Technical Report No. 10-06

Stikine River Mining Activity Risk Assessment

by

Phyllis Weber Scannell

December 2012

Alaska Department of Fish and Game **Division of Habitat**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TECHNICAL REPORT NO. 10-06

STIKINE RIVER MINING ACTIVITY RISK ASSESSMENT

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December 2012

This report is funded (in part) with qualified outer continental shelf oil and gas revenues by the Coastal Impact Assistance Program, Fish and Wildlife Service, U.S. Department of the Interior.

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Scannel Scientific, Inc.

This document should be cited as:
Weber Scannell, P. 2012. Stikine River mining activity risk assessment. Alaska Department of Fish and Game, Technical Report No. 10-06, Douglas, Alaska.

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ACKNOWLEDGMENTS

The Alaska Department of Fish and Game, Division of Habitat supported this project. I thank Ms. Jackie Timothy for her support and guidance and Dr. Alvin G. Ott for providing biomonitoring data on chlorophylls, direction for this project and helping define the objectives. Rivers without Borders generously granted their permission to use maps of the upper and lower Stikine River Watersheds. Mr. Paul Wojdak, BC Ministry of Energy Mines & Petroleum Resources provided information on mining history and current prospects in the Stikine River Watershed. Ms. Celia Rosen provided access to the Alaska Resources Library Information Services. Ms. Tally Teal and Ms. Amy Carroll prepared the document for ADF&G publication. I gratefully acknowledge all of the assistance provided for this project.

EXECUTIVE SUMMARY

Two hard rock mineral mines are proposed for the Stikine River Watershed: the Galore Creek Project and the Schaft Creek Project.

The proposed Galore Creek Project is located between the Stikine and Iskut Rivers and Highway 37 in northwestern British Columbia. Galore Creek flows northward to the Scud River, a tributary to the Stikine River. The Stikine River is an important transboundary system that supports 19 fish species, including all 5 species of Pacific salmon.

The Galore Creek deposit contains copper, gold and silver; current estimates for mine production are 5.9 billion pounds of copper, 3.7 million ounces of gold and 40 million ounces of silver over the 20-year life of the mine. The proposed filter plant and ore concentrate loading facility is located near the Iskut River, near the confluence with More Creek. The projected mine life is 20 years.

The proposed Schaft Creek Project is located approximately 60 km south of the village of Telegraph Creek in the upper Schaft Creek watershed. Schaft Creek drains to the north into Mess Creek, a tributary to the Stikine River. The Schaft Creek deposit is a polymetallic (copper-gold-silver-molybdenum) deposit; mineral claims cover approximately 20,932 ha.

The current mine plan describes an open pit, mined at the rate of 100,000 tonnes per day with a projected mine life of 23 years. The deposit will be mined with large truck/shovel operations. The ore will be crushed, milled and filtered on site to produce separate copper and molybdenum concentrates. At the end of the project, the mine pit will encompass an area of 4.9 km^2 and extend 330 m below the current elevation. The project will generate over 812 million tonnes of tailings. An access road will be constructed from the Galore Creek road.

This document presents a review of the environmental effects monitoring programs for the proposed Galore and Shaft Creek mines. The review is divided into four sections. The first section presents the history of mining in the Stikine River Drainage and historical data on water quality, hydrology, fish and wildlife. The second part of the report examines the environmental baseline reports for the Galore Creek proposed project. Data gaps are identified and an analysis of the appropriateness of sampling methods is presented. Baseline data appear adequate to describe pre-mining populations of fish and wildlife; however, the water quality data were not collected with sufficient frequency or through the range of low and peak flows. Samples during peak flows, in particular, are minimal or missing. Studies of metals concentrations in fish and shellfish were limited to muscle tissue. Most metals are found in organ tissues, not muscle. Therefore, these data should not be used to establish baseline conditions. Fish and shellfish should have been sampled for whole body concentrations of smaller species and discrete organ concentrations for larger species. This section also presents a risk assessment for potential mining activities in the Galore Creek watershed and for discharges from the proposed filter plant to the Iskut River watershed. Predictions for water quality downstream of the mine and from the filter plant discharge suggest that water quality objectives will be maintained and that there will be minimal or no added metals to the receiving waters. However, a monitoring program that includes water quality of both the discharges and receiving waters is necessary to confirm predictions.

The review then examines the environmental baseline reports for the Schaft Creek proposed project. Both the water quality and the hydrology data contained errors—analytes were mislabeled in the 2008 data and dates were wrong in the 2007 hydrology data. These errors in the data, along with data gaps and an analysis of the appropriateness of sampling methods are presented. Reports of studies on metals concentrations in aquatic species were not available. Included is a risk assessment for potential mining activities in the Schaft Creek–Mess Creek watershed. The risk assessment should be considered preliminary because much of the raw data has not been verified and many data reports are not yet available. The water management report, a critical component to predicting downstream effects, is not yet available. Therefore, the risk assessment is limited to identifying possible sources of metals input to receiving water and preliminary plans for water management.

The final section of the report presents an Environmental Monitoring Plan for the affected watersheds and for the lower reaches of the Stikine River in Alaska. Important factors for monitoring are identified, detailed sampling methods are given along with sampling frequency and recommended numbers of sample replicates. The emphasis of the Environmental Monitoring Plan is to provide for long-term monitoring with methods that are defensible, cost-effective and will produce valuable information about the stream conditions. The Monitoring Plan includes suggestions for quickly identifying unexpected increases in metals input.

THE STIKINE RIVER WATERSHED

The Stikine River begins as a small stream flowing from a nearly spent glacier on a high plateau near Mount Umbach in the Spatsizi Plateau Wilderness Park in British Columbia. The river flows about 644 km to the Pacific Ocean in Southeast Alaska, past glaciers, volcanoes and mountain ranges. The Stikine River watershed covers over 80,290 km^2; major tributaries are, in descending order from its source:

River	Tributary
Duti River	
Chukachida River	
Spatsizi River	
Pitman River	
McBride River	
Klappan River	Little Klappan River
Tanzilla River	
Klastline River	
Tuya River	Little Tuya River
Tahltan River	Little Tahltan River
Chutine River	
Porcupine River	Sphaler Creek
Choquette River	
Scud River	Galore Creek
Iskut River	Little Iskut River, More Creek
Anuk River	

The river is navigable for approximately 210 km upstream from its mouth. It was used by the coastal Tlingit as a transportation route to the interior region. The first European to explore the river was Samuel Black, who visited the headwaters during his Finlay River expedition in 1824. It was more extensively explored in 1838 by Robert Campbell, of the Hudson's Bay Company, completing the last link in the company's transcontinental canoe route. In 1879 the lower third was travelled by John Muir who likened it to a Yosemite that was 160 km long. Muir recorded over 300 glaciers along the river's course.

UPPER ISKUT-STIKINE

The Iskut River, the largest tributary of the Stikine, flows for 236 km from Kluachon Lake near Iskut, BC to its confluence with the lower Stikine River near the US/Canada border. The Stikine-Iskut watershed can be divided into two sections, the upper Iskut-Stikine and the lower Iskut Stikine.

The Upper Iskut-Stikine region (Figure 1) lies to the east of Highway 37, the Stewart-Cassiar Highway, where it flows through the Spatsizi Plateau. The upper reach of the river runs for 260 km from Tuaton Lake to the Highway 37 Bridge over the Stikine.

LOWER ISKUT-STIKINE

The Lower Iskut-Stikine region (Figure 2) includes 386 km of the main stem Stikine River, from the Highway 37 Bridge over the Stikine to the sea, including the 100 km Grand Canyon section with its 300 m walls. This area also includes the Iskut River, the main tributary to the Stikine River, which flows for 236 km from Kluachon Lake near Iskut, BC to its confluence with the lower Stikine River near the US/Canada border.

The confluence of the Stikine and Iskut Rivers is an important wetland complex providing habitat for many species, including migratory birds, moose, mountain goats, wolves and bear. This lower region also is part of an extensively mineralized belt known as the Golden Triangle.

The mouth of the river in the United States provides a habitat for migratory birds and is protected as part of the Stikine-LeConte Wilderness Area. The force of the current in the river's Grand Canyon limits salmon migration to the lower one-third of the river.

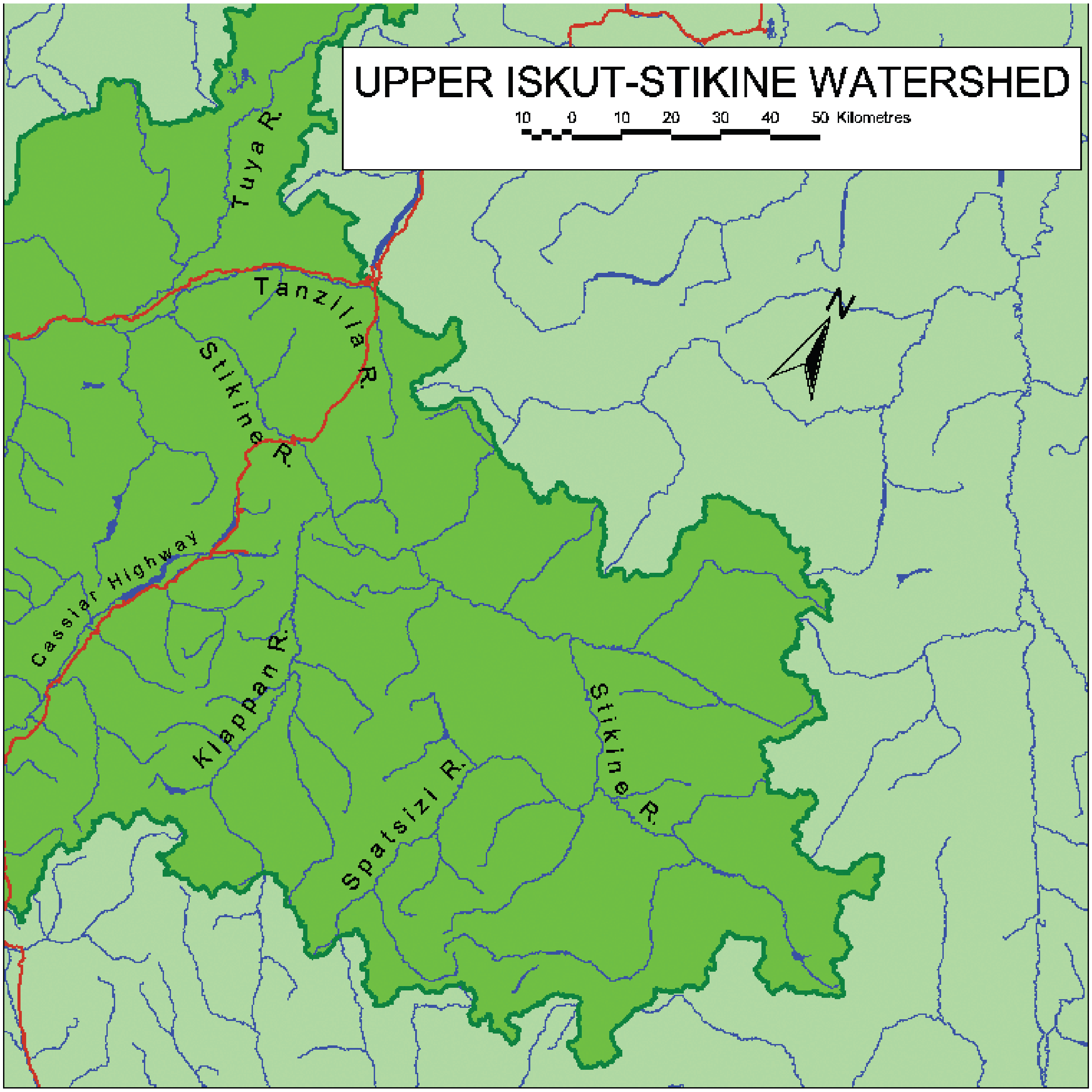

Figure 1.– Upper Iskut: Stikine River Watershed.

Source: Map from Rivers without Borders, used with permission, the red lines are established roads.

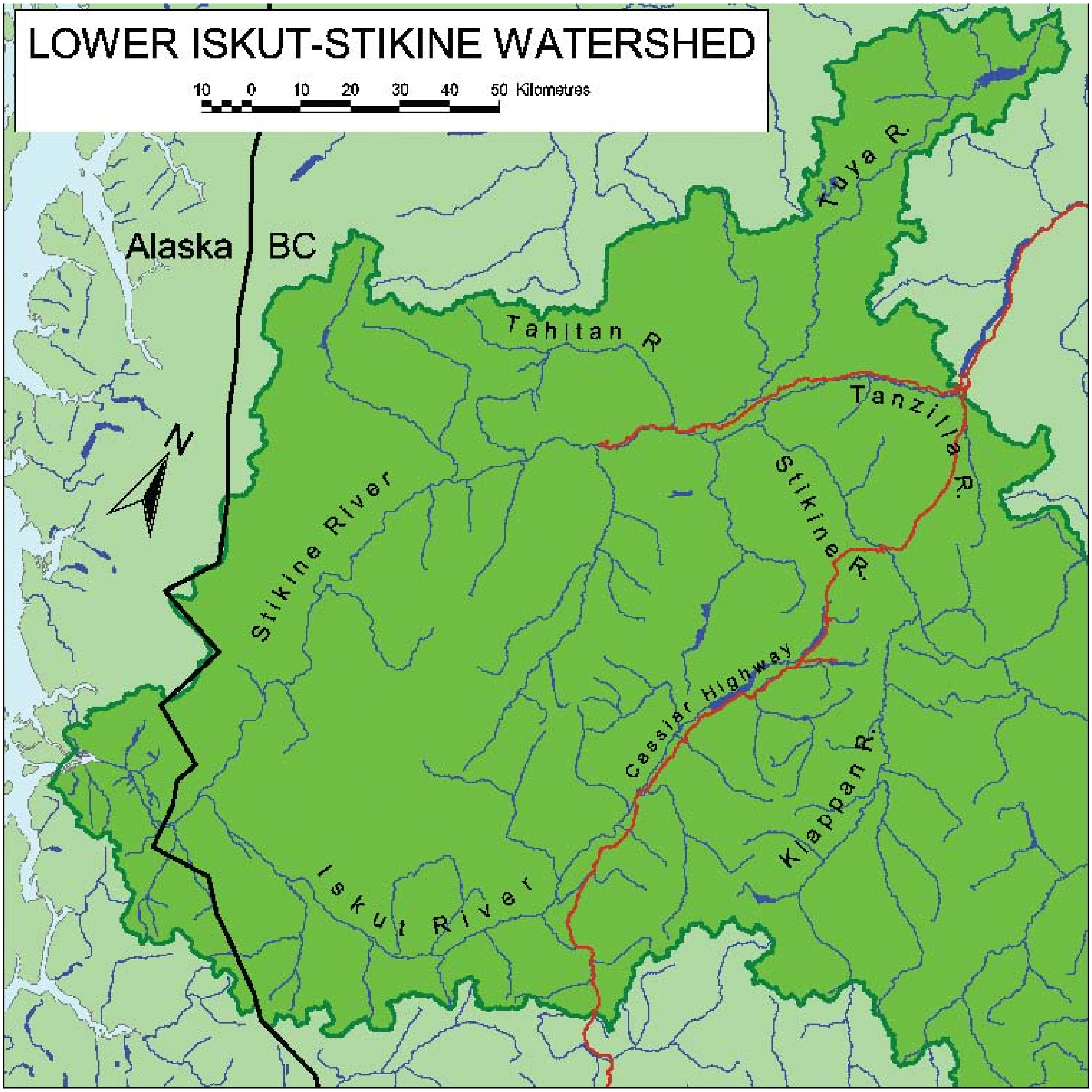

Figure 2.–Lower Iskut: Stikine River Drainage.

Source: Map from Rivers without Borders, used with permission, the red lines are established roads, the black line is the US/Canada border.

HISTORY OF MINING IN STIKINE DRAINAGE

Early Mining, the Gold Rush

Early prospectors found gold by wandering through the drainage and panning. By 1861, placer miners were operating in the Telegraph Creek area. Telegraph Creek (Figure 3) was a significant stopping point because it was the farthest navigable point on the Stikine River for steamships. By the 1870s, Telegraph Creek and the Stikine River formed the gateway to the Cassiar gold rush in 1873 through 1875 and the Klondike gold rush in 1896 through 1900. Placer mining occurred throughout the Stikine River drainage, with concentrations around Telegraph Creek and Deese Lake. Placer gold mining was largely responsible for development of settlements at Telegraph Creek and Deese Lake.

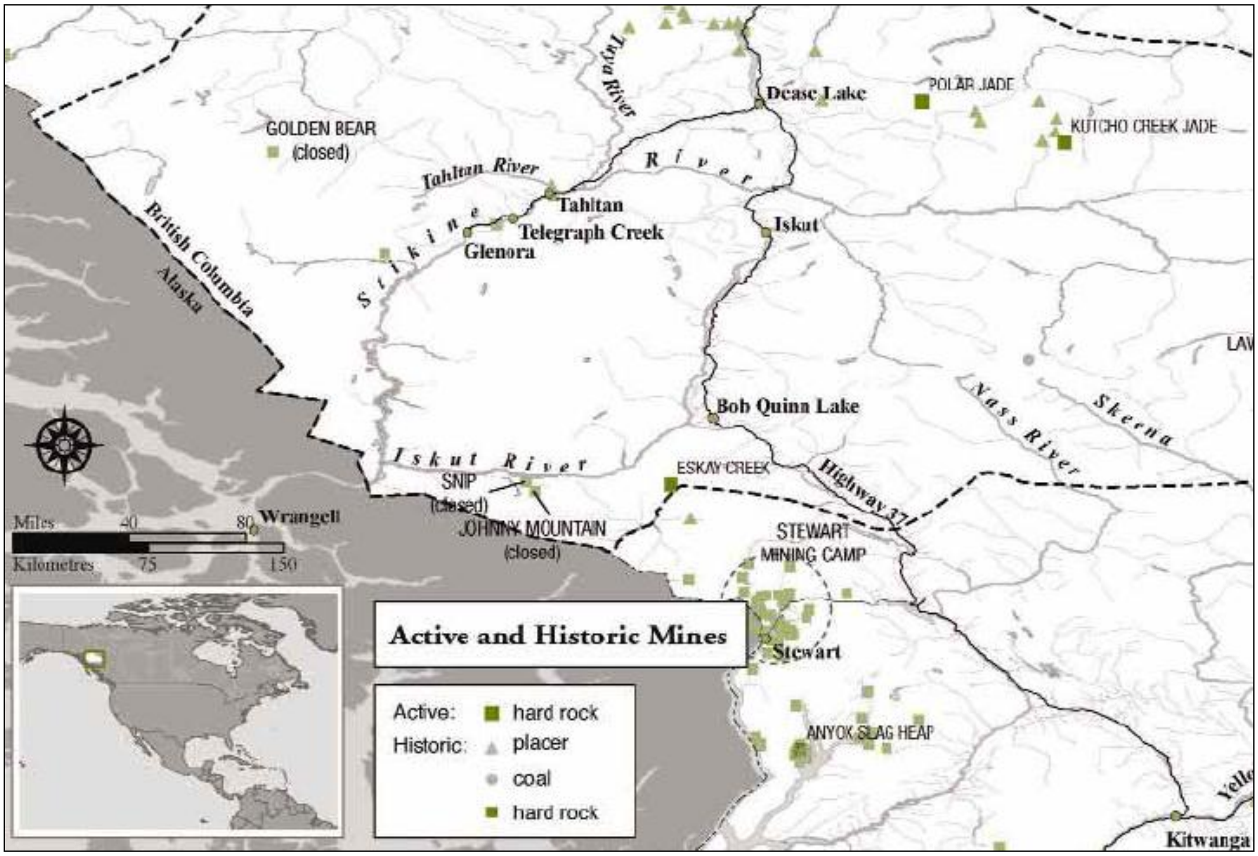

Figure 3.–Map showing location of closed mines Johnny Mountain, Snip and Golden Bear.

Source: Tahltan First Nation (2003).

The early prospectors identified mineral occurrences in the Stikine River drainage; this was followed by more systematic bedrock mapping, geochemical sampling, and geophysical surveying (Baker 2002). The International Boundary survey crews surveyed the Iskut River area about the same time as the Klondike Gold Rush and identified a number of prominent mineral outcroppings, including Johnny Mountain (Martin 1996). The first claims in the Johnny area were staked by the Iskut Mining Company of Wrangell Alaska in 1907. The nine original claims covered the east side of Bronson Creek on Johnny Ridge (Figure 3, Martin 1996). The Red Bluff claim group, 5 km northeast of the Johnny Mountain property, was staked in 1909. Cominco staked 42 claims in 1929 in the Iskut River area; these claims were never developed.

The development of mining in the Stikine Drainage correlates with the development of methods to sample and map deposits and to identify geologic formations that likely contained concentrations of metals. Barr (1980) divides the gold production in the Canadian Cordillera according to three types of deposits that define distinct periods in the search for gold: placer gold (1858–1917), lode gold (1918–1967), and base metal (1967–present).

Abandoned or Closed Mines

Since the gold rush 150 years ago, thousands of mines have been developed in the Stikine River and adjacent drainages (Baker 2002). Many of these mines were abandoned when few minerals were found or when mining became unprofitable. There remain many historic mine sites that have not been documented. Since 1980s, two mines have been closed in the Iskut Creek drainage: the Snip Mine and Johnny Mountain. North of the Stikine River was the now reclaimed Golden Bear Mine. In the Shelslay River Drainage and south of the Iskut River is the reclaimed Eskay Creek Mine in the Unuk River drainage (Figure 3).

Iskut Drainage

Snip Mine

Location: Latitude 56º40'07"N, Longitude 131º06'32"W
Current Status: closed
Minfile # 104B 089, 104B 250
Minerals: Au, Ag, Cu, Zn

The Snip Mine (Figure 3), currently owned by Barrick Gold, operated from 1991 to 1999. Snip is currently an inactive underground mine located 31 km west of Volcano Creek near Bronson Creek, about 2.1 km south of the Iskut River. While in operation, the Snip Mine was a high-grade gold mine and mill that processed about 400 tons per day using simple gravity flotation. About 1.2 million tons of ore were mined to produce 1.13 million ounces of gold, 420,000 ounces of silver, and 550,000 pounds of copper (Wojdak 1999). The deposit was wide high-grade quartz-carbonate-sulfide veins. Access to the Snip Mine was from Wrangell by hovercraft along the Iskut River and aircraft by an airfield adjacent to the mine. Concentrate was hauled out by hovercraft and fixed-wing aircraft. The mine closed in 1999 and the site has been reclaimed.

Johnny Mountain

Location: Latitude 56º37'25"N, Longitude 131º04'03"W
Minfile # 104B 107
Minerals: Au, Ag, Cu, Zn
Current Status: Closed and reclaimed

Skyline Gold operated the Johnny Mountain Mine (Figure 3) from August 1988 to August 1990 and periodically in the mid-1990s. The mine produced 92,500 ounces of gold, 145,000 ounces of silver, and 2.3 million pounds of copper. High operating costs and low gold prices contributed to Johnny Mountain's early shutdown. Access to and from the mine was by air from Wrangell and Bob Quinn Lake using a 1,585 m long airstrip near the mine site. Air shuttles hauled in supplies and diesel for onsite electricity generators (3,000 gallons per day) and hauled out the gold ore bars and concentrates. Buildings and equipment remain at the mine site.

Nearby Drainages

Golden Bear Mine

Sheslay River Drainage
Latitude: 58°44'09"N, Longitude: 133°36'04"W
Minerals: Au
Current Status: Closed and reclaimed

The Golden Bear mine (Figure 3) was located 100 km west of Dease Lake. The mine is accessible by a 153 km long access road from the Telegraph Creek road. Mining started at the Golden Bear mine in 1989 as an underground and open pit operation that fed a small mill with a roaster and gold leach (cyanide heap leach) circuit (Goldcorp Inc. 2006). The mining and milling shut down in 1994 and then re-opened in 1997 as a seasonal heap leach operation; the Golden Bear Mine included the Grizzly Prospect. A combination of open pit and underground ore was used to build two heap leach pads. Mining at the Golden Bear mine was completed in 2000 when the economic ore was depleted; the leach pads were operated until 2001.

The Golden Bear mine was originally operated by Chevron Minerals in partnership with Homestake Mining (1989 to 1993). In 1993 the property was sold to Wheaton River Minerals and was operated by North American Metals Corp, a subsidiary of Goldcorp Inc. The mine produced more than 265,000 ounces of gold at a cash cost of approximately US $170 per ounce, giving the company about $43 million cash flow during a time of record low gold prices. Production at Golden Bear peaked in 2000 at 94,000 ounces (Goldcorp Inc. 2006).

At the time of closure, the Golden Bear site had three small open pits, two underground portals, two heap leach pads, five mine rock storage areas, one tailings impoundment, and a reclaimed camp and mill area. Most of the major reclamation took place between 2003 and 2004. The mine rock storage areas were recontoured to stabilize the slopes. The tailings impoundment, located beside Bearskin Creek, was covered with 1 m of alluvial gravel and soil. The exploration and site access roads were deactivated and seeded to reduce erosion. The camp, mill, and heap leach plants were demolished and removed from the site. The camp and mill areas were covered in till and re-vegetated with grasses and forbs. The mining areas, mine rock storage areas, and heap leach pads were not revegetated because they are located at high altitudes where vegetation is restricted. In 2005, the company received "The Jake MacDonald Mine Reclamation Award" for its reclamation of the Golden Bear Mine (Goldcorp Inc. 2006).

Eskay Creek Mine

Watershed: Eskay Creek mine drains into Ketchum Creek, then Unuk River
Location: Latitude: 56°39'14"N, Longitude: 130°25'44"W, S of Iskut River
Current Status: closed and reclaimed
Minfile # 104B 9W
Minerals: Au, Ag, Zn, Cu

The Eskay Creek deposit (Figure 3), located about 800 m above sea level, was first explored in 1932 by T. S. Mackay. Early exploration identified extensive mineral zones in upper Coulter and

Eskay creeks that extended over more than 7 km. The Eskay Creek mine site drains into Ketchum Creek, which flows into the Unuk River.

The Eskay Creek deposit was unusually rich in gold and silver. The deposit was described as massive sulphide bodies and in veins within Middle Jurassic Hazelton Group sedimentary and volcanic rocks. The Eskay Creek deposit contained sphalerite, galena, chalcopyrite, barite and pyrite (Wojdak 2004).

In 1999, Eskay Creek was 100% owned and operated by Homestake Canada Inc. The Eskay Creek site was mined by drift and fill; stopes were backfilled with cemented river gravel. Waste rock was disposed underwater in Albino Lake. Mill tailings also were trucked to Albino Lake for disposal until 2001–2002 when a 5 km tailings pipeline was built to Tom Mackay Lake. In 2001 Barrick merged with Homestake Canada Inc. and became the sole owner.

Mining was completed at Eskay Creek in March 2008, although stockpiled ore remained to be processed. Since start-up in 1995 Eskay Creek has produced more than 100 tonnes of gold and 5000 tonnes of silver. Wojdak (2004–2008; Wojdak and Febbo 2009; Wodjak 2010, 2011) provides in-depth descriptions of the geology and development of the Eskay Creek Mine.

Developed Prospects and Mineral Showings

Grieve et al. (2010) identified three proposed mines and three major exploration projects in the Stikine-Iskut River Drainage in the 2009 mining season (Figure 4). The proposed mines are Galore Creek, Schaft Creek and Red Chris and the major exploration projects are Trek, Rock and Roll and Bronson Slope. The remaining exploration projects shown in Figure 4 are not located in the Stikine-Iskut Drainage.

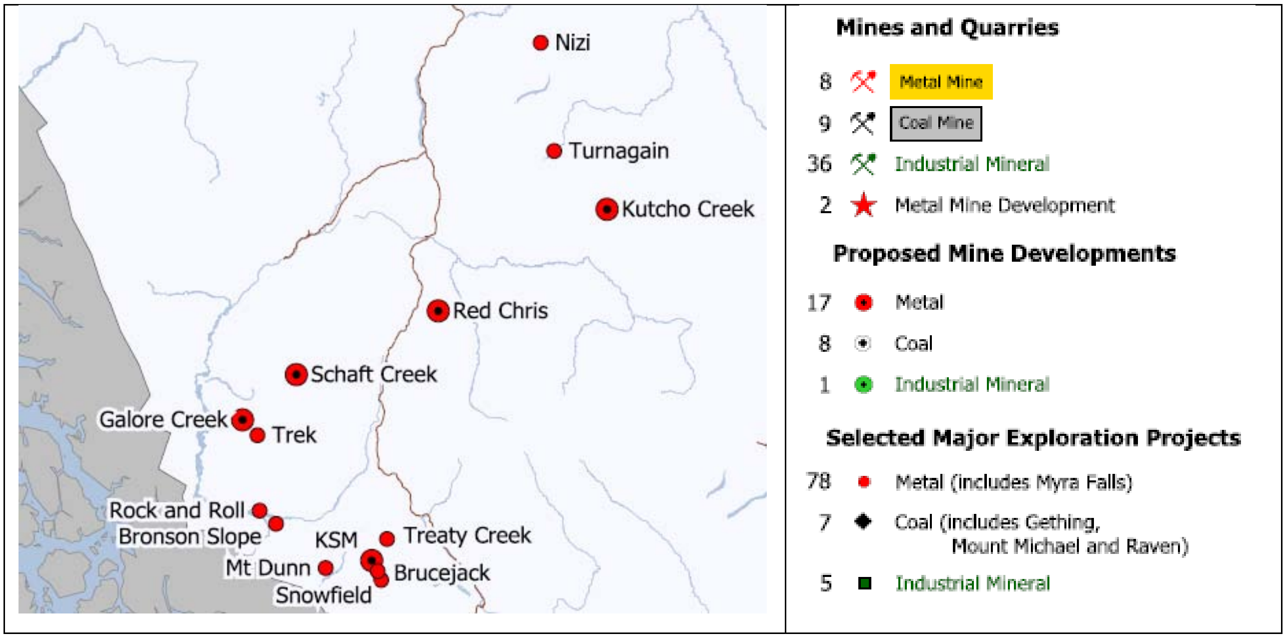

Figure 4.–Proposed mine developments and major exploration projects in the Stikine-Iskut River Drainage.

Source: Grieve et al. (2010).

Rock and Roll

Location: Latitude 56°43'06"N, Longitude 132°14'02"W
Minfile # 104B 377
Minerals: Ag, Cu, Pb, Zn

The Rock and Roll prospect (Figure 4) is near the former Snip gold mine. This prospect is currently held by Minerals Ltd. and adjoins the Phiz gold vein (held by Newcastle) and the Black Dog zone. Exploration to date identifies this property as a massive sulfide mineralization containing silver, copper, lead and zinc. The property remains undeveloped.

Red Chris

Location: Latitude 57º41'59"N, Longitude 129º48'19"W
Minfile # 104H 005
Minerals: Au, Cu, Ag, Pb, Zn, Mo
Current status: Developed Prospect

Red Chris is a porphyry copper-gold deposit, located 80 km south of Dease Lake (Figure 4). The 2004 estimates of the deposit were 446.1 million tonnes grading 0.36% Cu and 0.29 g/t Au. In addition, there is an estimated resource in the Main and East zones of 268.7 million tonnes grading 0.30% Cu and 0.27 g/t Au and in the Far West and Gully zones of 116.0 million tonnes grading 0.32% Cu and 0.30 g/t Au (Wojdak 2005). In 2005, the Red Chris project was awarded a BC Environmental Assessment Certificate, but this certificate was revoked in 2006. In 2008, the Federal Court of Appeal overruled the earlier trial court decision, thereby upholding the federal process and reinstating the federal environmental certificate.

Imperial Metals Corporation constructed a 17 km access road to enable transportation of equipment for deep drilling and year-round operation. Drilling continued into 2009 (Wojdak 2010).

Trek

Sphaler Creek Drainage
Location: Latitude 57°01'50"N, Longitude 131°19'30"W.
Minfile # 104G 029
Minerals: Cu, Pb, Zn, Au, Ag
Current Status: Prospect

The Trek Prospect, located on Sphaler Creek south of the Galore Creek property, is owned by Romios Gold Resources Inc. The company reported that 2009 drilling found 0.10% to 0.61 % Cu and from 0.39 to 0.51 g/t Au in 2009 (Wojdak and Febbo 2009).

Bronson Slope

Iskut River Drainage
Location: Latitude 56°40'00"N, Longitude 131°05'33"W
Minfile # 104B 077
Minerals: Au, Cu
Current Status: Proposed Mine

Bronson Slope (Figure 4) is the site of a proposed $98 million gold and copper mine near the former Snip and Johnny Mountain mines; Bronson Slope includes the Bonanza, Grizzly and

McFadden deposits. Bronson Slope will likely be an open pit gold and copper mine (McDowell Group 2004).

According to McDowell Group (2004), “Reserves are estimated at 76 million tons with an average grade of 0.015 ounces of gold, 0.16 percent copper, and 0.09 ounces silver per ton. Metallurgical testing indicates recoveries of 79 percent gold, 86 percent copper, and 70 percent silver. . . The Skyline project appears to be close to break-even but requires better ore or lower costs, or both, to proceed.”

On September 30, 2002, the Skyline Gold Corporation withdrew its application from the BC environmental approval process; however, exploration work resumed in 2006 (Wojdak 2007).

Stikine Drainage

A number of base metal, or hard rock, prospects have been identified in the Stikine River drainage and adjacent drainages. Two developed prospects, 104G 110 and 104G 027 occur south of the Schaft Creek proposed mine (Figure 5), along with numerous undeveloped prospects.

Two properties were identified in the region of the proposed Galore Creek Mine: Pass Lake (Trek Project, described above) and Paydirt along with a number of staked mineral claims. The Paydirt Project, on a tributary to the Porcupine River south of the Galore Creek project, is owned by Longreach Resources Ltd. and Consolidated Silver Standard Mines Ltd. Preliminary drilling identified approximately 200,000 tons ore grading to 0.12 oz/ton Au. Both Trek and Paydirt properties currently are undeveloped. The Galore Creek region also contains a number of mineral claims.

Several additional properties in the Stikine-Iskut River drainage were explored in 2000 through 2010 and remain undeveloped. The Newmont Lake property (Figure 6), 30 km southeast of Galore Creek, was explored by Romios Gold Resources Inching 2006. No economically viable mineral deposits were reported by the company.

Foremore

Location: Latitude 57º 03' 49" N, Longitude 130º 54' 00" W
Watershed: Tributary to More Creek (More Creek is a tributary to the Iskut River)
Current Status: Exploration
Minfile # 104G 148
Minerals: Au, Ag, Pb, Zn, Cu

Roca Mines Inc. explored the Foremore Property (Figure 6) in 2005 (Wojdak 2006). Several drill holes showed massive sulfide layers, each 0.3 to 1.2 meters thick. One sample assayed as 26.5 g/t gold, 85 g/t silver, 2.2% copper, 1.3% lead, 8.6% zinc; other samples contained lower metal grades. This site remains in exploration.

RDN Property

Location: Latitude 57º 00' 29" N, Longitude 130º 38' 48" W
Watershed: Tributary to More Creek (More Creek is a tributary to the Iskut River)
Current Status: Exploration
Minfile # 104G 148
Minerals: Au, Ag, Pb, Zn, Cu

Northgate Minerals Corp. acquired the RDN property in 2004; the property is located 40 km north of the now closed Eskay mine (Wojdak 2006, Figure 6). Drilling and exploration continued through 2006. The geology of the RDN property is believed to be similar to the Eskay Creek deposit.

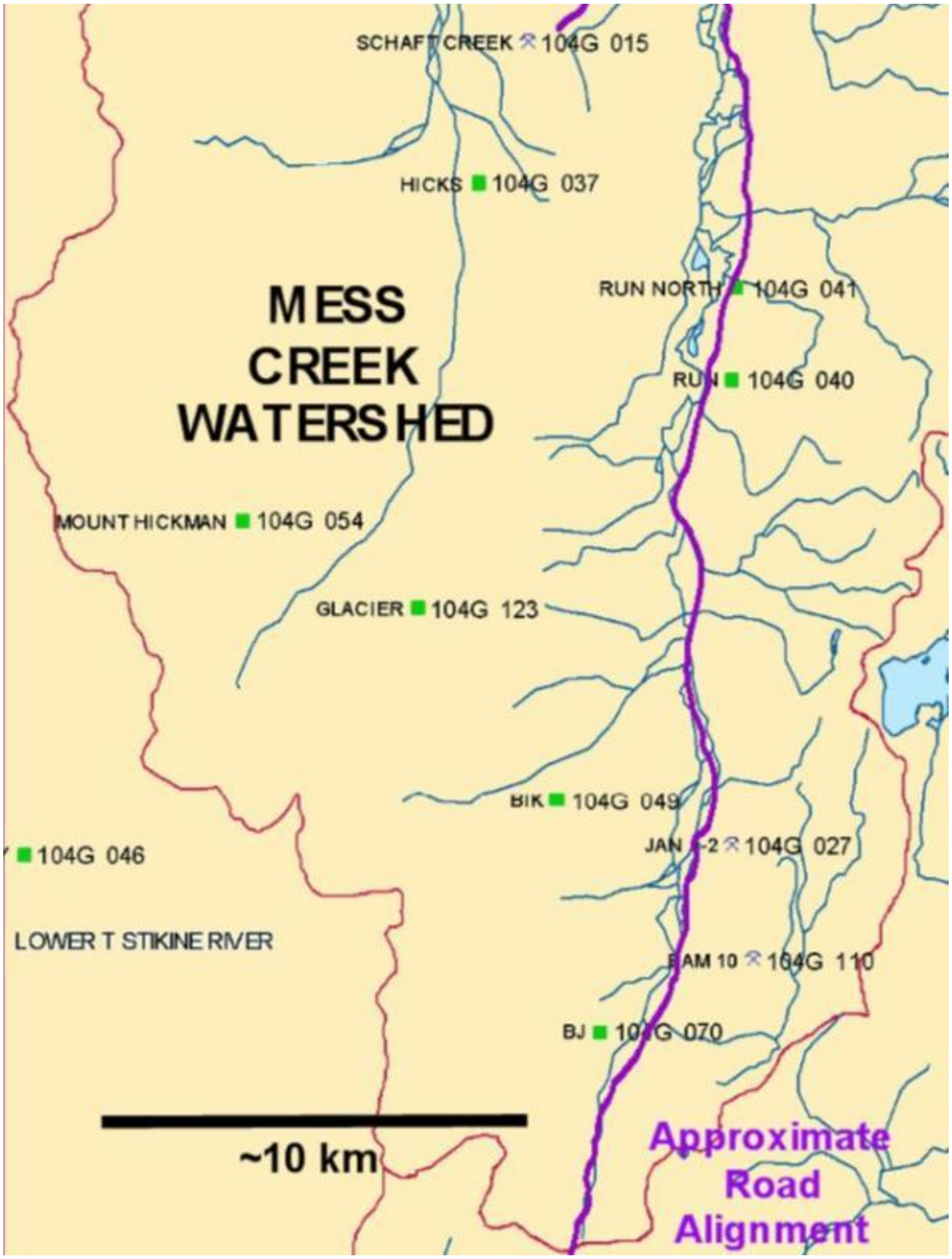

Figure 5.–Location of Schaft Creek proposed mine, showing other developed prospects (blue pickax) and mineral showings (green square). The purple line is the proposed road alignment for the Schaft Creek Project.

Source: British Columbia MapPlace, map taken from Morin and Hutt (2008).

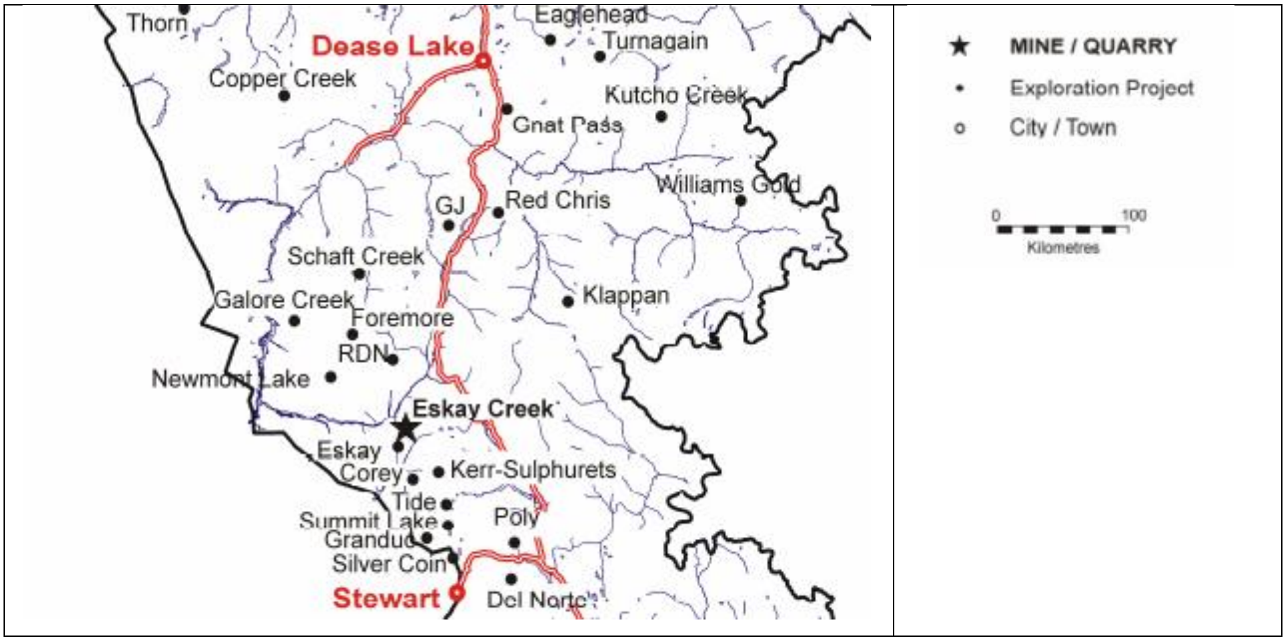

Figure 6.–Map showing locations of exploration projects in 2005.

Source: Map from Wojdak 2006.

Mount Klappan Coal

Location: Near headwaters of Stikine River, Latitude 57°14'37"N, Longitude 128°54'0"W
Current Status: Proposed Mine
Minfile # 104H 021
Minerals: Coal

Fortune Minerals' proposed Klappan open pit coal project is just on the edge of the Spatsizi Provincial Park (Figure 6), with the haul road to go from the headwaters of the Little and Big Klappan drainages of the Stikine through the headwaters of the Nass and Bell-Irving drainages.

The Mount Klappan Coal Project is approximately 100 km southeast of the village of Iskut and 160 km northeast of the town of Stewart. Fortune Minerals (2009) described the Mount Klappan coal deposit as "one of the world's largest undeveloped resources anthracite coal. The four at Mount Klappan—Lost Fox, Hobbit-Broatch, Sumitt, and Nass—contain measured resources of 107.9 million tonnes (Measured), 123 million tonnes (Indicated), and 2.572 billion tonnes (Inferred and Speculative)." The Mount Klappan Coal Project is considered to be in a "pre-application" phase (Fortune Minerals 2009). As of 2009, Fortune Minerals has completed a technical feasibility study on the mine and a preliminary economic assessment.

Kutcho Creek Prospect

Location: Latitude 58º12'19"N, Longitude 128º21'36"W
Watershed: Turnagain River Drainage
Current Status: Developed Prospect
Minfile # 104I 060
Minerals: Cu, Zn, Ag, Au

The Kutcho Creek property, located around Sumac Creek, 7 km east of Kutcho Creek (Figure 6), was first explored by Sumac Mines Ltd. in 1972 and 1973. The property is in the Turnagain

River Drainage, less than 8 km north of the Stikine River. The prospect contains three massive sulfide zones of copper, zinc, silver and gold. The property was explored and mapped between 1973 and 1984.

Late in 2003, Western Keltic Mines Inc acquired the Kutcho Creek property and in 2004, continued exploratory drilling. In 2009, the Kutcho Property was owned by Capstone Mining and its subsidiary, Kutcho Copper Corp. According to information released by Kutcho Copper, the Kutcho project will be developed as a small scale open pit mine, followed by underground extraction. Kutcho Copper estimated that annual production would be 33.9 million pounds of Cu, 41.7 million pounds of zinc, 2,858 ounces of gold and 454,000 ounces of silver in concentrates over the 12-year mine life.

Corey Site

Unuk River watershed
Minfile # 104B 011
Minerals: Cu, Pb, Zn, Ag

On the Corey property, 10 km south of Eskay Creek (Figure 6), Kenrich-Eskay Mining Corporation conducted a program of geological mapping and rock and silt geochemistry in search of new targets for a precious metal-enriched massive sulfide deposit. The claims cover the southern portion of the Eskay bimodal volcanic rift sequence. Smitty is a new mudstone-hosted bedded sulfide showing that was discovered in a 5 km long area of multi-element geochemical anomalies that extends south of the volcanogenic massive sulphide-style Cumberland showing. Four chip samples on the Smitty showing spaced one meter apart average 0.75% copper, 0.18% lead, 7.98% zinc and 204 g/t silver across 0.65 meters. Gold was not reported. The property remains undeveloped.

Kerr-Sulphurets Property

Location: Latitude 56º30'16"N, Longitude 130º15'46"W
Watershed: Unuk River
Current Status: Developed Prospect
Minfile # 104B 182
Minerals: Au, Cu, Mo, Ag

Exploration of the Kerr-Sulphurets-Mitchell (Figure 6) area began in the 1960s and was focused on gold. Evidence suggests that early prospectors were in this area as early as 1935 and that small-scale placer miners operated even earlier.

The Kerr-Sulphurets-Mitchell Project consists of three large low-grade copper porphyry deposits located fairly close to each other in the Sulphurets and Mitchell valleys. The deposits contain significant gold, copper and silver. The initial ore resource indicates at least a 20-year mine with a throughput of 120,000 million tonnes per day from the Mitchell zone. The waste to ore strip ratio appears to be in the range of 0.3:1 during the initial years of production from the Mitchell zone increasing to an overall average of 1.35:1 for all three zones (Kerr, Sulphurets and Mitchell).

Mining will be by open pit methods with a tunnel and conveyor from the north side of the Mitchell deposit. Waste rock will be separated into nonacid-generating (NAG) and potentially acid-generating (PAG) material and stored separately.

Access to the mine site will be from the Eskay Creek road and a new road will be built alongside Tom MacKay Lake towards Coulter Creek, across the Unuk River and continue up the Sulphurets Creek Valley towards Mitchell Creek. In 2008, the Kerr-Sulphurets-Mitchell project entered the BC Environmental Assessment process.

Forrest Kerr Proposed Hydroelectric Project

The Coast Mountain Hydro Corp. has proposed a run-of-river hydroelectric plant for the Iskut River near its confluence with Forrest Kerr Creek. The proposed plant was originally designed to generate 100 MW of electricity (Coast Mountain Hydro Corp 2002); the project has since been revised to produce 195 MW. As of April, 2010, the hydro project was still in a planning stage.

HISTORIC DATA FOR STIKINE RIVER DRAINAGE

This section of the report presents a summary of historic data on geology, hydrology, water quality, fish and wildlife resources for the Stikine River drainage.

Geology

Price (2002) presents a nontechnical overview of the geologic history of the Stikine area. The Stikine area was first formed about 4.5 billion years ago, when tectonic plates collided, forming mountain ranges. “Some 200 million years ago, the region currently known as northern British Columbia sloped off into the sea where, for the previous 1,500 million years, sediment had been deposited on the continental shelf that stretched from the Okanagan through Quesnel to Cassiar. Up to 2,000 km offshore, the volcanic island chains of Quesnellia and Stikinia sat on two terranes, exotic pieces of the earth's crust which still exist today but in much different form and location.”

Price describes the geological processes following the major plate collisions:

> When the pattern of plate movement changed and the continent began moving west, it inevitably collided with these island terranes some 181 million years ago, in a slow-motion process which was most dramatic, but which also took 30 million years.
>
> Between the islands and the mainland of the day, was the seafloor of the Slide Mountain Terrane, and between the island arcs was the limestone rich seafloor of the Cache Creek Terrane. All four are now known as the Intermontane Superterrane, which collided with the continental shelf.
>
> Rather than sliding below the shelf in a relatively peaceful process, portions of each terrane began to peel off, and the rocks were jammed and folded into what are now the Cassiar, Omenica and Columbia mountains. By 120 million years ago, the western edge of the Rockies was stacking up. At about the same time, the Wrangellia and Alexander terranes were meeting up with the Stikinia Terrane to create more mountains.
>
> In the Tertiary epoch, BC was the focus of large and small volcanoes, some of which were silica-rich, forming typical cones and domes, and others more iron-magnesium rich that formed broad flat flows such as are seen in the Cariboo. There were also many inter-volcanic sedimentary basins in which we now find well-reserved fossils, such as Princeton, Kamloops, and Driftwood Creek near Smithers.
>
> The age of glaciation, culminating about 10,000 to 20,000 years ago ground at the mountains, creating huge lakes such as Babine, and deposited enormous amounts of

> sediment at river mouths. (At one time, the headwaters of the Skeena River, including the Babine system, were dammed by huge chunks of ice, forcing its waters to flow out through the Nechako River into the Fraser. A large glacial lake formed in the plains around Vanderhoof.)

The Stikine Region is made of high mountains, deep canyons, massive ice fields and river valleys. Taylor (2003) presents an in-depth description of the mineralized zones of the Stikine Region. Prospectors have sought gold, silver, lead, zinc, copper and molybdenum since the 1800s.

The Additional Literature Reviewed section contains a list of published reports on the geological history of the Stikine Region.

Hydrology

Both the US Geological Survey and the Province of British Columbia have established stream gauging sites and collected stream flow data in the Stikine River drainage. Tables 1 and 2 present the periods of record for individual gauge sites.

Table 1.–Stream Gauges installed and operated by the Province of British Columbia.

Gauge site	Station No.	Latitude	Longitude	Gross Drainage Area km^2	Period of Record	Years
Iskut River below Johnson River	08CG001	56°44'20"N	131°40'25"W	9350	1959–2008	2000-2008
Iskut River at outlet of Kinaskan Lake	08CG003	57°31'50"N	130°10'45"W	1250	1964–1996	1986-1996
Iskut River above Snippaker Creek	08CG004	56°41'55"N	130°52'23"W	7230	1966–1995	1985-1995
Iskut River above Forrest Kerr Creek	08CG007	56°44'30"N	130°36'50"W	6290	1981–1984 Stage data only	1981-1984

Table 2.–Stream Gauges installed and operated by the US Geological Survey.

Gauge Site	Station No.	Latitude	Longitude	Gross Drainage Area km^2	Period of Record	Years
Stikine River Below Spatsizi River	08CA002	57°43'59"N	128°6'30"W	7690.00	1980-1995	1986-1995
Stikine River Above Grand Canyon	08CB001	58°2'38"N	129°56'45"W	18800.00	1957-1995	1986-1995
Stikine River At Telegraph Creek	08CE001	57°54'3"N	131°9'16"W	29000.00	1954-2008	1999-2008
Stikine River Above Butterfly Creek	08CF001	57°29'10"N	131°45'0"W	36000.00	1971-1995	1986-1995
Stikine River Above Choquette River Water level data only	08CF002	56°49'48"N	131°45'57"W		1983-1984	
Stikine River Near Wrangell	08CF003	56°42'7"N	132°8'28"W	51600.00	1984-2008	2000-2008

Stikine River

The US Geological Survey has gauged the Stikine River near Wrangell since 1976 with an instantaneous flow gauge. The site of the Stikine River gauge is described as follows:

- Latitude 56°42'29", Longitude 132°07'49" NAD27
- Wrangell-Petersburg Division, Alaska, Hydrologic Unit 19010201
- Drainage area: 51,593 km^2
- Datum of gage: 7.6 m above sea level NGVD29.

US Geological Survey also has collected data at this site on water quality (discussed under water quality section).

Water Quality

- Environment Canada, water quality for Stikine
- Environment Canada, water quality for Iskut River below Johnson River
- US Geological Survey, water quality for Stikine River near Wrangell

Stikine River

Environment Canada assessed the water quality of the Stikine River upstream of the confluence with the Iskut River between 1981 and 1994 (Jang and Webber 1996, Table 3). During the same time period, flow data was collected at a Water Survey of Canada flow gauge located 58 km southwest of Telegraph Creek and about 70 km upstream from the water quality station.

Environment Canada (2005) reported that there were “no environmentally significant trends in water quality” and that elevated metals likely were in particulate form. Environment Canada (2005) reported: “Total aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc, organic carbon, apparent color, non-filterable residue and turbidity values did not meet various water quality criteria at times due to high levels of suspended sediment carried by high river flow. Copper levels exceeded the aquatic life criteria most of the time, suggesting a naturally high copper mineralization in the watershed.”

The US Geological Survey sampled water quality in the Stikine River near Wrangell, Alaska from 1975 through 1993 (Alexander et al. 2001). Stream flow also was sampled at the same location from 1976 through 1993.

According to data from the US Geological Survey, water quality in the Stikine River near Wrangell was generally good (Table 4), although 13% of the samples exceeded the chronic criterion for Cu, 20% exceeded the chronic criterion for Cd and 38% exceeded the chronic criterion for Pb (US EPA 2009; Canadian Water Quality Guidelines for the Protection of Aquatic Life 2007; Nagpal et al. 2006). Al was sampled as total Al and the higher values are likely a result of suspended sediments. Only one sample was analyzed for dissolved Al; the concentration was lower than both the acute and chronic criteria. There was no apparent correlation with exceedences in water quality and stream flow (Alexander et al. 2001).

Table 3.–Summary of water quality data for the Stikine River above the Choquette River.

	Form	median ug/L	maximum ug/L	minimum ug/L	count	Canadian Guideline, ug/L	# > CWQG
Ag	E	0.1	0.1	0.1	1	0.1	0
Al	T	1930	10800	77	27	100	26
As	E	0.7	3.7	0.1	29		
As	T	1	4.8	0.2	50	5	0
Ba	T	62.9	179	50.7	27		
Be	T	0.08	0.34	<0.05	27		
Cd	E	0.5	2	0.5	28		
Cd	T	0.3	2.3	<0.1	32	0.017	32
Cr	T	4.45	24.9	0.2	26	8.9 for Cr^{iii}, 1 for Cr^{vi}	6 for Cr^{iii}, 20 for Cr^{vi}
Cu	E	10	60	1	28		
Cu	T	1.5	8.3	0.1	27		
Cu	T	7.15	48.4	0.9	32	3	24
Fe	E	2900	14900	100	28		
Fe	T	3220	19400	139	48	300	47
Li	T	2.9	12.8	1.9	27		
Mg	D	3.1	5.79	2.22	13		
Mn	E	115	450	10	28		
Mn	T	80.55	388	18.5	48		
Mo	T	1.4	1.8	0.6	27	73	0
Ni	T	4.5	26.4	<0.2	27	65	0
Pb	E	2.5	30	1	28		
Pb	T	1.6	7.9	<0.2	32	2	8
Se	E	0.2	0.4	0.1	33		
Se	T	0.3	0.7	0.1	46	1	0
Sr	T	132	183	85.9	27		
V	T	6.3	36.5	0.6	27		
Zn	E	11.5	60	1	28		
Zn	T	9.8	77.2	0.9	32	30	3

Source: Data from Environment Canada (2005), Stikine River above Choquette River, Federal Monitoring Station.
Note: T = total metals, E = extractable metals and D = dissolved metals.

Table 4.–Summary of water quality data for the Stikine River near Wrangell, AK.

	Form	Median µg/L	Maximum µg/L	Minimum µg/L	count	Freshwater CMC µg/L	Freshwater CCC µg/L	# > CMC	#> CCC
Al	T	45	560	10	42	750	87	0	10
As	T	1	2	1	66				
As	D	1	8	1	31	850		0	
Ba	T	39.5	300	8	66				
Ba	D	100	500	100	22				
Be	T	0.5	1	0.5	34	130	5.3	0	0
Cd	D	1	44	1	61	3.9	1.1	7	12
Cd	T	13	20	1	20				
Cr	D	1	20	1	48	570	74	0	0
Cr	T	20	60	4	25				
Co	D	3	7	1	60				
Co	T	7	100	1	27				
Cu	D	4	75	1	68	13	9	3	9
Cu	T	20	130	2	33				
Fe	D	63	860	10	75		1000	0	
Fe	T	3800	45000	150	33				
Pb	D	3	43	1	60	65	2.5	0	23
Pb	Total	41.5	200	1	28				
Li	D	4	13	4	42				
Mn	D	12	80	2	75				
Mn	Total	120	1200	40	33				
Hg	D	0.2	20	0.1	60	1.4	0.77	9	13
Hg	Total	0.5	35	0.1	33				
Mo	D	10	10	10	42				
Mo	Total	2	2	2	1				
Ni	D	1	13	1	48	470	52	0	0
Ni	T	14	68	2	13				
Se	D	1	1	1	66				
Se	T	1	4	1	26	13	5	0	0
Ag	D	1	1	1	45	1.7	0.12	0	0
Ag	T	1	20	1	5				
Sr	D	88.5	170	66	42				
V	D	6	6	6	42				
Zn	D	17.5	81	2	64	120	110	0	0
Zn	T	40	170	8	33				

Source: USGS (Alexander et al. 2001).
Note: T = total metals, D = dissolved metals.

Iskut River

Environment Canada sampled water quality in the Iskut River below the Johnson River between 1980 and 2002 (BWP Consulting 2003, Table 5). Stream flow was sampled at a Water Survey of Canada flow gauge at the same location. BWP Consulting (who conducted the data analysis) concluded that "There were no obvious environmentally significant trends in water quality that could be identified through visual examination of the data.". . . maximum nonfilterable residue and turbidity values occurred during peak flows, and were probably a natural occurrence. BWP further reported: "Total aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese and zinc, organic carbon, apparent color, non-filterable residue and turbidity values did not meet various water quality guidelines due to the high levels of suspended sediment in the water during freshet." The report states that elevated metals occurred with elevated suspended sediments, indicating that metals were in particulate form. The authors do not speculate about the bioavailability of the elevated metals.

Table 5.–Summary of water quality data for the Iskut River below Johnson River.

Analyte	Form	median µg/L	maximum µg/L	minimum µg/L	count	CWQG µg/L	#>CWQG
Ag	E	0.021	0.289	0.001	58		
Ag	T	0.1	1.2	0.001	61		
Al	E	1120	19500	68.4	21		
Al	T	1610	23500	12	97	5	97
As	D	0.5	0.5	0.5	1		
As	E	1	12	0.1	52		
As	T	0.71	12.6	0.1	120	5	12
B	E	5.5	18.7	1.3	56		
B	T	6.1	10.7	1.6	21		
Ba	E	61.8	361	2.51	56		
Ba	T	62.1	372	2.6	97		
Be	E	0.043	0.923	0.001	56		
Be	T	0.07	0.978	0.003	97		
Bi	E	0.008	0.087	0.001	21		
Bi	T	0.015	0.09	0.001	21		
Cd	E	0.174	4	0.005	85		
Cd	T	0.2	4.8	0.019	103	0.017	101
Co	E	0.803	18	0.027	56		
Co	T	1.2	18.7	0.1	97		
Cr	E	2.1	36.9	0.152	54		
Cr	T	3.05	43.9	0.2	94	8.9 for Cr^{iii}, 1 for Cr^{iv}	26 for for Cr^{iii}, 64 for Cr^{iv}
Cu	E	8.3	70	0.47	85		
Cu	T	5.6	67.4	0.3	103	3	66
Fe	E	4300	32500	69.9	50		
Fe	T	2780	43800	19.2	121	300	97
Ga	E	0.321	6.95	0.018	56		
La	E	0.5355	13.7	0.016	56		
Li	E	2.6	19.8	0.134	56		
Li	T	3.6	21.7	0.2	97		
Mn	E	80	1030	1.69	85		
Mn	T	73.5	1060	6.3	121		
Mo	T	1.3	2.7	0.1	96	73	0
Ni	E	2.245	51.9	0.02	56		
Ni	T	3.6	53.3	0.2	97	65	0
Pb	E	1.54	11.5	0.01	85		
Pb	T	1.1	18.2	0.044	103	2	45
Rb	E	1.815	11.1	0.279	56		
Sb	E	0.126	0.52	0.075	21		

-continued-

Table 5. Page 2 of 2.

Analyte	Form	median µg/L	maximum µg/L	minimum µg/L	count	CWQG µg/L	#>CWQG
Sb	T	0.131	0.519	0.078	21		
Sb	E	0.022	0.064	0.005	15		
Se	E	0.4	0.86	0.1	56		
Se	T	0.5	1.2	0.1	116	1	2
Sr	E	145.5	218	40.7	56		
Sr	T	144.5	209	58.6	80		
Tl	E	0.012	0.132	0.001	56		
Tl	T	0.014	0.14	0.001	21		
U	E	0.31	0.838	0.03	56		
U	T	0.335	0.942	0.108	21		
V	E	3.07	61.9	0.25	34		
V	T	4.86	70.9	0.1	97		
Zn	E	14.3	130	0.36	84		
Zn	T	10.65	148	0.2	102	30	27

Note: E = extractable metal, T = total metal, D = dissolved metal.
Source: Federal Monitoring Station, Environment Canada.

Distribution of Fish

Several documents summarized the distribution of fish species within the Stikine and Iskut Drainages, including the Forrest Kerr Hydroelectric Project Application for Project Approval (Coast Mountain Hydro Corp. 2002) and the Galore Creek Aquatic Baseline Studies Reports by Rescan (2006) for NovaGold.

Twenty one different species of fish have been reported to occur in the Stikine River and its tributaries (Table 6, adapted from Rescan 2006 and Coast Mountain Hydro Corp. 2002). In addition to the species listed on Table 6, Coast Mountain Hydro Corp. identified sculpin as coast range sculpin (*Cottus aleuticus*), slimy sculpin (*C. cognatus*) and prickly sculpin (*C. asper*). The anadromous species are Chinook, chum, coho, pink and sockeye salmon, Dolly Varden char, cutthroat and steelhead trout and Pacific lamprey.

Stikine Drainage

Stikine River

The Stikine River is reported to support all of the fish species listed on Table 6, except bull trout and dace. The upper portion of the Stikine River is inaccessible to migrating anadromous fish because of natural barriers and regions of high velocity. The Stikine River is one of the largest producers of Chinook salmon in Northern British Columbia / Yukon Territory / Southeast Alaska (Pahlke et al. 2010). Most of the spawning occurs in tributaries to the Stikine River, including the Tahltan and Little Tahltan rivers and Andrew Creek, at the lower portion of the Stikine River in the US.

The Department of Fisheries and Oceans, Canada operates a counting weir on the lower Stikine River (Canada Department of Fisheries and Oceans 2010). In September 2010, the Department of Fisheries and Oceans reported 22,849 adult Sockeye salmon had passed the fish weir. This number compares to 30,621 adult sockeye reported in 2009. The Department of Fisheries and Oceans also reported a count of 557,562 sockeye smolt in Tahltan Lake; the average smolt count for this lake from 2000 through 2009 was 1,056,394 smolt per year.

Galore Creek

Galore Creek flows through a narrow, steep-walled canyon with high flow velocities and cold, turbid water. There is a natural barrier to fish migration approximately 1.8 km upstream of the confluence of Galore Creek and the Scud River.

Table 6.–Fish species reported in the Stikine and Iskut Drainages. No fish were reported from Galore or Sphaler Creeks.

Species	Stikine River	Iskut River		Porcupine River	Scud River	More Creek	Sphaler Creek	Galore Creek	Scott Simpson Creek
		Lower	Upper						
Chum salmon *Oncorhynchus keta*	x	x		x					
Chinook salmon *O. tshawytscha*	x	x		x	x				
Coho salmon *O. kisutch*	x	x		x	x				
Pink salmon *O. gorbuscha*	x	x							
Sockeye salmon *O. nerka*	x	x		x	x				
Dolly Varden *Salvelinus malma*	x	x	x	x	x	x	x Lower reaches		x Lower reaches
Bull trout *Salvelinus confluentus*			x						
Rainbow trout *O. mykiss*	x	x	x		x				
Steelhead trout *O. mykiss*	x	x							
Cutthroat trout *O. clarki*	x	x							
Mountain whitefish *Prosopium williamsoni*	x	x	x	x	x				
Arctic grayling *Thymallus arcticus*	x	x							
Burbot *Lota lota*	x	x							
Green sturgeon *Acipenser medirostris*	x								
Lake chub *Couesis plumbeus*	x	x							
Lamprey *Lampetra sp.*	x	x							
Longnose sucker *Catostomus catostomus*	x	x							
Rainbow smelt *Osmerus dente*	*x*								
Sculpin *Cottus sp.*	x	x	x						
Threespine stickleback *Gasterosteus aculeatus*	x	x							
Dace *Rhinichthys sp.*		x							

Source: Data from Rescan (2006) and Coast Mountain Hydro Crop (2002).

Scud River

The Scud River is a major spawning stream for coho and sockeye salmon, and likely for Chinook, chum, and steelhead (Rescan 2006). The Scud River also supports populations of bull trout, mountain whitefish and Dolly Varden. Sockeye salmon have been observed spawning in the Scud River near the outlet of Northwest Creek. Downstream of the confluence of Galore Creek and the Scud River, Dolly Varden and coho salmon juveniles inhabit side channels, backwaters and shallow riffles (Rescan 2006).

Contact Creek

Contact Creek, a tributary to the Scud River, flows toward the northeast. Rescan (2006) reported high invertebrate and periphyton standing crop in Contact Creek; Dolly Varden are present in the first 100 m. The high quality habitat suggests that other fish species would inhabit Contact Creek at different times of the year. (The area was not sampled with sufficient frequency to determine the presence of other fish species.)

A waterfall prevents fish migration into the upper reaches of the stream. Contact Creek flows into the Scud River in an area where spawning salmon are common.

Porcupine River Drainage

Scotsimpson Creek

Scotsimpson Creek, a tributary to the Porcupine River, has cold, turbid water and moderate to high flow velocities. Dolly Varden and coho salmon inhabit the lower 3 km of the creek, up to a natural barrier to fish.

Porcupine River

The Porcupine River is an important spawning river for coho and sockeye salmon and supports populations of Dolly Varden char and mountain whitefish.

Sphaler Creek

There were no reports of fish found in Sphaler Creek, a tributary of the Porcupine River.

Iskut River Drainage

Iskut River

The lower portions of the Iskut River, below the Iskut Canyon near Forrest Kerr Creek, supports a diverse fish population that includes chum, Chinook, coho, pink and sockeye salmon; Dolly Varden char; Rainbow, steelhead, bull, and cutthroat trout; mountain whitefish; arctic grayling; burbot; lake chub; lamprey; longnose sucker; three-spine stickleback; dace and sculpin species.

The upper portion of the Iskut River, upstream of the canyon, has a more limited fish population. Dolly Varden char, bull trout, rainbow trout, mountain whitefish and sculpin were reported from this region of the Iskut River.

The Project Approval Certificate Application for the Forrest Kerr Hydroelectric Project presented a concise summary of temporal ecological events in the Iskut River (Table 7). Their report gives the approximate times for fish spawning, rearing and out-migration as well as peak times for benthos productivity.

More Creek

More Creek is a tributary to the Iskut River; the headwaters are in the region of the West More Creek proposed tailings disposal. Dolly Varden were the dominant fish in More Creek (Rescan 2006).

Table 7.–A summary of approximate timing of ecological events in The Iskut River.

Month	Stream Flow	Water Temp. °C	Benthos	Fish
January	Low	0-1	Low production and biomass	incubating eggs in tributaries, not likely in canyon (see Section 3.1.3.3); overwintering juveniles & adults in main stem pools & cover areas; few fish likely in canyon, although some may be present in winter only.
February	Low	0-1	Low	as for January
March	Low	0-1	Low	as for January-February
April	Low	+ 0-4	Low; larvae begin growth	eggs hatch in gravels; alevins develop; adult spring spawners (RB) migrating upstream; some juveniles (smolts of anadromous fish) begin moving downstream
May	Rising – mid	1-6	Biomass increasing;	continued egg hatching; spring spawning; alevin-fry rearing; adults move to summer feeding areas; main downstream smolt migration in lower river
June	High	2-6	Biomass increasing	juvenile rearing; adult feeding/ holding; initial upstream movement of anadromous fish
July	High	2-8	High	rearing/ feeding; some anadromous fish moving up Iskut River well below project area
August	High	2-10	High	anadromous fish (SO, CH, CO, DV) moving up lower Iskut; BT and MW upstream of project also ripening for fall spawning
September	High	2-10	High	SO, CH, CO, DV in Iskut and tributaries downstream of project; little if any main stem spawning; juveniles feeding; BT and MW moving to spawning areas - not likely in canyon area
October	High but dropping	1-6	Moderate	anadromous and resident fall spawning; juveniles & resident fish move to overwintering areas
November	Med-Low, dropping	0-2	Low	as in October; anadromous salmon adults die; DV, BT and MW spawners live on; all sizes overwintering; eggs incubating
December	Low	0-1	Low	overwintering (a few possible in mid-canyon); eggs incubating (not likely in canyon)

Source: Adapted from Forrest Kerr Hydroelectric Project, Project Approval Certificate Application, Vol. I (Coast Mountain Hydro corp. 2002).

Note: RB=rainbow, SO=sockeye, CH=chum, CO=coho, DV=Dolly Varden, BT=brook trout, MW=mountain whitefish

Fish Life Histories

Coho Salmon

Coho salmon frequent smaller clear water tributaries. Important spawning areas include the wetland complexes on the north bank of the Iskut River near the mouth and in Johnson Creek (Rescan 2006). Rescan also has documented coho spawning in side channels and tributaries of the Porcupine and Scud Rivers.

Sockeye Salmon

Sockeye salmon are abundant in the Stikine River watershed; they spawn in main stem, side channels, and tributaries of the Stikine, Iskut, and Porcupine Rivers and in tributaries farther upstream. Rescan (2006) reported that important spawning sites were in tributaries and side channels on the north side of the Iskut River between the Hoodoo and Twin Rivers, near the outlets of Bronson Creek and the Verrette River, at the outlet of Andismith Creek near the Stikine River and in tributaries of the Scud River.

Chinook Salmon, Steelhead trout

Chinook salmon have been captured in large numbers in the Stikine and Iskut systems, and appear to have important spawning grounds in these systems. Steelhead trout spawn in similar regions of the two rivers.

Chinook salmon enter the Stikine River estuary in April and May, migrate upstream in June and July and spawn in late summer/early fall. The eggs incubate over the winter and hatch in spring. Juveniles remain in fresh water for rearing for 3 months or 1 year, depending on the stocks before migrating to sea. In the Iskut River, Chinook salmon are found only downstream of the canyon.

Alaska Department of Fish and Game (ADF&G) fish surveys from 1997 through 2006 estimated an annual average of 7,315 Chinook passing the weir and an average spawning escapement of 7,302 Chinook. Aerial counts over the same time period yielded an estimated 2,555 Chinook salmon in the Stikine River system (Pahlke 2009).

Steelhead trout occur in the Iskut River below the canyon; the eggs incubate and hatch in spring and juveniles remain in fresh water for 1 to 3 years.

Pink and Chum Salmon

Pink and chum salmon spawn in the Iskut River downstream of the canyon during fall months. Spawning is most common in side channels. The eggs hatch in spring and the fry migrate downstream immediately after emergence, usually in April and May. Chum salmon are more common than pink salmon.

Wildlife

Although the emphasis of this report is on mining in the Stikine River Drainage and possible effects to aquatic resources, a short summary of wildlife species is included below.

Swarth (1922) studied the birds and mammals of the Stikine River region. Swarth provides descriptions of the land forms, vegetation and wildlife species present from Telegraph Creek to the mouth of the Stikine River, near Wrangell. The region upstream of Telegraph Creek was considered "impenetrable." An interesting aspect of Swarth's report, that is likely applicable today, is his description of recolonization after the last glaciations and the division of two distinct habitats: coastal and interior.

Mountain Goats

Since 1985, 16% of the mountain goat harvest from Game Management Unit 1B was from the Stikine River Area (Healy 2002).

Moose

Moose inhabiting the Alaska portion of the Stikine drainage represent the westernmost tip of a mainland population emanating from Canada. Since 1983, most winters have been mild and the moose population, based on harvest records and subjective impressions, appeared to increase until 1989. Moose populations appeared to decline after 1989 because of poor calf survival. (Brown 2004). Brown reported that the Stikine moose population appeared to be at "moderate densities" and stable by 2002.

Winter moose surveys conducted in 2005 by Rescan and ADF&G found 397 moose within the coastal ecosystem and 80 moose in the interior ecosystem (Rescan 2006). An additional 135 moose were observed on the USA side of the Stikine River valley.

Moose are dispersed throughout the river valleys of the proposed Galore Creek Mine; winter surveys found moose distributed in the Stikine River valley and the Iskut River valley from the confluence with the Stikine River upstream to Bob Quinn Lake. Summer distributions included the Porcupine River, Sphaler Creek and More Creek and the upper regions (upstream of Bob Quinn Lake) of the Iskut River (Rescan 2006).

PROPOSED GALORE CREEK PROJECT

Two mining projects are in planning stages for the Stikine River watershed: Galore Creek and Shaft Creek. This section of the document discusses the proposed Galore Creek project and reviews the environmental effects monitoring programs for the Galore and Shaft Creek projects.

The Galore Creek project, as proposed in the Environmental Assessment document of 2006 (Rescan 2006) encompasses the Galore, Scud, Scotsimpson, Sphaler, Porcupine, More and Iskut drainages, all of which form part of the Stikine Watershed.

PROJECT DESCRIPTION

This section presents a brief description of the Galore project design, as it was described in the Application for Environmental Assessment Certificate (Rescan 2006). Although substantive changes in the design of the Galore Mine project may be made before project development, the project elements, as described below, help identify potential risks to the water quality of the Stikine River.

Project Location

The Galore Creek Project is located between the Stikine and Iskut rivers and Highway 37 (The Cassiar Highway) in northwestern British Columbia. The ore body is located in the Galore Creek Valley, a steep and narrow drainage that is surrounded on three sides by high ice-covered mountains. Galore Creek flows northwards to the Scud River, a tributary of the Stikine River which flows into the Pacific Ocean near Wrangell, Alaska. The proposed Galore Creek Mine covers an area of 29,850 ha.

The Galore prospect was first identified in 1955 and explored by large mining companies in the 1960s, 1970s and 1990s. In 2003, Nova Gold acquired 50% of interest in the mine; Teck Resource is a co-owner. Since acquiring the property, the Galore Creek Mining Company (GCMC) has tripled the estimated mineral resources. In 2007, Nova Gold began construction of the support infrastructure, including six camps and access road, bridges and tunnel. Construction was suspended in November 2007 because of increasing capital costs. The companies (operating as GCMC) began studies to identify alternatives to reduce construction costs.

During 2008, GCMC worked with the Tahltan Nation and the provincial government to develop and implement a program to maintain the road, bridges and related infrastructure. Road work during 2008 connected portions of the access road to km 40 to allow surplus equipment to be driven out. According to a news release from NovaGold (2010), the proposed configuration of the Galore Creek Mine is being revised to optimize construction and operation.

Proposed changes to the project include:

- Relocation of the tailings facility allowing for construction of a conventional tailings dam.
- Relocation of the processing facilities allowing for future expansion.
- Realignment of the tunnel and access road.
- Potential increase of daily throughput to 90,000 metric tons per day.
- Eliminate the need for helicopter support.

Metallurgical Description of Ore

Copper in the Galore Creek ores occurs predominantly as chalcopyrite and chalcopyrite-bornite in a mixed silicate host. Pyrite occurrence is variable, with pyrite-copper sulfide mass ratio averaging 3:1. Gold particles are fine at nominally 10 microns. Approximately 69% of the gold occurs with chalcopyrite, while the majority of the remainder occurs as inclusions in pyrite.

POSSIBLE SOURCES OF CONTAMINATION TO STIKINE RIVER DRAINAGE

GCMC proposes to develop the Galore Creek copper-gold-silver resources by open pit mining. The mine will consist of one main pit (the Central Pit) in the Galore Creek valley and several satellite pits (Southwest, Junction, and West Fork Pits). Copper and gold will be produced as a bulk concentrate after crushing, grinding and flotation in an onsite mill. The concentrate will be moved to an offsite smelter, first by a slurry pipeline to Highway 37 where it will be dewatered, then transported by truck to Stewart. The open pits, processing plant and related support facilities such as shops and employee accommodation will be located in the Galore Creek valley. The dewatering facility will be located near Highway 37 and the Iskut River. Diesel fuel will be transported from the filter plant to the mine site with a small diameter pipeline located next to the slurry pipeline.

The description of the proposed Galore Creek Mine project, as described in the Environmental Assessment, suggests several possible sources of metals input into the Stikine River Drainage (Table 8).

Table 8.–Possible sources of contaminants to waterways in the proposed project area.

Watershed	Watershed Area (km2)	River is tributary of	Possible sources of metals input from project
Galore Creek	145	Scud River	Proposed mine site, including waste rock and tailings facilities Tailings water release Drainage from waste rock Drainage from ore stockpile
More Creek	876	Iskut River	Mine site access corridor through More Creek watershed
Sphaler River	327	Porcupine River	Mine site access corridor through Sphaler Creek
Scotsimpson Creek	49	Porcupine River	Mine site access corridor through Scotsimpson Creek
Scud River	1,130	Stikine River	Receives flows from Galore Creek
Iskut River	9,400	Stikine River	Filter plant discharge into Iskut River Concentrate loading facility
Porcupine River	740	Stikine River	Aerodrome facility on floodplain of Porcupine
Stikine River	51,600	-	Receiving water for drainages in the Galore Creek Mine site. River flows across border into Alaska

The project elements are described in greater detail below.

Transportation Route

The preferred access route starts at Highway 37 north of Bob Quinn Lake, follows More Creek upstream from its junction with the Iskut River to the pass at the head of More and Sphaler creeks, descends the Sphaler Creek Canyon to the Porcupine River, then ascend Scotsimpson Creek to a 3.8 km tunnel. The tunnel will provide access from Scotsimpson Creek Valley to the Galore Creek Valley. With relatively minor variations, the access road, concentrate slurry pipeline and electric power transmission line will follow the same alignment.

Tailings Dam

According to the Environmental Assessment (Rescan 2006), the main tailings dam will be in a steep canyon with densely jointed volcanic rock subject to shallow rock fall. Water will be discharged from the tailings impoundment into Galore Creek. Dilution from Galore Creek will reduce the metals concentrations; no water treatment is planned for water released from the tailings impoundment.

Waste Rock

Rescan (2006) reported estimates for waste rock of more than a billion tonnes for the projected life of the project. Based on estimates of acid rock drainage potential, approximately half of the waste rock will be stored under water for perpetuity. The remaining rock that is not required for construction of dams, roads and other facilities will be disposed in localized dumps and perhaps in mined out pits. Estimates of acid rock drainage potential predict a lag time of 23 years before the flooded waste rock becomes acid-generating.

Rescan (2006) describes water management plans to limit the input of fresh water into the waste rock and tailings storage areas. Fresh water will be collected in diversion ditches and moved around the mine site and ground water input will be limited by dewatering wells. Excess water will be used in processing ore or pumped to the tailings or waste rock impoundments.

Water Storage in Impoundment

Water pumped to the tailings and waste rock impoundment that is not used for ore processing will be reclaimed and returned to the mill. Excess water will be released by controlled pumping into Galore Creek. Discharge to Galore Creek will be limited to the ice-free months. Descriptions of the water management plans do not include treatment of the stored water before it is discharged.

Marginal Ore Storage

Low grade mill feed mined during the early years of the mine life will be stockpiled for later processing. Drainage from the marginal ore storage will be pumped to the tailings or waste rock storage impoundments.

Ore Stockpile

The mill stockpile pad will be located adjacent to the intermediate stockpile immediately north of the crusher area. Metal leaching from the low-grade ore stockpile is likely. Any drainage that may emanate from the pile will flow into the tailings and waste rock impoundment.

Concentrate Dewatering, Water Treatment and Discharge

A concentrate dewatering facility will be constructed near Highway 37 and the Iskut River. The dewatering process includes the use of flocculants to settle solids. Surplus water will be treated with lime to raise the pH to 10.8 for metals removal to a projected concentration of 30 µg/L dissolved Cu. The pH will be adjusted to 8.5. Rescan (2006) stated that the projected Cu concentrations after neutralization and filtration will be 20 µg/L for dissolved Cu and 150 µg/L for particulate Cu.

Background Cu concentrations in the Iskut River range from 0.6 µg/L in February and 18 µg/L during freshets. The receiving water quality criterion is 2 µg/L; this requires a dilution of approximately 120:1 during the critical low flow period. GCMC plans to use a diffuser to facilitate mixing.

No information was given on the predicted concentrations of other metals contained in the ore body that may be released to the aquatic environment. For example, water data suggests that sites in the Galore valley often had elevated metal concentrations; Gal-1A (an upstream site near the proposed mine pit) had some of the highest concentrations of total Ag, Cu, Pb, Ni, Sr, Ti, and Zn and dissolved Co, Cu, and Pb.

Loading and Hauling of Concentrate

Concentrate will be hauled by trucks to Highway 37 and along Highways 37 and 37A to the Port at Stewart. Final design of the load out facility has not been completed. Two options were considered in the environmental assessment: the use of a front end loader to transfer concentrate from the covered stockpile area to trucks, and a concentrate silo and flow through loading system.

No information was provided for wheel washing or covering trucks to prevent spills. Use of a front-end loader to load concentrate onto trucks has been shown to cause considerable metals pollution at other mine sites. These mines have since changed practices to load from an enclosed system and to clean all concentrate from trucks before leaving the loading facility with a wheel-wash facility (e.g., Greens Creek mining co.). Where a wheel-wash facility could not be used (e.g., Red Dog Mine), trucks remained outside of the concentrate storage facility and were loaded by an enclosed conveyer.

ENVIRONMENTAL EFFECTS MONITORING

Baseline ecological studies conducted by Rescan included surveys of physical components, including air quality, climate, noise, water quality and quantity (both groundwater and surface water), and sediment quality; aquatic resources, including periphyton, benthic invertebrates, fish and fish habitat and wetlands; terrestrial ecosystems, including vegetation and soils, wildlife, with a focus on mountain goats and grizzly bears, and including small mammals, bats, herpetiles, harlequin ducks, waterfowl and moose; archaeology; navigable waters; socio-economic effects; and an analysis of cumulative effects. Baseline studies were initiated in early 2004. Following is a discussion of the baseline ecological studies and possible effects to select species from the proposed project; the emphasis of this review is on water quality sampling.

Surface Hydrology

Twenty stream sites were gauged for stream flow in 2004 and 2005. Most of the sites were selected to correspond to proposed stream crossings or mine development (Rescan 2006) Data were also used to determine if water quality samples were collected at representative stream flows.

Water Quality

Water samples were collected from sites in 12 different drainages (Table 9). Sample sites were selected to include areas potentially affected by the proposed project, including stream crossings, areas proximal and downstream of potential impact from the proposed mine site, as well as reference sites. Water samples were collected monthly from May through December, 2004, at 13 sites, including sites within the Galore Watershed and downstream sites in the Scud and Stikine Rivers. Water samples were collected quarterly (May, August, and November) at the remaining sites within the Project area. Three sites were sampled in Jack Wilson Creek in September and October. Contact Creek, Oksa Creek, a tributary to the upper Scud River and Ball Creek were considered reference sites.

One water sample was collected per site per sampling period. Duplicate samples were collected at 20% of these sites for quality assurance and quality control purposes. Water samples were analyzed for general physico-chemical variables, anions, nutrients, total cyanide, total organic carbon, and total and dissolved metals. The method reporting limits (MRLs) were below the water quality criteria for aquatic life for most of the analytes that are usually considered in studies of aquatic toxicity (Table 10). Occasionally, MRLs were reported that were higher than water quality criteria.

This report presents a summary of water quality samples collected at each site. Data in the summaries are taken from the raw data presented in Rescan (2006). Median values, rather than average are used to avoid misrepresenting values reported at the MRL. Sample duplicates were not counted as samples; therefore, the sample count varies from numbers reported by Rescan.

Table 9.–Sites sampled for water quality in baseline studies. Replicates were not counted.

River or Creek	Sample Site	Description	No. of Samples
Iskut River	Iskut-0		4
	Iskut-1	U/s of More Cr	9
	Iskut-2	D/s of More Cr.	17
	Iskut-3	Downstream of Eskay Creek	6
	Iskut-4	Downstream of closed Snip Mine	4
	Iskut-5	~30 km upstream of Stikine River	5
	Iskut-6	~15 km upstream of Stikine River	6
More Creek	More-1	West More Cr, d/s of Round Lake	12
	More-2	West More Cr	10
	More-5	D\s of More and West More confluence	13
Ball Creek	Ball Cr	Trib. To Iskut R. u/s of More Creek	6
Contact Creek	Contact Cr.	Trib. to Scud R.	10
Galore Cr.	Gal-1A	Near headwaters	15
	Gal-1B	Near headwaters	24
	Gal-2	Near proposed tailings	7
	Gal-3	Near mouth	24
Adit Cr		Trib. to Upper Scud	11
Porcupine River	Porc-1	d/s Sphaler Cr.	22
	Porc-2	Trib. to Stikine, u/s of mouth	22
Scud River	Scud-1	Trib. to Stikine R., u/s Galore Cr	16
	Scud-2	d/s Galore Cr	25
	Scud-3	d/s Contact Cr	7
	Scud-4	u/s Stikine R.	25
Sphaler Cr	Spahl-1	Trib. to Porcupine, near headwaters	13
	Sphal-2	Mid-river	7
	Sphal-3	u/s of Porcupine R.	7
	Sphal-4		9
Scotsimpson Cr		Trib. to Porcupine River, sampled 2005 only	9
Oksa Creek	Reference Site 1	Trib. to Stikine R., u/s Scud R.	6
Reference 2	Ref-2	Trib. to Scud R., u/s Galore Cr	24
Stikine River	Stik-1	d/s Oksa Creek	11
	Stik-2	d/s Scud River	15
	Stik-3	d/s Jack Wilson Creek	3
	Stik-4	d/s Porcupine River	6
	Stik-5	Near Great Glacier Provincial Park	5
	Stik-6	d/s Iskut River	10
	Stik-7	Near Kaden Island	5
Jack Wilson Cr	Jack-1	Near mouth (Sept-Oct only)	2
	Jack-2	North fork (Sept-Oct only)	2
	Jack-3	South fork (Sept-Oct only)	2

Note: u/s = upstream, d/s = downstream.

Table 10.–Method reporting limits for water quality samples from Galore Creek baseline studies compared with US EPA water quality criteria for freshwater aquatic life (US EPA 2009).

	Form	Units	MRL	USEPA CMC (maximum)	USEPA CCC (continuous)
Cyanide	free		5	22	5.2
N-ammonia		mg/L	0.005		0.0027
Aluminum	D	µg/L	1	750	87
Arsenic	T	µg/L	0.1	340	150
Cadmium	D	µg/L	0.05	2	0.25
Cr III	D	µg/L	0.5*	570 to 1700	74 to 210
Cr VI				16	11
Copper	D	µg/L	0.1	13 to 18	9 to 12
Iron	D	µg/L	30		1000
Lead	D	µg/L	0.05	65 to 83	2.5 to 3.2
Mercury	D	µg/L	0.05	1.4 to 2.4	0.012 to 0.77
Nickel	D	µg/L	0.5	470 to 1400	52 to 160
Selenium	D		1		5 as total
Silver	D	µg/L	0.01	3.2	
Zinc	D	µg/L	1	120	110 to 120

In some instances, the calculated mean, maximum and minimum values in this report vary from summary numbers given by Rescan. There may be several reasons for the discrepancies, including not all of the raw data were reported in the Rescan documents. Major discrepancies were noted in the descriptions of water quality from individual streams.

Representative water data require that samples be collected at a variety of stream discharges, including high and low flows. The Baseline Report on water quality sampling does not provide information on how representative the water samples are; however, plots of the hydrologic data with times water samples were collected show if samples were collected over a range of high and low flows. Graphs of flow and water quality sampling dates are given for each drainage that had sufficient data.

Iskut River and Tributaries

Iskut River

The Iskut River is a glacially fed drainage with highly variable flows. In 2005 (the year most water quality samples were collected), highest flows in the Iskut River at Johnson River occurred in August with 61,450 cfs (1740 m^3/s), low flows occurred in February with 2,225 cfs (63 m^3/s) and the average summer flows (May through August) were 35,225 cfs (998 m^3/s) (Environment Canada 2005). Project plans provided by Rescan (2006) state that the proposed filter plant will discharge treated concentrate filtrate water into the Iskut River near More Creek (Figure 7). The estimated annual average stream flow at the location of the filter plant is 2825 cfs (80 m^3/s).

Figure 7.–Water quality sampling sites for Iskut River and tributaries, Ball and More Creeks. Sites ISK 3 – 6 are farther downstream.

Source: Map from Rescan 2006.

Water quality data were collected at six sites in the Iskut River (Table 9). Iskut-1 is upstream of the proposed concentrate plant discharge and Iskut-2 is downstream (Figure 7). From a disturbance/water quality perspective, these two sites are probably the most important monitoring sites in the Iskut system.

Water sampling in the Iskut drainage in 2004 did not capture peak flow periods; samples collected in 2005 are more representative of the range of stream flows (Figure 8).

Table 11 provides a summary of the water quality data for the Iskut River, including median, maximum and minimum values and numbers of samples that exceeded US EPA aquatic criteria (both continuous and maximum, US EPA 2009). Because only a few samples (4 to 6 at most sites) were collected, it is not possible to provide a meaningful discussion of water quality results. In general, the concentrations of metals of concern appear low.

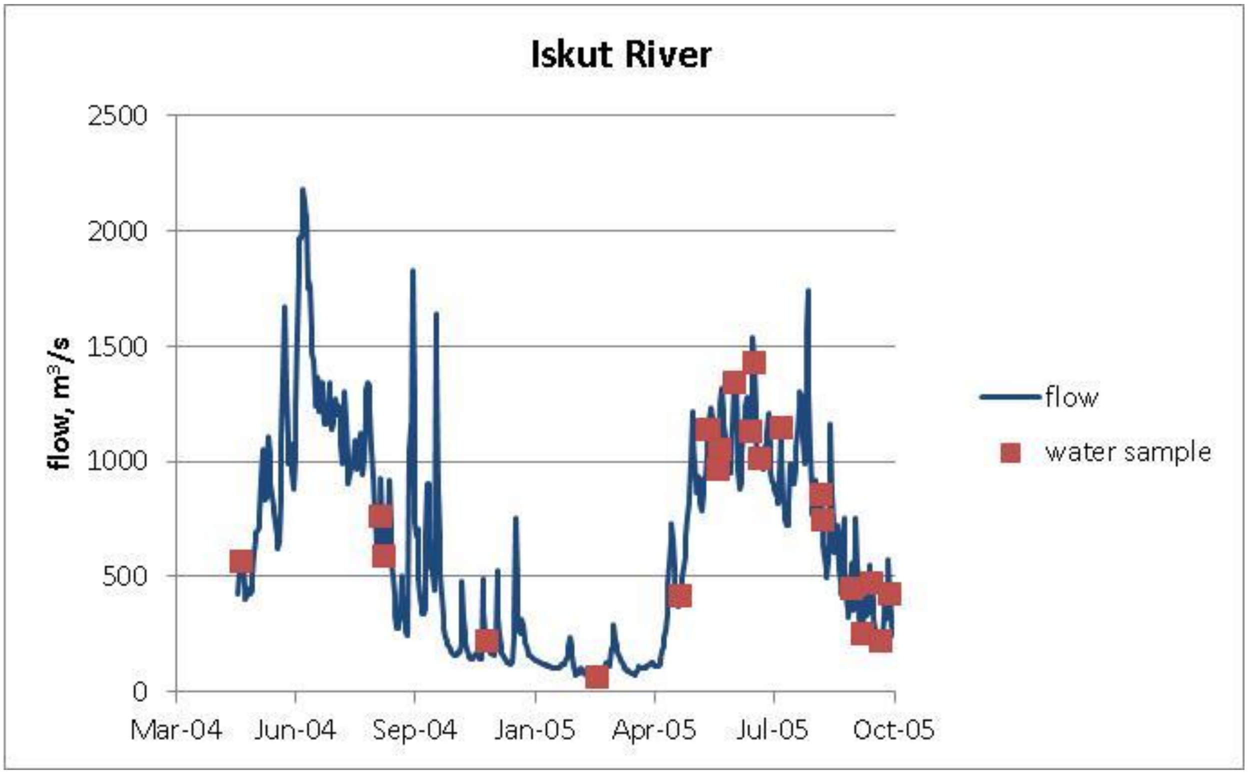

Figure 8.–Stream discharge at times when samples were collected for water quality, Iskut River. Discharge data taken from Canada's Hydat Data Base for the Iskut River at Johnson River. Sampling times for all six sites along the Iskut River are shown on the graph.

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Table 11.–Summary of water quality data for Iskut River sites and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L, sample replicates were not counted.

		D-Al	T-As	D-Cd	D-Cr	D-Cu	T-Fe	D-Pb	T-Hg	D-Ni	T-Se	D-Ag	D-Zn
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
US EPA CMC		750	340	2	570	13		65	1.4	470		3.2	120
US EPA CCC		87	150	0.25	74	9	1000	2.5	0.77	52	5		120
ISK-0	median	172.5	0.175	<0.02	0.565	0.65	101	<0.05	<0.01	1.01	1.55	<0.01	1.35
	max.	229	0.21	<0.02	0.78	0.93	154	<0.05	<0.01	1.19	2.07	<0.01	1.5
	min.	121	0.14	<0.02	<0.5	<0.5	82	<0.05	<0.01	0.74	1.05	<0.01	1
	count	4	4	4	4	4	4	4	4	4	4	4	4
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
ISK-1	median	90.8	0.22	0.021	<0.5	0.6	76	<0.05	<0.01	0.61	<1	<0.01	1.3
	max.	184	0.26	<0.05	0.95	2.02	202	0.084	<0.01	1.74	7.39	0.011	1.7
	min.	21.4	0.17	<0.02	<0.5	0.47	<30	<0.05	<0.01	<0.5	0.9	<0.01	1
	count	9	9	9	9	9	9	9	9	9	8	9	9
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	5	0	0	0	0	0	0	0	0	1		0
ISK-2	median	143	<0.2	<0.02	<0.5	0.6	105	<0.05	<0.01	<0.5	1.12	<0.01	1
	max.	306	0.28	<0.05	0.95	1.68	242	0.072	<0.01	2.68	3.22	<0.01	1.8
	min.	9.4	0.12	0.015	<0.5	<0.3	<30	<0.05	<0.01	<0.5	0.6	<0.01	1
	count	17	17	17	17	17	17	17	17	17	16	17	17
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	11	0	0	0	0	0	0	0	0	0		0

-continued-

Table 11. Page 2 of 2.

		D-Al	T-As	D-Cd	D-Cr	D-Cu	T-Fe	D-Pb	T-Hg	D-Ni	T-Se	D-Ag	D-Zn
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
US EPA CMC		750	340	2	570	13		65	1.4	470		3.2	120
US EPA CCC		87	150	0.25	74	9	1000	2.5	0.77	52	5		120
ISK3	median	107	0.25	<0.05	<0.5	0.675	112.5	<0.05	<0.01	<0.5	<1	<0.01	1
	max.	418	0.34	<0.05	0.66	1.3	328	0.104	<0.01	0.92	<1	<0.01	1.3
	min.	7.9	0.18	<0.02	<0.5	0.34	<30	<0.05	<0.01	<0.5	<0.5	<0.01	1
	count	6	6	6	6	6	6	6	6	6	6	6	6
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
ISK4	median	68.2	0.23	<0.05	<0.5	0.705	82	<0.05	<0.01	<0.5	<1	<0.01	1.05
	max.	132	0.29	<0.05	<0.5	1.47	157	<0.05	<0.01	0.92	<1	<0.01	1.1
	min.	9.8	0.21	<0.05	<0.5	0.31	<30	<0.05	<0.01	<0.5	<1	<0.01	1
	count	4	4	4	4	4	4	4	4	4	4	4	4
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	2	0	0	0	0	0	0	0	0	0		0
ISK5	median	124	0.31	<0.05	<0.5	0.81	68	<0.05	<0.01	<0.5	<1	<0.01	1
	max.	184	0.37	<0.05	0.74	1.61	119	<0.05	<0.01	0.92	1.08	<0.01	1.6
	min.	10.3	0.22	<0.02	<0.5	<0.4	<30	<0.05	<0.01	<0.5	<1	<0.01	1
	count	5	5	5	5	5	5	5	5	5	5	5	5
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	3	0	0	0	0	0	0	0	0	0		0
ISK6	median	105	<0.3	<0.05	<0.5	0.705	69	<0.05	<0.01	<0.5	<1	<0.01	1.1
	max.	284	0.34	<0.05	0.52	1.64	233	0.088	<0.01	0.74	<1	<0.01	1.5
	min.	6.1	<0.25	<0.02	<0.5	0.41	<30	<0.05	<0.01	<0.5	0.71	<0.01	1
	count	6	6	6	6	6	6	6	6	6	6	6	6
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Ball Creek

Ball Creek, sampled as a reference site, is located in the upper Iskut basin, upstream of the confluence of More Creek and the Iskut River (Figure 7). The Ball Creek watershed is 356 km^2 with a median elevation of 1530 m. Ten percent of the Ball Creek watershed is covered by glaciers. The mean annual flow (2004–2005) is 565 cfs (16.3 m^3/s), the average open water low flow is 42 cfs (1.2 m^3/s),

Water quality data were collected at 1 site in Ball Creek, near the mouth (Table 12); only samples samples were collected for water quality. None of the water samples were collected during peak flow periods (Figure 9). Because of the small number of samples, only general observations can be made: all three water samples contained concentrations of Al that were higher than the aquatic life criterion and one sample showed elevated iron (Table 12).

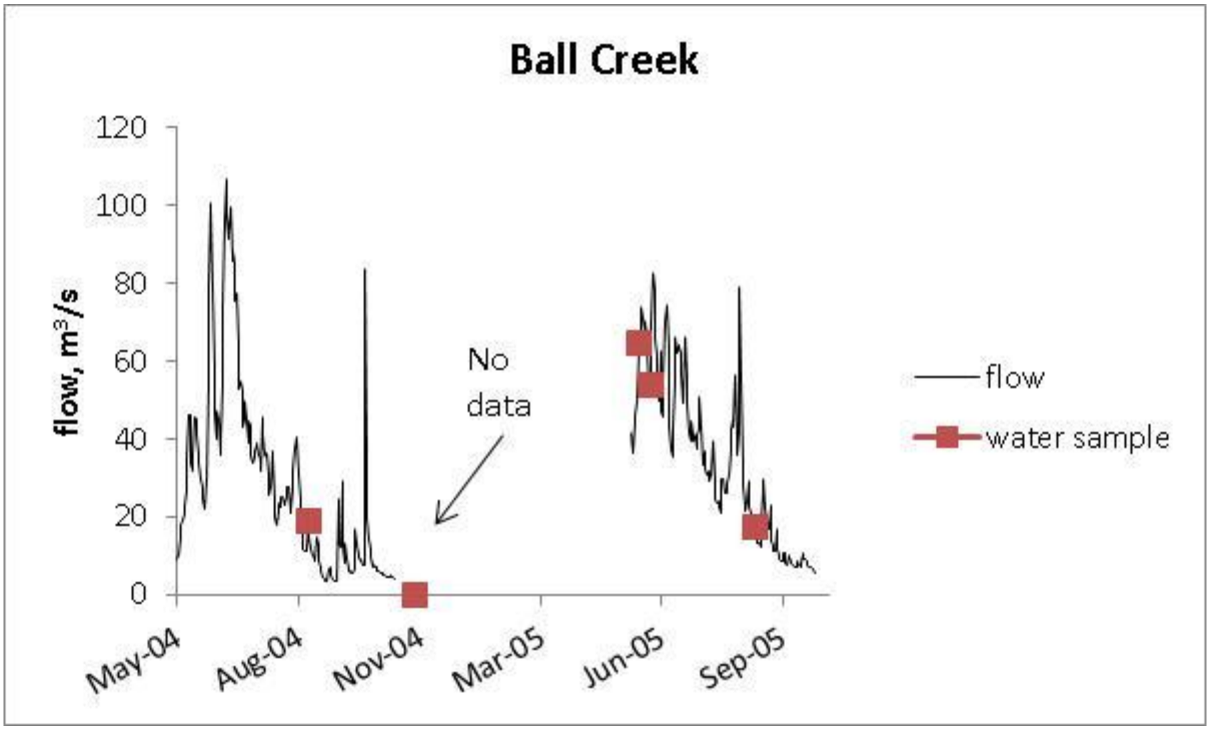

Figure 9.–Stream discharge at times when samples were collected for water quality, Ball Creek.

Table 12.–Summary of water quality data for Ball Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metals, except Se, which is total.

	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Se	Ag	Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
median	128	0.26	<0.05	<0.5	0.46	51	<0.05	<0.05	<0.5	1.5	<0.01	2.1
maximum	259	0.42	0.051	0.75	1.4	164	0.099	<0.05	0.6	1.9	<0.01	4.3
minimum	83.8	0.22	0.021	<0.5	0.38	<30	<0.05	<0.01	<0.5	<1	<0.01	<1
count	6	6	6	6	6	6	6	6	6	6	6	6
# > CMC	0	0	0	0	0		0	0	0		0	0
#> CCC	5	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

More Creek

More Creek is a tributary to the Iskut River near Ball Creek (Figure 8). More Creek flows through a steep, mountainous watershed of 876 km^2; approximately 40% of the watershed is covered by glaciers. More Creek is described (Rescan 2006) as a high energy system with highly variable flows. Peak discharge for More-7 (downstream of the confluence of More and West Fork of More) as estimated at 9380 cfs (268 m^3/s) and mean annual discharge was 2170 cfs (61.5 m^3/s). The proposed mine access road follows portions of More Creek.

Water quality samples were collected in More Creek during periods of low to moderate flows (Figure 10). One sample was collected at peak flows. Water quality samples are fairly representative of median flows.

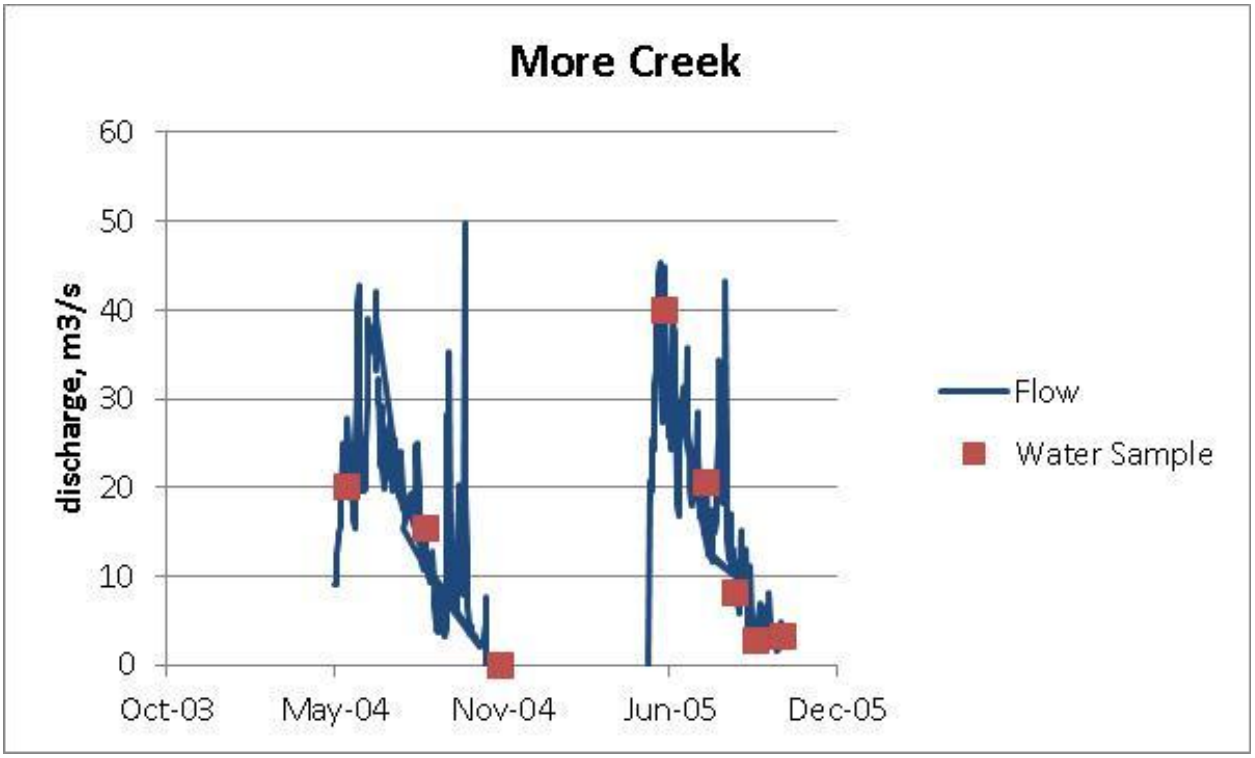

Figure 10.–Stream discharge at times when samples were collected for water quality, water samples from More Creek, Site 5, discharge from More Creek, Site 4.

Water samples collected at all three sites in More Creek showed elevated concentrations of Al that were higher than the US EPA Fresh Water Aquatic Life Criteria for chronic exposure (Table 13). None of the other metals sampled exceeded aquatic life criteria. MRLs for some of the silver samples are above water quality criteria.

Table 13.–Summary of water quality data for More Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L, sample replicates were not counted.

		Al µg/L	As µg/L	Cd µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Pb µg/L	Hg µg/L	Ni µg/L	Se µg/L	Ag µg/L	Zn µg/L
	CMC	750	340	2	570	13		65	1.4	470		3.2	120
	CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
MORE-1	median	7.55	<0.1	<0.05	<0.5	0.235	30	<0.05	<0.05	<0.5	<1	<10	<1
	max.	241	<0.1	<0.05	<0.5	0.83	139	0.065	<0.05	<0.5	1.16	<10	1.1
	min.	1.9	<0.1	0.015	<0.5	<0.1	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	12	12	12	12	12	12	12	12	12	12	12	12
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
MORE-2	median	85.2	0.145	0.035	<0.5	0.435	91.5	<0.05	<0.03	<0.5	<1	<0.01	1.15
	max.	452	0.24	<0.05	0.9	0.91	334	0.089	<0.05	0.68	1.33	<10	3.7
	min.	1	<0.1	0.015	<0.5	0.13	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	10	10	10	10	10	10	10	10	10	10	10	10
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	5	0	0	0	0	0	0	0	0	0		0
MORE-5	median	168	0.24	<0.02	<0.5	0.77	163	0.052	<0.01	<0.5	0.835	<0.01	<1
	max.	432	0.32	<0.05	0.65	1.4	439	0.095	<0.05	<0.5	<1	<10	2.3
	min.	5.4	0.16	<0.02	<0.5	0.25	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	13	13	13	13	13	13	13	12	13	12	13	13
	#>CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	8	0	0	0	0	0	0	0	0	0		0

Note: CMC = "acute" and CCC = "chronic."

Scud River and Tributaries

The Scud River and its tributaries, Contact Creek, Galore Creek and unnamed Reference site 2 were sampled during the project baseline studies (Figure 11). The brown shading on the map and inset is the proposed location of the tailings disposal. Gal-1B is in the tailings area; Gal-1A is downstream. Adit Creek, which receives drainage from an abandoned mine adit, is located near Gal-1A. Gal-2 is in the middle of the proposed tailings area and Gal-3 is near the confluence with the Scud River.

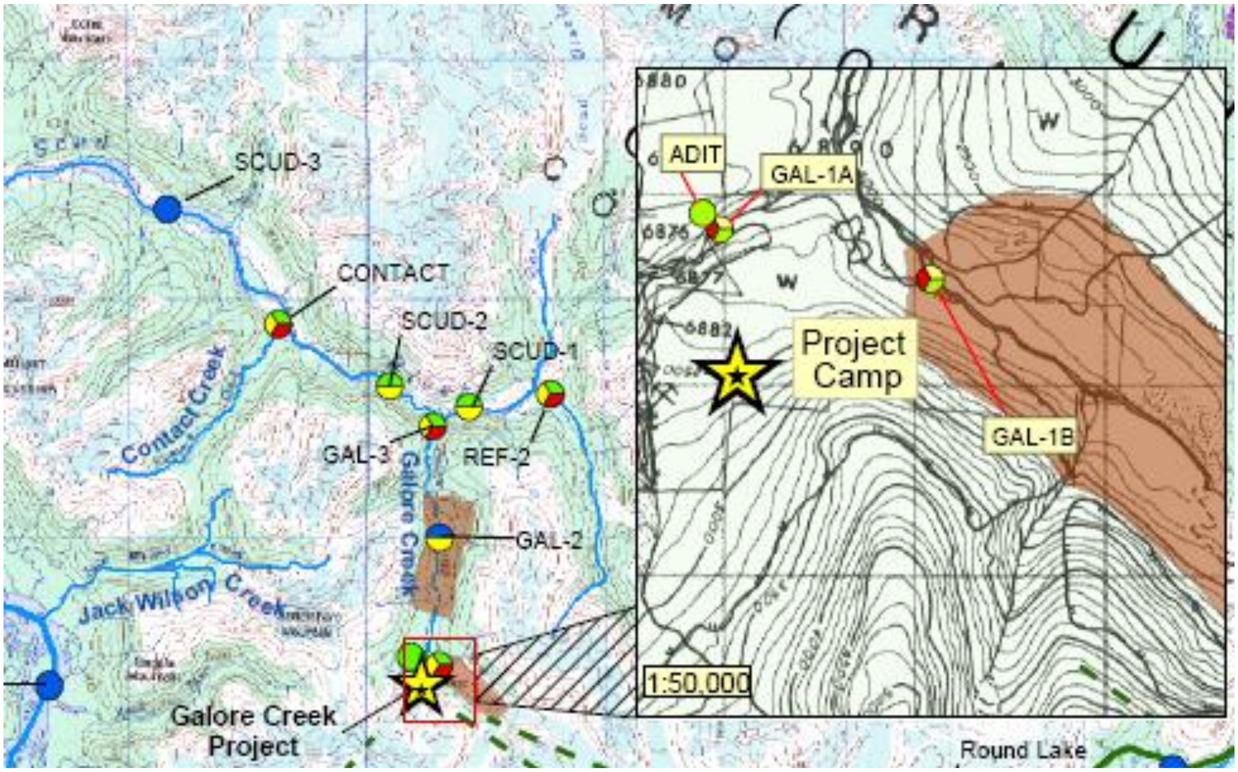

Figure 11.–Location of water sampling areas in the Scud River Watershed.

Source: Rescan 2006.

Scud River

The Scud River drains an area of approximately 1,110 km^2. The river is approximately 300 m wide and has a 1% to 3% gradient. Salmonid fish spawn in back and side channels where the water is clear. Much of the Scud River has a rough substrate of cobble and boulders, is incised in steep valley walls and is braided with multiple channels. Because of the dynamic floodplain, it was not possible to install stream gauges. Stream flow data from three subbasins were used to estimate mean monthly flows and high and low flows (Figure 12). The predicted Q_{100} high flow in Scud Creek is 49,793 cfs (1410 m^3/s) and the predicted Q_{10} low flow was 114 cfs (3.25 m^3/s). Upstream of the confluence with Galore Creek, 47% of the Scud River watershed is covered by glaciers.

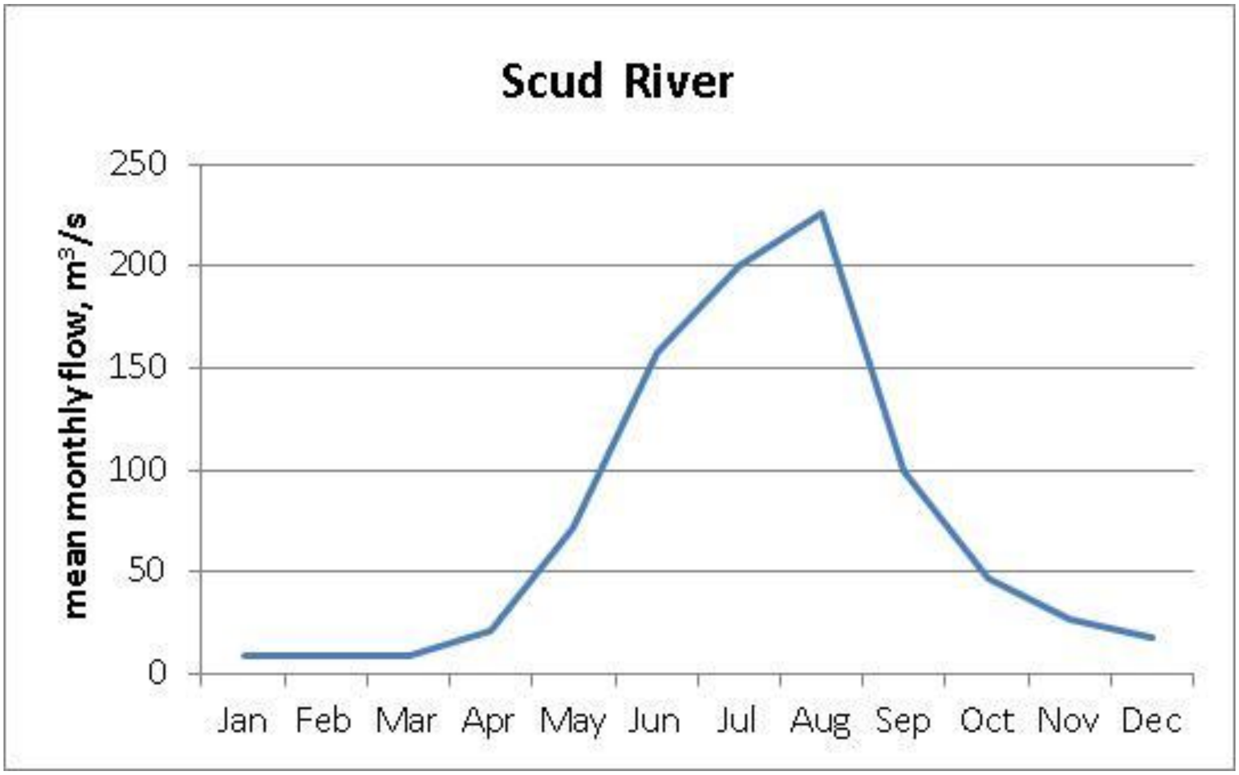

Figure 12.–Estimated mean monthly stream flow in Scud River.

Source: Rescan 2006.

Because stream flows were not measured, flow could not be correlated with times for collected samples for water quality. Water quality samples were collected from Scud Creek Sites 1, 2 and 4 on June 30, July 28, August 29, September 29, October 29, November 24 in 2004 and on Jan 2 and May 5 in 2005. Scud-3 was sampled four times: August 29, September 29 and November 24 in 2004 and May 5, 2005. Concentrations of Al were elevated above the US EPA aquatic life criteria for chronic toxicity in all four Scud River sites (Table 14), especially during June through September. Higher Al concentrations correlate with higher suspended sediment concentrations; this is an expected correlation as Al is a major component of clays and other sediments.

Concentrations of the other metals of concern were lower than aquatic criteria. Scud-1 is located upstream of Galore Creek and near the mineralized zones.

Table 14.–Summary of water quality data for Scud River and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L.

		D-Al	T-As	D-Cd	D-Cr	D-Cu	T-Fe	D-Pb	T-Hg	D-Ni	T-Se	D-Ag	D-Zn
CMC		750	340	2	570	13		65	1.4	470		3.2	120
CCC		87	150	0.25	74	9	1000	2.5	0.77	52	5		120
SCUD-1	median	215	1.44	<0.05	<0.5	0.86	146	0.067	<0.05	<0.5	<1	<0.01	<1
	max.	1640	2.01	<0.05	1.5	2.8	1200	0.249	<0.05	1.48	<1	<0.01	3.6
	min.	9.9	0.68	<0.02	<0.5	0.38	<30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	16	16	16	16	16	16	16	15	16	15	16	16
	# > CMC	1	0	0	0	0		0	0	0		0	0
	#> CCC	11	0	0	0	0	1	0	0	0	0		0
SCUD-2	median	155	1.01	<0.03	<0.5	1.18	106	0.06	<0.01	<0.5	<1	<0.01	1.1
	max.	1540	1.34	<0.1	1.34	3.02	692	0.26	<0.05	1.24	<2	<0.02	5.1
	min.	3.4	0.2	0.015	<0.5	0.49	<30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	25	25	25	25	25	25	25	24	25	24	25	25
	# > CMC	1	0	0	0	0		0	0	0		0	0
	#> CCC	18	0	0	0	0	0	0	0	0	0		0
SCUD-3	median	61.2	0.65	<0.05	<0.05	<0.5	1.09	30	<0.05	<0.05	<0.05	<0.5	<1
	max.	490	0.87	<0.05	0.139	0.75	1.74	340	0.166	<0.05	<0.05	0.63	1.2
	min.	8.1	0.37	<0.02	<0.05	<0.5	0.25	30	<0.05	<0.01	<0.01	<0.5	0.64
	count	7	7	7	7	7	7	7	7	7	7	7	7
	# > CMC	0	0	0	0	0		3	0	0		0	0
	#> CCC	3	0	0	0	0	0	7	0	0	0		0
SCUD-4	median	120	0.64	<0.02	<0.5	1.03	66	<0.05	<0.01	<0.5	<1	<0.01	<1
	max.	898	1.04	<0.1	1.1	2.33	413	0.221	<0.05	<1	<2	0.02	4.4
	min.	7.9	0.34	0.015	<0.5	<0.5	<30	<0.05	<0.01	<0.5	<0.5	0.01	<1
	count	25	25	25	25	25	25	25	24	25	24	25	25
	# > CMC	1	0	0	0	0		0	0	0		0	0
	#> CCC	15	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Contact Creek

Contact Creek, a reference site, flows through a small (approx. 25 km^2) watershed and enters the Scud River downstream of the Galore Creek ore body (Figure 13). Only 8% to 9% of the watershed is glaciated. Peak flows occur in Contact Creek during early June, following snowmelt, and decrease over the summer (Figure 13). Stream flows in Contact Creek are considerably lower than in other sites; the mean annual flow was 92 cfs (2.6 m^3/s) (Rescan 2006).

Although only 10 water samples were collected in 2004 and 2005, the samples appear to be representative of different stream flows (Figure 13). There were no flow measurements for three of the water samples (red squares on x-axis of figure).

Because of the limited number of water samples, only general conclusions can be made about the water quality in Contact Creek. Concentrations of metals are low (Table 14); none of the 10 samples exceeded US EPA chronic or acute aquatic life criteria for Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Se, Ag or Zn. Hardness ranges from 35 to 91 mg/L as $CaCO_3$, depending on stream flows and snow melt.

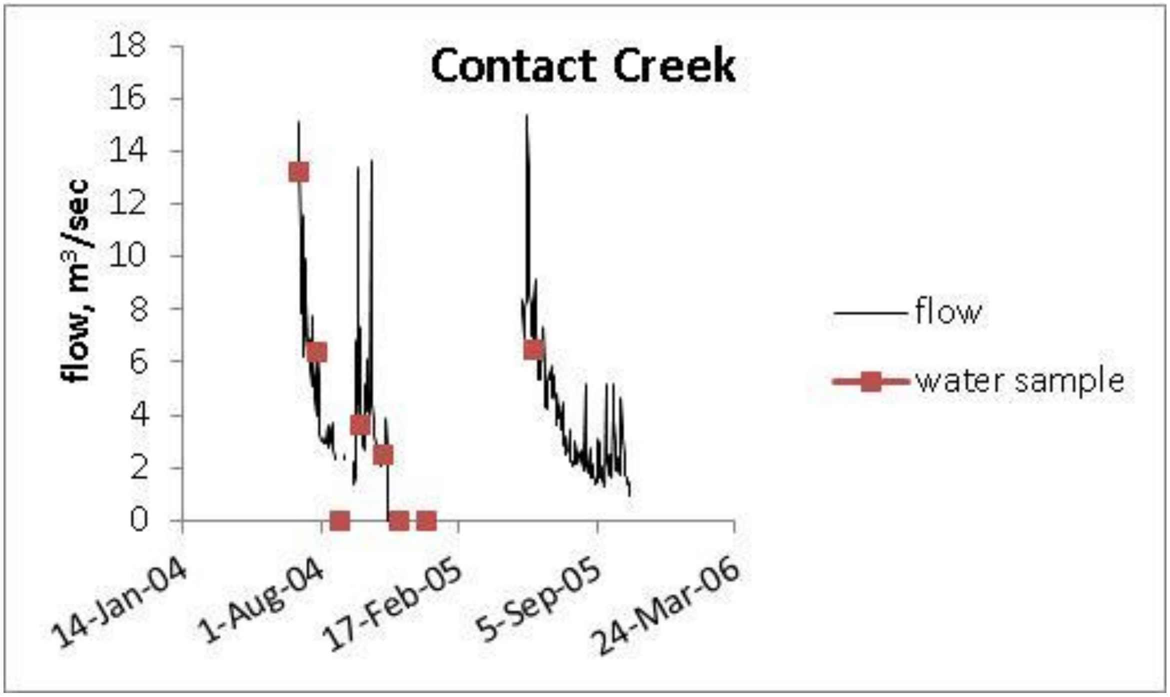

Figure 13.–Stream discharge at times when samples were collected for water quality, Contact Creek.

Table 15.–Summary of water quality data for Contact Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L. Hardness-dependent elements were calculated at 100 mg/L hardness.

	D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
USEPA CMC	750	340	2	570	13		65	1.4	470		3.2	120
USEPA CCC	87	150	0.25	74	9	1000	2.5	0.77		5		120
median	10.35	0.185	<0.05	<0.5	0.26	<30	<0.05	<0.05	<0.5	<1	<0.01	<1
Max.	22.3	0.25	<0.05	<0.5	0.65	<30	<0.05	<0.05	0.6	<1	<0.01	1.1
Min.	5.9	0.17	<0.05	<0.5	0.1	<30	<0.05	0.01	<0.5	<1	<0.01	<1
count	10	10	10	10	10	10	10	10	10	10	10	10
# > CMC	0	0	0	0	0		0	0	0		0	0
#> CCC	0	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute and CCC = chronic.

Galore Creek

The Galore Valley, location of the Galore ore body, will experience the greatest effects from mine development. Current mining plans describe a complete alteration of the Galore Creek watershed by open mine pits; freshwater, waste rock, and tailings impoundments; and multiple diversion channels. Construction of these features will completely alter existing subcatchments within the watershed.

Upon closure, the Tailings Containment Facility will be permanently flooded and all runoff upstream of the Main Dam will drain into the resulting tailings pond. Although this will have little effect on mean annual or monthly flows, the tailings pond will affect the timing and shape of the hydrograph at the mouth of Galore Creek during individual runoff events.

Water quality in Galore Creek was sampled at three different locations: Gal-1, near the headwaters, Gal-2, near the proposed tailings impoundment and Gal-3, near the confluence with the Scud River (Figure 11). Stream flows were monitored at seven different sites, including headwater tributaries. Sample times for collecting water quality data were compared with the Gal-1A because it was the only station on Galore Creek that was gauged during the same months and years that water quality samples were collected (Figure 14). No samples for water quality were collected during peak flow periods.

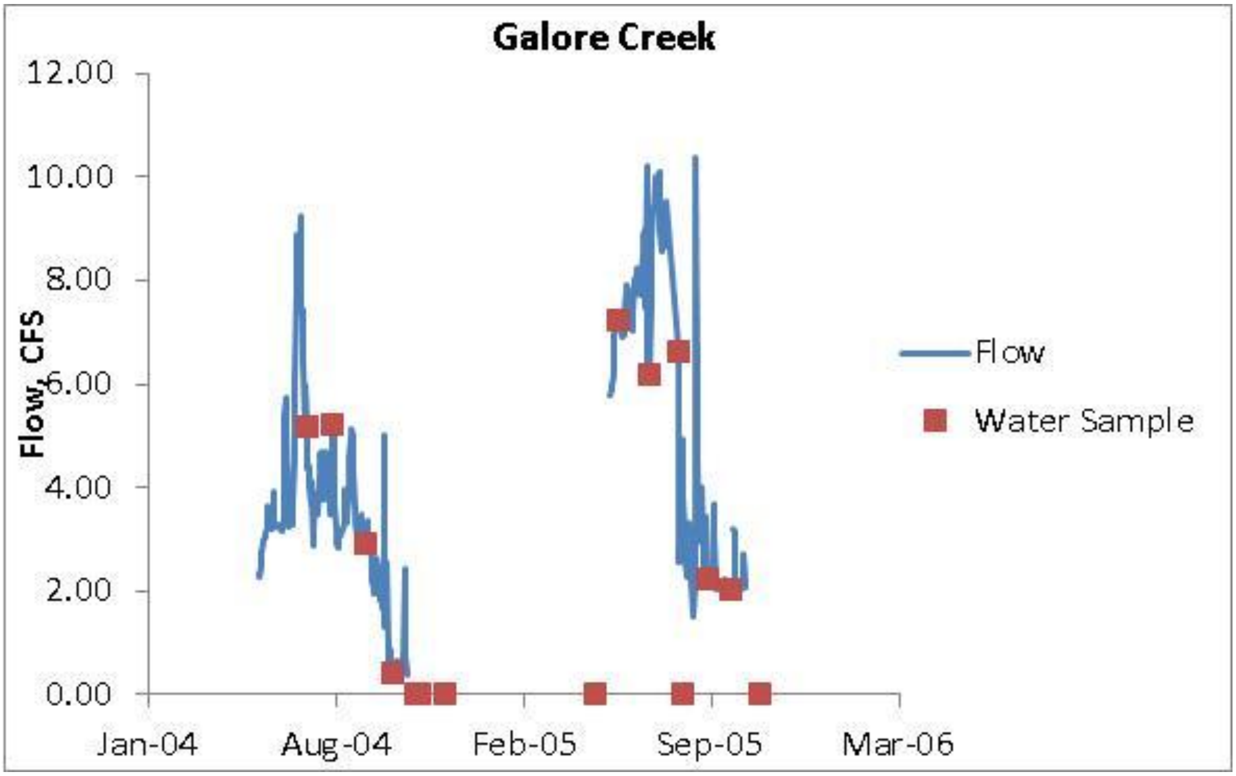

Figure 14.–Stream discharge at times when samples were collected for water quality, Galore Creek. Samples shown on x-axis had no associated stream flow data.

Although Galore Creek flows through the mineralized zone of the proposed Galore Creek Mine, the water quality shows only limited evidence of mineralization (Table 16). Water samples collected near the headwaters of Galore Creek (Gal-1A and Gal-1B) had elevated concentrations of Al and Cu that were higher than the US EPA chronic criteria for aquatic life. Water quality at Gal-3, near the confluence with the Scud River, had elevated Cu.

Galore Creek near the proposed mine site had seasonally high conductivity (maximum of 682 µSi/cm, total dissolved solids (maximum of 496 mg/L) and hardness (maximum of 344 mg/L). The stream water pH was slightly basic, with a median pH of 8.02. The pH value above neutral suggests that natural acid rock generation is not occurring in this region.

Comparisons of water hardness (median = 344 mg/L as $CaCO_3$) to median alkalinity (86.6 mg/L as $CaCO_3$) suggest that the water is predominated by $CaSO_4$ rather than $CaCO_3$. The measurements for sulfate (median 285 mg/L) support a $CaSO_4$ system.

Table 16.–Summary of water quality data for Galore Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metals, except Se, which is total.

		D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
USEPA CMC		750	340	2	570	13		65	1.4	470		3.2	120
USEPA CCC		87	150	0.25	74	9	1000	2.5	0.07	52	5		120
GAL-1A	median	28	0.22	0.089	<0.5	9.28	<30	<0.1	<0.03	0.54	1.135	<0.01	4.4
GAL-1A	Max.	113	4.44	0.36	2.5	30.5	68	0.293	<0.05	2.5	<5	0.05	38
GAL-1A	min.	15.9	<0.2	0.047	<0.5	1.71	<30	0.05	<0.01	<0.5	0.61	<0.01	<1
GAL-1A	count	15	15	15	15	15	15	15	14	15	14	15	15
GAL-1A	# > CMC	0	0	0	0	6		0	0	0		0	0
GAL-1A	#> CCC	2	0	2	0	8	0	0	0	0	0		0
GAL-1B	median	108	1.13	0.0455	<0.5	2.2	75	0.0685	<0.01	<0.5	<1	<0.01	1.45
GAL-1B	max.	1650	10.4	<0.1	1.2	6.87	377	0.342	<0.05	<1	<2	<0.02	3.4
GAL-1B	min.	0	0.12	0.024	<0.5	0.6	<30	<0.05	<0.01	<0.5	<0.5	<0.01	1
GAL-1B	count	25	25	24	24	24	24	24	23	24	24	24	24
GAL-1B	# > CMC	1	0	0	0	0		0	0	0		0	0
GAL-1B	#> CCC	14	0	0	0	0	0	0	0	0	0		0
GAL-2	median	42.2	0.33	0.053	<0.5	4.01	<30	<0.05	<0.05	<0.5	<1	<0.01	2.1
GAL-2	Max.	144	2.93	0.092	<0.5	7.03	126	0.115	<0.05	0.73	1.13	<0.01	7.7
GAL-2	Min.	7	0.15	0.042	<0.5	0.59	30	<0.05	<0.01	<0.5	0.81	<0.01	<1
GAL-2	count	7	7	7	7	7	7	7	7	7	7	7	7
GAL-2	# > CMC	0	0	0	0	0		0	0	0		0	0
GAL-2	#> CCC	2	0	0	0	0	0	0	0	0	0		0
GAL-3	median	52.8	0.6	0.05	<0.5	3.31	31.5	0.054	<0.01	<0.5	<1	<0.01	1.5
GAL-3	Max.	3370	8.94	0.064	2.5	14	383	0.827	0.05	1.19	1.44	0.022	7.3
GAL-3	Min.	4.8	0.19	0.023	<0.5	0.85	<30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
GAL-3	count	24	24	24	24	24	24	24	23	24	23	24	24
GAL-3	# > CMC	1	0	0	0	1		0	0	0		0	0
GAL-3	#> CCC	8	0	0	0	2	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Reference Site 2

Unnamed tributary, Reference Site 2, flows into the Scud River upstream of the Galore Creek ore body (Figure 11). Reference Creek is a slightly larger watershed (216 km^2) than Galore Creek, and like Galore Creek, it is heavily glaciated in its headwaters.

Flows in Reference Site 2 were highest from June to early September (Figure 15) when melting snow and glacial inputs are greatest. The highest flows occurred in August, during a period of prolonged rainfall. The peak daily discharge was 1680 cfs (47.6 m^3/s) and the mean annual low flow was 49 cfs (1.4 m^3/s).

Twenty-four water samples were collected from Reference Creek 2 in 2004 and 2005 (Figure 15, Table 17). Water samples were collected over a range of flows, suggesting a good representation of water quality conditions. Except for Al, metals were not elevated in this site (Table 17).

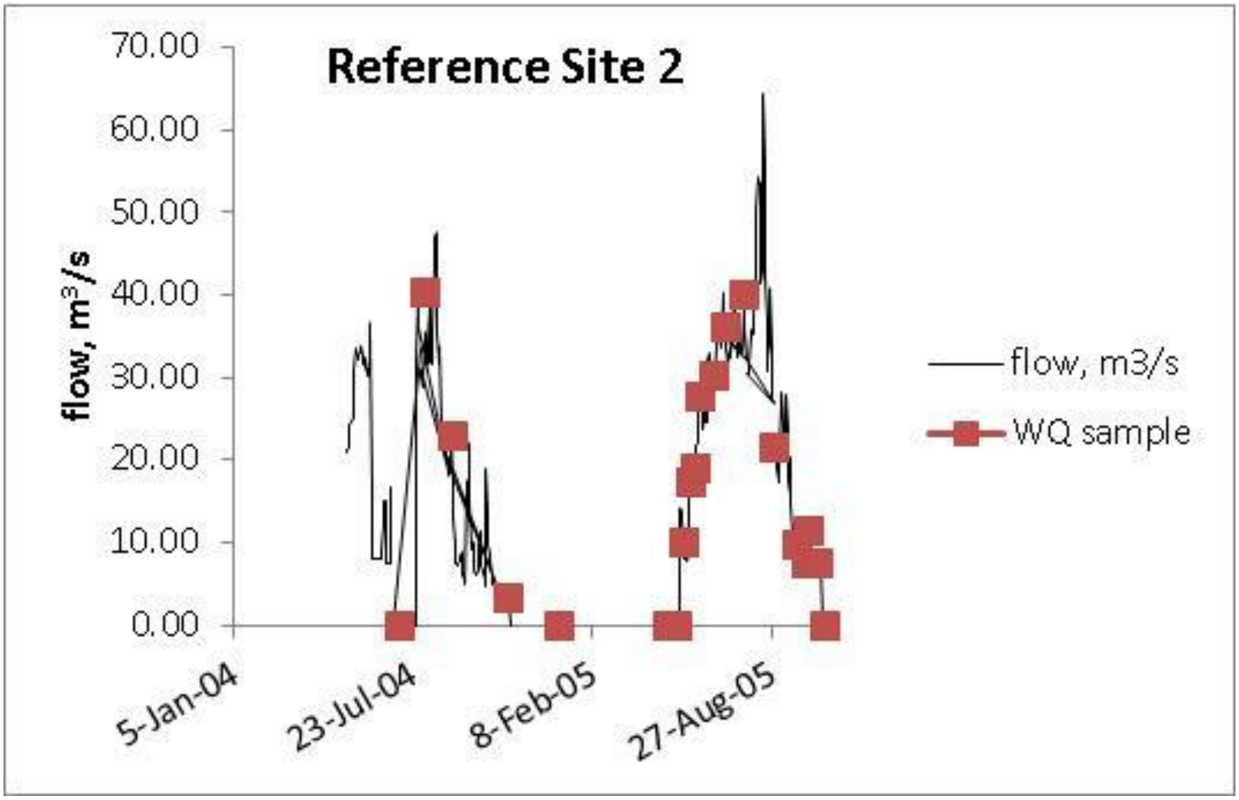

Figure 15.–Stream discharge at times when samples were collected for water quality, Reference Site 2.

Adit Creek

Limited sampling was done at Adit Creek, near the headwaters of the Scud River (Figure 11); no descriptions of the creek were given in the Rescan reports. An abandoned mine adit drains into the creek; water samples contained elevated concentrations of Cd and Zn (Table 18). Rescan (2006) reported that sediments in Adit Creek had the highest concentrations of 13 of 25 metals detected (Al, Be, Cd, Co, Cu, Fe, Pb, Mn, Mo, P, Sr, V, Zn), "often by a large margin, and had also one of the highest concentrations for arsenic." High metals concentrations in the sediments result from both previous mining development and characteristics of the Galore Valley geology.

Table 17.–Summary of water quality data for Reference Creek 2 and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metal, except Se, which is total. Replicate samples were not counted.

	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	T-Se	Ag	Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
Med.	204.5	1.345	<0.02	<0.5	0.775	114	0.072	<0.01	<0.5	<1	<0.01	<1
Max.	1450	1.8	<0.1	1.65	3.32	699	0.31	<0.05	2.1	2.37	<0.02	3.6
Min.	10.2	0.58	<0.01	<0.5	<0.3	<30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
count	24	24	24	24	24	24	24	23	24	23	24	24
#> CMC	1	0	0	0	0		0	0	0		0	0
#> CCC	18	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Table 18.–Summary of water quality data for Adit Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metal, except Se, which is total. Replicate samples were not counted.

	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	T-Se	Ag	Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
Med.	7.1	0.54	1.79	2.5	2.7	30	0.25	0.03	2.5	3.21	0.05	199
max.	17.9	1.5	2.35	5	5.48	37	0.5	0.05	5	10	0.1	258
min.	5	0.5	1.31	2.5	0.8	30	0.25	0.01	2.5	0.79	0.05	161
count	11	11	11	11	11	11	11	10	11	10	11	11
# > CMC	0	0	3	0	0		0	0	0		0	11
#> CCC	0	0	11	0	0	0	0	0	0	1		11

Note: CMC = acute, and CCC = chronic.

Porcupine River and Tributaries

Porcupine River

The Porcupine River begins at Porcupine Lake, below the Porcupine Glacier. Much of the Porcupine River is a braided system with small islands vegetated by willow. The Porcupine River Watershed is approximately 740 km^2 with about 18% covered by glaciers. The Porcupine River flows into the Stikine River downstream of the Scud River. Water quality samples were collected at two locations: Porc-1, near the confluence with Sphaler Creek, and Porc-2, near the confluence with the Stikine River (Figure 16).

Stream flows were estimated at the mouth based on 2005 flows in Sphaler Creek; the estimated annual stream flow was 1615 cfs (45.8 m^3/s). The water quality in the Porcupine River results from glacial inputs: both turbidity and total suspended solids are high (maximum 739 NTU and 782 mg/L); pH is slightly basic and did not vary much over the sampling period (median pH =8.11 and range 8.05 to 8.35). Hardness and alkalinity are similar (76.7 mg/L for hardness, 60.3 mg/L for alkalinity), suggesting that the contributing ions are predominately $CaCO_3$. Because few water samples were collected for metals analysis, only general observations can be made. Metals concentrations are generally low, except Al (Table 19). Concentrations of dissolved Al were higher than the US EPA chronic criteria for aquatic life; concentrations of total Al were even higher, with maximum concentrations reaching 14,100 µg/L. The high concentrations of Al likely are related to the sediment load in this system.

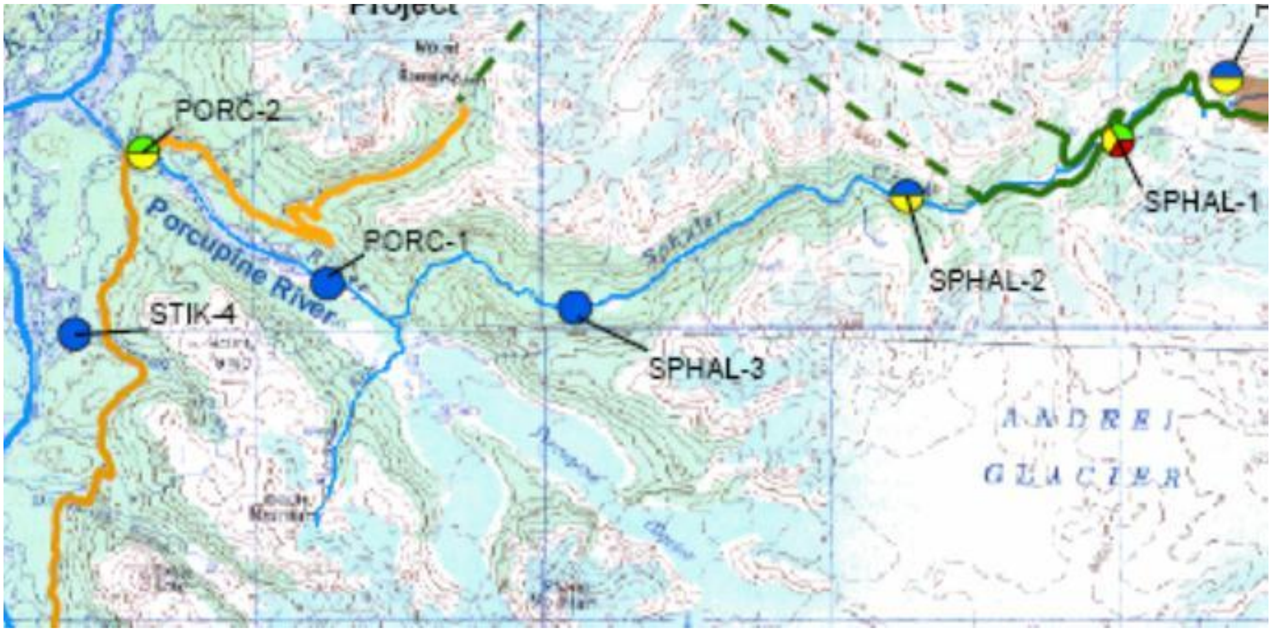

Figure 16.–Water sampling sites on the Porcupine River and Sphaler Creek. Map taken from Rescan 2006.

Table 19.–Summary of water quality data for Porcupine River and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metal, except Se, which is total. Replicate samples were not counted.

	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	T-Se	Ag	Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
Porc-1												
med.	232	0.51	0.02	0.64	0.895	306	0.087	0.01	0.545	1	0.01	1
max.	770	0.88	0.05	1.22	1.8	621	0.214	0.05	0.89	1.5	0.02	3.9
min.	89.5	0.32	0.015	0.5	0.25	51	0.05	0.01	0.5	0.5	0.01	0.5
count	22	22	22	22	22	22	22	22	22	22	22	22
# > CMC	2	0	0	0	0		0	0	0		0	0
#> CCC	22	0	0	0	0	0	0	0	0	0		0
Porc-2												
med.	232	0.51	0.02	0.64	0.895	306	0.087	0.01	0.545	1	0.01	1
max.	770	0.88	0.05	1.22	1.8	621	0.214	0.05	0.89	1.5	0.02	3.9
min.	89.5	0.32	0.015	0.5	0.25	51	0.05	0.01	0.5	0.5	0.01	0.5
count	22	22	22	22	22	22	22	22	22	22	22	22
# > CMC	2	0	0	0	0		0	0	0		0	0
#> CCC	22	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Sphaler Creek

Much of Sphaler Creek drains a steep, mountainous watershed where it dominated by braided river channels. The watershed is characterized by high runoff rates and about 20% is glaciated.

Sphaler Creek was sampled at three locations (Figure 16), with Sphal-3 being the farthest downstream.

Water quality samples collected in Sphal-2 were compared with stream flow data; no samples were collected during peak flows and only one sample was collected during low flow (Figure 18).

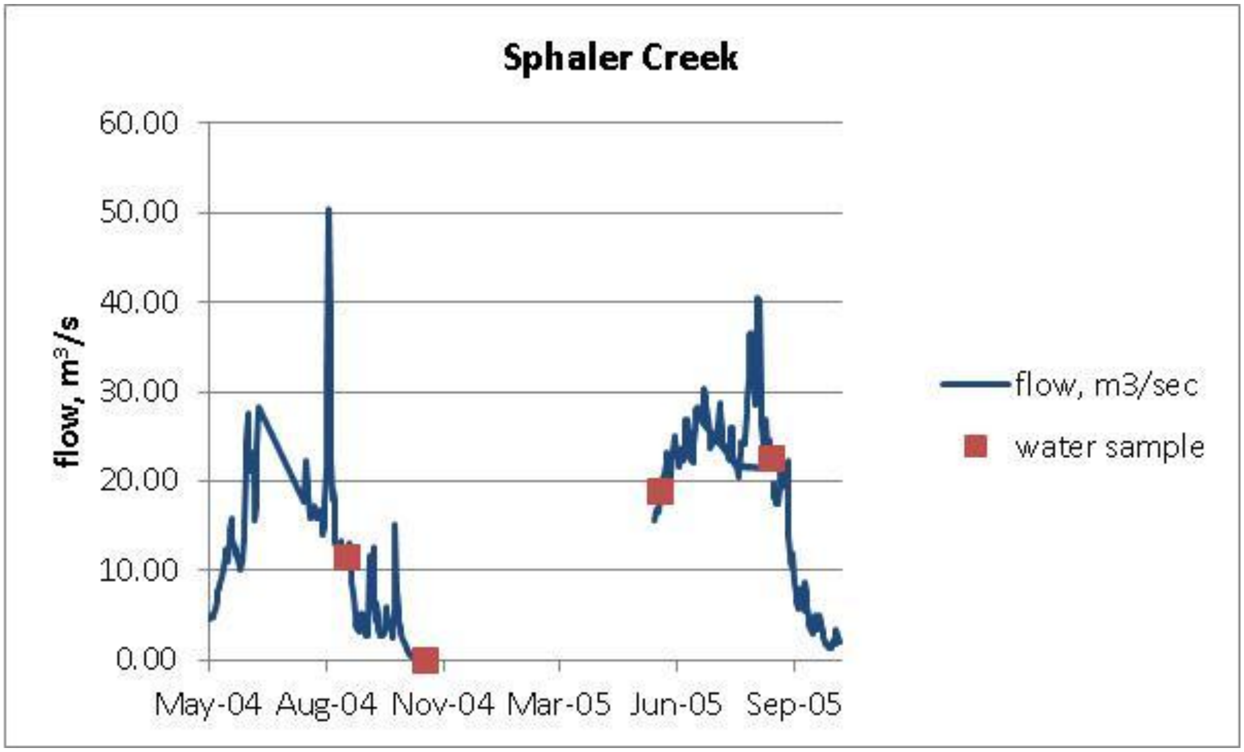

Figure 17.–Stream discharge at times when samples were collected for water quality, Sphaler Creek.

Water quality in Sphaler Creek reflects the glacial inputs: seasonally, total suspended solids ranged from 3 to 1,730 mg/L and turbidity ranged from 0.61 to 1990 NTU. Metals concentrations were generally low (Table 20), although concentrations of Al exceeded the US EPA chronic criteria for aquatic life in many of the samples. As with other glacially-influenced sites, Al is most likely a result of higher sediment loads.

Table 20.–Summary of water quality data for Sphaler Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metal, except Se, which is total. Replicate samples were not counted.

		D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
	CMC	750	340	2	570	13		65	1.4	470		3.2	120
	CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
SPHAL-1	median	184	0.32	<0.05	<0.5	0.4	98	<0.05	<0.05	<1	<1	<0.01	<1
	max.	459	0.62	0.25	2.5	0.97	320	0.25	<0.05	2.5	5	0.05	10.5
	min.	2.8	<0.1	0.015	<0.5	<0.1	30	<0.05	<0.01	0.5	0.95	<0.01	<1
	count	13	13	13	13	13	13	13	13	13	13	13	13
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	9	0	0	0	0	0	0	0	0	0		0
SPHAL-2	median	128	0.29	<0.05	0.5	0.28	73	0.055	<0.05	1.4	1.1	<0.01	<1
	max.	438	0.46	<0.1	<1	0.7	299	0.491	<0.05	1.93	2	0.02	2
	min.	8.7	0.21	<0.02	<0.5	0.22	30	<0.05	<0.01	0.59	0.95	<0.01	<1
	count	7	7	7	7	7	7	7	7	7	7	7	7
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	5	0	0	0	0	0	0	0	0	0		0
SPHAL-3	median	68.7	0.39	<0.05	<0.5	0.55	65	<0.05	<0.05	1.1	<1	<0.01	1.1
	max.	244	0.42	0.078	0.61	1.23	154	<0.05	<0.05	1.51	1.92	<0.01	1.6
	min.	4.6	0.27	0.017	<0.5	0.26	30	<0.05	<0.01	0.69	0.68	<0.01	<1
	count	7	7	7	7	7	7	7	7	7	7	7	7
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	3	0	0	0	0	0	0	0	0	0		0
SPHAL-4	median	157	0.4	0.022	<0.5	0.38	72	<0.05	<0.01	<1	1.595	<0.01	<1
	max.	2420	1.04	0.04	2.32	2.9	577	0.394	<0.01	2.02	2.27	0.027	5.6
	min.	22	0.29	0.015	<0.5	0.17	30	<0.05	<0.01	0.79	0.5	<0.01	<1
	count	9	9	9	9	9	9	9	8	9	8	9	9
	# > CMC	1	0	0	0	0		0	0	0		0	0
	#> CCC	7	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Scotsimpson Creek

Scotsimpson Creek, a tributary to the Porcupine River (Figure 16), is predominantly a braided, gravel bed stream with high run-off. Approximately 21% of the 49 km^2 watershed is glaciated. The upper portions of the drainage contain mineralized zones that have been identified as the Paydirt Prospect. Dolly Varden, mountain whitefish and sculpin inhabit the lower reaches. The proposed Galore Mine access route crosses the upper portion of the Scotsimpson drainage.

The water quality in Scotsimpson Creek contains fairly low hardness (range = 26 to 68 mg/L as $CaCO_3$) and alkalinity (range = 22 to 56 mg/L as $CaCO_3$). Concentrations of SO_4 are low (<0.5 to 24 mg/L) and pH is slightly basic. Concentrations of most metals (Table 21) are generally low; only aluminum exceeded the US EPA aquatic criteria for chronic exposure. Concentrations of aluminum are likely related to total suspended solids in Scotsimpson Creek.

Table 21.–Summary of water quality data for Scotsimpson Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metal, except Se, which is total. Replicate samples were not counted.

	D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
Med.	45.8	0.4	<0.02	<0.5	0.74	30	<0.05	<0.01	<0.5	0.605	<0.01	<1
Max.	183	0.46	<0.02	<0.5	1.77	168	0.097	<0.01	<0.5	0.89	<0.01	2
Min.	11.4	0.29	0.015	<0.5	0.41	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
count	9	9	9	9	9	9	9	8	9	8	9	9
# > CMC	0	0	0	0	0		0	0	0		0	0
#> CCC	2	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Rescan (2006) notes that the water quality in Scotsimpson Creek contains high total suspended solids, with average values of 427 mg/L and high turbidity (average = 250 NTU. It could not be determined if some of the water quality data from this site were omitted from the raw data contained in the appendices.

Stikine River and Tributaries

Stikine River

The Stikine River drains a watershed of about 52,000 km^2; extending from its headwaters in the Spatsizi Plateau to its outlet near Wrangell, Alaska. Most of the drainage is inaccessible to anadromous fish by natural and velocity barriers. Only 2% of the Stikine River is in Alaska (Pahlke 2008). Seven sites on the Stikine River were surveyed in 2004 and 2005: Stikine-1, upstream of the Scud River; Stikine-2 to Stikine-5, between the Scud and the Iskut rivers; Stikine-6, downstream of the Iskut River and Stikine-7, near Kaden Island in US waters.

The Stikine River near the proposed Galore Creek Mine is typical of a large river system, with moderate temperatures, turbid water and a channel punctuated with islands, side channels and sloughs. Numerous wetland areas along the margins of the river provide important rearing and overwintering habitat for salmonids. The river substrate is sand, silt and gravel.

There are few human-caused alterations to the Stikine River: small cabins, fish camps and docks. Downstream of the Canada/U.S. border, the river empties onto a wide, shallow delta. Tidal influence extends several kilometers upstream.

The Stikine is a large river with high discharge volumes. According to US Geological Survey data, the mean annual flow is approximately 65,225 cfs (1847 m^3/s), mean low flow is 9,600 cfs (272 m^3/s) and mean peak flow is 245,000 cfs (6937 m^3/s). Water quality is good, with low metals concentrations, except Al. All seven sites sampled on the Stikine River showed elevated Al concentrations. Overall, the Stikine River had lower dissolved metals, lower conductivity and lower water hardness than most of the other sites sampled in the baseline studies.

Rescan (2006) reported that water samples in the Stikine Watershed periodically exceeded the Canadian and British Columbia water quality guidelines for cyanide, total and dissolved aluminum, and total cadmium, chromium, cobalt, copper, iron, lead, mercury, selenium, silver, titanium and zinc. Note that the summary presented in Table 22 is for dissolved metals (except Se), consistent with US EPA water quality criteria.

Rescan also sampled wetlands in the Stikine River watershed for water quality. According to Rescan (2006), wetland water quality occasionally exceeded water quality guidelines for all analytes except pH and total barium, manganese and molybdenum.

Oksa Creek (Ref. Site 1)

Oksa Creek (designated as Ref 1) flows into the Stikine River north of the confluence with Scud Creek. Oksa Creek is outside of the mineralized area of the Galore Creek project. Only six samples were collected from Oksa Creek; therefore, only general observations can be made about the water quality.

The water in Oksa Creek was of moderate hardness, ranging from 41 to 115 mg/L; alkalinity had a similar range of 35 to 122 mg/L. Stream pH was slightly neutral (median 7.9) and sulfate was low (about 8 mg/L) except in February when stream flows were low. The February sulfate concentration was 55.6 mg/L. Concentrations of most metals were below the MRL, except Al, As, Cu, total Fe, and Ba. Only Al exceeded US EPA aquatic life criteria for chronic exposure (Table 23).

Jack Wilson Creek

Three sites in the Jack Wilson Creek watershed were sampled in August and September 2004: Sites Jack-1 and Jack-2 are located on upper tributaries of the creek, and Jack-3 was located downstream where the creek enters the Stikine River. The sites were sampled because this drainage was being considered for an alternative transportation route. However, the alternative that included Jack Wilson Creek was eliminated and these sites were dropped from the water quality program.

Table 22.–Summary of water quality data for Stikine River and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L.

		D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
	CMC	750	340	2	570	13		65	1.4	470		3.2	120
	CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
STIK-1	median	97.9	0.3	0.02	<0.5	0.88	106	0.067	<0.01	<0.5	1	<0.01	<1
	max.	174	0.32	<0.05	0.57	2.22	241	0.107	<0.05	0.76	1.92	<0.01	4
	min.	5.9	0.25	<0.015	<0.5	0.48	30	<0.05	<0.01	<0.5	0.57	<0.01	<1
	count	11	11	11	11	11	11	11	11	11	11	11	11
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	6	0	0	0	0	0	0	0	0	0		0
STIK-2	median	90.2	0.34	<0.05	<0.5	<1	106	<0.05	0.03	<0.5	<1	<0.01	<1
	max.	395	0.46	<0.05	0.77	2.27	280	0.13	<0.05	0.88	1.79	<0.01	3.5
	min.	12.7	0.26	0.015	<0.5	0.53	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	15	15	15	15	15	15	15	14	15	14	15	15
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	8	0	0	0	0	0	0	0	0	0		0
STIK3	median	37.1	0.28	<0.05	<0.5	0.66	105	<0.05	<0.05	<0.5	<1	<0.01	<1
	max.	89.1	0.29	<0.05	<0.5	2.31	261	<0.05	<0.05	0.67	<1	<0.01	<1
	min.	27.4	0.12	<0.05	<0.5	0.46	46	<0.05	<0.05	<0.5	<1	<0.01	<1
	count	3	3	3	3	3	3	3	3	3	3	3	3
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0
STIK-4	median	88.45	0.38	<0.05	<0.5	0.755	52	<0.05	<0.05	<0.5	<1	<0.01	<1
	max.	209	0.59	<0.05	<0.5	1.53	190	0.082	<0.05	0.62	1.13	<0.01	1.1
	min.	6.2	0.34	0.02	<0.5	0.35	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	6	6	6	6	6	6	6	6	6	6	6	6
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	3	0	0	0	0	0	0	0	0	0		0

-continued-

Table 22. Page 2 of 2.

		D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Pb	D-Hg	D-Ni	T-Se	D-Ag	D-Zn
	CMC	750	340	2	570	13		65	1.4	470		3.2	120
	CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
STIK-4	median	88.45	0.38	<0.05	<0.5	0.755	52	<0.05	<0.05	<0.5	<1	<0.01	<1
	max.	209	0.59	<0.05	<0.5	1.53	190	0.082	<0.05	0.62	1.13	<0.01	1.1
	min.	6.2	0.34	0.02	<0.5	0.35	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	6	6	6	6	6	6	6	6	6	6	6	6
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	3	0	0	0	0	0	0	0	0	0		0
STIK-5	median	50.4	0.31	<0.05	<0.5	0.75	52	<0.05	<0.05	<0.5	<1	<0.01	<1
	max.	189	0.42	<0.05	<0.5	1.27	167	0.129	<0.05	0.51	<1	<0.01	1.9
	min.	5.8	0.18	0.032	<0.5	<0.5	30	<0.05	<0.01	<0.5	0.77	<0.01	<1
	count	5	5	5	5	5	5	5	5	5	5	5	5
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	2	0	0	0	0	0	0	0	0	0		0
STIK-6	median	126	0.32	0.02	<0.5	0.855	103	0.0585	0.03	<0.5	0.955	<0.01	<1
	max.	243	0.37	<0.05	0.68	1.59	259	0.122	<0.5	0.76	1.04	<0.01	2.3
	min.	4.3	0.1	0.015	<0.5	0.3	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	10	10	10	10	10	10	10	10	10	10	10	10
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	7	0	0	0	0	0	0	0	0	0		0
STIK-7	median	90.5	0.3	<0.05	<0.5	0.72	117	<0.05	<0.05	<0.5	1	<0.01	<1
	max.	230	0.36	<0.05	<0.5	1.63	191	0.098	<0.05	0.73	1	<0.01	2
	min.	23.8	0.26	0.02	<0.5	0.59	49	<0.05	<0.01	<0.5	<0.5	<0.01	<1
	count	5	5	5	5	5	5	5	5	5	5	5	5
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	3	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute and CCC = chronic.

Note: Duplicate samples are not included.

Table 23.–Summary of water quality data for Oksa Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved, except Total Se.

	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Se	Ag	Zn
CMC	750	340	2	570	13		65	1.4	470		3.2	120
CCC	87	150	0.25	74	9	1000	2.5	0.77	52	5		120
Median	36.8	0.85	<0.05	<0.5	0.385	30	<0.05	<0.05	<0.5	<1	<0.01	<1
Max.	105	1.27	<0.05	<0.5	0.57	143	0.065	<0.05	<0.5	<1	<0.01	<1
Min.	2	0.37	<0.02	<0.5	<0.2	30	<0.05	<0.01	<0.5	<0.5	<0.01	<1
Count	6	6	6	6	6	6	6	6	6	6	6	6
# > CMC	0	0	0	0	0		0	0	0		0	0
#> CCC	1	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute and CCC = chronic.
Note: Duplicate samples are not included.

COMMENTS ON WATER SAMPLING

Quality Control/Quality Assurance

With a few exceptions, water quality samples were analyzed with acceptable method reporting limits that were below water quality criteria. Thirty field duplicate pairs were collected and compared to determine the variability that might result from field sampling and laboratory analysis. Only 2% of the duplicate pairs showed unacceptably high differences; most of these samples were at the MRL (Note: measurements at or near the MRL are approximations, many water quality scientists do not consider a lab result to be a “real” number unless it is 5 or 10 times higher than the MRL). Duplicates for Al, Fe and Ti showed higher variability between sample duplicates.

Field and travel blanks (of deionized water) were used to detect possible contamination resulting from taking and transporting samples. The field and travel blanks showed little evidence of contamination.

The detection limit for CN was 5, which is equal to the Canadian Water Quality Guideline. For mine monitoring, this detection limit should be smaller.

Sampling Frequency

Approximately 40 different sites were sampled for water quality (some sites were dropped) in 2004 and 2005. At many of the sites, samples were not collected over a range of stream flows; in many sites the peak flows and low flow periods are not represented. The baseline water quality data gives a general representation of water quality in these systems and, at some sites, documents effects of the mineralized zones.

Periphyton and Phytoplankton

Rescan sampled stream periphyton from 20 different sites in late August and early September. Samples were collected at all sites where accumulation on the substrate was noticeable by scraping from three rocks per site with a razor and a brush and then washed into a bottle. Multiple areas of each rock were scraped to characterize periphyton coverage. In sites without rocks on the stream bed, periphyton was collected from the top of the stream sediment. Three replicates were collected from each site.

No descriptions were given of how the sample area was delineated or what area was sampled. Collections from the *top of the stream sediment* were not associated with a sample area.

Each sample was split; half was used for a taxonomic identification and enumeration, and the other half for measurement of chlorophyll *a* biomass. Taxonomic samples were stored in 250 mL plastic bottles and preserved in Lugol's iodine solution. Chlorophyll *a* samples were prepared by filtering the remaining half sample through a 0.45 μm filter. Filters were frozen until analysis in a commercial laboratory. No information was given on analysis procedures used by the laboratory.

According to the 2004 results presented by Rescan (2006) periphyton was observed only in 7 of the 19 sites sampled. Sites with reported periphyton were Contact Creek, Galore Creek (2 sites), More Creek (1 site), Reference Sites (2 out of 3, streams were not identified) and Sphaler Creek. The table presented on pages 3–96 (Rescan 2006) states that no periphyton was found in the Iskut River, Scud River or Stikine River. However, data from 2005 (Rescan 2006) shows measured chlorophyll-a concentrations of 0.865 mg/m^3 to 68.3 mg/m^3 from the Iskut River and from 37.2 mg/m^3 to 81.5 mg/m^3 from Ball Creek. Note the discussion below of units for measuring chlorophyll-a in periphyton. It is not clear where samples from the Stikine River were collected; it is unlikely that periphyton would be found in substrates that are subjected to scour.

Taxonomic richness in 2004 periphyton samples ranged from 7 to 22 different genera; Sphal-2 had the fewest taxa, Ball Creek was intermediate, the remaining sites had higher taxonomic richness. The highest taxonomic richness was found at More Creek, site 1.

Rescan did not present the 2004 chlorophyll data because of the *qualitative nature of most samples.*

In 2004, phytoplankton was sampled in Round and Newmont Lakes. In 2005, phytoplankton was sampled in 27 wetlands and lakes along the proposed road route which passes through the Bob Quinn/Iskut, Lower More, Upper More, and Sphaler/Porcupine Watersheds. Of the 27 sites, four were control lakes, and three were control wetlands. Samples were collected for chlorophyll analysis by filtering a measured amount of water onto a glass fiber filter. Samples were analyzed for biomass, total abundance, relative abundance, diversity, evenness, and genus richness.

Phytoplankton samples contained a variety of genera, although in most groups a single group was clearly dominant. All of the major phytoplankton phyla were represented: diatoms (Phylum Bacillariophyceae), Cyanophyta, Chrysophyta, Cryptophyta and Chlorophyta. Phytoplankton biomass ranged from 0.05 μg/L at CL-5 to 2.08 μg/L. Biomass was lowest in the Upper More Creek watershed and highest in the lower More Creek watershed.

Taxonomic richness was highly variable among sites. Insufficient numbers of replicate samples were collected to determine within site variability.

Comments on Periphyton and Phytoplankton Samples

Periphyton measured as chlorophyll-a is a metric that is sensitive to changes in water quality, especially to an increase in metals (see discussion under Long-Term Monitoring of the Galore an Schaft Creek Projects); however, community measures (taxonomic richness, etc.) frequently do not show a significant correlation with metals concentrations. Sampling must be done with care, using standard methods and limiting sample collection to areas of each stream site that remain submerged and with minimal scour. Samples should be collected during summer when primary productivity is likely highest.

Rescan reported chlorophyll-a concentrations from 1.16 mg/m^3 in Sphaler Creek to 160 mg/m^3 in Galore Creek (Rescan 2006). These results need to be verified. First, a surface area was sampled, not a volume. Therefore, results should have been reported as mg/m^2. Second, many of the values are outside of the expected range for chlorophyll-a values. For example, ADF&G has reported chlorophyll-a concentrations in the range of 0.3 to 4.7 mg/m^2 from a naturally mineralized area in northwest Alaska (A. G. Ott, Operations Manager, ADF&G, Fairbanks, AK, personal communication) and in a range of <MRL to 32 mg/m^2 (average approximately 10 mg/m^2) from a variety of mineralized and control sites at the Greens Creek Mine on Admiralty Island (Durst and Jacobs 2009). Wetzel (1983) classified eutrophic lakes as having chlorophyll-a concentrations of 14 mg/m^3 or higher. Rescan reported values from 0.864 mg/m^3 to 160 mg/m^3; 10 of the 16 sites they sampled had chlorophyll-a concentrations of 19.6 mg/m^3 or higher. The higher values reported by Rescan seem outside of the range of expected values, especially in turbid streams that are subject to scour.

Descriptions of the sampling methods should include more detail about how the samples were collected and the size of the area sampled. Field collection methods for phytoplankton are described in greater detail. Sample results for periphyton in wetlands along the proposed road site have correct units.

Laboratory methods should include information about calibration, which equations were used to convert to chlorophyll-a, values for chlorophyll-b and -c, and corrections for phaeophytin.

Macroinvertebrates

Streams and Rivers

Benthic macroinvertebrate communities were sampled at 20 stream and river sites in September 2004 and at 29 sites in August 2005. Samples were collected with a Hess sampler, three replicates were collected at each site. Samples were identified and analyzed for density, relative abundance, richness, diversity, and evenness. Results were compared to earlier benthic invertebrate samples were collected using Ekman grab samples at three sites along the Stikine River between Porcupine River and Oksa Creek.

Density of benthic invertebrates in the study streams was low, ranging from 7 invertebrates/m^2 (Ref-2 and More-5) to 239 invertebrates/m^2 (More-1). Contact Creek had substantially higher average density (1,244 invertebrates/m^2) than the other sites. Rescan (2006) attributed the higher density in Contact Creek to the habitat, as samples were collected in a slow moving riffle zone below a series of large waterfalls

Overall, densities were lowest in the Scud, Sphaler–Porcupine and Galore Watersheds. Rescan related the benthic invertebrate abundance and density to habitat characteristics, but not to water quality conditions.

Rescan examined the invertebrate community structures, especially the proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. EPT is frequently used as an indicator of the health of streams because these three orders usually respond quickly to changes in water quality. Overall, there was a low abundance of EPT taxa at most sites; Rescan concluded that the absence or low numbers of EPT taxa was a result of habitat conditions more than water quality.

Taxonomic richness was highest in Contact Creek, likely a reflection of the higher abundance. Taxonomic richness was lowest in Ref-2, More-5, Sphal-2, Scud-2, Gal-3, and Scud-4—sites with overall low abundance.

Benthic invertebrate samples in 2005 had similar low density and taxonomic richness. Sites in the Sphaler–Porcupine River watershed had the lowest densities and richness; these sites also tend to have the highest concentrations of metals.

Lakes and Wetlands

Zooplankton was sampled in 2004 from Round and Newmont Lakes, using small plankton net. The volume of water passing through the net was calculated and zooplankton densities were estimated. Benthic macroinvertebrates in the lakes were sampled with an Ekman dredge. Samples were identified to the lowest practical taxonomic level, usually genus, except nematodes, oligochaetes, arachnids, ephydrid diptera, and clams, which were classified at higher levels.

There are no fish in either lake, although, waterfowl are commonly observed at Round Lake.

Zooplankton samples were dominated by two species of rotifers (*Kellicottia longispina* and *Polyartha*), one species of cladoceran (*Daphnia middendorffiana*) and two copepod species (*Cyclops scutifer* and *Cyclops capillatus*). Densities were higher in deep water areas than near shore habitats in Round Lake, but more common near shore in Newmont Lake

Total benthic invertebrate densities ranged from 726 to 17,748 individuals/m^2 in the two lakes. As with zooplankton, deep regions of Round Lake and shallow regions of Newmont lake had the highest densities. Benthic samples contained a variety of taxa, including Oligochaetes, amphipods, water mites, crane flies (Tipulidae), five chironomid subfamilies, and clams (Sphaeridae; Mollusca).

The benthic communities in wetlands and lakes along the road route (sampled in 2005) showed considerable variability in both abundance and community structure. Commonly found taxa were chironomids (dominant in most lakes), Oligochaeta worms, nematode worms, crustaceans, and Mollusca.

Comments on Stream and Lake Invertebrate Sampling

Samples of stream invertebrates showed generally low abundance, density and taxonomic richness at most sites. Both 2004 and 2005 sampling used standard methods that are acceptable for evaluating benthic invertebrate communities. Within site variability was high, although only three replicates were collected at each site.

The inherent variability of benthic invertebrate samples makes it difficult to detect changes that may occur with changes in water quality. The value of the invertebrate sampling is to demonstrate continued productivity in receiving waters. Large changes in water quality usually result in substantial changes in abundance and density and the loss of many taxonomic groups. The sampling conducted by Rescan provides an adequate baseline for future comparisons.

The presence of fresh water clams in the lakes is notable. Fresh water clams often are among the most sensitive taxa to water quality changes, especially changes in pH and metals concentrations. This group should be considered for future long-term monitoring.

Wildlife

Wildlife Populations in or near Project Area

Incidental Observations

Incidental wildlife observations from winter surveys included a wolverine (*Gulo gulo*) observed on the floodplain of the Iskut River (February 16, 2005), across from the confluence of Volcano Creek. No trumpeter swans (*Cygnus buccinator*) were observed along the rivers during the course of the surveys.

Incidental wildlife observations during summer surveys included a grizzly bear (*Ursus arctos horribilus*) in upper Sphaler Creek. An active osprey (*Pandion haliaetus*) nest with eggs was located on an island in Devil Lake and a herring gull (*Larus argentatus*) nest with eggs was observed on the edge of a small lake to the north of Devil Lake. A mountain goat (*Oreamnos americanus*) nanny and newborn kid were observed in Sphaler Canyon within forest habitat at an elevation of 460 m. Additional nannies and kids (numbers not specified) were reported in forested areas along Sphaler Creek during June.

Wolf Surveys

Wolf (*Canis lupus*) kills and packs were observed throughout the surveyed area during winter. A pack of nine wolves was observed over a recent moose kill on the Iskut River just across from the confluence with the More Creek. A pack of six wolves was observed on the Stikine River. Wolf sign was observed near the lake at the terminus of the Porcupine Glacier. Wolf sign was usually detected in areas of winter moose habitat.

A group of four wolves was observed in summer at the confluence of the More Creek and Iskut River, and a single wolf was observed on a wetland complex above More Creek, about 10 km west of the Iskut River confluence.

Moose Surveys

Rescan (2006) focused winter aerial moose surveys in areas of the two alternative mine access roads: the northern access road via More and Sphaler creeks and the southern access road following the Iskut and Stikine rivers. In late May 2005, NovaGold decided to pursue a modified version of the northern access road, through More and Sphaler Creeks. This decision shifted the focus of moose surveys, including calving, to a smaller study area which encompassed the northern access road and areas of potential Project.

The majority of moose were observed in coastal areas, and flat regions of slightly higher elevations associated with nonlimiting snow pack within the interior regions. These findings are consistent with similar studies focusing on the Coast Mountains portion of the Taku River drainage in Canada, moose were also mainly located in floodplain and riparian areas during the winter (Rescan 2006).

Grizzly Bear Surveys

The baseline studies of Rescan (2006) identified two distinct populations of grizzly bears: the coastal and interior groups. Grizzly bear studies conducted in 2004 focused on the coastal and interior areas associated with the northern and southern access road options. The 2005 studies focused on a smaller study area encompassing the northern access road and areas of potential project impact.

In 2004, Rescan's estimated coastal grizzly bear population was 138 and interior grizzly bear population was 126. Human-caused mortality (largely from hunting) during 1993 to 2002 averaged 3.8 grizzly bears per year for the southern half of the Edziza-Lower Stikine Grizzly Bear Population Unit.

Small Mammals, Bats, and Herpetile Surveys

Rescan (2006) sampled the Galore Creek proposed project area for small mammals (mice, voles, and lemmings and shrews). Total sampling effort was 1779 live trap and 576 pitfall trap nights. Traps were placed in a variety of ecotones, including seral stage wetlands and old growth forest; trap sites were concentrated along the proposed northern access site, the proposed airstrip in the Porcupine River Valley and the proposed mine site. The primary goal of the field inventory was to characterize species composition, and to identify species at risk.

Eight species of small mammals were positively identified, including Keen's mouse, meadow vole, long-tailed vole, northern red-backed vole, meadow jumping mouse, common shrew, dusky shrew, and water shrew. No species at risk were detected.

Bats were sampled at 10 different locations, including sites along the proposed northern access road, the proposed airstrip in the Porcupine River Valley, and at the proposed mine site: only one bat was captured. At least two species of *Myotis* are likely present: little brown myotis and at least one species of long-eared myotis, probably western long-eared myotis. Rescan reported that it was unlikely that the red-listed Keen's long-eared myotis exists within the study area.

Field sampling of Herpetiles was limited to the tailed frog. Incidental observations made by field biologists reported three amphibian species: western toad, spotted frog, and long-toed salamander. Western toad was widely distributed throughout wetlands and moist terrestrial habitats from the lowest elevations along the Stikine River to above 1200 m. Spotted frog was identified within lower elevation wetlands, and the long-toed salamander was found only below 700 m in cedar–hemlock forests.

Wildlife Habitat Ratings

Rescan (2006) developed wildlife habitat ratings for a select group of species and identified potential changes to individual species that may result from the proposed mine.

Two populations of Mountain Goats reside in the region of the proposed Galore project: a population in the upper Galore Creek watershed (Copper Canyon) and a population above More Creek near the confluence with the Iskut River (More Canyon).

Two distinct populations of grizzly bear were recognized: the coastal and the interior. Coastal bears are nearly exclusively dependant on salmon during summer and fall, while interior bears are dependent on vegetation. Important habitat for interior grizzly bears was identified along the Porcupine, Stikine and Scud Rivers. Suitable denning habitat was identified at high elevations near the Galore ore body. Areas north of Bob Quinn Lake (near old burns) and regions around Round Lake provide high quality vegetation for interior grizzly bears.

High quality habitat for American marten was identified along Sphaler Creek, More Creek and within the lower elevation forested areas of the Galore Creek valley. American marten relies on mature to old growth conifer forests with a closed canopy. Suitable habitats for hoary marmots were found at higher elevations, with most areas above the proposed access corridors and mine infrastructure. Limited hoary marmot habitat was identified along Scotsimpson Creek, near Round Lake and at some of the higher elevations in the region of the Galore ore body.

The western toad was widespread throughout well-vegetated regions of lower elevation.

Comments on Wildlife Sampling

The wildlife surveys and identification of wildlife critical habitats conducted by Rescan appear to adequately define critical habitats and wildlife species that may be affected by development of the Galore Mine project. Rescan provides numerous maps showing the distributions of different animal species. The Rescan baseline studies, however, do not discuss measures to minimize human/wildlife interactions, measures that could be taken to lessen human/wildlife interactions, or measures to protect or mitigate for loss of wildlife habitat. For example, the Red Dog Mine in northwestern Alaska prohibits travel along the haul road during caribou migration, prohibits hunting by mine workers, prohibits use of all-terrain vehicles by mine workers, provides bear safety training and uses animal-proof garbage containers. These measures should be a required component of a mine plan.

Freshwater Fish Surveys

Rescan sampled two categories of *affected environments*: receiving waters potentially affected by the mine project and stream crossings. Receiving environment sites were mostly located on larger rivers downstream of proposed mine features and stream crossing sites included both small streams and large rivers that will be crossed by the proposed road.

Two different receiving environments were sampled: the Galore/Scud/Stikine environment downstream of the proposed mine pit, tailings and waste rock facilities; and the More/Iskut environment, in the area of the concentrate dewatering and loading facilities. Fish sampling was done in July and September 2004.

At each fish sampling station, the stream habitat was described by habitat types (such as pools, glides, riffles, and cascades) and physical features of slope, mean depth, mean width, substrate composition, flow velocity, availability of cover for fish, potential barriers, bank stability, and bank height were recorded. The degree of hill slope coupling and channel confinement, presence of bars, and stream pattern were also described.

Fish were sampled with backpack electrofishers (in small streams), minnow traps (in small streams and shallow areas of large rivers), gillnetting, angling, and beach seining (in large rivers). Only one electrofishing pass per reach was made; electrofishing was avoided in spawning areas during the spawning season. The purpose of the fish sampling was to determine species composition.

Fish Populations

Seventeen sites were surveyed in the Galore/Scud/Stikine receiving environment and eight sites were surveyed in the More/Iskut environment. Twelve species were captured Galore/Scud/Stikine (Table 24). Although fish sampling was not quantitative, it appeared that the Galore/Scud/Stikine drainage had more species and higher population numbers than the More/Iskut drainage. Condition of coho salmon was lower and Dolly Varden condition was higher in the Galore/Scud/Stikine sites than the More/Iskut drainage. Mountain whitefish condition was similar in the two drainages.

Coho salmon spawning was documented in the Scud and Porcupine Rivers within 10 km of the Stikine River. One bull trout and one hybrid bull trout/Dolly Varden were collected from the Scud River.

Table 24.–Fish collected from the Iskut and Stikine River basins.

Watershed	Species
Iskut River	Coast range sculpin, Cutthroat trout, Rainbow trout, Dolly Varden, coho salmon, mountain whitefish, prickly sculpin, sculpin spp.
More Creek	Dolly Varden
Porcupine River	coho salmon, Chinook salmon, sockeye salmon, Dolly Varden, Cutthroat trout, mountain whitefish, prickly sculpin, sculpin spp.
Contact Creek	Sockeye salmon
Galore Cr (Gal-3)	Dolly Varden
Reference 2	Dolly Varden
Scud River	Chinook salmon, Dolly Varden, Sockeye salmon, coho salmon, slimy sculpin, mountain whitefish, Cutthroat trout
Stikine River	Chinook salmon, Dolly Varden, Sockeye salmon, coho salmon, slimy sculpin, mountain whitefish, Cutthroat trout, Longnose sucker, pink salmon, Sculpin spp., threespine stickleback
Jack Wilson Cr	Dolly Varden
Oksa Creek	Sockeye salmon, coho salmon, Dolly Varden, Mountain whitefish, rainbow trout,

Source: Rescan 2006.

Results

Fish at potential stream crossings

Fifty-five stream crossings were surveyed between July and September 2004: 28 along the south route, 21 along the north route, and 6 along the southern alternative route (Jack Wilson Creek). Nine fish species were captured during sampling from July to October 2004 at the crossings. Of these, Dolly Varden were caught on all road route options. Coho salmon, cutthroat trout, and mountain whitefish were also abundant along the south route, while rainbow trout were captured at two sites east of the Iskut River on the northern road route. Stream crossings sites along the southern route had higher fish species diversity and higher fish density.

Lake Samples

Two lakes also were sampled for fish presence and fish habitat. Round Lake is near the tailings facility and Newmont Lake (approximately 45 km southeast) and is a reference system. Fish habitat in the lakes was characterized by substrate composition, cover, and by the extent of the visible littoral zone. Emergent vegetation was noted. Fish in Round Lake were sampled by gillnet and baited minnow traps in July (Round Lake) and September (Round Lake and Newmont Lake).

Captured fish were identified, measured to fork length, weighed, and scale or fin ray samples taken to determine age. Most fish were released at the capture site; 90 fish from 4 sites fish were collected for genetic identification, diet analysis, and tissue analysis.

Lake habitat surveys indicated that both of the lakes surveyed were dominated by cobble substrate; however, Round Lake had a higher percentage of gravel, while Newmont Lake had a higher percentage of boulders. Available cover for fish was minimal in both lakes. No aquatic vegetation or large woody debris was observed in either lake. Minimal cover was provided by overhanging lakeshore vegetation. No fish were caught from either lake.

Comments on Fish Sampling

Rescan presents the fish data as average age, average length, average weight and average condition factor. The use of averages decreases the usefulness of the information. Of greater importance is the identification of young of the year, juvenile and adult fish and the subsequent descriptions of life stage use of each stream. Sampling conducted by Rescan was adequate to describe the distribution of different fish species in the drainages and provides a baseline for future studies. Rescan also provided a detailed literature review of fish presence in the Stikine River Watershed (Rescan 2006). The distribution of fish in the literature review is similar to the distribution described in Rescan's fishery studies. The two reports provide important information on baseline distributions of fish.

Tissue Analysis

Fish collected for laboratory analysis of metals concentrations included Dolly Varden from More Creek, Galore Creek, Oksa Creek (Reference Stream #1). Mountain whitefish were collected from the Stikine River.

Marine species (Staghorn sculpin (*Leptocottus armatus*), Dungeness crab (*Cancer magister*), and shrimp (*Crangon alaskensis*) were collected at the north end of Kadin Island, 5 km from Wrangell, Alaska for metals analysis. All samples were frozen, and the muscle tissue and stomach of each of these fish were removed in the lab.

Five different groups were sampled for metals concentrations in tissues: Dolly Varden, Mountain whitefish, staghorn scuplin, Dungeness crab and shrimp (Table 25). All samples were frozen and the muscle tissue and stomachs removed. Muscle was analyzed for concentrations of Al, Sb, As, Ba, Be, Bi, Cd, Ca, Cr, Co, Cu, Pb, Li, Mg, Mn, Hg, Mo, Ni, Se, Sr, Th, Sn, Ur, Vn and Zn. Stomach samples were used for diet analysis.

Table 25.–Tissue Samples collected for baseline studies.

Species	Collection Site	No. of Samples
Dolly Varden	Galore-3	13
Dolly Varden	More-5	9
Dolly Varden	Oksa Creek	5
Mountain Whitefish	Stikine-2	16
Dungeness crab, *Cancer magister*	Stikine-8	5
Shrimp, *Crangon alaskensis*	Stikine-8	6
Staghorn Sculpin, *Leptocottus armatus*	Stikine-8	15

Both Dolly Varden and mountain whitefish were juvenile fish, ranging in length from 57 mm to 199 mm for Dolly Varden and 79 mm to 121 mm for the whitefish.

The Pacific staghorn sculpin, *Leptocottus armatus*, is a common sculpin (Cottidae) found in shallow coastal waters along the Pacific coast. The staghorn sculpin feeds on a variety of marine invertebrates, including crabs, shrimps and amphipods; this sculpin usually remains in the same saline habitat throughout its life. Its maximum length is 460 mm (Eschmeyer et al. 1983). The sculpin sampled in this study ranged from 151 to 214 mm; only the muscle tissue was tested.

Comments on Tissue Sampling

Most metals that would occur in this type of mineral deposit would accumulate in the organs of the species; gills, liver and kidney are areas were many metals concentrate. Examination of data from the literature and ADF&G data for the Red Dog Mine identifies gills, kidneys and liver as tissues where greatest concentrations of most metals occur (Table 26). Samples of muscle tissue alone do not provide adequate data to predict changes to the health of the fish or invertebrate population or to predict exposure of animals eating the fish and invertebrates (bears, river otters, etc.). Individual tissues (gill, liver, kidney, muscle and reproductive) should be sampled; juvenile fish should be tested as *whole body*, with no removal of any organs. The fish tissue data presented by Rescan does not provide an adequate representation of baseline metals concentrations in fish tissue.

Table 26.–Accumulation of metals in various fish tissues, listed by uptake preference, from most likely (1) to least likely (5).

Element	Gill	Liver	Kidney	Brain	Reproductive	Muscle	Digestive Tract
Al	1	4	2	No data	5	3	No data
Ca	1	5	4	No data	3	2	No data
Cd	3	2	1	No data	5	4	No data
Cu	3	1	2	No data	4	5	No data
Cr	1	2	3	No data	No data	No data	4
Hg	4	2	1	3	4	4	No data
Pb	2	1	4	No data	5	3	No data
Se	3	3	1	No data	1	5	No data
Zn	2	4	3	No data	1	5	No data

Source: Eisler (1986 and 1993) and ADF&G fish tissue data for the Red Dog Mine.

Genetic Identification

DNA Analysis was done on 33 Dolly Varden char to determine if they were Dolly Varden or bull trout. These fish were collected from More Creek (MORE-5), Galore Creek (GAL-3), and from Oksa Creek (REF-1).

Bird Surveys

In 2004 and 2005, Rescan conducted bird surveys that included migratory birds, waterfowl, trumpeter swan (*Cygnus uccinators*), harlequin duck (*Histrionicus histrionicus*), marbled murrelet, songbirds and raptors. An additional survey for harlequin ducks and waterfowl was conducted in 2006. The studies were designed to collect baseline information on species distribution (species presence or absence) and habitat use (breeding, migration staging and over-wintering). A total of 117 bird species were identified within the proposed project area during 2004 and 2005 surveys. Rescan's results are summarized below.

Waterfowl

During May of 2004, a waterfowl survey was conducted along the access road to characterize waterfowl diversity and identify habitats used for breeding and migration staging. Aerial and ground breeding habitat surveys were conducted in June, July and August of 2005. Migration staging surveys were conducted within major wetlands and lakes along the Iskut and Stikine rivers during spring migration (mid-May 2005), along the More Creek portions of the proposed access corridor during spring migration (May 2006), and along the access corridor and within the Porcupine River Valley during fall migration (September and October 2005).

Rescan identified 20 different species of waterfowl within the proposed project area, including seven diving species, three merganser species, seven species of dabbler ducks, two species of geese, two species of loons and trumpeter swans. One great blue heron was observed in wetlands at the confluence of the Porcupine and Stikine rivers. Surf scoters were observed; however, breeding was not observed.

Breeding Habitat

Nine waterfowl species were observed using lakes and wetlands along the Devil Creek Forest Service Road and More and Sphaler creeks during surveys in June 2005. Breeding species were Barrow's goldeneye, common merganser, ring-necked duck, lesser scaup, mallard, blue-winged teal, green-winged teal, Canada goose, and common loon. Broods were observed for lesser scaup and common loon. Barrow's goldeneye was common in lakes along More and Sphaler creeks, although broods were not observed.

Migration Staging Habitat

Fall migration surveys documented seven species: American wigeon, black scoter, gadwall, great blue heron. northern pintail, northern shoveler, and white-winged scoter. Fall migrants were most commonly observed on lakes near More and Sphaler Creeks.

Raptors and Songbirds

Raptors observed in the proposed project area (including the access corridor) included bald eagle, peregrine falcon (subspecies not differentiated), gyrfalcon, golden eagle, osprey, red-tailed hawk, American kestrel, sharp-shinned hawk, merlin and rough-legged hawk (Table 27). Songbird surveys focused on Smith's longspur, hairy woodpecker, pine grosbeak, and Le Conte's sparrow.

Table 27.–Specific observations of birds in the proposed project area.

Location	Habitat Type	Species Observed	Notes
Galore Creek Valley	High elevation lakes	Barrow's goldeneye Rough-legged hawks	No broods observed
Porcupine River	Confluence with Stikine	Barrow's goldeneye blue-winged teal bufflehead Canada goose hooded merganser mallard red-breasted merganser trumpeter swan Bald eagles	Important breeding habitat
Porcupine River	Marsh area	Barrow's goldeneye mallard	Breeding fall migration
	Along river	Red tail hawks, merlin	
Lower Stikine River	Scud River to US border	Trumpeter swan	Nesting, wintering
Scotsimpson Creek		Harlequin duck	4 breeding pairs
More Creek	Site-channel	Harlequin duck	1 nesting female
		Red tailed hawk	1 pair
Iskut River	Confluence with Stikine	Marbled murrelet	10 flying in area
Sphaler Creek		Golden eagles, gryfalcon	3 nests

ENVIRONMENTAL EFFECTS RISK ASSESSMENT

Galore Creek

Discharge Limits

In 2002, the Federal Government of Canada adopted Metal Mining Effluent Regulations (MMERs). These effluent regulations were revised in 2006. The MMER set limits for eight substances associated with mining (Table 28). The Effluent Regulations also specified Method Detection Limits for the eight substances (with revisions in 2006). The MMER require sampling of effluent and the submission of quarterly and annual reports of results within specified time limits. Required under the MMER are monthly mean concentrations for metals and total suspended solids, monthly pH range; and acute tests (LC50) for rainbow trout and *Daphnia magna*.

Table 28.–Authorized Limits of Deleterious Substances, Schedule 4, Metal Mining Effluent Regulations. Method Detection Limits are from Schedule 3.

Analyte	Maximum mean monthly concentration,	Maximum authorized Concentration in a composite sample,	Maximum authorized concentration in a grab sample	Method Detection Limit
Arsenic, mg/L	0.50	0.75	1.00	0.01
Copper, mg/L	0.30	0.45	0.60	0.01
Cyanide, mg/L	1.00	1.50	2.00	0.01
Lead, mg/L	0.20	0.30	0.40	0.03
Nickel, mg/L	0.50	0.75	1.00	0.02
Zinc, mg/L	0.50	0.75	1.00	0.01
Total Suspended Solids, mg/L	15.00	22.50	30.00	2
Radium 226, Bq/L	0.371	0.74	1.11	0.01

Rescan (2006) presents a description of the proposed Galore Mine and measures that will be taken to ensure that the MMER limits are met. Following is a brief discussion of the identified sources of contaminants and proposed measures to limit input into waterways.

Sources of Metals Exposure

Mine Area and Receiving Environment

The mineralized zone, or ore body, on Galore Creek contains sulfide ores. When exposed to oxygen and water, the rock will naturally weather and leach. Crushing and redistributing large quantities of rock can accelerate the rates of metals leaching. Oxidation of sulfide minerals can result in lower pH if neutralizing minerals are not sufficient. The resulting acidic drainage can create higher rates of metals leaching.

The water management plan for the Galore Creek project is critical for protecting receiving waters from metals contamination. The catchment area upstream of the main dam is 86% or 125 km^2 of the Galore Creek watershed, requiring that large volumes of fresh water be diverted around the mine area.

According to the proposed water management plan, 38 km^2 of Galore Creek will drain into the tailings and waste rock impoundment and 87 km^2 will drain into the diversion channel.

Tailings process water and water in contact with the waste rock, open pits, low-grade ore, access tunnel and the northern face of the tailings dam will be diverted to the tailings and waste rock impoundment. No water treatment system is planned for this water before it is released to Galore Creek. The proposed Water Management Plan calls for discharges during periods of higher flows.

Open Pits

Water seeping into the open mine pits will likely contain elevated concentrations of metals. Some areas of the pit walls are PAG. Water from the open pits will be routed to a pond adjacent to the process plant and used as plant makeup water.

Low-Grade Ore Stockpile

Low-grade ore will be stockpiled for short time periods. Predictions of acid rock drainage generation suggest that the low-grade ore will not be acid generating within the life of the mine. Metal leaching from the low-grade ore stockpile is likely; drainage from the low-grade ore will be diverted into the tailings and waste rock impoundment. No treatment is planned for this water.

Waste Rock

Waste rock will be segregated into PAG and NAG. PAG waste rock will be submerged in the tailings impoundment. The submerged waste rock likely will leach copper, cadmium, fluoride, manganese, selenium, sulfate and zinc into the tailings water.

A well-designed water quality monitoring program must be implemented to preserve water quality in downstream waters (especially Galore Creek and Scud River). It is possible that metals leaching rates are sufficiently slow to not affect downstream water quality; however, should metals concentrations in the tailings supernatant increase, the Galore Creek Mine must be prepared to take measures to limit contamination.

Dam Runoff

Runoff in the form of precipitation and snowmelt along the northern, exposed face of the dam will contain low concentrations of leached metals, especially sulfate, calcium, iron, aluminum, nickel, cadmium, boron, copper, selenium and antimony. The current mining plan provides for collection of this leachate.

Discharge to Galore Creek

Using a pilot Process Plant, Rescan undertook a study to predict metals concentrations in tailings discharge water. Samples of ore from the Galore Creek Project site were passed through a small scale processing plant to determine the composition of the solid tailings and the water quality of the tailings supernatant. Leach tests of oxidized layers in the ore body also were done; oxidized ore is believed to produce higher concentrations of many metals than reduced portions of the ore body.

Initial tests indicated that the tailings have sufficient neutralization potential to prevent acid generation. The process water will have high loadings of sulfate, calcium and dissolved manganese, iron, zinc, aluminum, copper, lead, boron, molybdenum and selenium (Table 29). Concentrations of metals in downstream waters will be reduced by limiting effluent discharge to Galore Creek to periods of higher flows.

Table 29.–Predicted concentrations in tailings supernatant.

	Pilot Plant µg/L	Average of leach tests of oxide ore µg/L	Concentrations used for Years 1–5 µg/L
Aluminum	360	38	360
Antimony	2	0.78	2
Arsenic	2	6.8	3.4
Barium	59	61	60
Beryllium	10	2.5	10
Boron	200	50	200
Cadmium	0.4	0.28	0.4
Cobalt	2	0.89	2
Copper	2	44	14
Iron	300	30	300
Lead	1	0.25	1
Manganese	4.6	1100	320
Molybdenum	18	140	54
Nickel	10	5	10
Selenium	7.4	27	13
Uranium	0.48	5.4	2
Zinc	20	5.2	20
	mg/L	mg/L	mg/L
TOC[a]	not sampled	14.8	14.8
Sulfate	1530	1160	1530
Fluoride	1.01	1.91	1.28
Ammonia	0.023	0.005	0.023
Nitrate	0.05	0.068	0.055
Nitrite	0.047	0.01	0.047
Calcium	650	470	650

Source: Rescan (2006) Appendix 7-D, page 57.

Note: In the table below metals, non-metals, metalloids, etc. were converted to µg/L for consistency with Water Quality Criteria. Nutrients, total organic and major ions remain as mg/L.

[a] TOC = totally organic compounds.

Predictive Water Quality Models

Chronic Toxicity Bioassays

Rescan conducted chronic toxicity bioassays on rainbow trout, green algae, duckweed, and *Ceriodaphnia dubia* exposed to tailings supernatant generated from the pilot plant and with water from Galore Creek. Tests on tailings supernatant were done on undiluted samples, or water as it would occur in the tailings impoundment. Results indicated that the undiluted tailings supernatant is toxic to the development of rainbow trout embryos; Rescan estimated an LC50 of 10.2% (2006).

Water Quality / Discharge Models

According to Rescan (2006), the predictive water quality models suggested a potential for low-level effects to aquatic life in Galore Creek (Gal-3, at the mouth) and the Scud River (Scud-2). No water quality predictions were done for waterways downstream of Scud-2, however, Rescan "conservatively estimated that effects could potentially extend as far as the confluence of Contact Creek (approximately 6 km downstream of Scud-2), the first significant tributary after Scud-2."

Because Galore Creek flow comprises only 0.3% of the flow in the Stikine River, Rescan predicted that effluent release to Galore Creek would not adversely affect water quality in the Stikine River.

The predictive model makes a number of important assumptions: (1) clean, nonmineralized water will be captured and diverted around the mine area, (2) water quality in the tailings impoundment will mimic the water quality predicted by the pilot test, (3) the tailings impoundment has sufficient storage capacity to contain water during low flow periods, and (4) all seepage from the mineralized ore body will be captured and pumped to the tailings impoundment.

Characterization of Background Levels

Rescan conducted baseline monitoring of sediment and water quality in all sites potentially affected by the proposed project. Water quality results indicated systems that had frequently low concentrations of most dissolved and total metals. However, water quality sampling was not conducted over the full hydrograph; at many sites there were no samples collected during higher flow events. Elevated concentrations of Al likely are related to high total suspended solids in many of the systems. Comparisons of dissolved metals concentrations (total for Se) with US EPA aquatic life criteria found that most metals, with the exception of Al, did not exceed chronic or acute criteria. Metals concentrations in these watersheds reflect the natural mineralization.

The baseline studies leave a level of uncertainty about the environmental background concentrations because samples were collected infrequently and, in many watersheds, not collected over the full hydrograph.

Exposure Pathways

Primary producers, decomposers (fungi, bacteria, etc.), macroinvertebrates and fish would be exposed to metals by several pathways. These pathways include movement from water to sediments, from sediments to water (especially if a substantial change in water pH is realized), and through the food web.

For aquatic macroinvertebrates and fish, potential routes of exposure include uptake through respiratory organs, through the skin (or equivalent), through ingesting sediment and from food.

Comments and Recommendations

Overall, the acid rock drainage and discharge models appear conservative and in many instances, relied on worst case scenarios. However, protection of downstream water quality and aquatic species will depend on monitoring. It is imperative that the water quality in the tailings supernatant be sampled as well as water quality in Galore Creek and the Scud River. Juvenile fish in downstream waters should be sampled for whole body concentrations of metals. Should metals concentrations increase in downstream waters, the Galore Creek Mine should be prepared to install a water treatment system to remove metals. Because of the high degree of dilution, it is not likely that increased metals concentrations will be detected in the Stikine River.

Mining practices, including water treatment of effluent (if needed), control of point and non-point sources, control of erosion and subsequent sediment input, and long-term stability of the mine site are integral to limiting metals exposure. The total metals loading to the ecosystem should be assessed. Included in this assessment are factors that may limit uptake and availability, such as concentrations of dissolved organic carbon, water hardness and total alkalinity and stream pH.

Iskut River Drainage

Sources of Metals Exposure

Filter Plant

A second possible source of metals contamination from the Galore Creek Mine is from the filter plant. Concentrate slurry will be sent to the filter plant for dewatering. Excess water will be treated to remove metals before discharge. The proposed treatment includes flocculation, settling, fine filtering, removal of dissolved organics and adjustment of pH. The treated effluent will be discharged into the Iskut River through a buried pipeline and diffuser to increase the rate of mixing. The predicted discharge rate from the diffuser is about 0.5 cfs (0.016 m^3/s).

Metals concentrations in the filter plant effluent are limited by both the Provincial and the Federal guidelines. According to the guidelines, the total copper concentration in the receiving water downstream from the discharge point should not exceed 2 µg/L. The Federal MMER criteria state that the maximum total copper concentration must not exceed 300 µg/L at the discharge point.

Rescan (2006) conducted pilot tests to predict the concentrations of metals, major ions and other constituents of the filtrate water (Table 30).

According to their pilot tests, Cu, Se and Cd may be elevated above the water quality criteria for aquatic life. However, the metals concentrations resulting from the pilot tests are not diluted. The proposed discharge is approximately 0.5 cfs. Flows in the Iskut River in winter and early spring are low; Rescan estimated the annual seven-day low flow of approximately 375 cfs (10.6 m^3/s). Even at low flows, there is a large dilution (Table 31).

Table 30.–Galore Creek Pilot Plant Copper Concentrate Filtrate Water, predicted water quality.

	Fresh Pilot Plant Filtrate	Aged Pilot Plant Filtrate	Aged Pilot Plant Filtrate Water , lime treatment	Dissolved Metals	Fresh Pilot Plant Filtrate Water	Aged Pilot Plant Filtrate Water,	Aged Pilot Plant Filtrate Water, lime treatment	US EPA Water Quality Criteria, CMC	US EPA Water Quality Criteria, CCC
Physical Factors				Al ug/L	540	11	34	750	87
Cond. µS/cm	2412	2405	-	Sb ug/L	2.3	3.1	2.9		
TDS mg/L	2676	2275	-	As ug/L	<2	1	<1	340	150
Hardness mg/L	1596	1685	-	Ba ug/L	50	11	10.7		
pH	10.2	7.65	10.8	Be ug/L	<10	<5	<5		
Turbidity	1515	4.05	-	Bi ug/L	<10	<5	<5		
				B ug/L	<200	<100	<100		
Dissolved Anions				Cd ug/L	<0.4	0.3	0.27	2	0.25
Bromide mg/L	<0.50	0.56	-	Cr ug/L	<10	<5	<5	570 (III), 16(IV)	74(III), 11(IV)
Chloride mg/L	29.3	25.2	-	Co ug/L	<2	1.6	<1		
Fluoride mg/L	0.79	0.81	-	Cu ug/L	21	208	22.3	13	9
Sulfate mg/L	1550	1460	-	Fe ug/L	<300	34	<90		1000
Nutrients				Pb ug/L	<1	1.7	<0.5	65	2.5
Nitrate mg/L		<0.050	0.057	Li ug/L	<100	<50	<50		
Nitrite mg/L		0.034	0.013	Mn ug/L	3.3	276	12.5		
TOC mg/L[a]	-	46	-	Hg ug/L	<0.01	<0.01	<0.01	1.4	0.77
Major Ions				Mo ug/L	30	52.1	49.1		
Ca mg/L	635	660	608	Ni ug/L	<10	7.3	<5	470	52
Mg mg/L	1.81	9.09	8.18	Se ug/L	50	25	35.6		5 (T)
P mg/L	<3.0	<3.0	<0.90	Ag ug/L	0.51	6.57	<0.1	3.2	
K mg/L	42.6	54.6	61.4	Tl ug/L	<2	<1	<1		
Si mg/L	1.11	0.97	1.06	Sn ug/L	<2	<1	<1		
Na mg/L	31	30.6	34.8	Ti ug/L	<100	<10	<30		
Sr mg/L	9.6	14.6	13.1	U ug/L	<0.2	3.83	0.86		
				V ug/L	<20	<10	<10		
				Zinc ug/L	28	168	11	120	120

Source: Rescan 2006.

Note: The units for metals were changed to µg/L for consistency with the US EPA Water Quality Criteria.

[a] TOC = total organic compound. TDS = total dissolved solids.

Table 31.–Estimated dilution of water discharged from the filter plant into the Iskut River.

	Dilution Ratio at Distance Downstream from Diffuser			
Distance downstream, m	7-day Q10, m^3/s	Annual 7-day low flow, m^3/s	Annual Average Flow, m^3/s	Annual Peak Flow, m^3/s
3	90:1	90:1	70:1	60:1
7	90:1	140:1	130:1	100:1
13	90:1	140:1	180:1	160:1
51	90:1	140:1	330:1	360:1
103	90:1	140:1	330:1	490:1
200	90:1	150:1	330:1	490:1
1,000	150:1	240:1	390:1	500:1
	Theoretical maximum			
Dilution	440:1	640:1	6,875:1	45,455:1
Distance (m)	1400	7,200	22,500	133,000

Source: Data from Rescan 2006, page 294.

Comments and Recommendations

The models for water quality of the filter plant effluent and dilution in the Iskut River suggest that increases in concentrations of metals will be minimal. Protection of the water quality in the Iskut River depends on ensuring that maximum amounts of metals have been removed from the filter plant effluent before discharge and that the water quality of the Iskut River is monitored. The Iskut River should be sampled both upstream and downstream of the effluent discharge (downstream of mixing) to detect any changes in water quality. A monitoring program for both water quality and metals concentrations in fish is essential to ensuring that water quality objectives are met.

The water quality models do not address potential effects of elevated total dissolved solids (TDS). Increased TDS, usually in the form of $CaSO_4$ can be harmful to spawning and early egg development. Stekoll et al. (2003) found that for short (24- to 96-hour) exposures, fertilization was the most sensitive stage to TDS exposure. Concentrations of TDS as low as 250 ppm resulted in reduced fertilization rates. In addition, Chinook, pink, and coho salmon were most sensitive, and Arctic char were least sensitive. Fertilization and hatch were stages of development most vulnerable to long term, or chronic, TDS exposure.

PROPOSED SCHAFT CREEK MINE

PROJECT DESCRIPTION

The Schaft Creek property is located in northwestern British Columbia, 80 km southwest of Telegraph Creek and approximately 76 km west of the Stewart-Cassiar paved highway (Highway 37). The Schaft Creek prospect lies near the headwaters of Schaft Creek, a tributary of Mess Creek, which flows into the Stikine River downstream of the community of Telegraph Creek.

On September 29, 2010, the Canadian Environmental Assessment Agency issued a finding that the proposed Schaft Creek project was subject to an environmental assessment under the British Columbia Environmental Assessment Act. A cooperative environmental assessment process is being undertaken pursuant to agreements between the Government of Canada and Government of British Columbia. The finding further stated that the proposed project also was subject to the environmental assessment requirements of the Government of British Columbia.

The major receiving environment streams in the Project area include Schaft Creek, Hickman Creek, and Mess Creek. Mess Creek flows into the Stikine River approximately 45 km downstream of the Project area.

The Mess Creek watershed supports a variety of aquatic and terrestrial wildlife, including salmon, grizzly and black bear, moose, mountain goat and Stone's Sheep. Fish have never been recorded in the upper reaches of Schaft Creek (Hickman Creek), but are known to occur as high as 11 km upstream from Mess Lake. No fish have been recorded in Skeeter Lake. The lower portion of Mess Creek supports spawning salmon.

The proposed Schaft Creek Project is targeted to be an open pit copper, gold, molybdenum and silver mine. Current estimates of ore production rates are 100,000 tonnes per day over a minimum 15-year operation period (likely up to 23 years). The current project plans describe a conventional truck and shovel operation with drilling and blasting. The ore would be crushed, milled, and filtered onsite to produce ore concentrates of Cu and Mo. The Process Plant will include a flotation circuit and a copper circuit with thickener, filtration and concentrate loading and transportation. Molybdenum would be processed in a separate circuit with thickener, filtration, drying and bagging. The project includes an access road and a 287 kV transmission line within the Mess Creek watershed. The mine pit, plant/mill, and waste rock storage facilities are proposed to be located along the east bank of Schaft Creek. The tailings impoundment would be located within the Skeeter Creek watershed (a tributary of Schaft Creek). Ore concentrate likely will be transported by truck along Highway 37 to the Port of Stewart, British Columbia (RTEC. 2008a).

POSSIBLE SOURCES OF CONTAMINANTS TO ENVIRONMENT

Open Pit

The open pit would be located within the Schaft Creek drainage at the base of Mount Lacasse. At end of mine life, the Schaft Pit is estimated to encompass an area of 4.9 km^2 and extend 330 m below the current elevation. To date, a water management plan has not been developed and there is no information on how excess water in the pit will be treated and discharged or how possible seepage water will be monitored.

Processing Mill

The ore processing mill is projected to be constructed within the Mess Creek drainage. The processing system will consist of crushing, grinding, copper flotation, concentrate thickening and filtration, concentrate storage, disposal of tailings and reclaiming excess water. To date, there are no details on how these processes will be done, which reagents will be used, how water will be treated and discharged or how waste materials will be disposed.

Tailings Storage Area

Current estimates for ore production suggest that the Schaft Creek Mine will generate more than 800 million tonnes of tailings over the life of the project. Rescan Tahltan Environmental Consultants (RTEC 2008a) identified three possible locations for the tailings storage facility: Tailings impoundment option A is located in the Skeeter Lake Valley, Tailings and mill option B is located in the Hickman Creek watershed, and Tailings and mill option C is located along an unnamed eastern tributary of Schaft Creek. The September 2008 Schaft Creek Project Description (RTEC 2008a) states that tailings will be stored in the Skeeter Lake area. As described, the Skeeter tailings storage facility will require three embankments to contain the tailings generated over the life of the mine and will have a positive water balance. Discharge will be to Skeeter Creek; no information was provided on water treatment. Preliminary water balance models suggest a positive water balance in the tailings storage facility with an annual excess of 5 million m^3.

Although most of the tailings options are located in nonfish bearing watersheds, they flow directly into fish-bearing streams. Consideration will need to be given to the discharge water quality and effects on downstream aquatic populations. Tailings impoundment option A (currently the stated option) is located in the Skeeter Lake Valley, tailings and mill option B is located in the Hickman Creek watershed, and tailings and mill option C is located along an unnamed eastern tributary of Schaft Creek.

Waste Rock Storage Area

The proposed Schaft Creek Project will generate over a billion tonnes of waste rock. Currently, waste rock dumps are proposed to be located around the perimeter of the mine pit, with the majority of the material placed on the east side of Schaft Creek. Preliminary studies of PAG waste rock suggest that 10% of all waste is assumed to be PAG. More in-depth studies to identify PAG waste rock and to estimate rates of metals leaching have been initiated; however, the results are not available. There currently are no designs for the waste rock dumps, how water will be channeled around the site or how excess water will be treated and discharged.

Water Management

The 2008 Project Description (RTEC 2008a) gives a general description of a surface water management plan that consists of a network of diversion ditches, collection ditches and settling ponds. The diversion ditch network will direct surface water away from the project area to prevent contamination. These diversion ditches will be located around the perimeter of the Schaft Pit, the waste dumps and the ore stockpile.

The collection ditch network will collect all water that comes into contact with the mining area. Water will be pumped to the tailings storage facility. Treatment of the tailings water has not been described.

A detailed water management plan has yet to be developed for the Project. The water management plan is a critical component to determine how metals contamination of downstream waters will be minimized. The plan needs to include estimates of PAG, metals concentrations, plans to minimize natural drainage into the tailings facility, the pit and the waste rock dumps, plans to divert clean water away from the project facility and plans to treat and discharge excess water.

Transportation Routes

The transportation routes for trucking ore concentrate will likely consist of an access road from the mine site to the Galore Creek Access Road, then to Highway 37. The Schaft Access Road would begin at km 65 of the Galore Creek Access Road, head north over the More–Mess watershed divide, and continue north along the Mess Creek Valley. The road would enter the mine site area and Schaft Creek drainage near Snipe Lake.

ENVIRONMENTAL EFFECTS MONITORING

Environmental Baseline studies were initiated in 2006. The objective of the studies is to develop a biophysical understanding of the Mess Creek watershed within the areas of potential impact from development of the Schaft Creek project. The main components of the Environmental Assessment are as follows:

- Atmospheric Environment
- Hydrology and Water Management
- Aquatic Environment:
    - Surface and Groundwater Quality
    - Sediment Quality
    - Limnology
    - Fish Habitat and Community
- Wetland Resources
- Ecosystem Mapping and Reclamation
- Terrestrial Wildlife
- Metal Leaching/Acid Rock Drainage (Rock Geochemistry)
- Traditional Knowledge
- Archaeology

This review focuses on the water quality and fisheries information collected to support the proposed Schaft Creek project. Environmental monitoring was conducted in the major drainages in the vicinity of the proposed Schaft Creek project (Table 32, Figure 18).

Table 32.–Major drainages in the proposed Schaft Creek project area.

Watershed	Watershed Area (km^2)	Tributary to:	Possible sources of metals input from project
Hickman Creek	87	Schaft Creek	Reference Site, flows into Schaft Creek upstream of proposed mine site
Schaft Creek	688	Mess Creek	Drains area of the proposed main pit, downstream of proposed tailings impoundment
Skeeter Lake Creek	38.6	Mess Creek	Receives outflow of Skeeter Lake valley
Mess Creek		Stikine River	
Yehiniko Creek		Stikine River	Reference site. Flows to west of property, unaffected by mine site
Walkout Creek		Mess Creek	Flows from the east into Mess Creek, downstream of proposed mine area

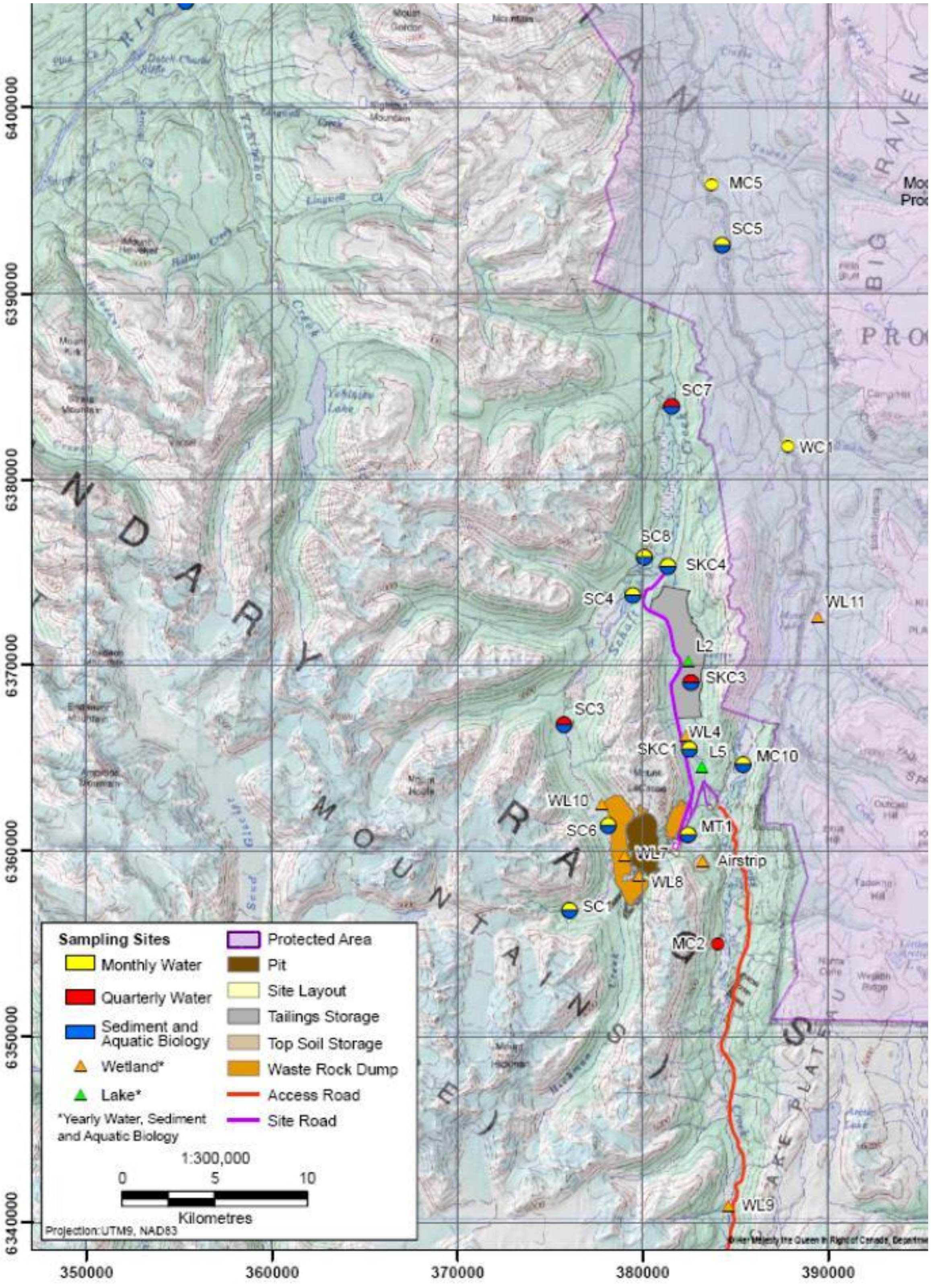

Figure 18.–Sampling sites in the Schaft Creek project area.

Source: RTEC 2008b.

Water Quality

Water quality data in this review came from three sources: RTEC 2006, 2007 and 2008 Aquatic Resources Baseline Reports (RTEC 2007a, 2008b, 2010b). There are discrepancies in the data that should be considered during study development for future monitoring programs. Additionaly, metals concentrations in the raw data were converted from mg/L to µg/L, to maintain consistency with other data bases and with the Canadian and US EPA water quality criteria and guidelines.

Water quality samples were collected from sites in the major drainages: Hickman Creek, Mess Creek, Schaft Creek, Skeeter Creek and Yehiniko Creek (Table 33). Water quality characteristics from these drainages are summarized below. Much of the water quality data for physical factors, nutrients and major ions for 2008 (RTEC 2010b) is incorrectly labeled; for example, hardness and color appear to be switched, as do many other analytes. These values are deleted from the data files included with this report; it simply is not possible to re-assign the values to the correct analytes. 2008 metals and pH data appear to be correct (based on numbers within the expected range and the consistent MRLs) and are included in the summaries.

Schaft Creek and Tributaries

Schaft Creek

Schaft Creek originates at a glacier in the southwestern portion of the Mess Creek watershed. The upper reaches are confined in narrow valley, but after about 2 km, it spreads out into a braided river with associated wetlands. The main channel of Schaft Creek flows for approximately 50 km to its confluence with Mess Creek.

The tailings and mill option C is located along an unnamed eastern tributary of Schaft Creek. Eight sites were sampled for water quality; SC1 is a reference site upstream of the proposed mine, the remaining sites were downstream of possible mine influence. The water quality sampling sites in Schaft Creek, in order from farthest upstream to farthest downstream were SC1, SC6, SC2, SC3, SC4, SC7, and SC5. The RTEC documents for aquatic studies (RTEC 2007a, 2008b, 2010b) do not provide a description or exact location of each sampling site.

The stream flow measurements were compared with days that water quality samples were taken to determine the representativeness of the water quality samples (Figure 19). Most water quality samples in 2006 were collected at the mean or slightly high flows; all of the samples collected in 2007 were collected at low flow. No samples were collected during periods of peak flows.

Water quality in Schaft Creek has low concentrations of most metals (Table 34), except Al and Se. In general, metals concentrations (Al, As, Cu, Fe and Se) are higher than in the reference sites and in many of the other sites. Only Al and Se exceeded US EPA Aquatic Life Criteria.

Table 33.–Sample sites with number of samples collected from 2005–2008 in the Schaft Creek project area, sample replicates are not counted.

River or Creek	Sample Site	Description	No. of Samples
Hickman Creek	HC-1	Near confluence with Schaft Creek	15
	HC-2		4
	HC-3		14
Walkout Creek	WC-1	Reference Site	29
Yehiniko Creek	YC-1	Reference Site	7
Mess Creek	MC-1	Upstream of proposed project area	17
	MC-2		25
	MC-3		1
	MC-4		5
	MC-5	Near Stikine River	28
	MC-6		2
	MC-7		7
	MC-8		2
	MC-9	Near Stikine River	10
	MC-10	East of mine site, slightly downstream	18
Schaft Creek	SC-1	Near headwaters	20
	SC-2		15
	SC-3		21
	SC-4		29
	SC-5	Near confluence with Mess Creek	32
	SC-6	Flows near pit and waste rock dump	18
	SC-7		5
	SC-8		4
Start Lake	SK-1	Southern outflow of Start Lake Valley, flows into Mess Creek	
Skeeter Lake	SKC-1	Northern outflow of Skeeter Lake Valley, flows into Schaft Creek	31
	SKC-2		13
	SKC-3		19
	SKC-4		20

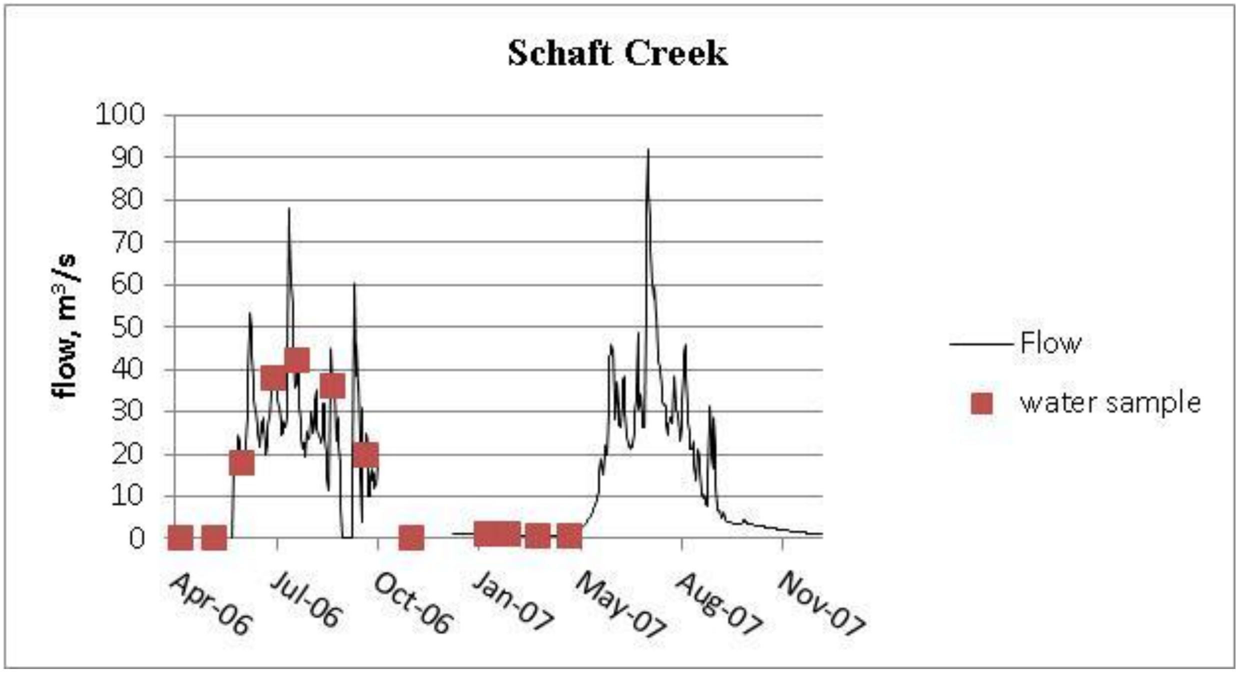

Figure 19.–Stream discharge at times when samples were collected for water quality, Schaft Creek. 2006 samples on the x-axis had no associated flow data.

Table 34.–Summary of water quality data for Schaft Creek sites and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved, except Total Se. Sample replicates were not counted.

		Al	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Ag	Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
SC1	median	106	0.29	<0.02	<0.5	0.57	42	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	626	0.45	<0.05	<1	1.51	365	<0.05	<1	0.16	5.51	<0.01	2
	min.	14.8	0.19	0.017	<0.5	0.16	<30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	21	21	21	21	21	21	21	21	21	21	17	21
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	10	0	0	0	0	0	0	0	0	1		0
SC-2	median	9	0.54	<0.02	<0.5	0.76	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	383	0.83	<0.05	0.69	1.32	198	<0.05	<0.5	0.083	3.89	<0.01	2
	min.	4.6	0.46	<0.02	<0.5	0.4	30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	count	15	15	15	15	15	15	15	15	15	15	15	15
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
SC3	median	8.4	0.49	<0.02	<0.5	0.7	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	320	0.83	0.031	0.78	1.52	186	<0.01	<0.5	0.068	4.09	<0.01	1.7
	min.	4.2	0.4	0.017	<0.5	0.16	<30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	19	19	19	19	19	19	19	19	19	19	19	19
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
SC4	median	15.1	0.41	<0.02	<0.5	0.62	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	346	1.11	0.035	<0.5	1.77	163	<0.01	0.79	0.084	5.88	<0.01	2.3
	min.	3.7	<0.1	0.017	<0.5	<0.1	<30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	27	27	27	27	27	27	27	27	27	27	27	27
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	5	0	0	0	0	0	0	0	0	1		0

-continued-

Table 34. Page 2 of 2.

		Al	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Ag	Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
SC5	median	36.7	0.35	<0.02	<0.5	0.605	50	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	314	0.63	<0.05	<0.5	1.92	237	<0.05	<0.5	0.085	5.65	0.016	1.3
	min.	2.1	0.21	0.017	<0.5	0.2	<30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	32	32	32	32	32	32	32	32	32	32	32	32
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	5	0	0	0	0	0	0	0	0	1		0
SC6	median	61.8	0.7	0.017	<0.5	0.655	31	<0.01	<0.5	<0.05	0.35	<0.01	<1
	max.	531	1.75	0.026	0.74	9.74	735	<0.01	1.25	0.792	0.95	<0.01	4.7
	min.	7.8	0.46	0.017	<0.5	<0.3	30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	16	16	16	16	16	16	16	16	16	16	16	16
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	7	0	0	0	1	0	0	0	0	0		0
SC7	median	47.1	0.4	0.017	<0.5	0.37	43	<0.5	<0.05	<0.01	<0.1	<0.01	<1
	max.	89.9	0.59	0.017	<0.5	<0.5	53	<0.5	<0.05	<0.01	0.19	<0.01	<1
	min.	6.7	<0.1	0.017	<0.5	0.17	<30	<0.5	<0.05	<0.01	<0.1	<0.01	<1
	count	5	5	5	5	5	5	5	5	5		5	5
	# > CMC	0	0	0	0	0		0	0	0	0	0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Hickman Creek

Hickman Creek drains the eastern slopes of Hickman Mountain in the southern portion of the Mess Creek watershed. The creek is approximately 20 km long and flows through a narrow valley to its confluence with Schaft Creek. Two sites were sampled: HC-1 near the mouth and HCTR-1, a small tributary. HC-1 is located downstream of one of the possible tailings impoundment locations and a mill option; HCTR-1 is considered a reference site.

Water quality in Hickman Creek is excellent with low concentrations of metals (Table 35). Concentrations of dissolved Al occasionally exceeded US EPA aquatic life criteria for chronic exposure. In general, the water in Hickman Creek is moderately hard (50 to 100 mg/L), turbidity and total suspended solids usually are usually low and median concentrations of SO4 are 15 to 22 mg/L.

Stream flow data was collected at Hickman Creek Site 1; however, comparisons with water quality sampling times with stream flow could not be made because the stream flow data (RTEC 2008b) erroneously includes the 2006 data, not 2007. No water quality samples were collected at Hickman Site 1 in 2008.

Stream flows are low, until May (Figure 20). Seasonal storms and snow melt contribute to increased discharges.

Table 35.–Summary of water quality data for Hickman Creek sites and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metals, except Total Se. Sample replicates were not counted.

		Al	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Ag	Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
HC-1	Median	12.4	1.22	<0.02	0.84	0.69	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	Max.	177	1.54	<0.05	1.47	1.15	153	<0.05	2.2	<0.05	<1	<0.01	1.4
	Min.	2.5	0.77	<0.02	<0.5	0.32	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	Count	15	15	15	15	15	15	15	15	15	15	15	15
	# > MC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	0	0	0	0	0		0
HC-2	Median	7.85	1.465	<0.02	0.745	0.6	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	Max.	126	1.66	<0.02	1.12	0.6	54	<0.01	<0.5	<0.05	0.74	<0.01	<1
	Min.	3.2	1.1	0.017	<0.5	<0.3	<30	<0.01	<0.5	<0.05	<0.3	<0.01	<1
	Count	4	4	4	4	4	4	4	4	4	4	4	4
	# >CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0
HC-3	Median	10.55	1.18	<0.02	0.645	0.65	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	Max.	131	1.32	<0.02	1.02	2.98	80	<0.01	1.01	<0.05	0.87	<0.01	1.8
	Min.	2.5	0.59	0.017	<0.5	<0.3	<30	<0.01	<0.5	<0.05	0.12	<0.01	<1
	Count	14	14	14	14	14	14	14	14	14	14	14	14
	# >CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

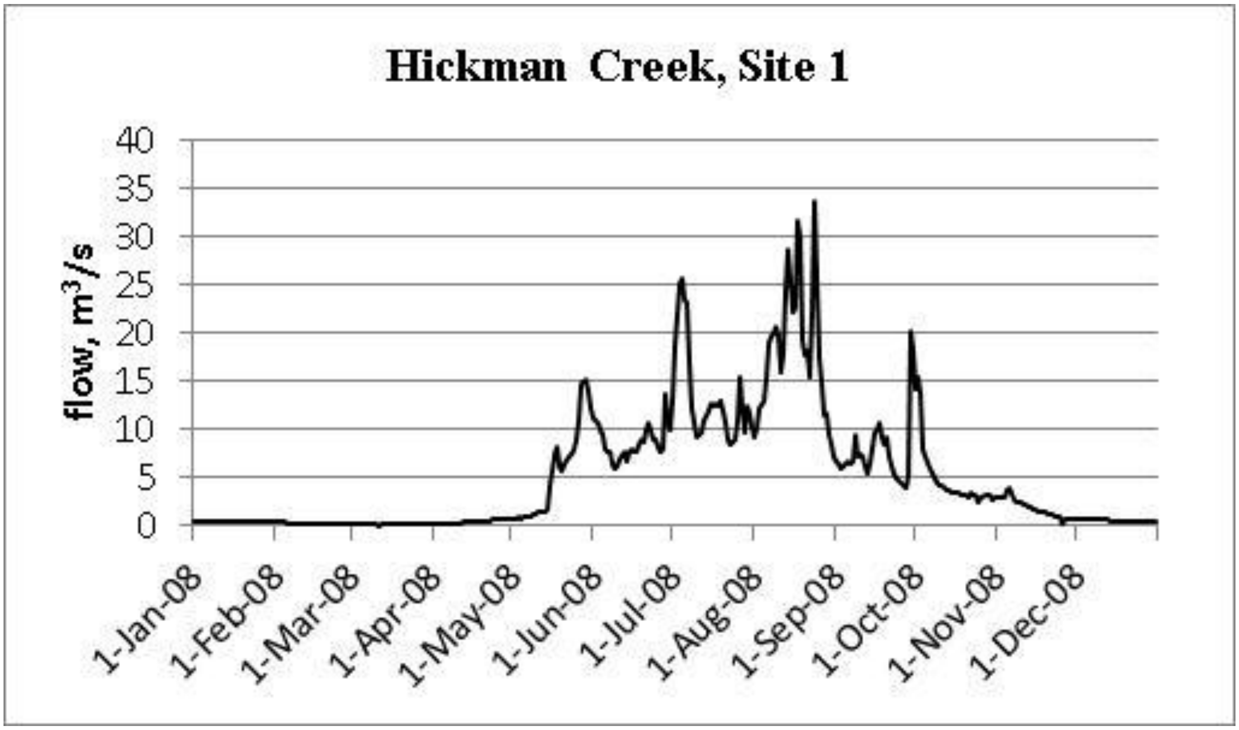

Figure 20.–Mean monthly stream flow in Hickman Creek, Site 1.

Source: RTEC 2008b.

Mess Creek and Tributaries

Mess Creek flows north from its divide with More Creek through a moderately deep valley parallel to Hickman Creek. Shortly after its origin, it forms a meandering braided creek in a broad valley with numerous wetland complexes. After 35 km it is joined by the southern outflow of Skeeter Lake. Downstream of Skeeter Lake, the creek flows into Mess Lake, after which it continues meandering through a broad valley. A large waterfall at the Mess Lake outlet likely limits migration of anadromous fish. Below Mess Lake, Mess Creek is joined by Schaft Creek. Mess Creek flows for approximately 115 km^2 to its confluence with the Stikine River near the village of Telegraph Creek. Mess Creek is considered navigable per Transportation Canada criteria.

The water quality sampling sites in Mess Creek, in order from farthest upstream to farthest downstream were MC1, MC7, MC2, MC10, MC5 and MC9. The RTEC documents for aquatic studies (RTEC 2007a, 2008b, 2010b) do not provide a description of each sampling site.

Water quality in all sample sites of Mess Creek was excellent, with low concentrations of metals (Table 36). Concentrations of Al were slightly elevated at some of the sites. Mess Creek has fairly high hardness and alkalinity; the similarity between these two values suggests that the major ions are predominantly $CaCO_3$; pH is slightly basic and both total suspended solids and turbidity are periodically elevated. Stream discharge varies seasonally (Figure 22), similar to seasonal variations in Hickman Creek.

Dates for 2006 and 2007 water quality sampling were compared with stream flow in Mess Creek, Site 1. No water quality samples were collected during high flow periods; in 2007, all of the samples were collected during periods of lower flow (Figure 22).

Table 36.–Summary of water quality data for Mess Creek sites and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L dissolved metals, except total Se. Sample replicates were not counted.

		Al	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Ag	Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
MC-1	median	4	0.39	<0.02	<0.5	0.3	<30	<0.01	0.65	<0.5	0.6	<0.01	<1
	max.	125	0.49	<0.5	0.56	0.63	64	<0.5	2.31	<0.5	1.73	<0.01	1.5
	min.	1.2	<0.1	<0.02	<0.5	0.19	<30	<0.01	<0.5	<0.5	<0.5	<0.01	<1
	count	11	11	11	11	11	11	11	11	11	11	11	11
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	2	0	0	0	0	0	0	0	0	0		0
MC-2	median	2.1	0.54	<0.02	<0.5	0.36	<30	<0.01	3.05	<0.5	0.65	<0.01	<1
	max.	103	0.69	<0.5	<1	0.9	52	<0.5	4.94	0.054	3.55	<0.01	2.9
	min.	<1	0.36	0.017	<0.5	0.23	<30	<0.01	0.91	<0.5	0.4	<0.01	<1
	count	17	17	17	17	17	17	17	17	17	17	17	17
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0
MC-4	median	4	0.69	<0.02	<0.5	<0.5	30	<0.01	1.25	<0.05	0.9	<0.01	<1
	max.	22.1	0.71	<0.05	<0.5	0.73	30	<0.05	1.8	<0.05	1	<0.01	2.2
	min.	2.1	0.53	<0.02	<0.5	0.4	30	<0.01	0.91	<0.05	<0.5	<0.01	<1
	count	5	5	5	5	5	5	5	5	5	5	5	5
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	0	0	0	0	0	0	0	0	0	0		0
MC-5	median	22.3	0.425	<0.02	<0.5	0.64	53	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	202	0.6	0.051	<0.5	1.48	156	<0.05	0.67	0.085	1.17	<0.01	3
	min.	2.2	0.23	0.017	<0.5	0.28	0.07	<0.01	<0.5	<0.05	<0.1	<0.01	<1
	count	26	26	26	26	26	26	26	26	26	26	26	26
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	6	0	0	0	0	0	0	0	0	0		0

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Table 36. Page 2 of 2.

		Al	As	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Se	Ag	Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
MC-7	median	2	0.35	<0.02	<0.5	0.2	<30	<0.01	0.79	<0.5	0.84	<0.01	<1
	max.	121	1.02	<0.02	<0.5	0.4	69	<0.01	1.01	<0.5	1.01	<0.01	2
	min.	<1	0.27	<0.02	<0.5	<0.1	<30	<0.01	<0.5	<0.5	<0.5	<0.01	<1
	count	7	7	7	7	7	7	7	7	7	7	7	7
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0
MC-9	median	26.3	0.405	<0.02	<0.5	0.7	40.5	<0.01	<0.5	<0.5	0.6	<0.01	<1
	max.	1830	1.27	0.059	2.92	1.65	3030	<0.01	5.2	1.42	0.98	0.012	10.4
	min.	3.8	0.31	0.017	<0.5	0.42	<30	<0.01	<0.5	<0.5	0.36	<0.01	<1
	count	10	10	10	10	10	10	10	10	10	10	10	10
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	4	0	0	0	0	2	0	0	0	0		0
MC-10	median	13.55	0.6	<0.02	<0.5	0.535	30	<0.01	1.135	<0.05	<0.5	<0.01	<1
	max.	40.8	1.09	<0.02	<0.5	0.94	143	0.03	3.46	<0.05	0.9	<0.01	1.7
	min.	1	0.4	0.017	<0.5	0.12	30	<0.01	0.64	<0.05	0.19	<0.01	<1
	count	18	18	18	18	18	18	18	18	18	18	18	18
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	0	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

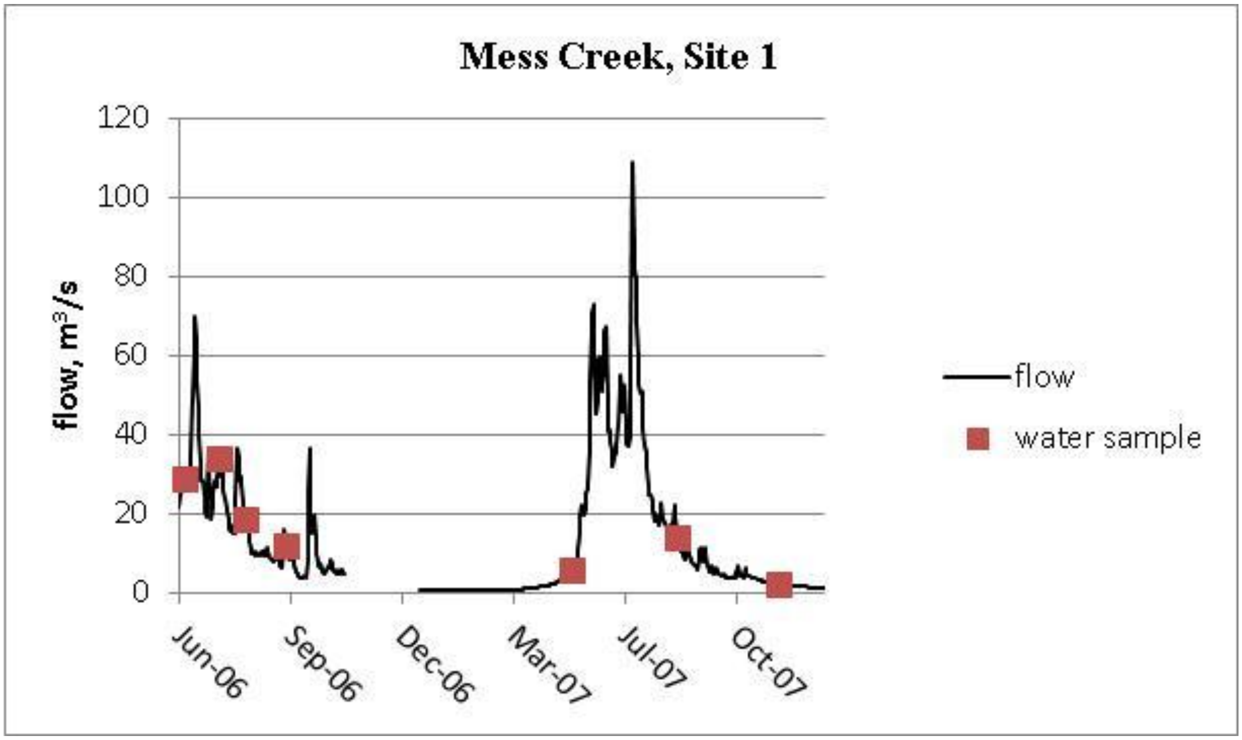


Figure 21.–Stream discharge at times when samples were collected for water quality, Mess Creek. 2006 samples on the x-axis had no associated flow data.

Skeeter Lake/Start Lake Outflows

The Skeeter Creek watershed is located in a small valley between Schaft Creek and Mess Creek near the proposed Schaft Creek Project. The watershed has a natural hydrologic divide; the northern half (which includes Skeeter Lake) flows north to Schaft Creek and the southern half (which includes an unnamed lake nicknamed Start Lake) flows south to Mess Creek. The naming and numbering of the Skeeter Lake and Start Lake sites are confusing; it appears that in 2008 the name for SK-1 was changed from Skeeter Lake outlet 1 to Start Lake outlet 1 and that SK-2 remained the outlet from Skeeter Lake. However, in the 2008 Aquatic Baseline Studies (RTEC 2010b), the sites SKC-1, SKC3 and SKC-4 refer to sites along Skeeter Creek. The confusion in these sites underscores the need to clearly define, name and locate all sampling sites. The review of water quality data from these sites is limited to those sites that are clearly defined (Table 37).

Reference Sites

Yehiniko Creek

Yehiniko Creek flows to the west of the proposed Schaft Creek project area and would be unaffected by the project. The sampling site on Yehiniko Creek is located near the confluence with the Stikine River. The water in Yehiniko Creek is of high quality with few metals (Table 38). No samples exceeded US EPA aquatic life criteria for either acute or chronic exposures.

Walkout Creek

Walkout Creek arises on the Edziza Plateau and flows west, emptying into Mess Creek approximately 8 km downstream from Mess Lake, far downstream of the proposed Schaft Creek project. Water quality is excellent; only one sample exceeded US EPA aquatic life criteria for chronic exposures of Al, no other metals were elevated (Table 39). Walkout Creek was sampled as a reference site.

Table 37.–Summary of water quality data for Skeeter Creek sites and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). All values are as µg/L, sample replicates were not counted.

		D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Hg	D-Ni	D-Pb	T-Se	D-Ag	D-Zn
	CMC	750	340	2	570	13		1.4	470	65		3.2	120
	CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
SKC-1	median	3	0.27	0.02	<0.5	<0.5	<30	<0.01	<0.5	<0.05	0.75	<0.01	<1
	max.	136	0.82	0.053	0.79	1.1	168	<0.05	0.61	0.07	3.76	<0.01	7
	min.	<1	0.11	0.017	<0.5	0.21	<30	<0.01	<0.5	<0.05	0.44	<0.01	<1
	count	31	31	31	31	31	31	31	31	31	31	31	31
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	1	0	0	0	0	0	0	0	0	0		0
SKC-2	median	3.5	0.25	0.02	<0.5	0.45	32	<0.01	<0.5	<0.05	0.71	<0.01	<1
	max.	7.1	0.33	<0.05	<0.5	0.68	133	<0.05	0.85	<0.05	3.13	<0.01	<1
	min.	2.1	0.22	0.02	<0.5	0.37	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	count	13	13	13	13	13	13	13	13	13	13	13	13
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	0	0	0	0	0	0	0	0	0	0		0
SKC-3	median	5.3	<0.1	0.02	<0.5	0.28	<30	<0.01	<0.5	<0.05	<0.5	<0.01	<1
	max.	9.2	0.13	<0.05	<0.5	<0.5	67	<0.05	<0.5	<0.05	2.32	<0.01	1.4
	min.	2.7	<0.1	0.017	<0.5	<0.1	<30	<0.01	<0.5	<0.05	0.13	<0.01	<1
	count	19	19	19	19	19	19	19	19	19	19	19	19
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	0	0	0	0	0	0	0	0	0	0		0
SKC-4	median	4.5	0.225	0.0185	<0.5	0.6	33	<0.01	<0.5	<0.05	0.545	<0.01	<1
	max.	30.3	0.4	0.02	<0.5	1.19	86	<0.01	1.08	<0.05	0.96	<0.01	2
	min.	2.1	0.18	0.017	<0.5	0.17	<30	<0.01	<0.5	<0.05	0.33	<0.01	<1
	count	20	20	20	20	20	20	20	20	20	20	20	20
	# > CMC	0	0	0	0	0		0	0	0		0	0
	#> CCC	0	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Table 38.–Summary of water quality data for Yehiniko Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). CMC All values are as µg/L, sample replicates were not counted.

	D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Hg	D-Ni	D-Pb	T-Se	D-Ag	D-Zn
CMC	750	340	2	570	13		1.4	470	65		3.2	120
CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
median	14.5	0.3	0.0185	<0.5	<0.5	<30	<0.01	<0.5	<0.05	<0.01	0.15	<1
Max.	82.3	0.39	<0.02	<0.5	3.61	68	<0.01	1.05	0.104	<0.01	<0.5	1.3
Min.	5.8	0.22	<0.017	<0.5	0.14	<30	<0.01	<0.5	<0.05	<0.01	<0.1	<1
count	7	7	8	7	7	7	7	7	7	7	7	7
# > CMC	0	0	0	0	0		0	0	0		0	0
#> CCC	0	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Table 39.–Summary of water quality data for Walkout Creek and number of samples that exceeded US EPA aquatic criteria (US EPA 2009). CMC All values are as µg/L, sample replicates were not counted.

	D-Al	D-As	D-Cd	D-Cr	D-Cu	D-Fe	D-Hg	D-Ni	D-Pb	T-Se	D-Ag	D-Zn
CMC	750	340	2	570	13		1.4	470	65		3.2	120
CCC	87	150	0.25	74	9	1000	0.77	52	2.5	5		120
median	31.7	0.16	<0.02	<0.5	<0.3	30	<0.01	<0.5	<0.05	<0.5	<0.01	1.5
maximum	90	<0.3	<0.05	<0.5	0.74	111	<0.05	<0.5	0.073	<1	<0.01	8
minimum	8.4	<0.1	0.017	<0.5	0.16	30	<0.01	<0.5	<0.05	<0.1	<0.01	<1
count	29	29	29	29	29	29	29	29	29	29	29	29
# > CMC	0	0	0	0	0		0	0	0	0	0	0
#> CCC	1	0	0	0	0	0	0	0	0	0		0

Note: CMC = acute, and CCC = chronic.

Comments on Water Quality Monitoring

Water quality samples were collected from 2005 through 2008. Frequently, new sites were added and existing sites deleted from the sampling program. The locations of the water sampling stations were not clearly defined; this report attempted to locate the sites from maps and discussions in the RTEC reports.

In 2008, water quality was sampled in 15 different stream sites in the Schaft Creek, Mess Creek, Skeeter Creek and Yehiniko Creek watersheds. Schaft Creek site 1 (SC-1) and Yehiniko Creek site 1 were reference sites. Twelve of the sites also were sampled for periphyton, benthic invertebrates and sediment quality.

Water quality samples were collected either monthly or quarterly, depending on the proximity to the mine site. RTEC (2007a, 2008b and 2010b) used standard methods for collecting samples and ensuring quality control/quality assurance.

Many of the water quality analytes were below the MRL; from 95% to 100% of the samples collected from all sites combined had concentrations of dissolved Ag, Be, Bi, Hg, Li, Sn, Ti and Tl and total concentrations of Be, Bi, Hg and Tl that were below the MRL.

Dissolved aluminum concentrations ranged from below detection limits at several sites to 540 µg/L at SC6. Total Al concentrations were higher and likely are related to sediments being transported in the streams. Dissolved Al exceeded the US EPA water quality criteria for chronic exposure in a few samples from most of the sites.

Most of the other analytes were below US EPA Water Quality Criteria for aquatic life (Tables 35 to 40). Overall, surface water in the Schaft Creek proposed project area is of good quality with low concentrations of metals.

The raw data in the 2008 document (RTEC 2010b) appear to be in the wrong columns for physical factors, nutrients and major ions. It is not possible to sort the data correctly; therefore, results that appear outside of the expected values were not used. Metals data appear correct and were used in the summary data.

There is some confusion with names and identifications of sites, especially Start Lake outflow and Skeeter Lake outflow. It appears that in 2006 or 2007 a site on Skeeter Lake was renamed Start Lake in 2008. This report compared descriptions in the RTEC descriptions of sample sites in the hydrology and aquatic baseline reports to attempt to name these sites correctly. Errors in designating the water quality data may remain.

The hydrology data presented in the 2008 document (2007 data) is labeled in Appendix 3, first page as “Summary of Daily Mean Flow (m^3/s) 2007.” This flow data on the table is labeled 2006, not 2007. It is not possible to determine if the title of the page is wrong or the dates on the mean daily flows for Hickman Creek are improperly labeled. There were no data on stream flow for the dates that water quality data were collected in many of the sites; therefore, it was not possible to determine if water samples were collected over representative flows: peak, low and average flows. These comparisons were made for Schaft Creek and Mess Creek.

Freshwater Fish Surveys

The freshwater fish surveys focused on two areas: crossings of the proposed access road and drainages in the region of the proposed Schaft Creek Mine. In addition, the fish surveys identified, or confirmed, the existence of barriers to fish migration. Fish surveys included documentation of the presence of different fish species, assessments of quality of fish habitats, and identification of spawning, rearing and overwintering areas.

Rainbow trout were distributed through Mess Creek but their distribution was more limited in sites near the proposed Schaft Creek Project (Table 40). Rainbow trout were caught in all sites; coho salmon, slimy sculpin, Dolly Varden and mountain whitefish also were caught in Yehiniko Creek. Barriers from waterfalls, canyons and turbulent flow limit the upstream migration of most fish species to the lower reaches of Mess Creek (Table 41).

Table 40.–Presence of fish and possible barriers to fish migration in the proposed Schaft Creek project area.

Site	Fish Prescence/Absence	Fish Barriers	Notes
Hickman Cr	No fish caught	Barrier on Schaft Creek	Prevents fish migration
Mess Cr	RBT found at all sites sampled, Chinook salmon and mountain whitefish in lower reaches	11 km upstream of Stikine River	Pacific salmon
		Turbulent flow at outlet to Mess Lake	May impede fish passage
Schaft Cr	RBT in lower reaches, downstream of proposed mine pit	Cascade barrier 10 km north of project site	Fish migrating upstream
Skeeter Cr	RBT in SKC-1 only	30 m high waterfall	Fish migration into Skeeter Lake
Tailings C Creek	No fish caught	Bedrock chute	May impede fish passage

Note: RBT = Rainbow trout.

Table 41.–Reference sites.

Site	Fish Prescence/Absence
Walkout Cr	RBT
Yehiniko Cr	RBT, coho, Dolly Varden, slimy scuplin and mountain whitefish

Note: RBT = Rainbow trout.

RTEC Fisheries Baseline Report (RTEC 2008c) surveyed different types of fish habitats in the proposed project area. The following descriptions are summarized from their reports.

Spawning Habitat

Spawning habitat for rainbow trout was poor throughout all of the receiving environment watersheds and in the reference site, Walkout Creek. Spawning habitat in Yehiniko Creek was rated as good.

Rearing Habitat

Rearing habitat was also poor throughout most of the receiving environment watersheds except the Mess and Schaft watersheds, where rearing habitat quality was fair. Rearing habitat in Walkout Creek was rated as poor and in Yehiniko Creek as fair.

Overwintering Habitat

Overwintering habitat quality was poor within all receiving environment watersheds except Mess Watershed, where it was rated as fair. Both reference sites, Walkout Creek and Yehiniko Creek, had poor overwintering habitat.

Wetland Habitat

Wetlands ranged from bogs laced with small, poorly defined stream channels to large ponds with multiple inlets and outlets. Some wetlands included swift, glacial-fed stream channels. Rearing habitat quality was fair to good in most wetlands surveyed, while habitat for overwintering was mostly poor to fair. Spawning habitat quality was poor in most wetlands; however, some fair to good quality spawning habitat was present in streams that flowed through wetlands. Rainbow trout were the only species captured in receiving environment wetlands (in 6 out of the 11 wetlands surveyed).

Lake Habitat

Habitat in lakes within the project area was generally fair to good for fish. Fish were found in three of the sampled lakes: Lake 1, Mess Lake; Lake 5, Start Lake and Lake 7. The presence of fish did not seem to be related to lake size but to the presence of barriers. Fish density in most lakes was low.

Mess Lake is located on the main stem of Mess Creek, approximately 55 km south of the Stikine River. The lake is large and turbid with steep slopes to the west and sloping shorelines to the east. The maximum depth of the lake was measured at 15 m. Mess Creek is the main inlet and outlet of the lake; however, numerous small streams feed the lake. Rainbow trout and resident kokanee salmon (*O. nerka*) were captured in Mess Lake.

Skeeter Lake is a relatively deep, clear lake located on Skeeter Creek in a valley between Schaft Creek and Mess Creek. Eight streams flow into Skeeter Lake, five of which contain habitat suitable for spawning and rearing fish, although no fish reside in Skeeter Lake. The main inlet and outlet is the main stem of Skeeter Creek, which contains excellent spawning, rearing and overwintering habitat. The outlet stream flows at a low gradient through a wetland with abundant deep pools, gravel substrate and cover.

Lake 3 is a long, narrow, turbid lake at the headwaters of Mess Creek. Nine tributaries flow into Lake 3; three contained suitable spawning habitat for salmonids, although no fish were found in the lake.

Lake 4 is a large, clear, relatively shallow lake located on the plateau between Schaft Creek and Mess Creek, approximately 22 km north of the Project site. Two inlet streams were identified, both were small with low flow and may provide fair rearing habitat. No spawning habitat was observed.

Start Lake is a moderately sized, deep, turbid lake located in the southern part of the Skeeter Valley, between Schaft Creek and Mess Creek. Eight inlet streams were identified, three of which contain habitat suitable for salmonid spawning. Some of the other inlets also have fair to good rearing habitat. Rainbow trout were captured in Start Lake.

Lake 7 is a small, shallow (1.3 m), unmapped lake located north of Start Lake and drains into Start Creek. Rainbow trout were caught in Lake 7.

Comments on Fish Sampling

The fish surveys and habitat surveys appear adequate to identify the distribution and relative abundance of fish in the Schaft Creek project area. The Fisheries Baseline Reports (RTEC 2007b, 2008c, 2010a) state that fish were collected for tissue analysis; to date there are no reports of fish sampled for concentrations of metals in tissues. Fish were collected for stomach analysis and adipose fins were used for genetic analysis.

The distribution of fish in the Mess Creek Watershed (including Schaft Creek) is limited by a natural fish barrier in Mess Creek. The barrier consists of 6 m high falls and an 11.5 km canyon with turbulent flow. According to the Rescan Fisheries Baseline Reports (RTEC 2007b, 2008c and 2010a), it has not been confirmed if the rainbow trout inhabiting the watershed upstream of the fish barrier is a natural or introduced population.

Periphyton and Phytoplankton

Periphyton was sampled from benthic substrates in each stream sample site in August 2006 and early September 2007 and 2008. Samples were collected at each site for taxonomic identification and for chlorophyll a content. Three replicate samples were collected from each site; standard methods were used for collection, preservation and determination of chlorophyll-a.

Phytoplankton was collected by dipping a 1 L bottle and filling it with surface water. At each site, 1 L was collected for chlorophyll and 1 L for taxonomic identification.

In both 2007 and 2008, periphyton biomass (as measured by chlorophyll a concentrations) was generally low (below 0.8 $\mu g/cm^2$) in all sites except SC1. For 2006 chlorophyll data were not included in the 2006 aquatic resources baseline report.

Diatoms were, by far, the predominant organism: from 91% to 100% of the periphyton communities were comprised of diatoms. Most stream sites had average periphyton genus richness between 5 and 12 taxa.

Aquatic Invertebrates

Benthic macroinvertebrate communities were sampled at all stream sites and from Wetland 8 in August 2006 and early September 2007 and 2008. Samples were collected with a Hess sampler. At each site, benthic invertebrate samples from three different locations were composited; a total of five composite samples were collected. Samples were sorted and identified to the lowest practical taxonomic level—usually genus. Lake benthos were sampled with an Ekman grab; as with the stream samples, three samples were composited. Zooplankton was sampled with plankton nets with three composite samples. Sample depths were recorded to calculate volumes of water sampled.

In 2008, benthic invertebrate communities were sampled in 14 streams. Macroinvertebrate density ranged from a low of 394 organisms/m^2 at SC1 to 145,763 organisms/m^2 at SKC3. In 2006, 2007 and 2008, the average density for the Skeeter Creek Watershed sites (53,317 organisms/m^2), known as *Tailings Option A*, was greater than other watersheds. The average density of sites in the Schaft watershed was 1,832 organisms/m^2.

EPT composed between 50% and 70% of the community at most sites. Site SC1 samples had only 10% EPT taxa and SKC3 only 27%. The lower numbers of taxa and biomass in Site SC1 makes it less suitable as a reference site. According to RTEC Aquatic Baseline Study (2008b), Yehiniko Creek site 1 is a better reference site because stream order, general morphology and productivity are more representative of the receiving environment. Taxonomic richness (numbers of genera) correlated with invertebrate densities, with the lowest richness in SC1 and the highest in the Skeeter Creek watershed.

Zooplankton were found in all lakes that were sampled. Populations were usually dominated by cyclopoid and calanoid copepods and contained Rotifers, Amphipoda, Bosminidae, Insecta and *Daphnia*.

Comments on Biotic Sampling

Both periphyton and macroinvertebrate samples provide baseline information to estimate the undisturbed (or preproject) conditions of the stream sites in the proposed Schaft Creek area. The sampling effort was adequate to characterize the biotic communities in each site; however, a long-term biomonitoring (postproject) program might be developed around a sampling strategy with fewer components. For example, samples of chlorophyll-a concentrations are frequently used at other mine sites for monitoring because the laboratory analysis is more cost effective and results can be obtained more quickly. Refer to the section below on a proposed sampling program.

ENVIRONMENTAL EFFECTS RISK ASSESSMENT

Discharge Limits

The same discharge limits as described for the Galore Creek Project would apply to the Schaft Creek Project.

Sources of Metals Exposure

Metals input to the Schaft Creek watershed could originate from a variety of point and nonpoint sources, including discharge from the tailings storage facility, discharge of excess water from the mine pit and uncontrolled surface runoff from waste rock storage areas and exposed mineral surfaces. Currently, there is insufficient information on water and waste management and water treatment to determine sources of metals contamination.

Predictive Water Quality Models

As of November 2010, the water management plan has not been available for review. The water management plan is a critical component to understanding how contamination of downstream watersheds will be minimized.

The report on metals leaching and acid rock drainage is preliminary; however, investigations done to date (Morin and Hutt 2008) report that paste pH showed no samples were acidic, and the Sobek Neutralization Potential suggested a long lag time (years to decades) before any sample might become acidic. Morin and Hutt recommended that laboratory based humidity cell tests should be initiated on various types and acid rock drainage categories of Schaft Creek samples and that onsite leach tests be started. It is not possible to evaluate the potential for acid rock drainage until all tests are completed.

Characterization of Background Levels

Water quality monitoring was conducted in the Schaft Creek and Mess Creek watersheds from 2005 through 2008. Data from 2008 should be verified; it appears that many of the measurements for physical characteristics (color, etc.) and major ions are mislabeled. Hydrology data also should be verified; the appendix for 2007 hydrology data for some sites contains some 2006 data and no data for 2007.

Data on metals concentrations in fish tissues was not available for this review.

Dissolved and total metals concentrations in the Schaft Creek and Mess Creek watersheds are generally low. This review compared dissolved (total for Se) metals with US EPA aquatic life criteria: few samples exceeded acute and chronic criteria for most metals. Concentrations of Al occasionally were higher than chronic criteria.

When there was sufficient water quality and hydrology data, comparisons were made of sample times and stream flow. These comparisons suggest that water quality samples were not collected at high flows and that this stream condition may not be adequately represented.

Exposure Pathways

The aquatic communities, comprised of decomposers, primary producers, macroinvertebrates and fish, would be expected to be exposed to metals concentrations along the same exposure pathways as described for the Galore Creek Project.

Comments and Recommendations

The studies for the Schaft Creek Project are preliminary with many major components not yet competed. A useful evaluation of the risk assessment for this project requires a completed water management plan and a predictive model for PAG material and its management.

LONG-TERM MONITORING OF THE GALORE AND SCHAFT CREEK PROJECTS

Monitoring of water quality and biological communities is necessary to ensure that contamination that may result from mining activities is minimized and that there are no long term detrimental effects. Water quality and biomonitoring also can alert mine operators and government agencies to potential problems so modifications can be made before aquatic systems are harmed. An effective monitoring program must be designed for the operating life of the mine, including construction, mining and close-out. Biomonitoring programs must be designed to minimize the amount of time between data collection, laboratory analysis and data analysis; the value of monitoring data is greatly diminished if there is a long lag time before results are available.

Environmental monitoring over the duration of the project should consider changes from baseline conditions and changes over the life of the project. Studies conducted to date do not have sufficient baseline data to adequately characterize these systems, especially during low and high flows. Fish tissue samples from Galore Creek included only muscle—a tissue where metals are least likely to accumulate. Fish tissue data from Schaft Creek is not yet available. The ability to detect any changes from the proposed mine projects is contingent upon sufficient and appropriate baseline data. In particular, water quality samples should be collected more frequently.

Biomonitoring has been conducted by ADF&G at various mine sites since the early 1990s. With cooperation of the operating mining company, ADF&G has designed and conducted biomonitoring at a number of sites, including the Greens Creek Mine in southeast Alaska, Pogo

Mine near Delta, Fort Knox Mine near Fairbanks, Illinois Creek Mine southwest of Galena and Red Dog Mine near Kivalina. Biomonitoring studies recently have been initiated for the Pebble Creek Prospect.

The long-term biomonitoring projects conducted by ADF&G are designed to sample a few clearly defined components of the community over a long period of time with the objective of maximizing information while minimizing both cost and time to produce data reports. Each sample site was selected for long-term monitoring and permanent stations were established.

Two separate monitoring programs are needed for the proposed Galore and Schaft Creek projects: the first should be conducted near the mine and in receiving waters, and the second should be conducted in the lower Stikine River in Alaska. The first program, to sample the mine receiving waters, should be designed cooperatively by the mining company, British Columbia and Canada government agencies and US and Alaska government agencies. This monitoring is intended to identify any changes to aquatic systems that may take place in the drainages adjacent to and downstream of mining activities. The second monitoring program would be conducted by the State of Alaska, in cooperation and consultation with other government and agencies, would focus on monitoring the lower Stikine River to ensure that aquatic resources in Alaska are adequately protected. The two monitoring programs are different in both scope and factors to be monitored. Each is discussed below.

WATERSHEDS NEAR THE PROPOSED MINE PROJECTS

Galore Creek

The following sampling sites are recommended for water quality and biomonitoring.

- Galore Creek upstream and downstream of the mine pit, tailings impoundment and waste rock dumps
- Iskut River upstream and downstream of the filter plant discharge
- Scud Creek downstream of the confluence with Galore Creek
- Other sites that may be affected by waste dumps, ore stockpiles, ore hauling, etc.
- Suitable Reference Sites, possibly Oksa Creek

Biomonitoring should include the following.

- Periphyton
- Macroinvertebrates
- Fish presence and habitat use (i.e. spawning, rearing, migration)
- Fish tissue analysis

Water quality monitoring should include the following.

- Discharge from tailings impoundment
- Discharge from filter plant

Each of the water quality/biomonitoring sites should be sampled for water, discharge, periphyton, macroinvertebrates, fish density and habitat use (spawning, rearing, migration, etc) and concentrations of metals in fish tissues, if fish are present. Descriptions of sampling methods, including quality assurance/quality control procedures are presented below.

Schaft Creek

Water quality and biomonitoring should be done in sample sites downstream of the affected area, upstream of mining activities and in reference sites. The following is a list of possible sites; the list is not inclusive and should be modified as final project plans are developed.

- Hickman Creek, locations depend on final location of tailings impoundment.
- Mess Creek: MC-1, upstream of the proposed project area.
- MC-10, east of the project.
- MC-5, downstream of the proposed project and downstream of Schaft Creek confluence
- Schaft Creek, site selection depends on final project plans. At least one site above the project, a site directly below the pit and waste rock dump and a site farther downstream
- Skeeter Creek, locations depend on final project plans. At least one site upstream of project, one at outflow of Skeeter Lake (especially if this is selected as site for tailings disposal), and one site farther downstream.
- Start Lake Outlet.
- Reference site: likely Yehiniko Creek.

Biomonitoring should include the following.

- Periphyton
- Macroinvertebrates
- Fish presence and habitat use (i.e. spawning, rearing, migration)
- Fish tissue analysis

Water quality monitoring only should include the following.

- Discharge from tailings impoundment
- Discharge from any water treatment or filter plant

Water quality and biomonitoring of the Schaft Creek project area should include the same elements described for Galore Creek: water quality and quantity, periphyton, benthic invertebrates, fish presence and habitat use and metals concentrations in fish tissues. Sampling should use the same methods (described below).

Because natural barriers limit the distribution of most fish species into the Mess Creek/Schaft Creek drainages, the target species for both fish tissue samples and distribution and abundance of fish would be rainbow trout. It may not be possible or desirable to sample fish from all of the biomonitoring sites for tissue analysis because this is a limited, and most likely, nonmigratory population. There is not enough information on the distribution of fish or the migration of fish through the different watersheds. Until more is known about the fish population in the Mess Creek/Schaft Creek drainage, collecting fish should be limited. Fish could be collected for tissue analysis in Mess Creek downstream of the project, but upstream of the migration barriers.

DOWNSTREAM REGIONS OF THE STIKINE RIVER

The following water quality and aquatic environment factors were considered for a long-term monitoring project in the lower Stikine River and Stikine Delta.

Water Quality

The water in Galore Creek contributes only 0.3% and Schaft Creek about 0.7% to the total flow in the Stikine River near Wrangell. It is unlikely that an increase in metals concentrations in either of these creeks will have a detectable effect on water quality of the Stikine River in Alaska. However, water quality in the Stikine River upstream and downstream of the mine receiving waters is a critical component of the long-term monitoring program.

Sediment Quality

The Stikine River in Alaska is downstream of many rich mineralized areas, as documented by the long history of mining in this region. Over thousands of years, these regions have gradually eroded and sediments have been carried downstream. In addition, early mining frequently discharged sediment and metals-laden water directly into river systems with little or no treatment. The lower Stikine and the Stikine Delta are depositional areas and subject to accumulation of metal-laden sediments. The lower Stikine and the delta also are critical habitat areas for migratory waterfowl, shellfish and juvenile salmonids.

There are two possible approaches to monitoring sediment quality in the lower Stikine regions. The first is to collect and analyze sediment samples for metals and compare them with baseline data. This requires that the baseline data are adequate to provide good representation of pre-mining conditions. The second approach is to sample organisms inhabiting these regions for metals concentrations (see below). Juvenile and small fish should be analyzed as whole body samples, large fish should be sampled only if they have resided in and fed in these areas for a defined time period—at least a month. If larger fish are sampled, discrete tissues (liver, gill, kidney and muscle) should be analyzed separately.

Fish and Shellfish Tissues

Fish should be collected and sampled for whole body concentrations of metals. Staghorn sculpin was collected during baseline and is likely the best target species for sampling estuarine habitats. If possible, samples of salmon smolt during outmigration should be collected and analyzed for whole body concentrations of metals. Although it is likely not possible to identify the water bodies where these fish have reared, any detectable changes in metals body burdens would alert state and federal agencies to possible upstream contamination.

Juvenile and small fish should be analyzed as whole body samples with at least 10 replicates per year. Large fish should be sampled only if they have resided in and fed in these areas for a defined time period—at least a month. If larger fish are sampled, discrete tissues (liver, gill, kidney and muscle) should be analyzed separately; at least six replicate adult fish should be collected. Sampling methods are described in greater detail below.

Distribution and Abundance of Fish and Shellfish

The proposed Galore and Schaft Creek mines and infrastructures are in watersheds that drain to the Stikine or Iskut Rivers. Five species of Pacific salmon use the Stikine River watershed for migration and spawning; three species rear in this watershed and all species likely use the associated wetlands, tributaries and estuarine habitats.

Sockeye and Chinook salmon are the most valuable salmon resources in the Stikine River watershed. Most of the spawning occurs in Canadian waters, rearing for one to three years is in the Stikine watershed, and then the fish migrate to Alaska waters where the majority of growth occurs. ADF&G has estimated that the combined sockeye salmon returns from the Mainstem Stikine River and Tahltan Lake ranged from about 36,000 to 400,000 fish during 1979–2002.

ADF&G and Canada and British Columbia government agencies have monitored salmon populations in the Stikine River for more than 30 years. The continued monitoring of these populations is an important component of the biomonitoring for the proposed mining projects.

Fish and shellfish should be sampled in the Stikine River delta to detect any changes in the populations during mine operation.

Locations of Sampling Sites

The US Department of Interior (Pamela Bergman, Regional Environmental Officer, Department of the Interior, to Anne Currie, Project Coordinator, Environment Assessment Office, British Columbia, April 20, 2005, letter) recommended that the lower Stikine River site (Stik-8) be moved from Kadin Island to Sergief Island and that water and sediment samples be collected quarterly and tissue samples annually at the new Stik-8 Sergief location. This change in location should be considered for the long-term biomonitoring program.

RECOMMENDED SAMPLING METHODS

Identification of Sample Sites

Permanent sampling stations should be established at the onset of the monitoring program. Stations should be clearly marked, described (below the confluence of . . ., below tailings effluent, etc.) and exact locations determined and recorded. All sites downstream of a confluence or an effluent discharge should be located below the zone of complete mixing.

Water Quality

Samples for water quality should be collected on a regular and frequent basis (at least once per month, perhaps every two weeks depending on sample variability and stream flows). Samples should be collected to represent the range of stream flows, from low water to peak flows. Samples from larger water bodies should be either depth-integrated or integrated across the stream channel, as appropriate. The list of analytes can be trimmed from the baseline sampling, for example, metals sampled during baseline that consistently fell below the MRL's could be eliminated unless they are known to be part of the ore deposit. Although cyanide was below the MRL in nearly all samples, if should be included in water quality monitoring during mining if it is used in ore processing.

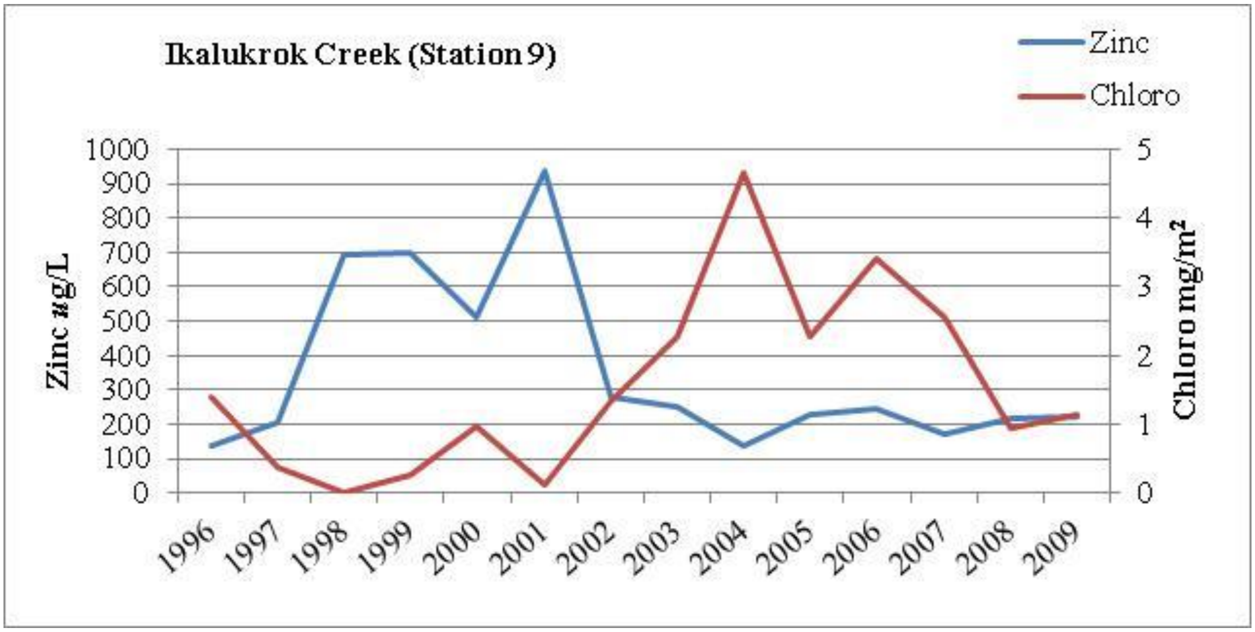
Stream gauges should be installed at all water sampling stations (where possible) and stream flows (or stage) should be recorded when water samples are collected.

Quality Assurance/Quality Control

Water samples should be collected according to Standard Methods (APHA 1992 or later) in pre-cleaned bottles and preserved with a preservative appropriate for the type of sample or analysis (Ryan et al. 2005). Both field and travel blanks should be used for each sampling event and 10% of the samples should be duplicated. The analytical laboratory should provide a standard quality assurance program.

Periphyton Standing Crop

Periphyton, or attached micro-algae, is sensitive to changes in water quality, especially metals (Hill et al. 2000, Crossey and LaPoint 1988). Hill et al. showed that chlorophyll-a content of periphyton showed significant downstream decreases associated with increasing dissolved metals concentrations; however, numbers of periphyton genera and community similarity were not significantly correlated with metals concentrations. Long-term monitoring at the Red Dog Mine showed definite responses to concentrations of different metals (Figure 22,). The presence of periphyton, as evidenced by concentrations of chlorophyll affirms continued *in situ* productivity.



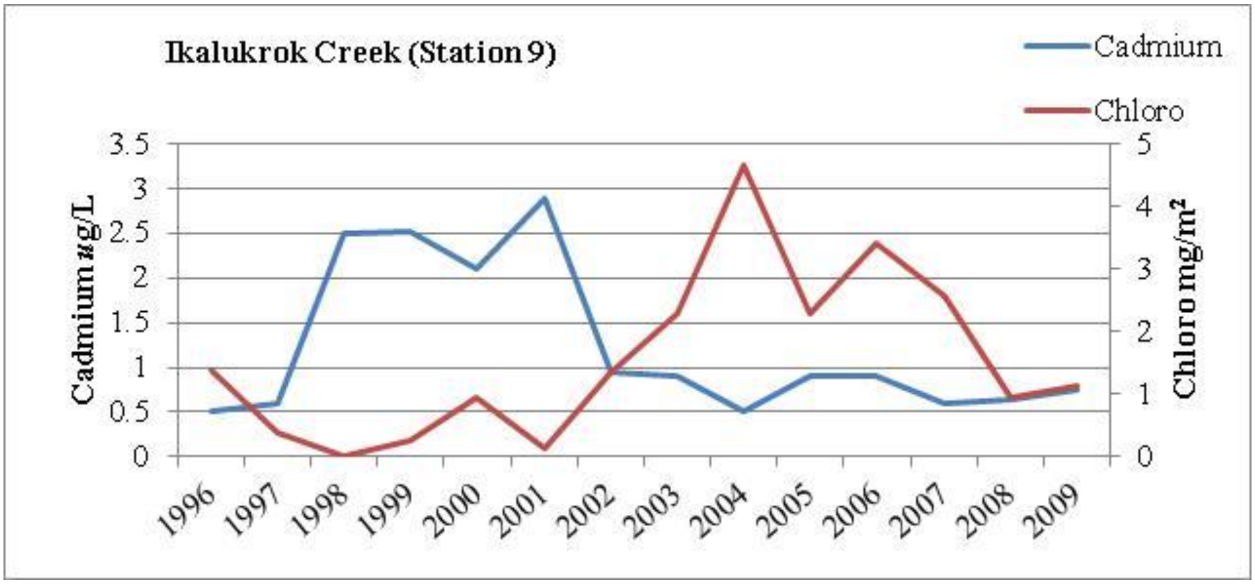


Figure 22.–Concentration of Zn and Cd and concentration of chlorophyll-a at Station 9 in the Red Dog Creek area. Station 9 is unaffected by the Red Dog Mine, but receives flow from naturally mineralized tributaries.

Source: A.G. Ott PhD., Operations Manager, ADF&G, Fairbanks, AK, personal communication

Although periphyton samples for taxonomic identification can reveal much about stream biodiversity, such samples are expensive to analyze and the inherent variability from natural factors (such as stream freshets) can make interpretation difficult. In contrast, measurements of chlorophyll concentrations are relatively inexpensive and take little time to analyze. These factors allow samples to have a meaningful number of replicates and results that are available soon after collection.

Periphyton is sampled directly from cobble on the streambed. According to methods defined by Ott et al. (2010), sampling is done once per year, during the summer and only under low flow conditions. Sampling during low flows ensures that the submerged cobble material has been wetted continuously. Sampling should not follow high water events when stream beds may have been subjected to scour.

Field Methods

Periphyton is brushed from flat rocks and washed onto a 47 um glass fiber filter. First, the flat rock is removed from the stream and a small square of closed cell foam placed on the rock. The size of the foam patch should be large enough (for example, 5 × 5 cm) that most of the samples will have a detectable amount of chlorophyll. All attached periphyton is removed from around the foam square and then the area is rinsed with a wash bottle. After rinsing the brush, the foam square is removed and the remaining periphyton under the foam is carefully brushed onto the filter held in a hand-operated vacuum pump. Sufficient water from the wash bottle is used to rinse all dislodged material onto the filter. After pumping out most of the water, about 3 to 5 drops of saturated, resuspended $MgCO_3$ is added to the filter, then all remaining water is pumped out. The $MgCO_3$ is added to prevent acidification and degradation of chlorophyll-a to phaeophytin.

After removing as much water as possible, the filter is removed, folded in half with the sample enclosed, and wrapped in a dry larger filter, such as a coffee filter. The dry coffee filters are used to absorb any residual water. The samples are placed in a labeled, sealable plastic bag with silica gel desiccant and placed in a light-proof container with ice. Periphyton samples must be kept dry and in the dark; the samples should be frozen as soon as possible. A minimum of 10 replicate samples should be collected from each site. Replicates are separate samples collected at the same time and place under identical circumstances and treated exactly the same throughout field and laboratory procedures. Analyses of field replicates give a measure of the precision associated with sample collection, preservation and storage, as well as with laboratory procedures.

The recommended holding time at –20°C is about 1 month.

Laboratory Methods

Periphyton samples are analyzed for concentrations of chlorophyll-a, -b and -c in a split-beam spectrophotometer, according to methods described by APHA (1992 or later) and Arer (1997). Before chlorophyll analysis begins, the spectrophotometer should be calibrated and checked. The instrument is first zeroed with a 90% acetone blank, then the linear dynamic range and the estimated instrument detection limits are determined. See descriptions of these procedures under Quality Assurance/Quality Control.

Periphyton samples are removed from the freezer, the glass fiber filters are cut into small pieces, placed in individual 15 ml centrifuge tubes with 10 ml of 90% spectrophotometric grade acetone, and soaked overnight in a dark refrigerator. Sample identification, the amount of acetone added and the time that acetone was added should be recorded. Tubes are wrapped in aluminum foil to ensure they remain completely dark during the extraction. Within 24 hours of adding acetone (but not less than 2 hours), samples are placed in a centrifuge and spun at 1600 rpm for 20 minutes. Samples are then decanted individually into cuvettes and absorption values at 750 nm, 664 nm, 647 nm, and 630 nm are recorded on a split beam spectrophotometer. About 0.08 ml of 0.1 N HCl acid is then added to each cuvette and the sample covered to exclude light for about 90 seconds. Absorption values at 750 nm and 665 nm are recorded.

Most standard methods, including those described by APHA (1992) and Arer (1997) include an additional step of grinding the filters in acetone with a tissue grinder. ADF&G has opted to omit this step because it was exposing the technicians to large amounts of acetone. Tests of chlorophyll analysis with and without grinding did not produce significant differences in chlorophyll content. Freezing samples before analysis lyses the cells and may be sufficient without grinding.

Spectrophotometer readings are used to calculate chlorophyll-a, -b, and -c concentrations using tri-chromatic equations (APHA 1992). Concentrations of phaeophytin are calculated to correct chlorophyll-a concentrations.

Quality Assurance / Quality Control

The Linear Dynamic Range of the Spectrophotometer (LDR) should be determined before sample analysis. The LDR is the absolute quantity or concentration range over which the instrument response to an analyte is linear. The LDR is determined with chlorophyll standards or a preparation with fresh spinach that are serially diluted. The serial dilutions also can be used to establish the estimated detection limit.

To establish the LDR and the estimated detection limit, a minimum of five standard solutions ranging in concentration from 1 to 15 mg/L should be prepared. The standard solutions can be made from available chlorophyll standards or fresh spinach. Spinach leaves are placed in a 90% spectrophotometric grade acetone solution, covered in aluminum foil to exclude light and soaked overnight in a refrigerator. Chlorophyll standards should be prepared according to the accompanying directions.

The spectrophotometer is first zeroed with an acetone blank. The acetone blank should be read periodically throughout the run.

The dilutions are read on the spectrophotometer and a linear regression of absorbance response vs. concentration should be calculated. The constants, m and b, where m is the slope and b is the y-intercept should be determined. Incrementally higher concentrations should be measured until the measured absorbance response, R, of the standard no longer yields a calculated concentration that is ±10% of the known concentration. That concentration defines the upper limit of the instrument; however, all samples should read well below the upper limit of the LDR, ideally between 0.1 and 1.0 AU.

The instrument detection limit is established with serial dilutions of chlorophyll standard until the response at the selected wavelength is between 0.005 and 0.008 AU.

Filter blanks are processed and run on the spectrophotometer. Two new filters are placed on the laboratory bench before any sample preparation. Both filters are prepared in the same way as the sample filters; one blank filter at the beginning of the sample run and one at the end. These filters serve as laboratory blanks to check for contamination. Sample duplicates are analyzed from dividing the acetone in a select number of filter extracts. A minimum of two sample duplicates is analyzed in each sample run.

Benthic Macroinvertebrates

Aquatic invertebrate communities are sampled to ensure the continued productivity and biological integrity of sites that may be affected by the proposed mine. Reference sites are sampled for comparison and to detect variations from natural conditions, including weather, freshets, etc. EPT are sensitive groups that readily respond to environmental stresses.

Sampling benthic invertebrates can be done by either a stream bottom sampler, such as a Hess Sampler, or by drift nets. Invertebrate sampling is usually more effective with either drift or bottom samplers, depending on physical features of the site. For example, ADF&G uses modified Hess samplers at the Greens Creek Mine site and drift nets at the Red Dog Mine Sites. These two methods should be tested to determine which approach is more effective and to determine the length of time needed for drift nets to collect an adequate sample—reported sampling times vary from 1 to 24 hours, depending on the site. If drift nets are used, stream flow should be measured at each net to estimate the volume of water flowing through the net.

A minimum of five replicate samples should be taken from each site. Samples should not be collected after storm events when the community may have been dislodged. Because sorting, identification and enumeration of benthic invertebrate samples are both time-consuming and costly. In addition, these samples have inherent high variability. Therefore, the sampling schedule can be adjusted to provide maximum benefit—for example, samples could be collected one per year for the first three years of mine operation to establish a solid data base about the community. If water quality conditions in the receiving waters are stable, invertebrate sampling can be conducted at longer time intervals, such as once every three or five years.

Metals Concentrations in Juvenile and Adult Fish

Muscle tissue, as was sampled in the baseline studies, does not accumulate most of the metals of concern at the proposed Galore Creek mine. Fish should be sampled either as whole body juveniles or as discrete tissues (gill, liver, kidney, reproductive [if available], and muscle) from adult fish.

Baseline fish sampling by Rescan (2006) suggests that juvenile fish inhabit many of the drainages downstream of the proposed mine and filter plant. Therefore, whole body juvenile fish samples are most likely to provide the best characterization of metals uptake and concentration by fish.

Pilot tests for the tailings effluent (Rescan 2006) suggests that most metals in the tailings effluent have an expected concentration less than the MRLs. However, metals in stream water also may come from erosion of exposed mineralized areas, seepage water and water flowing through waste rock. Background information on the ore deposit suggests that target metals for tissue monitoring might include Cu, Pb, Mo, Zn, Se and Al. This list is not intended to be inclusive. The decision about which metals should be monitored should be made by the state, provincial and federal agencies. Results from early sampling may result in modifications of laboratory analysis—if specific metals are consistently below the MRLs, they should be considered for elimination in future samples.

ADF&G (Ott et al. 2010) has described methods for collecting juvenile fish for tissue analysis. According to their methods, fish are collected from each sample site one each year, as close to the same time as possible—late summer is usually the preferred time for collection because it allows for maximum residency time before fish move to overwintering areas or outmigrate. Fish are collected with minnow traps baited with salmon eggs. Fish of the same species (likely juvenile Dolly Varden) and the same age/size class (usually between 90 and 140 mm fork length) should be selected. Fork length and weight are recorded in the field. Clean techniques for collecting fish, as described by Ott at al. (2010) should be followed, including wearing clean gloves to handle fish.

Experience of ADF&G has highlighted the importance of establishing a numbering system that can be used every year and provides sufficient information about the sample. For example, ADF&G uses a label code in the form of 081005MSRDDVJ1, where the first 6 characters give the date, characters 7–10 refer to the stream, characters 11 and 12 identify the species of fish (Dolly Varden), character 13 signifies that it is a juvenile (J), and character 14 identifies the number of the sample replicate (fish 1, fish 2, etc.). The individual plastic bags containing juvenile fish are numbered consecutively.

Fish should be collected for tissue samples from More-5, Oksa Creek (Ref-1), Galore 3, Stikine Site 1, Stikine Site 2 and the Iskut River upstream and downstream of the discharge from the filter plant. A minimum of 10 fish should be collected from each site.

Quality Assurance/Quality Control

Clean techniques should be followed for handling fish, including wearing niter gloves, using only new, clean sample bags and placing fish in a clean cooler. All samples should be clearly labeled.

Laboratory analysis should include a full quality assurance/quality control program, including matrix spikes, standard reference materials, laboratory calibration data, sample blanks, and sample duplicates. All raw data, including laboratory calibration curves and internal quality control should be included in the laboratory report.

If adult fish that are sufficiently large, duplicate samples can be taken. Tissues from one fish per sample event (all samples from the year) can be split in half and submitted to the laboratory as a duplicate. These samples should be labeled as though they are an individual fish. The collector should consult with the laboratory to determine the minimum weight of sample required for analysis—usually 2 to 5 grams. If tissues are too small for the minimum weight, they should not be split.

Fish Presence and Use

The objectives of the fish monitoring study are to assess distribution and use of streams and to determine any disruptions in fish communities. Fish monitoring should focus on the distribution and relative catch of juvenile fish at the defined sample sites, including both sites potentially affected by the mine as well as reference locations.

Fish presence and use can be assessed by a variety of methods, including visual and aerial surveys, baited minnow traps and fake nets. Because of possible damage to fish vertebrae, electro shockers are not a preferred sampling method. The choice of sampling method depends on the time of year sampling is done and physical features of the stream system. However, consistency should be maintained in sampling method, sampling effort and seasons that fish are sampled.

Minnow traps should be baited with treated salmon roe placed in perforated plastic bait sacs. Salmon eggs are pretreated with a 1% solution of betadine for at least 10 minutes. Rocks are picked from the streambed and placed in each minnow trap to both hold the trap and bait in place and to provide refuge for fish caught in the trap. Traps are placed in moving water and not in backwater areas if the target species has a preference for higher velocity water, as do juvenile Dolly Varden. Traps are numbered for each sample reach and are fished for 24 hours. Each sample reach is permanently marked with an upper and lower point; the same reaches are sampled every year although the locations of individual traps may vary within the reach due to natural changes in the stream and variations in stream flow at the sample time

All collected fish should be identified to species and measured to fork length. Fish should be kept in water until measured and then released close to the site of capture.

Spawning fish should be counted at the time of the spawning run and the upstream extent of spawning should be noted.

Biomonitoring Reports

Reports of the annual biomonitoring should be made available to all state, federal and provincial agencies as early as possible after data collection. In addition, agencies should be notified of any substantial changes identified in the sampling program, such as a large increase in metals concentrations in fish tissues. Protection of downstream environments requires that agency and mining company officials can take corrective actions quickly. An electronic file of all raw data should be made available to regulatory agencies.

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