MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA

FINLAY-OMINECA AREA
UPPER FINLAY SUB-BASIN
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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March, 1986

ACKNOWLEDGEMENTS

Thanks are due to the following for supplying data and information: Du Pont of Canada Exploration Limited, Ker Priestman and Associates Limited, Health and Welfare Canada, Waste Management Branch and Planning and Assessment Branch. The assistance of the following Water Management Branch staff is acknowledged: Roland Rocchini and Larry Pommen for editing, Georgie Rhodes and Lorna Rounds for typing, and Rachel Mackie for draughting.

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1. INTRODUCTION

Several water quality issues in the Finlay-Omineca Planning Area were reviewed and priorized for further detailed assessment (Figure 1). Three areas (the Upper Finlay, Lower Finlay and the Mackenzie area) were selected for detailed water quality assessments. This report is the technical appendix to the summary report of the same title (Kangasniemi 1986). The Upper Finlay sub-basin is defined as the drainage area upstream from the community of Ware, which is located in the northern portion of the planning unit (Figure 2).

This report is an assessment of water quality information available up to December 1982 for the Upper Finlay Sub-basin. The goal of this assessment was to identify the water quality problems which existed, and to make recommendations concerning their management. The major water quality problems in the study area were associated with the operation of a gold/silver mine and cyanidation mill known as the Baker Mine. The mine operated from 1981 until its closure in 1983. Receiving water quality objectives are proposed to protect designated water uses should the mill be reactivated.

Water quality objectives are developed on a site specific basis taking into account generally accepted criteria, background water quality, waste discharges and other water uses. The objectives proposed in this report are to be considered provisional, as they are subject to change as new information from research and monitoring programs becomes available.

2. HYDROLOGY

The Upper Finlay Sub-basin drains 11 100 km^2 mainly including portions of the Skeena Mountains, Spatsizi Plateau, Omineca Mountains and the Rocky Mountains. The unit runoff of 546 mm is typical of unit runoff from other drainage areas west of the Rocky Mountain Trench within the Finlay-Omineca Unit. Unit runoff from the eastern slope is considerably higher.

The Finlay River has its source in Tatlatui Park and the Thutade Lake watershed, and flows across the sub-basin in a north-easterly and easterly direction. It leaves the sub- basin at Ware and then flows south into the north end of Williston Lake (Figure 2). Some tributaries of the Upper Finlay which are of interest include the Sturdee River, Toodoggone River, Bower Creek, Carcajou Creek and Jock Creek (Figure 3).

A continuous recorder flow gauge was located on the Finlay River at Ware (station 07EA001) until 1983. Three ungauged sites have been proposed as additions to an expanded hydrometric network, two on a tributary to Bower Creek and one on Carcajou Creek (Figure 3) (Obedkoff, 1982).

3. WATER USES

The Upper Finlay Sub-basin is largely undeveloped wilderness. Presently, there is no road access, although two roads have been proposed. One road would provide access to the Sturdee River (Figure 3) (R.A.B. 1978), and another would provide access to Ware. More recently SEREM Inc. has re-activated the Sturdee River road proposal which would involve a road from the Moose Valley to the Lawyers Project mine located on Attorney Creek.

The only licenced water user in the sub-basin was a gold and silver mine and mill known as the Baker Mine, which was operated by Du Pont of Canada Exploration Ltd. until it was shut down in November 1983. The mill could be re-activated depending on the results of further exploration and the feasibility of processing ore from other potential mines. The Baker Mine is located in an alpine cirque, which drains into the Toodoggone River via Galen and Jock Creeks (Figures 3,4). The water requirement for the mill and for domestic use was about 90 m^3/d which was drawn from Galen Creek upstream from the mine.

The proposed Sturdee Road will link the Toodoggone and Sturdee River valleys with Germansen Landing, providing access from Fort St. James (R.A.B. 1978). This will encourage further mineral exploration and the development of claims in this highly mineralized area. The majority of mineral resource development in the Finlay-Omineca area is likely to occur in the Toodoggone River drainage, based on present knowledge of mineralization. An area on the Toodoggone River is already designated for placer mining (Figure 3).

The community of Ware, with a population of approximately 178, obtains its water supply from shallow wells and the Finlay River. Ware does not have a public water distribution system. Future road access to the Cyprus Anvil Cirque Mine, discussed in the report on the Lower Finlay Sub-basin, may also be extended to link Ware with Ingenika, Germansen Landing and points south. Road access may stimulate population growth at Ware, and will encourage further resource development of the Upper Finlay Sub-basin. Assessments of fishery resources have been carried out in the Finlay, Sturdee and Firesteel Rivers (R.A.B. 1978), and Jock Creek. Galen and Jock Creeks are believed to be devoid of fish with the exception of a 100 m reach near the mouth of Jock Creek, which is a holding, rearing and a likely overwintering habitat for fish (Beak, 1982). Dolly Varden (Salvelinus malma) and arctic grayling (Thymallus arcticus) were found in this 100 m reach of Jock Creek. Several fish migration barriers were noted upstream from this reach. R.A.B. (1978) determined that Black Lake, located at the headwaters of Jock Creek, also was devoid of fish (Figure 4). Fish and Wildlife, Northern Region, has indicated interest in stocking the Black Lake, Jock Creek and Galen Creek system.

Other water uses are related to hiking, hunting, fishing and trapping activities of those people who live in or visit this wilderness area. Tatlatui Wilderness Park (106 000 ha), located in the southwest portion of the sub-basin, attracts a limited number of visitors who must reach the area by floatplane or helicopter.

4. WASTE DISCHARGES AND RECEIVING WATER QUALITY: AN ASSESSMENT UP TO DECEMBER, 1982

4.1 BAKER MINE WASTE DISCHARGES

The only permitted effluent discharges in the Upper Finlay Sub-basin are associated with the Baker Mine which closed in November 1983. The major operations were surface and underground mining, grinding of ore, extraction of gold and silver with a cyanide solution and disposal of wastes to a tailings pond. Open pit and waste rock runoff was collected by a ditch system leading to a settling pond which discharged to Adit Creek, a tributary to Galen Creek (PE 5809-02) (Figure 5). Downstream, treated sewage effluent from the mine camp was discharged to Adit Creek (PE 5892). Further downstream past the confluence of Galen and Adit Creeks, waste water from the mine tailings exfiltration pond entered Galen Creek from surface seepage springs, and possibly groundwater flow (PE 5809-01) (Figure 5). The Waste Management permit requirements and other details are given in Table 1.

The Baker Mine commenced production in March, 1981. Initial assessment of mineral reserves indicated that the mine would operate for 2.7 years. Subsequent estimates predicted the mine would operate for 5 years, until 1986. However, the mine did shut down operations in November 1983, during preparation of this assessment. It is possible that the mill facilities may continue to be used and process ore from other nearby potential mines. Examination of the results of further exploration of the Baker Mine could also lead to its reopening.

4.2 BAKER MINE OPEN PIT/WASTE ROCK DISCHARGE (PE 5809-02)

The settling pond which received drainage from the open pit and waste rock dumps was permitted to discharge 541 m^3/d as a maximum daily average (amended to 1 000 m^3/d in December 1983). Actual discharge has been estimated to range from 250 to 533 m^3/d, with an average of 336 m^3/d. The dissolved zinc, iron and copper concentrations of the effluent were within the permitted maximums, and were below or close to generally accepted receiving water quality criteria for the protection of aquatic life (Table 2).

Dissolved lead concentrations in excess of permit limits were reported after June 20, 1982, ranging from 0.082 to 0.14 mg/L. Prior to June 20, 1982, lead concentrations were much lower, and ranged from <0.001 to 0.006 mg/L. As of June 20, 1982, high lead levels also were reported from the Galen Creek control station, located upstream from all disturbances and discharges (Site No. 1, Figure 5). A recent assessment of the lead analysis techniques indicated that the acid used to preserve the samples was contaminated with lead, resulting in lead concentrations of 0.10 to 0.20 mg/L in blanks and other samples. The lead values are thus not considered reliable (see Section 4.4.3).

Suspended solids were well below permitted levels except on one occasion when a concentration of 323 mg/L was reported. On the same date, suspended solids in Adit Creek a short distance downstream from the settling pond (Site No. 3, Figure 5) were <0.5 mg/L, indicating minimal impact.

Effluent pH values were within permit limits, and ranged from 7.35 to 8.00. The moderately basic pH indicates acid generation from this drainage is not presently a concern. However, the elevated total sulphate concentrations (615 to 1 000 mg/L) suggest acid generation was occurring and that future increases in acidity could occur. Occasional low pH values in the 4-5 range have been reported from the site upstream from this discharge. Downstream pH values at the mine site indicate that if acid drainage is occurring, stream buffering capacity seems adequate to maintain normal pH.

No flow data are available for Adit Creek although, based on watershed area (about 4 km^2) and comments made by mine personnel, it seems likely that zero low flow occurs, particularly during winter months. However, as the quality of the effluent meets generally accepted receiving water criteria for aquatic life, the lack of further dilution does not present a problem. Also, effluent flow will vary in a similar pattern to Adit Creek flow. Present effluent monitoring is adequate (Table 1), with the exception of the need to test for mercury. (see Section 4.6.2).

4.3 BAKER MINE CAMP SEWAGE DISCHARGE (PE 5892)

Sewage treatment for an operating work force of approximately 38 included aeration and chlorination. Average discharge rates were estimated to be less than 20 m^3/d. The permit allows up to 45 m^3/d to be discharged. The effluent was discharged to Adit Creek downstream from the open pit/waste rock discharge and upstream from the confluence with Galen Creek (Figure 5). Effluent data are presented in Table 3.

Suspended solids levels exceeded the permitted maximum 50% of the time and BOD_5 levels exceeded the permitted maximum 59% of the time (Table 3). Excessive fecal coliform levels in the effluent also have been reported occasionally by the permittee, although the geometric mean was only 101 MPN/100 mL (Table 3). A sample collected August 24, 1982 by the Ministry of Environment from Galen Creek downstream from the sewage discharge, contained a fecal coliform count of 240 MPN/100 mL. The fecal coliform count was reduced to 7 MPN/100 mL 50 m downstream from the confluence of Adit and Galen Creeks. Fecal coliform criteria for water-contact recreation are 200 MPN/100 mL (geometric mean) to 400 MPN/100 mL (90th percentile) (Richards 1983). Total residual chlorine has not been reported regularly, but a sample collected in Adit Creek 10 m downstream from the discharge in August, 1982 by the Ministry of Environment, contained 0.1 mg/L. This exceeds the maximum residual chlorine criterion of 0.014 mg/L recommended for the protection of aquatic life (EPA 1983).

Although the permit does not require the monitoring of nitrogen compounds, a sample collected by the Ministry of Environment on August 24, 1982 contained 0.226 mg/L of nitrite-nitrogen in Adit Creek downstream from the sewage discharge (Site No. 4, Figure 5 and Table 8). This concentration is in the range that is acutely toxic for salmonids, and is 10 times the level considered safe for salmonids (0.02 mg/L NO_2-N) (Pommen 1983). Upstream levels on the same date were undetectable. Further downstream past the confluence with Galen Creek, but upstream from the mine tailings pond (Site No. 5), nitrite-nitrogen was reduced to 0.01 mg/L (Table 8). Sampling of these same sites on August 10, 1983, indicated nitrite-nitrogen concentrations were less than 0.005 mg/L.

Due to poor effluent quality, and very low dilution in Adit Creek, discharge from the sewage treatment plant was reducing the water quality of Adit Creek. However, more serious pollution was occurring about 600 m downstream due to the mine tailings pond. Improvement in quality of the sewage discharge would have been of little consequence as long as excessive cyanide, copper and nitrite loading was occurring as a result of the tailings pond exfiltration into Galen Creek (refer to Section 4.4). The present monitoring requirements for the sewage effluent (Table 1) are adequate. Although residual chlorine is specified as a monitoring requirement, very few data were reported by the permittee.

4.4 BAKER MINE MILL TAILINGS DISCHARGE (PE 5809-01)

4.4.1 TAILINGS TREATMENT

Gold and silver were extracted from approximately 100 metric tonnes of ore per day by crushing, grinding, cyanidation, filtration and precipitation. Sodium cyanide, zinc dust, lead acetate, lead nitrate, diatomaceous earth, and "super flocculant" were reagents used in this process. The liquid portion of the tailings was treated with an alkaline chlorination process using lime and calcium hypochlorite before being discharged to a tailings pond. The 2.2 ha tailings pond is located 76 m northeast and 6 m above Galen Creek. Discharge occurred by exfiltration.

After the gold and silver were leached from the ground ore with an alkaline cyanide solution, they were precipitated and filtered from solution. The remaining solution (the barren bleed) and the remaining leached ore (the filter cake) comprise the liquid and solid fractions of the mill tailings. The barren bleed was then treated with lime and calcium hypochlorite to oxidize the toxic cyanides to less toxic cyanates. Initially, the chlorinated barren bleed was combined with the washed filter cake and they were discharged together to the tailings pond.

High gold and silver concentrations in the ore necessitated high cyanide use. Despite chlorination, high cyanide concentrations occurred in the tailings pond. It was believed that adequate cyanide oxidation was prevented by the presence of the filter cake solids. As of August 1982, certain modifications to the treatment method were made. First, the chlorinated barren bleed, containing excess chlorine to facilitate further oxidation of cyanide, was discharged separately to the tailings pond. The filter cake solids were discharged to the tailings pond untreated, and were directed to the berm in an attempt to build up a less permeable layer on the floor and outer wall of the pond. Generally, the solid fraction, or filter cake, contains most of the cyanide (Brodie, 1982). After these modifications, cyanide levels in the pond supernatant and receiving waters became highly variable, making it difficult to determine if the changes were beneficial (Figure 6).

As of December 20, 1982, the barren bleed and solid fraction were combined again prior to discharge due to problems caused by ice cover. Between December 6 and 20, 1982, another treatment method known as the Inco SO_2/air process was tested, rendering the monitoring data reported for December 20 unrepresentative of the performance of the chlorination procedure. The Inco process uses sodium sulphite and air to oxidize cyanide to thiocyanate, and was expected to reduce cyanide levels in the solid fraction more effectively than the chlorination process. The Inco process was used on a trial basis on four separate occasions for periods of about two weeks each between December 1982 until the mine shut down in November 1983. Cyanide concentrations in the tailings effluent remained well above the amended permit level of 2 mg/L throughout 1983 during the testing of Inco SO_2/air process, and during the use of the alkaline chlorination treatment process.

The detailed water quality assessment presented here only includes data up to December 1982. However, cyanide levels in excess of aquatic life criteria continued to occur in Galen Creek during 1983 until the mine closed.

Assessment of receiving water quality downstream from the tailings pond indicated that cyanide, lead, copper and nitrite concentrations have exceeded generally accepted water quality criteria for the protection of aquatic life. Each of these substances is discussed separately in the following sections. Other measured variables were at concentrations below these criteria.

4.4.2 TOTAL CYANIDE

(a) Summary of Total Cyanide Levels

The majority of cyanide data reported by the permittee are expressed as total cyanide which is based on the strong-acid dssociable analysis. The aquatic life criterion used here is expressed as weak-acid dissociable cyanide (Singleton 1986). Free cyanide is defined as HCN and CN^-, and is generally considered the toxic component. Cyanide determined by weak-acid dissociable analysis is considered a reliable estimation of free cyanide. However, many of the metal cyanide complexes and thiocyanate which are produced in the cyanation process are readily converted to free cyanides upon exposure to ultra-violet light at intensities which occur in the environment. Therefore, strong-acid dissociable cyanide and thiocyanate analysis are also important measurements.

Extensive total cyanide data are available for effluent and receiving waters. A data summary for the 18 sites sampled is presented in Table 4, and the sites are shown in Figures 4 and 5. Table 5 presents the results of concurrent analysis of total (strong-acid dissociable) cyanide and weak-acid dissociable cyanide. This comparison indicates that the two methods produce similar results.

Cyanide entered the receiving waters as a result of exfiltration from the tailings pond, and no direct surface discharge occurred. The initial test well located at the base of the pond berm was usually dry since commencement of tailings disposal. Mine personnel undertook a more intensive cyanide sampling program during 1982 than was required by the terms of the original permit. The resulting data indicated that seepage springs downslope from the tailings pond draining into Galen Creek contained extremely high total cyanide concentrations (up to 31.6 mg/L) (Site Nos. 18, 19; Table 4, Figure 5). Concentrations of total cyanide in excess of the 0.005 mg/L (30 day average) and the 0.01 mg/L (maximum) cyanide criterion for the protection of aquatic life (Singleton 1986) have been reported in Galen and Jock Creeks 7.5 km downstream from the tailings pond (Site No. 12, Fig. 4). The maximum total cyanide concentration found in Jock Creek at Site No. 12 was 0.09 mg/L; the mean was 0.026 mg/L (Table 4).

Total cyanide concentrations in Galen Creek often exceeded the 0.1 mg/L limit allowed by the permit in the tailings pond effluent. Total cyanide concentrations in Galen Creek adjacent to the tailings pond (Site No. 9) averaged 1.3 mg/L, ranging from <0.01 to 47.7 mg/L (Table 4, Figure 6). These concentrations are above the maximum acceptable concentration of 0.2 mg/L free cyanide for drinking water (B.C. Ministry of Health, 1982).

(b) Loading

Cyanide loading to receiving waters can be calculated using the following assumptions and formula:

1. Exfiltration flow rate is equal to the average rate of effluent discharge to the tailings pond (160 m^3/d).

2. All exfiltrating effluent eventually enters Galen Creek.
3. The cyanide concentration of exfiltrating effluent is represented by the range of concentrations found in the seepage springs (Site Nos. 18 and 19 from Table 4).

4. $$\text{CN loading (kg/d)} = \frac{\text{tailings inflow (m}^3\text{/d)} \times \text{CN in seepage (mg/L)}}{1\ 000}$$

The minimum, maximum and mean cyanide loadings were respectively, 0.26 kg/d, 5.1 kg/d and 3.3 kg/d. The original effluent permit allowed a maximum average loading of 0.006 kg/d (60 m^3/d at a concentration of 0.10 mg/L CN).

A new permit issued by the Waste Management Branch in December 1983 allows a maximum discharge of 250 m^3/d at 2 mg/L total cyanide resulting in a maximum allowable cyanide loading of 0.5 kg/d to the tailings pond. Direct surface discharge is not permitted. The loading to the tailings pond that is allowed under the new permit will be at the lower end of the range of loading which was estimated to have occurred to the receiving waters. Therefore, under the terms of the new permit, future loading to the receiving waters will be expected to be greatly reduced if the mill resumes operation.

(c) Extent of Downstream Influence

Site No. 12, located near the confluence of Galen and Jock Creek, 7.5 km downstream from the tailings pond, is the furthest downstream site sampled for cyanide (Figure 4). Using the minimum, maximum and mean cyanide concentrations encountered at this site (Table 4), the expected concentrations in Jock Creek at the confluence with the Toodoggone River (35 km downstream) can be estimated assuming that the unit discharge of the Galen Creek drainage area is representative of the whole Jock Creek drainage. This calculation also assumes no breakdown or volatilization of cyanide. The cyanide concentrations expected at the mouth of Jock Creek can therefore be estimated as follows:

$$\text{mg/L CN at mouth of Jock Cr.} = \text{mg/L CN at Site No. 12} \times \frac{\text{drainage area of Galen Cr. upstream from Site No. 12}}{\text{total drainage area of Jock Cr.}}$$

The minimum, maximum and mean total cyanide concentrations calculated at the mouth of Jock Creek are 0.002, 0.02 and 0.006 mg/L, respectively. The mean estimate exceeds the 0.005 mg/L (30 day average) criterion and the maximum estimate exceeds the 0.01 mg/L (maximum) criterion. The range of cyanide concentrations in the Toodoggone River at the mouth of Jock Creek likely would have been at levels below the water quality criteria due to the approximately five-fold dilution for Jock Creek in the Toodoggone River. Although this calculation is very simplistic, it does demonstrate that cyanide levels in most of Jock Creek may have exceeded aquatic life criteria.

(d) Cyanide Trends

The highest cyanide concentrations in receiving waters were consistently reported during April through May of 1982, presumably during a period of low stream flow. Inadequate data are available to determine whether modifications to the chlorination process instituted in August 1982 resulted in a reduction of cyanide in receiving waters. After the modifications, cyanide levels in the tailings pond supernatant became extremely variable, and uninterpretable because of infrequent sampling (Figure 6). This assessment does not present and discuss data from the last year of operation between December 1982 and November 1983 during which time tailings treatment alternated between alkaline chlorination and the INCO SO_2/Air process. Excessive cyanide in the tailings pond and the receiving waters continued during this period.

(e) Impact on Aquatic Life

A recent survey suggests that most of Galen and Jock Creeks are believed to be devoid of fish due to migration barriers. This presents some difficulties in interpreting the relevance of the cyanide criteria which are largely based on toxicity to fish. The little toxicology work done on other aquatic life suggests that algae and invertebrates may be less sensitive to cyanide than fish (McKee and Wolf 1963; Water Quality Criteria 1972; Singleton 1986).

The theoretical dilution calculation for cyanide indicates that concentrations in excess of the 0.005 mg/L criterion could have occurred for the full length of Jock Creek, including the 100 m reach near its confluence with the Toodoggone River which is known as a holding, rearing and overwintering habitat for fish. A process of dilution, volatilization and breakdown over the 35 km watercourse is expected to have reduced cyanide to harmless concentrations at the mouth; however, there are no data to confirm this assumption.

4.4.3 DISSOLVED LEAD

Concentrations of dissolved lead in excess of certain water quality criteria for aquatic life and drinking (Demayo et al. 1980) were reported in the receiving waters in the Baker Mine area.

A recent assessment of the lead analysis technique indicated that the acid used by the mine personnel to preserve the samples was contaminated with lead. This contamination appears to have affected results since June 20, 1982. Lead levels in the 0.1 mg/L range have been reported by the permittee for Adit and Galen Creeks since June 20, 1982. These high lead levels were also reported in Galen Creek upstream from all discharges. Prior to June 20, 1982, the maximum dissolved lead concentration detected adjacent to the tailings pond (Site No. 9) was 0.026 mg/L, with other sites ranging from <0.001 to 0.01 mg/L (Table 6).

Water hardness ranged from 46 to 88 mg/L $CaCO_3$ on one occasion in Galen Creek. The water quality criterion recommended for total lead by Demayo et al. (1980) for the protection of aquatic life is 0.005 mg/L for water with hardness less than 95 mg/L $CaCO_3$. Lead concentrations appear to be enhanced as a result of seepage from the tailings pond, but in view of the acid contamination problem the reliability of all the lead data reported by the mine is in question. On August 24, 1982, testing carried out by the Ministry of Environment throughout Galen Creek found that lead concentratons ranged from 0.001 to 0.004, and thus were below the 0.005 mg/L criterion level for aquatic life.

4.4.4 DISSOLVED COPPER

Concentrations of dissolved copper above the 0.002 mg/L total copper criterion recommended for the protection of aquatic life (Demayo and Taylor 1981) have been reported for Galen and Adit Creeks before and after commencement of mining operations. A survey carried out by Beak (1976) prior to the mine operation indicated that dissolved copper in the Baker Mine area varied from <0.005 to 0.035 mg/L with 67 percent of the values <0.005 mg/L (Ker, Priestman and Associates 1980). During mining operations, relatively high concentrations of dissolved copper were encountered upstream from all discharges in Adit Creek (Site 2) with values ranging from <0.001 to 0.048 mg/L with a mean of 0.029 mg/L. However, all values in Galen Creek upstream from all discharges and the runoff from the open pit/waste rock area (Site 1) were undetectable (Table 7). After commencement of tailings discharge, dissolved copper concentrations in Galen Creek (Site No. 9) adjacent to the tailings pond ranged from <0.001 to 0.23 mg/L, with a mean of 0.066 mg/L (Table 7). On three of the seven sampling dates, concentrations in Galen Creek were equal to or greater than the 0.05 mg/L level allowed in the permit for the tailings pond effluent. Testing carried out by the Ministry of Environment in August, 1982, indicated that the copper concentrations in Galen Creek 100 m downstream from the confluence of the tailings seepage springs with Galen Creek was 0.07 mg/L, which was above the 0.05 mg/L level allowed by the permit for the tailings effluent. At that time, the copper concentration in the seepage spring downslope from the tailings pond was 18.3 mg/L. Near the confluence with Jock Creek, approximately 6 km downstream from the tailings pond, a copper concentration of 0.03 mg/L was detected (Table 7).

Applying a simple dilution calculation based on drainage area using the same assumptions as outlined for cyanide in Section 4.4.2(c), it appears possible that copper concentrations in excess of the water quality criterion of 0.002 mg/L could occur throughout Jock Creek downstream as far as the confluence with the Toodoggone River.

There is some question whether the 0.002 mg/L criterion is appropriate because the baseline concentrations reported by Ker Priestman and Associates (1980) before mining operations ranged from <0.005 mg/L to 0.035 mg/L. Similarly, copper concentrations upstream from all discharges in Adit Creek during mining operations ranged from <0.001 to 0.048 mg/L (Table 7). Further copper monitoring is needed to confirm whether background copper levels exceed the 0.002 criterion, or whether the higher concentrations encountered in Adit Creek are due to other mining disturbances.

Copper concentrations in Galen Creek downstream from the tailings pond appear to be increased by mining activities during low flows. Concentrations above background levels, in excess of the effluent permit limit and above water quality criteria, have occurred in Galen Creek as a result of the mining operation.

The water quality criterion for copper recommended by Demayo and Taylor (1981) for the protection of aquatic life is partly based on toxicity to algae and invertebrates. It is therefore relevant to waterways such as Galen and Jock Creeks, which are presently devoid of fish.

4.4.5 NITROGEN

Monitoring of nitrogen is not presently a requirement of the three effluent permits issued for the Baker Mine. The nitrogen data presented in Table 8 are based on a survey carried out by the Ministry of Environment in August, 1982. As mentioned in Section 4.3, discharge of sewage effluent resulted in high nitrite levels in Adit Creek (0.226 mg/L-N). Further downstream in Galen Creek, exfiltration from the tailings pond also resulted in a nitrite level of 0.052 mg/L-N which was in excess of the water quality criterion for continuous exposure of 0.020 mg/L-N (Pommen 1983). The maximum concentration criterion proposed by Pommen (1983) is 0.060 mg/L-N.

At 100 m downstream from the tailings pond seepage springs, a nitrite concentration of 0.052 mg/L-N was detected. On that date, the nitrite concentration upstream from the influence of the tailings was 0.010 mg/L-N, indicating that the tailings seepage is an important source of NO_2 in addition to the sewage discharge. Nitrite levels were below 0.020 mg/L -N at sample Site No. 10, 3.8 km further downstream.

4.5 WATER QUALITY OBJECTIVES

4.5.1 RATIONALE

Receiving water quality objectives are derived from published criteria and are designed to protect site-specific water uses. However, as the criteria are only conservative estimates with built-in safety factors to compensate for incomplete knowledge, they are subject to change as further knowledge becomes available. Therefore, the site-specific objectives proposed here must be considered provisional. The water uses which have been designated for protection in the Baker Mine area include recreational use, aquatic life and wildlife. These objectives can be used to interpret the results of future monitoring and evaluate the effectiveness of effluent discharge restrictions.

There is presently little human activity in the area affected by the Baker Mine discharges other than the work and recreational activities of the Baker Mine employees and other exploration personnel. Occasional visits by hunters and other people seeking wilderness recreation is also possible.

Adit and Galen Creeks and most of Jock Creek are presently believed to be devoid of fish due to migration barriers. The Fish and Wildlife, Northern Region, considers Black Lake, Jock Creek and Galen Creek to be good fish habitat and has indicated interest in stocking this system when water quality improves. It is therefore considered desirable to set water quality objectives that will protect this potential fishery resource.

Significant dilution of effluents does not occur in Galen Creek until the confluence of Galen and Halfway Creeks, approximately 2.5 km downstream from the mine. It is estimated that the flow from Halfway Creek results in a 2:1 dilution of Galen Creek water (Beak 1982). Galen Creek, upstream from the confluence with Halfway Creek, has limited value as fish habitat and is subject to zero flow. It is therefore recommended that the provisional objectives apply to Galen Creek downstream from the point where Galen and Halfway Creeks are well mixed. It is estimated that this point is 2.5 km downstream from the tailings pond. As a consequence of meeting these objectives, this 2.5 km initial dilution zone should be protected from conditions acutely toxic to adequate life.

4.5.2 PROTECTION OF AQUATIC LIFE

The majority of objectives proposed here are derived from criteria based on studies of chronic and lethal toxicity to fish. There are few criteria specific to non-fish aquatic life. It is assumed that other forms of aquatic life, including fish food organisms and terrestrial wildlife, will also be protected by these objectives.

This assessment has indicated that during the life of the mine, cyanide, copper, nitrite and residual chlorine levels in the receiving waters exceeded levels considered safe for aquatic life. Should the mill resume operation, provisional objectives are proposed for these variables, plus several other variables which are considered potentially toxic to aquatic life. These eleven objectives shall apply to surface waters beyond the initial dilution zone. The objectives are presented in Table 9.

4.5.3 PROTECTION OF MINE EMPLOYEES, EXPLORATION PERSONNEL, HUNTERS AND VISITORS

4.5.3(a) Drinking Water

Adit, Galen and Jock Creek are not subject to licenced drinking water use. All of the water quality objectives proposed to protect aquatic life in Galen Creek, with the exception of fecal coliforms, are more stringent than needed for drinking water. As drinking untreated water is not a designated use nor is it recommended, no fecal coliforms objective is proposed.

4.5.3(b) Recreational Contact

All the water quality objectives proposed to protect aquatic life afford adequate protection for recreational contact. However, the presence of fecal coliforms presents a problem. It is recommended that people working or recreating downstream from the initial dilution zone be protected from contracting infectious diseases associated with fecal contamination. The fecal coliforms objective in Table 9 affords this protection.

4.6 RECOMMENDED MONITORING

4.6.1 LOCATION OF MONITORING SITES

On December 22, 1983, a permit amendment changed the monitoring requirements of the mine tailings discharge (Table 1). A new monitoring site was added upstream from the open pit/waste rock discharge in Adit Creek to provide background water quality data upstream from all mining disturbances. Another groundwater monitoring station was added to improve measurement of effluent quality. A new site (site 21) will be used to monitor receiving water quality in Galen Creek. This site is further downstream than the original site 9, and should be more representative of water quality immediately downstream from seepage from the tailings pond. The amended permit also requires monitoring of site 10, located at the bridge crossing on the road to Baker Mine. Compliance with the water quality objectives should ideally be monitored at a site located on Galen Creek near the confluence of Galen and Halfway Creeks where mixing is complete (Figure 4). Unfortunately, this location is not accessible, particularly in winter. Site 10 is the nearest accessible site, and is therefore recommended for objectives monitoring.

It is noted that the amended tailings discharge permit requires that site 9 continue to be monitored. It appears that this site is made redundant by the addition of site 21. It is recommended that the monitoring required at site 9 be transferred upstream from the tailings seepage area to site 5, thereby facilitating distinction between the influence of tailings seepage and the combined upstream influence of the sewage and open pit/waste rock discharges (Figure 5). Table 12 summarizes all the monitoring sites required by the amended permit and Table 13 summarizes all the monitoring sites proposed in this assessment.

4.6.2 RECOMMENDED VARIABLES

The following monitoring recommendations are in addition to the monitoring required by the 1983 permit (Tables 12 and 13). It is recommended that the flow in Galen Creek slightly upstream from the tailings pond be monitored, such as at Site No. 5. Flow measurements from Galen Creek are critical in assessing whether adequate dilution occurs throughout the year. It is noted that although residual chlorine monitoring is specified by the original tailings discharge permit, no residual chlorine data were reported. Residual chlorine discharge is expected to be reduced by the future use of the INCO SO_2/air treatment process which, unlike the alkaline chlorination process, does not involve the addition of chlorine. Extensive monitoring of residual chlorine is, therefore, not required.

The substitution of the alkaline chlorination process by the INCO SO_2/air process may eliminate the tailings pond as a major nitrogen source and reduce the need for monitoring nitrogen in the tailings effluent. Leaching of nitrogen-based explosives residues, and camp sewage discharge can, however, enhance nitrogen concentrations in the receiving waters. Therefore, ammonia and nitrite nitrogen should be monitored. The water temperature and pH must be measured at the time of sampling to interpret the ammonia data.

It is recommmended that both the total and dissolved fractions of copper, iron, lead, mercury, zinc and silver be tested. Total metal analysis is essential to compare results with water quality criteria which are usually expressed in terms of total metals. The use of both total and dissolved analysis is helpful in tracing origins and evaluating relative toxicity. Total hardness should also be measured whenever metals are sampled to aid in the interpretation of their toxicity.

Monitoring of total mercury is recommended to determine if concentrations significant to aquatic life occur. An extensive mercury rich deposit is known to exist along the Pinchi Lake Fault Zone which extends northerly along the western portion of the Finlay-Omineca Strategic Unit. Mercury levels in fish tissue approaching the commercial fisheries limit (0.5 ppm) have been found in Weissener Lake, and in the Finlay River downstream from Ware (see Section 4.7.2). The physical disturbance caused by mining may enhance naturally high background levels.

In the case of cyanide, it is recommended that weak-acid and strong-acid dissociable cyanide plus thiocyanate be measured. Although free cyanide is generally believed to be the toxic component, metal cyanide complexes and thiocyanate can be converted to free cyanide under certain environmental conditions.

All variables recommended for testing, including those required by the permit, are summarized in Table 13. The present monitoring requirements based on the 1983 permit amendment are presented in Table 12.

4.6.3 MONITORING FREQUENCY

Weekly monitoring of cyanide, copper and nitrite, and monthly monitoring for the remaining variables is recommended. Streamflow in Galen Creek also should be monitored weekly using a staff gauge and developing a stage-discharge curve. The monitoring frequency recommended here and previously required by the permit is summarized in Tables 12 and 13. If it is suspected that a certain variable may be exceeding or approaching the provisional objective level, monitoring frequency should be increased beyond what is recommended here to increase statistical confidence and to determine if the objective is being met.

4.6.4 MONITORING RESPONSIBILITY

Due to the remote location, it is not feasible for the Ministry of Environment and Parks to carry out routine monitoring of the Baker Mine mill should it reopen. The monitoring recommendations presented here should therefore be considered for incorporation into the tailings pond discharge permit. It should be noted that no additional monitoring sites are necessary. The recommended monitoring, which is beyond the terms of the present discharge permits, requires addition of six routinely tested variables. These monitoring requirements can be reduced assuming favorable receiving water quality results.

4.7 OTHER WATER QUALITY INFORMATION

4.7.1 TATLATUI PARK

Basic physical limnological information, plus total dissolved solids, dissolved oxygen and pH data are presented in Osmond-Jones et al. (1977) for the Upper Stalk, Lower Stalk, Trygve, Kitchener and Tatlatui Lakes (Figure 3). This information is not reviewed here.

4.7.2 WEISSENER LAKE

The location of Weissener Lake is shown in Figure 3. Water quality data are available for Weissener Lake (Table 11). Weissener Lake can be characterized as oligotrophic and having moderately hard water. Dissolved metal concentrations were low or undetectable, although the level of detection for certain metals was above water quality criteria.

As part of a mercury testing program, Health and Welfare Canada (1981) measured methyl-mercury levels in fish from Weissener Lake in 1981. Ten lake whitefish (Coregonus clupeiformis) and 10 lake char (Salvelinus namaycush) were analyzed. The limit allowed by the Canadian Food and Drug Directorate for commercial fisheries is 0.5 ppm (wet weight). The U.S. Food and Drug Administration has set a guideline of 1 ppm. None of the lake whitefish were found to have levels exceeding 0.2 ppm organic mercury, but nine out of the ten lake char showed organic mercury levels in the 0.2 to 0.5 ppm range. Fish tissue levels between 0.2 ppm and 0.5 ppm are considered by Health and Welfare Canada as medically significant for individuals with blood-mercury levels greater than 20 ppb. Logistical difficulties prevented the testing of mercury levels of individuals from the community of Ware who presumably consume fish from Weissener Lake. Health and Welfare Canada (1981) recommended lake char taken from Weissener Lake be alternated with other fish food species, and that pregnant women refrain from consuming lake char from Weissener Lake.

4.7.3 WARE

Ware is the only settlement in the Upper Finlay Sub-basin, other than the camp at the Baker Mine. Health and Welfare Canada has monitored the quality of the drinking water at Ware which is derived from wells and the Finlay River. Based on the 27 variables tested, a sample from the Finlay River in 1977 was of excellent quality for human consumption, and the protection of aquatic life (Table 10).

Food fish from the Finlay River near Ware tested by Health and Welfare Canada (1981) had high organic mercury levels. Five Dolly Varden (Salvelinus malma) and five lake whitefish (Coregonus clupeiformis) were tested; the lake whitefish levels were below acceptable limits, but the heavier Dolly Varden contained organic mercury levels three times higher than the commercial fisheries limit of 0.5 ppm. Health and Welfare Canada (1981) recommended that Dolly Varden taken from the Finlay River should not be consumed.

4.7.4 ROAD CONSTRUCTION

The Upper Finlay Sub-basin has been, and is expected to continue to be subject to intensive mineral exploration. Road construction associated with mineral exploration has been responsible for serious sedimentation problems (Willett, 1985). Due to the remote and inaccessible location, road construction has proceeded largely unmonitored, and to some extent unregulated. Although no water quality analyses have been carried out, field observations indicate that a serious conflict with fisheries values exists (King, personal communication). Completion of the proposed road access from Fort St. James via the Sturdee River Valley (Figure 3), is expected to intensify mineral exploration and encourage further placer mining resulting in greater potential for sedimentation problems.

5. FUTURE RESOURCE DEVELOPMENTS

The Baker Mine may reopen, or ore from other nearby potential mines may be processed by the Baker Mine mill. Mineral resource development of the highly mineralized Upper Finlay Sub-basin is likely to continue. Presently, there are three other potential gold and silver mines being explored within a 24 km radius of the Baker Mine. One of these mines, the Lawyers Project, may go into production by 1987. The water quality implications of such development will depend on site specific factors.

SEREM Inc. has proposed developing a cyanidation gold/silver mine (Lawyers Project) in the Attorney Creek Watershed located 8 km northeast of the Baker Mine. The production rate is expected to be about 500 tonnes/day with reserves of about 900,000 tonnes. The mine is expected to operate 5 years. This project also involves construction of a 96 km extension to the Omineca Road, stream diversions and reservoir construction.

Background levels of mercury are high enough for Health and Welfare Canada to issue a precautionary recommendation to residents in the Ingenika, Finlay-Forks and Ware areas concerning the consumption of lake char and Dolly Varden. No mercury-related medical problems traceable to environmental mercury have been identified in this area. Extensive mercury deposits occur along the Pinchi Lake Fault Zone, which extends along the western portion of the Finlay-Omineca Strategic Planning Unit. The physical and chemical disturbances caused by mining can potentially enhance the availability of mercury, and result in increased fish tissue levels. In view of this possibility, it is recommended that fish tissue be tested from representative areas throughout the Sub-basin to determine the extent and significance of present mercury levels. Such a sampling program should be carried out in consultation with Health and Welfare Canada, which has an on-going mercury surveillance program.

It is also recommended that mercury monitoring be done as part of any environmental assessment prior to resource developments. Due to the difficulties of detecting significant mercury levels in water, fish tissues and sediments should also be considered for mercury monitoring.

Logging plans indicate that the majority of the Upper Finlay will not be logged in the foreseeable future (Figure 3). Limited logging adjacent to Ware and along the Fox River is expected to commence after 1990. Water quality impacts of logging can be significant, but can be largely mitigated by appropriate logging practises.

In order to aid in the development of future water quality objectives for particulate matter (suspended sediment) to protect fisheries values, it would be desirable to start accumulating a background data base of natural particulate matter concentrations. Most of the mineral exploration, mine development and placer mining is likely to occur within the Toodoggone River watershed, therefore sampling efforts should include this area.

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FIGURE I FINLAY-OMINECA WATER QUALITY ASSESSMENTS

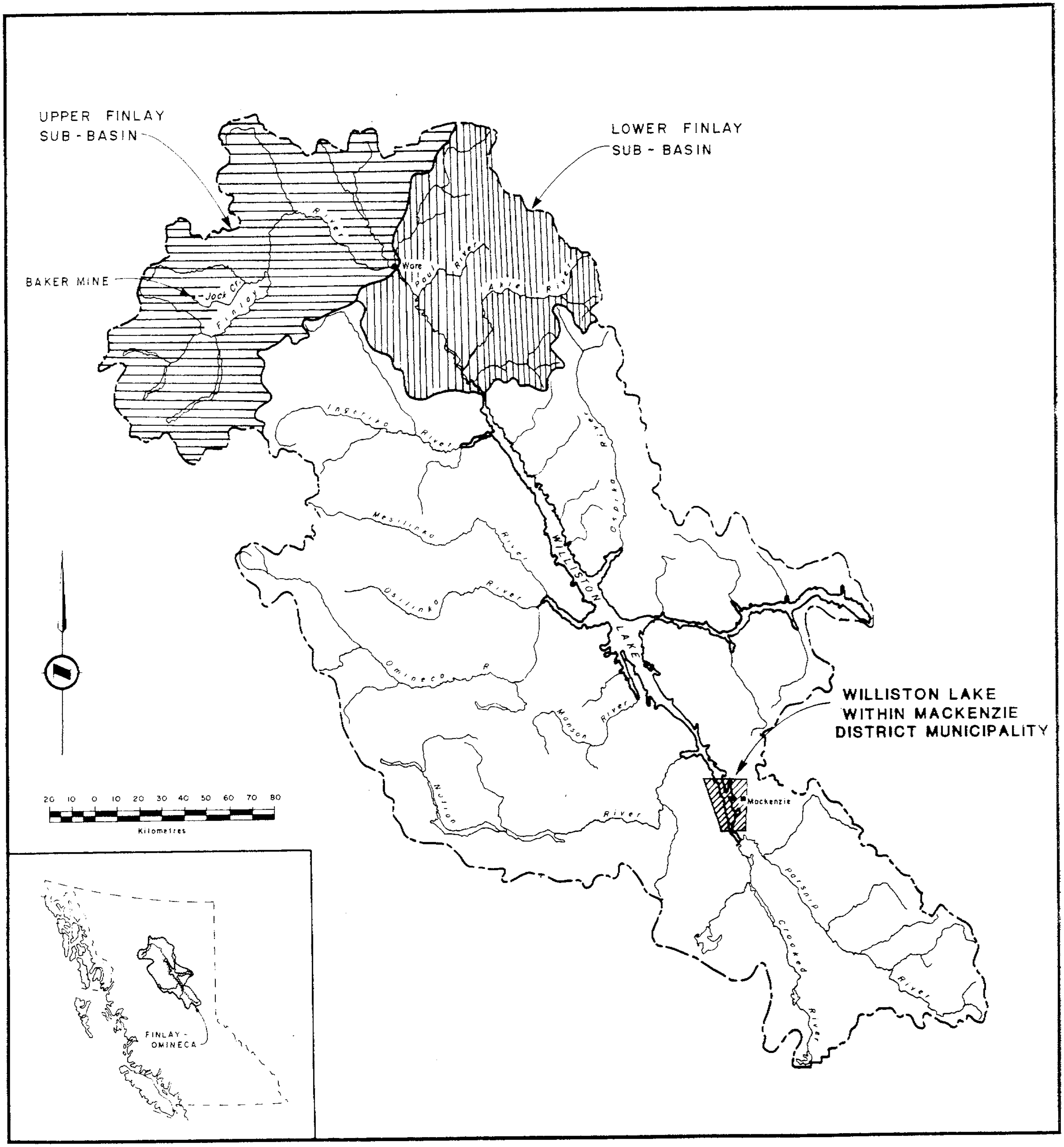

FIGURE 2 UPPER FINLAY SUB-BASIN

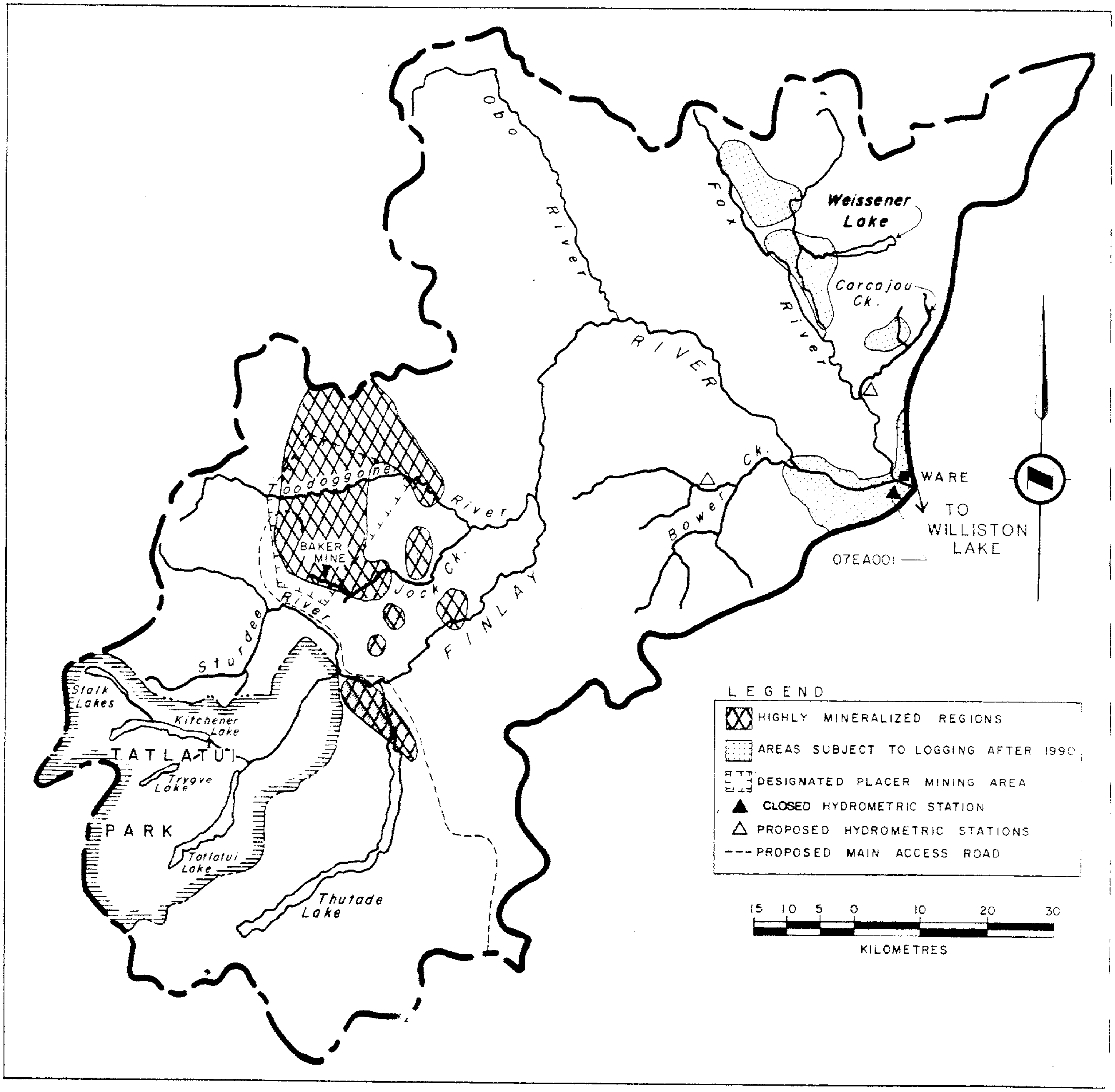

FIGURE 3. JOCK CREEK DRAINAGE

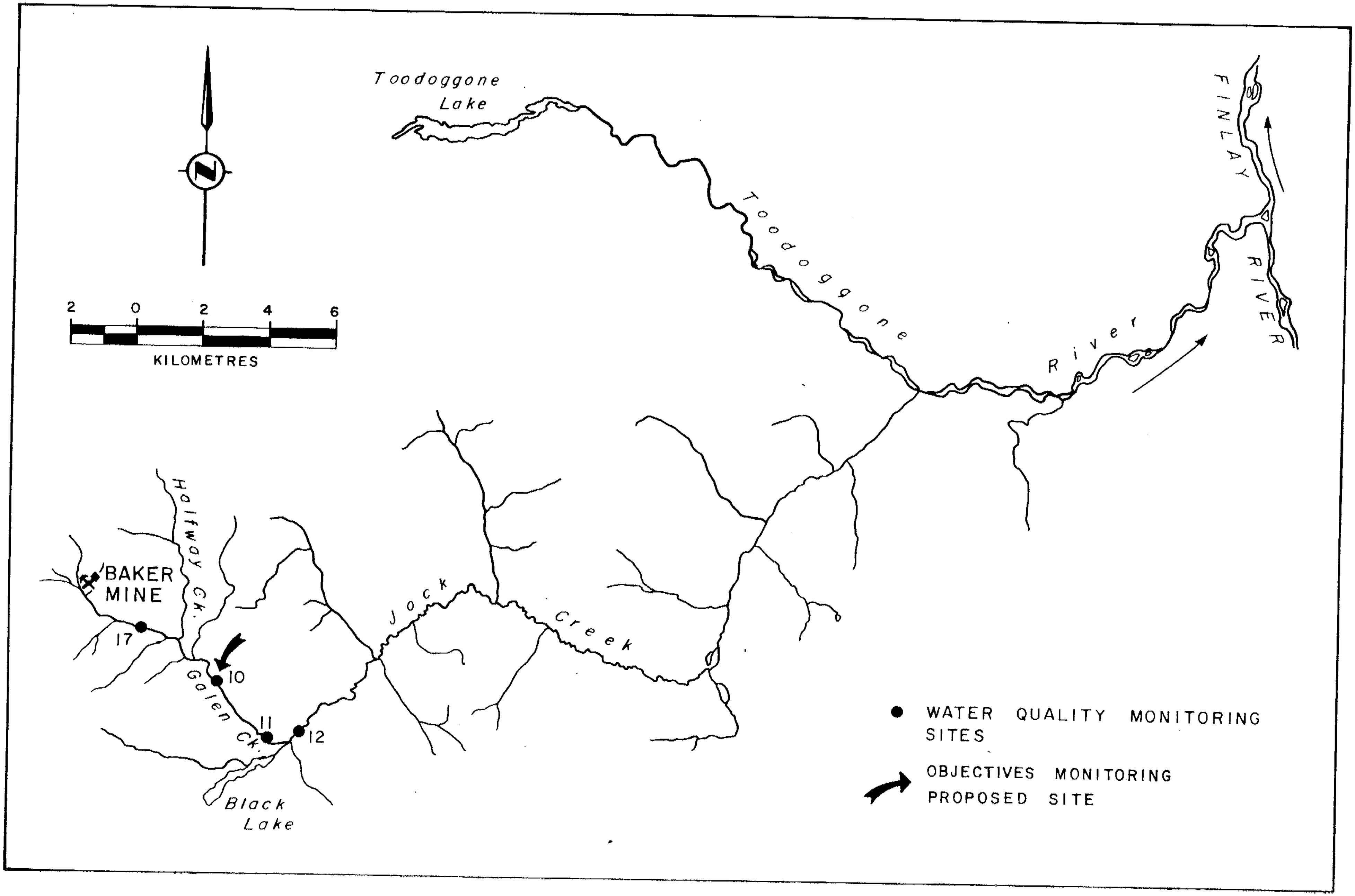

FIGURE 4 BAKER MINE SITE DETAILS
(Mine elevation - 1750 metres)

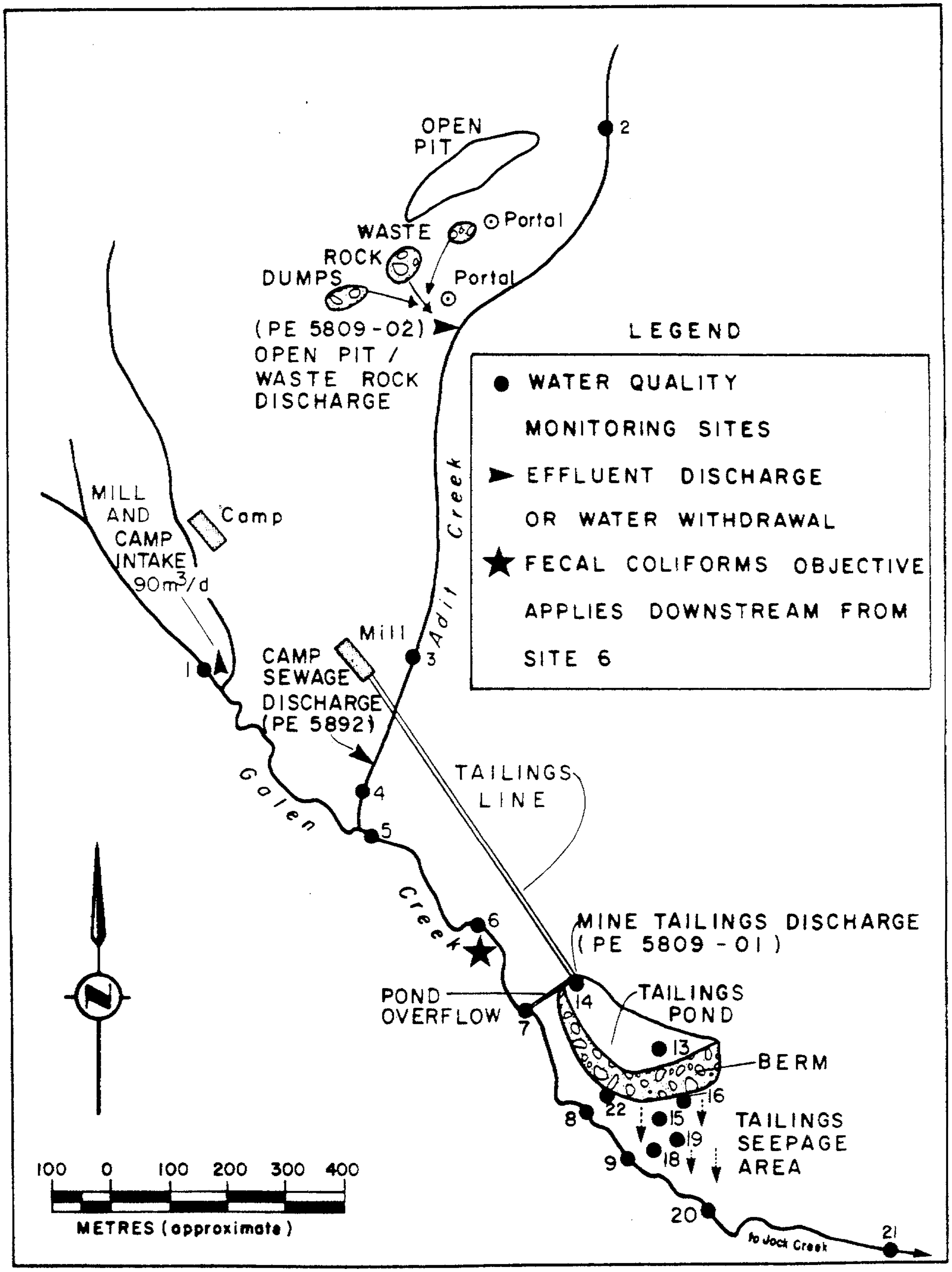

FIGURE 5. CYANIDE CONCENTRATIONS IN BAKER MINE TAILINGS POND SUPERNATANT AND GALEN CREEK

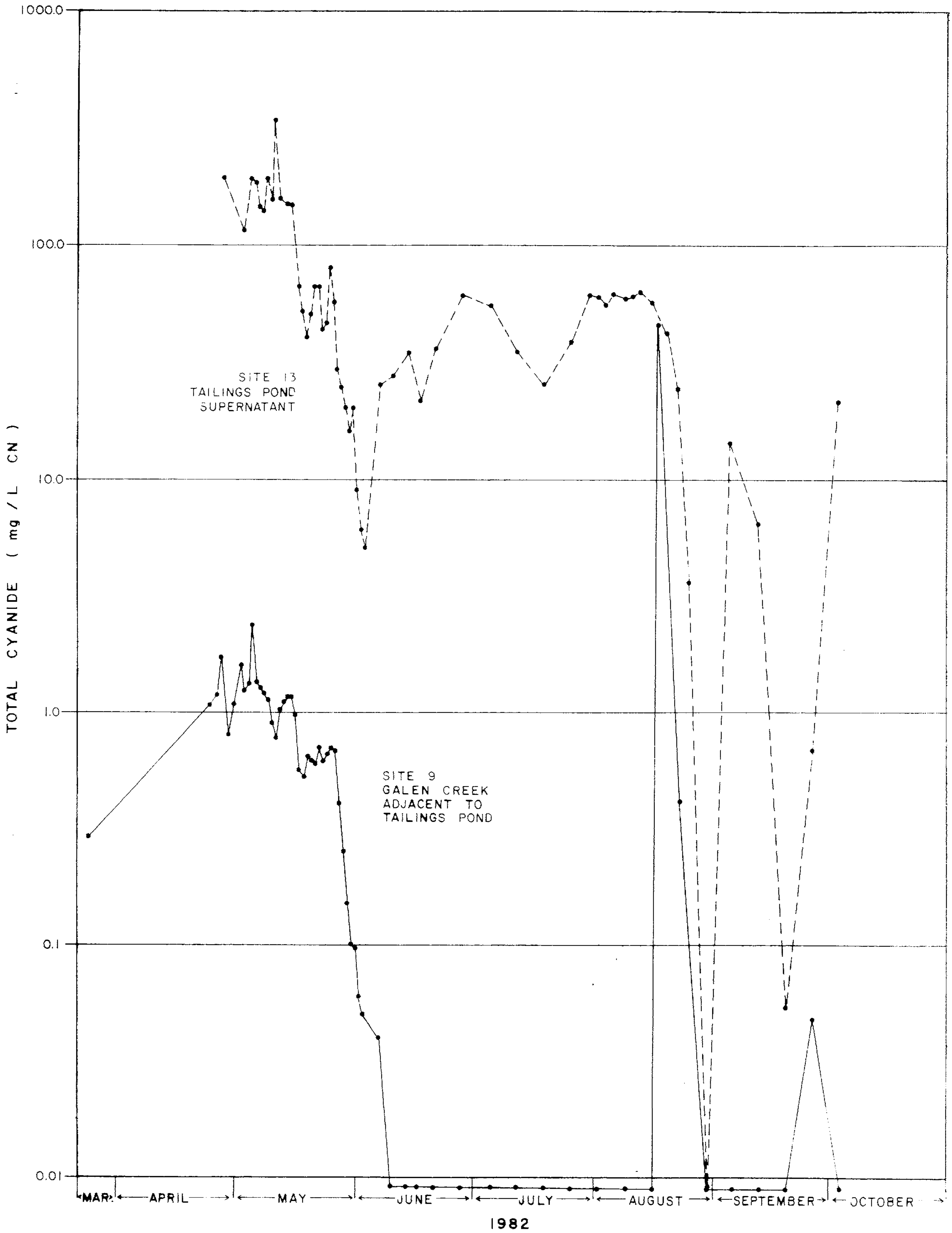

TABLE 1

BAKER MINE EFFLUENT PERMIT DETAILS (amended December 1983)

PERMIT NO.	PERMITTEE	OPERATION TYPE AND EFFLUENT TREATMENT	DISCHARGED TO	EFFLUENT PERMIT SPECIFICS		PERMITTEE EFFLUENT MONITORING FREQUENCY
				VARIABLE	LIMITS	
PE 05809 01	DuPont of Canada Exploration Ltd. (Baker Mine)	Gold and Silver Mine: ore dressing and cyanidation - effluent treated by the INCO/SO_2 process	Galen Creek (exfiltration only)	pH	Maximum 9.5 Minimum 6.5	D
				Flow (to tailings pond)	250 m³/day maximum 200 m³/day maximum monthly average	M
				Flow (tailings water & solids to pond)		M
				Total sulphate	not specified	Q/W
				Total Cyanide	2.0 mg/L maximum	W
				Diss. Copper	4.0 mg/L maximum	Q/W
				Diss. Iron	0.50 mg/L maximum	Q/W
				Diss. Lead	0.10 mg/L maximum	Q/W
				Diss. Zinc	1.0 mg/L maximum	Q/W
				Diss. Silver	0.30 mg/L maximum	Q/W
02	DuPont of Canada Exploration Ltd. (Baker Mine)	Open pit and waste rock dump area: miscellaneous waste water-settling pond	Adit Creek	pH	Maximum 9.5 Minimum 6.5	Q
				Non-filterable residue (105°C)	50 mg/l maximum	Q
				Flow	1 000 m³/day maximum	M
				Diss. Copper	0.05 mg/l maximum	Q
				Diss. Iron	0.30 mg/l maximum	Q
				Diss. Lead	0.05 mg/l maximum	Q
				Diss. Zinc	0.50 mg/l maximum	Q
PE 05892	DuPont of Canada Exploration Ltd. (Baker Mine)	Mining camp sewage: secondary treatment	Adit Creek	Non-filterable residue (105°C)	60 mg/l maximum	Q
				Chlorine residual	1.0 mg/l maximum 0.10 mg/l minimum	-
				Flow	45 m³/day maximum	M
				Biochemical oxygen demand	45 mg/l maximum	M
				Bacteria: fecal coliforms	-	M

TABLE 2

SUMMARY OF OPEN PIT/WASTE ROCK EFFLUENT QUALITY AT BAKER MINE (PE 5809 02)

	MINIMUM	MAXIMUM	MEAN	NUMBER OF SAMPLES	PERMIT LIMITS
pH	7.35	8.00	7.60	7	6.5-9.5
Suspended solids mg/L	<0.5	323	54.7	7	50 max.
Dissolved Pb mg/L	<0.001	0.14	0.049	7	0.05 max.
Dissolved Zn mg/L	0.013	0.089	0.031	7	0.50 max.
Dissolved Cu mg/L	<0.001	<0.015	0.003	7	0.05 max.
Dissolved Fe mg/L	0.044	0.34	0.16	7	0.30 max.
Dissolved SO_4	615	1000	729	5	none

(1) EPA (1976)
(2) EPA (1972)
(3) Demayo et al. (1980)
(4) Taylor and Demayo (1980)
(5) Demayo and Taylor (1981)

Note: Data submitted by permittee, June 10/81 - December 17/82.

TABLE 3

SUMMARY OF SEWAGE EFFLUENT QUALITY AT BAKER MINE (PE 5892)

	MINIMUM	MAXIMUM	MEAN	NUMBER OF SAMPLES	PERMIT LEVELS	% ABOVE PERMIT LEVELS
pH	6.10	7.55	6.99	18	-	-
Suspended Solids mg/L	13	262	99	16	60	50%
BOD_5 mg/L	<5	412	85	17	45	59%
Fecal Coliforms MPN/100 mL	<2	1 500 000	101([1])	18	-	-
Total residual chlorine mg/L	<0.1	2.7	1.4	2	0.1 min. 1.0 max.	too few data

Note: Data submitted by permittee, June 10/81 - December 19/82.
[1]Geometric Mean.

TABLE 4

SUMMARY OF TOTAL CYANIDE DATA FROM ALL SITES AT BAKER MINE

MINE NO./ MINISTRY NO.	SITE DESCRIPTION	MINIMUM mg/L CN	MAXIMUM mg/L CN	MEAN mg/L CN	NUMBER OF SAMPLES	% UNDETECTABLE (<0.01 mg/L)
1 0400403	Galen Cr upstream from camp intake	<0.01	0.014	0.009	6	83
4 0400385	Adit Cr. down-stream from sewage discharge	<0.01	0.87	0.35	3	33
5 0400386	Galen Cr. 50 m downstream from Adit Cr. con-fluence	<0.01	0.45	0.01	17	94
6	Galen Cr. down-stream from Site 5	<0.01	<0.01	<0.01	1	100
14 0400346	Tailings Line outlet	2.81	508	102	145	0
13 0400399	Tailings Pond supernatant	<0.01	340	74	69	1
7	Galen Cr. at tailings pond overflow	<0.01	<0.01	<0.01	2	100
8	Galen Cr.next to tailings pond	<0.01	1.14	0.58	2	50
15	Tailings Seepage Area above road	0.035	0.08	0.06	4	0
16 0400348	Tailings Seepage Area above road	0.072	0.14	0.10	3	0
18 0400423	Tailings Seepage Area below road	1.64	29.6	16.4	18	0
19 0400420	Tailings Seepage Area below road	7.34	31.6	24.5	10	0

TABLE 4 (Continued)

SUMMARY OF TOTAL CYANIDE DATA FROM ALL SITES AT BAKER MINE

MINE NO./ MINISTRY NO.	SITE DESCRIPTION	MINIMUM mg/L CN	MAXIMUM mg/L CN	MEAN mg/L CN	NUMBER OF SAMPLES	% UNDETECTABLE (<0.01 mg/L)
9 0400349	Galen Cr. next to tailings pond ex-filtration zone	<0.01	47.7	1.31	61	30
20 0400402	Galen Cr. 100 m downstream from seepage area	13.1	13.1	13.1	1	0
17	Galen Cr. 1.6 km downstream from site No.9	<0.01	0.12	0.04	16	31
10 0400355	Galen Cr. 50 m upstream of bridge crossing	<0.01	0.43	0.08	63	48
11 0400350	Galen Cr. 1 km upstream from mouth	<0.01	0.10	0.03	19	58
12	Jock Cr. near confluence with Galen Cr.	<0.01	0.09	0.03	18	50

Note: Data submitted by Permittee (September 14/81 - October 3/82).

TABLE 5

COMPARISON OF TOTAL AND WEAK-ACID DISSOCIABLE CYANIDE IN GALEN CREEK AT SITE NO. 9

DATE	TOTAL CN mg/L	WEAK-ACID DISSOCIABLE CN mg/L	% WEAK-ACID DISSOCIABLE
Mar. 24	0.29	0.22	76
Apr. 24	1.08	0.97	90
26	1.17	0.85	73
29	0.80	0.60	75
30	1.07	0.93	87
May 2	1.59	1.41	89
3	1.21	1.46	121*
4	1.30	1.25	96
5	2.55	2.52	99
6	1.32	1.32	100
7	1.28	1.16	91
8	1.25	1.25	100
9	1.11	1.03	93
10	0.90	0.15	17
11	0.66	0.69	105*
12	1.01	1.01	100
13	1.10	1.12	102*
14	1.21	1.24	102*
15	1.16	1.10	95
16	0.95	0.93	98
17	0.56	0.62	111*
18	0.52	0.52	100
19	0.64	0.62	97
20	0.61	0.60	98
21	0.60	0.57	95
22	0.71	0.64	90
23	0.61	0.61	100*
24	0.66	0.64	97
25	0.70	0.63	90
26	0.68	0.67	99
27	0.40	0.38	95
28	0.25	0.23	92
29	0.15	0.13	87
30	0.10	0.11	111*
31	0.097	0.088	91
June 1	0.060	0.057	95
2	0.050	0.035	70
6	0.040	0.034	85
Aug. 17	47.7	38.0	80
22	0.043	0.021	49
			$\bar{X}$ 90

* Percentages above 100% were converted to 100% for computation of mean.
Note: Data submitted by permittee.

TABLE 6

TRENDS IN DISSOLVED LEAD LEVELS AT BAKER MINE

Site	10/6/81	14/9/81	6/12/81	19/3/82	20/6/82	24/8/82[1]	26/9/82	17/12/82
Galen Cr. Site 1 Upstream from Camp Intake	-	<0.001	0.001	0.012	0.12	-	0.11	0.12
Adit Cr. Site 2 Upstream from Waste Rock Discharge	<0.001	0.005	0.005	-	0.10	-	0.070	0.14
Open Pit/Waste Rock Discharge to Adit Cr. (PE 5809-02)	<0.001	<0.001	0.005	0.006	0.082	-	0.11	0.14
Galen Cr. Site 5 50 m Downstream from Confluence (0400386)	-	-	-	-	-	0.003	-	-
Galen Cr. Site 9 Adjacent to Tailings Pond	0.002	<0.001	0.010	0.026	0.087	-	0.080	0.17
Galen Cr. Site 20 100 m Downstream from Seepage (0400402)	-	-	-	-	-	-	0.002	-
Galen Cr. Site 10 50 m Upstream from Bridge (0400355)	-	-	-	-	-	-	0.004	-
Galen Cr. Site 11 1 km Upstream from Mouth (0400350)	-	-	-	-	-	-	0.001	-

[1]Data collected by Ministry of Environment.

TABLE 7

DISSOLVED COPPER DATA FROM GALEN AND ADIT CREEKS

Site	1/1/81[1]	10/6/81	14/9/81	6/12/81	19/3/82	20/6/82	24/8/82[2]	26/9/82	17/12/82[3]
Galen Cr. Site 1 Upstream from Camp Intake	0.001	-	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.015
Galen Cr. Site 5 50 m Downstream from Confluence (0400386)	-	-	-	-	-	-	<0.01	-	
Adit Cr. Site 2 Upstream from Waste Rock Discharge	0.001	0.027	<0.001	0.040	-	0.022	-	0.034	0.048
Open Pit/Waste Rock Discharge to Adit Cr. (PE 5809-02)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.015
Tailing Seepage Site 19 below Road	-	-	-	-	-	-	18.3	-	-
Galen Cr. Site 9 Adjacent to Tailings Pond	<0.001	<0.001	<0.001	0.18	0.23	<0.001	-	<0.001	0.050
Galen Cr. Site 20 100 m Downstream from Seepage (0400402)	-	-	-	-	-	-	0.07	-	-
Galen Cr. Site 10 50 m Upstream from Bridge (0400355)	-	-	-	-	-	-	<0.01	-	-
Galen Cr. Site 11 1 km Upstream from Mouth (0400350)	-	-	-	-	-	-	0.03	-	

[1]Prior to commencement of milling operations.
[2]Data collected by Ministry of Environment.
[3]During Inco/SO_2 test.

TABLE 8

NITROGEN LEVELS IN RECEIVING WATERS AT BAKER MINE ON AUGUST 24, 1982

SITE NO.	SITE DESCRIPTION	pH	TEMPERATURE °C	NO_3-N µg/L	NO_2-N µg/L	NH_3+NH_4^+-N µg/L	Theoretical NH_3-N µg/L[1]
1 0400403	Galen Cr. upstream from camp intake	6.6	6.0	<20	<5	<5	<1
3 0400400	Adit Cr. 20 m upstream from sewage discharge	7.5	6.0	210	<5	<5	<1
4 0400385	Adit Cr. downstream from sewage discharge	7.7	6.0	220	226	58	<1
5 0400386	Galen Cr. 50 m downstream from Adit Cr. confluence	7.0	7.0	60	10	<5	<1
20 0400402	Galen Cr. 100 m downstream from seepage area	8.2	8.5	350	52	354	9
10 0400355	Galen Cr. 50 m upstream from bridge crossing	8.0	7.2	140	14	33	<1
11 0400350	Galen Cr. 1 km upstream from mouth	6.9	7.5	120	9	18	<1

[1] NH_3-N (un-ionized) Calculated using Trussell (1972).
Note: Ministry of Environment data.

TABLE 9

PROVISIONAL WATER QUALITY OBJECTIVES FOR JOCK AND GALEN CREEKS

Water Bodies	Jock Creek and Galen Creek
Designated Water Uses	Aquatic life, wildlife and recreation
Fecal Coliforms[1]	≤200 MPN/100 mL geometric mean ≤400 MPN/100 mL 90th percentile
Total Chlorine Residual[2]	0.002 mg/L maximum
Weak-acid dissociable Cyanide[3,4] (unfiltered)	≤0.005 average 0.01 mg/L maximum
Un-Ionized Ammonia -N[4]	≤0.007 mg/L average 0.03 mg/L maximum
Nitrite-nitrogen[4]	≤0.02 mg/L average 0.06 mg/L maximum
Total Copper[5]	0.002 mg/L maximum or increase of 20% over background whichever is greater
Total Iron	1.0 mg/L maximum
Total Lead	0.005 mg/L maximum
Total Mercury	0.0001 mg/L maximum
Total Silver[2]	0.0001 mg/L maximum
Total Zinc	0.05 mg/L maximum

Note: objectives apply to discrete samples from all parts of Galen and Jock creeks except from the initial dilution zone. For fecal coliforms, the excluded dilution zone extends 400 m downstream from the sewage discharge site. For all the other objectives, the excluded dilution zone extends 2.5 km downstream from the tailings pond seepage area.

[1]The geometric mean and 90th percentile are calculated from at least 5 weekly samples taken in a period of 30 days.

[2]Since the objective is less than the minimum detectable concentration, it will be necessary to estimate the receiving water concentration using effluent loading and estimated streamflow.

[3]the weak-acid dissociable cyanide analytical method should measure free cyanide, simple cyanides and weak-acid dissociable metal cyanides. The current minimum detection limit is 0.005 mg/L. A result of less than this detection limit would be deemed to be achieving the objective, until the detection limit can be lowered.

[4]the average is calculated from at least 5 weekly samples taken in a period of 30 days.

[5]the % increase is over levels measured at a site upstream from the discharge and as close to it as possible, and applies to downstream levels.

TABLE 10

FINLAY RIVER WATER QUALITY AT WARE

VARIABLE	LEVEL (mg/L UNLESS SPECIFIED)
pH (unit)	7.6
hardness (EDTA) as $CaCO_3$	104.0
total alkalinity as $CaCO_3$	94.0
total Fe	0.05
total Mn	N.D.
colour (units))	<5.0
turbidity (units)	0.1
odour	N.D.
NO_3-N	0.09
NO_2-N	N.D.
free ammonia-N	<0.01
albuminoid ammonia-N	0.02
Ca	30.0
Mg	7.1
Na (calculated)	1.1
Bicarbonate as CO_3	56.4
CO_3	nil
SO_4	12.0
Cl	<1.0
F	0.06
SiO_2	5.3
Total dissolved solids	118.5
Specific conductance (μmhos/cm)	205.0
Cd	<0.01

Sample collected Aug. 31/77 by Health and Welfare Canada.
N.D. = non-detectable.

TABLE 11

WEISSENER LAKE WATER QUALITY (SITE NO. 1130646)

VARIABLE (mg/L OR AS STATED)	MINIMUM	MAXIMUM	MEAN	NUMBER OF VALUES
pH	8.2	8.2	8.2	1
alkalinity (as $CaCO_3$)	140	140	140	1
dissolved oxygen	5.0	10	7.9	18
filterable residue	170	220	195	2
specific conductance (μmhos/cm)	279	349	314	2
ammonia-N	<0.005	<0.005	<0.005	2
nitrate plus nitrite	0.03	0.1	0.065	2
organic nitrogen	0.03	0.04	0.035	2
kjeldahl nitrogen	0.03	0.04	0.035	2
total nitrogen	0.07	0.13	0.1	2
ortho phosphorus	<0.003	<0.003	<0.003	2
total phosphorus	0.007	0.009	0.008	2
total arsenic	<0.25	<0.25	<0.25	2
total cadmium	0.0005	<0.01	0.005[1]	4
total calcium	39.1	48.2	43.7	2
total chromium	<0.01	<0.01	<0.01	2
total copper	0.001	<0.01	<0.006[1]	4
total iron	<0.01	<0.01	<0.01	2
total lead	<0.001	<0.1	<0.051[1]	4
total magnesium	10.8	13.2	12	2
total manganese	<0.01	<0.01	<0.01	2
total molybdenum	<0.01	<0.01	<0.01	2
total nickel	<0.01	<0.05	<0.03[1]	4
total zinc	<0.01	<0.01	<0.01	2
total aluminum	<0.02	<0.02	<0.02	2
total cobalt	<0.1	<0.1	<0.1	2

Note: Data from Ministry of Environment Equis file, Jan. 1981 - Nov. 1982

[1]Mean biased by undetectable values

TABLE 12

PRESENT EFFLUENT AND RECEIVING WATER QUALITY MONITORING REQUIREMENTS AT BAKER MINE

	FLOW	pH	FECAL COLIFORM	5-DAY BIO-CHEMICAL OXYGEN DEMAND	NON-FILTERABLE RESIDUE	TOTAL SULPHATE	TOTAL CYANIDE	DISSOLVED COPPER	DISSOLVED IRON	DISSOLVED LEAD	DISSOLVED ZINC	DISSOLVED SILVER
Site 1 Galen Cr. upstream of campsite		Q				Q	Q	Q	Q	Q	Q	Q
Site 2 Adit Cr. upstream from open pit/waste rock discharge		Q			Q	Q		Q	Q	Q	Q	Q
Open pit/waste rock discharge (PE5809-02)	M	Q			Q	Q		Q	Q	Q	Q	Q
Site 3 Adit Cr. downstream from open pit/waste rock discharge		Q			Q	Q		Q	Q	Q	Q	Q
Camp sewage discharge (PE 5892)	M		Q	Q	Q							
Site 14 tailings fluid to ponds	M	D				W	W	W	W	W	W	W
Site 13 tailings pond supernatant		W				W	W	W	W	W	W	W
Site 16 & 22 seepage wells		W				W	W	W	W	W	W	W
Site 18 & 19 seepage springs		W				W	W	W	W	W	W	W
Site 9 100 m downstream from tailings pond		W				W	W	W	W	W	W	W
Site 21 Galen Cr. 500 m downstream from tailings pond		W				W	W	W	W	W	W	W
Site 10 Galen Cr. 50 m upstream from bridge crossing		M				M	M	M	M	M	M	M

Q= quarterly
M = monthly
W = weekly
D = daily

TABLE 13
PROPOSED EFFLUENT AND RECEIVING WATER QUALITY MONITORING AT BAKER MINE

	FLOW	TEMPERATURE	pH	TOTAL HARDNESS	FECAL COLIFORM	5-DAY BIO-CHEMICAL OXYGEN DEMAND	NON FILTERABLE RESIDUE	TOTAL CHLORINE RESIDUAL	TOTAL SULPHATE	AMMONIA
Site No. 1. Galen Cr. upstream from campsite (0400403)			M				M		M	
Site 2 Adit Cr. upstream from open pit/waste rock discharge			M	M			M		M	
Open pit/waste rock discharge (PE 5809-02)	M	M	M	M			M		M	M
Site 3 Adit Cr. downstream from open pit/waste rock discharge (0400400)		M	M	M			M		M	M
Camp sewage discharge (PE 5892)	M				M	M	M	M		
Site 6 Galen Cr. 300 m downstream from Adit Cr. confluence	Wk				M					
Site 14. Tailings fluid to ponds (0400346)	Wk		D							
Site 13. Tailings pond supernatant (0400399)		M	Wk							M
Seepage spring and wells between tailings pond and Galen Cr. (0400420, 0400423)			Wk						Wk	
Site 21 (or futher downstream). Galen Cr. 500 m downstream from tailings pond			Wk						Wk	M
Site No. 10 Downstream from confluence of Galen and Halfway Creeks. Objectives apply at this site (0400355).		Wk	Wk	Wk			Wk	Wk	Wk	Wk

M = monthly grab
Wk = weekly grab
D = daily average

Note: Analysis of cyanide should include both weak-acid and strong-acid dissociable fractions

TABLE 13 (Continued)

	NITRATE	NITRITE	CYANIDE AND THIOCYANATE	TOTAL MERCURY	TOTAL & DISS. COPPER	TOTAL & DISS. IRON	TOTAL & DISS. LEAD	TOTAL & DISS. ZINC	TOTAL & DISS. SILVER
Site No. 1. Galen Cr. upstream from campsite (0400403)				M		M	M	M	M
Adit Creek upstream from open pit/waste rock discharge				M	M	M	M	M	M
Open pit/waste rock discharge (PE 5809-02)	M	M		M	M	M	M	M	M
Site No. 3 Adit Cr. downstream from open pit/waste rock discharge (0400400)	M	M		M	M	M	M	M	M
Camp sewage discharge (PE 5892)									
Site No. 6 Galen Cr. 300 m downstream from Adit Cr. confluence									
Site No. 14. Tailings fluid to pond (0400346)			Wk	Wk	Wk	Wk	Wk	Wk	Wk
Site No. 13. Tailings pond supernatant (0400399)	M	M	Wk	Wk	Wk	Wk	Wk	Wk	Wk
Seepage spring and wells between tailings pond and Galen Cr. (0400420, 0400423)			Wk	Wk	Wk	Wk	Wk	Wk	Wk
Site No. 21 (or further downstream). Galen Cr. 500 m downstream from tailings pond			Wk	Wk	Wk	Wk	Wk	Wk	Wk
Site No. 10 Galen Cr. near confluence with Halfway Cr. Objectives apply at this site (0400355).	Wk	Wk	Wk	Wk	Wk	Wk	Wk	Wk	Wk

M = monthly grab
Wk = weekly grab
D = daily average

Note: Analysis of cyanide should include both weak-acid and strong-acid dissociable functions.