 7.6 and 7.3, respectively.

Working water quality criteria for pH are that values should be within a range from 6.5 to 8.5 for drinking water(7) and 6.5 to 9.0 for the protection of freshwater aquatic life(7). Two of 12 values at Site W-1 were less than the lower criteria value of 6.5.

If the tailings piles are re-processed, as is planned, it is possible that alkaline solutions will be used to destroy cyanide. Although the companies do not expect that there will be any discharge from the operations, accidental spills or discharges may occur. For this reason, <u>a provisional water quality objective is proposed for pH of Hedley Creek.</u> The objective is that the pH, to protect drinking water supplies, <u>should be in the range of 6.5 to 8.5.</u> The objective applies along the length of Hedley Creek and its tributaries, except in the initial dilution zones of effluents. These excluded initial dilution zones extend up to 100 m downstream from a discharge point or in the case of the tailings piles, along their length, and extend up to 50% of the width of the creek, from the surface to the bottom.

In those situations where the pH in Hedley Creek above a discharge or series of discharges is outside the range of values described in the objective, <u>there should be no increase in pH values if upstream values exceed 8.5 pH units or decrease in pH values if upstream values are less than 6.5 pH units</u>, the increase or decrease being identified by differences in excess of 0.2 pH units.

Alkalinity values at Site W-1 ranged from 3.24 mg/L to 39.9 mg/L (Table 2) and from 9.8 mg/L to 49.5 mg/L at Site 0500032 (Table 1). The variability of these data sets was not significantly different (F-test: P = 0.05) and the mean values of 19.0 mg/L and 23.5 mg/L were statistically similar (student's t-test: P = 0.05). This indicates that there is no difference in alkalinity between the two data sets. These mean values indicate that Hedley Creek has a moderate sensitivity to acidic inputs[8].

6.1.2 HARDNESS AND METALS

The variability of total hardness between the pair of sites on Hedley Creek was significantly different (F-test: P = 0.05). The mean value of 19.4 mg/L at Site W-1 was the lower mean value in Hedley Creek for the two sites.

The toxicity of several metals increases with decreasing hardness. A mean hardness value of 20 mg/L and equations relating hardness to criteria were used to calculate appropriate water quality criteria for certain metals. This was deemed a good average value since if the one high hardness value of 69 mg/L was excluded from the data set, hardness values ranged from 8.9 to 33.6 mg/L. To protect freshwater aquatic life, the average total copper criterion should be ≤0.002 mg/L and the maximum total copper criterion 0.004 mg/L[9]; the average total lead criterion should be ≤0.004 mg/L and the maximum total lead criterion 0.044 mg/L[10].

6.1.2.1 Aluminum

Water quality criteria to protect freshwater aquatic life from adverse effects of aluminum are a 30-day average dissolved aluminum ≤0.05 mg/L and a maximum = 0.1 mg/L[11] at pH >6.5.

Five of 11 dissolved aluminum values at Site W-1 (Table 2) exceeded the criterion of 0.05 mg/L for an average value to protect aquatic life. Only 1 of 11 values (0.11 mg/L) exceeded the criterion for maximum dissolved aluminum to protect aquatic life.

An analysis of the two tailings piles to be re-processed by Candorado Mines indicated aluminum concentrations of 1.07% and 1.39%(3). It is likely that the two tailings piles located further upstream on Hedley Creek have a similar aluminum content. Dissolved aluminum concentrations in groundwater near the tailings piles were as high as 0.25 mg/L(3).

Since the aluminum in the tailings piles may become mobilized when the tailings piles are disturbed, a provisional water quality objective is proposed for dissolved aluminum in Hedley Creek. The objective is that the maximum concentration should not exceed 0.10 mg/L and the average concentration should not exceed 0.05 mg/L. The objective applies outside the initial dilution zones, described in Section 6.1.1. The average is to be calculated from a minimum of five weekly samples collected in a 30-day period.

Since values at Site W-1 can exceed the proposed objective on some occasions, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.05 mg/L average or 0.1 mg/L maximum, there should be no significant increase in mean or maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum or average background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site.

However, 20% is statistically conservative since a significant increase at the 95% confidence level using five samples with the F-test and Student's "t" test would be at least 80% going from upstream to downstream (see Appendix).

6.1.2.2 Chromium

Working water quality criteria for total chromium are 0.020 mg/L as a maximum to protect freshwater fish and 0.002 mg/L maximum to protect phytoplankton and zooplankton[7]. The criterion of 0.020 mg/L was exceeded by 1 of 11 total chromium values measured at Site W-1 (Table 2). All other values were below varying detection limits which were higher than the criterion of 0.002 mg/L, so that potential impacts of chromium on phytoplankton and zooplankton could not be determined. Chromium levels in the tailings piles were from 13 to 24 ppm, but dissolved chromium could not be detected (≤0.005 mg/L) in groundwater near the tailings piles[3].

Since the chromium in the tailings piles may become mobilized when the tailings are disturbed, a provisional water quality objective is proposed for total chromium in Hedley Creek. The objective is that the maximum concentration should not exceed 0.02 mg/L and the 30-day average should not exceed 0.002 mg/L. The objective applies along the length of Hedley Creek, except in initial dilution zones of effluents described in Section 6.1.1.

Since values at Site W-1 can exceed the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.02 mg/L maximum or 0.002 mg/L average, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.3 Copper

Water quality criteria to protect freshwater aquatic life from total copper were calculated earlier to be ≤0.002 mg/L as an average value and 0.004 mg/L as a maximum value. Four of 8 detectable total copper values exceeded both criteria at Site W-1 (Table 2), with values as high as 0.018 mg/L. These higher values occurred between May and July, when flows in Hedley Creek would have been high (Section 2.0) and tailings may have been scoured.

Analyses of the two tailings piles to be re-processed by Candorado Mines revealed copper concentrations of 277 and 297 ppm[3]. It is likely that the two tailings piles located further upstream on Hedley Creek have a similar copper content. Dissolved copper concentrations in groundwater near the tailings piles were 0.085 mg/L[3].

Due to the presence of copper in the tailings piles which may become mobilized when the tailings piles are disturbed, a provisional water quality objective is proposed for total copper in Hedley Creek. The objective is that the total copper should not exceed (0.094 (hardness) +2)µg/L and the 30-day average copper concentration should not exceed 0.04 (hardness) µg/L if hardness is >50 mg/L or 2 µg/L if hardness is ≤50 mg/L. The average is to be calculated from five weekly samples collected in a 30-day period. The objectives apply outside the initial dilution zones of effluents, described in Section 6.1.1.

Since values at Site W-1 can exceed the proposed objective on some occasions, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.002 mg/L average or 0.004 mg/L maximum, there should be no significant increase in mean or maximum values measured downstream from the piles. To compare values, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum or average background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.4 Iron

Total and dissolved iron concentrations at Site W-1 were all less than the working water quality criteria of 0.3 mg/L to protect aquatic life[7] and for aesthetics of drinking water supplies[12]. At Site 0500032, 1 of 3 total iron values exceeded the criteria (Table 1). Values measured in the groundwater near the tailings piles were less than these criteria. However, high iron contents of 3.49% and 4.23% were measured in the tailings piles[3]. Since iron may be mobilized when the tailings piles are disturbed, a provisional water quality objective is proposed for total iron in Hedley Creek. The objective is that the maximum total iron concentration should not exceed 0.3 mg/L. The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1.

Since one value at Site 0500032 exceeded the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.3 mg/L maximum, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.5 Lead

Criteria to protect freshwater aquatic life from lead are ≤0.004 mg/L as an average and 0.044 mg/L as a maximum, as derived earlier in this Section. All values at Site 0500032 (Table 1) and W-1 (Table 2) met the criterion for the maximum value; however, out of the two data sets, 1 of 17 dissolved values and 1 of 10 total values exceeded slightly the criterion for the average of ≤0.004 mg/L. Dissolved lead values as high as 0.63 mg/L were measured in groundwater near the tailings piles[3]. As well, the lead content of the tailings piles was measured as 16 and 18 ppm. Due to the potential for lead to enter Hedley Creek if the tailings piles are disturbed, a provisional water quality objective is proposed for total lead. The objective is that the average value should not exceed 3.31 + exp (1.273 ln (average hardness) - 4.705 µg/L and the maximum should not exceed 3 µg/L when the hardness is ≤8 mg/L or exp (1.273 ln (hardness)-1.460) µg/L if hardness is > 8 mg/L. These objectives do not apply in initial dilution zones of effluents, described in Section 6.1.1. The average value is to be calculated from five weekly samples collected in a 30-day period. In addition, total lead concentrations in edible tissues of fish caught anywhere in Hedley Creek should not exceed 0.8 µg/g (wet-weight).

Since one value at Site 0500032 exceeded the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.004 mg/L average or 0.044 mg/L maximum, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.6 Manganese

Working water quality criteria to protect aquatic life from manganese range from 0.1 to 1.0 mg/L[13]. All but one value of 0.13 mg/L at Site 0500032 (Table 1) met this range for criteria. The criterion for aesthetics of drinking water supplies is 0.05 mg/L[12] which was not met by 1 of 4 total values but was met by all 15 dissolved manganese values. Analyses of manganese in the tailings piles indicated manganese values of 685 and 875 ppm[3]. Since there is a potential for manganese to be mobilized from the tailings piles when these are disturbed, a provisional water quality objective is proposed for total manganese. The objective is that the maximum value should not exceed 0.05 mg/L. The objective does not apply in initial dilution zones of effluents, described in Section 6.1.1.

Since one value at Site 0500032 exceeded the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.05 mg/L maximum, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.7 Mercury

Water quality criteria to protect aquatic life from mercury are a maximum of 0.0001 mg/L and ≤0.00002 mg/L as a 30-day average[23]. One of 12 total mercury values at Site W-1 (Table 2) exceeded the maximum criterion, while all 12 values measured at Site 0500032 (Table 1) met this criterion. At Site W-1, only two values exceeded the detection limit of 0.00005 mg/L, in June and July 1987. High creek flows in these months (Section 2.0) may have caused some of the tailings to be scoured. To protect heavy consumers of fish, mercury concentrations in fish tissue should not exceed the values listed in Table 13 These criteria apply only when the diet is based primarily on fish[23].

Mercury concentrations in the tailings were 1 ppm[3]. It is likely that if the tailings are disturbed, that mercury may be of concern in Hedley Creek. Therefore, a provisional water quality objective is proposed. The objective is that the maximum total mercury concentration should not exceed 0.1 µg/L while the average concentration should be ≤0.02 µg/L. In edible fish tissue, the concentration should not exceed 0.5 µg/g wet weight from fish collected anywhere in Hedley Creek.

6.1.2.8 Molybdenum

Molybdenum (dissolved and total) could not be detected (varying detection limits) in Hedley Creek (Tables 1 and 2).

Approved B.C. criteria for total molybdenum to protect irrigation are ≤0.01 mg/L as an average and 0.05 mg/L maximum during the irrigation section. Molybdenum concentrations in the tailings were 12 and 13 ppm[3]. If the tailings are disturbed, molybdenum may become a concern in Hedley Creek.

A provisional water quality objective is proposed for total molybdenum. The objective is that the average concentration should be ≤0.01 mg/L while the maximum should be 0.05 mg/L during the irrigation season (May - September). The average is to be calculated from a minimum of five weekly samples collected in a 30-day period from outside the initial dilution zones of effluents, described in Section 6.1.1.

6.1.2.9 Nickel

Working water quality criteria to protect aquatic life are maximum concentrations of 0.025 mg/L at hardness ≤60 mg/L and 0.065 mg/L at hardness values between 60 and 120 mg/L[7]. All but 1 of the 11 total nickel values (Table 2) were less than the criterion of 0.025 mg/L.

Nickel concentrations in the tailings piles have ranged from 29 to 53 ppm[3]. Adjacent to the piles, total nickel concentrations in groundwater were 0.011 mg/L[3]. Since nickel may be mobilized in any disturbances to the tailings piles, a provisional water quality objective is proposed. The objective is that the maximum total nickel concentration in any sample should not exceed 0.025 mg/L when hardness is ≤65 mg/L or 0.065 mg/L when hardness exceeds 65 µg/L. The objective applies along the length of Hedley Creek, except in initial dilution zones of effluents described in Section 6.1.1.

Since one value at Site W-1 exceeded the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.025 mg/L maximum, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.10 Uranium

Working water quality criteria for uranium are a maximum of 0.1 mg/L to protect drinking water supplies[12], 0.01 mg/L maximum for continuous irrigation use on all soils or 0.10 mg/L maximum for up to 20 years use[7], and 0.3 mg/L to protect aquatic life[14]. One total uranium value (of 12) at Site W-1 (Table 2) was 0.15 mg/L, this high value being measured in June 1986. The second highest value was 0.03 mg/L, measured in June 1987. Since peak flows in Hedley Creek occur in June (Section 2.0), it is possible that these higher values reflect the presence of tailings which have been scoured by the creek.

Uranium values measured in the tailings were twice determined to be 10 ppm[3]. Further disturbances to the tailings piles may cause the release of uranium to the creek. For this reason, a water quality objective is proposed for total uranium. The objective is that the maximum uranium concentrations should not exceed 0.1 mg/L in any sample, and the 30-day average should not exceed 0.01 mg/L. The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1.

Since maximum uranium concentrations at Site W-1 can exceed the proposed objective on some occasions, it is desirable to distinguish background concentrations from levels caused by disturbances to tailings piles. Thus, at times when values upstream from the tailings piles exceed the maximum 0.1 mg/L concentration, there should be no significant increase in maximum concentrations measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% of background levels will be construed as not being significant. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site. However, it is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.2.11 Zinc

The maximum total and dissolved zinc values in Hedley Creek at Site W-1 (Table 2) were 0.05 mg/L in September 1987, although the other 20 values were less than 0.01 mg/L. Peak flows in Hedley Creek can occur between May and September (Section 2.0). Therefore the high zinc values may be the result of tailings being scoured, but more likely are the result of high groundwater concentrations entering the creek. Water quality criteria are a maximum of 0.03 mg/L to protect aquatic life[7] and 1 mg/L maximum for irrigation[7]. The CCREM guideline is "tentative" since phytoplankton have been affected at lower levels. The International Joint Commission (1987) recommends a level of 0.01 mg/L since data have shown effects at 0.015 mg/L[25].

Zinc concentrations in the tailings pile were from 82 to 90 ppm[3]. Groundwater samples collected near the tailings pile had concentrations of 0.10 mg/L[3]. Since disturbances to the tailings piles may release zinc to Hedley Creek, a provisional water quality objective is proposed. The objective is that the maximum zinc concentration should not exceed 0.03 mg/L and the 30-day average should not exceed 0.01 mg/L. The objective applies in all areas of Hedley Creek except in the initial dilution zone of effluents, described in Section 6.1.1.

On those occasions when zinc concentrations upstream from the tailings piles exceed the proposed objectives, no significant increase should occur in zinc concentrations in Hedley Creek downstream from the tailings piles. For the purposes of determining achievement of objectives, and taking into account sampling vagaries and analytical precision and accuracy, a significant increase will be considered as occurring if the increase exceeds 20% of the upstream value. This arbitrarily derived percentage would not likely reflect the real variability of the data at any of these sites. It is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.1.3 ARSENIC

Total arsenic concentrations have been as high as 0.024 mg/L at Site W-1 (Table 2). This is below the working water quality criteria of 0.05 mg/L to protect aquatic life[7] and drinking water supplies[12]. The value of 0.024 mg/L was recorded in June 1987, with a coincident dissolved arsenic value of 0.024 mg/L.

Arsenic concentrations in the tailings piles ranged from 0.97 to 1.3 %[3]. Groundwater near the tailings piles had a total arsenic concentration of 0.064 mg/L[3]. Since disturbances to the tailings piles potentially could release arsenic into Hedley Creek, a provisional water quality objective is proposed. The objective is that the total arsenic concentration in any sample should be a maximum of 0.05 mg/L. The objective applies to Hedley Creek, except in initial dilution zones of effluents described in Section 6.1.1.

6.1.4 CYANIDE

Approved B.C. criteria for cyanide are as follows: ≤0.005 mg/L as a 30-day average and 0.010 mg/L maximum of weak-acid dissociable cyanide to protect aquatic life and a maximum of 0.20 mg/L strong-acid dissociable cyanide plus thiocyanate to protect drinking water supplies[15]. Criteria to protect aquatic life have not been recommended for cyanate and thiocyanate due to insufficient toxicity data.

Swain[5] has proposed a water quality objective for cyanate in Cahill Creek, a tributary to the Similkameen River just downstream from Hedley Creek. Swain[5] cited Singleton[15] who reported that the lowest cyanate concentration reported to cause mortality in rainbow trout after 96 hours had been 7.3 mg/L as CNO, and that other 96 h LC_{50} values had been greater than 20 mg/L. The objective for cyanates was a maximum of 0.45 mg/L as CN^-. It was based upon the lowest concentration of cyanate (7.3 mg/L CNO^- or 4.5 mg/L CN^-) to cause mortality to rainbow trout after 96 hours and an application factor of 0.1. The value of a maximum of 0.45 mg/L cyanate will be used as a working criterion in this assessment.

Cyanide has only been measured at Site W-1. All weak-acid dissociable cyanide values were less than the criteria of ≤0.005 mg/L as an average and 0.010 mg/L maximum to protect aquatic life[15]. The criterion of a maximum of 0.20 mg/L of strong-acid dissociable cyanide plus thiocyanate was exceeded on 2 of 12 occasions by thiocyanate alone. Values of 0.64 mg/L and 1.24 mg/L as CNS (or 0.29 mg/L and 0.56 mg/L as CN, respectively), were reported in June 1986 and June 1987 samples. These high values coincide with a period of high flows in Hedley Creek (Section 2.0), and may reflect the fact that some tailings had been scoured by the river, or the results may be questionable (see Section 6.2.4).

Since it would appear that the tailings can impact cyanide levels in the river, provisional water quality objectives are proposed. The objectives are that the 30-day average value and maximum value of weak-acid dissociable cyanide should not exceed 0.005 mg/L and 0.010 mg/L, respectively, while the maximum concentration of strong-acid dissociable cyanide plus thiocyanate should not exceed 0.20 mg/L. The average is to be calculated from five weekly samples collected in a 30-day period.

The maximum cyanate value of 1.12 mg/L as CNO (0.69 mg/L as CN) exceeded the working criterion of a maximum concentration of 0.45 mg/L. This one detectable (of 11) cyanate concentration was present in a June 1986 sample from Hedley Creek, once again implicating the possible scouring of the tailings piles. Since disturbances to the tailings piles may cause cyanide to enter the creek as cyanates, a water quality objective is proposed. The objective is that the maximum cyanate concentration in Hedley Creek should not exceed 0.45 mg/L as CN. The objectives for all the cyanide compounds apply along the length of Hedley Creek, except in initial dilution zones of effluents described in Section 6.1.1.

Since values at Site W-1 for some of the cyanide compounds can exceed the proposed objectives on some occasions, it is desirable to distinguish background levels from levels caused by disturbances to tailings piles. Thus at times when values upstream from the tailings piles exceed maximum or 30-day average values, there should be no significant increase in mean or maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical precision and accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and likely does not reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.10). If strong-acid dissociable cyanide values are greater than the objective for weak-acid dissociable cyanide, further sampling is recommended at the same site and at sites further downstream.

6.1.5 NUTRIENTS

Total phosphorus concentrations in Hedley Creek ranged from <0.001 mg/L to 0.11 mg/L at Site W-1 (Table 2). The maximum value at Site 0500032 (Table 1) was 0.156 mg/L. The one (of 11) value higher than 0.01 mg/L at Site W-1 was measured in July 1987. High phosphorus concentrations are present in the tailings piles, where values were between 1 000 and 1 020 ppm.

B.C. water quality criteria related to nutrients and the potential for algal growths in streams are based on periphyton chlorophyll-*a*. The criteria are a maximum concentration of 100 mg/m^2 for the protection of aquatic life, and 50 mg/m^2 for recreation[16]. Recreation is not a designated use in Hedley Creek.

Since phosphorus can possibly enter Hedley Creek through disturbances to the tailings piles and since the potential exists to cause algal growths, <u>a provisional water quality objective is proposed for Hedley Creek.</u> The objective is that <u>the maximum periphyton chlorophyll-a concentration on natural substrate should not exceed 100 mg/m^2.</u> The maximum value is to be determined by taking five replicate samples and averaging these results to obtain one value. The objective applies along Hedley Creek, except in the initial dilution zones of effluents described in Section 6.1.1.

The maximum ammonia concentration in Hedley Creek was 0.046 mg/L at Site 0500032 (Table 1), well below B.C. criteria for average and maximum ammonia concentrations (Tables 8 and 9)(17). An ammonia concentration of 1.12 mg/L was measured in the groundwater near the tailings piles(3). This value was two to ten times ammonia levels in groundwater further from the piles. This may indicate that the tailings are a potential source of ammonia. Since ammonia may enter Hedley Creek due to disturbances of the tailings piles, <u>a provisional water quality objective is proposed for ammonia.</u> The objective is that <u>the 30-day average value should not exceed values listed in Table 8 and the maximum value should not exceed values listed in Table 9.</u> The objective applies along the length of Hedley Creek, except in initial dilution zones of effluents, described in Section 6.1.1. The average value is to be calculated from five weekly samples collected in a 30-day period.

B.C. criteria to protect aquatic life from the effects of nitrite are in Table 10(17). All nitrite concentrations in Hedley Creek at Site 0500032 (Table 1) or Site W-1 (Table 2) have been <0.005 mg/L. As well, nitrite in groundwater from near the tailings impoundments were only 0.006 mg/L(3). A concern could exist for nitrite if ammonia is not completely oxidized to nitrate. However, this is probably not likely due to the high oxygen levels found in the creeks. For this reason, no objective is proposed for nitrite.

The maximum nitrate or nitrate/nitrite concentration was 0.10 mg/L at Site W-1 (Table 2). This is well below the most stringent B.C. criterion of 10 mg/L maximum to protect drinking water supplies(17). The oxidation of the maximum ammonia concentrations in groundwater to form nitrate in Hedley Creek would result in nitrate concentrations well below this criterion. Therefore, no objective is proposed for nitrate in Hedley Creek.

6.1.6 SOLIDS

The maximum dissolved solids concentration in Hedley Creek of 60 mg/L (Table 2) was well below the working water quality criteria of 500 mg/L to protect aesthetics of drinking water[12] or to protect livestock watering[7]. Dissolved solids measured in groundwater near the tailings impoundment were at only 122 mg/L[3]. It does not seem likely that dissolved solids concentrations will be of concern in Hedley Creek; therefore, no water quality objective is proposed.

Suspended solids measured at Site 0500032 were as high as 104 mg/L (Table 1) in October 1972. B.C. criteria for particulate matter relate to allowable increases over background concentrations[18]. Since disturbances to the tailings piles could cause increases in suspended solids concentrations in Hedley Creek, <u>a provisional water quality objective is proposed.</u> The objective is that <u>the maximum induced suspended solids concentrations over background should not exceed 10 mg/L when background levels are less than 100 mg/L nor be more than 10% of background when background exceeds 100 mg/L.</u> These objectives apply to discrete samples collected outside the initial dilution zones of effluents as described in Section 6.1.1.

In addition, to protect salmonid spawning areas near the mouth of Hedley Creek, <u>there should be no significant induced benthic sedimentation on the basis of accumulation by weight for particles <3 mm.</u> To compare values on any date, and taking into account analytical precision and accuracy, <u>a maximum increase of 20% over background levels should be permitted</u>. This percentage increase is arbitrarily derived, likely does not reflect the true variability at any site, and is conservative from a statistical viewpoint (see Section 6.1.2.1).

The proposed objective for suspended solids addresses the aspect of physical damage to aquatic life. Turbidity addresses the aspects of aesthetics and light penetration. Turbidity levels have generally been low in Hedley Creek, except for one high value of 33 NTU at Site 0500032 (Table 1) in October 1972. Turbidity levels in Hedley Creek may be affected by disturbances to the tailings piles.

B.C. criteria which exist for induced turbidity[18] will be used for proposed provisional water quality objectives. The objectives are that induced turbidity levels should not exceed 1 NTU when background is less than 5 NTU or 5 NTU when background is less than 50 NTU, nor be more than 10% of background when background is greater than 50 NTU. The objectives apply along Hedley Creek, except in initial dilution zones of effluents described in Section 6.1.1.

6.1.7 DISSOLVED OXYGEN

There are no approved British Columbia criteria for dissolved oxygen. The following is the rationale to derive working water quality criteria to be used in this document for dissolved oxygen.

The CCREM[7] has developed criteria for dissolved oxygen, based on EPA criteria[19]. The criteria are based on warm-water and cold-water biota being present in a system. Cold-water systems were defined as any with at least one salmonid present. In British Columbia, this definition covers virtually the entire Province.

The EPA[19] had based its criteria and its findings on salmonids and nonsalmonids. Table 3-7 in CCREM (Page 3-14) is from EPA[19]. The EPA[19] indicated that there was no impairment at 11.0 mg/L when embryo larvae were present or 8.0 mg/L for other life stages, and slight impairment at 9.0 mg/L and 6.0 mg/L, respectively. The EPA[19] derived its criteria (accepted by CCREM) from the slight impairment levels plus 0.5 mg/L. In British Columbia, we are fortunate enough to generally have high quality waters, and there is no need to accept the slight impairment level. Therefore, the criteria which will be used for dissolved oxygen in this document will be based on salmonids and should provide for no impairment (i.e., 8.0 mg/L and 11.0 mg/L minima).

Dissolved oxygen concentrations ranged from 7.7 to 15.8 mg/L at Site 0500032 (Table 1). Only 1 of 21 values was below the criterion levels of 8.0 mg/L (7.7 mg/L in November 1973), while an additional 6 of 21 were below 11.0 mg/L (between May and October). Embryo larvae could have possibly been present on 2 of those 6 dates (9.5 mg/L in late June 1977 and 10.1 mg/L in early May 1973). Thus on those two occasions, any embryo larvae present would have experienced slight impairment.

Since there are no anthropogenic activities discharging oxygen-consuming wastes to Hedley Creek, a water quality objective is not proposed.

6.1.8 BACTERIOLOGICAL QUALITY

Fecal coliforms were measured only at Site 0500032 on Hedley Creek (Table 1) on four occasions, with a maximum value of 5 MPN/100 mL. Raw waters with fecal coliform concentrations ≤10 MPN/100 mL can be used as drinking water supplies with disinfection only[20]. No increase is expected due to mining proposals or livestock, therefore no objective is proposed.

6.2 SIMILKAMEEN RIVER: STEMWINDER PARK TO THE INTERNATIONAL BOUNDARY

This section of the Similkameen River had been included in the earlier review of the larger reach from Princeton to the International Boundary[1]. In order to maintain continuity and since water uses are the same, any new or revised water quality objectives will apply to the entire reach downstream from Princeton, even though these new proposed objectives have been developed on the basis of activities downstream from Stemwinder Park.

Designated water uses in this river reach are drinking water, protection of aquatic life, wildlife, livestock watering, primary- contact recreation, and irrigation.

Candorado has sampled at five sites in the Similkameen River: Site W-5 about 2.5 km upstream from Hedley Creek (Table 6); Site W-2 about 100 m upstream from Hedley Creek (Table 3); Site W-3 downstream and near the confluence of (and may be influenced by) Hedley Creek (Table 4); Site W-4 downstream from the last tailings pile (Table 5); and Site W-6 upstream from Red Top Gulch Creek (Table 7). The Ministry of Environment has sampled at similar locations in May and September 1988; however, these data were not available at the time of preparation of this assessment.

The largest data set for the Similkameen River is at Site 0500073, about 10 km from the U.S. border (Figure 3), where Environment Canada and the B.C. Ministry of Environment have been collecting data. Data for this site to the end of 1982 had been reported earlier[1] and are in Table 12. Data collected since 1983 are in Table 11.

Although other smaller data sets have been collected by the B.C. Ministry of Environment on the Similkameen River, these will not be reported. The data collected by Candorado show the present influence of the tailings on Similkameen River water quality while data collected at Site 0500073 provide evidence of changes, over time, of water quality downstream from Princeton.

6.2.1 pH AND ALKALINITY

Upstream from Hedley Creek, the pH in the Similkameen River ranged from 6.9 to 8.2 at Site W-2 (Table 3) and from 6.10 to 8.45 at Site W-5 (Table 6). The median pH at both sites was about 7.8. Downstream from Hedley Creek, pH values were about the same or slightly higher although a minimum pH of 5.92 was recorded near the Hedley Creek confluence (Site W-3, Table 4), similar in magnitude to the minimum pH in Hedley Creek (Section 6.1.1).

<u>The water quality objective for pH in the Similkameen River is 6.5 to 8.5</u>[1]. This objective is also applicable to two tributaries, Cahill Creek and Red Top Gulch[5]. It is evident that there are some occasions when this objective is not achieved near Hedley. All data collected downstream from Cawston at Site 0500073 were within the range for the objective (Tables 11 and 12). Therefore, there is no apparent reason to modify the provisional water quality objective other than to <u>allow no increase greater than 0.2 pH unit if upstream values are above 8.5 range or no decrease if values are less than 6.5</u>.

Alkalinity values at the two sites upstream from Hedley Creek were statistically similar (F-test and Student's "t"-test: P = 0.05) with mean values of 66.6 mg/L at Site W-5 (Table 6) and 63.9 mg/L at Site W-2 (Table 3). This was also the case for alkalinity values at Sites W-3, W-4, and W-6 Tables 4, 5 and 7), as well as between each of these sites and Sites W-2 and W-5. The variability of data between these sites and Site 0500073 was significant (F-test: P=0.05), likely due to the difference in size of the data sets, the fact that different laboratories made the measurements, or an actual difference in alkalinity at Site 0500073. These mean alkalinity values indicate that the water is well buffered to acidic inputs[8].

The minimum recorded alkalinity value at any of these five sites was 7.67 mg/L at Site W-3 which may reflect Hedley Creek water. Alkalinity values of <10 mg/L indicate that the water is highly sensitive to acidic inputs[8].

6.2.2 HARDNESS AND METALS

Mean hardness values of 70.5 mg/L at Site W-5 and 79.4 mg/L at Site W-2 were statistically similar (F-test and Student's "t"-test: P = 0.05). Downstream from Hedley Creek mean hardness values of 81.9 mg/L at Site W-4, and 77.2 mg/L at Site W-6 were statistically similar (F-test and Student's "t"-test: P = 0.05). The mean hardness of 45 mg/L at Site W-3 was significantly different, likely due to its close proximity to the Hedley Creek confluence.

At Site 0500073 near the International Boundary, the mean hardness value for data collected until 1983 (68 mg/L) was statistically similar (F-test and Student's "t"-test: P = 0.05) to those data collected since 1983 (78.2 mg/L). The mean value of 68 mg/L (data prior to 1983) was also similar to data collected upstream from Hedley Creek; however, the mean value of 78.2 mg/L since 1983 was based on a more variable data set (F-test: P = 0.05).

Since toxicity of heavy metals to aquatic life increases with softer water, hardness values of 85 mg/L for August to 65 mg/L for April and July, and 40 mg/L for May and June will be used to determine appropriate levels of water quality criteria for certain metals. It should be noted that the average hardness on a monthly basis at Site 0500073 from 1983 to 1988 ranged from 40 mg/L in May to 96 mg/L in January.

6.2.2.1 Aluminum

Water quality criteria to protect freshwater aquatic life from adverse effects of aluminum are that the average dissolved aluminum should be ≤0.05 mg/L and the maximum 0.1 mg/L[11] at pH >6.5.

Upstream from Hedley Creek, at Sites W-2 and W-5, the mean values of 0.021 mg/L and 0.025 mg/L were statistically similar (F-test and Student's "t"-test: P = 0.05) and both were less than the criteria levels. Downstream from Hedley Creek, both criteria were sometimes exceeded at Site W-3, the maximum criterion of 0.10 mg/L was exceeded by one value (of 8) at W-4, while no values exceeded the criteria levels at Site W-6. Data at Site W-6 were also statistically similar to those at Sites W-2 and W-5 upstream from Hedley Creek (F-test and Student's "t"-test: P = 0.05).

Aluminum values at Sites W-3 near the confluence of Hedley Creek and W-4 downstream in the Similkameen River from a tailings pile were significantly different (F-test and Student's "t"-test: P = 0.05), likely due to the influence of nearby tailings piles at W-3.

At Site 0500073, the data base prior to 1983 was statistically different (F-test: P = 0.05) (i.e., less variable) from the data base collected thereafter. Regardless, the water quality criteria levels were achieved by all data except 1 of 23 values which exeeded the criterion of 0.10 mg/L as a maximum. Five other values were 0.06 mg/L which exceeded the criterion level of 0.05 mg/L as an average.

A water quality objective does not at present exist for aluminum in the Similkameen River[1]. However, an approved objective for total aluminum of 0.30 mg/L maximum[5] exists in Cahill Creek and Red Top Gulch Creek. Because the aluminum level in the tailings and groundwater near Hedley Creek (Section 6.1.2.1) and in the Similkameen River adjacent to the tailings is high, and the aluminum may become mobilized when the tailings piles are disturbed, a provisional water quality objective is proposed for dissolved aluminum in the Similkameen River downstream from Princeton. The objective is that the maximum concentration should not exceed 0.10 mg/L and the average concentration should not exceed 0.05 mg/L. The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1. The average is to be calculated from a minimum of five weekly samples collected in a period not to exceed 30 days.

Since values can exceed the proposed objectives on some occasions, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.05 mg/L average or 0.10 mg/L maximum, there should be no significant increase in mean or maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum or average background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.2.2.2 Chromium

Working water quality criteria for total chromium are 0.020 mg/L as a maximum to protect freshwater fish and 0.002 mg/L maximum to protect phytoplankton and zooplankton[7]. The criterion for fish was exceeded by 5 of 10 values at Site W-5, but by 0 of 8 values at Site W-2. Downstream from Hedley, the criterion for fish was exceeded by 5 of 9 total chromium and 4 of 9 dissolved chromium values at Site W-6 (Table 7). Although the data for downstream Sites W-5 and W-6 appear at odds with those for upstream Sites W-2 and W-4, samples were not collected at Sites W-2 and W-4 when high chromium values were recorded at Sites W-5 and W-6.

The varying detection limits were all greater than the criterion of 0.002 mg/L, so that the potential impacts of chromium on phytoplankton and zooplankton could not be determined at all the sites. Chromium values at Site 0500073 were usually less than varying detection limits, although one value of 0.01 mg/L was measured.

No water quality objective for chromium exists in the Similkameen River downstream from Princeton[1] or in Cahill Creek or Red Top Gulch Creek[5]. As well, chromium values greater than the criterion of 0.02 mg/L were apparent at sites apparently unaffected by mining activities, and not in evidence at locations where chromium might be expected. However, an objective is proposed for chromium in Hedley Creek, since chromium in the tailings piles may become mobilized when the tailings are disturbed. A provisional water quality objective is proposed for total chromium in the Similkameen River. The objective is that total chromium should not exceed 0.02 mg/L, and the 30-day average should not exceed 0.002 mg/L.

Since values upstream from the piles may exceed the proposed objective, it is desirable to distinguish background levels from levels caused by disturbances to the tailings piles. Thus at times when values upstream from the tailings piles exceed the 0.02 mg/L maximum, there should be no significant increase in maximum values measured downstream from the piles. To compare values on any date, and taking into account sampling vagaries and analytical accuracy, a maximum increase of 20% over maximum background levels should be permitted. This percentage increase is arbitrarily derived and does not likely reflect the true variability at any site, but is conservative from a statistical viewpoint (see Section 6.1.2.1).

6.2.2.3 Copper

A water quality objective exists for dissolved copper in the Similkameen River above Princeton[1]; however, none exists below Princeton. The objective varies from ≤0.002 to ≤0.006 mg/L as an average and from 0.004 to 0.008 mg/L as a maximum, depending upon hardness. As well, an objective for total copper exists for Cahill Creek and Red Top Gulch Creek[5] of ≤0.005 mg/L as an average and 0.007 mg/L as a maximum value. Objectives at all areas allow a 20% increase over background for those times when upstream values exceed the objectives[1,5].

Since the time that these objectives were finalized, approved B.C. criteria for copper were issued by the Ministry of Environment[9]. For average hardness values of 40, 65 and 85 mg/L, the B.C. criteria for total copper to protect aquatic life are ≤0.002, ≤0.003, and ≤0.003 mg/L as average values and 0.006, 0.008, and 0.010 mg/L as maximum values, respectively[9].

The criteria for maximum copper concentrations were exceeded by 5 of 10 of each dissolved and total values at Site W-5 and 4 of 9 of each dissolved and total values at Site W-6. Maximum copper values were <0.01 mg/L at Site W-2, W-3, and W-4. At Site 0500073, 10 of 79 total copper values exceeded the criterion for a maximum while 33 of 79 values exceeded the 0.003 mg/L average criterion since 1983 (Table 11).

In Section 6.1.2.3, it was indicated that there was an appreciable copper content associated with the tailings. This fact, in conjunction with the facts that copper objectives exist upstream in the Similkameen River, in Cahill Creek, and are being proposed for Hedley Creek point to a need for <u>a water quality objective for total copper in the Similkameen River downstream from Princeton</u>. The proposed objective is that <u>the total copper value should not exceed (0.094 (hardness) +2)µg/L and the 30-day average copper concentration should not exceed 0.04 (hardness)µg/L if hardness is >50 mg/L or 2 µg/L if hardness is ≤50 mg/L</u>. When upstream values naturally exceed the proposed objectives, <u>no significant increase from upstream to downstream from a point source or series of point source discharges should occur. In practice, this should allow a maximum 20% increase from upstream to downstream</u>, which is a conservatively small increase from a statistical viewpoint (see Section 6.1.2.1).

These proposed objectives are more restrictive than those which exist upstream from Princeton. This is because criteria developed for British Columbia, which were not available at the time of the initial assessment, have been used herein. When objectives for copper upstream from Princeton are reviewed at some later date, it is anticipated that they would be revised in line with the British Columbia criteria.

6.2.2.4 Iron

No water quality objective exists for iron in the Similkameen River at the present time(1). In Cahill Creek and Red Top Gulch Creek, the maximum dissolved iron is to be 0.3 mg/L(5). The working water quality criteria for total iron are 0.3 mg/L each to protect aquatic life(7) and the aesthetic quality of drinking water supplies(1).

Upstream from Hedley Creek, total iron values were as high as 1.18 mg/L at Site W-5 and 0.48 mg/L at Site W-2. At these sites, these were the only values which exceeded the criteria (of 10 and 8 samples, respectively). The variability in the data sets for total iron between these sites was determined to be statistically significant (F-test:P = 0.05).

Downstream from Hedley Creek, total iron values were as high as 0.40 mg/L at Site W-4 and 1.49 mg/L at Site W-6. These were the only values at these sites (of 8 and 9, respectively) which exceeded the criteria. The criteria were achieved for all values at Site W-3.

Some extremely high total iron values have been measured at Site 0500073 (Table 11) since the end of 1982. Seventeen of 79 values exceeded the criteria, with all but one occurring during freshet (March to June). The average value of 0.81 mg/L is reduced to 0.45 mg/L when the maximum value of 29 mg/L is excluded from the data set and to 0.34 mg/L when the second highest value of 8.4 mg/L is excluded. This, and the fact that the 75th percentile for the total data set is 0.26 mg/L indicates that criteria for total iron were generally achieved in the Similkameen River.

High iron contents (up to 4.23%) have been measured in the tailings piles (Section 6.1.2.4). Since iron may be mobilized in any disturbances of the tailings piles adjacent to the Similkameen River, and since a water quality objective exists for iron in Cahill and Red Top Gulch creeks, a provisional water quality objective is proposed for total iron in the Similkameen River, downstream from Princeton. The objective is that the maximum total iron concentration should not exceed 0.3 mg/L. The objective applies in all areas of the Similkameen River, except in initial dilution zones of effluents described in Section 6.1.1. When values upstream from a point source discharge exceed the objective, no significant increase in total iron should occur. For the purpose of determining if the objective is achieved, and taking into account the vagaries of sampling and analytical precision and accuracy, no significant increase will be defined as an increase in downstream values not exceeding 20% of upstream values. This percentage increase is conservative and small from a statistical viewpoint (see Section 6.1.2.1).

6.2.2.5 Lead

B.C. criteria for lead based on average hardness values of 40, 65, and 85 mg/L are that the average total lead concentration should be ≤0.004, ≤0.005 and ≤0.006 mg/L and the maximum total lead concentration should not exceed 0.025, 0.047, and 0.066 mg/L, respectively. Water quality objectives are not in place for lead in the Similkameen River, although objectives for Cahill and Red Top Gulch creeks are that the average total lead should be ≤0.005 mg/L and the maximum 0.015 mg/L (or 20% increase).

Upstream from Hedley Creek, both total and dissolved lead values were low, with a maximum dissolved level of 0.007 mg/L at Site W-5 (Table 6) and most values at both Sites W-2 and W-5 being not detectable (<0.001 mg/L). Downstream from Hedley Creek, the maximum total lead value at the three sites (W-3, W-4, W-6) was equal to or less than 0.004 mg/L. Similarly low lead values were recorded at Site 0500073 (Tables 11 and 12).

High lead concentrations (up to 0.63 mg/L) have been recorded in groundwater from near the tailings piles (Section 6.1.2.5). This fact, and the fact that objectives exist for Cahill Creek and Red Top Gulch Creek, and are proposed for Hedley Creek, point to the need to have water quality objectives for total lead in the Similkameen River downstream from Princeton. The proposed provisional objective is that the average total lead value should not exceed 3.31 + exp (1.273 ln (average hardness) -4.705)μg/L and the maximum should not exceed 3 μg/L when the hardness is ≤8 mg/L or exp (1.273 ln (hardness) -1.460)μg/L if hardness is >8 mg/L. When lead values upstream exceed these level, no significant increase (≤20%) over background should occur. The average value is to be calculated from a minimum of five weekly samples collected in a 30-day period. The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1. In addition, total lead concentrations in edible tissues of fish caught anywhere in the Similkameen River downstream from Princeton should not exceed 0.8 μg/g (wet-weight).

6.2.2.6 Manganese

Working water quality criteria to protect aquatic life from manganese range from 0.1 mg/L to 1.0 mg/L(13), while a value of 0.05 mg/L is the criterion to protect aesthetics of drinking water supplies(12). There are no approved water quality objectives for the Similkameen River or Cahill or Red Top Gulch creeks for manganese.

This range of criteria to protect aquatic life has been achieved at all sites except Site 0500073, where the maximum total manganese value was 0.54 mg/L (Table 11) for post-1982 data. Only 4 of 79 values have exceeded 0.1 mg/L as follows:

Date	**Total Manganese (mg/L)**
860526	0.27
860527	0.54
870428	0.129
870512	0.205

All of these higher values occurred during freshet.

High concentrations (up to 875 ppm) of manganese exist in the tailings piles. Since there is a potential for manganese to be mobilized from the tailings piles when disturbed, <u>a provisional water quality objective is proposed for total manganese.</u> The objective is that <u>the maximum total manganese should not exceed 0.05 mg/L.</u> When values upstream from a point source exceed 0.05 mg/L, <u>a maximum increase of 20% in downstream samples</u> is allowable. <u>This percentage increase is</u> meant to define that <u>no significant increase</u> in actual manganese levels has occurred. The percentage increase takes into account vagaries in sampling and problems with analytical precision and accuracy. The objective does not apply in initial dilution zones of effluents, described in Section 6.1.1.

6.2.2.7 Mercury

Water quality criteria to protect aquatic life from mercury are a maximum of 0.0001 mg/L and ≤0.00002 mg/L as an average[23]. To protect drinking water, the criterion is a maximum of 0.001 mg/L. To protect consumers of fish, mercury values in the muscle should not exceed 0.5 µg/g or the values listed in Table 13 when the diet is based primarily on fish[23].

Upstream from Hedley Creek, 1 of 18 total mercury values exceeded the lower criterion for a maximum (0.00016 mg/L at Site W-2). Downstream from Hedley Creek, 1 of 27 total mercury values at Sites W-3, W-4, and W-6 exceeded the criterion of 0.0001 mg/L (0.00013 mg/L at Site W-4, Table 5). The maximum total mercury value (of 70 values) at Site 0500073 since 1982 was 0.00005 mg/L (Table 11). Present mercury values in the Similkameen River generally are below water quality criteria.

Mercury concentrations in the tailings were 1 ppm (Section 6.1.2.7). It is likely that if the tailings are disturbed, mercury may be of concern in the river. A water quality objective for mercury exists for fish flesh and water for Cahill Creek[5]. This was based on the potential of mercury to be released from a mining operation.

In order to protect users of the Similkameen River downstream from Princeton from mercury, <u>a provisional water quality objective is proposed.</u> The objective is that <u>the maximum total mercury concentration in the water column should be 0.1 µg/L and the average ≤0.02 µg/L, while the maximum concentration in edible fish flesh should be 0.5 ug/g (wet-weight).</u> Fish can be taken from anywhere in the river to determine achievement of the objective. The objective for the water column applies outside the initial dilution zones of effluents, described in Section 6.1.1.

6.2.2.8 Molybdenum

Molybdenum could only be detected in the Similkameen River at Site 0500073. This occurred on 3 of 23 occasions, twice at 0.01 mg/L and once at 0.03 mg/L. These samples were collected between January and March 1984. Approved B.C. criteria for total molybdenum to protect irrigation are: ≤0.01 mg/L as an average and 0.05 mg/L maximum during the irrigation season[21].

Approved water quality objectives exist for molybdenum in Wolfe Creek[1] and Cahill and Red Top Gulch Creeks[5], three tributaries to the Similkameen River. Molybdenum concentrations in the tailings piles were 12 and 13 ppm[3]. Due to the importance of the Similkameen River as an irrigation water supply, a provisional water quality objective is proposed for total molybdenum. The objective is that the average concentration should be <0.01 mg/L while the maximum should be 0.05 mg/L during the irrigation season (May - September). The average is to be calculated from a minimum of 5 weekly samples collected in a 30-day period. The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1.

6.2.2.9 Nickel

Working water quality criteria to protect aquatic life are maximum concentrations of 0.065 mg/L total nickel at hardness values between 60 and 120 mg/L and 0.025 mg/L total nickel at hardness values <60 mg/L[7]. There are no approved water quality objectives for nickel in the Similkameen River or its tributaries.

Upstream from Hedley Creek, the criteria were met at Site W-2 but at Site W-5, the criterion of 0.025 mg/L was not achieved on 3 of 10 occasions.

Downstream from Hedley Creek, the criteria were achieved at Site W-4 (Table 5). At Site W-3, only 1 of 10 values (0.051 mg/L) exceeded the applicable criterion of 0.025 mg/L, while at Site W-6, 3 of 9 values exceeded the applicable criterion of 0.025 mg/L. Detection limits (0.05 mg/L) were too high at Site 0500073 to allow for a meaningful interpretation of those data.

Nickel concentrations in the tailings piles have been as high as 53 ppm (Section 6.1.2.9). Since nickel can be mobilized in any disturbances to the tailings piles with the potential to enter the Similkameen River, a provisional water quality objective is proposed. The objective is that the maximum total nickel concentration should be 0.025 mg/L for average hardness values <65 mg/L and should be 0.065 mg/L for average hardness values greater than 65 mg/L. If values above a discharge exceed the applicable maxima, there should not be a significant increase in downstream values. In practical terms, the maximum value should not increase by more than 20% of upstream. This is a conservative and small increase from a statistical viewpoint (see Section 6.1.2.1) The objective applies outside the initial dilution zones of effluents, described in Section 6.1.1.

6.2.2.10 Uranium

Working water quality criteria for uranium are a maximum of 0.1 mg/L to protect drinking water supplies[12], 0.01 mg/L maximum for continuous irrigation use on all soils or 0.10 mg/L maximum for up to 20 years use on neutral to alkaline fine-textured soils[7], and 0.3 mg/L to protect aquatic life[14]. There are no approved water quality objectives for uranium in the Similkameen River or its tributaries.

Upstream from Hedley Creek, only 1 of 18 total uranium values (at Site W-2) exceeded the more restrictive criterion of 0.01 mg/L. Downstream from Hedley Creek, all values met the criterion of 0.01 mg/L except 2 of 11 values at Site W-3 and 2 of 9 values at Site W-4. Dissolved uranium values were not always measured at Sites W-2, W-3, or W-4. Uranium concentrations have not been measured at Site 0500073.

Uranium concentrations in the tailings were 10 ppm(3). Further disturbances to the tailings could cause the release of uranium to the river. For this reason, a provisional water quality objective of a maximum of 0.1 mg/L and a 30-day average of 0.010 mg/L total uranium is proposed for the Similkameen River downstream from Princeton. At those times when values upstream from a point discharge exceed the proposed objective, the downstream value can only increase by a maximum of 20%, the indicator assumed in this document as practical in terms of no significant increase. It is conservative and small from a statistical viewpoint (see Section 6.1.2.1). The objective applies in the Similkameen River except in initial dilution zones of effluents, described in Section 6.1.1.

6.2.2.11 Zinc

Working water quality criteria for total zinc are maximum concentrations of 0.03 mg/L(7) and 0.01 mg/L(25) to protect aquatic life and 1.0 mg/L to protect irrigation(9). Approved objectives for dissolved zinc upstream from Princeton are for average concentrations to be ≤0.05 mg/L and maximum values to be 0.08 mg/L (hardness <50 mg/L) and 0.18 mg/L (hardness >50 mg/L(1). More recently approved objectives for Cahill and Red Top Gulch Creeks are for maximum total zinc concentrations to be 0.05 mg/L(5).

The maximum total zinc concentration in the Similkameen River was 0.03 mg/L upstream from Hedley Creek at Site W-2, and downstream from Hedley Creek at Site W-3. The high values for maximum dissolved zinc at Sites W-3 and W-4 are questionable, inasmuch as these values were reported for the same day (June 9, 1986) when total zinc concentrations were <0.005 mg/L.

At Site 0500073, only 3 of 79 total zinc values since 1982 have exceeded the 0.03 mg/L Criterion, as follows:

Date	**Total Zinc (mg/L)**
86/05/27	0.064
86/09/02	0.0308
87/01/02	0.243

On these occasions, it is suspected that the sediment concentrations in the river was high. On only one occasion (86/05/27) was it measured, at 680 mg/L. The associated turbidity value was 140 NTU. Turbidity levels on the other two occasions were 0.3 NTU and 2.2 NTU, respectively.

Zinc concentrations in the tailings piles have been as high as 90 ppm[3]. Groundwater samples collected near the tailings piles had concentrations of 0.1 mg/L[3]. Since disturbances to the tailings piles could release zinc to the Similkameen River, and since approved water quality objectives are in place for the Similkameen River upstream from Princeton and for Cahill and Red Top Gulch Creeks, <u>a provisional water quality objective is proposed for total zinc.</u> The objective is that <u>the maximum total zinc concentration should not exceed 0.03 mg/L while the 30-day average concentration should not exceed 0.01 mg/L</u>. The objective applies in all areas of the Similkameen River downstream from Princeton, except in the initial dilution zones of effluents described in Section 6.1.1. The objective is not based on hardness since chronic toxicity does not appear to be influenced by hardness. The proposed objective is more restrictive than that upstream from Princeton since the working criteria used in this assessment were not available earlier. It is likely that the objective for zinc upstream from Princeton will be revised to reflect the most recent knowledge at the time of any future review.

On those infrequent occasions when upstream concentrations exceed the proposed objectives, maximum values downstream from a discharge should not increase by more than an arbitrary 20%. This percentage increase is meant to indicate no significant increase from upstream to downstream. It likely is restrictive in terms of data variability; however, it is meant to reflect the inaccuracies associated with analyses and the vagaries of sampling. It is small and conservative from a statistical viewpoint (see Section 6.1.2.1).

6.2.3 ARSENIC

Total arsenic concentrations have been as high as 0.22 mg/L at Site W-3 (Table 4). This is above the working water quality criterion of 0.05 mg/L to protect aquatic life(7) and drinking water supplies(12). The value of 0.22 mg/L was recorded in early July 1988 and may indicate that high flows in Hedley Creek and/or the Similkameen River (Section 2.0) were scouring tailings into the river.

However, the coincident suspended solids concentration was 2.7 mg/L, and all the arsenic was in the dissolved form. All other values at Sites W-2, W-3, W-4, W-5 and W-6 were below the criterion except one dissolved value of 0.053 mg/L. It is suspected that this may be an incorrect reporting of the data since the coincident total value was 0.0063 mg/L. At Site 0500073, only 1 of 73 values (0.0563 mg/L) exceeded the criterion, on May 27, 1986 when the associated suspended solids concentration was 680 mg/L and a high zinc concentration was recorded (Table 12).

Since arsenic concentrations in the tailings near Hedley and the groundwater are high, and disturbances to the tailings piles potentially could release arsenic to the Similkameen River, <u>a provisional water quality objective is proposed.</u> The objective is that <u>the maximum total arsenic concentration should not exceed 0.05 mg/L.</u> The objective applies in the Similkameen River, downstream from Princeton, except in the initial dilution zones of effluents described in Section 6.1.1. On those occasions when maximum values upstream from a discharge or series of discharges exceed the proposed objective, <u>no significant increase should occur.</u> In practice, for single measurements, no significant increase shall be <u>defined as a maximum increase over upstream values of 20%.</u> This percentage increase is likely more restrictive than the data variability at any site; however, it is an arbitrary factor to reflect vagaries of sampling and analytical precision and accuracy. It is small and conservative from a statistical viewpoint (see Section 6.1.2.1).

6.2.4 CYANIDE

Approved B.C. criteria for cyanide are as follows: ≤0.005 mg/L as a 30-day average and 0.010 mg/L maximum of weak-acid dissociable cyanide to protect aquatic life; also a maximum of 0.20 mg/L strong-acid dissociable cyanide plus thiocyanate to protect drinking water supplies[15]. Criteria to protect aquatic life have not been recommended for cyanate or thiocyanate due to insufficient toxicity data.

Swain[5] has proposed a water quality objective for cyanate in Cahill Creek, a tributary to the Similkameen River just downstream from Hedley Creek. Swain[5] cited Singleton[15] who reported that the lowest cyanate concentration reported to cause mortality in rainbow trout after 96 hours had been 7.3 mg/L as CNO, and that other 96 h LC_{50} values had been greater than 20 mg/L. The objective for cyanate was a maximum of 0.45 mg/L as CN. It was based upon the lowest concentration of cyanate (7.3 mg/L CNO or 4.5 mg/L CN) to cause mortality to rainbow trout after 96 hours and an application factor of 0.1. The value of a maximum of 0.45 mg/L cyanate as CN will be used as a working criterion in this assessment.

Cyanide has not been measured at Site 0500073 since 1982, although cyanide measurements were begun again in late 1988. All weak-acid dissociable cyanide values at Sites W-2 to W-6 were below detection (<0.005 mg/L) as were all cyanate values (<0.31 mg/L as CN). The B.C. criterion for strong-acid dissociable cyanide plus thiocyanate (0.2 mg/L maximum as CN) was exceeded by thiocyanate values alone at Site W-4 (0.67 mg/L CN maximum), Site W-3 (0.87 mg/L CN maximum) and Site W-2 (0.31 mg/L CN maximum). These maximum values were the only detectable (>0.22 mg/L CN) thiocyanate concentrations at the three sites, all recorded on June 30, 1987. Since one of the three sites (W-2) is upstream from Hedley Creek and removed from the tailings, the accuracy of the values is questionable.

Disturbances to the tailings piles may impact cyanide levels in the Similkameen River. As well, approved water quality objectives exist for Cahill and Red Top Gulch Creeks. For these reasons, provisional water quality objectives are proposed for the Similkameen River downstream from Princeton. The objectives are that (1) the 30-day average value and maximum value for weak-acid dissociable cyanide should not exceed 0.005 mg/L and 0.01 mg/L, respectively, (2) the maximum concentration of strong-acid dissociable cyanide plus thiocyanate should not exceed 0.20 mg/L, and (3) the maximum cyanate concentration should not exceed 0.45 mg/L. Average values are to be calculated from five samples collected in a 30-day period. The objectives apply in all areas of the Similkameen River, except initial dilution zone of effluents described in Section 6.1.1. If strong-acid dissociable cyanide values are greater than the objectives for weak-acid dissociable cyanide, further sampling is recommended at the same site and sites further downstream.

6.2.5 NUTRIENTS

Total phosphorus values ranged from <0.001 to 0.093 mg/L at Site W-2 upstream from Hedley Creek (Table 3) to <0.001 to 0.12 mg/L at Site W-3 (Table 4) downstream from Hedley Creek. Values at Site 0500073 were even higher since 1982, from <0.002 to 1.048 mg/L (Table 11). The variability between data sets for total phosphorus pre- and post 1982 was significant (F-test: $P = 0.05$).

Water quality objectives were not proposed for phosphorus in the earlier review[1]. Phosphorus levels in the tailings piles were from 1 000 ppm to 1 020 ppm[3]. However, the phosphorus in the tailings is in some insoluble mineral form and not available as a nutrient. In addition, cattle wastes (Section 4.1) and other agricultural products can increase phosphorus concentrations in the Similkameen River.

B.C. water quality criteria related to nutrients and the potential for algal growths in streams are based on periphyton chlorophyll-a. The criteria are a maximum concentration of 100 mg/m^2 to protect aquatic life and 50 mg/m^2 for recreation[16]. Recreation is a designated water use for the Similkameen River from Princeton to the International Boundary[1].

Since phosphorus can enter the Similkameen River from agricultural and/or mining sources, a provisional water quality objective is proposed for periphyton chlorophyll-a. The objective is that the maximum periphyton chlorophyll-a concentration on natural substrate should not exceed 50 mg/m^2. The maximum value is to be determined by taking at least five replicate samples and averaging the results to obtain one result to compare against the objective. The objective does not apply in initial dilution zones of effluents, described in Section 6.1.1.

The maximum ammonia concentration upstream from Hedley Creek was 0.043 mg/L at Site W-2 (Table 3) while downstream it was 0.042 mg/L at Site W-6 (Table 7). These are well below B.C. criteria for average and maximum ammonia concentrations (Tables 8 and 9)[17] to protect aquatic life. At Site 0500073, the maximum ammonia concentration was 0.028 mg/L for data collected prior to 1982 (Table 12) and 0.017 mg/L for data collected since 1982 (Table 11).

Approved water quality objectives exist for this reach of the Similkameen River for un-ionized ammonia. These objectives had been based on working water quality criteria which were considered in the formulation of the approved B.C. criteria. The need for water quality objectives for ammonia still exists, and is reinforced by the fact that groundwater near the tailings piles had ammonia concentrations of 1.12 mg/L[3]. Also ammonia objectives exist for Cahill and Red Top Gulch Creeks[5]. Therefore, revised provisional water quality objectives are proposed for ammonia for the Similkameen River downstream from Princeton. The objectives are that the 30-day average value should not exceed values listed in Table 8 while the maximum values should not exceed values listed in Table 9, for concurrent pH and temperature. The objectives do not apply in initial dilution zones of effluents, described in Section 6.1.1. The average value is to be calculated from five weekly samples collected in thirty days.

B.C. criteria to protect aquatic life from the effects of nitrite are in Table 10[17]. The maximum measured nitrite concentration was 0.004 mg/L at Site W-2 (Table 3) upstream from Hedley Creek and 0.0024 mg/L at Site W-6 (Table 7), downstream from Hedley Creek. At Site 0500073, the maximum concentration of 0.017 mg/L was recorded prior to 1983 (April 1982) and meets the most restrictive criteria[17]. A concern could exist for nitrite if ammonia is not completely oxidized to nitrate. However, this will likely not be a concern in the Similkameen due to high oxygen levels found. Therefore no objective is proposed for nitrite.

The maximum nitrate or nitrate/nitrite concentration was 0.55 mg/L at Site 0500073 in data collected since 1982 (Table 11). This is well below the most stringent B.C. criterion of 10 mg/L maximum to protect water supplies[17]. Therefore no objective is proposed for nitrate.

6.2.6 SOLIDS

The maximum dissolved solids concentration in the Similkameen River was 202 mg/L at Site W-2 (Table 3) upstream from Hedley Creek. This is well below the working water quality criterion of 500 mg/L to protect aesthetics of drinking water[12] or to protect livestock water[7]. Dissolved solids in groundwater near the tailings piles were only 122 mg/L[3].

Three tributaries to the Similkameen River, Wolfe Creek[1] and Cahill and Red Top Gulch Creeks[5], have approved objectives of 500 mg/L maximum dissolved solids concentration. These are based on mining operations present in the watershed raising dissolved solids concentrations. However, it seems unlikely that dissolved solids will be a concern in the much larger Similkameen River. Therefore no objective is proposed for dissolved solids.

The highest suspended solids concentrations were measured at Site 0500073, likely due to the large number (40) of values since 1982. The highest values were recorded in May of 1985 (110 mg/L), May 1986 (587 and 680 mg/L), and late April (161 mg/L) and May 1987 (173 mg/L). These high values would be associated with freshet in the Similkameen River.

B.C. criteria for particulate matter relate to allowable increases over background concentrations. Since disturbances to the tailings piles could cause increases in suspended solids in the Similkameen River, a provisional water quality objective is proposed for suspended solids. The objective is that the maximum induced suspended solids concentration over background should not exceed 10 mg/L when background levels are less than 100 mg/L nor be more than 10% of background when background exceeds 100 mg/L. These objectives apply to discrete samples collected outside the initial dilution zones of effluents as described in Section 6.1.1.

In addition, to protect salmonid spawning areas near the mouths of creeks tributary to the Similkameen River, there should be no significant induced benthic sedimentation on the basis of accumulation by weight for particles <3 mm. To compare values on any date, and taking into account analytical precision and accuracy, a maximum increase of 20% over background levels should be permitted. This percentage increase is arbitrarily derived, likely does not reflect the true variability at any site, and is conservative from a statistical viewpoint (see Section 6.1.2.1).

The proposed objective for suspended solids addresses the aspect of physical damage to aquatic life. Turbidity addresses the aspects of aesthetics and light penetration. Turbidity levels have generally been low near Hedley Creek (maximum value of 21 NTU at Site W-5, upstream from Hedley Creek), although this is likely due to the small data base (n = 8 to 12).

At Site 0500073 since 1982, the data base is considerably larger (n>100) and the maximum recorded value was 140 NTU. Prior to 1983, the maximum recorded value at Site 0500073 was 55 NTU. The F-test (P = 0.05) indicated that the variability of the data at Site 0500073 for the two time periods was statistically similar. The mean turbidity values of 6.3 NTU prior to 1983 and 4.4 NTU after 1982 were statistically similar (Students "t"-test, P = 0.05). At Site 0500073, all turbidity values greater than 20 NTU have been recorded between April and June during freshet (see Section 2.1) in the Similkameen:

Date	**Turbidity (NTU)**
80/04/24	24
82/06/16	55
85/05/28	33
86/05/26	42
86/05/27	140
87/05/12	46

B.C. Criteria which exist for induced turbidity[18] will be used for proposed provisional water quality objectives. The objective is that the induced turbidity levels should not exceed 1 NTU when background is less than 5 NTU (only 13 of 103 values of Site 0500073 since 1982 exceeded 5 NTU), nor exceed 5 NTU when background is less than 50 NTU, nor be more than 10% of background when background is greater than 50 NTU. The objective applies along the Similkameen River, except in the initial dilution zones of effluents described in Section 6.1.1.

6.2.7 DISSOLVED OXYGEN

The rationale for working water quality criteria for dissolved oxygen were explained in Section 6.1.7, and led to use of the following minima: 8.0 mg/L at all times and 11.0 mg/L when embryo larvae are present.

Dissolved oxygen concentrations have been recorded only at Site 0500073 (Tables 11 and 12). Values since 1982 (n = 16) have ranged from 8.7 to 14.2 mg/L while those prior to 1983 (n = 29) ranged from 5.8 to 14.5 mg/L. The variability in the data for the two time periods was not significant (F-test: P = 0.05), but the mean concentrations of 10.9 mg/L (pre-1983) and 12.0 mg/L (1983 to present) were significantly different (Student's "t"-test: P = 0.05).

Only 1 value (November 1973) out of 45 at Site 0500073 for the entire period of record was less than the minimum of 8.0 mg/L while an additional 13 of 45 values were less than 11.0 mg/L as shown below:

Dissolved Oxygen (mg/L) Values <11.0 mg/L

Date	Concentration	Date	Concentration
72/01/12	8.0	77/06/23	9.1
72/07/24	9.6	78/07/20	9.2
73/05/15	10.0	79/08/16	8.9
73/11/14	5.8	80/04/24	8.5
75/02/20	10.4	81/06/22	10.8
75/09/18	10.0	84/07/25	8.7
77/04/26	10.6	84/08/22	9.6

The 11.0 mg/L criterion would apply generally in the April to June period, when only 4 of the 14 values were recorded. Only 2 of these 4 values were less than the slight impairment level of 9.0 mg/L (Section 6.1.7).

Oxygen consuming wastes are being discharged indirectly via infiltration to the Similkameen River from the Villages of Princeton[1] and Keremeos (Section 5.3) as well as directly in runoff associated with agricultural wastes. In order to ensure that good oxygen concentrations are maintained in the Similkameen River, provisional water quality objectives are proposed for dissolved oxygen in the Similkameen River downstream from Princeton. The objectives are that the minimum dissolved oxygen should be 8.0 mg/L except when embryo larvae are present (April - June), when the minimum concentrations should be 11.0 mg/L. The objectives do not apply in initial dilution zones of effluents, described in Section 6.1.1.

6.2.8 BACTERIOLOGICAL QUALITY

Fecal coliforms have been collected only at Site 0500073 (Tables 11 and 12). Since 1982, values (n = 38) ranged from <2 MPN/100 mL to 79 MPN/100 mL and values prior to 1983 (n = 6) ranged from <2 to 130 MPN/100 mL.

The approved objectives for this reach of the Similkameen River for fecal coliforms are that the 90th percentile value in a 30-day period should be <10 MPN/100 mL to protect raw drinking water supplies[1]. Ten of 38 values were >10 MPN/100 mL, suggesting that partial treatment in addition to disinfection would probably be required to use the river as a drinking water supply. The fact that the approved objective was not attained at Site 0500073 was confirmed by data collected in 1987, although it was achieved at sites downstream from Keremeos (Sites 0500693), downstream from Princeton (Site 0500725), and upstream from Newmont Mines (Site 0500075)[22]. Approved Ministry criteria for drinking water supplies with disinfection only are the same as the present objective[20]. Thus the objective should be maintained. In addition, the approved criteria propose comparable levels of protection citing Escherichia coli and Enterococci values of ≤10/100 mL and ≤3/100 mL, both as 90th percentiles. These are also proposed as objectives. The objectives do not apply in initial dilution zones of effluents, described in Section 6.1.1.

An existing objective is that the total chlorine residual should not exceed 0.002 mg/L maximum in order that aquatic life be protected[1]. Approved Ministry criteria are that the average total chlorine residual should be ≤0.002 mg/L for continuous exposure while permitting some excursions above the 0.002 mg/L level for intermittent exposure[24]. It is proposed that the existing provisional water quality objectives for total chlorine residual of 0.002 mg/L maximum be maintained.

7.0 RECOMMENDED MONITORING

The minimum frequency at which monitoring should be undertaken is five samples collected weekly for a thirty-day period. This frequency will permit objectives with both maximum and average values to be checked.

Although the highest flows in both Hedley Creek and the Similkameen River occur in the spring, sampling is recommended during the April to June period when runoff is likely to carry contaminants into these two waterbodies from agricultural land or the tailing piles.

Samples should be analyzed for those characteristics for which water quality objectives have been proposed. Samples should be collected from three sites on Hedley Creek: upstream from both tailings piles, at the highway bridge (Site 0500032), and near the mouth. Three additional sites should be sampled on the Similkameen River. These are approximately 100 m upstream from Hedley Creek, just downstream from Hedley Creek but above the "new" tailings pile, and about 100 m downstream from the "new tailings pile.

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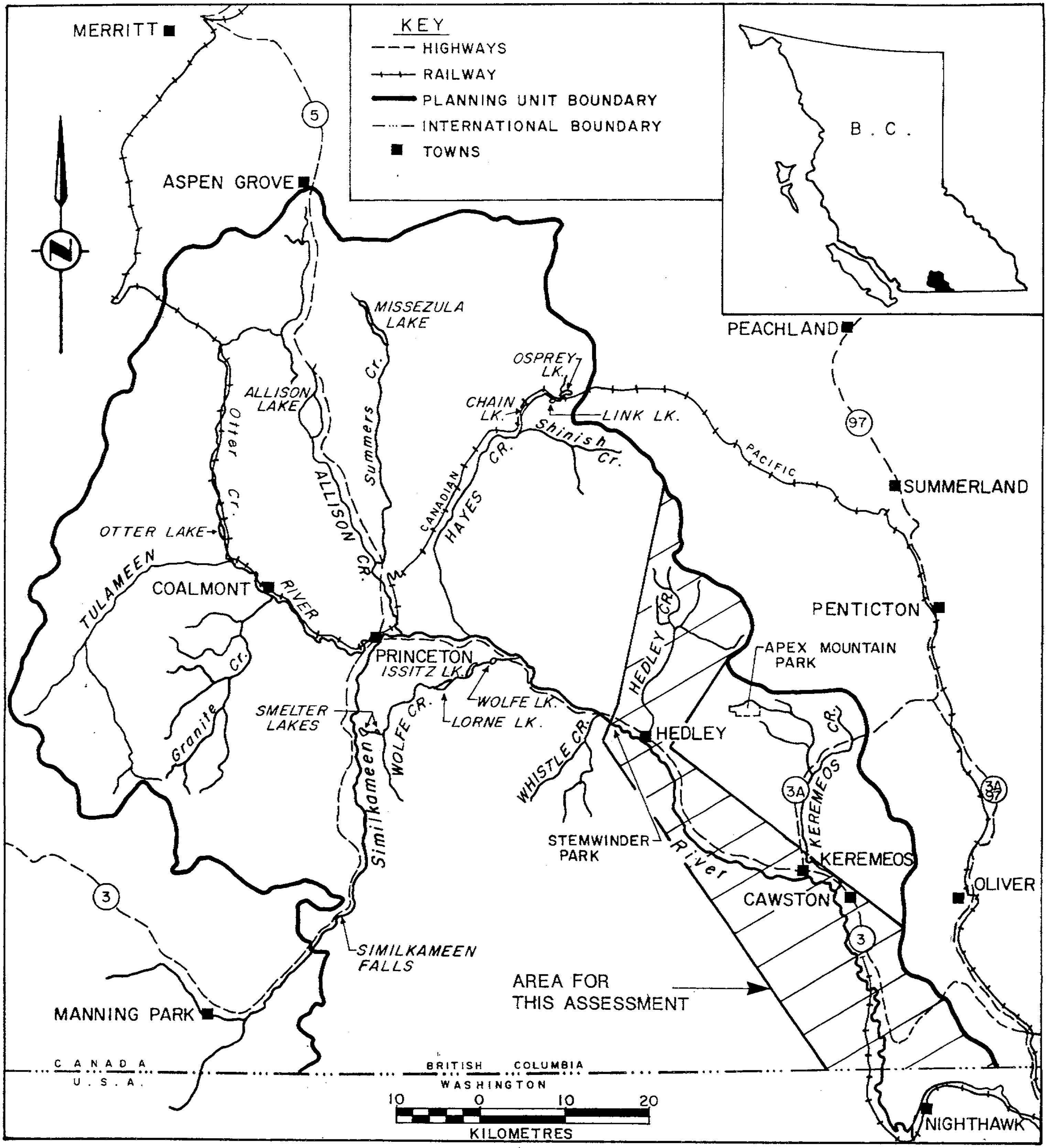


FIGURE 1: AREA OF SIMILKAMEEN RIVER AND HEDLEY CREEK DISCUSSED IN THIS ASSESSMENT

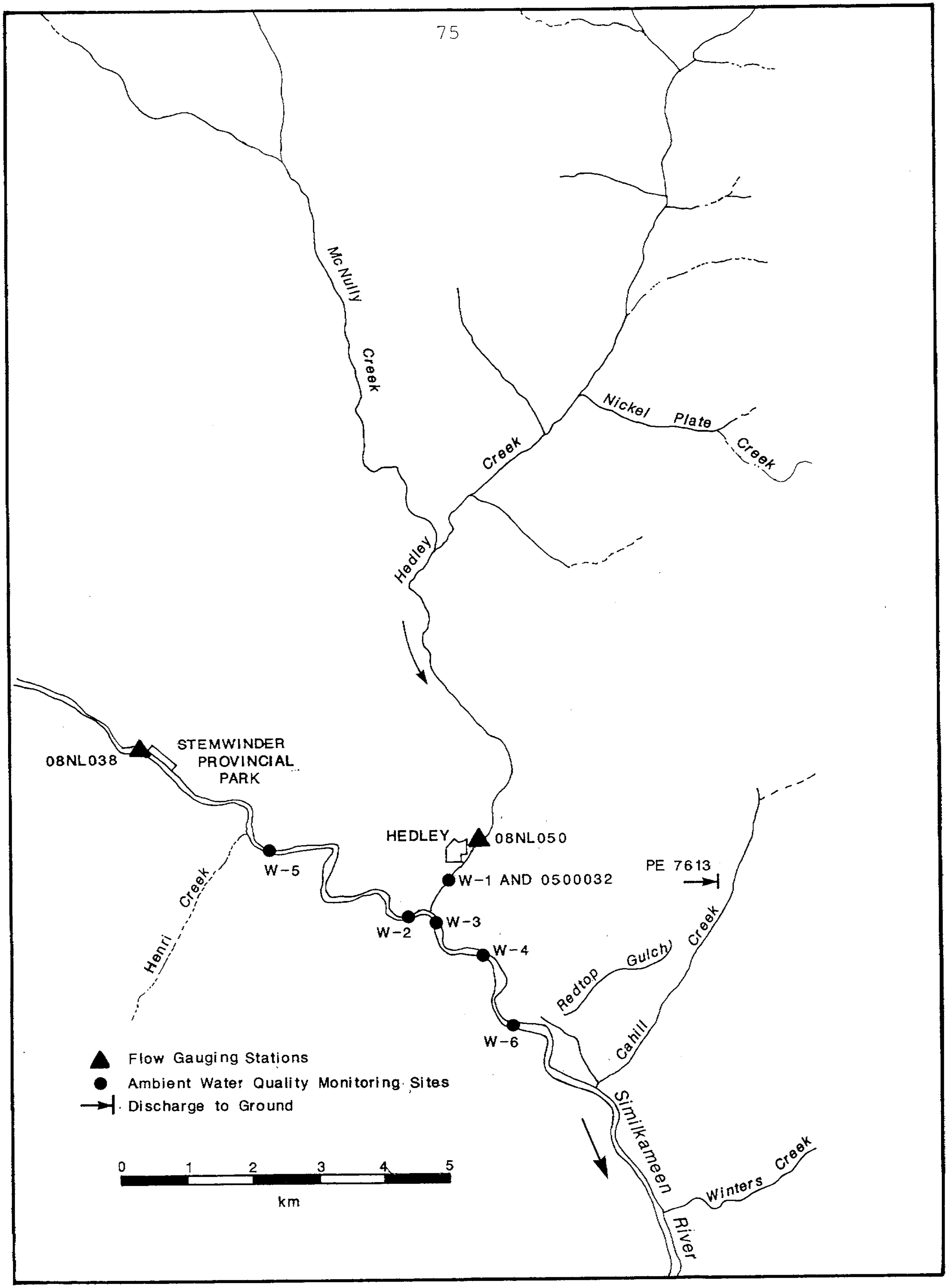
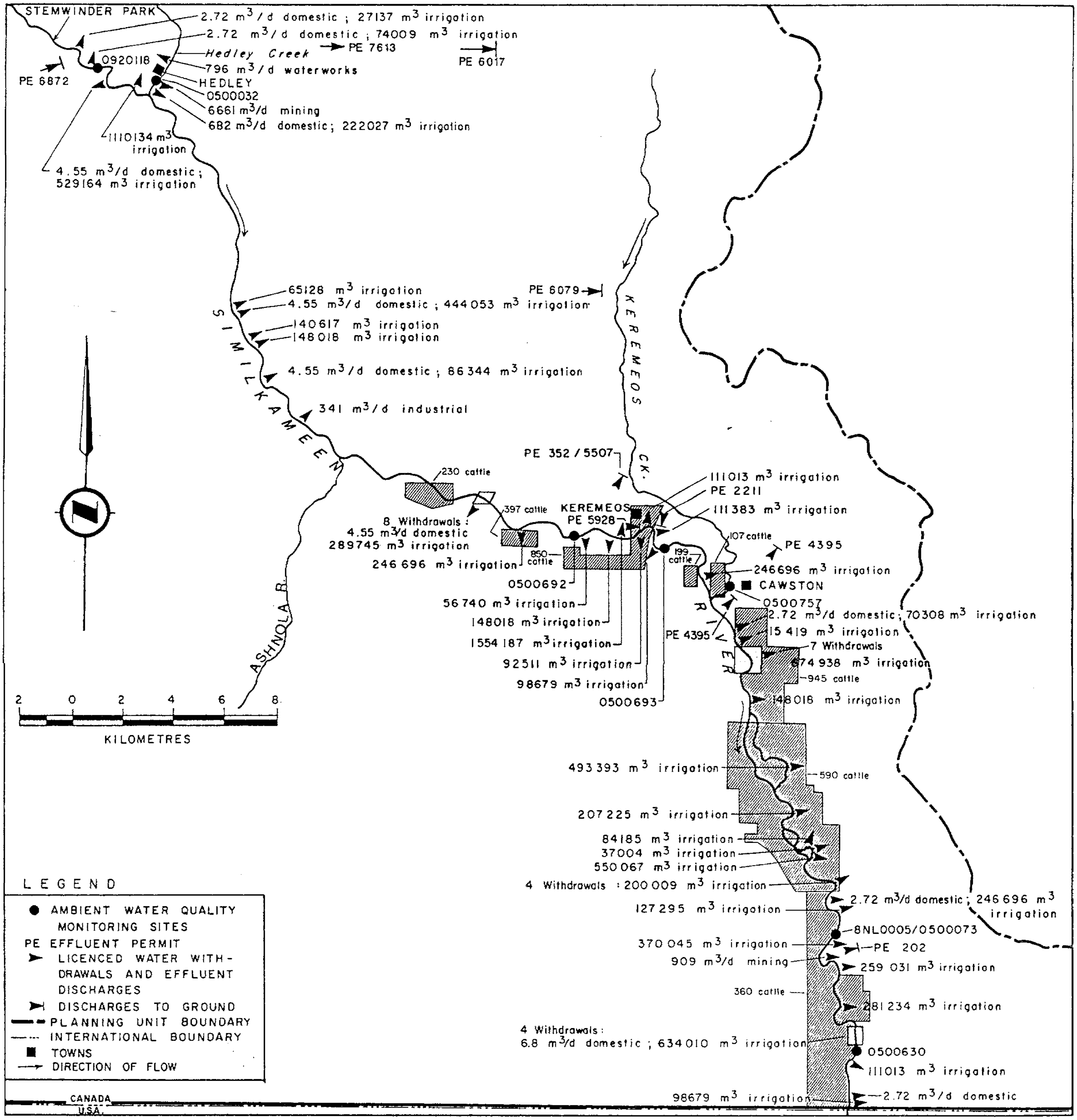


FIGURE 2: LOCATIONS OF FLOW MEASUREMENT STATIONS AND AMBIENT WATER QUALITY SITES

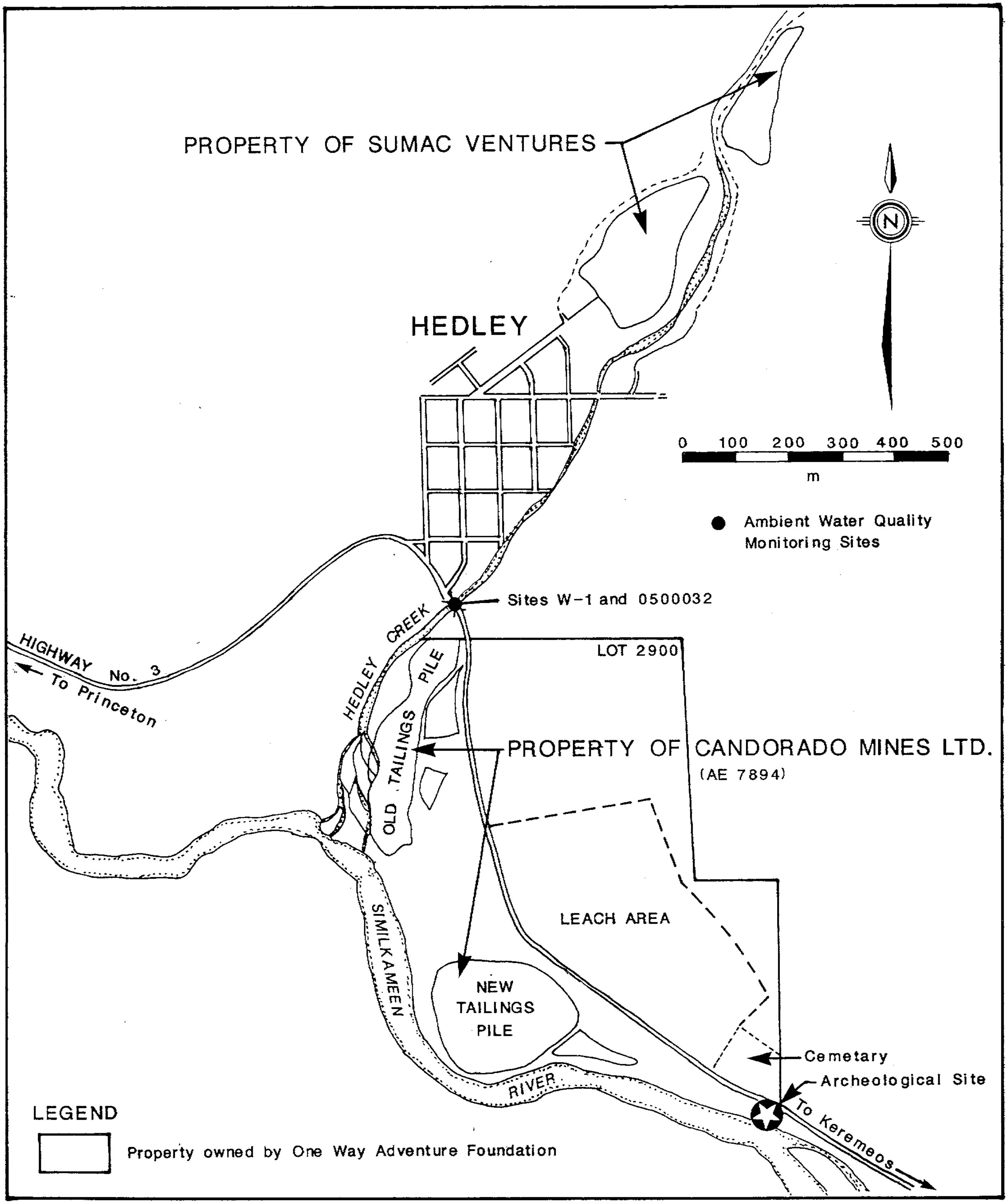
FIGURE 3:

LOCATIONS OF SITES DISCHARGING EFFLUENTS, AMBIENT WATER QUALITY MONITORING SITES AND LICENCED WATER WITHDRAWALS - SIMILKAMEEN RIVER, STEMWINDER PARK TO INTERNATIONAL BOUNDARY



AFTER FIGURE 14: REFERENCE 1.

FIGURE 4: LOCATION MAP OF SUMAC VENTURES AND CANDORADO MINES LTD. TAILINGS PILES



AFTER REFERENCE 3

TABLE 1
AMBIENT WATER QUALITY DATA SUMMARY
SITE 0500032 : HEDLEY CREEK AT HIGHWAY 3

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	18	49.5	9.8	23.5	10.9
BOD5	3	<10	<10	<10	-
Carbon-organic	20	14	1	6.6	4.15
Chloride	20	5.3	<0.5	0.92	1.10
Colour	17	50	5	21.2	17.4
Coliforms-fecal	4	5	<2	2+	-
Dissolved Oxygen	21	15.8	7.7	11.5	1.92
% Saturation of O2	20	118.9	54.4	95.3	-
Fluoride	12	0.11	<0.1	<0.1	-
Hardness-Calcium	21	23.6	2.9	7.5	4.52
-Magnesium	21	2.4	0.4	1	0.48
-Total	18	69	8.9	24.3	14.1
Metals :					
-Aluminum-Diss	3	0.03	<0.02	0.03+	-
-Arsenic-Diss	3	<0.25	<0.25	<0.25	-
-Barium-Diss	3	<0.01	<0.01	<0.01	-
-Boron-Diss	3	<0.01	<0.01	<0.01	-
-Cadmium-Diss	18	<0.01	<0.0001	<0.0005+	-
-Total	3	<0.0005	<0.0005	<0.0005	-
-Chromium-Diss	10	<0.01	<0.005	<0.005+	-
-Total	1	<0.005	-	-	-
-Cobalt-Diss	4	<0.1	<0.001	<0.1+	-
-Copper-Diss	18	<0.01	<0.001	0.004	0.004
- Total	3	0.01	<0.001	<0.001+	-
-Iron-Diss	16	0.3	0.07	0.14	0.074
-Total	3	4.39	0.1	1.6	2.45
-Lead-Diss	15	<0.1	<0.001	<0.001+	-
-Total	3	0.003	<0.001	0.001+	-
-Manganese-Diss	18	0.02	<0.01	<0.02+	-
-Total	3	0.13	<0.02	<0.02+	-
-Mercury-Total	12	<0.00005	<0.00005	<0.00005	-
-Molybdenum-Diss	6	<0.01	<0.0005	-	-
-Nickel-Diss	11	<0.05	<0.01	<0.01+	-
-Total	3	<0.01	<0.01	<0.01	-
-Zinc-Diss	18	0.07	<0.005	0.011	0.015
-Total	3	0.011	<0.005	0.005	-
Nitrogen					
-Ammonia	17	0.046	<0.005	0.010	0.010
-Kjeldahl	24	0.41	<0.01	0.12	0.088
-Nitrate	14	0.02	<0.02	-	-

TABLE 1 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Nitrite	23	<0.005	<0.005	<0.005	-
-Nitrate/ Nitrite	20	0.05	<0.02	0.023	0.009
-Organic	22	0.36	0.05	0.14	0.082
pH	29	7.9	7	7.6+	-
Phosphorus					
-Ortho Diss	10	0.004	<0.003	0.003	0.0003
-Total	29	0.156	<0.003	0.015	0.028
Potassium	18	5.3	0.3	0.98	1.14
Silica	21	17.8	10	14.3	1.99
Sodium	21	3.2	1.4	2.3	0.57
Solids-Suspended	21	104	0.7	7.7	22.33
-Total	21	164	44	68	32.4
Specific Conductivity	28	89	23	53	19
Sulphate	21	24.5	<5	6.2	4.25
Temperature	31	17	0.2	6.7	5.45
Turbidity	20	33	0.2	2.3	7.24

PERIOD OF RECORD : 1972 - 1982

+ Median Value

*All values are as mg/L except:
1) Coliforms as MPN/100mL
2) Colour as Colour units
3) % Sat as percent
4) pH
5) Specific Conductivity as uS/cm
6) Temperature as °C
7) Turbidity as NTU

DATA SOURCE :B.C. MINISTRY OF ENVIRONMENT
DATA RETRIEVAL SYSTEM

TABLE 2
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-1 : HEDLEY CREEK JUST U/S HIGHWAY 3 BRIDGE

CHARACTERISTIC	NUMBER OF VALUES	VALUES*			
		MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	11	39.9	3.24	19	11.1
Arsenic-Diss	11	0.024	<0.0001	0.0003	0.007
-Total	12	0.024	<0.0001	0.0028	0.0068
Chloride	10	0.5	<0.5	<0.5+	-
Cyanide-Total	12	0.009	<0.005	<0.005	-
-WAD	11	0.005	<0.005	<0.005	-
-Thiocyanate(CNS)	12	1.24	<0.5	<0.5	-
-Cyanate (CNO)	11	1.12	<0.5	<0.5	-
Hardness-Calcium	10	9.09	3.46	6.28	2.04
-Magnesium	10	1.44	0.54	0.92	0.31
-Total	11	28.6	11	19.4	5.59
Metals-Aluminum-Dis	10	0.11	0.010	0.049	0.031
-Total	11	0.34	<0.0001	0.077	0.096
-Barium-Diss	11	0.020	<0.005	0.010	0.005
-Total	11	0.020	<0.005	0.010	0.006
-Cadmium-Dis	11	<0.005	<0.0002	-	-
-Total	11	<0.005	<0.0002	-	-
-Chromium-Dis	11	0.019	<0.005	-	-
-Total	11	0.027	<0.005	-	-
-Cobalt-Diss	11	0.011	<0.001	<0.001	-
-Total	12	0.019	<0.001	<0.001	-
-Copper-Diss	11	0.018	<0.001	0.005	0.005
-Total	11	0.018	0.001	0.005	0.005
-Iron-Diss	11	0.10	<0.03	<0.03+	-
-Total	12	0.16	<0.03	<0.03+	-
-Lead-Diss	11	0.005	<0.001	<0.001+	-
-Total	11	0.007	<0.001	<0.001+	-
-Manganese-Dis	11	0.015	<0.005	<0.005+	-
-Total	11	0.026	<0.005	<0.005+	-
-Mercury-Diss	4	<0.0001	<0.00005	<0.00005+	-
-Total	12	0.00015	<0.00005	<0.00005+	-
-Molybdenum-D	11	<0.005	<0.001	<0.005+	-
-Total	11	<0.005	<0.001	<0.005+	-
-Nickel-Diss	11	<0.020	<0.001	<0.001+	-
-Total	11	0.033	<0.001	-	-
-Strontium-Dis	11	0.058	0.022	0.038	0.013
-Total	11	0.059	0.024	0.038	0.012
-Uranium-Diss	7	0.00043	<0.00005	0.00024	0.00014
-Total	12	0.15	<0.0005	0.0153	0.043
-Zinc-Diss	11	0.050	<0.005	<0.005+	-
-Total	11	0.050	<0.005	<0.005+	-

TABLE 2 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	11	0.023	0.001	<0.005+	-
-Nitrate	11	0.10	<0.003	<0.005+	-
-Nitrite	11	0.002	<0.001	<0.001+	-
pH	12	8.17	5.96	7.3+	-
Phosphorus-Total	11	0.11	<0.001	0.015	0.032
Potassium	11	1.01	0.38	0.55	0.17
Sodium	10	5.82	1.42	2.40	1.34
Solids-Dissolved	12	60	1.7	31.3	16.2
-Suspended	12	14.7	<1	2.8	3.92
Specific Conductivity	12	62	21	41	13
Sulphate	11	4	<1	<1+	-
Turbidity	12	1.4	<1	<1	-

PERIOD OF RECORD : 1986 - 1988

+ Median Value

*All values are as mg/L except:
1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 3
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-2 : SIMILKAMEEN RIVER 100 M U/S HEDLEY CREEK

CHARACTERISTIC	NUMBER OF VALUES	VALUES*			
		MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	8	140	25.6	63.9	39.5
Arsenic-Diss	8	0.053	0.0001	0.0087	0.0018
-Total	8	0.0065	0.0002	0.0029	0.0025
Cyanide-Total	8	<0.005	<0.005	<0.005	-
-WAD	8	<0.005	<0.005	<0.005	-
-Thiocyanate(CNS)	8	0.7	<0.5	<0.5+	-
-Cyanate (CNO)	8	<0.5	<0.5	<0.5	-
Hardness-Calcium	8	36.1	10.6	24.6	10.3
-Magnesium	8	7.1	1.94	4.38	1.88
-Total	8	119.3	34.5	79.4	33.2
Metals					
-Aluminum-Dis	8	0.066	0.006	0.021	0.021
-Total	8	0.71	0.008	0.128	0.239
-Barium-Diss	8	0.033	<0.005	0.023	0.010
-Total	8	0.036	0.02	0.028	0.007
-Cadmium-Dis	8	<0.005	<0.0005	<0.0005+	-
-Total	8	<0.005	<0.0005	<0.0005+	-
-Chromium-Dis	8	<0.010	<0.005	<0.005+	-
-Total	8	<0.010	<0.005	<0.005+	-
-Copper-Diss	8	<0.010	0.001	0.004+	-
-Total	8	<0.010	0.001	0.004+	-
-Iron-Diss	8	0.08	<0.03	<0.03+	-
-Total	8	0.48	<0.03	0.09	0.16
-Lead-Diss	8	0.003	<0.001	<0.001+	-
-Total	8	0.003	<0.001	<0.001+	-
-Manganese-Dis	8	<0.005	<0.005	<0.005	-
-Total	8	0.024	<0.0005	<0.005+	-
-Mercury-Diss	4	<0.0005	<0.0001	<0.0001+	-
-Total	8	0.00016	<0.00005	<0.0001+	-
-Molybdenum-D	8	<0.005	<0.001	<0.005+	-
-Total	8	<0.005	<0.001	<0.005+	-
-Nickel-Diss	8	<0.020	<0.001	<0.001+	-
-Total	8	<0.020	<0.001	<0.001+	-
-Strontium-Dis	8	0.23	0.066	0.15	0.062
-Total	7	0.22	0.10	0.16	0.049
-Uranium-Diss	4	0.00054	0.0001	0.00037	0.00019
-Total	8	0.10	0.0002	0.019	0.037
-Zinc-Diss	8	0.030	<0.005	<0.005+	-
-Total	8	0.030	<0.005	<0.005+	-

TABLE 3 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	8	0.043	<0.005+	<0.005+	-
-Nitrate	8	0.24	<0.005	0.097	0.10
-Nitrite	8	0.004	<0.001	<0.001+	-
pH	8	8.20	6.90	7.80+	-
Phosphorus-Total	8	0.093	<0.001	<0.005+	-
Potassium	8	1.14	0.44	0.84	0.29
Sodium	8	6.71	1.63	3.87	1.83
Solids-Dissolved	8	202	52.1	130	53.5
-Suspended	8	24.4	<1	5.5	8.1
Specific Conductivity	8	217	43.2	131	66.4
Sulphate	8	20.5	<1	9.8	7.7
Turbidity	8	18	<1	<1+	-

PERIOD OF RECORD : 1986 - 1987

+ Median Value

*All values are as mg/L except :
1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 4
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-3 : SIMILKAMEEN RIVER D/S HEDLEY CREEK

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	11	120	7.67	41.6	35.9
Arsenic-Diss	11	0.22	<0.0001	0.0265	0.068
-Total	10	0.22	0.0004	0.029	0.068
Chloride	9	2.67	<0.5	<0.5+	-
Cyanide-Total	10	0.007	<0.005	<0.005+	-
-WAD	10	<0.005	<0.005	<0.005+	-
-Thiocyanate(CNS)	10	1.94	<0.5	<0.5+	-
-Cyanate (CNO)	10	<0.5	<0.5	<0.5+	-
Hardness-Calcium	10	31.1	3.89	14.2	9.28
-Magnesium	10	6.0	0.53	2.34	2.02
-Total	10	102.3	11.1	45	31.4
Metals-Aluminum-Dis	10	0.68	0.006	0.092	0.21
-Total	11	0.24	<0.0001	0.049	0.067
-Barium-Diss	10	0.024	<0.005	0.011	0.007
-Total	10	0.036	<0.005	0.016	0.012
-Cadmium-Dis	10	<0.005	<0.0002	-	-
-Total	10	<0.005	<0.0002	-	-
-Chromium-Dis	10	0.013	<0.005	-	-
-Total	10	0.017	<0.005	-	-
-Cobalt-Diss	10	<0.01	<0.001	<0.001	-
-Total	11	0.018	<0.001	<0.001	-
-Copper-Diss	10	<0.01	<0.001	0.003+	-
-Total	10	<0.01	0.001	0.004	-
-Iron-Diss	10	0.07	<0.03	<0.03+	-
-Total	11	0.20	<0.03	<0.03+	-
-Lead-Diss	10	0.003	<0.001	<0.001+	-
-Total	10	0.004	<0.001	0.001+	-
-Manganese-Dis	10	<0.005	<0.005	<0.005+	-
-Total	11	0.007	<0.005	<0.005+	-
-Mercury-Diss	6	<0.0001	<0.00005	<0.00005+	-
-Total	10	0.0001	<0.00005	<0.00005+	-
-Molybdenum-D	10	<0.005	<0.001	<0.005+	-
-Total	10	<0.005	<0.001	<0.005+	-
-Nickel-Diss	10	0.026	<0.001	<0.001+	-
-Total	10	0.051	<0.001	<0.001+	-
-Strontium-Dis	10	0.26	0.026	0.105	0.082
-Total	10	0.28	0.026	0.099	0.089
-Uranium-Diss	6	0.00041	0.00015	0.00029	0.00009
-Total	11	0.10	<0.0005	0.0167	0.037
-Zinc-Diss	10	0.089	<0.005	<0.005+	-
-Total	10	0.03	<0.005	<0.005+	-

TABLE 4 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	10	0.009	<0.001	<0.005+	-
-Nitrate	10	0.20	<0.005	0.043	0.068
-Nitrite	10	0.002	<0.001	<0.001+	-
pH	11	8.2	5.92	7.82+	-
Phosphorus-Total	10	0.12	<0.001	<0.005	-
Potassium	10	1.06	0.36	0.64	0.24
Sodium	10	5.59	1.54	2.79	1.44
Solids-Dissolved	11	170	<1	55.4	52
-Suspended	11	12	<1	3.2	3.02
Specific Conductivity	11	202	14	71	60
Sulphate	10	133	<1	18.7	40.8
Turbidity	11	2.4	<1	<1+	-

PERIOD OF RECORD : 1986 - 1988

+ Median Value

*All values are as mg/L except:

1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 5
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-4 : SIMILKAMEEN RIVER D/S NEW TAILINGS PILE

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	8	139	25.6	66.9	42
Arsenic-Diss	8	0.0023	0.0006	0.0015	0.0006
-Total	8	0.0025	0.0007	0.0015	0.0006
Cyanide-Total	8	<0.005	<0.005	<0.005+	-
-WAD	8	<0.005	<0.005	<0.005	-
-Thiocyanate(CNS)	8	1.5	<0.5	<0.5+	-
-Cyanate (CNO)	8	<0.5	<0.5	<0.5	-
Hardness-Calcium	8	37.1	9.67	24.9	11.2
-Magnesium	8	7.61	1.77	4.78	2.29
-Total	8	123.9	31.4	81.9	37.1
Metals					
-Aluminum-Dis	8	0.11	0.007	0.034	0.035
-Total	9	0.66	<0.0001	0.105	0.212
-Barium-Diss	8	0.036	<0.005	0.023	0.011
-Total	8	0.041	0.017	0.030	0.010
-Cadmium-Dis	8	<0.005	<0.0005	<0.0005+	-
-Total	8	<0.005	<0.0005	<0.0005+	-
-Chromium-Dis	8	<0.010	<0.005	<0.005+	-
-Total	8	<0.010	<0.005	<0.005+	-
-Copper-Diss	8	<0.010	<0.001	0.004	0.003
-Total	8	<0.010	0.001	0.004	0.003
-Iron-Diss	8	0.09	<0.03	<0.03+	-
-Total	9	0.40	<0.001	<0.03	-
-Lead-Diss	8	0.002	<0.001	<0.001	-
-Total	8	0.002	<0.001	<0.001	-
-Manganese-Dis	8	<0.005	<0.005	<0.005	-
-Total	9	0.014	<0.0005	<0.005+	-
-Mercury-Diss	5	<0.0001	<0.00005	<0.00005+	-
-Total	8	0.00013	<0.00005	<0.00005+	-
-Molybdenum-D	8	<0.005	<0.001	<0.005+	-
-Total	8	<0.005	<0.001	<0.005+	-
-Nickel-Diss	8	<0.020	<0.001	<0.001+	-
-Total	8	<0.020	<0.001	<0.001+	-
-Strontium-Dis	8	0.24	0.026	0.15	0.076
-Total	8	0.24	0.064	0.16	0.07
-Uranium-Diss	4	0.00075	0.00031	0.00056	0.00018
-Total	9	0.10	0.0003	0.015	0.033
-Zinc-Diss	8	0.079	<0.005	<0.005	-
-Total	8	0.012	<0.005	<0.005+	-

TABLE 5 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	8	0.042	<0.001	0.062	0.145
-Nitrate	8	0.12	<0.003	0.027	0.04
-Nitrite	7	0.002	<0.001	<0.001+	-
pH	9	8.29	7.05	8.20+	-
Phosphorus-Total	8	0.10	<0.005	0.004	0.003
Potassium	8	1.20	0.47	0.89	0.30
Sodium	8	7.05	1.55	4.06	1.99
Solids-Dissolved	9	200	10.9	125.8	69.5
-Suspended	9	18.4	<1	6.2	5.95
Specific Conductivity	9	238	57.8	155	65
Sulphate	8	25.1	3.5	12.9	7.9
Turbidity	9	12	<1	<1+	-

PERIOD OF RECORD : 1986 - 1988

+ Median Value

*All values are as mg/L except :
1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 6
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-5 : SIMILKAMEEN RIVER 2.5 KM U/S HEDLEY CREEK

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	10	101	11.7	66.6	36.2
Arsenic-Diss	10	0.014	<0.0001	0.0018	0.0043
-Total	10	0.035	0.0001	0.0041	0.0109
Chloride	10	3.1	<0.5	1.82	1.21
Cyanide-Total	10	0.007	<0.005	<0.005	-
-WAD	10	<0.005	<0.005	<0.005	-
-Thiocyanate(CNS)	5	<0.5	<0.05	<0.5	-
-Cyanate (CNO)	10	<0.5	<0.5	<0.5	-
Hardness-Calcium	10	32.8	3.88	21.4	9.85
-Magnesium	10	6.94	0.6	4.18	2.23
-Total	10	109.5	12.2	70.5	33.5
Metals-Aluminum-Dis	5	0.045	0.007	0.025	0.017
-Total	5	0.037	0.005	0.019	0.013
-Barium-Diss	10	0.035	<0.005	0.022	0.009
-Total	10	0.038	0.011	0.027	0.009
-Cadmium-Dis	10	<0.005	<0.0002	-	-
-Total	10	<0.005	<0.0002	-	-
-Chromium-Dis	10	0.040	<0.010	0.024	0.013
-Total	10	0.049	<0.010	0.028	0.017
-Cobalt-Diss	10	<0.01	<0.005	<0.005	-
-Total	10	<0.01	<0.005	<0.005	-
-Copper-Diss	10	0.018	<0.005	0.010	0.006
-Total	10	0.019	<0.005	0.010	0.006
-Iron-Diss	10	0.084	0.008	0.03	0.02
-Total	10	1.18	0.014	0.17	0.36
-Lead-Diss	10	0.007	<0.001	<0.001+	-
-Total	10	0.003	<0.001	<0.001+	-
-Manganese-Dis	10	<0.005	0.001	-	-
-Total	11	0.026	<0.005	0.008	0.010
-Mercury-Diss	4	0.0007	<0.00005	<0.00005+	-
-Total	10	0.00007	<0.00005	<0.00005+	-
-Molybdenum-D	10	<0.005	<0.001	<0.005+	-
-Total	10	<0.005	<0.001	<0.005+	-
-Nickel-Diss	10	0.020	<0.010	<0.015+	-
-Total	10	0.051	<0.010	0.016	-
-Strontium-Dis	10	0.210	0.022	0.126	0.067
-Total	10	0.210	0.027	0.130	0.067
-Uranium-Diss	10	0.0008	<0.0004	0.00048	0.00026
-Total	10	0.001	0.00018	0.00059	0.00031
-Zinc-Diss	10	<0.005	<0.003	<0.005+	-
-Total	10	0.005	<0.005	<0.005+	-

TABLE 6 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	10	<0.02	<0.005	<0.005+	-
-Nitrate	10	0.11	<0.005	0.035	0.042
-Nitrite	10	0.001	<0.001	<0.001+	-
pH	10	8.45	6.10	7.83+	-
Phosphorus-Total	10	0.015	0.002	0.007	0.005
Potassium	10	1.01	0.44	0.73	0.22
Sodium	10	5.43	1.48	3.53	1.65
Solids-Dissolved	10	178	19.6	111	63.8
-Suspended	10	38	<1	7.8	11.5
Specific Conductivity	10	248	32	152	78
Sulphate	10	21.4	<1	11.7	7.03
Turbidity	10	21	<1	<1+	-

PERIOD OF RECORD : 1988

+ Median Value

*All values are as mg/L except:
1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 7
AMBIENT WATER QUALITY DATA SUMMARY
SITE W-6 : SIMILKAMEEN RIVER U/S RED TOP GULCH

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	9	101	33.6	72.6	31.9
Arsenic-Diss	9	0.0011	0.0005	0.0008	0.0002
-Total	9	0.008	0.0007	0.0018	0.0024
Cyanide-Total	9	<0.005	<0.005	<0.005+	-
-WAD	9	<0.005	<0.005	<0.005	-
-Thiocyanate(CNS)	5	<0.5	<0.5	<0.5+	-
-Cyanate (CNO)	9	<0.5	<0.5	<0.5	-
Hardness-Calcium	9	33.4	10.8	23.5	8.4
-Magnesium	9	6.81	1.89	4.51	1.9
-Total	9	110.7	34.7	77.2	28.5
Metals					
-Aluminum-Dis	5	0.05	0.007	0.024	0.018
-Total	5	0.046	0.007	0.025	0.014
-Barium-Diss	9	0.033	0.013	0.021	0.006
-Total	9	0.036	<0.005	0.024	0.012
-Cadmium-Dis	9	<0.005	<0.0002	<0.0002+	-
-Total	9	<0.005	<0.0002	<0.0002+	-
-Chromium-Dis	9	0.042	<0.01	<0.015+	-
-Total	9	0.071	<0.01	0.032	0.022
-Copper-Diss	9	0.015	<0.005	0.009	0.005
-Total	9	0.018	<0.005	0.010	0.006
-Iron-Diss	9	0.04	0.012	<0.03+	-
-Total	9	1.49	0.027	<0.03+	-
-Lead-Diss	9	0.003	<0.001	<0.001	-
-Total	9	0.002	<0.001	0.002	0.001
-Manganese-Dis	9	<0.005	0.001	<0.005	-
-Total	9	0.011	<0.005	<0.005+	-
-Mercury-Diss	4	<0.00005	<0.00005	<0.00005+	-
-Total	9	<0.00005	<0.00005	<0.00005+	-
-Molybdenum-D	9	<0.005	<0.001	<0.005+	-
-Total	9	<0.005	<0.001	<0.005+	-
-Nickel-Diss	9	0.070	<0.010	0.016+	-
-Total	9	0.078	<0.010	0.037	0.026
-Strontium-Dis	9	0.21	0.062	0.138	0.058
-Total	9	0.21	0.083	0.146	0.055
-Uranium-Diss	9	0.00077	0.00010	0.00046	0.00027
-Total	9	0.001	0.00016	0.00054	0.00036
-Zinc-Diss	9	0.008	<0.003	<0.005+	-
-Total	9	0.010	<0.005	<0.005+	-

TABLE 7 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Nitrogen					
-Ammonia	9	0.042	<0.005	<0.020+	-
-Nitrate	9	0.10	<0.005	0.033	0.03
-Nitrite	9	0.004	<0.001	<0.001+	-
pH	9	8.49	6.35	8.05+	-
Phosphorus-Total	9	0.01	0.002	0.007	0.003
Potassium	9	1.01	0.42	0.76	0.23
Sodium	9	5.61	1.91	3.84	1.59
Solids-Dissolved	9	181	46.1	121	59.6
-Suspended	9	32.7	<1	6	10.2
Specific Conductivity	9	248	80.3	167	70.3
Sulphate	9	18.7	5.4	12.6	5.5
Turbidity	9	20	<1	<1+	-

PERIOD OF RECORD : 1988

+ Median Value

*All values are as mg/L except :
1) pH
2) Specific Conductivity as uS/cm
3) Turbidity as NTU

DATA SOURCE : CanDorado Mines Ltd.

TABLE 8
AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF 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	.989	.976	.963	.952	.942	.932	.922	.914	.906	.899
8.2	.799	.788	.777	.768	.759	.751	.743	.736	.730	.724	.718
8.3	.636	.628	.620	.613	.606	.599	.594	.588	.583	.579	.575
8.4	.508	.501	.495	.489	.484	.479	.475	.471	.467	.464	.461
8.5	.405	.400	.396	.381	.387	.384	.380	.377	.375	.372	.370
8.6	.324	.320	.317	.313	.310	.308	.305	.303	.301	.300	.298
8.7	.260	.257	.254	.251	.249	.247	.246	.244	.243	.242	.241
8.8	.208	.206	.204	.202	.201	.200	.198	.197	.197	.196	.196
8.9	.168	.166	.165	.163	.162	.161	.161	.160	.160	.160	.160
9.0	.135	.134	.133	.132	.132	.131	.131	.131	.131	.131	.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	1.78	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.78	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	.970	.904

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
8.0	1.12	1.11	1.10	1.10	1.09	1.02	.944	.878	.818	.762
8.1	.893	.887	.882	.878	.874	.812	.756	.704	.655	.611
8.2	.714	.709	.706	.703	.700	.651	.606	.565	.527	.491
8.3	.571	.568	.566	.564	.562	.523	.487	.455	.424	.396
8.4	.458	.456	.455	.453	.452	.421	.393	.367	.343	.321
8.5	.369	.367	.366	.366	.365	.341	.318	.298	.278	.261
8.6	.297	.297	.296	.296	.296	.277	.259	.242	.227	.213
8.7	.241	.240	.240	.241	.241	.226	.212	.198	.186	.175
8.8	.196	.196	.196	.197	.198	.185	.174	.164	.154	.145
8.9	.160	.161	.161	.162	.163	.153	.144	.136	.128	.121
9.0	.132	.132	.133	.134	.135	.128	.121	.114	.108	.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 values in this Table .

TABLE 9
MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF 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	.871	.863	.856	.849	.844	.839	.836	.833	.832	.831	.831
9.0	.703	.697	.692	.683	.685	.682	.681	.681	.680	.681	.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	23.6	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

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
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	.832	.834	.838	.842	.847	.853	.861	.870	.880	.891
9.0	.684	.688	.692	.698	.704	.711	.720	.729	.740	.752

TABLE 10

CRITERIA FOR NITRITE FOR PROTECTION OF FRESHWATER AQUATIC LIFE

	Concentration (mg/L)	
Chloride	Maximum Nitrite	Average Nitrite
<2	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
>10	0.60	0.20

NOTE: The 30-d average chloride concentration should be used to determine the appropriate 30-d average nitrite concentration .

TABLE 11
AMBIENT WATER QUALITY DATA SUMMARY
SITE 0500073:SIMILKAMEEN RIVER AT CHOPAKA RD. BRIDGE

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	27	94.3	30.7	68.3	18.7
Arsenic-Extractable	75	0.0563	0.0004	0.0032	0.0076
-Total	3	0.002	0.001	0.0017	-
Chloride	97	2.9	0.6	1.5	0.41
Coliforms-Fecal	38	79	<2	5+	-
Colour	76	70	<5	9.8	10.47
Hardness-Calcium	98	33.3	9.35	24.2	7.08
-Magnesium	98	9.75	1.2	3.97	1.28
-Total	87	106	28.5	78.2	21.2
Metals:					
-Aluminum-Dis	23	0.12	<0.02	0.038	0.024
-Tot	3	0.17	<0.02	0.07	0.09
-Barium-Dis	23	0.04	0.01	0.025	0.007
-Boron-Dis	23	0.01	<0.01	<0.01	-
-Cadmium-Tot	78	<0.01	<0.0001	<0.001+	-
-Chromium-Tot	7	0.010	0.002	0.009	0.003
-Copper-Dis	23	0.01	<0.01	<0.01+	-
-Tot	79	0.072	<0.001	0.007	0.011
-Iron-Dis	23	0.1	<0.01	0.039	0.028
-Tot	79	29	<0.01	0.81	3.44
-Lead-Dis	23	<0.1	<0.1	<0.1+	-
-Tot	79	<0.1	<0.0007	<0.001+	-
-Manganese-Dis	23	0.53	<0.01	0.034	0.108
-Tot	79	0.54	0.003	0.028	0.07
-Mercury-Tot	70	0.00005	<0.00002	<0.00002+	-
-Molybdenum-D	23	0.03	<0.01	<0.01+	-
-Tot	4	<0.01	0.0016	0.006	0.005
-Nickel-Dis	23	<0.05	<0.05	<0.05	-
-Tot	7	<0.05	0.0005	<0.05+	-
-Zinc-Dis	23	0.03	<0.01	<0.01+	-
-Tot	79	0.243	<0.0003	0.009	0.028
Nitrogen					
-Ammonia	59	0.017	<0.005	<0.005	-
-Kjeldahl	25	0.26	<0.01	0.11	0.07
-Nitrate	22	0.11	<0.02	0.03	0.03
-Nitrite	25	<0.005	<0.005	<0.005	-
-Nitrate/ Nitrite	102	0.55	0.004	0.06	-
-Organic	22	0.26	<0.01	0.11	0.07
-Total	97	0.6	0.02	0.14	-

TABLE 11 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Oxygen-Dissolved	16	14.2	8.7	12	1.5
pH	160	8.3	6.53	7.8+	-
Phosphorus					
-Ortho Diss	1	0.075	-	-	-
-Total Diss	56	0.139	<0.003	0.018	0.035
-Total	103	1.048	<0.002	0.049	0.129
Potassium	99	4.1	0.4	0.86	0.38
Sodium	99	16.8	1.5	3.93	1.61
Solids-Dissolved	8	121	45	73.6	22.2
-Suspended	40	680	<1	51.4	141.6
Specific Conductivity	139	267	60.6	165	48.2
Sulphate	103	21.4	3.4	14.1	5.04
Temperature	99	20	-0.5	7.4	5.8
Turbidity	103	140	0.2	4.4	15.3

PERIOD OF RECORD : 1983 - 1988

+ Median Value

*All values are as mg/L except:

1) Coliforms as MPN/100mL
2) Colour as Apparent Colour units
3) pH
4) Specific Conductivity as uS/cm
5) Temperature as °C
6) Turbidity as NTU

DATA SOURCE :B.C. MINISTRY OF ENVIRONMENT AND ENVIRONMENT CANADA DATA RETRIEVAL SYSTEM

TABLE 12
AMBIENT WATER QUALITY DATA SUMMARY
SITE 0500073:SIMILKAMEEN RIVER AT CHAPOKA RD (DATA TO 1983)

CHARACTERISTIC	NUMBER OF VALUES	VALUES* MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Alkalinity	24	105	28.3	63.5	22.03
Arsenic-Dis	4	<0.05	<0.005	-	-
Carbon-Organic	20	9	<1	4.02	2.76
Chloride	23	2.2	0.6	1.05	0.39
Coliforms-Fecal	6	130	<2	3.5+	-
Colour	21	30	<5	11.1	8.43
Cyanide-Tot	1	<0.01	-	-	-
Fluoride	13	<0.1	<0.1	<0.1	-
Hardness-Calcium	29	38	9.1	21.1	7.96
-Magnesium	27	6	1.6	3.4	1.29
-Total	22	120	29.3	68	26.7
Metals :					
-Aluminum-Dis	4	0.04	<0.02	0.03	0.0082
-Boron-Dis	3	<0.01	<0.01	<0.01	-
-Cadmium-Dis	24	<0.01	0.0002	<0.0005+	-
-Tot	2	<0.01	<0.0005	-	-
-Chromium-Dis	12	<0.01	<0.005	-	-
-Tot	1	<0.005	-	-	-
-Copper-Dis	25	0.11	<0.001	0.009	0.022
-Tot	3	<0.01	<0.001	0.004+	-
-Iron-Dis	27	0.44	0.01	0.09	0.089
-Tot	2	0.8	0.05	0.42	-
-Lead-Dis	20	<0.1	<0.001	-	-
-Tot	3	<0.1	0.001	<0.003+	-
-Manganese-Dis	25	0.04	<0.01	<0.01	-
-Tot	3	0.03	<0.01	<0.01	-
-Mercury-Tot	13	<0.00005	<0.00005	<0.00005	-
-Molybdenum-D	8	0.01	<0.0005	0.007	0.005
-Nickel-Dis	18	<0.05	<0.01	-	-
-Tot	2	<0.05	<0.01	-	-
-Zinc-Dis	22	0.08	<0.005	0.013	0.017
-Tot	3	<0.01	<0.005	0.006+	-
Nitrogen					
-Ammonia	24	0.028	<0.005	0.010	0.006
-Kjeldahl	30	0.38	0.02	0.14	0.097
-Nitrate	19	0.07	<0.02	0.03	0.015
-Nitrite	27	0.017	<0.005	0.005	0.0023
-Nitrate/ Nitrite	24	0.13	<0.02	0.04	0.026
-Organic	27	0.6	0.02	0.16	0.13

TABLE 12 (CONTINUED)

CHARACTERISTIC	NUMBER OF VALUES	VALUES MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Oxygen-Dissolved	29	14.5	5.8	10.9	1.84
pH	30	8.2	7.2	7.9+	-
Phosphorus					
-Ortho Diss	15	0.015	<0.003	0.005	0.004
-Total	35	0.331	0.004	0.044	0.08
Potassium	24	2.7	0.6	0.96	0.51
Silica	23	14.4	7.4	10.6	1.92
Sodium	24	5.9	2.1	3.5	1.04
Solids-Dissolved	3	130	62	106.7	38.7
-Suspended	25	267	1	41.4	79.2
-Total	25	3722	68	144.5	73.8
Specific Conductivity	59	250	59	145.5	50.8
Sulphate	27	28.7	<5	12.9	6.27
Temperature	39	19	0	7.5	5.34
Turbidity	17	55	0.4	6.3	13.8

PERIOD OF RECORD : 1972 - 1982

+ Median Value

*All values are as mg/L except:

1) Coliforms as MPN/100mL
2) Colour as Colour units
3) pH
4) Specific Conductivity as uS/cm
5) Temperature as °C
6) Turbidity as NTU

DATA SOURCE :REFERENCE 1 (FROM B.C. MINISTRY OF ENVIRONMENT DATA RETRIEVAL SYSTEM)

TABLE 13

VARIATIONS IN AQUATIC LIFE CRITERIA FOR FISH/SHELLFISH WHEN THE DIET IS BASED PRIMARILY ON FISH

Concentration of Total Hg in edible portion of fish and shellfish (ug Hg/g wet wt.)	Safe quantity for weekly consumption on regular basis (g wet wt.)
0.5	210
0.4	260
0.3	350
0.2	525
0.1	1 050

APPENDIX 1

CONSIDERATIONS IN THE USE OF AN ARBITRARY 20% INCREASE FROM UPSTREAM TO DOWNSTREAM FOR WATER QUALITY OBJECTIVES

When it is known in the setting of Water Quality Objectives that values at sites upstream from a second site may exceed a Water Quality Objective , an allowable percentage increase at the downstream sites has been used in British Columbia as a means to ensure that significant increases do not occur at the downstream locations . This allows a Water Quality Objective to continue in effect at the downstream location on such occasions .

Generally , the percentage increase has been defined as a 20% increase , in an attempt to identify occasions when a significant increase in the concentration of a particular characteristic has occured . The 20% figure has generally been applied to increases in characteristics such as metals , which have low values (ng/L) and for which analytical precision and accuracy are not high at such low levels . In the case of percentage increase for turbidity and suspended solids , the question of analytical precision and accuracy at lower levels has been addressed in the Water Quality Criteria by the use of increases in the absolute concentration rather than by the use of percentage increases (e.g., a 10 mg/L increase when concentrations are less than 100 mg/L) . Percentage increases apply at higher background levels .

Regardless of the percentage applied , the intent of such Objectives is to convey the intent that no significant change in concentrations should occur , while taking into account that differences in concentrations can result from any number of factors , including but not limited to , sample collection and analysis , or an anthropogenic source . The question that remains is to determine whether statistical methods should be applied to indicate a significant difference , or whether the arbitrarily derived percentage increase is sufficient .

Traditionally , statistical significance for mean values has been measured using Student's "t" tests and F test procedures . In British Columbia , Water Quality Objectives are normally checked by taking five samples in a thirty day period (i.e. once a week for five consecutive weeks) . This frequency of sample collection is a practical one from the viewpoint of cost when considering the large number of sites at which Objectives must be checked in the province .

1.0 APPLICABILITY FOR SMALL DATA SETS

In order to determine if a 20% increase is too lenient from a scientific basis , the equations used in the Student's "t" test and the F test statistical procedures were manipulated .

The "t" value is calculated as follows :

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{Sd} \quad ..... (1)$$

For five samples collected at each of an upstream (Site 1) and downstream site (Site 2) , the total number of degrees of freedom are 8 . The associated "t" value at the 95% confidence level is 2.306 . Therefore , a value of 2.307 will be chosen to illustrate an occasion when the "t"test indicates failure .

The term Sd is defined as follows :

$$Sd = Sc\ [N_1^{-1} + N_2^{-1}] \quad .....(1a)$$

When the usual number of samples (5) collected at each site is considered , the equation is simplified to :

$$Sd = Sc\ [0.4]^{0.5}$$

$$= 0.6324555\ Sc$$

Substitution of this into equation (1) yields the following:

$$2.307 = \frac{|\bar{X}_1 - \bar{X}_2|}{0.6324555\ Sc}$$

Re-arrangement of the terms yields the following expression for Sc :

$$Sc = \frac{|\bar{X}_1 - \bar{X}_2|}{1.4590748}$$

In the normal calculation of Sc in the "t" test , the following equation is used :

$$Sc = \left[\frac{(N_1-1)\sigma_1^2 + (N_2-1)\sigma_2^2}{(N_1-1) + (N_2-1)} \right]^{1/2}$$

Therefore , when five samples are collected (n=5) at each site , or as in our situation , when an equal number of samples are collected at both the upstream and downstream sites ,

$$Sc = [(\sigma_1^2 + \sigma_2^2)/2]^{0.5} \qquad .....(1b)$$

Equating the two previous expressions for Sc yields :

$$\frac{| \bar{X}_1 - \bar{X}_2 |}{1.4590748} = \left[\frac{\sigma_1^2 + \sigma_2^2}{2}\right]^{1/2} \qquad .....(2)$$

In order that a Student's "t" test be used , normal distribution of the data must be assumed and the F test (which indicates that the variability of the two data sets are similar) must be passed . There are two extremes to passing the F test, passing when the calculated F value is just below the cutoff value for a certain number of degrees of freedom , and passing by an extremely high margin .

1.1 <u>CASE 1 : JUST PASSING THE F-TEST</u>

At the 95% confidence level , for the usually small data sets considered in checking Objectives in British Columbia , failure is indicated (4 degrees of freedom in each data group) at a level of 5.19 . Therefore , a value of 5.18 will be assumed. The F statistic is calculated from :

$$F\ cal = \frac{\sigma_2^2}{\sigma_1^2} \qquad .....(3)$$

Thus ,in this case , $\sigma_2^2 = 5.18\sigma_1^2$.....(3a)

and , $\sigma_2 = 2.28\sigma_1$ .....(3b)

Substitution of equation (3a) into equation (2) yields the following expression for the standard deviation in terms of the absolute difference of the mean values :

$$\sigma_1 = 0.389891 \, | \bar{X}_1 - \bar{X}_2 | \qquad .....(4)$$

What this expression tells us is that in real life , the standard deviation at the upstream site is approximately one-third the difference in mean values going from upstream to downstream .

Downstream values must be higher than upstream values , or there would be no concern about applying the percentage increase . A number of values often seen for the standard deviation of metal values will be considered as examples.

SITUATION 1 : $\sigma_1 \simeq \bar{X}_1$

Using equation (4) , substituting terms , and realizing that the downstream value is greater than the upstream value , yields:

$$\bar{X}_1 = 0.389891 \; (\bar{X}_2 - \bar{X}_1)$$

or,

$$\bar{X}_2 = 3.56 \; \bar{X}_1$$

Thus , in this situation , the mean value at the downstream site is over 300 % greater than the mean value at the upstream site .

SITUATION 2 : $\sigma_1 \simeq 0.5 \; \bar{X}_1$

Using the same techniques as were used in situation 1 ,

$$\bar{X}_2 = 2.28 \; \bar{X}_1$$

or , the mean value at the downstream site is over 200 % greater than the mean value at the upstream site .

SITUATION 3: 20 % increase over upstream values

For the presently used 20 % increase going from upstream to downstream sites ,

$$\bar{X}_2 = 1.2 \; \bar{X}_1$$

$$0.389891 \; \bar{X}_2 = 0.4678692 \; \bar{X}_1$$

$$0.389891 \; (\bar{X}_2 - \bar{X}_1) = 0.0779782 \; \bar{X}_1$$

That is to say that the standard deviation at Site 1 is only 7.8% of the mean value . Thus for five samples , a very small standard deviation at the upstream site would be necessary to measure a 20% increase statistically . The standard deviation at Site 2 would be 2.28 times higher , or 17.8 % of the downstream mean value . Such small standard deviations are seldom encountered in data sets for metals in rivers .

1.2 CASE 2 : PASSING THE F-TEST BY A HIGH MARGIN

For situations where the F test is passed with great ease (i.e. values surrounding the mean value at one site , say the downstream site , are all very close to the mean), a value of 0.01 has been assumed for the F value in equation (3) . Substitution into equations (2) and (3) leads to the following relationship :

$$\sigma_1 = 0.9644434 \, | \bar{X}_1 - \bar{X}_2 | \qquad .....(5)$$

This expression is telling us that the standard deviation of the data at the upstream site is very nearly equal to the absolute difference between the mean values for the upstream and downstream sites .

The ramifications of this equation must be considered . If the standard deviation at the upstream site is very close to , or equal to the mean value at this site , the mean value at the downstream site would either have to be approximately twice that at the upstream site or very close to zero for the equation to be valid . However , if the mean value at the downstream site were zero , we would have no concern . Therefore , when the standard deviation is approximately the mean value for the upstream site , this equation tells us that the mean value at the downstream site would have to be twice the upstream value , <u>or an increase of 100% from upstream !</u> As previously stated , small standard deviations are seldom encountered in data sets for metals in rivers .

The other possibility is that the standard deviation at the upstream site is very large in comparison to the mean value at the same site . In such a case , the mean value at the downstream site would have to be extremely large (certainly greater than the 100% increease previously cited) to have this relationship hold true .

The case of a 20 % increase can be considered to determine the relevance of this situation .

$$\bar{X}_2 = 1.2 \, \bar{X}_1$$

Substitution of this term into equation (5) leads to the following expression :

$$\sigma_1 = 0.1928887 \, \bar{X}_1$$

This expression , in a real life situation , means that if the mean value at the upstream site is 0.008 mg/L , the standard deviation of the mean will be 0.0015 mg/L , or smaller . In this case , the standard deviation at the downstream site would be 0.000015 mg/L .

1.3 CONCLUSIONS

The 20% increase allowed by the Water Quality Objectives for small data sets (n = 5) is very restrictive relative to what would be permitted if statistical techniques were applied to determine occasions when no significant increase occurred .

2.0 APPLICABILITY FOR LARGE DATA SETS

Two cases where more than five samples are collected in a monthly period will be considered . The Objectives indicate that a minimum of five samples collected on a weekly basis are needed to calculate mean values . Case (1) will be where samples are collected twice per week (n = 10 at each site) . Case (2) will be where samples are collected daily (n = 30 at each site) .

2.1 CASE 1 : SAMPLING TWICE PER WEEK (n = 10)

For this case , equation (1a) becomes :

$$Sd = Sc \; [\; 1/10 + 1/10 \;]^{0.5}$$

$$Sd = 0.4472136 \; Sc$$

Substitution into equation (1) for 18 degrees of freedom , knowing that the "t" value to just pass is 2.101 , and assuming that failure occurs at a "t" of 2.102 , yields

$$2.102 = \frac{| \bar{X}_1 - \bar{X}_2 |}{0.4472136}$$

$$Sc = 1.0637811 \; | \bar{X}_1 - \bar{X}_2 |$$

Using the relationship of equation (1) leads to :

$$[(\sigma_1^2 + \sigma_2^2)/2]^{0.5} = 1.0637811 \; | \bar{X}1 - \bar{X}2 | \quad .....(6)$$

For the F-test to be passed , a calculated F value for 9 degrees of freedom in each data set could not exceed 3.18 . If a value of 3.17 is assumed , equation (3a) becomes :

$$\sigma_2^2 = 3.18\,\sigma_1^2 \qquad .....(7)$$

Substitution into equation (6) yields :

$$\sigma_1 = 0.7358328 \, | \bar{X_1} - \bar{X_2} | \qquad .....(8)$$

Thus , the standard deviation at the upstream site is equal to almost three-quarters of the difference in the mean values for the two sites . In checking attainment of Water Quality Objectives , the only concern occurs if the mean value at the downstream site exceeds the mean value calculated at the upstream site . Once again , a number of examples will be considered .

SITUATION 1 : $\sigma_1 \sim \bar{X_1}$

Using equation (8) and substituting terms , yields the following relationship :

$$\bar{X_2} = 2.36\,\bar{X_1}$$

For times when the value of the standard deviation at the upstream site is about the same value as the mean value at the same site , which often occurs in real data sets , the mean value at the downstream site would be over 200 % greater than the mean value at thew upstream site .

SITUATION 2 : $\sigma_2 \sim 0.5\,\bar{X_1}$

Using the same techniques as were used for Situation 1 , the relationship between the mean values for the upstream and downstream sites becomes :

$$\bar{X_2} = 1.2\,\bar{X_1}$$

This shows that the mean value calculated at the downstream site will still have to be over 100 % of that found at the upstream site . A standard deviation which is one-half the mean value is also a value which often occurs in real sets of data .

SITUATION 3 : 20 % INCREASE OVER UPSTREAM VALUES

The Water Quality Objectives presently use a maximum increase from upstream to downstream to indicate when significant increases have occurred . What does this mean in terms of the F-test and Students "t" test statistical procedures ?

$$\overline{X}_2 = \overline{X}_1$$

Equation (8) can be written in the following form to take into account that the mean value at the downstream site is greater than the mean value at the upstream site .

$$\sigma_1 = 0.7358328 \; (\overline{X}_2 - \overline{X}_1)$$

$$= 0.1471666 \; \overline{X}_1$$

This means that the standard deviation at the upstream site is only 14.7 % of the mean value . If the mean value is 0.008 mg/L , the standard deviation would be 0.0012 , a value seldom seen in real data sets .

Using equation (7) , the standard deviation at the downstream site is calculated to be :

$$\sigma_2 = 0.2624356 \sigma_1$$

Thus , the standard deviation at the downstream site is only one-quarter of the standard deviation at the upstream site . In the case where the value upstream is 0.0012 , the value downstream is 0.0003 .

These standard deviations are so small that they are not usually encountered .

2.2 CASE 3 : DAILY SAMPLING (n=30)

For this case , equation (1) becomes :

$$Sd = Sc \; [\; 1/30 + 1/30 \;]^{0.5}$$

$$= 0.2581989 \; Sc$$

Substitution into equation (1) for 58 degrees of freedom , a "t" value for failure above 2.002 , and assuming failure occurs at 2.003 :

$$2.003 = \frac{| \overline{X}_1 - \overline{X}_2 |}{0.2581989}$$

$$Sc = 1.9335912 \mid \bar{X}_1 - \bar{X}_2 \mid$$

Using the relationship of equation (1b) yields :

$$\left[\frac{\sigma_1^2 + \sigma_2^2}{2} \right]^{1/2} = 1.9335912 \mid \bar{X}_1 - \bar{X}_2 \mid \quad ...(9)$$

For the F-test to just be passed , the calculated F value for 29 degrees of freedom in each data set could not exceed 1.86 . Therefore , a value of 1.85 is assumed . Equation (3a) becomes :

$$\sigma_2^2 = 1.85\sigma_1^2 \quad .....(10)$$

When substituted into equation (9) ,

$$\sigma_1 = 1.6197845 \mid \bar{X}_1 - \bar{X}_2 \mid \quad .....(11)$$

Thus , the standard deviation at the upstream site is over one and one-half times the difference in the mean values for the two sites . In checking attainment of Water Quality Objectives , there is only a concern if the mean value at the downstream site is greater than the mean value at the upstream site .

<u>SITUATION 1 : $\sigma_1 \sim \bar{X}_1$</u>

Using equation (11) ,

$$\bar{X}_2 = 1.62 \bar{X}_1$$

In this case , the mean value at the downstream site is over one and one-half times larger than the mean value at the upstream site .

<u>SITUATION 2 : $\sigma_2 \sim 0.5 \bar{X}_1$</u>

Using the same techniques as were used earlier ,

$$\bar{X}_2 = 1.31 \bar{X}_1$$

In this case , the mean value at the downstream site is about 130% of the mean value at the upstream site .

SITUATION 3 : 20 % INCREASE OVER UPSTREAM VALUES

In this situation ,

$$\bar{X}_2 = 1.2\ \bar{X}_1$$

Using equation (11) ,

$$\sigma_1 = 1.6197845\ |\ \bar{X}_1 - \bar{X}_2\ |$$

Substitution yields

$$\sigma_1 = 0.3239569\ \bar{X}_1$$

What this indicates is that the standard deviation at the upstream site is only about 30 % of the mean value , a very small deviation for ambient monitoring , but one which can occasionally be found .

Using equation (10) ,

$$\sigma_2^2 = 1.85\ \sigma_1^2$$

$$\sigma_2 = 1.36\sigma_1$$

Thus , the standard deviation at the downstream site would be approximately 40 % of the upstream mean value , or about 35 % of the mean value at the downstream site . Once again , this would be considered a very small standard deviation for ambient water quality monitoring , but one which can be found on occasion .

2.3 CONCLUSIONS

The previous examples have shown that the 20 % increase presently used by British Columbia in allowing increases in certain water quality characteristics in going from upstream to downstream of a discharge or series of discharges , when considered for small data bases , will be more restrictive a definition for "no significant increase at a 95 % confidence level" than if the determination of a significant increase were based upon statistical methods (F and Student's "t" tests) . Only when samples are collected on a daily basis (n=30) during a one month period do the two methods of determining a " significant increase " compare .

This analysis has verified that when the attainment of Water Quality Objectives is to be determined in situations where upstream values exceed numerical concentrations , that the data sets must be assessed by experienced professionals who can judge if increases noted in a system are possibly " real " (if these can possibly be related to a variable such as flow, or related to a waste discharge) , or simply aberrations related to sampling or analysis techniques .