The mine effluent did not have a measurable effect on the species composition or community abundance of benthic macroinvertebrates in Contwoyto Lake. Macroinvertebrate communities in Outer Sun Bay were similar to communities in the control area. The study concluded that, given the changes in water quality that have been shown in Outer Sun Bay, monitoring of benthic invertebrates should be continued to further establish long-term data trends among sampling locations that will allow for an assessment of the ecological significance of any mine-related contamination of water and sediment.

Phase 2 – Long-term Assessment (Porter et al. 1992)

Environment Canada carried out a second study in 1990 to determine the effects of tailings effluent from the Lupin Gold Mine on the benthic macroinvertebrates and sediment chemistry (arsenic, metals and particle size) in regions of the West Arm of Contwoyto Lake (Porter et al. 1992). Sampling took place during August, with the specific objective of determining trends in sediment chemistry and potential changes in the benthic invertebrate community resulting from mining effluent disposal.

Study Conclusions

The sediment analysis for arsenic and metals in the 1990 study did not indicate any clear trends. For example, the 1990 study showed significant decreases in arsenic concentrations at three stations and increases at two other stations as compared with the 1985 study. For example, the control site (Station 2) had 43.4 and 40.3 mg/kg of arsenic in August and September of 1985, whereas in August 1990 this station had 15.7 mg/kg of arsenic. There is an indication of increased deposition of fine sediment particles at some of the deeper sample sites in the 1990 study. Inter-station comparisons within the 1990 study support the hypothesis that deeper stations may be acting as repositories for solids and metals.

Out of the 72 taxa identified during the 1990 study, 31 taxa showed significant differences in mean abundance between stations. Most of these differences were explained because of major substrate differences among the stations. The total number of taxa found during the 1990 survey was double the number found during the 1985 study. To compare species abundance between respective stations for each survey period, only species common to all periods could be used in statistical analysis. This analysis indicated that species common between the two study years decreased. This may have been due to the increased percentage of fine particles observed during the 1990 study compared to the 1985 study. The 1990 study concludes that sediment and benthic invertebrate sampling be continued and that future monitoring studies should focus on lower taxonomic levels to quantify benthic impacts.

Field Evaluation of Aquatic Effects Monitoring (EVS 1996)

As part of the Aquatic Effects Technology Evaluation (AETE) Program, a field survey was conducted at the Lupin Mine. Studies included a review of historical information and field programs related to water quality, sediment quality, benthic macroinvertebrates, and fisheries resources. With regard to benthic invertebrates, six exposure (Inner and Outer Sun bays of Contwoyto Lake) and six reference (South Bay of Contwoyto Lake) sites were sampled.

Study Conclusions

In total, 60 benthic invertebrate taxa were identified and enumerated. Overall, the benthic communities did not differ greatly between the reference and exposure areas. Midges, bristle worms, and bivalves were the dominant taxonomic groups encountered among all samples collected.

While benthic communities in both study areas were similar, there were some general differences noted. Bristle-worms of the family Enchytraeidae were generally more abundant in the exposure area. Harpacticoid copepepods (Copepoda, Harpacticoida) were generally more prevalent in the reference area. The midge, *Heterotrissocladius*, was more abundant in the exposure area.

Despite significant differences in sediment quality and habitat characteristics between the reference and exposure sites, benthic community variables did not vary significantly between the two areas. These results were attributed to either a) habitat difference between the two study areas confounding potential adverse effects of exposure to higher sediment metal concentrations, or b) elevated sediment metal concentrations do not adversely affect benthic communities.

EVS (1996) noted that the subtle differences in the benthic communities between the reference and exposure areas may be due to natural factors (e.g., water depth, substrate composition) and that the inclusion of a second reference location and/or a new reference location in future studies would help to distinguish real effects from natural variability.

Phase 3 – Long-term Assessment (RL&L 1996a)

RL&L (1996a) carried out an office-based study (i.e., data management and statistical analyses of data collected by Environment Canada) to determine trends in sediment quality (arsenic, cadmium, chromium, copper, lead, nickel, selenium, zinc, and mercury) as well as the benthic macroinvertebrate community. Data were collected from five study locations within Inner and Outer Sun bays of Contwoyto Lake over four sampling sessions: August 1985, September 1985, August 1990, and August 1991. With minor exceptions, the sampling protocols and analytical methods used during the 1991 study were identical to those used during the previous studies.

Study Conclusions

Similar to previous studies, arsenic and metal concentrations in the sediments of the West Arm of Contwoyto Lake were highly variable, and spatial trends indicating significant changes in sediment quality could not be identified. For example, mean (±1 SD) arsenic concentrations ranged from 20.8 ± 1.7 to 65.0 ±10.0 mg/kg among six sampling sites spread over a distance of 18 km.

Several temporal trends were observed that indicated significantly decreasing sediment quality with time. Higher concentrations of copper, lead, zinc, arsenic, mercury, cadmium, chromium and selenium were observed at various stations in 1991 in comparison to 1990 or 1985, and in 1990 in comparison to 1985. For example, mean (±1 SD) arsenic concentrations at the control site (Station 2) were 43.4 ± 15.3, 40.3 ± 4.0, 15.7 ± 3.7, and 56.8 ± 24 mg/kg in August 1985, September 1985, August 1990, and August 1991, respectively.

In general, surface sediment concentrations of arsenic and metals among the four surveys (August 1985, September 1985, August 1990, and August 1991) were variable, and trends were inconsistent; however, some of the sediment quality variables illustrated results suggesting an impact occurred. For example, at the control site (Station 2), mean copper, lead, and zinc concentrations tended to be significantly greater during 1991 than during the three previous sampling sessions.

Some factors that likely contributed to the data variability included variations in collection methods, use of different analytical laboratories, and a "control" station that is exposed to Lupin's effluent. During the two 1985 surveys, sediment samples consisted of the top five centimetres, whereas the 1990 and 1991 surveys collected the top one centimetre. Three of the surveys (August 1985, September 1985, and 1991) had sediment samples analyzed at Environment Canada, Environmental Protection Branch's analytical laboratory. The sediment samples collected during 1990 were analyzed by Chemex Labs Alberta Inc. Use of different methodologies and analytical laboratories contributed towards variable results.

Subsequent sampling and analysis of sediment data suggests that the control site (Station 2) may be impacted by the effluent. Without a proper control, or controls, outside of and independent of the potential impact(s) under investigation, natural variability and trends in data are difficult to interpret. The monitoring program was originally designed with Station 2 as a temporal control, not a spatial control site.

During 1991, three replicate cores that were sub-sectioned into 10 1-cm, vertical sections were collected at a deep (27.1 m) basin to assess whether or not sediment focusing was occurring. Sediment focusing is the process where sediments are re-suspended, due to wind and other disturbances, and moved from shallow to deep parts of basins. This process can result in a greater net accumulation of fine sediments and organic materials in deeper lake basins. Statistical analyses of the vertical cores suggest that there were significant and non-significant trends of decreased sediment quality near the surface.

Statistical power analysis (the probability of detecting a significant difference if, in fact, there is one) was performed on the sediment quality data. Power analyses on the spatial distribution (i.e., among stations) of sediment quality data suggested that by increasing the number of replicates collected at each station from five to six, power for most of the variables would be considerably improved. Conversely, power analyses on the temporal distribution (i.e., among the four sample periods) suggested that, for most of the sediment quality variables, reducing the number of replicates collected at each station from five to four would not considerably affect the probability of detecting a significant difference. Depending on the objectives of future monitoring programs and pressure to reduce costs, researchers will have to decide whether or not it is necessary to increase or decrease the number of replicates collected per station by one. A compromise would be to leave the number of replicates at five.

The total number of benthic macroinvertebrate taxa identified during the 1991 survey was 52, whereas 32 and 73 taxa were identified during the 1985 and 1990 surveys, respectively. There were 21 taxonomic groups that were common to all four sampling sessions. These taxa contributed 67% of all invertebrates collected during all four sampling sessions. Of the 21 common taxa, 12 taxa contributed at least 1% towards the total number of macroinvertebrates, and were deemed abundant. The majority of significant differences observed for benthic macroinvertebrate densities indicate decreased numbers in 1991 compared to the 1990 survey as well as a decrease from August to September 1985, at most stations.

Several sampling stations had unique trends in densities of dominant taxa among the study periods. These results may be due to impacts associated with tailings effluent; however, other sources of variation cannot be precluded. Natural factors also may contribute to the variability observed. Biological (e.g., timing of emergence and seasonality) and physical events (e.g., weather conditions and basin morphology) may account for differences in results. The report concluded that these factors and results support the need for continued study in Contwoyto Lake, with the possible inclusion of an appropriate spatial control station.

3.7.4 Fisheries

Fish have been sampled from waterbodies in the vicinity of the Lupin Mine between the late 1970s and 1994 (e.g., Moore 1978; RCPL and RL&L 1985b; RL&L 1996b and 1996c). Eight species of fish have been recorded from the Contwoyto Lake area (Table 3-11). Sportfish species include lake trout (*Salvelinus namaycush* [Walbaum]), Arctic char (*Salvelinus alpinus* [Linnaeus]), and Arctic grayling (*Thymallus arcticus* [Pallus]). Non-sportfish species encountered included round whitefish (*Prosopium cylindraceum* [Pallus]), cisco (*Coregonus artedii* Lesueur), burbot (*Lota lota* [Linnaeus]), ninespine stickleback (*Pungitius pungitius* [Linnaeus]), and slimy sculpin (*Cottus cognatus* Richardson). Of the sportfish species, lake trout are the most abundant. Other species, such as burbot, are infrequently caught in the study area. Moreover, capture of some species requires substantial effort without guarantee of success.

Table 3-11 Summary of Fish Captured in Three General Areas near the Lupin Mine[a], 1981-1994

Common Name	Sampled Areas			Total	%
	Contwoyto Lake	Concession Lake	Interior Sites[b]		
Arctic char	111	2	2	115	5.4
Arctic grayling	61	1	617	679	32.1
Burbot	4	0	3	7	0.3
Cisco	233	7	9	249	11.8
Lake trout	600	162	84	846	40
Ninespine stickleback	10	0	35	45	2.1
Round whitefish	132	13	30	175	8.3
Slimy sculpin	1	0	0	1	<0.1
Total	**1152**	**185**	**780**	**2117**	**100**

[a] Source: RL&L (1996b); [b] Comprised of five small lakes (colloquially known as Long, Norma, Test, Bar and Post lakes) situated to the south and southeast of the TCA (Figure 2-1).

Primary studies conducted on the fisheries resources of Contwoyto Lake and waterbodies exposed to Lupin Mine tailings effluent include RCPL and RL&L (1985b), RL&L and DFO (1991), EVS (1996), and RL&L (1996b). The focus of the studies were to a) summarize existing fisheries monitoring information, b) detect changes, if any, in the contaminant burdens carried by the fish, and c) to examine fish morphometrics (size). In 1996, a brief sampling program was conducted by EVS (1996) to evaluate aquatic effects monitoring programs among several candidate mining operations in Canada, including the Lupin Mine. RL&L (1996b) summarized data from a variety of capture methods including gill nets, fish traps and dip nets, angling/creel census, minnow traps, beach seining, and backpack electrofishing, whereas EVS (1996) only used gill nets to capture fish. With the exception of RCPL and RL&L (1985b), these documents are appended to Golder (2003a). The amount of fish capture data available in these reports are extensive; as such, only synoptic data are provided below.

Physical Habitat

Aquatic habitat in the receiving environment downstream of the tailings area (Figures 2-1, 3-1, and 3-2) is comprised of three shallow lakes (colloquially referred to as Dam 2 Lake, Dam 1a Lake, and Unnamed Lake), two streams (Seep Creek and Concession Creek), two shallow ponds, and two embayment areas of Contwoyto Lake (Inner and Outer Sun Bay). With the exception of Dam 2 Lake, all of the small lakes and ponds freeze to the bottom in winter. Much of Inner Sun Bay also freezes to the bottom. Due to low winter flows, both Seep Creek and Concession Creek freeze to the bottom in winter. As a consequence, over-wintering habitat for fish is limited primarily to Outer Sun Bay and the main body of Contwoyto Lake (RCPL and RL&L 1985b).

Seep Creek is approximately 6.5 km in length, flowing from its source in Dam 2 Lake and Dam 1a Lake (via separate branches which join about 2 km downstream) to Unnamed Lake (Figures 2-1 and 3-2). The stream channel in upper Seep Creek generally is poorly defined, often flowing through marshy areas, or between large boulders or through bedrock fractures. This section of the creek generally was less than 0.5 m in depth and less than 2 m wide. The dominant substrate type is boulders, although localized areas of cobble and gravel are present. Lower Seep Creek (i.e., the 400 m section upstream of Unnamed Lake) is characterized by a well developed channel varying in width from 1 to 4 m, although during freshet, maximum wetted width was about 20 m. The dominant substrate type is boulder, with localized areas of cobble and gravel (RCPL and RL&L 1985b).

Two ponds are located near the downstream end of Seep Creek. The maximum depths of these ponds are about 1.5 m; the surface areas of the upstream-most pond was 3 ha and the surface area of the downstream-most pond was 2 ha. Unnamed Lake (16 ha) is the receiving waterbody for Seep Creek; it is shallow (maximum depth of about 1 m), had substrate composed of organic debris/silt and small boulders, and likely freezes to the bottom during winter (RCPL and RL&L 1985b).

Inner Sun Bay is characterized by the following:

- primarily littoral habitat;
- maximum depth of 6.5 m;
- a surface area of 150 ha;
- is primarily shallow (mean depth of 1.7 m);
- over 91% of the surface area is shallower than 3 m; and,
- features substrates largely consisting of sand/silt and boulders.

Outer Sun Bay has not been examined extensively, but consists of large lake habitat (maximum depths exceeding 10 m) and near-shore substrates largely composed of large cobbles and boulders (RCPL and RL&L 1985b).

Seep Creek

Lake trout, Arctic grayling, cisco, round whitefish, ninespine stickleback and slimy sculpin have been documented in Seep Creek (RCPL and RL&L 1985b). RL&L and DFO (1991) assessed Seep Creek and encountered Arctic grayling, ninespine stickleback and round whitefish in the stream during spring and summer. RL&L and DFO (1991) indicated that fish use the stream for spawning, feeding and juvenile rearing in the early part of the open water season. The majority of the fish where moving downstream when captured in 1990. RL&L and DFO (1991) suggested that this was in response to decreasing water levels as snowmelt run-off subsided. RCPL and RL&L (1985b) documented Arctic grayling spawning in Seep Creek in 1983 and 1984.

RL&L and DFO (1991) reported that of 76 Arctic grayling in their catch, 66 were juveniles (75 to 190 mm; age 1 to age 3 fish); sampling was conducted between 28 June and 3 July 1990. RCPL and RL&L (1985b) used a box trap to monitor upstream fish migrations into Seep Creek in 1983 (19 June through 1 July) and 1984 (9 through 28 June). RCPL and RL&L (1985b) captured 26 adult grayling in 1983 and seven adult Arctic grayling in 1984; their total grayling catch for both years was 335. Thus, it appears that the spawning Arctic grayling population in Seep Creek is small and that the stream is used extensively by Arctic grayling for rearing.

AQUAMIN (1996b, appended to Golder 2003a) reviewed data provided in RCPL and RL&L (1985b) and RL&L and DFO (1991). Arctic grayling data sets for Seep Creek were compared and they suggested that there had been a decrease in growth rate between 1983 and 1990. It was speculated that the difference may be a result of natural variation of the thermal regime or due to the exposure of fish to metals in sediments of Seep Creek. The apparent difference may also be a result of the later start to the sampling program in 1990, which only monitored the end of the post-spawning run. The Age-3 and Age-4 groups in the 1990 sample were represented by 13 and 6 individuals, respectively; whereas there had been 53 Age-3 and 90 Age-4 fish in the 1984 catch. Thus, the mean fork length values in 1990 may have been lower because many of the larger adult fish may have moved out of Seep Creek before sampling commenced.

Sun Bay/West Arm

Areas of interest in the West Arm of Contwoyto Lake include Inner Sun Bay and Outer Sun Bay. All of the species recorded from the Contwoyto Lake area (Table 3-11), with the exception of burbot, have been captured in the West Arm. The absence of burbot in the catch is due, in large part, to the selectivity of capture gear. Burbot are most effectively caught on set lines, a capture technique not employed during fisheries studies since burbot were not a target species during any study; lake trout was the species of interest because it is the most abundant and is the target species for domestic use. Ninespine stickleback and slimy sculpin have been recorded from Seep Creek, and are likely present along the margins of Sun Bay (RL&L 1996b). RCPL and RL&L (1985b) and EVS (1996) captured lake trout, Arctic char, cisco, round whitefish, and ninespine stickleback from Inner and Outer Sun bays.

3.7.5 Fish Tissue Metal Monitoring

Analysis of the metal burden in fish tissues of exposure and reference areas has been undertaken periodically. The data reflects both pre-decant (i.e., prior to 1985) and post-decant periods. RL&L (1995) provides a summary of the data collected up to 1993. Detailed information on the metals data is available in RL&L and DFO (1991) and RL&L (1995), which were appended to Golder (2003a).

AQUAMIN (1996b, appended to Golder 2003a) reviewed fish tissue data through to 1994 and summarized the data as follows:

> "Lake trout from Contwoyto Lake and Concession Lake were sampled over a number of years and the concentrations of arsenic, lead, nickel, copper, cadmium, mercury, and zinc were determined in muscle and liver samples. Only mercury residues in muscle and liver increased significantly with body length. Elevated concentrations of mercury in fish tissues may be related to natural geological sources since similar levels of mercury were found in fish collected from reference and exposed sites.
>
> No significant relationships were found to exist between body length and any of the other metals monitored in the studies. In general, for arsenic, nickel, lead, and cadmium, a large portion of the muscle samples contained

> concentrations of these metals below detection limits. These metals were detected more often in liver samples, but non-detected values were still present. The lack of relationship with body weight and the high number of values below detection limits for arsenic, lead, nickel, and cadmium suggest that the contamination of fish by these metals is not a problem in Contwoyto Lake. Low concentrations of copper and zinc were found in the muscle and liver of all fish tested, as would be expected of essential minerals."

RL&L (1995) examined the trace metals data for lake trout muscle and liver tissue reported by RCPL and RL&L (1985c), RL&L (1989), RL&L and DFO (1991), and RL&L (1993a). The RL&L (1995) report summarized the muscle and liver concentrations of arsenic, cadmium, copper, mercury, nickel, lead and zinc. Data were pooled to examine Inner Sun Bay (exposure area), the West Arm of Contwoyto Lake (Outer Sun Bay was considered as part of the West Arm), and Concession Lake (reference area). Data are compared to timelines regarding operations at the Lupin Mine; 'pre-decant' period indicates data collected prior to the initial onset of effluent discharge (5 September 1985). The following summary of trace metals data are excerpts from RL&L (1995).

All data are reported as mg/kg as 'dry weight'. To express laboratory results as milligrams of element per 'wet' kilogram of tissue, the values must be converted using the percentage 'dry content' of the tissue. Tissues contain approximately 80% moisture.

Arsenic

Muscle Tissue

Lake trout muscle tissues from Inner Sun Bay had concentrations of arsenic that peaked in 1988 (i.e., 0.21 mg/kg). By 1993, the mean arsenic concentration was approximately 25% of the 1988 mean value, and the 1993 mean concentration was approximately 50% of the pre-decant mean concentration.

In all periods, lake trout from Concession Lake had a lower mean arsenic concentration than lake trout from Inner Sun Bay.

Liver Tissues

Arsenic burdens in liver tissues of lake trout in Inner Sun Bay rose from the pre-decant period to 1988, and then declined substantially in 1990 and 1993. The general trend observed in arsenic concentrations for lake trout muscle tissues was reflected in the arsenic burdens in lake trout liver tissues. The decrease in arsenic concentrations in 1993 in comparison to 1990 was observed for both muscle and liver tissues.

The 1993 data show lower mean concentrations of arsenic in liver tissues of both the Inner Sun Bay and Concession Lake samples in comparison to 1990 samples, whereas the Contwoyto Lake site mean concentration remained relatively consistent between 1990 and 1993.

Cadmium

Muscle Tissues

Throughout the five sampling periods, most cadmium levels in lake trout muscle tissue have been below the detection limit of 0.05 mg/kg.

Liver Tissues

Cadmium concentrations in lake trout liver tissues from Inner Sun Bay and Contwoyto Lake sites generally remained stable over the sampling period. All post-decant mean cadmium concentrations from Inner Sun Bay samples of lake trout liver tissue have been below the pre-decant level (mean of 2.5 mg/kg). With the exception of the pre-decant period, lake trout liver samples from the Contwoyto Lake site have had higher mean cadmium concentrations than Inner Sun Bay lake trout, and they have always been higher than corresponding samples from Concession Lake.

Copper

Muscle Tissues

Copper concentrations in lake trout muscle tissues have decreased since the pre-decant period; this finding is consistent across sites. With the exception of the pre-decant period, the Inner Sun Bay samples have had a slightly higher mean concentration of copper than have the Contwoyto Lake samples.

Liver Tissues

Comparison of the data between muscle and liver tissues indicated that liver tissues carry substantially higher copper burdens than muscle tissues. Mean concentrations of copper in lake trout liver tissues were always higher in the Inner Sun Bay (e.g., mean of 115 mg/kg in 1993) samples than in the Contwoyto Lake samples (e.g., mean of 66.2 mg/kg in 1993). In years for which comparable data are available, mean liver tissue copper concentrations for lake trout from Inner Sun Bay were always higher than lake trout from Concession Lake.

Mercury

Mercury was not used in the gold extraction process at the Lupin Mine. Mercury was not required as a substance to be monitored and reported under the provisions of the Water License issued by the NWB (2000, appended to Golder 2003a). Mercury noted in the various fish tissue analysis would be a result of local geology and naturally occurring mercury and methyl mercury; however, the MMER (2002) require that mercury be monitored in effluents. If 12 consecutive samples of mercury are less than 0.10 μg/L, then no fish tissue analyses are required if this criteria is met. In addition, the MMER (2002) specify a threshold limit of 0.45 mg/kg 'wet' weight (equivalent to approximately 2.25 mg/kg on a 'dry' weight basis, assuming 80% moisture content) for fish tissues. Some of the tissue data from the Lupin Mine have exceeded this threshold. As these data were raised in review comments to the Lupin Mine historical information report (Golder 2003a), data are further examined in Appendix A.

Muscle Tissues

The mean mercury concentration in lake trout muscle tissue samples from Inner Sun Bay in 1993 was 1.16 mg/kg; Contwoyto Lake samples had a mean mercury concentration of 1.12 mg/kg. The 30 Concession Lake samples had a mean concentration of 2.85 mg/kg. The lake trout sampled from Concession Lake were larger than fish from Inner Sun Bay, and this would account for their greater mercury burdens.

Liver Tissues

Mercury burdens found in Inner Sun Bay lake trout liver tissues were consistently lower in the post-decant period than in the pre-decant period; however the mean concentration of mercury in these tissues increased between 1985 and 1993. The mean concentration of mercury in lake trout liver tissues from the Contwoyto Lake site have also increased in each sampling session between 1985 and 1993, and show a similar pattern to that observed for Inner Sun Bay lake trout. The mercury burden in lake trout liver tissues from Concession Lake in 1993 (5.92 mg/kg) is more than twice the level found in 1990.

Lead

Muscle Tissues

The mean concentration of lead in lake trout muscle tissues in the post-decant period to 1993 remained below the detection limit for the Contwoyto Lake and Concession Lake sites. At the Inner Sun Bay site, the mean concentration of lead was below the detection limit in 1988 and 1993, although it was above this limit in 1985 and 1990. The higher mean concentration of lead in 1990 samples can be explained by two samples having relatively high values. With the exception of these two samples, lead levels in lake trout muscle tissues from Inner Sun Bay in 1993 were consistently below the pre-decant levels.

Liver Tissues

For all sites and all years, the mean concentration of lead in lake trout liver tissues in the post-decant period was less than in pre-decant samples. In all years in which samples were collected from both Inner Sun Bay and Concession Lake, the mean concentration of lead in lake trout liver tissues was lower at Inner Sun Bay.

Nickel

Muscle Tissues

The mean concentration of nickel in lake trout muscle tissues from Inner Sun Bay was consistently equal to or less than mean nickel concentrations from Contwoyto Lake samples. In 1988 and 1990, all lake trout muscle tissues from Inner Sun Bay and Contwoyto Lake were below the detection limit. The mean concentration of nickel in muscle tissues from Inner Sun Bay and Contwoyto Lake increased in 1993 over 1990; however, the concentration in lake trout tissues from Concession Lake decreased from 1990 to 1993. Changes in the mean nickel concentrations over time likely reflect natural variability.

Liver Tissues

Nickel burdens in lake trout liver tissues were highest in 1988. There was no apparent trend in mean concentrations of nickel among sites or years.

Zinc

Muscle Tissues

The 1993 mean concentration of zinc in lake trout muscle tissues was lower at all sites than in the pre-decant period. In three of four years the mean zinc concentration was higher at the Contwoyto Lake site than at Inner Sun Bay. For years in which samples were collected from both Inner Sun Bay and Concession Lake, the zinc burdens carried by Concession Lake fish were slightly higher than those from Inner Sun Bay.

Liver Tissues

The mean concentration of zinc in lake trout livers was slightly higher in 1993 than in the pre-decant period. A consistent pattern of zinc burden in lake trout livers was observed, with the mean concentrations from Inner Sun Bay samples always being slightly higher than in Contwoyto Lake samples. Contwoyto Lake samples consistently had higher mean zinc concentrations than Concession Lake samples.

3.8 Reference Area Selection and Characterization

A reference area is defined as water frequented by fish that are not exposed to effluent (MMER 2002). In choosing a reference area, the following criteria were considered:

- similarity to exposure area, in terms of depth, substrate, flow, cover and water quality;
- location in respect to effluent discharge and exposure area. The area should not be exposed to effluent but should be situated relatively close to the exposure area;
- location of previous environmental monitoring programs;
- the number and type of fish to be collected as part of the EEM study program;
- accessibility of site; and,
- other factors that might affect fish movement.

Historically, Shallow and South bays of Contwoyto Lake have been used as reference areas during various fisheries assessments (e.g., AQUAMIN 1996b; EVS 1996). The use of Shallow and South bays as a reference site may not be appropriate because of a TCA spill event that occurred in 1992. In that year, an extremely rapid and large spring snowmelt led to over-filling of TCA Cell No. 3 (Dave Hohnstein, former Lupin Environmental Coordinator personal communication, 22 November 2004). A considerable amount of snowmelt, mixed with tailings effluent, spilled into Long Lake. This material then flowed downstream into Test Lake (colloquially named waterbodies), eventually reaching Shallow and South bays of Contwoyto Lake (Figure 2-1). To date, it is likely that the water quality of affected lakes, streams, and bays would have recovered to near background conditions; however, sediments in exposed waterbodies would likely still have elevated metal concentrations (D. Hohnstein, pers. comm.). A summary of post-spill water quality monitoring, initiated by EBM, of affected waterbodies was provided to the NWB (EBM 2001b, appended to Golder 2003a). Although far downstream, EVS (1996) stated that sediment-metal concentrations in samples collected from South Bay in 1996 did not reveal results that could be attributable to the 1992 spill event.

Most benthic macroinvertebrate assessments have used Outer Sun Bay as a reference area (e.g., Mudroch and Sutherland 1988; Porter et al. 1992) and only one used Shallow and South bays of Contwoyto Lake as reference study (i.e., EVS 1996). As a whole, all of the benthic macroinvertebrate assessments concluded that results were variable and that adverse effects to invertebrate communities in exposure areas were difficult to elucidate from reference areas. EVS (1996) noted that the subtle differences in the benthic communities between the reference and exposure areas may be due to natural factors (e.g., water depth, substrate composition) and that the inclusion of a second reference location and/or a new reference location in future studies would help to distinguish real effects from natural variability. This opinion also was expressed by AQUAMIN (1996b, appended to Golder 2003a).

Based on the above, sampling similar habitats between the exposure area and a reference area would help to remove confounding factors due to habitat variability. Sampling Seep Creek proper, as part of the exposure area, and a similar sized reference stream would meet this goal. There are a few streams in the vicinity of the Lupin Mine that could be considered as candidates for the reference area (Figure 2-1). One candidate stream originates from Fingers Lake and drains directly into Contwoyto Lake; historical data are not available for this stream. Another candidate stream drains Norma Lake, and flows for approximately 600 m prior to emptying into Long Lake. Norma Lake was not subjected to the 1992 tailings spill and features native populations of Arctic grayling, ninespine stickleback, and slimy sculpin. These species are also native to Long Lake. The extent to which the fish populations in these two lakes mix is not known; however, the life histories of the fish species (i.e., life cycles of up to approximately 12 years) would suggest that present fish populations would not have been exposed to the 1992 spill event. The following sections summarize characteristics of Norma Lake and its outlet stream (hereafter referred to as Norma Creek).

3.8.1 General Characteristics of Norma Lake and Norma Creek

Water Quality

RCPL and RL&L (1985) collected baseline water quality data from Norma Creek prior to the initial effluent discharge from the Lupin Mine. In general the water quality of Norma Creek is similar to that of exposure area sites, with low pH, low alkalinity, and low dissolved and total solids. Nutrient and total metal concentrations in Norma Creek tended to fall between higher concentrations encountered in Dam 1a Lake and Seep Creek, and lower concentrations in Concession Creek and Inner Sun Bay (see Section 3.7.2; Appendix C).

Aquatic Habitat and Fish Species

Norma Lake is a comparatively large lake (about half the size of Inner Sun Bay) to the south of the TCA (Figure 2-1). It has a rocky shore with a thick organic deposit in the main basin. The lake is approximately 3.0 m deep (RCPL and RL&L 1985b).

RL&L (1994, appended to Golder 2003a) conducted habitat surveys of Norma Creek. For discussion purposes the creek was divided into two sections (upper and lower Norma creeks), with each section divided by a small unnamed pond. Both upper and lower Norma creeks are approximately 300 m in length. Lower Norma Creek consists of two separate channels, separated by a distance of approximately 15 m. Upper Norma Creek water depths were less than 1 m and wetted channel widths ranged from 4.5 to 7.5 m. Habitat and substrate composition varied among stream reaches. Shallow flats and slow flowing runs were common in upper Norma Creek, whereas lower Norma Creek featured braided sections of riffle-run through boulder gardens. Substrate of upper Norma Creek primarily consisted of fines, whereas lower Norma Creek featured greater amounts of bedrock, boulder, cobbles, and gravel.

On 19 September 1983, discharge at the outlet to Long Lake was 0.09 m^3/s. On this same date, Seep Creek discharge was estimated to be 0 m^3/s (RCPL and RL&L 1985b).

Benthic macroinvertebrates were collected by RCPL and RL&L (1985b) from Norma Lake during autumn of 1982, 1983, and 1984 using a 0.225 cm^2 Ekman grab and 0.250 mm sieve (five replicate samples per sampling session). The benthic community of Norma Lake was dominated by midges (60-85% of total abundance, among years), bivalves (5-23%), and bristle worms (less than 1 to 3%). Mean total number of invertebrates per sample ranged from 386 in 1982 to 1547 in 1984.

Fish sampling in Norma Creek was carried out by RCPL and RL&L (1985b) and by RL&L (1994, appended to Golder 2003a). On 16 August 1983, RCPL and RL&L (1985b) backpack electrofished 450 m of Norma Creek; the catch consisted of nine Arctic grayling, seven slimy sculpin and 25 ninespine stickleback. Studies conducted by RL&L (1994) focussed on Arctic grayling spawning; drift nets were deployed to capture eggs and larvae. Incidental catch among three drift nets deployed for at least seven days (30 June through 7 July 1993) included eight slimy sculpin and 2473 ninespine stickleback.

On two separate occasions, a single gill net set was placed in Norma Lake for one night (RCPL and RL&L 1984; RL&L 1996c). The catch retrieved on 5 August 1983 was comprised of 22 Arctic grayling. On 19 September 1992, 13 Arctic grayling and two burbot were netted.

4.0 PROPOSED STUDY DESIGN

The required study components consist of fish population health, fish tissue analysis (mercury), and a benthic invertebrate community survey. If for any reason one of the components is not completed, a rationale as to why the study is not being conducted is provided. Methodology, field program schedules, interpretative report submissions, and quality assurance and quality control measures are included in the study design.

4.1 Fish Population Survey

4.1.1 Objectives

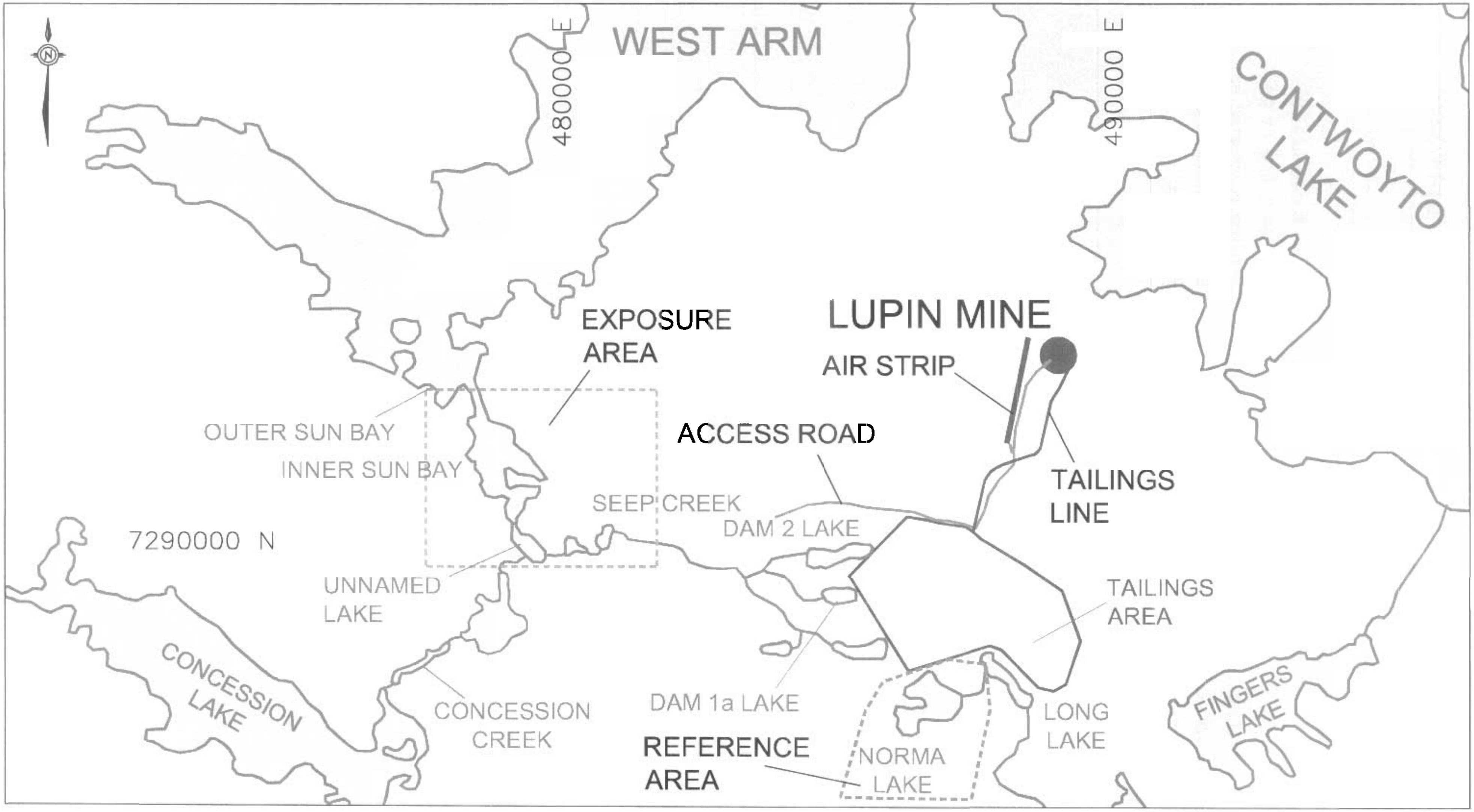
The objective of the fish population survey is to determine if mine effluent discharged into the aquatic environment has any significant negative effect on the growth, reproduction, survival, or condition of fish relative to fish populations in a reference area. An effect on a fish population is defined as a statistical difference between fish population measurements taken in an exposure area and reference area (control/impact design as recommended by Environment Canada 2002).

4.1.2 Study Area

The areas were selected based on similarity in habitat types, the ability to capture the number and type of fish species required for the fish population survey. Fish collected in the exposure area must be exposed to the effluent.

A control/impact design will be completed for the fish population survey. Fish health parameters will be compared between the fish populations from reference and exposure areas (Figure 4-1). The reference area will consist of Norma Lake and Norma Creek. The exposure area will be downstream sections of Seep Creek, Unnamed Lake and Inner Sun Bay. Sampling will be focussed on stream habitats because sufficient amounts of fish have been collected in these streams (e.g., RCPCL and RL&L 1985b; RL&L and DFO 1991; RL&L 1993a) over short time periods (less than one week). In addition, AQUAMIN (1996b) stated that Seep Creek may provide an excellent site for monitoring the biological effects of the Lupin Mine on the receiving environment, partly due to presence of all year classes of Arctic grayling.

R:\CAD\2004\1370-Edmonton\1373-ES\04-1373-046\1000\ Drawing file: Fig 4-1 PROPOSED REFERENCE AND EXPOSURE AREAS.dwg Dec 03, 2004 - 11:43am



PROJECT

KINROSS GOLD CORPORATION
LUPIN MINE
BIOLOGICAL STUDY REPORT

TITLE

PROPOSED REFERENCE AND EXPOSURE AREAS

Golder Associates
Edmonton, Alberta

PROJECT 04-1373-046.1000			FILE No.	Ref_Exposure
DESIGN	MD	01/12/04	SCALE 1:100000	REV. 1
CADD	PSR	02/12/04		
CHECK	JD	03/12/03	**FIGURE: 4-1**	
REVIEW				

4.1.3 Fish Species Selection

The metal mining EEM guidance document (Environment Canada 2002) recommends that fish surveys monitor adult (sexually mature) fish of two species that are relatively sedentary and have been exposed to effluent for a long period of time. In addition, there has been a general shift towards the use of small-bodied forage fish as sentinel species. Historical sampling was used to aid in the determination of appropriate sentinel fish species.

Ninespine stickleback was the only small-bodied forage fish species captured in sufficient numbers in both areas to meet the requirements of EEM. Slimy sculpin is the only other small-bodied forage fish species found in the study area (Table 4-1).

Table 4-1 Summary of Forage Fish Species Captured in the Proposed EEM Exposure and Reference Areas

Study	Location	Capture Methods and Effort	Species	Number
RCPL and RL&L (1985b)	Seep Creek[a]	Box trap (19 June to 1 July 1983; 9 June to 28 June 1984)	Ninespine Stickleback	11
		Backpack electrofishing and seine netting (three dates between 1982 and 1984)	Slimy Sculpin	2
	Norma Creek	Backpack electrofishing (one sampling event)	Ninespine Stickleback	25
			Slimy Sculpin	7
RL&L and DFO (1991)	Seep Creek	Primary method = hoop net[b], period of four days	Ninespine Stickleback	27
		Secondary methods = dip nets and gill nets	Slimy Sculpin	0
RL&L (1993a)	Norma Creek	Drift nets[c] (three nets set for seven consecutive days)	Ninespine Stickleback	2473
			Slimy Sculpin	8

[a] Lower Seep Creek, stream reach that includes the unnamed ponds to the mouth of Unnamed Lake; [b] 6.4 mm mesh; [c] 0.243 mm mesh.

Other adult fish species collected in sufficient numbers/effort to meet the criteria of the EEM program includes the following: Arctic char, Arctic grayling, cisco, lake trout, and round whitefish (Table 3-11). Of these, only Arctic grayling were captured in Norma Lake and Norma Creek (see Section 4.1.2, above).

Although small numbers of slimy sculpin were captured in both Seep and Norma creeks, and a small number of ninespine stickleback from Seep Creek (Table 4-1), these species will be targeted as the two sentinel fish species. Alternatives to these species, should catches prove to be insufficient to meet study design needs, could include Arctic grayling. AQUAMIN (1996b) selected Arctic grayling as a sentinel fish species for monitoring the biological effects of the Lupin Mine on the receiving environment.

As past studies have encountered difficulties in catching sufficient numbers of small-bodied species, the study design and the target species cannot be fully elucidated until the field survey is initiated. Rather, they will be chosen in consultation with Environment Canada during the survey based on sampling success in the exposure area, Seep Creek. The fish study design will be chosen in a priority sequence, as outlined in Figure 4-2, depending on the presence and abundance of adult or juvenile small-bodies fish (i.e., ninespine stickleback and slimy sculpin) or juvenile large-bodied species (e.g., juvenile Arctic grayling).

The fish survey, using small-bodied fish species, involves the collection of 20 adult males, 20 adult females and 20 juveniles. Fish are lethally sampled (where practicable) to assess for fork or total length (as applicable), total body weight, age, life stage and maturity, external condition, gonad weight and pathology (adults only), fecundity, egg size, liver weight and liver pathology (adults only), carcass weight (adults only), sex and internal condition. An adult survey of two small-bodied species is preferable but only one species will be studied if that is all that is available. If insufficient numbers of adults are available, a non-lethal survey of juvenile fish of two or one species will be conducted (according to protocols outlined below in Section 4.1.4). In this situation, 100 juvenile fish of each species (either small-bodied or large-bodied species) will be sampled at the exposure area, measured for fork or total length, body weight, age, external condition, and sex (if possible) and then released alive. If insufficient numbers of fish are available in the exposure area to conduct a lethal or non-lethal survey, then the survey will be stopped. Sufficient sampling effort is considered to be seven consecutive days of sampling in the exposure area using various gear types in different habitats and at different times of day.

4.1.4 Study Methods

Final selection of study species and data collections will be determined during field survey and will depend on the presence and abundance of fish in the exposure area (Figure 4-2). To conduct an adult fish survey, the study species should be small-bodied because adult large-bodied species likely move in and out of the exposure area and may also be affected by recreational fishing. However, if a non-lethal survey of juveniles is conducted, the study species may be small-bodied or juvenile large-bodied species. As