IMPACT ASSESSMENT OF FISH RESOURCES IN VANGORDA CREEK

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EXECUTIVE SUMMARY

Vangorda Creek is used by juvenile chinook salmon and Arctic grayling as well as small numbers of round whitefish, burbot and slimy sculpins. These fish are found throughout the lower 1.9 km of accessible stream channel.

Chinook salmon fry move into Vangorda Creek from the Pelly River sometime between June and August. Although some juvenile chinook overwinter in the creek the majority appear to drop into the Pelly River before late October. Sampling conducted in August 1989 resulted in a population of approximately 20,260 fry. The estimated population in Vangorda Creek declined to approximately 2,700 fry by late October. Sampling conducted in April 1989 indicated that approximately 700 juvenile chinook had overwintered in the creek. Important habitat characteristics appear to be the large cobble substrate and high ground water flows during the winter period.

Adult chinook salmon do not spawn in Vangorda Creek. Chinook fry in the creek are likely progeny from upstream tributaries such as Blind Creek or from mainstem spawners in the Pelly River. The chinook fry densities observed in August were extremely high when compared to those observed in other tributaries to the Pelly River during 1989. The brood year corresponding with 1989 fry production was one of the highest escapement years on record suggesting that observed fry densities and subsequent estimates of habitat use in Vangorda Creek during 1989 may have been near maximum levels.

Sub-adult grayling were found in Vangorda Creek during all three sample periods. Numbers were low during the summer sample and were highest in the fall. Population size was estimated at 655 fish during October. An absence of fry during the August sample suggests that the creek is not a major spawning area for adult grayling.

Available literature on the toxicity of zinc and other metals in relation to the aquatic environment were reviewed. Based on this review an assessment of background and predicted conditions in Vangorda Creek and the Pelly River was made.

Background concentrations of Zn, Cu and Pb in Vangorda Creek are relatively high compared to recommended levels for these metals as reported in the literature. Although background conditions on occasion exceed recommended levels, the presence of a viable population of rearing chinook salmon indicates fish have adapted to these conditions in Vangorda Creek.

Based on previously established relationships from the literature and available alkalinity data for Vangorda Creek, estimates of the maximum allowable toxic concentration (MATC) were made for each month. Threshold values ranged from 0.24 mg/L in May to 0.41 mg/L in February. These estimates were directly related to alkalinity levels. Comparing these MATC values to predicted Zn concentrations in Vangorda Creek indicated that waters would be non-toxic throughout the year during operations with water treatment.

Without water treatment Vangorda water would be toxic to salmonids for 11 months of the year. For this reason the above mentioned water treatment plant would be commissioned. Using the same approach for the Abandonment Phase indicated waters would likely be non-toxic for all months except April with or without till covers.

The above analysis was done on the basis on Zn alone and with limited water hardness and flow data. These are important factors in the assessment of toxicity and because of the limited background data these findings should be viewed as preliminary.

Predicted Zn levels alone, and in complexes with Cu could be high enough to cause avoidance reactions and interfere with juvenile salmon migrating in and out of Vangorda Creek during the Operation and Abandonment Phases.

If elevated Zn levels exceed threshold values for avoidance behaviour and migration interference, then the loss of juvenile rearing capabilities in Vangorda Creek can be expected. Based on 1989 data this could affect a rearing population of up to 20,260 chinook fry. Using a number of assumptions, it was estimated that this level of juvenile use in Vangorda Creek could translate into losses of up to 615 adult chinook salmon.

Preliminary analysis of predicted Zn values in the Pelly River indicated these waters would remain non-toxic to salmonids for all four scenarios examined. However, this assessment is very tenative due to the absence of water hardness or alkalinity data for the Pelly River. Interference with juvenile and adult fish migrations in the Pelly River due to elevated Zn levels are not anticipated.

A number of recommendations have been made. These include an expanded water quality sampling program, installation of a continuous flow recording station in lower Vangorda Creek, seasonal fish monitoring and toxicity studies on juvenile chinook salmon and Arctic grayling.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Vangorda Creek is a small 9,300 ha watershed which drains into the upper Pelly River (Figure 1.1). The Vangorda and Grum open pits and waste dumps presently being developed by Curragh Resources Inc. are located within the Vangorda drainage.

Previous fisheries studies have indicated that the lower 1.9 km of Vangorda Creek is used by juvenile chinook salmon and Arctic grayling (Harder and Bustard, 1987; and Montreal Engineering Ltd., 1977). Fish are not present in the watershed upstream of the road culvert near Faro townsite. A second barrier is present approximately one kilometer upstream from the road crossing.

Pre-development work on the Vangorda and Grum ore bodies has indicated there is potential for acid generation from the pit and waste dump areas at the new mine site during both the Operational and Abandonment Phases of the mine development. Significant downstream water quality impacts in Vangorda Creek and in the mixing zone of the Pelly River near the Vangorda Creek confluence may develop. Modelling studies undertaken by Curragh Resources Inc. (1989) indicate that water quality impacts would be most severe during the month of April, a period when snow cover at the mine site is melting rapidly and streamflows are expected to still be relatively low. Water quality changes could affect fish in Vangorda Creek and along the Pelly River margin near the Vangorda Creek confluence.

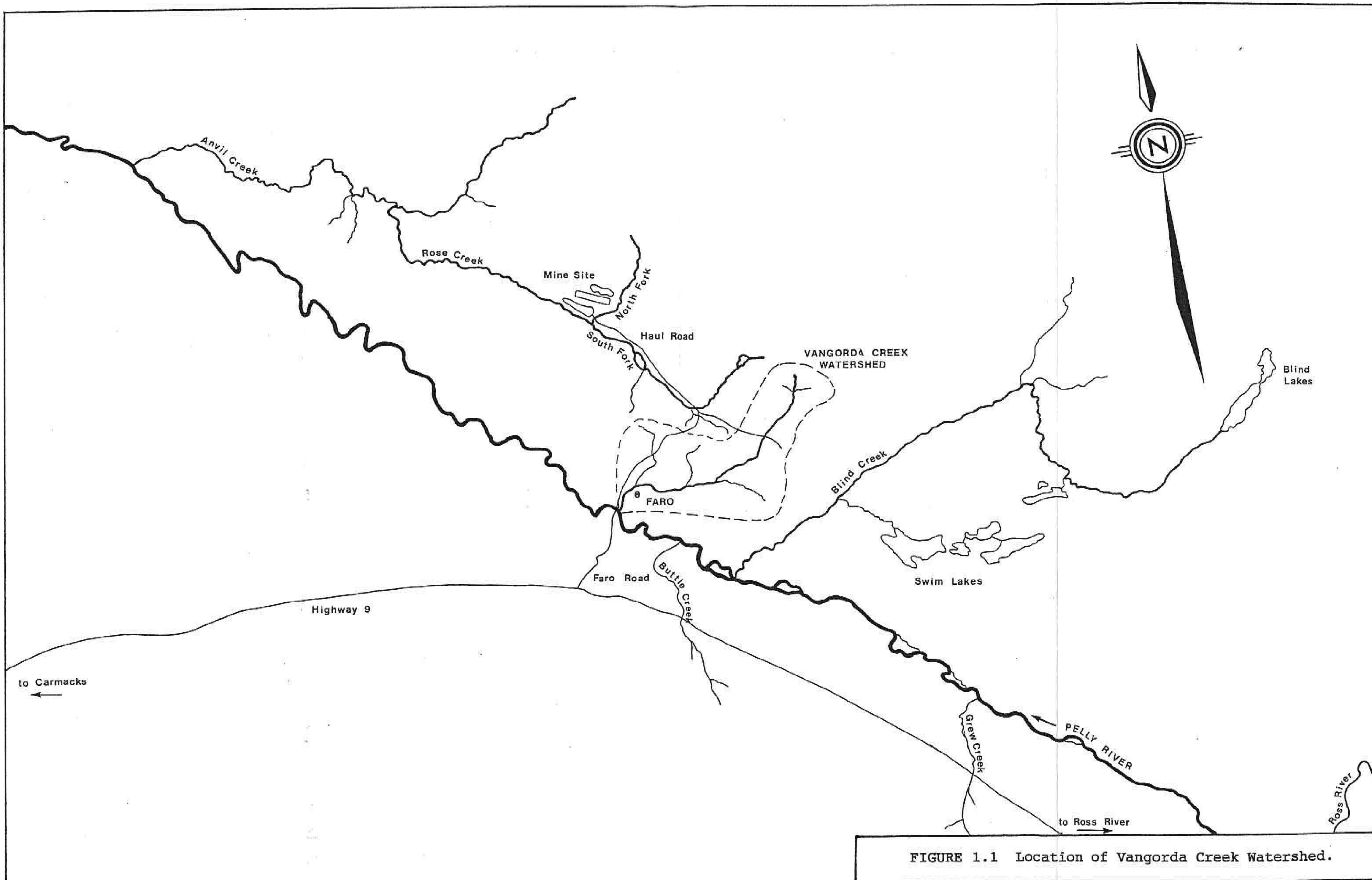

FIGURE 1.1 Location of Vangorda Creek Watershed.

Due to predictions of acid generation and the resultant downstream contaminant migration from the new mine sites in the upper Vangorda watershed, Curragh Resources Inc. requested that additional fisheries studies be undertaken in lower Vangorda Creek. The primary objectives of these studies were to:

1) Examine fish production capabilities and estimate populations during various seasons in lower Vangorda Creek;

2) Determine if Vangorda Creek is used by over-wintering fish;

3) Determine the amount of rearing and over-wintering habitat in lower Vangorda; and

4) Assess potential impacts of the proposed mine development on fish populations using lower Vangorda Creek and the Pelly River.

This report presents the findings of the 1989 fish sampling program, and initial research on zinc and other metal toxicity in relation to fish production. As well, it presents a number of recommendations for monitoring and further impact assessment work.

2.0 METHODS

2.1 Fish Habitat Assessment

Fish sampling and habitat measurements were undertaken in Vangorda Creek and the Pelly River during the spring, summer and fall of 1989.

2.1.1 Spring Survey

Vangorda Creek was sampled in the short period between the break-up of ice cover and the onset of the spring freshet prior to any potential upstream or downstream fish movements. Sampling during this period provided information on overwinter fish use of lower Vangorda. The sampling program was conducted between April 24 and 28.

Electrofishing was conducted at eight sites in lower Vangorda Creek and along the margin of the Pelly River below the Vangorda confluence (Figure 2.1). The total sample areas in Vangorda Creek and the Pelly River were 920 m^2 and 100 m^2 respectively. Two of the sample sites (V1 and V3) were enclosed with stopnets but ice and flow conditions prevented the use of stopnets for the remaining locations. Baited minnow traps set overnight at two locations were found to be ineffective.

All fish captured were measured to the nearest mm fork length and returned to the stream. Stream discharge was measured at Site V1. The length of channel sampled, water temperature and ice conditions were noted.

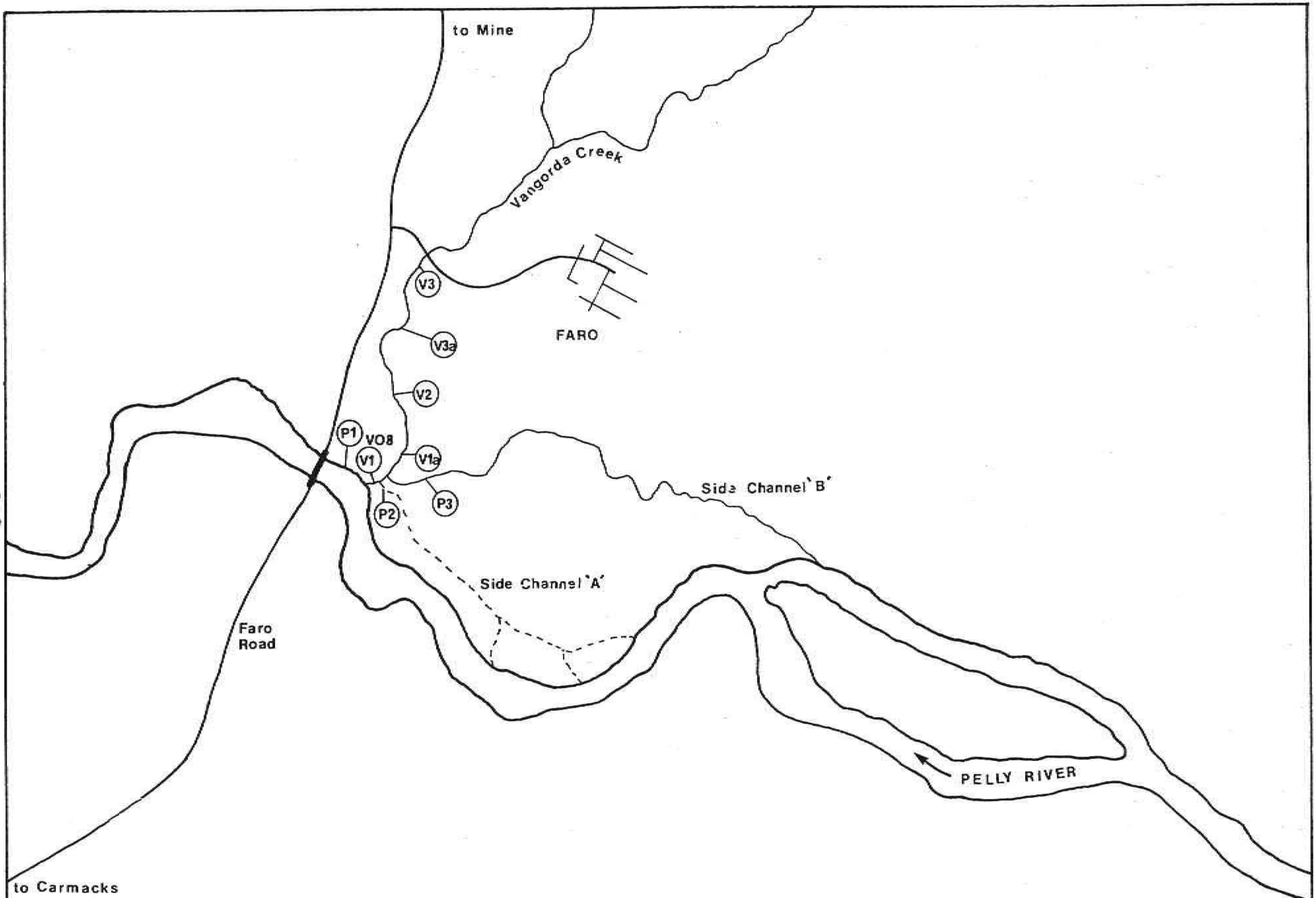

FIGURE 2.1 Sample Site Locations in Vangorda Creek and the Pelly River.

Dissolved oxygen levels in the Pelly River side channels were measured using a YSI Model 2 instrument on April 27 immediately prior to ice break-up.

2.1.2 Summer Survey

Summer fish surveys were conducted on August 11 and 12, 1989. Electrofishing was conducted at four sample sites (V1, V2, V3 and V4; Figure 2.1). A two-pass removal using stopnets was used to estimate fish populations (Seber and LeCren, 1967). Habitat measurements were recorded on DFO/MOE Stream Survey forms. As well, a detailed measurement of available habitat between the Pelly River and the Faro Road culvert was made. Wetted channel widths and slope measurements were taken at 50 m intervals along with a description of bed material size and channel form. The combined sample area for the four sites was 466 m^2. Fish fork lengths were measured at each sample site and a sample of fish was retained for weight measurement.

2.1.3 Fall Survey

A pre-winter survey was conducted between October 17 and 22. Fish sampling was conducted in Reaches 2 and 3 (Sites V3 and V4; Figure 2.1). Sampling was not conducted in Reach 1 due to ice that formed three days prior to the sample period. Sampling techniques were the same as those described for the summer survey. The combined sample area of all sites during the fall period was 420 m^2.

Minnow traps baited with roe were set in the Pelly River back channels during the summer and fall surveys. The October trapping was conducted through holes in the ice-covered channel.

2.2 Impact Assessment

The impact assessment presented in this report is based on an extensive review of the literature on metal toxicity and the aquatic environment. Estimations of maximum allowable toxic concentrations (MATC) were derived for various metals from the relationships developed in other studies. The equations used for estimating conditions in Vangorda Creek are presented in the text of this report. Predicted conditions in Vangorda Creek with respect to dissolved zinc were provided by Curragh Resources Inc. These predictions were based on a water balance metal load model which has been described in the Initial Environmental Evaluation (Curragh Resources Inc., 1989). Background water quality data was provided by Curragh Resources Inc.

3.0 FISH RESOURCES

3.1 Habitat Description

The lower 1.9 km of Vangorda Creek between the Faro Road culvert and the Pelly River has been divided into three reaches (Figure 2.1). The average gradient ranges from 2 to 3% in the three reaches. A stream profile for the accessible portion of Vangorda Creek is presented in Figure 3.1.

Reach 1 extends upstream from a side channel of the Pelly River for 300 m. The channel is unconfined with a bed material of gravels and small cobble. The average channel width is approximately 70 m with an average wetted width of 12 m in the late summer. Total wetted habitat area during the late summer period in this reach amounted to 3,840 m^2. Side channel habitat comprised approximately 30% of the wetted areas at this time. Downstream of Reach 1 there is a 200 m section of channel between the Pelly River side channel and mainstem. This channel is predominantly influenced by Vangorda Creek flows for 11 months of the year. During the high flow period (July) Pelly River flows predominate in this section of channel. Large quantities of fine sediment are deposited in the channel each summer.

Reach 2 is 550 m long, moderately confined and has minimal side channel habitat. The bed material is primarily large cobbles and boulders. The reach is typically steep riffles with less than 5% pools during the late summer period. The average channel width is 25 m and average wetted width was 6.3 m during late late summer.

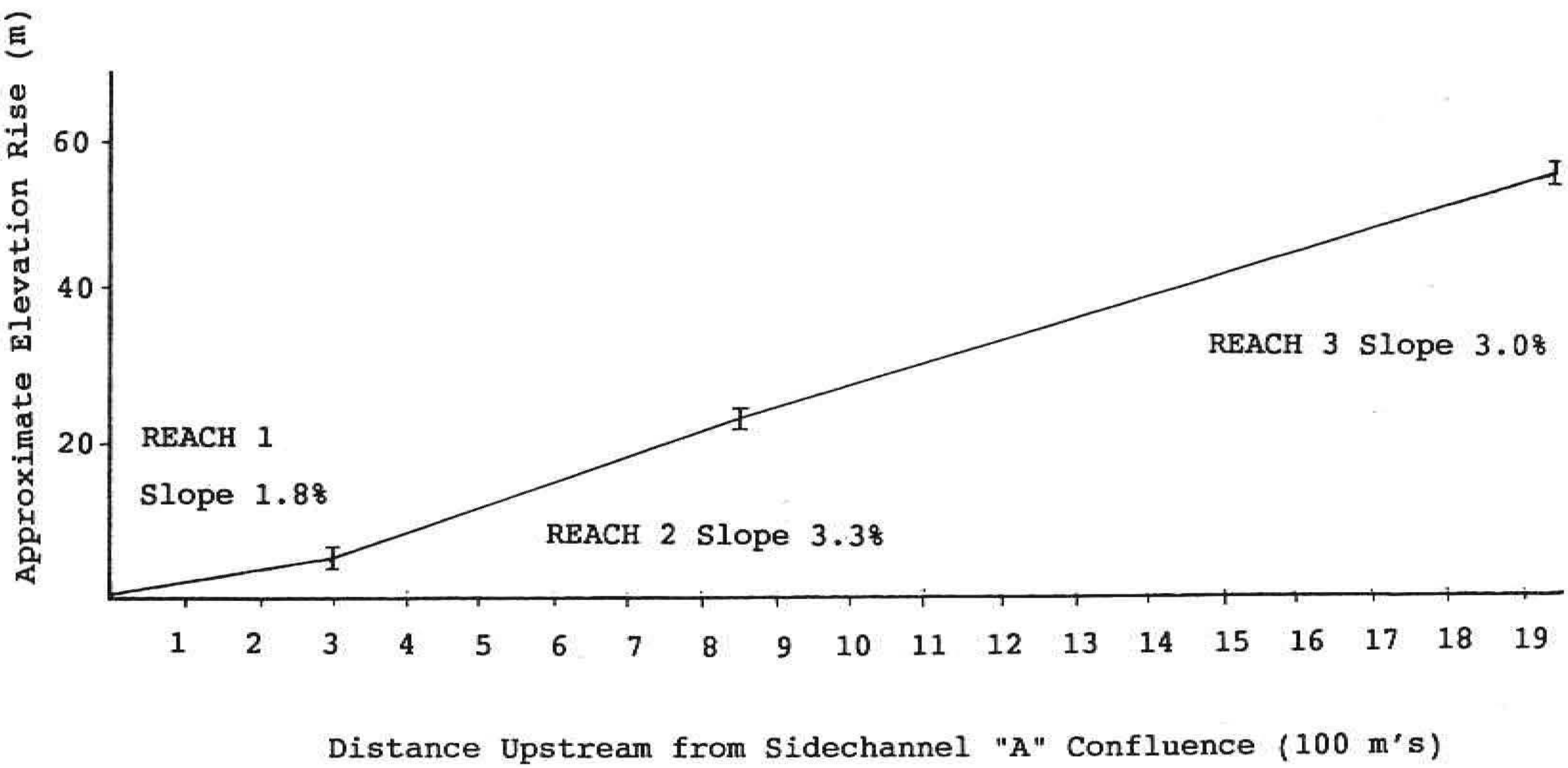

FIGURE 3.1 Stream Profile of Lower Vangorda Creek.

Total wetted habitat area during the late summer period in this reach amounted to 3,130 m^2 decreasing to an estimated 2,800 m^2 in the late fall just prior to freeze-up.

Reach 3 is 1,093 m long and extends upstream to the road culvert. This reach has more pool habitat than in the lower reaches. The bed material is primarily large cobble. Average channel width was 8 m with an average wetted width of 6.8 m during late summer. Total wetted habitat area during this period amounted to 7,370 m^2. Wetted habitat area was estimated to have declined to approximately 5,030 m^2 in the late fall based on measurements conducted in a portion of the reach.

A more complete description of habitat characteristics in Vangorda Creek is found in the baseline report prepared by Harder and Associates in 1987. Representative photographs of the lower three reaches of Vangorda Creek during the 1989 spring, summer and fall periods are presented in Appendix 1. Physical data for individual sample sites is found in Appendix 2.

Habitat near lower Vangorda Creek include two side channels of the Pelly River which enter the mainstem river near the Vangorda Creek confluence (Figure 2.1). Side channel "A" is approximately 1.7 km long and has an active channel width of 70 m with bed material of gravel and some small cobbles. The channel was intermittent during the spring and fall periods in 1989. Side channel "B" is 3.2 km long and joins side channel "A" approximately 200 m upstream of the Pelly mainstem. This is a well defined, meandering flood channel remaining wetted year-round. The channel is "U" shaped in cross section and the average water depth during April was between 0.5 and 1.0 m. The lower end of the channel has a silty substrate, an average wetted width of approximately 12 m and vertical 1 to 1.5 m vegetated banks (Appendix 1; Plate 17). The upper end of the channel is shallower and has a larger substrate size (Appendix 1; Plate 18). An examination of aerial photographs taken in 1967 indicate that this channel has remained relatively stable over the past 20 years.

3.2 Fish Distribution and Abundance

The following sections detail the survey conditions in Vangorda Creek during the spring, summer and fall periods, and are followed by fish habitat use data and population estimates from lower Vangorda Creek and the Pelly River side channels.

3.2.1 Vangorda Creek

3.2.1.1 Spring Survey

Survey Conditions

The spring sampling data and observations were collected as the ice cover was breaking up on the creek. By April 28 the entire creek was open except for a small ice-blocked section upstream of the lower road crossing. Ice and habitat conditions in lower Vangorda Creek at this time are shown on Plates 1 to 11 in Appendix 1. Stream discharge in Vangorda Creek below the lower road was 1.6 m^3/sec on April 28, approximately two to three times the volume first observed on April 24.

Much of the stream substrate in Reaches 2 and 3 was covered in thick anchor ice during late April.

Spring Habitat Use

Juvenile chinook salmon and Arctic grayling were found throughout lower Vangorda Creek during the spring survey. A total of 147 chinook (age 1+) and 59 juvenile grayling were collected. Most of the fish were captured in the lower two reaches. Abundances of juvenile chinook salmon ranged from 3.7 fish per 100 m of channel length in Reach 3 to 45.0 fish per 100 m of channel in Reach 2 (Table 3.1). Since sampling efforts were hampered by ice conditions and stopnets were not used for some of the samples, these are minimum estimates. Chinook sakmon average 71.0 mm fork length and ranged from 55 to 88 mm (Table 3.2). Grayling abundances were 6.5, 2.0 and 2.5 fish per 100 m of channel length in Reaches 1,2 and 3 respectively (Table 3.1). Grayling collected from the lower reach had a mean fork length of 68.5 mm while those taken further upstream in Reaches 2 and 3 had a mean fork length of 139.5 mm (Table 3.2).

The narrow channel of meltwater flowing over ice (Appendix 1; Plate 2) at the time of sampling created a distinct velocity barrier to potential upstream fish movements at the lower bridge crossing in Vangorda Creek. It was assumed that fish captured in Vangorda Creek during the April sample period had overwintered there However, it is possible that chinook and grayling catches below the bridge in lower Vangorda Creek may have been influenced by fish moving upstream from the Pelly River as this portion of

TABLE 3.1 Seasonal Catch Data for Juvenile Chinook Salmon and Arctic Grayling in Lower Vangorda Creek During 1989.

CHINOOK	Fish/100 m Channel Length			Fish/100 m² Channel Area		
Reach	Spring	Summer	Fall	Spring	Summer	Fall
1 Main	24.0	81.0	136.0	21.6	82.9	27.8
1 Side	ns	81.0	ns	ns	366.6	ns
2 Main	45.0	505.0	138.0	33.0	88.6	27.2
3 Main	3.7	1377.0	136.5	5.5	148.1	29.6

ARCTIC GRAYLING	Fish/100 m Channel Length			Fish/100 m² Channel Area		
Reach	Spring	Summer	Fall	Spring	Summer	Fall
1 Main	6.5	0.0	ns	10.9	0.0	ns
1 Side	ns	0.0	ns	ns	0.0	ns
2 Main	2.0	11.0	50.0	1.5	1.9	9.8
3 Main	2.5	0.0	21.0	4.2	0.0	4.7

"ns" indicates that no sample was taken.

TABLE 3.2 Seasonal Fork Length Data for Juvenile Chinook Salmon and Arctic Grayling in Lower Vangorda Creek During 1989.

SAMPLE PERIOD	Chinook Salmon			Arctic Grayling		
	Mean Fork Length (mm)	N	Range (mm)	Mean Fork Length (mm)	N	Range (mm)
Spring	71.0	93	55 - 88	93.6		61 - 234
Summer	65.2	120	52 - 82	124.0	2	118 - 130
Fall	71.2	116	58 - 89	134.0	26	105 - 195

the creek was ice-free and accessible from downstream areas.

An examination of habitat characteristics in this section tends to support this notion. The relatively small substrate size suggests marginal over-wintering capabilites for chinook salmon in comparison to upstream areas in Reaches 2 and 3.

Based on channel length and fish sampling data, it was estimated a minimum 720 chinook juveniles and 116 grayling sub-adults overwintered in lower Vangorda during the winter of 1988/89 (Table 3.3). These estimates were derived using fish sample data collected along a one meter wide margin of the open stream channel. The results were applied to the total reach length and then doubled to account for the opposite stream margin. This approach probably underestimates the true population size since there is no account made for mid-channel use and stopnets were not used at most sites. Therefore the catch data does not reflect escaped or missed fish from the sample.

3.2.1.2 Summer Period

Survey Conditions

Water conditions were clear, and a discharge of approximately 1 m^3/sec allowed for effective sampling during this period. Water temperatures ranged from 6 to 9°C.

Summer Habitat Use

Electrofishing in August resulted in a total catch of 892 fish over a combined sample area of 466 m^2. Chinook fry accounted

TABLE 3.3 Population Estimates for Juvenile Chinook Salmon and Arctic Grayling in Vangorda Creek During April, August and October, 1989. Based on Reach Length and Fish per Linear Meter Data.

1. Chinook Salmon Juveniles

Reach	Channel Length (m)	SPRING fish/ 100 m	SPRING Pop. Size	SUMMER fry/ 100 m	SUMMER Pop. Size	FALL ** fry/ 100 m	FALL ** Pop. Size
1	300	24.0	72	810.0	2430	138.0	414
2	550	45.0	248	505.0	2778	138.0	759
3	1093	3.7	40	1377.0	15051	136.5	1492
TOTAL FISH =			720*		20259		2665

2. Arctic Grayling (Sub-adult)

Reach	Channel Length (m)	SPRING fry/ 100 m	SPRING Pop. Size	SUMMER fry/ 100 m	SUMMER Pop. Size	FALL ** fry/ 100 m	FALL ** Pop. Size
1	300	6.5	20	0.0	0	50.0	150
2	550	2.0	11	11.0	61	50.0	275
3	1093	2.5	27	0.0	0	21.0	230
TOTAL FISH =			116*		61		655

* An adjustment factor of 2 times was applied to the estimated population size during the spring to account for the opposite stream margin that was not included in the electrofishing sample. Both margins of the stream were sampled during the summer and fall periods.

** Fall estimates for Reach 1 were derived on the basis of Reach 2 sample data.

for over 88% of the catch. Slimy sculpin comprised 10.5% of the catch followed by round whitefish (1.1%) and Arctic grayling (0.2%).

Juvenile chinook salmon were found throughout the lower three reaches of the creek with average fry abundances of 81, 505, and 1,377 fry per 100 m of stream channel in Reaches 1, 2 and 3 respectively (Table 3.1). Small numbers of sub-adult grayling were found only in Reach 2 (Table 3.1).

Population sizes were estimated both on the basis of channel length and habitat area coupled with catch data from the electrofishing surveys. Using reach length and applying catch per linear meter data, it was estimated that Vangorda Creek supported a population of approximately 20,260 chinook salmon fry during August, 1989 (Table 3.3). The estimated population size was similar the same (19,500 fry) when calculated on the basis of channel area and fry density data (Table 3.4). The grayling population was estimated at approximately 60 fish using both approaches (Table 3.3 and 3.4).

3.2.3 Fall Survey

Survey Conditions

The fall survey was conducted in late October after a period of cold weather. Lower Vangorda Creek (Reach 1) was frozen over and could not be sampled (Appendix 1; Plate 22). As well much of the channel below the Faro Road culvert was partially covered with ice and could not be sampled. However, several stream sections in

TABLE 3.4 Population Estimates for Juvenile Chinook Salmon and Arctic Grayling in Vangorda Creek During April, August and October, 1989. Based on Wetted Habitat Area and Fish Density (fish/m^2) Data.

1. Chinook Salmon Fry

REACH AND CHANNEL TYPE	SUMMER Area (m^2)	SUMMER fry/ 100 m^2	SUMMER Pop. Size	FALL * Area (m^2)	FALL * fry/ 100 m^2	FALL * Pop. Size
1 Main	2926	82.9	2484	1800	27.2	518
1 Sidechannel	898	366.6	3292	0	-	-
2 Main	3130	88.6	2773	2805	27.2	761
3 Main	7366	148.1	10909	5028	29.6	1488
	14390 m^2			9633 m^2		
TOTAL FISH =			19,458			2,767

2. Arctic Grayling (Sub-adults)

REACH AND CHANNEL TYPE	SUMMER Area (m^2)	SUMMER fry/ 100 m^2	SUMMER Pop. Size	FALL * Area (m^2)	FALL * fry/ 100 m^2	FALL * Pop. Size
1 Main	2926	0.0	0	1800	9.8	176
1 Sidechannel	898	0.0	0	0	-	-
2 Main	3130	1.9	60	2805	9.8	275
3 Main	7366	0.0	0	5028	4.7	236
	14390 m^2			9633 m^2		
TOTAL FISH =			60			687

* Fall estimates for Reach 1 were derived on the basis of Reach 2 sample data.

Reaches 2 and 3 in the vicinity of the August sample sites were open and were sampled effectively. Stream discharge was visually estimated to be 0.5 m^3/sec at this time.

Fall Habitat Use

A total of 146 fish were estimated in a sample area of 420 m^2. Of the total catch chinook salmon fry were the most abundant representing 81% of the total. Chinook fry had a mean fork length of 71.2 mm with a range of sizes of 58 to 89 mm (Table 3.2). Sub-adult grayling were the next most abundant species during the fall sample representing 18% of the catch. These fish ranged in size from 105 to 195 mm and had a mean fork length of 134 mm. The remaining 1% of the catch consisted of slimy sculpins.

Chinook fry abundances at the three sample sites (Sites V2a, V3a and V3b) were quite similar, ranging from 134 to 143 fry per 100 linear meters of channel (Appendix 2). Using these data for the upper two reaches and assuming that Reach 1 would have supported similar numbers of fish as found in Reach 2, it was estimated that the pre-winter chinook salmon population was approximately 2,670 fish (Table 3.3). This estimate increased to 2,770 fish when calculated on the basis of fish density (fish per 100 m^2) and wetted habitat area (Table 3.4). These estimates do not include fish production from the 200 m section of channel between the mainstem Pelly River and the confluence of Vangorda Creek with the Pelly River side channels. Habitat capabilities are low in this section due to a high fines content in the substrate.

Grayling abundances were substantially higher during the fall sample than in the spring and summer samples. Abundances of sub-adult fish ranged from 21 to 50 fish per 100 linear meters in Reaches 2 and 3 respectively (Table 3.1). Using these data it was estimated that lower Vangorda Creek supported a population of approximately 650 during the fall (Table 3.3). The estimated population size was slightly higher when made on the basis of fish density and habitat area (Table 3.4).

3.2.2 Pelly River Sidechannels

Extensive sampling during the spring was not conducted on the Pelly River due to the presence of ice along the river margins. Sampling conducted in the mainstem Pelly River 200 m below the confluence of Vangorda Creek and side channel "A" indicated relatively low densities of both juvenile chinook salmon and Arctic grayling. Chinook fry densities were estimated at 6.7 fry per 100 m^2 compared to 32.0 fry per 100 m^2 in the section of channel between the mainstem and the Vangorda confluence. Similarly grayling densities were estimated at 3.3 fish per 100 m^2 in the Pelly mainstem compared to 19.0 fish per 100 m^2 in the section of channel below the Vangorda Creek confluence.

Overwinter habitat capabilities in the Pelly River side channels were also assessed in this study. Side channel "A" (see Figure 2.1) was dry during April except for a few isolated, shallow pools near Vangorda Creek (Appendix 1; Plates 14 to 16). Live fish were not present during the April electrofishing sample; however, the decomposed remains of seven juvenile salmonids (suspected chinook) were observed in these pools. These observations suggest that side channel "A" did not provide suitable overwintering habitat during the winter of 1988/89.

Fish sampling was not conducted in side channel "B" due to the ice cover that was present in late April. However, the entire channel remained wetted throughout the winter and dissolved oxygen levels measured at the surface and near the bottom (7.4 to 9.0 ppm) indicated that the channel could support overwintering fish.

Five minnow traps were set for an eight-hour daylight period in sidechannel "B" during the summer survey. A total of 16 chinook salmon fry ranging in length from 61 to 80 mm were caught with an average catch per trap of 3.2 fry. The highest trap catches were associated with instream cover. No other species were caught at this site.

For comparative purposes nine traps were set in a side channel of the Pelly River below the Blind Creek confluence (Site P5) during the summer sample. The total catch was 140 fish or 15.5 fish per trap. Longnose suckers were the most abundant species with an average catch per trap of 13.1 followed by longnose dace with 2.0 fish per trap. A single chinook fry, round whitefish, slimy sculpin and burbot were also caught at this site. The trap site encompassed a deep pool and log jam habitat on the margin of the Pelly River as well as a long shallow run in the side channel.

Ten minnow traps set overnight in side channel "B" during the fall survey resulted in an average catch per trap of 9.3 chinook salmon. These data, coupled with physical habitat assessment work done in the spring, suggest that this side channel habitat may be relatively important as a chinook over-wintering area (Appendix 1; Plate 25). Catches of juvenile chinook during late October were approximately three times the level of August and suggest a movement of fish into this habitat since August.

3.3 Discussion - Fisheries

The results from fish sampling during the past two years suggests that large numbers of juvenile chinook move into the lower 1.9 km of Vangorda Creek sometime between June and early August. Sampling conducted at two sites during the first week of June, 1987 indicated no fish were present in lower Vangorda Creek whereas sampling conducted in August, 1989 resulted in extremely high catches of chinook fry throughout the lower creek. Subsequent sampling during the fall of 1989 suggested that many of these fish drop out of the system by late October, although a portion remain in the creek through the winter and presumably leave shortly after ice break-up in the spring. No adult chinook spawners have been observed during the August sampling or reported for other years, indicating that Vangorda Creek is used strictly for juvenile rearing.

A small number of Arctic grayling, slimy sculpin and round whitefish also use lower Vangorda Creek on a seasonal basis. Sub-adult grayling primarily use the creek as a rearing area and are most abundant during the fall. Grayling were virtually absent from the August sample while denisites averaged 7.3 fish/100 m during the October sample. Grayling were moderately abundant during the April sample period. Spawning adult grayling were not found during the spring survey in 1989. These observations, along with an absence of fry from the August 1989 and 1987 samples, suggest that the creek is not a significant spawning area for Arctic grayling.

The origin of chinook salmon fry in Vangorda Creek is not known. These fish may be the progeny of spawning populations in upriver tributaries such as Blind Creek or possibly from Pelly River mainstem spawners. Blind Creek enters the Pelly River approximately 12 km above the Vangorda Creek confluence. Chinook salmon spawn during the month of August in these systems. Fry emergence is thought to occur during May in the upper Yukon system (Walker, 1976). Following emergence the fry distribute downstream and occupy available mainstem and tributary rearing habitats. Previous studies (Davies and Shepard, 1981 and Anon., 1983) report chinook fry moving into the small tributaries of the upper Yukon system during the summer period. Walker (1976) reported that chinook fry move out of the small tributaries to the upper Yukon River during the fall and over-winter in the mainstem areas. This pattern of chinook salmon juveniles moving out of tributaries and into larger river systems in areas experiencing cold winters has been documented in Idaho streams (Chapman and Bjornn, 1967; and Hillman and Griffith, 1987). Extensive in Idaho streams suggest the September downstream movement of chinook juveniles is attributed to falling water temperature (<5°C) and lack of suitable winter cover (Morril, 1972). These trends are generally consistent with the findings of the 1989 sampling program in Vangorda Creek. However, the use of small tributary streams for overwintering in the Yukon had not been previously reported. Presumably the difficulty of sampling during the short time period between when the ice leaves the tributaries and the downstream smolt exodus accounts for the lack of information for this period.

Chinook fry densities collected in Vangorda Creek during 1989 (90 to 200 fry/100m^2) were very high when compared to sample results collected at the same time in Blind (4 to 55 fry/100m^2), Grew (18 fry/100 m^2) and Anvil Creeks (5 to 28 fry/ 100m^2; see Figure 1.1). In studies of the Morice River in northwestern B.C., Envirocon (1984) reported chinook densities ranging from 5 to 10 fry/ 100 m^2.

Population estimates for chinook fry in Vangorda Creek during the summer and fall of 1989 indicate that the majority (87%) of rearing fish moved out of the creek between mid-August and mid-October. Chinook fry remaining in Vangorda Creek during the winter period would likely seek cover in the interstitial spaces of the boulder and cobble substrate and remain inactive until the following spring. Based on physical habitat characteristics it appears that the most suitable overwintering habitat would be found in Reaches 2 and 3. These reaches are characterized by a large substrate size and a single channel. The side channels in Reach 1 are shallow and probably dewater or freeze during the winter. Mortalities due to dewatering and freezing have been reported as a significant constraint to overwintering fish in some northern B.C. systems (Bustard, 1986).

If it is assumed that there is a 30% survival rate over the winter period, it could be expected that the estimated 1989 fall chinook population would yield approximately 800 smolts next spring. Using a smolt to adult survival rate of 10% (T. Beacham; DFO Whitehorse, pers. comm.), 800 smolts would result in the production of approximately 80 adult chinook salmon which were dependent on the summer and over-wintering habitat capabilities in Vangorda Creek. Indications for the Yukon drainage suggest that the interception/ escapement ratio is in the order of 3:1 (Milligan et al., 1984); this would translate to a spawning escapement of approximately 20 adult chinook salmon into the upper Pelly system.

Using the same approach with the estimated 20,260 chinook fry in Vangorda Creek during the summer period yeilds an estimate of 615 adult fish. This is the estimated adult production that would be realized from fry using Vangorda Creek for rearing during the summer period only. These calculations would equate to a spawning escapement of approximately 154 adult fish into the upper system once fishery interceptions are accounted for.

The above estimates must be viewed with caution as the assumptions stated for survival rates during the various life history stages are not firmly supported with data from the Yukon River drainage.

Chinook fry sampled during the August and October, 1989 surveys were progeny from the 1988 brood year. This was a relatively strong year for returning adult chinook salmon in the upper Pelly system. The 1988 escapement of adult chinook salmon to the Ross River drainage, located approximately 60 km upstream from Vangorda Creek, was estimated to be approximately 200 fish (Data on file, DFO Whitehorse). This compares to an average annual escapement to this system of approximately 90 fish over 4 years of observation between between 1982 and 1987. Ross River is the only drainage in the upper Pelly system that is surveyed on an annual basis. It is assumed that escapement data from Ross River provides a reasonable indication of escapement trends in the upper Pelly system.

Average chinook fry densities in Vangorda Creek during late August 1987 ranged from 4.5 fish/100 m^2 in Reach 3 to 10.3 fry/100 m^2 in Reach 1. By comparison fry densities during mid-August 1989 were over 20 fold greater. Escapements for the corresponding brood years (1986 and 1988), using Ross River data as an index, were three-fold greater during 1988 than in 1986. These comparisons suggest that other factors such as a high egg survival during the winter incubation period may have contributed to the unusally high fry densities observed in 1989.

Chinook salmon sampled from Vangorda Creek during April, 1989 were progeny from the 1987 brood year. The chinook escapement to Ross River was estimated at 76 fish in 1987 which was approximately 38% of the 1988 escapement estimate. These data indicate that recruitment potential from 1987 spawners was relatively low compared to the 1988 brood year.

Assuming over-winter survival rates (30%) suggests a pre-winter population of approximately 3,000 chinook fry. Given that this estimate is similar to the fall 1989 estimate (Table 3.3) during a year of high recruitment potential, it is suspected that the assumed overwinter survival rates (30%) may underestimate actual overwinter survival in Vangorda Creek.

4.0 IMPACT ASSESSMENT

Development of the Vangorda and Grum ore deposits has entailed the draining of Doal Lake (November 1987) and extension of the haul road from the Faro mill to the new ore deposits. As well, the development will eventually necessitate the diversion of a 600 m section of upper Vangorda Creek to access the ore body. The development will consist of two open pits, two waste dumps and an overburden dump in the vicinity of the Grum Creek confluence with upper Vangorda Creek. Detailed descriptions of the mine design, development schedule and site plans have been presented in the Initial Environmental Evaluation (Curragh Resources Ltd., 1989).

Potential water quality impacts will be associated with erosion and sediment production at the mine site, acid mine drainage (AMD) and resultant metal contamination. These potential impacts are a concern during the Construction, Operation and Abandonment Phases of the project. Potential impacts to downstream habitat during the Construction Phase of the development are associated with sediment production; these potential impacts were assessed in an earlier report (Harder and Bustard, 1987). This report addresses potential impacts arising during the Operational and Abandonment Phases of the project.

4.1 Sediment Production

The potential impacts to fish from exposure to suspended solids are complex. The U.S. EPA (1976) notes that suspended solids can have the following deleterious effects:

1) Mortality; reduce growth rate and disease resistance;
2) Prevent successful development of eggs and larvae;
3) Disrupt natural migrations; and
4) Reduce abundance of food available to fish.

Using Arctic grayling, McLeay et al.,(1984) showed that placer mining sediments depressed growth at concentrations of 100 mg/L or greater. Noggle (1978) found that feeding was reduced in coho salmon fry at 300 mg/L. CCREM (1987) concluded from available data that no harmful effects occur below 25 mg/L, and that effects become deleterious in the range of 25 to 80 mg/L.

The magnitute of sediment related impacts to habitat quality is dependant on the degree of disturbed area and the capacity of the stream to flush the sediment out of the system. Vangorda Creek is characterized by high channel gradients throughout the watershed and a large spring freshet. Therefore, the capacity of the stream to flush material through the system is relatively high.

If disturbed areas are not stabilized and high suspended sediment events occurred frequently or on a prolonged basis, there could be an eventual degradation of fish production capabilities in the lower 1.9 km of the Vangorda Creek. This would be due to the sedimentation of the large gravel and cobble substrate that presently characterizes most of the lower reaches (upstream from side channel A). Infilling of the interstitial spaces in the substrate would result in a decrease in invertebrate production thereby affecting fish rearing capabilities. This would also be a concern in the upper watershed which is a source of invertebrate production for downstream areas. As well, infilling of interstitial areas in the substrate would degrade overwintering habitat for juvenile chinook. Potential impacts during the Construction, Operations and Abandonment Phases of the project are discussed below.

4.1.1 Potential Impacts

Construction Phase

The construction Phase was iniated in 1987. In addition to the draining of Doal Lake, the pit areas have also been stripped and roads built to and around the mine site. The Vangorda Creek diversion will entail a temporary culvert around the Vangorda Pit. Other activities during the Construction Phase will include the placement of culverts at existing waterways and excavation of drainage ditches around the pit and waste dump areas. These activities will likely result in elevated suspended sediment levels at the time of construction. These potential impacts and mitigation measures have been discussed in the overview report (Harder and Bustard, 1987).

Operations Phase

Once the drainage ditches and diversion channels around the new mine sites are completed it is anticipated that sediment production from the mine operation will be relatively minor. Although some sediment production can be expected due to road use, localized slope failures and expansion of the waste dumps during the Operational Phase, it is unlikely that any sediment input would be of a prolonged nature. Therefore, it is unlikely that there would be any long-term accumulation of sediment in the creek unless major destabilization of the upper channel occurred. Potential long term impacts related to sedimentation in the lower reaches of Vangorda Creek during the Operational Phase will be assessed as part of the ongoing benthic invertebrate monitoring program.

Abandonment Phase

The haul road would be inspected and maintained on a regular basis following abandonment of the Grum and Vangorda mines in anticipation of further use related to potential development of the Dy and Swim deposits (Curragh Resources Inc., 1989). The diversion ditches would be blocked or breached with flows being re-directed into the pit areas. If all mine site drainage is routed through the newly formed "lakes" in the pit areas, it is anticipated that suspended sediment levels below the mine site would be low due to the settling capacity of the "lakes".

4.1.2 Mitigation Measures

Control of suspended sediment during the Construction Phase can be managed with the use of temporary settling ponds put in place before the drainage ditches are excavated. Sediment production during the Operation Phase could be minimized by armouring unstable slopes and ensuring that the culverts and drainage ditches are maintained on a routine basis. Potentail sediment related impacts to downstream habitats could be effectively controlled be diverting mine drainage into the pit areas. Revegetation of disturbed areas would also reduce erosion potential. Details of the proposed mitigation measures are presented in the Initial Environmental Review (Curragh Resourcces Inc., 1989).

4.2 Background Water Quality

Background water quality data for lower Vangorda Creek are summarized in Table 4.1. These data are based on monthly samples

Date	Temp °C	pH	Alk mg/L	Sus Sol mg/L	SO_4 mg/L	Ammonia mg/L	Zn * mg/L	Cu * mg/L	Pb * mg/L	Mn * mg/L	Fe * mg/L
Jun 03/87	3.0	-	-	5.0	15.0	0.08	0.007	0.004	0.003	0.012	-
Jul 08/87	8.0	7.82	-	8.0	23.0	0.57	0.010	0.003	0.008	0.009	-
Aug 05/87	8.0	8.31	-	4.0	26.0	0.33	0.011	0.003	0.016	0.009	-
Aug 20/87	6.0	-	-	59.0	33.0	0.56	0.052	0.005	0.043	0.037	-
Sep 25/87	1.0	8.26	-	0.5	33.0	-	0.009	0.001	0.003	0.006	-
Oct 07/87	-	-	-	0.5	-	-	-	-	-	-	-
Oct 14/87	0.0	8.66	-	0.5	45.0	-	0.015	0.002	0.005	0.008	-
Oct 20/87	-	-	-	1.1	-	-	-	-	-	-	-
Oct 28/87	-	-	-	0.5	-	-	-	-	-	-	-
Nov 12/87	0.0	8.39	-	0.5	40.0	-	0.010	0.001	0.005	0.007	-
Nov 20/87	-	-	-	0.5	-	-	-	-	-	-	-
Dec 18/87	0.0	8.34	-	0.7	71.0	-	0.040	0.001	0.003	0.020	-
Feb 18/88	0.0	8.10	-	0.5	97.0	-	0.016	0.030	0.050	0.014	-
Apr 06/88	1.4	7.55	-	1.0	84.0	0.10	0.006	0.002	0.003	0.103	-
Apr 14/88	2.0	7.89	-	1.0	82.0	0.15	0.009	0.002	0.003	0.054	-
May 02/88	2.2	8.25	-	6.0	48.0	-	0.010	0.004	0.003	0.023	-
May 04/88	-	-	-	-	-	0.21	-	-	-	-	-
May 11/88	8.0	7.66	60.40	71.0	27.0	0.65	0.034	0.008	0.008	0.088	2.750
May 18/88	-	-	-	10.0	21.0	-	-	-	-	-	-
May 27/88	5.4	8.16	79.80	-	-	-	-	-	-	-	-
Jun 07/88	6.4	8.17	57.75	23.0	14.0	-	0.015	0.004	0.003	0.024	1.150
Jul 06/88	9.5	8.49	93.50	2.0	18.0	0.15	0.010	0.002	0.003	0.010	0.190
Aug 05/88	10.4	8.35	137.60	4.0	28.0	0.29	0.009	0.002	0.003	0.011	0.240
Sep 22/88	2.5	7.83	147.00	2.0	42.0	0.14	0.008	0.002	0.005	0.008	0.035
Oct 19/88	-	7.52	148.00	1.0	46.0	-	0.009	0.002	0.003	0.007	0.065
Nov 29/88	-	8.06	178.00	2.0	70.0	-	0.011	0.001	0.003	0.008	0.060
Jan 03/89	1.0	7.52	211.00	0.5	81.0	0.14	0.015	0.002	0.003	0.007	0.010
Feb 28/89	-	7.80	254.00	3.0	132.0	0.13	0.050	0.002	0.003	0.012	0.055
Mar 28/89	-	7.97	220.00	2.0	120.0	0.21	0.023	0.002	0.003	0.013	-
Apr 27/89	2.0	7.80	10.30	147.0	40.0	0.35	0.056	0.014	0.023	0.121	6.100
May 30/89	6.0	7.92	44.00	14.0	16.0	0.52	0.049	0.003	0.009	0.013	0.501
Jun 30/89	12.0	8.40	117.60	0.5	37.0	0.01	0.008	0.001	0.003	0.004	0.043
Jul 26/89	7.5	8.10	130.00	2.0	43.0	0.06	0.015	0.003	0.003	0.009	0.124
Aug 19/89	-	-	-	0.5	46.0	-	0.017	0.001	0.003	0.004	0.023

* extractable metals before May 10, 1988;
total metals after that date

TABLE 4.1 Background Water Quality Data from Station V08 in Lower Vangorda Creek.

collected from Station V08 (Figure 2.1) in lower Vangorda Creek between June 1987 and August 1989.

Water samples collected in Vangorda Creek prior to May 10 1988 were analysed for extractable metals. After this date,total metals were analyzed. If the amount of occluded metal (see Section 4.3.1.4) in these samples was subtracted from total metal estimates for metals such as Zn, Cu, Pb and Fe then values shown in Table 4.1 would be reduced to levels that more accurately reflect the biologically active metal component.

Water alkalinity data for Vangorda Creek between May 1988 and July 1989 are presented in Table 4.1. Data are not available for the Pelly River. Stream discharge for Vangorda Creek is presented in Figure 4.1.

4.3 Acid Mine Drainage

It is anticipated that acidic seepage from the pit walls and the waste dumps will contain elevated levels of heavy metals (primarily zinc) during the Operational and Abandonment Phases (Curragh Resources Inc., 1989). Discharge of this untreated water into Vangorda Creek would affect water quality in the lower system and could ultimately affect fish using lower Vangorda Creek.

Potential water quality impacts and factors affecting toxicity have been assessed in the following section. This assessment is based on a review of available literature, examination of background water quality data in lower Vangorda Creek and

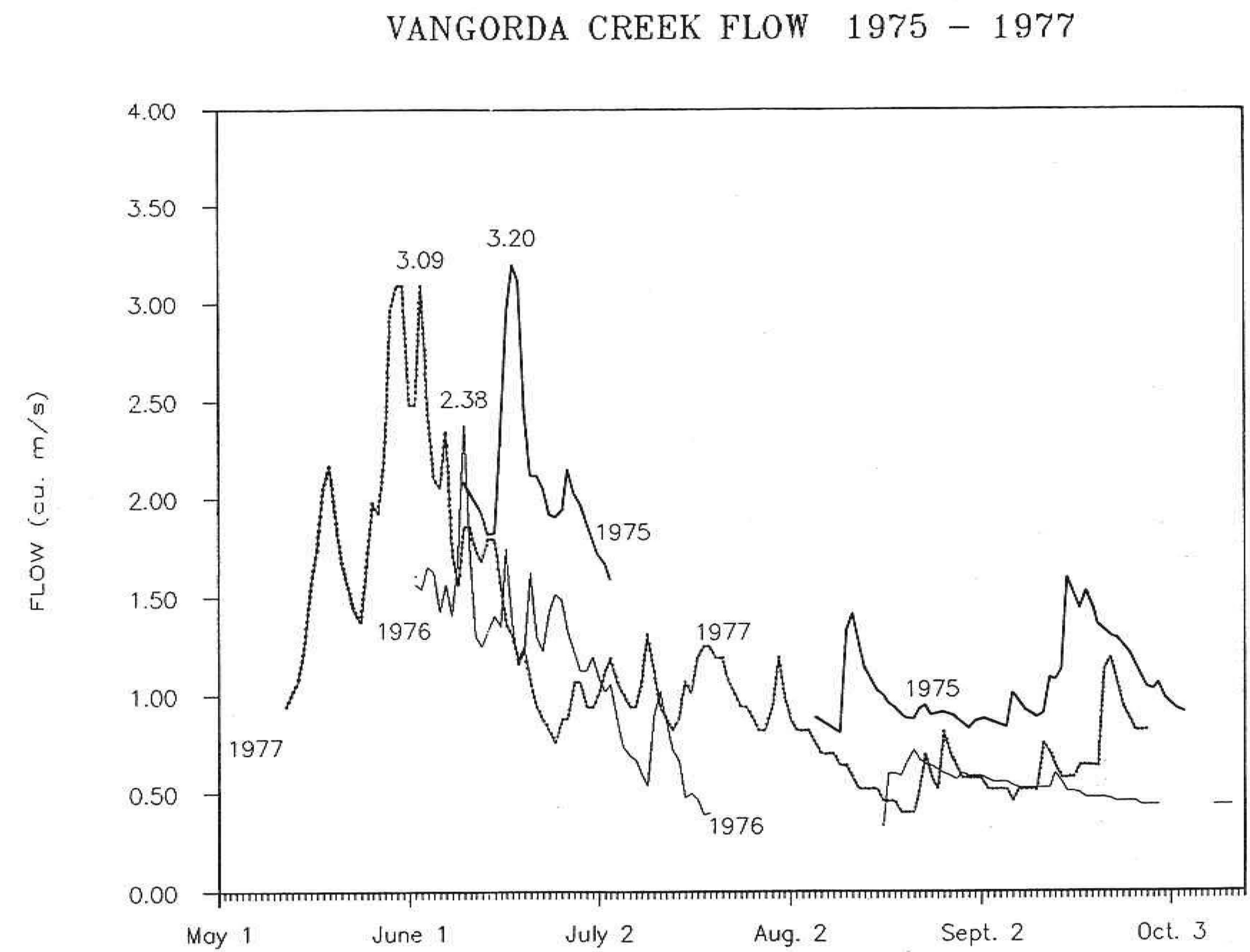

FIGURE 4.1 Stream Discharge Data for Vangorda Creek (source: Montreal Engineering Ltd., 1977).

projected water quality determined from modelling studies.

4.3.1 Influence of Zinc

Zinc is one of several heavy metals essential to living organisms at low concentrations. At higher concentrations, however, these same metals are deleterious to the health of aquatic organisms. Zinc may enter a living organism in several ways, the most likely being through the respiratory surfaces. In fish, zinc can effect gas transfer across the gill membrane directly, interfering with respiration. Internally, zinc will affect metabolic processes by inhibition of various enzymes. A number of life processes may be characterized relative to available concentration of Zn. From most to least sensitive, these may be ordered as follows (Spear,1981): reproduction; growth; swimming ability; chronic lethality; avoidance behaviour; enzyme inhibition; acute lethality; and gill ventilation.

The availability of zinc as it affects biological processes depend on a number of criteria. These include:

- species of fish
- pH
- metal concentration
- temperature
- presence of other metals
- metal state (occluded, adsorbed or dissolved
- ionic species present
- dissolved oxygen levels
- water hardness (alkalinity)

These factors will be addressed in the following sections.

4.3.1.1 Ion Species and Toxicity

Only a rudimentary understanding can be obtained from available data of the form zinc will take in water. The most comprehensive studies available predict that the aquo ion $[Zn(H_2O)_6]^2$ is the dominant ion in solution; it also is suspected of being the most toxic. Parallel studies on copper in solution (Howarth and Sprague, 1978) indicate that non-ionic species of Zn are likely to be less toxic or of low toxicity. Other Zn ion forms include $ZnHCO_3$, $ZnOH_3$, Zn-organic ions and Zn^{++} in fresh water. Non-ionic forms ($ZnCO_3$, $Zn(OH)_2$, $ZnSO_4$) cannot be disregarded as they contribute, albeit in a limited way, to the total Zn toxicity. Of interest in the present case is the fact that the aquo ion, of reputed highest toxicity, exists almost exclusively at pH levels less than 7.0. Background pH levels in Vangorda Creek (Table 4.1) are all above that level.

4.3.1.2 Zn-organic Complexing

Zn tends to form complexes with organic molecules in natural waters. However, the stability of such complexes is low, particularly in acid waters. In acidic fresh water containing 3 mg/L humic acid, organic complexes could bind from <0.1 to 2.0% of total dissolved zinc. Even at optimum pH (8.0 - 8.5) for Zn-humic acid binding, zinc humates may be only 10-15% of total dissolved zinc. Competition for organic ligands may occur when other divalent ions (e.g. Cu) are present. However, when Zn and Cu are both in solution, a greater tendency will exist for Zn complexation. In sediments, likely as a result of higher ligand concentration, Zn-organic complexes will be relatively stable at acid pHs (below 7.0). Under reducing conditions, Zn-complexes can dissociate, liberating free Zn ions. In the present case Zn and Cu are both present; binding could occur if ligands (e.g. humic acid) are present. However, in sediments these would be unstable at ambient pH conditions.

4.3.1.3 Effects of Alkalinity and pH on Toxicity

The relation between Zn ion speciation and alkalinity (or hardness) and pH is complex. In general, Zn concentrations are highest at acid pH values; they also increase with increasing alkalinity. In addition, the $ZnHCO_3$ ion species tend to be highest at acid pH values, although the percentage of total Zn as ZnHCO tends to decline with increasing alkalinity. Alkalinity (as mg/L of $CaCO_3$) measures the bicarbonate, carbonate and hydroxide components of a water supply. Water hardness measures (mg/L of $CaCO_3$) the Ca, Mg, and Sr components of a water supply, in terms of calcium. In a water containing Fe, Zn and other polyvalent ions, those ions will interfere with a hardness measure and must be analyzed separately. From a biological viewpoint the measure of Ca, Mg, and Sr makes much sense. However, ion speciation data are being accumulated as influenced by alkalinity. To improve the data set for future use, it is strongly recommended that Ca, Mg, and Sr analyses be added. Then water hardness may be calculated (APHA 1965) as:

$$\underline{\text{Hardness (mg/L as } CaCO_3\text{)} = f(\text{Ca, Mg, Sr; Fe, Al, Zn, Cu, Mn})}$$

In the present situation there is virtually no information available on water hardness in the Vangorda Plateau area. There are data, however, on alkalinity (Table 4.1). Further, equations are available showing the relation between salmonid sensitivity to Zn, as modified by water hardness. Similar data for alkalinity (rather than hardness) are not available.

In this study alkalinity data has been used as an estimate of water hardness for the following reasons. Chapman (1978b) measured and compared alkalinity and hardness in a study of zinc toxicity to sockeye salmon over an extended period. At low levels (as mg/L $CaCO_3$) the two measures were very similar. At high levels, hardness measures were considerably greater than those for alkalinity. Nevertheless, there was a high correlation between the two measures. Hence, using alkalinity to estimate the influence of hardness on zinc toxicity will lead to conservative estimates of Zn concentration/toxicity relationships. That is, using the equations relating Zn and hardness (estimated by alkalinity) will lead to higher estimates of ambient Zn than might be obtained if hardness were used instead.

4.3.1.4 Particle Size and Metal Availability

Either natural erosion or milling of ore can provide particles of small size, which can contribute to suspended solids. Such particles, suspended in water, may have some zinc occluded in the matrix of the particle where it will be biologically inactive. There also will be a portion of total zinc in solution as dissolved zinc. A third portion will be zinc ions that have become adsorbed electrically on the outside face of particles. Hence, of the total zinc in the water, that available in biological processes will be:

Available Zn = (Total zinc) - (occluded zinc)
= "Extractable" Zinc.

Under similar circumstances at a mine at Buttle Lake, Vancouver Island, where the average water hardness and pH were 21.5 and 7.3 respectively, the concentration of extractable zinc was 90.6% of total zinc (Alderice and McLean 1982).

4.3.1.5 Effect of Temperature on Toxicity

Most organisms that are highly susceptable to changes in water quality are gill breathers; that is, the repiratory apparatus is in direct contact with the water environment. These organisms tend to be cold blooded having body temperatures approximating that of their surroundings. Also, the rate at which most chemical or biochemical reactions occur increases with temperature. Generally the increase in such rates in a living organism is two to threefold for each 10°C rise in environmental temperature. Organisms tend to be more sensitive to water quality problems when they are not acclimated to the temperature of their environment. Therefore, a fish for example, unadjusted to its (higher) temperature surroundings may respond to a concentration of Zn in solution more rapidly and at a lower concentration than if it were acclimated to the temperature of its surroundings. Hence, under natural conditions increases in disssolved metals and higher temperatures usually result in lower tolerance among plankton and fishes in an ecosystem. At lower winter temperatures, a given concentration of a pollutant will generally be less deleterious than the same concentration at higher summer temperatures.

4.3.1.6 Determination of Toxicity

The influence of heavy metals or other biocides in solution on aquatic organisms usually is measured in a series of biological assays. In a typical assay, a sample (10-20) of fish of known age and similar size are introduced into a series of tanks in which given concentrations of toxicant are dissolved in the water. All other factors are held constant, such as temperature, water hardness, pH, dissolved oxygen concentration, and the density of fish (grams of fish/L of test solution). Techniques are used to maintain the amount of dissolved toxicant constant over the test period, which may last 4-7 days in short term (acute) tests. Acute tests usually measure survival or mortality. From such tests an estimate may be obtained of the concentration of toxicant that will kill (or affect in some quantitative manner) 50% of a sample of fish in a period of 4 or 7 days. The 4-day estimate is known as the 96-hour TLm (96-hr median tolerance limit). More difficult to obtain are estimates of chronic effects of toxicants at concentrations below that providing the 96-hr TLm. Such chronic measures may include reduced growth rate, interference with migration, and change or impairment of organ systems or biological functions over a much longer period (e.g. 3 months to several generations of exposure). Efforts are made to estimate the highest concentration of a toxicant at which chronic effects are just absent. The associated toxicant concentration is then known as the Maximum Allowable Toxicant Concentration (MATC).

Once 96-hour TLm and MATC concentrations of toxicant have been determined, their ratio can be used to obtain an Application Factor (AF) so that:

EQUATION 1: (MATC)/(96-hr TLm) = AF

Then, instead of trying to determine MATCs for different temperatures, water hardness levels, or pH conditions for example, the 96-hour TLm derived for a new set of background conditions can be used to derive a new estimate of the MATC using the former AF so that:

AF x new 96-hr TLm = new estimate of MATC

For chinook salmon swim-up fry, Alderice and McLean (1982) estimated the 96-hr TLm for zinc to be 0.097 mg/L at a water hardness of 24.0, based on Chapman's (1978) work. With the calculated application factor of 0.79, an MATC estimate (12°C and pH 7.1) is:

96-hr TLm x AF = 0.097 x 0.79 = 0.077 mg/L Zn = MATC

The MATC provides an estimate of the Zn concentration at and below which Zn should have no effect on swim-up fry of chinook salmon.

4.3.2 Additive Effects of Toxicants (Zn + Cu)

It is well known that the toxic effects of Zn and Cu are additive at low concentrations. This can be explained as follows. For each metal, Zn or Cu, the relationship between concentration and time to respond at each concentration follows a rectangular hyperbola. The asymptotes of this distribution are t_o, a minimum response time at some maximum concentration, and c_o, a minimum concentration at which response just fails to occur after maximum, long-term exposure. The latter asymptote is estimated by the incipient lethal level (ILL), the concentration beyond which the organism cannot live for an indefinite period of time. The toxicant concentration at the ILL can be considered in terms of "toxic units". Hence, exposures to a mixture of Cu and Zn at concentrations of one-half the ILL would not be toxic alone, but together in solution sum to produce the ILL.

Just as Equation 1 was used to define AF for Zn, the same can be done for Cu. Again, using the experience of Alderice and McLean (1982) for Cu (at 12°C and water hardness of 24 mg/L as $CaCO_3$) with chinook salmon swim-up fry the MATC can be estimated as follows:

96-hr TLm x AF = 0.019 x 0.66 = 0.0125 mg/L Cu = MATC

As before, the quantitiy 0.0125 mg/L Cu is a measure of the ILL which is a measure of the MATC.

In terms of additivity of Zn and Cu in providing a response, the following is presented:

$$\text{EQUATION 2: } C_a/L_a + C_b/L_b + \ldots + C_n/L_n > 1.0$$

where C_a, C_b, ..., C_n are measured ambient concentrations in the water, and L_a, L_b, ..., L_n are the corresponding ILL's or MATCs. The right hand-side of the equation indicates that if the sum of the fractions on the left side are equal to or greater than unity, then the mixture is toxic. Hence if the MATCs for swim-up chinook fry are as follows;

Zn, 0.0770 mg/L

Cu, 0.0125 mg/L

As an example, for background levels of Zn and Cu at the mouth of Vangorda Creek (Table 4.1) for April 27, 1989 toxic unit calculations would be (for Zn = 0.056, Cu = 0.014 mg/L):

$$C_{Zn}/L_{Zn} + C_{Cu}/L_{Cu} = 0.056/0.077 + 0.014/0.0125 = $$
$$= 0.727+1.12 =1.85$$

Additively the two metals are in excess of 1.0 toxic unit, hence the mixture is concluded to be toxic. The additivity of Zn and Cu was well described by Sprague (1964).

However, the above calculations refer to events occuring at a water hardness of 21.5 - 24.0 mg/L as $CaCO_3$, and it is known that the toxicity of both Zn and Cu are related to alkalinity and/or water hardness. As hardness increases, the MATC for both Zn and Cu rise. In considering water hardness, the CCREM (1987) adopts (their Table 3-14) Zn concentrations of 0.03, 0.2, 0.3 and 0.5 mg/L in association with hardness levels of 10, 50, 100 and 500 mg/L as $CaCO_3$ for MATC approximations, as taken from Alabaster and Lloyd (1982). These are equivalent to MATC values for soluble zinc (dissolved + adsorbed), or extractable zinc. The data of

Alabaster and Lloyd (1982) form semilog-linear series, so that:

$$\text{EQUATION 3: } (mg/L) = -0.2567 + 0.2782 \log H$$

where H = Hardness as mg/L $CaCO_3$

The MATC estimate for Zn in Section 4.2.1 (0.077 mg/L) at a hardness of 21.5 mg/L as $CaCO_3$ compares with an estimate of 0.11 mg/L from Equation 3. The difference between them could be due to original differences in temperature, species tested, other water parameters (Ca, Mg, Sr concentrations), experimental error, or a combination of all of these factors. Similar data for Cu (CCREM 1987) are more difficult to interpret. There are several data sets available for copper (CCREM 1987, Alderice and McLean 1982). Of these the U.S. EPA (1976) relationship has been accepted for further use:

$$\text{EQUATION 4: } Cu(ug/L) = e\ \exp(0.94[\ln(\text{hardness})] - 1.23)$$

Equation 4 provides MATC estimates for Cu that lie in the middle ground between maxima and minima given by the other sets. Hence accepting Equation 4 is equivalent to averaging all available data sets. Furthermore, of the five sets compared, the three interior sets give MATC estimates that are in reasonable agreement with each other. The following MATC estimates are obtained at the same hardness levels given for Zn:

Water Hardness (mg/l as $CaCO_3$)	Estimated MATC (mg/L Cu)
10	0.003
50	0.012
100	0.022
500	0.101

The MATC estimate for CU in Section 4.2.2 (0.0125 mg/L) at a hardness of 24 mg/L as $CaCO_3$ compares with an estimate of 0.0060 mg/L from Equation 4. Again the difference could be attributed to original differences in test conditions or experimental error.

It is now possible to examine the joint toxicity of Zn+Cu by Equation 2. This is undertaken for Vangorda Creek using tabled alkalinity as a reasonable measure of water hardness (May 11,1988 to July 26,1989). Examination of biological assay data for salmonids in which both alkalinity and water hardness were measured indicated that the values obtained are generally comparable (Chapman 1978a, Chapman and Stevens 1978).

For the Vangorda Creek background samples of April 27, 1989 (Table 4.1), for which Zn = 0.056 and Cu = 0.014 mg/L, and alkalinity = 10.3 mg/L as $CaCO_3$, the limiting (MATC) concentrations are:

$$Zn = -0.2567 + 0.2782 \log \text{hardness}$$
$$= 0.025 \text{ mg/L}$$

$$Cu = e \exp(0.94[\ln(\text{hardness})] - 1.23)$$
$$= 2.617 \text{ ug/L (or 0.0026 mg/L)}$$

If corresponding sample values are 0.056 and 0.014 for Zn and Cu, then by Equation 2:

$$C_{Zn}/L_{Zn} + C_{Cu}/L_{Cu} = 0.056/0.025 + 0.014/0.026 = 6.91$$

Hence, the April 27, 1989 sample for VO8 suggests the water in Vangorda Creek has on occassion been highly toxic to swim-up chinook fry in terms of joint (Zn + Cu) toxicity under background conditions. The sample appears to be toxic based on the low alkalinity measure, and on the high levels of Zn and Cu, particularly the latter. Background data on Zn and Cu concentrations in Vangorda Creek between May 11, 1988 and July 26, 1989 are shown in Table 4.2, where joint toxicity of (Zn + Cu) is based on Equation 2, 3 and 4. The data suggest that existing Zn and Cu levels in Vangorda Creek are not likely to injure salmonids directly for most of the year. However, in the period of April to May, for some reason, the metal levels are much higher. The VO8 data (Table 4.1) also show that there are increased loads of suspended solids on the sample days in question. Since the April to May tabled data are for single samples in each month, a closer evaluation would require expanded sampling in those months.

4.3.3 Effects of Lead (Pb)

The data employed in the CCREM (1987) recommendations for lead employed a mix of values for sensitive and tolerant fishes as well as animal plankton and algae. It recommends limiting levels of Pb of 1 - 7 ug/L for water hardness of 1 to >180 mg/L as $CaCO_3$. These values appear to have been derived to protect the most sensitive members of an ecosystem. While salmonids are sensitive examples of fishes, it is now generally recognized that some of the minute plankton organisms are even more sensitive to Pb. Thus, if Pb interferes with salmonid food production (e.g. Daphnia) it can have a negative influence on salmonids indirectly by reducing their food supply. However, the main focus in this section has to do with the direct effects of toxicants to chinook salmon and Arctic grayling. The broader implications of ecosystem damage will be dealt with in a further section of this report.

TABLE 4.2 Joint Toxicity for Background Levels of Zinc and Copper in Lower Vangorda Creek (VO8) Between May 11, 1988 and July 26, 1989

Date	Alk., mg/L	C_{Zn} mg/L	C_{Cu} mg/L	L_{Zn} mg/L	L_{Cu}	$(C/L)_{Zn}$	$(C/L)_{Cu}$	Sum of Toxic Units
May 11/88	60.4	0.034	0.008	0.239	0.014	0.14	0.57	0.71+
June 7/88	57.75	0.015	0.004	0.233	0.013	0.06	0.31	0.37
July 6/88	93.5	0.010	0.002	0.292	0.021	0.03	0.10	0.13
Aug. 5/88	137.6	0.009	0.002	0.338	0.030	0.03	0.07	0.20
Sep 22/88	147.0	0.008	0.002	0.346	0.032	0.02	0.06	0.08
Oct 19/88	148.0	0.009	0.002	0.347	0.032	0.03	0.06	0.09
Nov 29/88	178.0	0.011	0.001	0.369	0.038	0.03	0.03	0.06
Jan 03/89	211.0	0.015	0.002	0.390	0.045	0.04	0.04	0.08
Feb 28/89	254.0	0.050	0.002	0.412	0.053	0.12	0.04	0.06
Mar 28/89	220.0	0.023	0.002	0.395	0.047	0.06	0.04	0.10
Apr 27/89	10.3	0.056	0.014	0.025	0.003	2.24*	4.67*	6.91*
May 30/89	44.0	0.049	0.003	0.201	0.010	0.24	0.30	0.54+
Jun 30/89	117.6	0.008	0.001	0.319	0.026	0.03	0.04	0.07
Jul 26/89	130.0	0.015	0.003	0.331	0.028	0.05	0.11	0.16

* deleterious for salmonids
+ non-toxic but indicative of potential problems

NOTE: Joint toxicity of Zn and Cu estimated from Equations 2, 3 and 4, from Alabaster and Lloyd (1982) for Zn and from U.S. EPA (1980) for Cu as summarized by CCREM (1987). Joint toxicity is the sum of the ambient level of each metal (C) divided by the MATC at the given levels of alkalinity (L) as shown in the text (Eq.2); a total of > 1.0 toxic units is defined as deleterious (> the maximum acceptable toxicant concentration).

To resolve this difficulty here, an earlier data source (Thurston et al. 1979) has been used. This source provides a set of data giving near - MATC values for Pb over a series of water hardness levels. Levels for rainbow trout a comparable sensitive salmonid, are:

Water Hardness (mg/l as $CaCO_3$)	Lead Criteria (mg/L total lead
0 - 35	0.004
35 - 75	0.010
75 -150	0.025
150 -300	0.050
>300	0.100

For these data there is a linear relation between hardness (H) and near-MATC concentrations of Pb(mg/L) such that:

$$\text{EQUATION 5: } \underline{Pb\ (mg/L) = 1.06 + 0.328H}$$

Using this relationship, background levels of Pb in Vangorda Creek (Table 4.1) between May 11,1988 and July 26,1989 are compared with estimated MATC levels to derive toxic units as outlined in Equation 2 (Table 4.3). In Table 4.3 the estimates of toxic units provided from Thurston's et al. (1979) data (Column 5) are compared with those using CCREM (1987) data (Column 6). The estimates in Column 5 are more comparable to those for (Zn + Cu) in Table 4.2 for sensitive salmonid species. From Column 6 it appears that impact on plankton may be more general throughout the year in terms of Pb toxicity. The CCREM (1987) data for sensitive ecosytem members is as follows:

Water Hardness (mg/L as $CaCO_3$)	Lead Criteria (mg/L total lead
0 - 60	0.001
60 -120	0.002
120 -180	0.004
>180	0.007

TABLE 4.3 Background Levels of Lead in Lower Vangorda Creek (V08) and Estimated Toxic Units Based on near-MATC Values.

Date	Alk mg/L	C_{Pb} mg/L	L_{Pb} mg/L	$(C/L)_{Pb}$ **	$(C/L)_{Pb}$ ***
May 11/88	60.4	0.008	0.021	0.38+	4.0*
Jun 07/88	57.75	0.003	0.020	0.15	3.0*
Jul 06/88	93.5	0.003	0.032	0.09	1.5*
Aug 05/88	137.6	0.003	0.046	0.07	0.8+
Sep 22/88	147.0	0.005	0.049	0.10	1.3*
Oct 19/88	148.0	0.003	0.050	0.06	0.8+
Nov 29/88	178.0	0.003	0.059	0.05	0.8+
Jan 03/89	211.0	0.003	0.070	0.04	0.4
Feb 28/89	254.0	0.003	0.084	0.04	0.4
Mar 28/89	220.0	0.003	0.073	0.04	0.4
Apr 27/89	10.3	0.023	0.004	5.75*	23.0*
May 30/89	44.0	0.009	0.015	0.60+	9.0*
Jun 30/89	117.6	0.003	0.040	0.08	1.5*
Jul 26/89	130.0	0.003	0.044	0.07	0.8+

* toxic by definition
\+ raised but not toxic levels
** using Thurston et al. (1979) estimates for rainbow trout
*** using CCREM (1987) estimates for sensitive members of a freshwater ecosystem, including invertebrate food organisms

NOTE: Toxicity of Pb estimated from Equation 5 relating ambient levels of lead (C) at given ambient levels of water hardness. Where a C level is greater than the corresponding L level, the water can be regarded as deleterious in terms of lead content. (Eq.2).

4.3.4 Effects of Manganese (Mn)

The toxicological data on manganese is quite limited. The CCREM (1987) quidelines do not contain a section treating the effects of Mn on aquatic life. Thurston et al. (1979) show that toxic efects may occur above 0.1 - 1.0 mg/L. If the lower figure (0.1 mg/L Mn) were accepted as a limiting concentration, the background Mn in Vangorda Creek would be exceeded on two sampling occasions - between June 3, 1987 and August 19, 1989 (Table 4.1). On those two occasions (April 6, 1988 and April 27, 1989) Mn concentrations reached 0.103 and 0.121 mg/l, respectively. Again, the timing of high concentrations coincides with high levels of other metals examined to this point (Zn, Cu and Pb).

4.3.5 Effects of Iron (Fe)

As with Mn, there is very little information on Fe in the CCREM (1987). A similar view is obtained from examination of Thurston et al. (1979); they are unable to agree on a limiting value for iron. The level given by CCREM (1987) of 0.3 mg/L appears to be a tolerant limit for sensitive invertebrates. Fishes appear to tolerate higher levels (1.5 to 12.5 mg/L). Hence the 0.3 mg/L level is more likely to be a reasonable measure of ecosystem sensitivity. On that basis, the following Vangorda Creek (VO8) background samples could have been toxic:

May 11 1988:	2.75 mg/L;
June 7, 1988:	1.15 mg/L;
April 27, 1989:	6.10 mg/l; and
May 30, 1989:	0.501 mg/L.

Again the period of lower water quality appears to encompass the spring months of April, May and June.

4.3.6 Effects of Un-ionized Ammonia (NH_3)

Effects of ammonia on aquatic life vary with temperature and pH. There is an equilibrium established between un-ionized (NH_3) and ionized (NH_4^+) ammonia, and toxicity is increased at higher temperatures and pH values. The toxicity of ammonia is almost entirely associated with the concentration of un-ionized ammonia present. Hence, when total ammonia is measured, the amount of un-ionized ammonia can be computed if temperature and pH are known. The criterion for protection of freshwater aquatic life is 0.020 mg/L of un-ionized ammonia. For now this figure could be extended to salmonid fishes, based on data summarized by Thurston et al. (1979).

The amount of un-ionized ammonia (NH_3) in ammonia solutions in freshwater is presented in Table 4.4. The concentrations of total ammonia ($NH_4^+ + NH_3$) that contain 0.020 mg/L NH_3 (un-ionized), the U.S. EPA limiting level, are shown in Table 4.5.

The un-ionized levels of ammonia in the Vangorda Creek (V08) samples can be interpolated from tabled relations between NH , pH and temperature in U.S. EPA (1976). These are listed in Table 4.6. Examination of the table shows raised levels of un-ionized ammonia on August 5, 1987 and August 5, 1988; however, all values are below the 0.02 mg/L limit for protection of aquatic life. One concludes that background levels of ammonia in Vangorda Creek at ambient pH and temperatures are not a constraint.

TABLE 4.4 Percentage of Un-ionized Ammonia (%) in Freshwater, Aqueous Solution in Relation to Temperature (°C) and pH. (from SIGMA Environmental Consultants Ltd., 1983*).

	UN-IONIZED AMMONIA (%)								
Temp	pH Value								
(°C)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0	0.008	0.026	0.08	0.26	0.8	2.6	7.6	21.0	45.0
5	0.013	0.040	0.12	0.39	1.2	3.8	11.0	28.0	56.0
10	0.019	0.059	0.19	0.59	1.8	5.6	16.0	37.0	65.0
15	0.027	0.087	0.27	0.86	2.7	8.0	21.0	46.0	73.0
20	0.040	0.13	0.40	1.2	3.8	11.0	28.0	56.0	80.0
25	0.057	0.18	0.57	1.8	5.4	15.0	36.0	64.0	85.0

* SIGMA Environmental Consultants Ltd. 1983. Summary of water quality criteria for salmonid hatcheries. Revised edition, October, 1983. 163 p.

TABLE 4.5 Concentration of Total Ammonia ($NH_4^+ + NH_3$) that contain the Limiting Concentration of 0.020 mg/L NH Recommended for the Protection of Aquatic Life (from U.S. EPA 1976).

	TOTAL AMMONIA (mg/L)								
Temp	pH Value								
(°C)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	160	51	16	5.1	1.6	0.53	0.18	0.071	0.036
10	110	34	11	3.4	1.1	0.36	0.13	0.054	0.031
15	73	23	7.3	2.3	0.75	0.25	0.93	0.043	0.027
20	50	16	5.1	1.6	0.52	0.18	0.070	0.036	0.025
25	35	11	3.5	1.1	0.37	0.13	0.055	0.031	0.024

TABLE 4.6 Background Concentrations of Un-ionized Ammonia in Vangorda Creek Water Samples (VO8) in Relation to Ambient pH and Temperature Levels at Time of Sampling*.

Date	Temp (°C)	pH	Total ammonia mg/L	Un-ionized ammonia mg/L
Jul 08/87	8.0	7.82	0.57	0.007
Aug 05/87	8.0	8.31	0.33	0.013+
Apr 06/88	1.4	7.55	0.10	0.000
Apr 14/88	2.0	7.89	0.15	0.002
May 11/88	8.0	7.66	0.65	0.008
Jul 06/88	4.5	8.49	0.15	0.006
Aug 05/88	10.4	8.35	0.29	0.016+
Sep 22/88	2.5	7.83	0.14	0.002
Jan 03/89	1.0	7.52	0.14	0.001
Apr 27/89	2.0	7.80	0.35	0.004
May 30/89	6.0	7.92	0.52	0.006
Jun 30/89	12.0	8.40	0.01	0.000
Jul 26/89	7.5	8.10	0.06	0.001

+ highest levels, but still acceptable (0.03 mg/L NH)
* the proportion of un-ionized ammonia in a sample increases at more alkaline pH levels and at higher temperatures

4.3.7 Effects of Sulphates (SO_4)

Influence of sulphates has been given little attention in recent years. Compared to other potential toxicants the sulphate ion is relatively innocuous.

It could be important in an acid environment, but Vangorda Creek pH values are markedly alkaline. McKee and Wolf (1963) note for U.S. waters that support good game fish populations that 5% contain less than 11 mg/L SO_4, 50% contain less than 32 mg/L, and 95% contain less than 90 mg/L. On that basis if ranges of 0-11, 11-32, 32-90 and >90 mg/L SO_4 are graded as "excellent, good, fair, poor", respectively, then the modal concentration range of the Vangorda Creek data would fall into the category of "fair".

Of more concern would be the presence of sulphides or sulphates. However, these tend to oxidize to sulphates, using dissolved oxygen from the water medium. If dissolved oxygen were low, then the potential for presence of sulphides or sulphites might be explored.

4.3.8 Effects of pH.

No deleterious effects of pH may be expected within the range of 6.5 to 9.0 for salmonids (CCREM 1987). Vangorda Creek pH readings (VO8) range between 7.5 and 8.7, indicating that pH per se should have no effects on resident fishes. The higher the pH, the more toxic a given concentration of ammonia may become. However, background concentrations for un-ionized ammonia in Vangorda Creek (Table 4.1) are acceptable; therefore pH is not likely to be a problem.

4.3.9 Toxicity of Nickle (Ni)

CCREM (1987) recommends that Ni concentrations should not exceed the following:

Water Hardness (mg/l as $CaCO_3$)	Total Ni (ug/L)
0 - 35	0.004
35 - 75	0.010
75 -150	0.025
150 -300	0.050
>300	0.100

Acceptable Ni concentrations are related to hardness when they do not exceed:

$$Ni = {}_{e}(0.76\{\ln(hardness)\}+1.06 \ {}_{ug/L}$$

Threshold concentrations are low for plankton organisms such as Daphnia (14.8 ug/L), somewhat higher early life history stages of fishes, and higher still for fishes (eg. 2.48 to 35.5 mg/L). It is important to note that toxicity of Ni is increased in the presence of Cu.

4.3.10 Toxicity of Silver and Gold (Ag and Au)

The CCREM (1987) recommends that the concentration of total Ag should not exceed 0.1 ug/L. There is a relation with water hardness as follows:

$$Ag = {}_{e}(1.72\{\ln(hardness)\}-6.52) = ug/L$$

The threshold relationship given above is true for aquatic food organisms such as Daphnia (0.25 ug/L); fish are somewhat more tolerant (eg. 3.9 to 9 ug/L). Silver is very toxic as the nitrate or iodode, but less so as a thiosulphate, or sulphide. The

0.0003 mg/L could result in both avoidance and migratory impacts. However, background levels of Zn and Cu in Vangorda Creek (Table 4.1) are higher than these values. The presense of large numbers of juvenile chinook salmon in the creek suggests that these threshold values may be too high for Vangorda Creek.

4.4 Toxicity of Background Conditions

Of the entities shown for Vangorda Creek in Table 4.1 it appears that Zn, Cu and Pb will have the greatest influence on current productivity. Recommended levels of these metals that should not be exceeded are shown in Table 4.8. There, such limiting levels of Zn, Cu and Pb are also shown in relation to water hardness (Equations in Table 4.8). Aquatic organisms tolerate higher levels of these three entities at higher levels of water hardness (or alkalinity). The occurence of potentially limiting concentrations of inclusions in Vangorda Creek water samples are summarized in Table 4.9. This assessment is based on observed water quality data from Vangorda Creek (Table 4.1) and limiting concentrations identified in Table 4.8.

Annually, background conditions appear to be worst in the period March-April-May, particularly in April (Table 4.9). In addition it appears that Pb will have a deleterious influence on the Vangorda ecosystem, particularly on the invertebrate food organisms fishes would require for normal growth and development. At times, Fe may also have a deleterious influence on invertebrates in the Vangorda system. On occasion, water quality may deteriorate to the extent that fishes will be affected by Zn, Cu, Pb, Mn and suspended solids.

TABLE 4.8 Estimated Limits of Concentrations for Inclusions in Vangorda Creek Water in Relation to Biological Impacts.

Inclusion mg/L	Sensitive salmonid fishes mg/L	Protection aquatic ecosystem mg/L	Behaviour alteration mg/L
Zn*	>0.077	-	0.004
Cu**	>0.0125	-	0.005
Pb***	>0.004	0.001 - 0.007	-
Mn	0.1 - 1.0	-	-
Fe	-	0.3	-
NH_3	0.020	-	-
Susp. Sol.	25 - 80	-	-
SO	11 - 32 ("fair"/rating)	-	-
pH	6.5 - 9.0	-	-

EQUATIONS:

* Zn (mg/L) = -0.2567 + 0.2782 log Hardness

** Cu (mg/L) = e exp (0.94[ln(hardness)] - 1.23)

(Zn + Cu); $C_{Zn}/L_{Zn} + C_{Cu}/L_{Cu}$ > 1.0 toxic units

C = ambient
L = MATC concentrations (mg/L)

*** Pb (mg/L) = 1.06 + 0.328 (hardness)

TABLE 4.9 Occurence of Potentially Limiting Concentrations (mg/L) of Inclusions in Vangorda Creek Water Samples Collected Between June, 1987 and July, 1989.

Date	Zn	Cu	Zn+Cu	Pb*	Pb**	Mn	Fe**	NH_3	SO_4	pH
Jun 03/87	-	-	-	-	-	-	-	H	-	-
Aug 05/87	-	-	-	-	-	-	-	-	-	-
Aug 20/87	-	-	-	-	-	-	-	-	-	-
Apr 06/88	-	-	-	-	-	PD	-	-	-	-
May 11/88	-	-	H	H	PD	-	PD	-	-	-
Jun 07/88	-	-	-	-	PD	-	PD	-	-	-
Jul 06/88	-	-	-	-	PD	-	-	-	-	-
Aug 05/88	-	-	-	-	H	-	-	H	-	-
Sep 22/88	-	-	-	-	PD	-	-	-	-	-
Oct 19/88	-	-	-	-	H	-	-	-	-	-
Nov 29/88	-	-	-	-	H	-	-	-	-	-
Mar 30/89	-	-	-	-	-	-	PD	-	-	-
Apr 27/89	PD	PD	PD	PD	PD	PD	PD	-	-	-
May 30/89	-	-	H	H	PD	-	-	-	-	-
Jun 30/89	-	-	-	-	PD	-	-	-	-	-
Jul 26/89	-	-	-	-	PD	-	-	-	-	-

NOTES:

PD - indicates situations where concentrations are presumed high enough to be deleterious.

H - indicates situations where concentrations are high but not considered deleterious.

* - data assessed for sensitive salmonids

** - data assessed for protection of ecosystem.

4.5 Toxicity of Predicted Zinc Concentrations

A water balance/metal load model was developed by Curragh Resources Inc. to predict concentrations of dissolved zinc in Vangorda Creek during the Operation and Abandonment Phases of the mine development. This model is discussed in detail in the Initial Environmental Evaluation (Curragh Resources Inc., 1989) Predicted levels of dissolved zinc in lower Vangorda Creek and the Pelly River are summarized over four scenarios in Table 4.10.

4.5.1 Vangorda Creek

The predicted toxicity of Vangorda Creek at Faro has been estimated on a monthly basis for each of the four scenarios (Table 4.10). The predicted toxicity is based on Zn concentration only, and at hardness levels (Section 4.2) estimated from rather meagre data. A more thorough estimate would be made on the basis of Zn + Cu, and Pb concentrations and more detailed water hardness data. The MATC values for zinc presented in Table 4.10 are calculated on the basis of Equation 3 (see Section 4.3.1 and Table 4.9) using available alkalinity data. On this basis, operation with water treatment appears to be highly advantageous compared to predicted Zn concentrations in Vangorda Creek without treatment. On the other hand, Zn concentrations in the creek after abandonment suggest that the presence of till covers will provide relatively limited biological advantage to water quality. Despite reducing predicted levels, Zn concentrations will still exceed tolerable levels during the April period.

Mine operation without water treatment would have Vangorda Creek

Condition	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean monthly discharge m^3/sec	0.09	0.09	0.09	0.09	1.73	2.27	1.18	1.00	0.82	0.54	0.27	0.18
Est. alkalinity (mg/L as $CaCO_3$)	210	250	220	10	60	80	110	130	140	140	170	190
Est. MATC for Zn (mg/L)	0.39	0.41	0.39	0.02	0.24	0.27	0.31	0.33	0.34	0.34	0.36	0.38
Operational, with treatment	0.06	0.076	0.08	0.138*	0.040	0.037	0.040	0.041	0.039	0.045	0.030	0.060
Operational, without treatment	0.66*	0.656*	1.36*	4.058*	1.450*	0.887*	0.980*	0.991*	0.949*	0.905*	0.360*	0.440*
Abandonment with Till Covers	0.05	0.076	0.10	0.538*	0.100	0.067	0.080	0.071	0.069	0.065	0.040	0.060
Abandonment without Covers	0.07	0.116	0.22	0.698*	0.190*	0.127	0.140	0.141	0.129	0.145	0.060	0.080
Background Levels (V08)**	-	0.016	-	0.008	0.010	0.007	0.010	0.011	0.009	0.015	0.010	0.040

NOTES: 1) Estimates of Alkalinity from Table 4.2
2) Monthly Estimates of Zn from modelling studies
3) MATC Estimated from Equation 3

* Ambient Zinc concentration exceeds MATC (mg/L)
\+ Ambient Zinc concentration close to but less than MATC (mg/L)
** Background levels of zinc based on monthly data from Station V08 between June 1987 and May 10 1988. Extractable metals analysis.

TABLE 4.10 Predicted Toxicity of Zn Concentration (mg/L) in Vangorda Creek at Faro under four Scenarios during Operations and Abandonment.

toxic for 11 months of the year, and just below lethal levels to salmonids in the remaining month, November (Table 4.10). Operations with water treatment should allow salmonids to survive in the Vangorda in all months except April. One should realize also that if Zn levels are estimated to be toxic (Table 4.10), then Cu, Pb, Mn, Fe and suspended solids may also be a problem (Table 4.9). Again the possibility that Pb could contribute substantially to lowering of water quality, even with water treatments during operations, is suggestive of further inquiry.

Following abandonment, predicted Zn concentrations would be non-toxic throughout the year with the exception of April. Predicted values of Zn with till covers (0.538 mg/L) and without till covers (0.698 mg/L) would be over 26 times the estimated MATC for this period (Table 4.10). However, the calculated MATC for the month of April is strongly influenced by the depressed alkalinity value for this month. The implications of this and the occurrence of high Zn concentrations during April are discussed below.

Predicted concentrations of Zn in Vangorda Creek are highest during April for all scenarios under consideration. These high concentrations are the result of low dilution capabilites in Vangorda Creek during a period of rapid snow melt and run-off from the minesite. Modelled predictions have been based on mean monthly flow data. Daily stream discharge in April (mean discharge = 0.09 m^3/sec) can vary dramatically with the onset of the spring freshet. During 1989 the creek was in freshet with an measured flow (see section 3.2.1.1) of 1.6 m^3/sec on April 28. The alkalinity data used for the MATC calculation (Table 4.1) was based on a single measurement taken on April 27, 1989. Flows during this period were approximately twenty fold greater than the mean monthly value for April used in the model prediction (Table 4.10).

The obtained alkalinity value (10 mg/L) demonstrates a dramatic decline in water alkalinity between winter and the onset of the spring freshet which occurred earlier than normal in 1989. High alkalinity values during the December to March period are influenced by the predominance of groundwater flow during this period. As the snow melts and the relative proportion of groundwater to surface water decreases, there is a corresponding decrease in alkalinity. Thus, with increasing stream flow in the spring, alkalinity decreases. Therefore, predicted Zn levels in April would be highly variable, and a single sample at the latter part of the month (increasing flows) is not representitive of mean monthly conditions in Vangorda Creek. For example, if we assume the alkalinity measurement for March and the resultant MATC calculation are more representitive of conditions for early April (a low-flow period), then toxic conditions would not be present during the month of April under operations with water treatment. However, water would be toxic to salmonids (exceeding a MATC value of 0.39 mg/L Zn) during this month for the remaining three scenarios examined (Table 4.10).

Previous studies discussed in Section 4.3.9.2 and data summarized in Table 4.8 suggest that predicted Zn concentrations in the

Vangorda (Table 4.10) could be high enough (> 0.004 mg/L Zn) to cause avoidance reactions and interference with downstream migration among smolts under two scenarios: during operations, with water treatment; and after abandonmment, with till covers. However, examination of background water quality data in Vangorda Creek (using Zn data from extractable analysis only - prior to May 10/88; Table 4.1) indicates that these threshold levels are now exceeded for all months of the year. If these monthly data are representitive, then the presence of a viable juvenile chinook population throughout most of the year (1988/89) in Vangorda Creek suggests that actual tolerances may be considerably higher than the MATC values reported in the literature. At some point additional metal loading in Vangorda Creek may exceed threshold values affecting migration behavior and fish productivity could be affected.

If juvenile chinook do not move into Vangorda Creek due to an avoidance reaction to Zn (and probably Cu), then the existing habitat cababilities in Vangorda Creek would be lost. This would amount to 1.9 km of stream channel or approximately 14,400 m during the summer period. If some juvenile chinook do enter Vangorda Creek, the potential increase in metal load during operations may decrease the productivity of Vangorda Creek, affecting growth and survival of those juveniles in the creek.

4.5.2 Pelly River

In Table 4.6, the most sensitive measure of Zn affect on salmonids is that influencing behaviour alteration - upstream migration of adults and juvenile migrations. The limiting level shown is 0.004 mg/L Zn. From Table 4.10, the following maximum and minimum concentrations of Zn are predicted to occur annually in the Pelly River at Faro assuming complete mixing:

Condition	Annual Range Zn (mg/L)
Operational, with treatment	0.0005 - 0.0001
Operational, without treatment	0.0158*- 0.0010
Abandonment, with till covers	0.0021 - 0.0001
Abandonment, without till covers	0.0027 - 0.0002

* > 0.004 mg/L during April, May and June; near but <0.004 mg/L during August and September

We conclude from a review of the available data that interference with upstream migration of adults may be expected at Zn concentrations of 0.004 mg/L or more. Inspection of predicted Zn concentrations in the Pelly River under four scenarios (Table 4.8) indicates that adult migration with water treatment, and after abandonment with or without till covers, should not be affected. However, during operations, without water treatment, Zn concentrations in the Pelly River could be high enough to cause migratory interference during April, May and June. Adult chinook salmon are present in the upper Pelly River during July, August and September. Zn concentrations would be near but less than the 0.004 mg/L limit during these months during the operations without water treatment. However, mine operation without water treatment is not being considered.

4.6 Data Limitations

The assessment of impacts to water quality and fish production potential in Vangorda Creek is constrained by a number of deficiencies in the present database. These are discussed below.

4.6.1 Water Hardness

Metal toxicity is strongly influenced by water hardness. Without water hardness data it is not possible to determine toxicity. In Vangorda Creek there have been a limited number of monthly measurements taken between June 1987 and July 1989. From a biological perspective a measure of water hardness with separate analysis of Ca, Mg and Sr is the best measure for assessing toxicity. Particular emphasis should be placed on obtaining frequent measurements during the March through April period - a time of significant fluctuations that have direct bearing on th eimpact assessment.

4.6.2 Vangorda Creek Flow Data

Available water flow data for Vangorda Creek is limited to measurements taken between May and October during 1975, 1976 and 1977. Mean monthly flows for the creek have been calculated on the basis of watershed area and measured flow data. Assessing impacts of metal toxicity on the basis of mean monthly flows may not adequately predict worst case scenarios (ie. low-flow periods). This could be an important in situations where potential conditions of accute toxicity are anticipated. This would be particularily important in months like April when wide variations in daily flow occur between the beginning and end of the month.

Analysis of these potential impacts would require mean minimum daily flow data. It is also be important to consider the influence of dry versus wet years on the impact sensitivity.

4.6.3 Background Water Quality Conditions

Assessment of available water quality data from lower Vangorda Creek suggests that existing concentrations of Zn, Cu, Pb, Mn, Fe and suspended solids occassionally exceed levels which have been deemed to be deleterious to salmonids. Much of the data has been analysed for total metals and as such may overestimate the biologically active metals. The amount of occluded metals in these samples is unknown. Excluding occluded metals total metal estimates (e.g. Zn,Cu,Pb,Fe) for individual samples would reduce the numerical values now shown in the results.

4.6.4 Predicted Levels of Other Metals

Review of the literature indicate that the additive effect of various inclusions can have profound impacts on the biological system. Although Zn is anticipated to be the major constituent of the AMD, even minute quantities of other toxicants could have a large impact on combined toxicity. Predicted levels of Cu, Pb, Cd and Hg would be required to fully assess toxicity potential and the associated biological impacts in Vangorda Creek.

4.6.5 Dispersal of Vangorda Creek Waters

Large flow volumes in the Pelly River provide high dilution capabilities with respect to Vangorda Creek waters. However, predicted Zn values in the Pelly River have been developed on the basis of an assumed immediate mixing at the Pelly/Vangorda confluence. Although visual examination of the confluence area suggests that the mixing zone is quite restricted, it would be instructive to obtain a quantitative measure of actual dilution and dispersal rates in the Pelly River.

4.6.6 Site Specific Bio-Assay Data

In this study MATCs for various inclusions in Vangorda Creek waters have been estimated on the basis of available data in the literature. Although these estimates provide an initial basis for examining potential impacts, available MATC data are based on different conditions (temperature, water hardness, pH) and in some cases different fish species than found in Vangorda Creek. These factors make it extremely difficult to predict impacts to fish populations in Vangorda Creek.

Furthermore, existing information on threshold values affecting migratory and avoidance behavior appear to be inadequate to assess potential impacts in Vangorda Creek. Background conditions in Vangorda Creek exceed previously reported threshold values and yet viable fish populations are still present. Therefore it will be necessary to conduct avoidance behavior studies in a laboratory to assess these potential impacts.

4.7 Discussion - Toxicity

In general, Canadian guidelines (CCREM,1987) form the most up-to-date and useful set of water quality data currently available. However, examination of the guidelines in detail indicates there are some deficiencies. For example the additivity of effects of Zn and Cu has not been addressed in the CCREM (1987) Guidelines. Absence of these data make it necessary to consult Thurston et al. (1979), McFee and Wolf (1963), USEPA (1976) and U.S. EPA (1973).

Although much has been learned about the influence of water quality in the last 20 years, there is still much that is not understood. This is true in the current situation: some data of high importance are not available (eg. hardness, Pelly River; Zn+Cu+Pb levels, Vangorda Creek during operations and after abandonment). Other concerns, for which data are available, cannot be resolved because of associated, missing information. For example, the toxicity of affected waters cannot be judged for Arctic grayling because so little work has been done using grayling.

For these reasons, the conclusions drawn in this report should be viewed as reasonable projections based on available data.

In the CCREM (1987) guidelines and elsewhere, it is concluded that pollutants that are high enough concentration to affect salmonid fishes will affect the invertebrate community of planktonic and benthic organisms forming the food supply of resident fishes. That is, resident invertebrate fauna tends to be more suseptible to pollutants than sensitive fishes. Hence, when conditions have been shown to be deleterious to salmonids, they are most likely to be ecologically damaging to invertebrate organisms forming the food supply of fishes in the system.

On the basis previously reported toxicity data, background water quality conditions in Vangorda Creek appear to be on occassion, deleterious to fish. This is true for Zn,Cu, Pb Mn and suspended solids. Background concentrations of Pb and Fe are also high enough that a deleterious influence on the invertebrate community can be expected. However, the presence of a viable population of rearing chinook salmon indicates that fish have acclimated to these conditions.

Predicted Zn levels in Vangorda Creek and available water hardness data indicate that waters will be non-toxic throughout the year, with the exception of April, during operation of the mine with water treatment. However, predicted conditions of toxicity in April are confounded by non-representitive alkalinity data. These data were collected during the freshet (high snow melt dilution) which occurred earlier than normal in 1989. The modeled predictions of Zn concentration during April have have been made assuming that run-off has not yet diluted Zn loads. If it is assumed that the derived MATC for March (with a high alkalinity value) is more representitive of April low flow conditions, then it is predicted that waters would be non-toxic during this month. Without water treatment Vangorda Creek would be toxic for 11 months of the year.

Following mine abandonment (with or without till covers) waters in Vangorda Creek would be non-toxic except for the month of April. These conditions persisted when the MATC value derived for March was used to offset the confounding influence of non-representitive alkalinity data.

Although Vangorda water would be non-toxic (based on analysis of Zn only) for most and possibly all of the year with water treatment, preliminary analysis indicate Zn levels could be high enough to cause avoidance reactions and migratory interference with respect to juvenile chinook salmon during the Operations and Abandonment Phases of the project. However, monthly water samples collected in lower Vangorda Creek (Station V08) indicate that background levels of zinc are well above the threshold level of 0.004 mg/L (Sprague, 1964) used in this preliminary analysis. Based on 22 monthly samples taken between June 1987 and March 1989, an average value of 0.017 mg/L Zn with a range of 0.007 to 0.052 mg/L is indicated for background conditions in lower Vangorda Creek (Curragh Resources Inc., 1989) These data coupled with the presence of high abundances of chinook salmon fry in the creek suggest that the threshold level adopted for predicting avoidance behavior may in fact be too high for the circumstances in Vangorda Creek. There are several factors which may contribute to these apparent differences. One factor which may be of major significance is that Sprague's work was done for Atlantic salmon. Other confounding factors could include analytical procedures (extractable vs non-extractable metals) and the effect of previous exposure to dissolved metals.

Pelly River water would remain non-toxic to fish in all cases examined. Zn concentrations during the months of April, May and June could be high enough to interfere with migrating adult salmon. However, adult chinook salmon are not present in the upper Pelly system until late July. Therefore migratory impacts are not expected. Furthermore, some of the same concerns outlined above for juvenile avoidance in Vangorda Creek are also applicable to adult migration in the Pelly River.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Fisheries investigations indicate that the lower 1.9 km of Vangorda Creek is used by rearing juvenile chinook salmon and Arctic grayling. It was estimated that habitats in lower Vangorda Creek supported a rearing population of approximately 20,260 chinook fry during the summer of 1989; this number had declined to approximately 2,700 fish during the fall of the same year. The maximum estimated grayling population was made during the fall period with approximately 645 fish in lower Vangorda Creek. Juvenile chinook and grayling over-winter in the creek. Adult chinook salmon do not use the system and it is probable that any use by spawning grayling is minor.

It is suspected that chinook fry using Vangorda Creek are progeny of spawning populations from upstream tributaries such as Blind Creek or possibly from Pelly River mainstem spawners. Sampling data suggests that fry move into Vangorda between late June and July and rear throughout the August to September period. The majority (87% in 1989) of these fish move out of Vangorda and into the Pelly River before the onset of the overwintering period.

Analysis of background water quality data indicate that current productivity in Vangorda Creek may be constrained by high levels of Zn, Cu and Pb. These potential constraints are most evident in the spring period, but are based on very limited water quality samples.

Based on available alkalinity data and using the relationships developed in previous research, a range of estimated monthly MATC values were derived for Vangorda Creek. These values range from 0.02 in April to 0.41 mg/L Zn in February. These values are directly related to alkalinity levels for these periods. Preliminary analysis of predicted Zn concentrations and available toxicity and water hardness data indicate that waters in Vangorda Creek would be toxic throughout most of the year during operations without water treatment. With water treatment, toxic conditions in Vangorda Creek would not likely occur at anytime, however detailed early spring data are required to confirm this statement for the month of April.

Predicted Zn concentrations in Vangorda Creek could be high enough to cause avoidance responses and interfere with juvenile chinook migrations throughout the year during the Operations and Abandonment Phases of the development. However, this assessment has been based on research done with Atlantic salmon which may have different levels of tolerance than chinook salmon. Available water quality data indicate that the threshold levels of Zn to cause avoidance cited for Atlantic salmon are exceeded within the background conditions of Vangorda Creek.

These preliminary findings suggest that there could be a loss of existing production capabilities in Vangorda Creek. However, further work is required to establish threshold levels of zinc and other metal contamination in Vangorda Creek before a more conclusive statement can be made.

Based on 1989 fish sampling data this potential loss could affect a rearing poulation of approximately 20,260 chinook salmon fry in Vangorda Creek. It is estimated that this level of juvenile use could result in a total chinook salmon production loss of approximately 615 adult fish before any account for fishery interceptions. These projections are based on a high escapement yearand assume that chinook fry would not use alternate habitats and as such probably represent maximum loss potential. Although toxicity tolerance data are not available for Arctic grayling, it is suspected that predicted conditions could also result in the loss of grayling production from Vangorda Creek.

Predicted levels of Zn in the Pelly River indicate that conditions would be non-toxic throughout the year for all scenarios examined. However, predicted Zn concentrations during the August to September migration period for adult chinook salmon would be close to the threshold values reported at which migratory interference could occur.

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Predicted levels of Zn in the Pelly River indicate that conditions would be non-toxic throughout the year for all scenarios examined. However, predicted Zn concentrations during the August to September migration period for adult chinook salmon would be close to the threshold values reported at which migratory interference could occur.

Recommendations

The following recommendations are made:

1) Analysis of Ca, Mg and Sr from the Vangorda Creek water samples should be undertaken so that a measure of water hardness can be obtained. It is also recommended that Al be analysed so that interfering elements may also be considered and that the frequency of water samples taken in the March to May period be increased to a weekly basis for Station V08;

2) Collect water hardness data (as per 1 above) from the Pelly River;

3) Develop predictions for dissolved Cu, Pb and Cd during the Operation and Abandonment Phases of the development;

4) Install a water flow gauging station in lower Vangorda Creek as soon as possible;

5) Conduct a fish monitoring program in Vangorda Creek to determine potential changes in fish distribution and numbers during the initial operation of the mine and to gain a better understanding of juvenile fish movements in and out of the creek; and

6) Conduct a comparative study of toxicity tolerance for chinook fry and grayling juveniles to Zn, Cu and Pb. This would involve bio-assay work in a lab environment;

7) Conduct a study on juvenile fish avoidance behavior in relation to dissolved metals;

8) Conduct tests of sensitivity for chinook fry and grayling juveniles to Pb at Vangorda Creek since background conditions are above the generally accepted level for Pb toxicity during the month of April;

9) Analysis of extractable metal series from future water samples so that fractions of occluded metal in suspended solids can be subtracted to provide an estimate of biologically active metal. The extractable amount (dissolved + adsorbed) is most important for Zn, Cu and Pb; and

10) Monitor benthic invertebrate production levels in Vangorda Creek on an annual basis.

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APPENDIX 1

Photographs of Vangorda Creek and Pelly River Sidechannels - April, August and October 1989

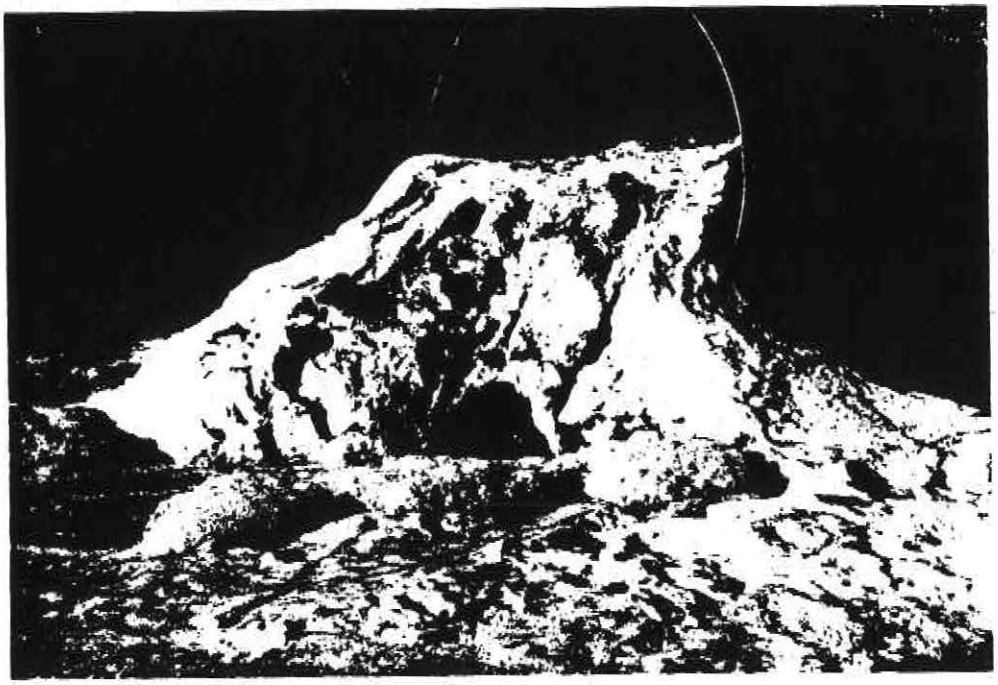

PLATE 1. Ice Filled Culvert at the Faro Road Crossing Showing Open Water in the Plunge Pool. April 25, 1989.

PLATE 2. Channelized Flow above Ice Surface in Reach 1 of Vangorda Creek below the Lower Road Crossing. April 25, 1989.

PLATE 3. Ice Cover on Vangorda Creek Immediately Upstream of Lower Bridge Crossing in Reach 1 of Vangorda Creek. April 25, 1989.

PLATE 4. Partial Open Water Area at Sample Site V3 in Reach 2 of Vangorda Creek. April 25, 1989.

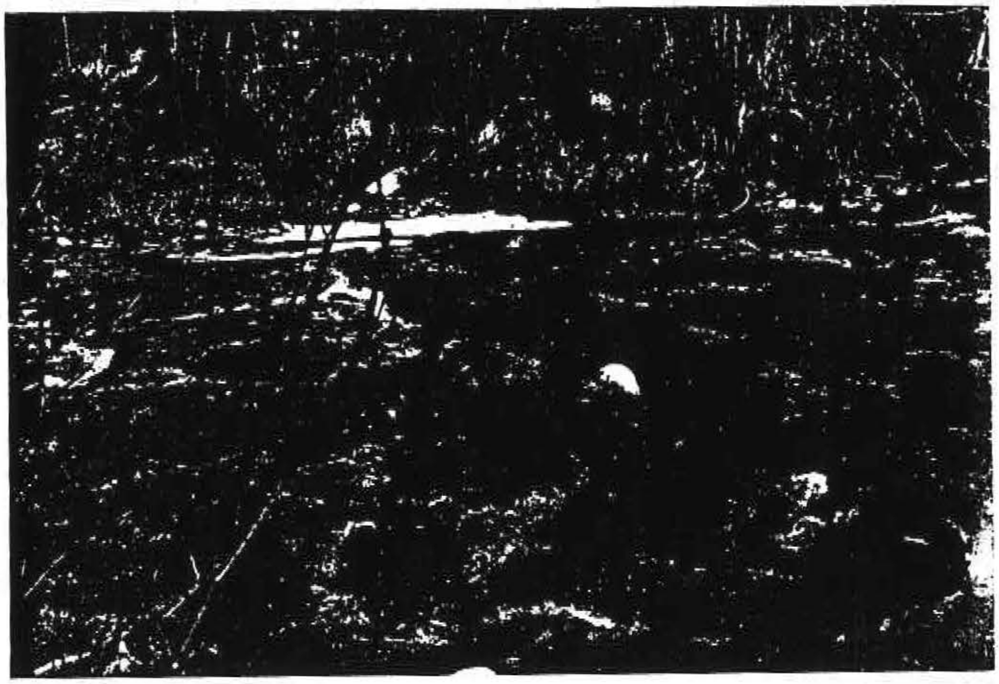

PLATE 7. Open Water Sample Area at Site V3b in Reach 2 of Vangorda Creek. Low Abundance of Fish Sampled Here. April 27, 1989.

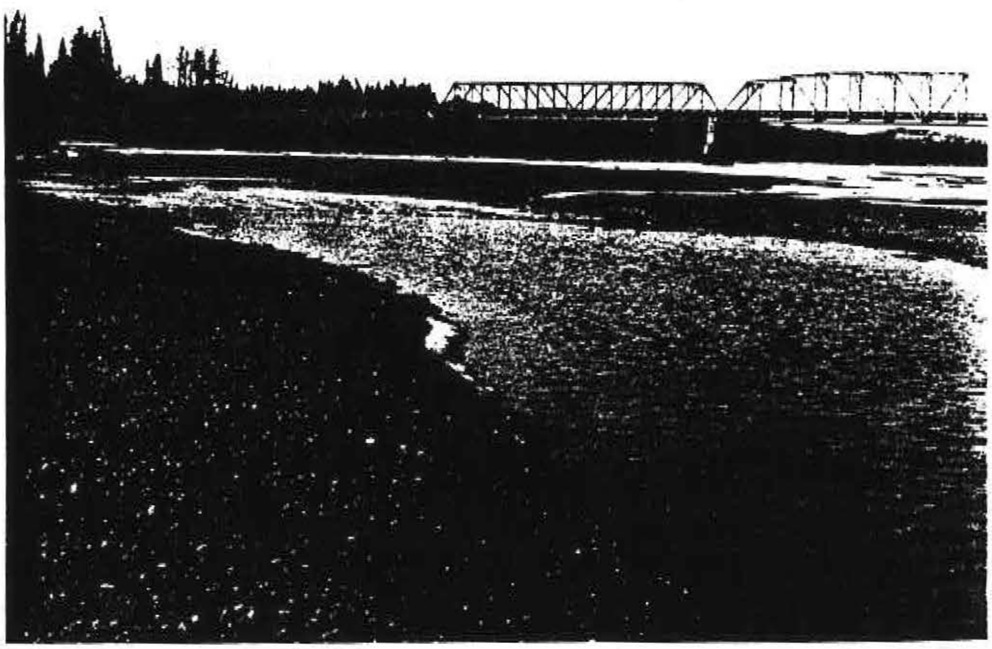

PLATE 8. Sample Site V1 in Reach 1 of Vangorda Creek 200 m Upstream of the Pelly River Confluence Showing Stop Net in Place. April 26, 1989.

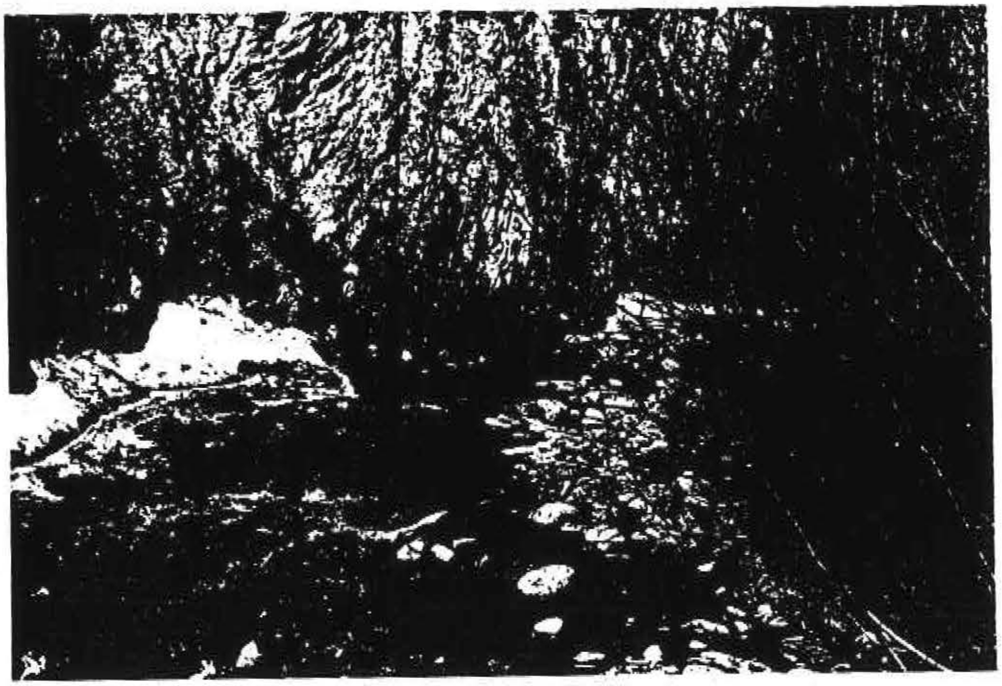

PLATE 9. Open Water Cobble Riffle Section at Sample Site V3 in Reach 3 of Vangorda Creek. April 25, 1989.

PLATE 10. Open Water Cobble Riffle Margin at Sample Site V3b in Reach 3 of Vangorda Creek. April 25, 1989.

PLATE 11. Example of Habitat Where Large Numbers of Chinook Fry were Sampled in Reach 3 of Vangorda Creek. April 26,1989.

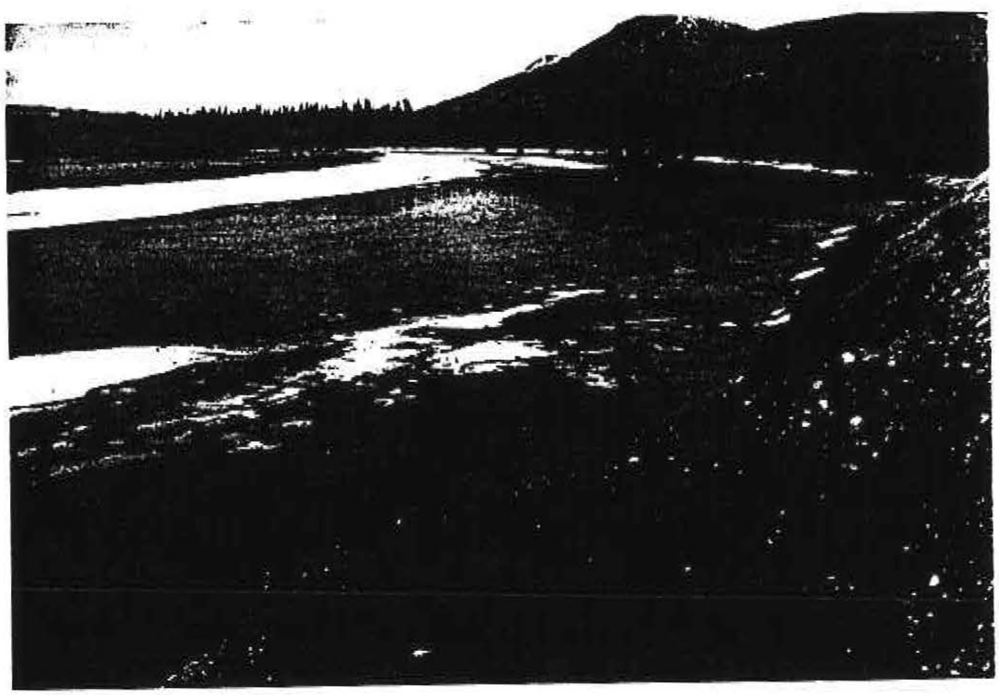

PLATE 12. Mixing Zone of Vangorda Creek and Pelly River Waters Approximately 50 m Downriver of the Pelly River Bridge. April 27, 1989.

PLATE 13. Entrance of Side Channel "A" into Reach 1 of Vangorda Creek 200 m Upstream of the Pelly River Confluence. Winter Killed Fish were Found Amongst the Debris in this Channel. April 26, 1989.

PLATE 14. Isolated Pool in Upper Section of Side Channel "A". April 27, 1989.

PLATE 15. Dry Section of Side Channel "A". April 27, 1989.

PLATE 16. Top Entrance of Side Channel "A" Along the Pelly River Margin. Note Height of Accumulated Gravel Deposit. April 27, 1989.

PLATE 19. Electrofishing within Net Enclosure at Site V1 in Mainstem of Vangorda Creek. August, 1989.

PLATE 20. Steep Confined Section in Reach 2 of Vangorda Creek August, 1989.

PLATE 19. Electrofishing within Net Enclosure at Site V1 in Mainstem of Vangorda Creek. August, 1989.

PLATE 20. Steep Confined Section in Reach 2 of Vangorda Creek August, 1989.

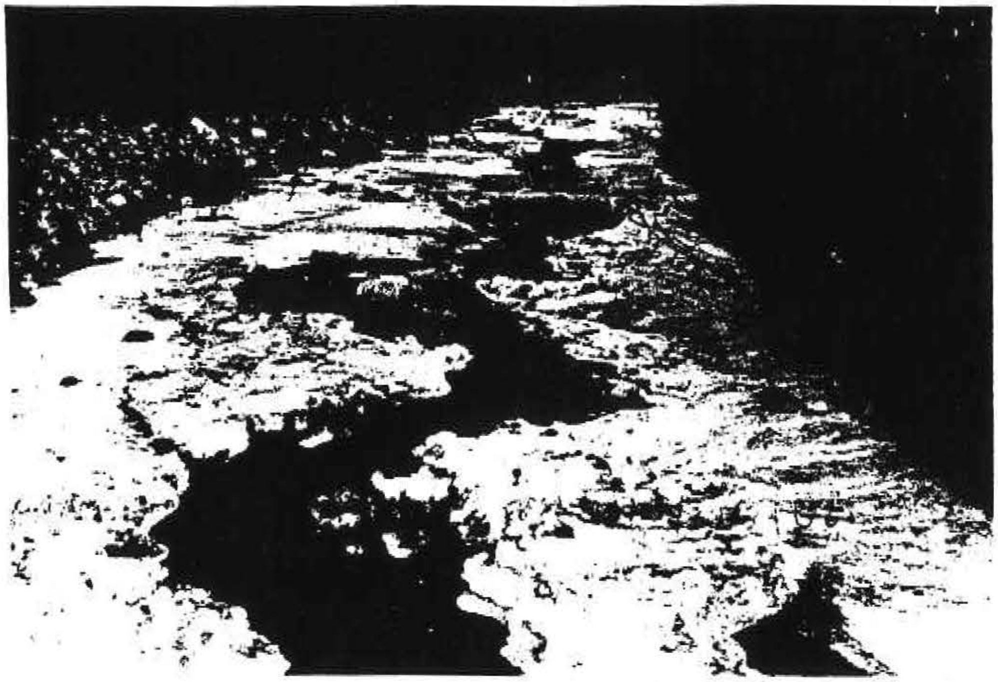

PLATE 21. Sample Site V2a in Reach 2 of Vangorda Creek before Ice was removed. October, 1989.

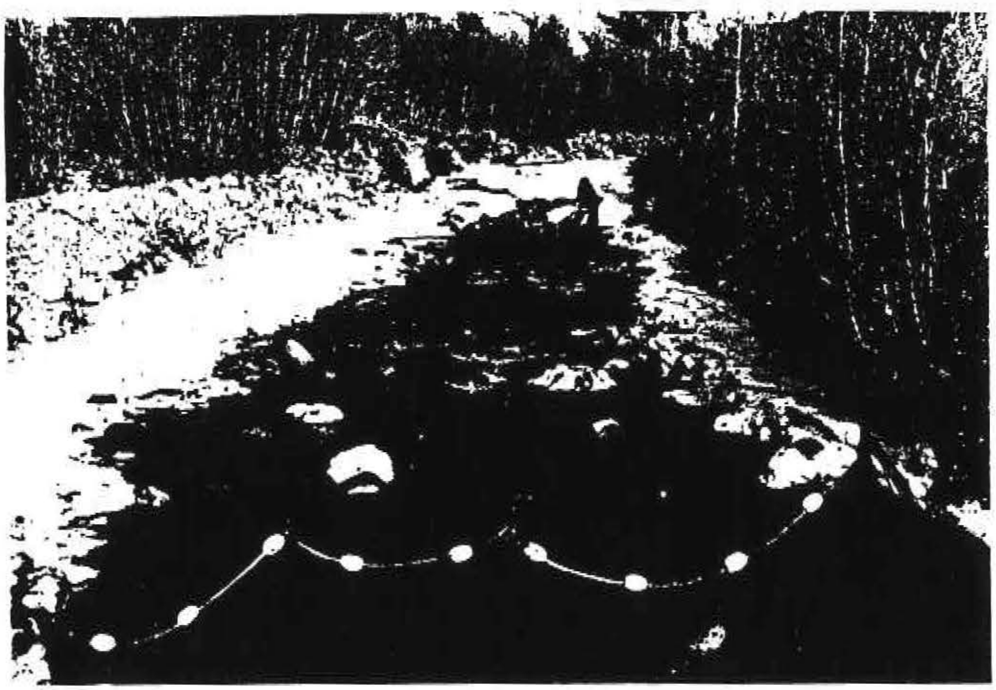

PLATE 22. Sample Site V2a in Reach 2 of Vangorda Creek after Ice was removed. October, 1989.

PLATE 23. Sample Site V3b in Reach 3 of Vangorda Creek. October 1989.

PLATE 24. Ice Cover at Sample Site V1 in Reach 1 of Vangorda Creek. October, 1989.

APPENDIX 2

Fish Sample and Habitat Description Data from Vangorda and Grew Creeks Collected during April, August and October 1989

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V1a REACH: 1 DATE: AUG 10/89 ACCESS: V2

SITE LOCATION: Mainstem location 20 m upstream of the lower bridge.

SLOPE (%) 1.5 TEMP (C) 6 PHOTO: 5-7 and 8

SAMPLING COMMENTS: Site totally enclosed.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	59-79	67.6	50	17	67	75.8	6.4	0.829	3.73	2.91
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+			0	0	0	0.0	0.0	0.000	0.00	
Slimy sculpin	all	50-77	65.9	22	10	32	40.3	8.6	0.442	1.99	1.55
Round whitefish	all	56-74	61.5	1	2	3	3.0	3.5	0.033	0.15	0.07
TOTAL									1.304	5.867	4.532

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	4.2	20	35		Cobble	/25	0/100	Present
5	5.4							
10	4.0							
15	4.3							
20								
25								
30								
	4.5							

AREA (M*M) 91.4 MARGIN (M) 20.3

HABITAT COMMENTS: Mainstem riffle site.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V1b REACH: 1 DATE: AUG 8/89 ACCESS: V2

SITE LOCATION: Side channel located 20 m upstream of lower bridge crossing.

SLOPE (%) 1.5 TEMP (C) 8.5 PHOTO: 4-27 to 29

SAMPLING COMMENTS: Two-pass. Similar sidechannel on the other side of the creek.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	57-70	61.4	347	47	394	401.4	3.6	3.666	12.46	9.53
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+			0	0	0	0.0	0.0	0.000	0.00	
Slimy sculpin	all	15-71	58.2	21	6	27	29.4	2.9	0.269	0.91	0.63
Round whitefish	all	60-79	66.7	5	2	7	8.3	2.9	0.076	0.26	0.20
TOTAL									4.011	13.637	10.357

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	3.6	15	40		Present	/10	40/30/30	
5	3.9							
10	3.7							
15	3.8							
20	3.4							
25	2.5							
30	4.4							
	3.4							

AREA (M*M) 109.5 MARGIN (M) 32.2

HABITAT COMMENTS: Small sidechannel with good debris cover.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V2a REACH: 2 DATE: AUG 8/89 ACCESS: V2

SITE LOCATION: Site starts 5 m upstream from the footbridge and up.

SLOPE (%) 3.0 TEMP (C) 8 PHOTO: 4-31 to 32

SAMPLING COMMENTS: Fast tumbling water. Enclosed with stopnets.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	52-82	63.9	82	8	90	90.9	1.1	0.886	5.05	2.60
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	118-130	124.0	2	0	2	2.0	0.0	0.019	0.11	0.42
Slimy sculpin	all	55-85	68.9	12	3	15	16.0	1.7	0.156	0.89	0.64
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									1.061	6.048	3.665

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	5.0	30	40	Boulder	None	/50	5/85/15	None
5	5.3							
10	5.9							
15	6.3							
20	6.0							
25								
30								
	5.7							

AREA (M*M) 102.6 MARGIN (M) 18.0

HABITAT COMMENTS:

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V3a REACH: 3 DATE: AUG 8/89 ACCESS: V2

SITE LOCATION: Approximately 1000 m upstream from footbridge.
Camp site at this location.

SLOPE (%) 2.0 TEMP (C) 9 PHOTO: 4-33 and 34

SAMPLING COMMENTS: Totally enclosed and effectively sampled.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	54-82	67.7	200	34	234	241.0	3.8	1.481	13.77	5.21
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+			0	0	0	0.0	0.0	0.000	0.00	
Slimy sculpin	all	59-100	77.6	13	7	20	28.2	11.3	0.173	1.61	1.05
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									1.654	15.379	6.262

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	11.0	30	55.0	Boulder	Present	/60	/90	None
5	9.9							
10	8.7							
15	7.4							
20								
25								
30								
	9.3							

AREA (M*M) 162.8 MARGIN (M) 17.5

HABITAT COMMENTS: Large cobble provides provides good cover.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V2a REACH: 2 DATE: OCT 18/89 ACCESS: V2

SITE LOCATION: Site starts 5 m upstream from the footbridge and up.

SLOPE (%) 3.0 TEMP (C) 0.5 PHOTO: 3&4

SAMPLING COMMENTS: Shelf ice had to be removed along the edge of this site prior to sampling. Enclosed with stopnets.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	58-86	70.9	30	2	32	33.1	0.4	0.272	1.38	1.11
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+	118-195		0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	118-195	153.1	6	3	9	12.0	6.0	0.098	0.50	2.91
Slimy sculpin	all	70	70.0	1	0	1	1.0	0.0	0.008	0.04	0.04
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.378	1.923	4.054

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	4.5	15	30	Boulder		/40	5/95	None
5	5.1							
10	4.5							
15	5.0							
20	5.7							
25	5.7							
30								
	5.1							

AREA (M*M) 122.0 MARGIN (M) 24.0

HABITAT COMMENTS: Some site disturbance was required prior to sampling. Therefore this estimate is a minimum estimate.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V3a REACH: 3 DATE: OCT 18/89 ACCESS: V2

SITE LOCATION: Campsite below town. This site is located approx. 40 m upstream of Aug. site.
Too much ice downstream of this location to effectively sample.
SLOPE (%) 2.0 TEMP (C) 0.5 PHOTO: DB-1

SAMPLING COMMENTS: Good enclosure and effective sampling.
Most of the reach is too iced over to sample. This site is faster and narrower than Aug site.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	58-84	70.4	32	0	32	32.0	0.0	0.294	1.39	1.17
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	105	105.0	1	0	1	1.0	0.0	0.009	0.04	0.09
Slimy sculpin	all	74	74.0	1	0	1	1.0	0.0	0.009	0.04	0.05
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.312	1.478	1.311

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	5.0	15	70	Present	Boulder	/35	70/30	None
5	4.7							
10	5.4							
15	4.1							
20	4.5							
25								
30								
	4.7							

AREA (M*M) 109.0 MARGIN (M) 23.0

HABITAT COMMENTS:

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V3b REACH: 3 DATE: OCT 19/89 ACCESS: V2

SITE LOCATION: This site is located immediately upstream from V3a.
A small groundwater seep is keeping it from icing over to this date.

SLOPE (%) 4.0 TEMP (C) 0.5 PHOTO: DB- 6 to 8

SAMPLING COMMENTS: Site effectively sampled within nets.
Conducted 3 passes due to high second pass catch.
Fish retained for weights and possible tissue analysis.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	62-89	72.4	45	9	54	56.3	2.3	0.298	1.34	1.30
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	115-178	144.0	16	0	16	16.0	0.0	0.085	0.38	2.10
Slimy sculpin	all			0	0	0	0.0	0.0	0.000	0.00	
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.382	1.720	3.398

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	5.0	15	40		Boulder	/40	35/65	Present
5	5.0							
10	4.5							
15	4.0							
20	4.7							
25	3.5							
30	4.0							
	4.5							

AREA (M*M) 189.0 MARGIN (M) 42.0

HABITAT COMMENTS: Nearly all fish were captured in the lower end of the site.
Left wondering whether groundwater area was influencing fish use in upper part of site.
Water temperature in the small channel was 6 C.

VANGORDA CREEK - FISH TISSUE SAMPLES

OCTOBER 19, 1989

Fish were collected at site V3b. An effort was made to collect 10-20 gram samples of chinook and grayling. The chinook samples were generally less than this due to the small fish size. Grayling samples were larger, and several larger fish were placed in the same bag.

Detailed length and weights for the samples are as follows:

CHINOOK

SAMPLE NUMBER	LENGTH (cm)	WEIGHT (grams)	TOTAL SAMPLE (grams)
1	80	5.0	
1	82	4.5	
1	89	6.7	16.2
2	69	2.5	
2	65	2.5	
2	87	6.0	
2	85	5.8	16.8
3	83	5.5	
3	82	5.3	
3	71	3.4	14.2
4	69	3.4	
4	75	4.0	
4	73	3.1	
4	73	4.0	14.5
5	77	4.7	
5	70	3.3	
5	62	2.4	
5	71	3.4	13.8
6	71	3.3	
6	72	3.3	
6	65	2.0	
6	68	3.3	
6	71	3.0	
6	69	3.8	
6	73	3.3	22.0
7	76	4.3	
7	75	3.5	
7	68	2.6	
7	69	3.2	
7	76	4.4	
7	72	3.2	21.2
8	74	3.3	
8	66	2.2	
8	66	2.6	
8	76	4.1	
8	76	4.1	16.3
9	75	3.5	
9	75	4.1	
9	70	2.7	
9	70	3.3	13.6
10	64	2.6	
10	66	2.5	
10	72	3.3	
10	72	3.8	
10	62	2.0	14.2

GRAYLING

SAMPLE NUMBER	LENGTH (cm)	WEIGHT (grams)	TOTAL SAMPLE (grams)
1	178	47.5	47.5
2	175	38.5	38.5
3	168	37.7	37.7
4	145	25.2	25.2
5	151	30.4	
5	142	25.2	55.6
6	141	22.4	
6	139	23.8	
6	121	14.5	60.7
7	145	26.5	
7	137	22.4	
7	134	20.4	69.3
8	140	23.6	
8	141	21.9	45.5
9	132	20.0	
9	115	12.0	32.0

BUTLE CREEK FISH SAMPLE SITE:

SITE: BU1 REACH: DATE: AUG 10/89 ACCESS: V2

SITE LOCATION: 70 m downstream of the Robert Campbell Highway.

SLOPE (%) TEMP (C) 12 PHOTO:

SAMPLING COMMENTS: Stopnets used and site enclosed totally.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+			0	0	0	0.0	0.0	0.000	0.00	
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+			0	0	0	0.0	0.0	0.000	0.00	
Slimy sculpin	all	NM		16	9	25	36.6	14.7	0.614	2.27	2.1[illegible]
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.614	2.272	2.14[illegible]

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	4.0	20	30.0	Present		/35	0/90/10	
5	4.2							
10	3.3							
15	3.1							
20								
25								
30								
	3.7							

AREA (M*M) 59.6 MARGIN (M) 16.1

HABITAT COMMENTS: DFO/MOE Stream Inventory Form completed.

GREW CREEK FISH SAMPLE SITE:

SITE: GR1 REACH: DATE: AUG 10/89 ACCESS: V2

SITE LOCATION: Site is located 20 m below highway culvert downstream.

SLOPE (%) 2.0 TEMP (C) 11 PHOTO: 5-13

SAMPLING COMMENTS: Site enclosed - two pass. Some shocker problems at this site.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	56-72	64.3	8	4	12	20.0	6.9	0.188	0.98	0.6
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+			0	0	0	0.0	0.0	0.000	0.00	
Slimy sculpin	all	43-91	66.0	9	2	11	11.6	1.2	0.109	0.56	0.3
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.296	1.540	1.01

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH(cm)	MAXIMUM DEPTH(cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE	SIDE CHANNELS
0	5.7	10	20			/12	0/80/20	None
5	5.6							
10	4.7							
15	4.9							
20								
25								
30								
	5.2							

AREA (M*M) 106.6 MARGIN (M) 20.5

HABITAT COMMENTS: Fines deposited along the margin from upstream placer activity?
0.3 m drop at the culvert may restrict juvenile movement upstream.
Angular substrate provides cover for chinook juveniles./pp

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V2a REACH: 2 DATE: OCT 18/89 ACCESS: V2

SITE LOCATION: Site starts 5 m upstream from the footbridge and up.

SLOPE (%) 3.0 TEMP (C) 0.5 PHOTO: 3&4

SAMPLING COMMENTS: Shelf ice had to be removed along the edge of this site prior to sampling. Enclosed with stopnets.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	58-86	70.9	30	2	32	33.1	0.4	0.272	1.38	1.11
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	118-195	153.1	6	3	9	12.0	6.0	0.098	0.50	2.91
Slimy sculpin	all	70	70.0	1	0	1	1.0	0.0	0.008	0.04	0.04
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.378	1.923	4.054

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	4.5	15	30	Boulder		/40	5/95	None
5	5.1							
10	4.5							
15	5.0							
20	5.7							
25	5.7							
30								
	5.1							

AREA (M*M) 122.0 MARGIN (M) 24.0

HABITAT COMMENTS: Some site disturbance was required prior to sampling. Therefore this estimate is a minimum estimate.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V3b REACH: 3 DATE: OCT 19/89 ACCESS: V2

SITE LOCATION: This site is located immediately upstream from V3a.
A small groundwater seep is keeping it from icing over to this date.

SLOPE (%) 4.0 TEMP (C) 0.5 PHOTO: DB- 6 to 8

SAMPLING COMMENTS: Site effectively sampled within nets.
Conducted 3 passes due to high second pass catch.
Fish retained for weights and possible tissue analysis.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	62-89	72.4	45	9	54	56.3	2.3	0.298	1.34	1.30
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	115-178	144.0	16	0	16	16.0	0.0	0.085	0.38	2.10
Slimy sculpin	all			0	0	0	0.0	0.0	0.000	0.00	
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.382	1.720	3.398

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	5.0	15	40		Boulder	/40	35/65	Present
5	5.0							
10	4.5							
15	4.0							
20	4.7							
25	3.5							
30	4.0							
	4.5							

AREA (M*M) 189.0 MARGIN (M) 42.0

HABITAT COMMENTS: Nearly all fish were captured in the lower end of the site.
Left wondering whether groundwater area was influencing fish use in upper part of site.
Water temperature in the small channel was 6 C.

VANGORDA CREEK FISH SAMPLE SITE:

SITE: V3a REACH: 3 DATE: OCT 18/89 ACCESS: V2

SITE LOCATION: Campsite below town. This site is located approx. 40 m upstream of Aug. site. Too much ice downstream of this location to effectively sample.

SLOPE (%) 2.0 TEMP (C) 0.5 PHOTO: DB-1

SAMPLING COMMENTS: Good enclosure and effective sampling. Most of the reach is too iced over to sample. This site is faster and narrower than Aug site.

POPULATION ESTIMATES:

SPECIES	AGE	FL-RANGE (mm)	MEAN FL (mm)	PASS 1	PASS 2	U1&U2	NUMBER	S.E.	N/M*M	N/LIN-M	BIOMASS (g/m*m)
Chinook	0+	58-84	70.4	32	0	32	32.0	0.0	0.294	1.39	1.17
Chinook	1+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	0+			0	0	0	0.0	0.0	0.000	0.00	
Grayling	>1+	105	105.0	1	0	1	1.0	0.0	0.009	0.04	0.09
Slimy sculpin	all	74	74.0	1	0	1	1.0	0.0	0.009	0.04	0.05
Round whitefish	all			0	0	0	0.0	0.0	0.000	0.00	
Burbot	all			0	0	0	0.0	0.0	0.000	0.00	
TOTAL									0.312	1.478	1.311

SITE MEASUREMENTS:

LOCATION (m)	WIDTH (m)	MEAN DEPTH (cm)	MAX DEPTH (cm)	BANK COVER	DEBRIS COVER	D50/D90 (cm)	POOL: RIFFLE: OTHER	SIDE CHANNELS
0	5.0	15	70	Present	Boulder	/35	70/30	None
5	4.7							
10	5.4							
15	4.1							
20	4.5							
25								
30								
	4.7							

AREA (M*M) 109.0 MARGIN (M) 23.0

HABITAT COMMENTS: