Technical Report No. 12-01

Taku-Tulsequah River Mining Activity: Background Environmental Monitoring and Potential Mining Effects

by

Phyllis Weber Scannell

December 2012

Alaska Department of Fish and Game Division of Habitat

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Special Publications and the Division of Commercial Fisheries Regional Reports. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

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By
Phyllis Weber Scannell
Scannell Scientific Inc.
Prepared for the Alaska Department of Fish and Game
Division of Habitat

Alaska Department of Fish and Game
Division of Habitat, Southeast Region
802 W. 3rd Street, Juneau, Alaska, 99824-0024

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Phyllis Weber Scannell
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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

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EXECUTIVE SUMMARY

The proposed Tulsequah Chief Mine is located in British Columbia, Canada, on the Tulsequah River near its confluence with the Taku River, approximately 31 km from where the Taku River crosses the U.S./Canada border. The region contains three inactive mines: Tulsequah and New Polaris on the Tulsequah River, and Big Bull on the Taku River a short distance upstream of the confluence of the two rivers. The Taku River flows across the U.S./Canada border and empties into Taku Inlet, in the U.S.

The Tulsequah and Taku valleys were explored for minerals, especially gold, as early as late 1800s; polymetalic massive sulfide deposits were reported in the late 1920s. In 1937, the Polaris-Taku Mine was brought into production, followed by the Tulsequah Chief Mine. All hardrock mining in this region was suspended in the 1950s.

Since the late 1980s, various mining companies have considered reopening the Tulsequah, New Polaris and Big Bull Mines. A number of environmental assessment, water quality and hydrologic studies have been conducted to support the reactivation of mining in this region. At the time of this report, the mining sites are undergoing exploration and delineation of the ore deposits; an airstrip and local access road have been constructed.

There is existing acid rock drainage from early mining; it emanates primarily from abandoned waste rock piles and exposed rock surfaces. Acid rock drainage and associated metals leach into the Tulsequah River and may affect aquatic populations, including spawning and rearing anadromous fish. The Taku-Tulsequah Drainage is an important transboundary system that supports 21 fish species, including all five species of Pacific salmon. The Taku River has been identified as the largest salmon producing river system in Southeast Alaska.

The objective of this report is to provide supporting information to resource agencies for future review and permitting of hard rock mines in the Taku-Tulsequah Drainage. The document contains three sections: A description of the mineral resources and past mining; a summary of resource information on hydrology, water quality and fish and wildlife; and identification of information needs and recommendations for long-term environmental monitoring.

INTRODUCTION

THE TAKU-TULSEQUAH WATERSHED

Early History of Mining

The Tulsequah and Taku valleys were explored for minerals, especially gold, as early as the late 1800s (SRK 2010; Figure 1). The Taku River provided transportation to the Klondike gold fields in the 1890s and later became an important route into interior northern British Columbia (BC).

Prospecting and mining in this watershed dates from the early 1920s; by the late 1920s, polymetalic massive sulfide deposits were reported. The three mine sites associated with the Tulsequah River drainage were Polaris Taku, Big Bull and Tulsequah Chief (Figure 2).

In 1937, the Polaris Taku mine was brought into production. This mine consisted of a 200-ton-per-.day mill and operated until the early 1950s. The Polaris-Taku mine produced 231,000 ounces of gold.

Prospectors discovered gold at the mine site in 1929. The New Polaris mine, then known as Polaris Taku mine, was built in 1936 and commissioned a year later. It operated until 1942, shut down during World War II and then restarted in 1946 and operated until 1951. In 1951, a barge loaded with gold concentrate sunk off of the coast of British Columbia in a violent storm; the Polaris Taku mine was subsequently shut down.

The Polaris Taku mine produced 232,000 oz gold from 15,796 m of underground development on 10 levels and 3,747 m of raise development. The lowest level of the mine is 187 m below sea level. Work at the Polaris Taku mine was suspended for 30 years until exploration was resumed in 1988 by Canarc and the mine was renamed New Polaris. The total resource at New Polaris (as of 2007) is 1,028,000 oz gold contained within 2,349,000 metric tonnes of mineralized vein material at an average grade of 13.56 grams per metric ton (0.4 oz. per U.S. ton).

The New Polaris project is situated in northwestern BC, 100 km south of Atlin, BC, and 60 km east of Juneau, Alaska, on the west bank of the Tulsequah River near the BC/Alaska border. The Tulsequah Chief Mine is located about 100 km south of Atlin, BC on the east side of the Tulsequah River (Figure 2) and about 10 km north of its confluence with the Taku River. The massive sulfide deposit has concentrations of Au, Ag, Cu, Pb, Zn and Cd. The Big Bull Mine is located approximately 10 km south of the Tulsequah Chief site and closer to the Taku River.

In 1947, exploration and production commenced at the Big Bull and Tulsequah Chief deposits. A road was constructed to connect the mine sites to the Taku River. Cominco owned and operated the Tulsequah Chief and Big Bull deposits and in 1952 leased the Polaris Taku site for ore processing. Ore from the Big Bull and Tulsequah Chief mines was trucked to the Polaris Taku site on the west side of the Tulsequah River where it was concentrated. The Big Bull mine produced Cu, Pb, Zn, Au and Ag from three underground levels until 1955, when low metals prices and more favorable economics at the Tulsequah Chief site forced Cominco to suspend mining activity at the Big Bull site. Cominco continued operation of the Tulsequah Chief mine until 1957.

Proposed Reopening of Mines

In 1981 Redfern Resources acquired an interest in the Tulsequah claims and began exploration. Drilling and characterizing the ore body began in 1987. In 1992, Redfern purchased Cominco's interest and continued exploration. In 2007, Redfern initiated mine permitting and development programs. Studies were initiated to address potential effects of mining, including studies of fish, wildlife, water quality and economic feasibility. Most of these studies were done by Gartner Lee Associates, under contract to Redfern. Between 2007 and 2009, the project was granted a number of operating permits; this allowed construction of more than 20 km of onsite roads, an airstrip and clearing for the mill and waste rock storage areas. In spring 2009, Redfern Corp. filed for bankruptcy.

In January 2010, Chieftain Metals Inc. negotiated to purchase the mining interests, including 13 mineral claims, 25 crown-granted assets and 4 fee simple lots. The purchase agreement included the partially constructed water treatment plant for the Tulsequah Chief Mine (SRK 2010). Title to the property and assets were transferred to Chieftain Metals in September 2010. Included in the transfer was the BC environmental assessment certificate along with other permits.

According to the Chieftain Metals Inc. website, the Tulsequah Project is "at an advanced development stage and covers two previously producing mines, the Tulsequah Chief deposit and the Big Bull Deposit…" A press release from Chieftain Metals Inc. (2011) stated "The Interim Water Treatment Plant is being commissioned and is on target to be completed by month end."

Figure 1.–Taku and Tulsequah River drainages.
Source: Map adapted from Google Maps, Inc.

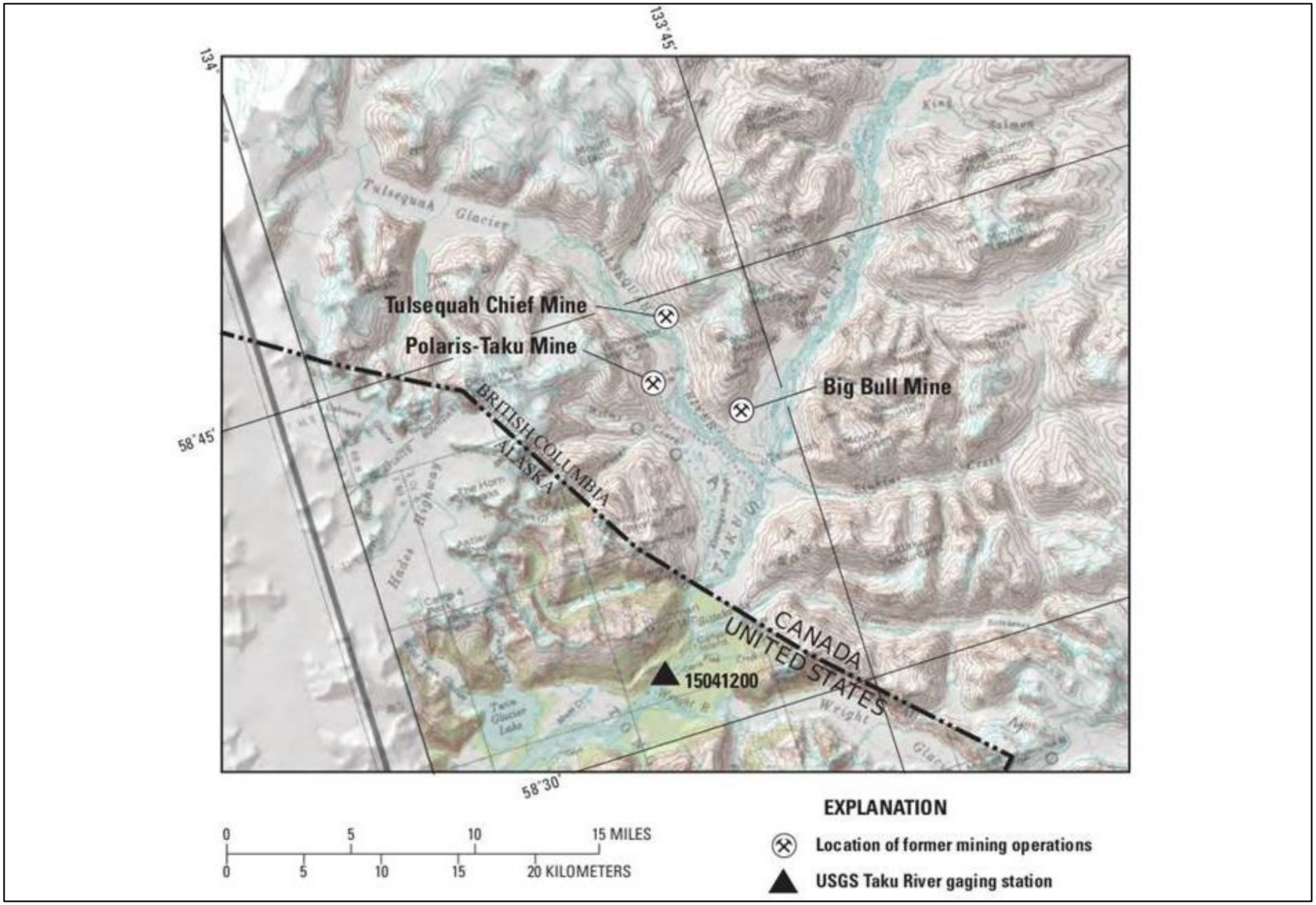

Figure 2.–Locations of Tulsequah Chief, Polaris and Big Bull mines.
Source: Map adapted from Neal 2007.

The Chieftain Metals press release (November 2011) described the current mining plans:

> Chieftain plans to build a new underground mine adjacent to and beneath the old workings. The property was originally developed by Cominco, and it operated from 1951 to 1957. The existing 5200 and 5400 level adits will be used as the primary access to the mine for all personnel, mine services, equipment and supplies. The adits will be enlarged to accommodate modern diesel trackless equipment.
>
> Access to the various mining levels will be provided by a spiral ramp located in the hanging wall of the deposit. This location was selected because of the predominantly non acid-generating nature of the hanging wall stratigraphy, as compared to the potentially acid-generating footwall. Ore will be trucked to the surface.
>
> Mining levels will be located at 30-metre vertical intervals. Each will be connected to an inclined ventilation raise to provide fresh air ventilation supply, vertical translation of services, and emergency egress to each level. Loading of trucks will be done on each mining level to minimize load-haul-dumper travel distances. The deepest mining level will be located 750 m below the 5200 level.
>
> Sub-level stoping will be the primary mining method employed. A minor amount of mechanized cut-and-fill stoping will be used in narrower portions of the ore body. Paste backfill and unconsolidated loose waste rock will be used for backfill for both methods. Where backfill walls will be exposed by future adjacent mining, additional cement will be added to the paste fill for strength.
>
> Waste rock will be preferentially retained in the mine as loose unconsolidated rock fill in secondary stopes. Waste that is required to be removed from the mine will be hauled by truck to the segregated waste dumps on surface for proper storage and reclamation."

According to a report by SRK (2010), current access to the mine is limited to fixed-wing aircraft or helicopter from Atlin or Juneau. There are three airstrips: a gravel strip at northwest of the confluence of the Taku and Tulsequah Rivers, an airstrip at the Polaris Taku mine site and a gravel airstrip west of Shazah Creek.

SRK (2010) stated "Shallow-draft boat access is available to the confluence of the Tulsequah and Taku Rivers; however, the Tulsequah River is not easily navigated due to high and variable flows, debris hazards and shallow areas. Hydrographic assessments determined that the Taku River broadens to extremely shallow water in its lower reach before the Taku glacier. Channel locations within this area vary and would require more or less continuous dredging during the shipping season to maintain an open channel." Road segments that had been previously built for the Tulsequah Chief and Polaris Taku mines are mostly overgrown and unusable. Access, both to the mine and to ship concentrate, is a major challenge to development.

HYDROLOGY

The hydrology and channel morphology of the Tulsequah River are largely influenced by natural breaching of glacial dammed lakes and resulting catastrophic floods (Neal 2007). The Tulsequah glacier, at the headwaters, impounds Tulsequah Lake (actually three small lakes) and Nolake Lake. The glacial outburst flood waters shape the Tulsequah River into a broad gravel bed floodplain which is mostly dry and with sparse vegetation (Neal 2007).

Neal (2007) provided an in-depth description of the hydrology of the Taku River and the effects of seasonal outburst floods. According to Neal, the Taku River drainage area is approximately 6,600 mi^2 with a mean annual flow of 13,700 cfs (ft^3/s). The minimum monthly mean flow is 1940 cfs in February and the maximum monthly mean flow is 34,400 cfs in June. Glacial lake outbursts can result in instantaneous peak flows as high as 128,000 cfs, although most peak flows are in the range of 60,000 to 80,000 cfs. Outburst floods are followed by a rapid decrease in stream flow, usually lasting 12 to 18 hours (Figure 3).

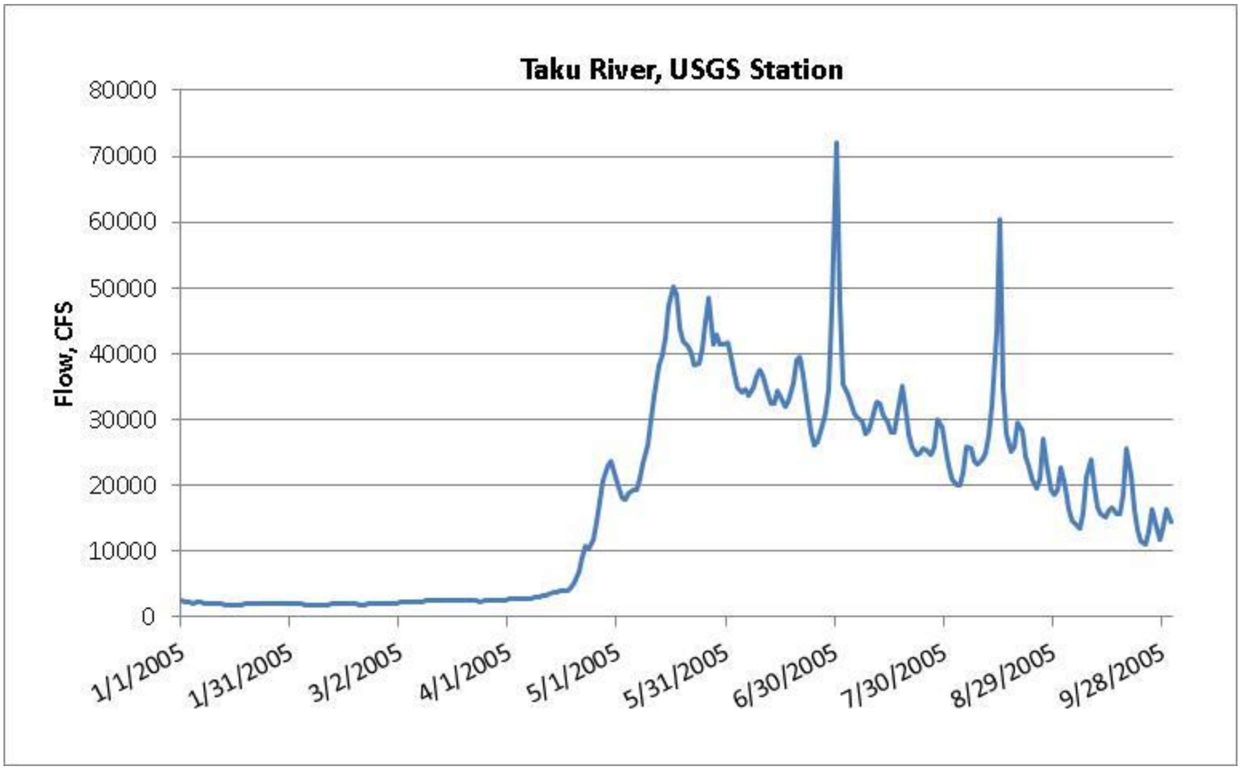

Figure 3.–Average daily discharge in Taku River at USGS Monitoring Station, 2005.

The U.S. Geological Survey (USGS) has operated a gauging station on the Taku River (Figure 2) from July 1987. The USGS data includes discharge and gauge height for the period of record and water temperature through 2005 only. In addition, the USGS record contains temporary data on water temperature, air temperature, wind speed and wind direction data. These data are available for 120 days.

Discharge into the Taku River is low from January through the beginning of April, and then increases with snowmelt. Seasonal storms account for the smallest peaks; however, the large peaks result from outbursts. Average daily flows from 2005 are presented as an example for this site.

The USGS also operated a gauge for peak stream flows in the Taku River upstream of the Tulsequah confluence from June 1953 through July 1987 (Station Number 15041100, Figure 4).

Figure 4.–Location of USGS peak flow gauge No. 15041100 on Taku River upstream of Tulsequah.

The daily peak flows from the Taku River site upstream of the Tulsequah Confluence (Figure 5) show similar peaks from local storms; however, there are no large spikes as seen in the downstream site. Peak flows from 1986 are presented as an example for this site.

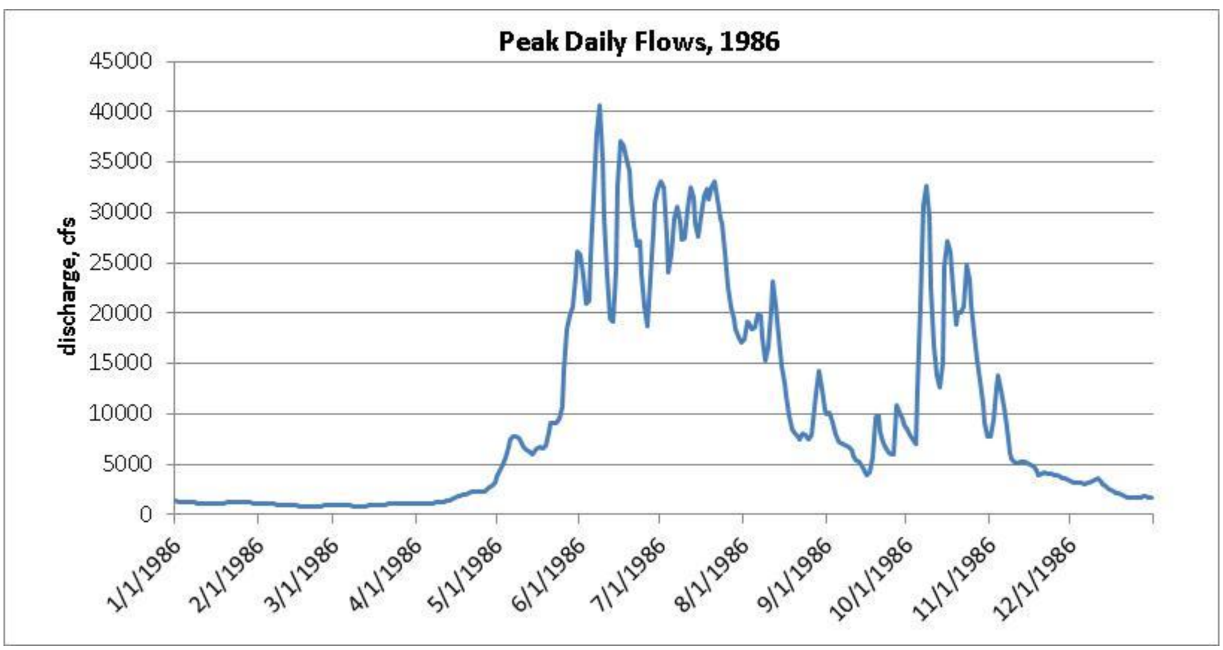

Figure 5.–Peak daily flows at USGS Station 15041100, Taku River upstream of the Tulsequah.

WATER QUALITY

REVIEW OF WATER QUALITY STUDIES

Water quality has been sampled throughout the Tulsequah and Taku river drainages (Figures 6–8; Table 1). Most of these studies were designed to meet specific objectives, such as developing mass balance relationships or evaluating the effects of glacial outburst. There has not been consistent monitoring of these rivers from established monitoring sites. The different water quality studies are briefly described below, followed by a description of the water quality of select sites.

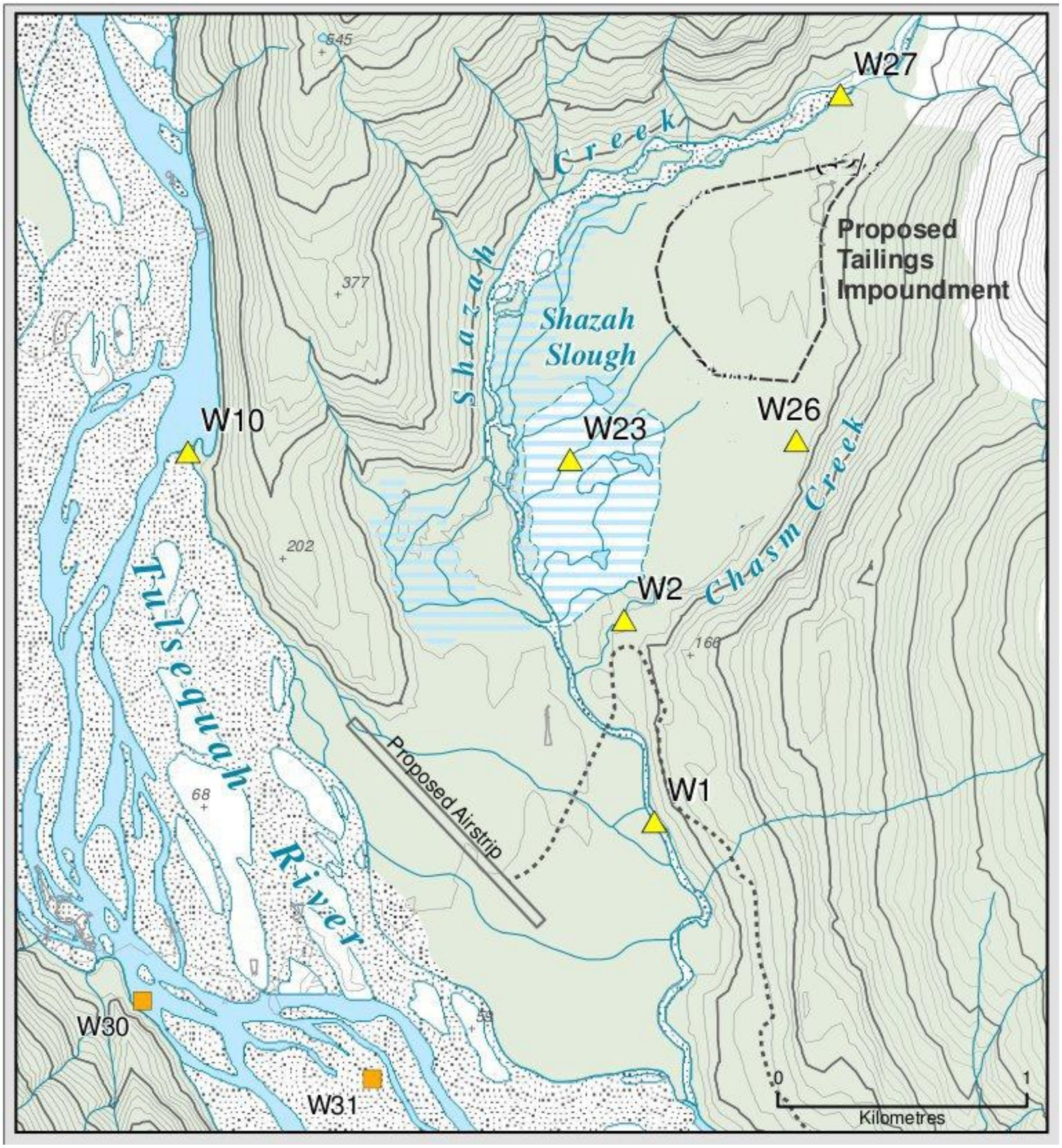

Figure 6.–Water quality sampling sites in Shazah Creek and the upstream portion of the Tulsequah River.

Source: Map from Gartner Lee 2007c. Site W6, not shown, is in the headwaters of Shazah Creek.

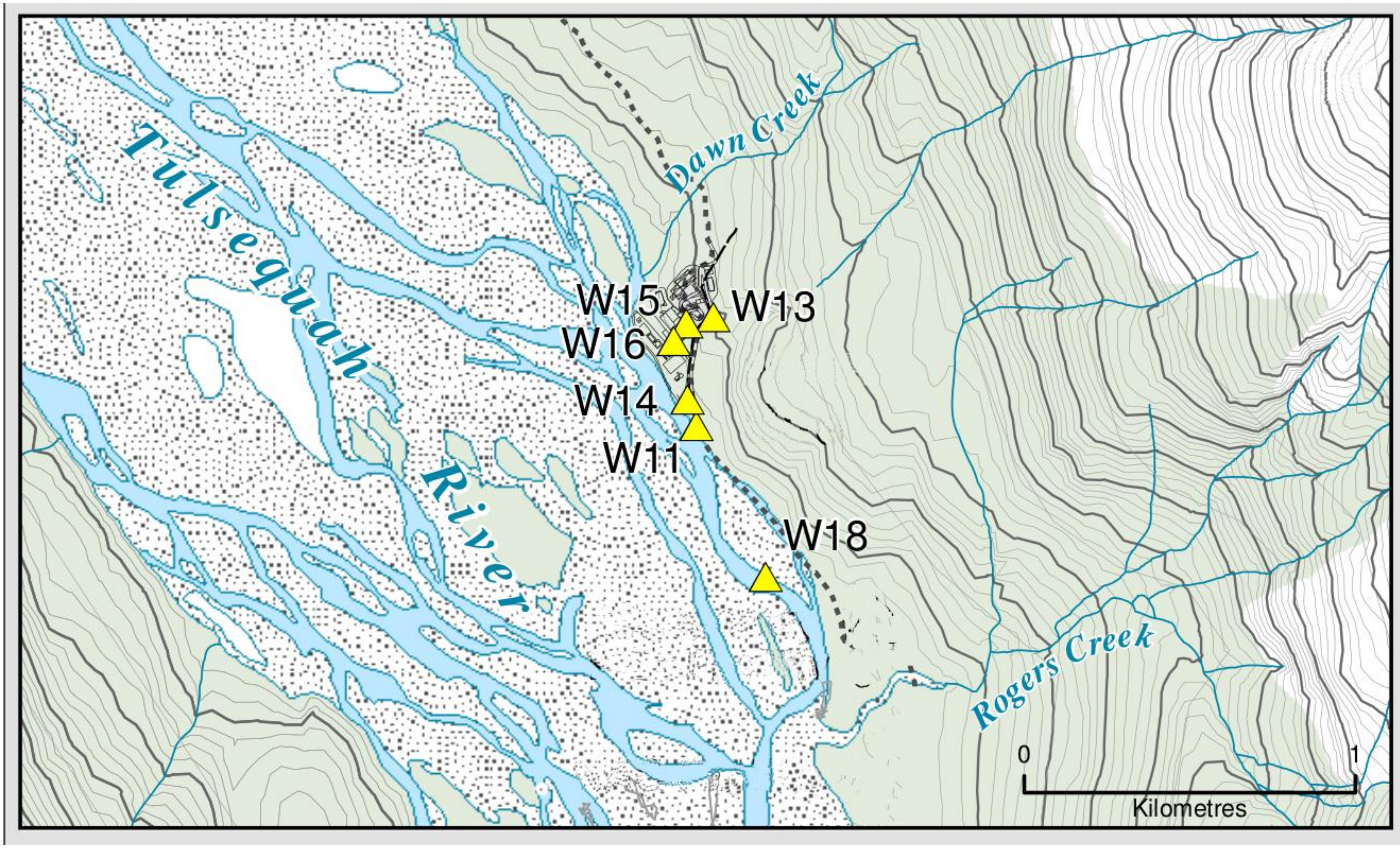

Figure 7.–Water quality sampling sites in the Tulsequah River near the mine sites.

Source: Map from Gartner Lee 2007c. Site W32, not shown, is downstream of W18, near a proposed limestone quarry.

Figure 8.–Water quality sampling sites in the Taku River.

Source: Map adapted from Google Maps Inc.

Table 1.–Surface water monitoring sites and data sources.

Sample Site	Site Number	Sample Dates	Source of Data	No. of Samples
		Taku River Watershed		
Taku River, upstream of Big Bull Slough	W21	1994-1999	Mehling 2001	22
		2001-2003	Lough & Sharpe 2003	5
Taku River, at border	W22	1994-2000	Mehling 2001	40
		2001-2002	Lough & Sharpe 2003	5
Taku River, near Juneau		1998-2003	Neal 2007	44
Big Bull, discharge	W19	1994-1998	Mehling 2001	35
		2001-2003	Lough & Sharpe 2003	4
Taku River, upper watershed		2001-2003	Lough & Sharpe 2003	4
		Shazah Cr. Watershed		
Shazah Creek, downstream of Chasm Creek	W1	1994-2007	Mehling 2001 Gartner Lee 2007c Lough & Sharpe 2003	45
Shazah Creek, upstream	W6	1994-1996	Gartner Lee 2007c	28
Shazah Slough	W23	1998-2007	Gartner Lee 2007c	10
Shazah Creek, upstream	W27	1998-2007	Gartner Lee 2007c	9
Chasm Creek	W2	1994-2007	Gartner Lee 2007c	37
Chasm Creek, upstream	W26	1998-2007	Gartner Lee 2007c	10
		Tulsequah River Watershed		
5400 Level Portal Drainage	W13	1994-1996	Gartner Lee 2007c	17
5200 Level Portal drainage	W14	1994-1996	Gartner Lee 2007c	22
Tulsequah, upstream of mines, upstream of Shazah Creek	W10	1994-1999	Mehling 2001	35
Tulsequah River, 200 m below mine, not mixed	W11	2007	Gartner Lee 2007c	26
Tulsequah River, 500 m downstream of Tulsequah Chief Mine Site, not mixed	W18	1994-1998 1998-2007 2001-2003	Mehling 2001 Gartner Lee 2007c Lough & Sharpe 2003	23
Tulsequah River upstream of Shazah Creek and Mine	W30	2007	Gartner Lee 2007c	4
Tulsequah River, upstream of mine	W31	2007	Gartner Lee 2007c	4
Tulsequah River, 3 km downstream of TC Mine	W32	2007	Gartner Lee 2007c	5
Boundary Creek		2001-2003	Lough & Sharpe 2003	5
Tulsequah River, 2 km downstream of mines		2001-2003	Lough & Sharpe 2003	5
Tulsequah River, above confluence		2001-2003	Lough & Sharpe 2003	3
Tulsequah River, below Polaris Taku Mine		2001	Lough & Sharpe 2003	2
Tulsequah River, below Tulsequah Chief Mine		2001-2003	Lough & Sharpe 2003	5
Tulsequah River, upstream of mines		2001-2003	Lough & Sharpe 2003	5
Wilms Creek		2001-2003	Lough & Sharpe 2003	5

Source: Gartner Lee 2007c.

Mehling Environmental Management Inc. (2001) updated a 1998 assessment of cumulative water quality effects in the Tulsequah River/lower Taku River watershed. The update included data collected since the 1998 report from W21 (Upstream Taku River), Site W10 (Upstream Tulsequah River), Site W 19 (Big Bull Mine Discharge), Site W22 (Taku River at BC/Alaska Border) and Site W1 (Shazah Creek). Sharpe (2001) conducted a review of the report by Mehling.

The most important predictions and conclusions of these reports were:

- Water quality will have lower concentrations and loadings of metals in the Taku River at the border if the mine is operated with a regulated treatment and discharge system.
- Models to predict downstream metals loading cannot be based simply on upstream concentrations and flows because metals are adsorbed and released from stream sediments.
- Site W21 on the Taku River is not representative of water quality in the upper portion of the Taku River. The river divides into several channels at this location and differences in concentrations of total metals among the channels (including Site W21) can be as high as 50%.
- Although concentrations of metals are usually lower in the Taku River than in the Tulsequah, loading rates are higher. High loading rates in the Taku River result from the substantially higher flows; discharge in the Taku River above the confluence with the Tulsequah River is an order of magnitude greater than the Tulsequah River.
- The British Columbia water quality criterion (Nagpal et al. 1995) for Cu was frequently exceeded in the Taku River at W21 and W22 and in the Tulsequah River throughout the year. Concentrations of Pb and Zn were frequently exceeded at Sites W21 and W22.

Gartner Lee (2007c) summarized the available water quality data collected from 1993 to 2007 (Table 2) by various field programs. Most of the same data collected from 1993 to 2001 also were reported by Mehling (2001). Data from the Gartner Lee document (2007c) were converted from mg/L to µg/L for consistency with the other reports. The USGS collected water quality samples from the Taku River gauging site between November 1998 and September 2003 as part of their study of glacial outbursts (Neal 2007). Samples were analyzed for pH, specific conductance, temperature, dissolved oxygen and dissolved and total concentrations of 13 trace elements, dissolved and total major inorganic constituents, selected nutrients and dissolved and organic carbon. Sampling was monthly during summer and less frequent from fall to spring. The purpose of the USGS study was to determine effects of outburst floods from Tulsequah glaciers (also the period of greatest sediment transport) on water quality in the Taku River Drainage.

Neal found excellent water quality at the gauging site with low concentrations of dissolved constituents. Trace elements were within acceptable limits of the Alaska Department of Environmental Conservation aquatic life criteria for fresh water. Concentrations of total trace elements were also low, although frequently were higher with higher river discharge. Concentrations of total trace elements were highest during glacial-outburst floods, likely associated with higher total suspended sediments during outburst flows.

Lough and Sharpe (2003) collected water quality samples throughout the Taku-Tulsequah Drainage and developed mass balance models for select metals. Water samples were collected within a narrow time frame and, where appropriate, samples were collected on transects across waterways. Their report summarizes the water quality and quantity data collected since the issuance of the 1999 Environmental Assessment Act certificate for the proposed Tulsequah Chief Mine.

Table 2.–Fish Species found in Taku River Drainage, including estuary.

	Scientific Name	Note
Fish found in estuary only		
Green Sturgeon	*Acipenser medirostris*	
Pacific Lamprey	*Lampetra tridentate*	
Longfin smelt	*Spirinchus thaleichthys*	
Threespine Stickleback	*Gasterosteus aculeatus*	
Fish occurring mostly in the lower reaches of the Taku River		
Eulachon	*Thaleichthys pacificus*	
Coastrange sculpin	*Cottus aleuticus*	
Prickly Sculpin	*C. asper*	
Fish occurring throughout the drainage		
Pink Salmon	*Oncorhynchus gorbuscha*	
Coho Salmon	*O. kisutch*	
Sockeye Salmon	*O. nerka*	
Chinook Salmon	*O. tshawytscha*	
Chum Salmon	*O. keta*	
Rainbow Trout	*O. mykiss*	
Steelhead Trout	*O. mykiss*	
Cutthroat Trout	*O. clarkia*	resident and anadromous
Dolly Varden	*Salvelinus malma*	resident and anadromous, BC Blue List
Longnose Sucker	*Catostomus catostomus*	
Slimy Sculpin	*Cottus cognatus*	
Round Whitefish	*Prosopium cylindraceum*	
Fish occurring mostly in the upper portions of the drainage:		
Bull Trout	*Salvelinus confluentus*	BC Blue List
Burbot	*Lota lota*	

An objective of the study of Lough and Sharpe was done to determine the extent to which metals were retained in the system then periodically flushed. Their mass balance studies showed substantial metals retention by comparing metals inputs upstream with loadings downstream.

They discussed the importance of instream biogeochemical reactions that affect concentrations in a stream reach where reaction rates are rapid with respect to transport rates. Metals retention is influenced by adsorption onto colloidal forms (especially Fe and Al) in the water column, redox reactions and bacteria. Mixing of metal-rich, acidic water from mine drainage with higher pH water results in the rapid formation of Fe and Al colloids in the water column. These submicron solids quickly aggregate and provide extensive surface area for the sorption of Cu, Pb, Zn and other metals. Metals adsorbed onto colloids are transported downstream where they are trapped by algae and fine particles, until the stream bottom is flushed by high flows.

Lough and Sharpe examined sediment data collected at the Tulsequah Chief property in 1990 that showed elevated Ba, Cu, Pb and Zn concentrations immediately downstream of the adit discharge in the Tulsequah River. They stated "This sediment information coupled with the graphic illustrations showing loss of mass in this reach of the river supports the suggestion that colloidal reactions play a significant role in sequestering metals in the Tulsequah and Taku Rivers."

Lough and Sharpe also expressed concern about elevated concentrations of metals in the water during periods of flushing flows and the effects these concentrations may have on aquatic communities.

Finally, Lough and Sharpe made several observations:

- Water sampling site W-21 is likely not a good representation of the Taku River.
- Water quality samples should be taken as integrated samples across stream channels because of the high variability of metals concentrations across channels.
- Cumulative loadings provide the most accurate model of the percent contribution of each metal to the system from each mine or tributary. A high proportion of the metals, particularly dissolved fractions, is adsorbed or otherwise transformed and not transported immediately downstream.
- Water quality data indicate that of the three mines, the Tulsequah Chief mine contributes the greatest percentage of dissolved zinc to the system, followed by Big Bull mine and then the Polaris Taku mine.
- The study of Lough and Sharpe supports a shift "in the regulatory approach from solely a water quality criteria attainment focus to one which includes limiting metals mass loadings from the three historic mine sites in the study area."

WATER QUALITY IN THE TULSEQUAH AND TAKU RIVER DRAINAGES

Data on select dissolved metals and pH were summarized for sites in the Shazah Creek drainage, the Tulsequah upstream and near the mine and the Taku River and lower Tulsequah River. These summaries are intended to help characterize the relative water quality of different areas of the Tulsequah and Taku drainages and of the tributaries, but do not account for metals retention and flushing or differences in stream flows and loadings.

Shazah Creek and Tributaries

The Shazah Creek Watershed was sampled at six different locations (Figure 6):

W23 – Shazah Slough
W6 – Upper Shazah Creek (Upstream of Chander Creek)
W27 – Upper Shazah Creek (Downstream of Chander Creek)
W1 – Lower Shazah Creek (Downstream of Chasm Creek)
W26 – Upper Chasm Creek (Upstream of proposed tailings impoundment)
W2 – Lower Chasm Creek. (Upstream of confluence with Shazah Creek)

Water quality in Shazah Slough was excellent (Figure 9), with circumneutral pH, moderate hardness and low concentrations of metals. 100% of the samples for total Be, Cr, Cd, Hg, Ni, Ag, Th, Ti, V and Zn and 100% of the samples for dissolved Cd, Cr, Co, Pb, Hg, Ni and V were below the Method Reporting Limit. Total Fe was somewhat elevated in Shazah Slough and ranged from 190 to 1540 µg/L, with a median concentration of 442 µg/L, which exceeds the BC Water Quality Guidelines (WQG) limit of 300 µg/L. Analysis for Cd, Ni and Mo used detection limits that were higher than the WQG; therefore, similar comparisons could not be made.

Chasm Creek, a tributary to Shazah Creek, was sampled at two sites, W2 near the mouth and W26, the upstream site (Figure 6). Water quality in Chasm Creek is generally good, with circumneutral pH during most sample periods (Figure 8). Two samples collected from W2 in July and August 1995 had pH levels lower than the WQG. Hardness and alkalinity varied over a wide range, from less than 20 to more than 100 mg/L.

Water quality in Shazah and Chasm Creeks had lower pH than Shazah Slough; pH in the creek ranged from 6.2 to 8.1 and 10% of the samples were lower than the WQG of 6.5 to 9. The BC WQG were exceeded for dissolved Al (17% of all samples), total As (6%), Cu (23%), Pb (4%) and Zn (17%). Median concentrations of dissolved metals were usually at or below detection (Figure 9).

Tulsequah River

The Tulsequah River was sampled at six locations (refer to Figures 6 and 7 for locations of sampling sites):

W10 – Tulsequah River upstream of Tulsequah Chief Mine site
W11 – Tulsequah River 200 m downstream of Tulsequah Chief discharge (not fully mixed)
W18 – Tulsequah River 500 m downstream of Tulsequah Chief discharge (not fully mixed)
W30 – Tulsequah River upstream of Tulsequah Chief Mine site
W31 – Tulsequah River upstream of Tulsequah Chief Mine site
W32 – Tulsequah River 3 km downstream of Tulsequah Chief discharge

In addition, samples were collected from 5400 level Portal drainage and 5200 level portal drainage.

Gartner Lee (2007c) stated that the "highest total metals concentrations occur during summer in the Tulsequah River, particularly the site upstream of mining. The higher summer concentrations likely are associated with glacial outbursts, or jokulhlaup events."

Site W10, Tulsequah River Upstream of Mining

Site W10 provides the most complete monitoring upstream of mining; few samples were collected from the other upstream sites (Table 1). Hardness was lower than at most of the other sites, ranging from 1.0 to 90 mg/L $CaCO_3$. Although median water quality at W10 was good (Figure 9) with circumneutral pH and low concentrations of most dissolved metals, concentrations of dissolved Al and total Cu, Fe and Zn exceeded WQG: Al exceeded in 88% of samples, Cu in 71%, Fe in 91% and Zn in 57%. Total Cd, Ni and Se occasionally exceeded WQG; however, the method detection limits were frequently too high to make valid comparisons with WQG. As in many glacial systems, concentrations of total metals were substantially higher than concentrations of dissolved metals (Figure 10).

The water quality data presented by Gartner Lee (2007c) from Site W10 does not show that elevated concentrations of metals, except Al and Fe (Figure 11), occur during summer months. Total Fe concentrations from 1995 were compared with discharge in the Taku River to detect correlations with peak, or outburst, flows (Figure 12). No correlation was evident; the July iron sample was collected on July 12 and the flood was detected at the Taku River site on July 26. In September, high iron was measured on September 15 and the peak flow occurred on September 11. Concentrations of metals do increase in both the Tulsequah River and the Taku River downstream of the Tulsequah confluence (Neal 2007); however, the data presented by Gartner Lee (2007c) were collected too infrequently to show effects from glacial outburst floods.

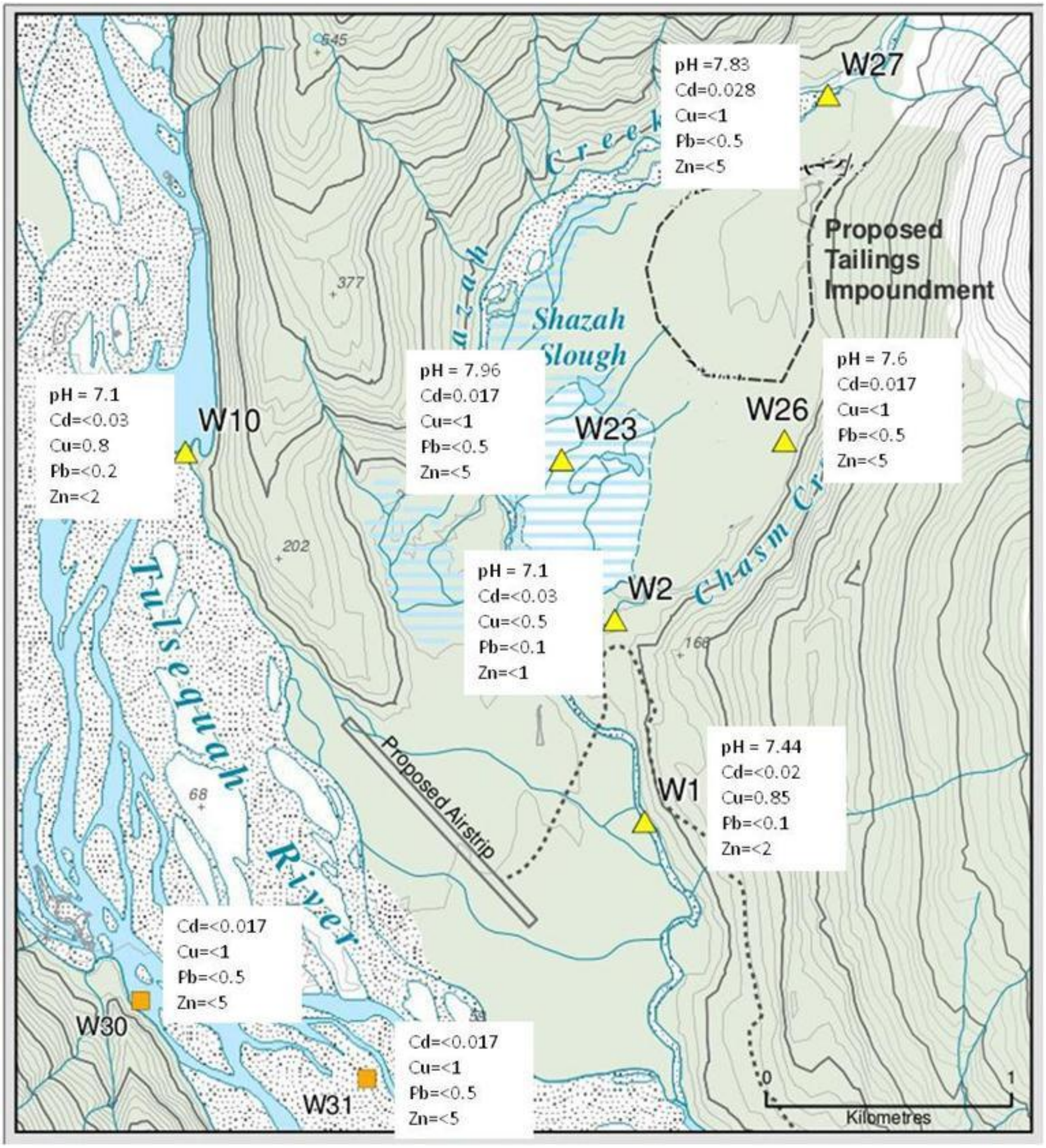

Figure 9.–Median concentrations of dissolved metals (µg/L) and pH, upper portion of the Tulsequah River drainage.

Source: Map adapted from Gartner Lee 2007c.

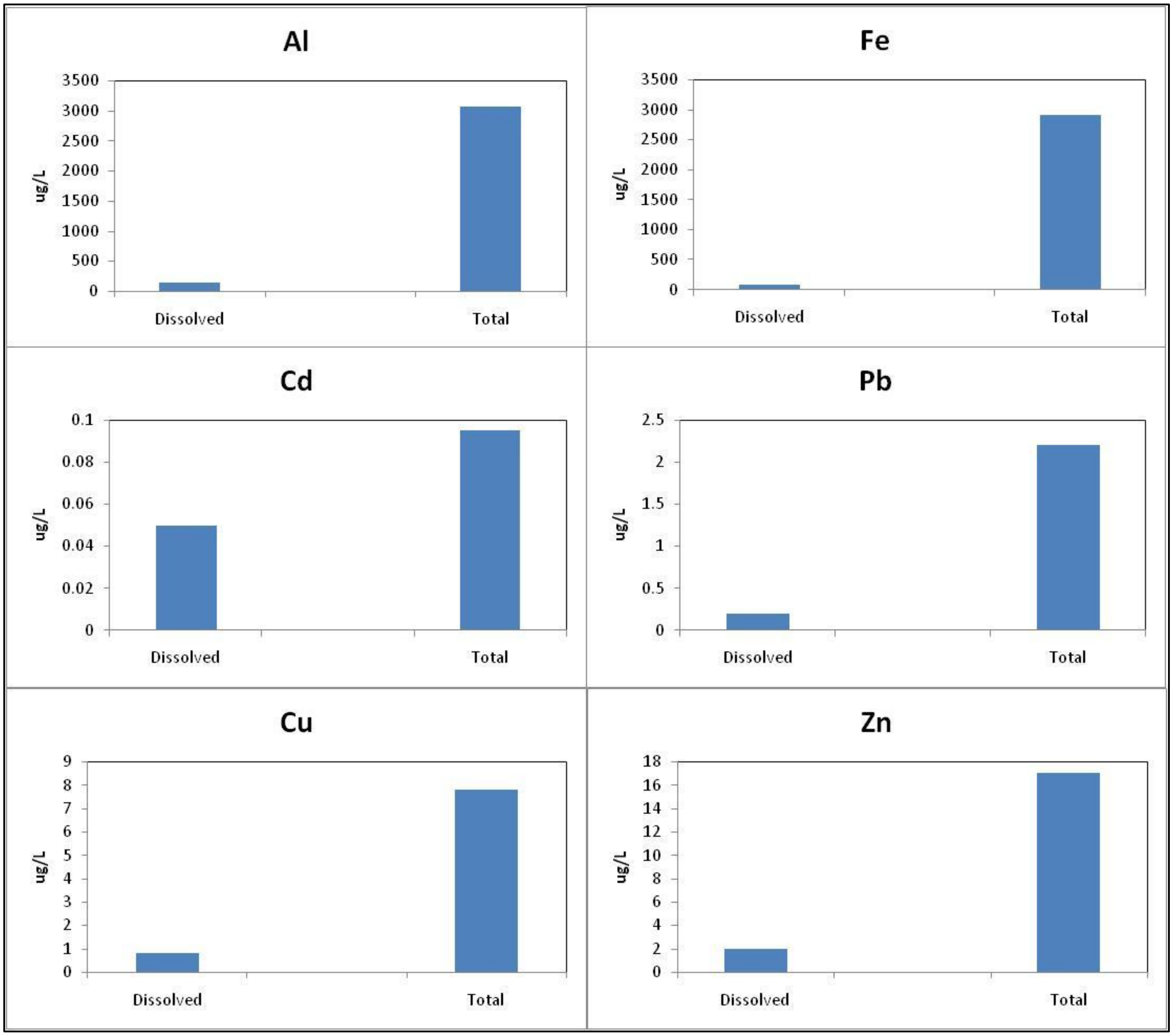

Figure 10.–Median concentrations of dissolved and total metals (µg/L), Site W10, Tulsequah River upstream of mining.

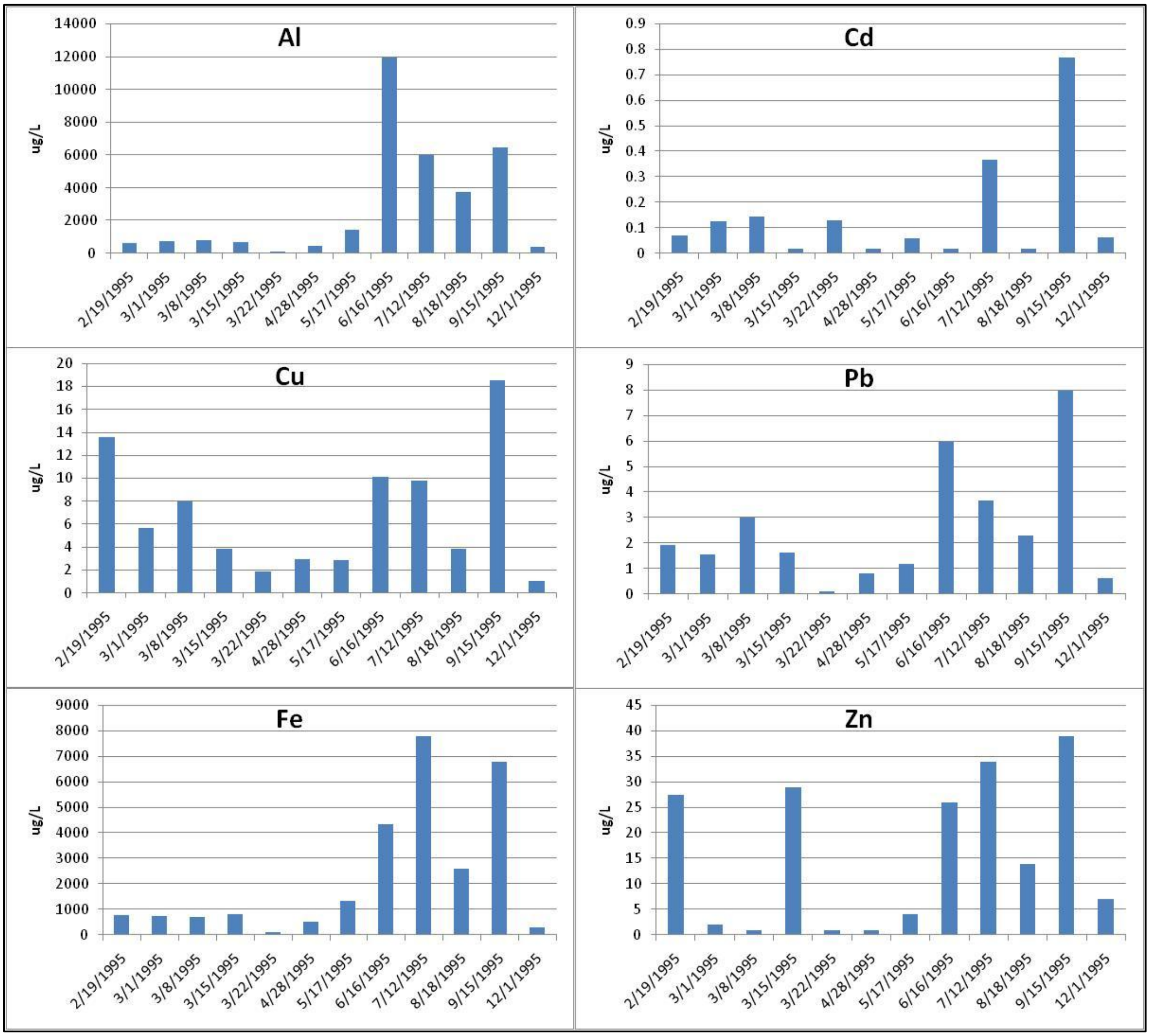

Figure 11.–Concentrations of select total metals (µg/L) at Site W10 in 1995.

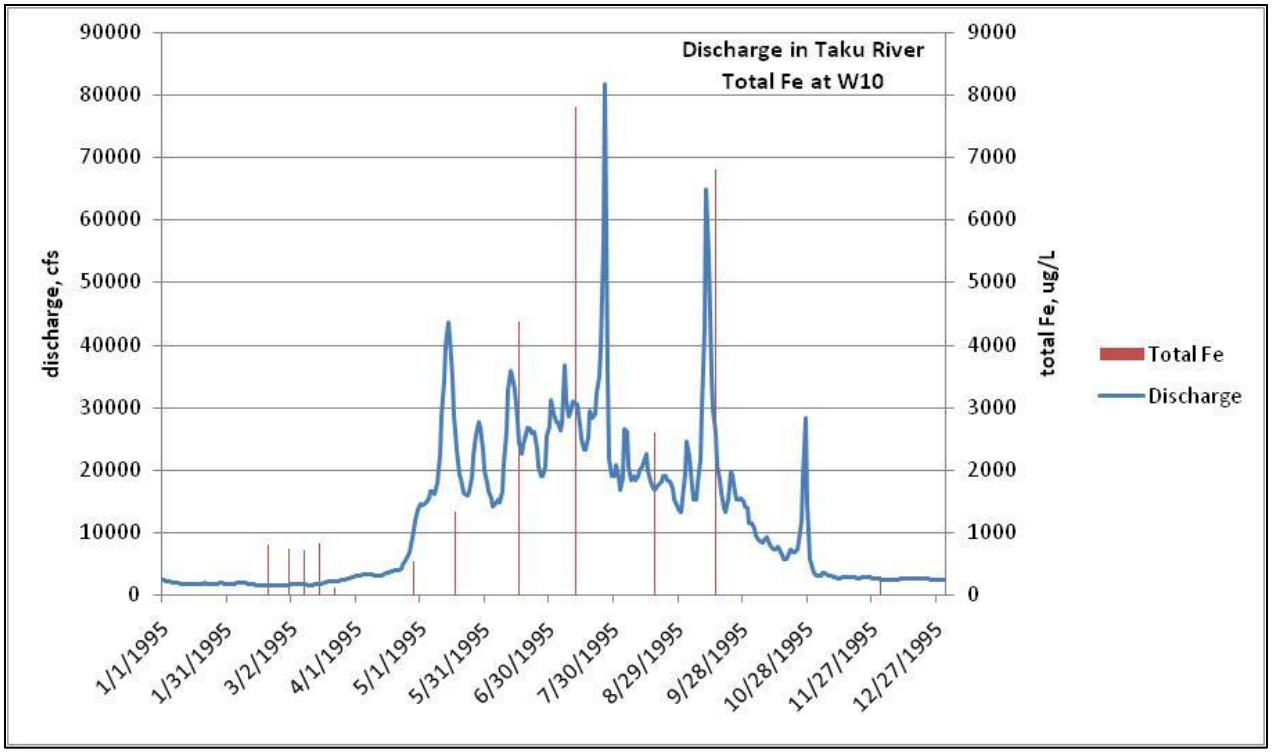

Figure 12.–Comparison of total metals concentrations at Tulsequah site W10 with discharge in the Taku River at the USGS gauging station. All data from 1995.

Concentrations of dissolved metals at Site W10 show even less correlation with season (Figure 13). Data from 1995 are used for comparisons of dissolved and total metals with season because samples were collected with the greatest frequency in 1995.

Sites W11 and W18, Tulsequah River below portal drainage

The Tulsequah River was sampled at two sites below portal drainage from the mine, W11 and W18 (Figure 7). The water at these sites is not completely mixed. Although metals concentrations are elevated at these sites (Figure 14), they do not adequately represent water quality in the Tulsequah River below mining.

Sites W32, 3 km downstream of mine

The Tulsequah River at W32 is 3 km downstream of mining; water at this site is believed to be mixed. Water quality at Site W32 (Figure 15) had high concentrations of metals that exceeded WQG. Dissolved Al was higher than the WQG in 80% of samples, total Cu in 60%, total Fe in 80% and total Zn in 40% of dissolved Al and total Cu, Fe and Zn. Too few samples were collected from this downstream site to characterize water quality over a range of discharges.

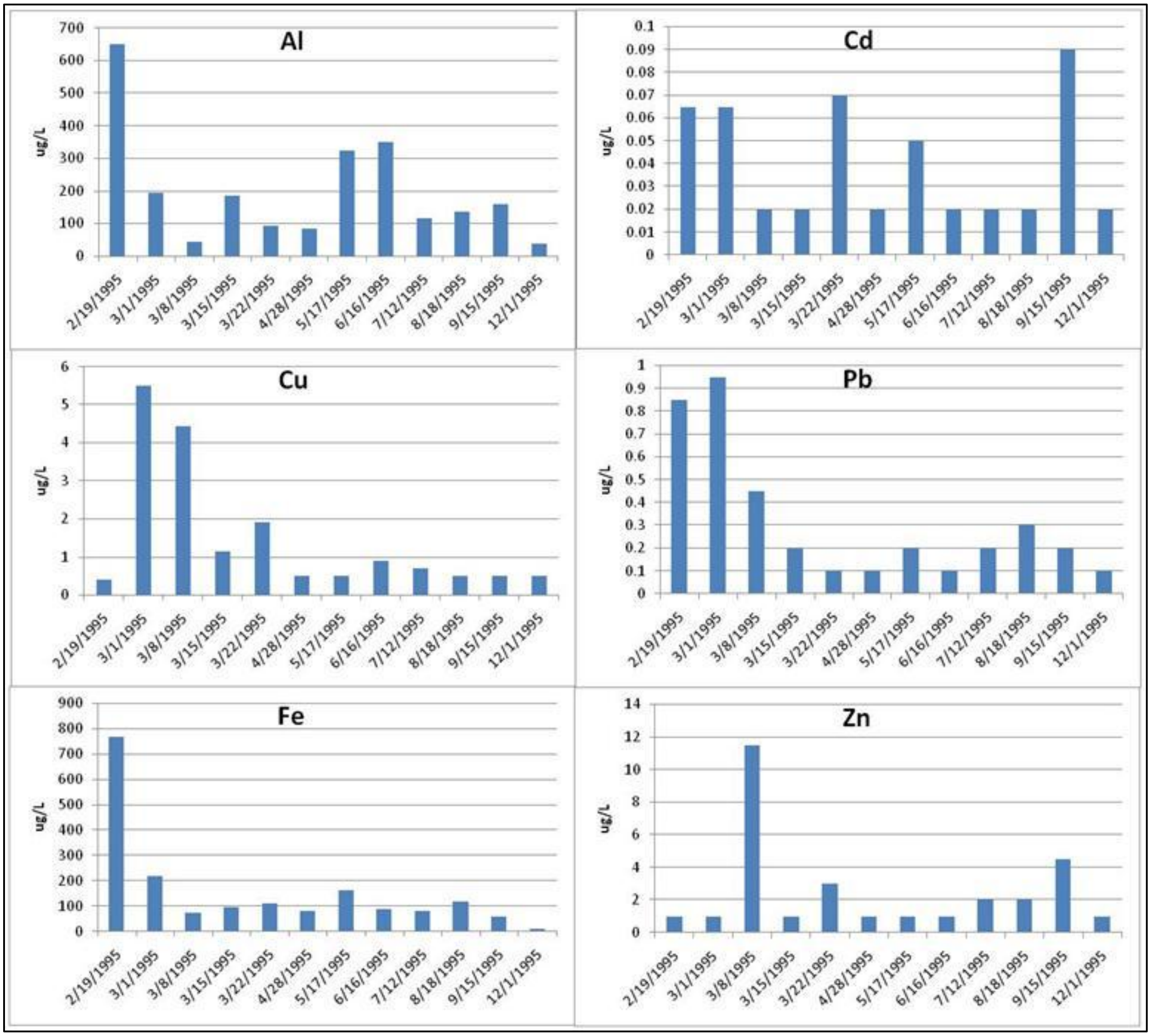

Figure 13.–Concentrations of select dissolved metals (µg/L) at Site W10 in 1995.

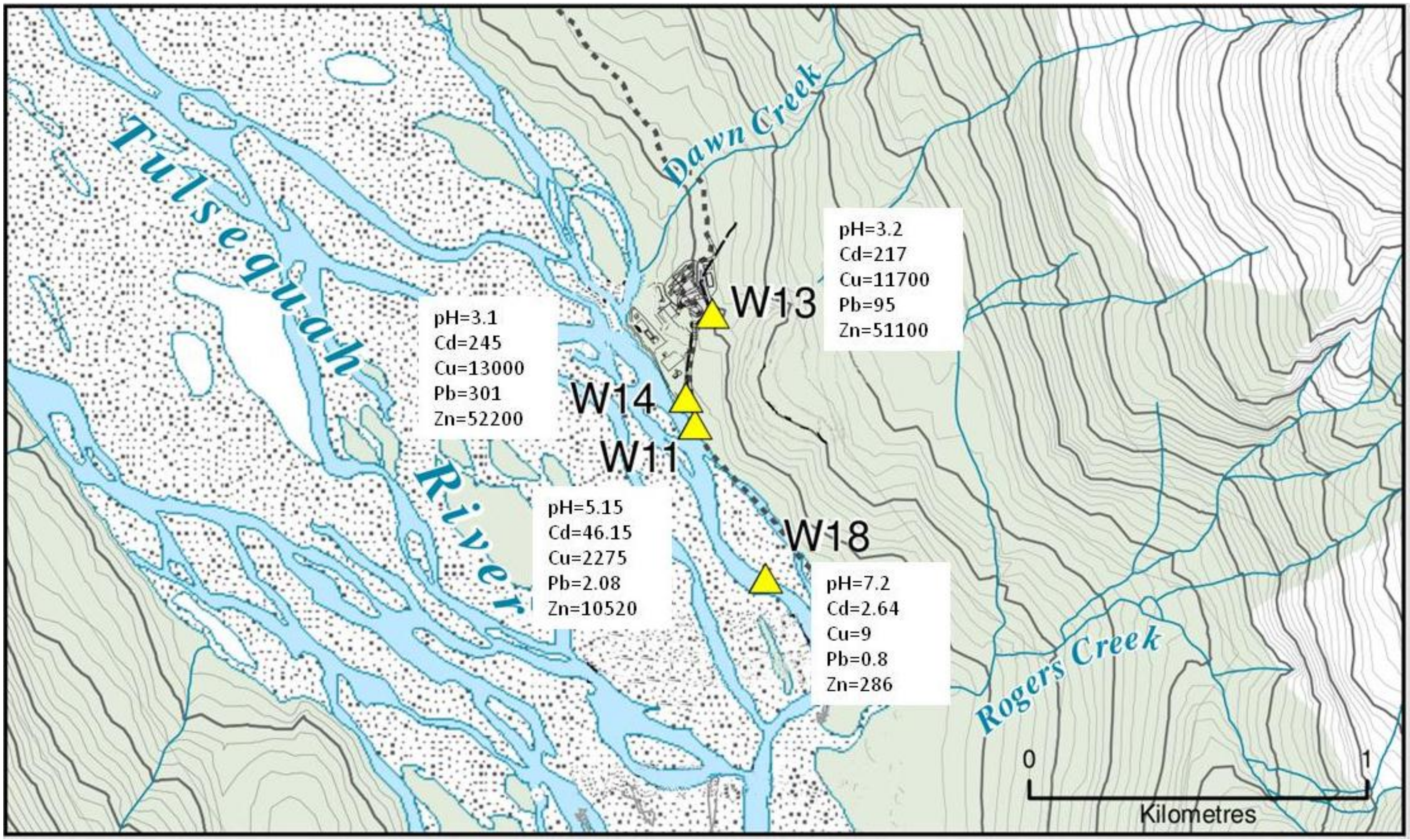

Figure 14.–Median concentrations of dissolved metals (μg/L) and pH near the Tulsequah Chief Mine. Sites W13 and W14 are mine drainage. *Source:* Map adapted from Gartner Lee 2007c.

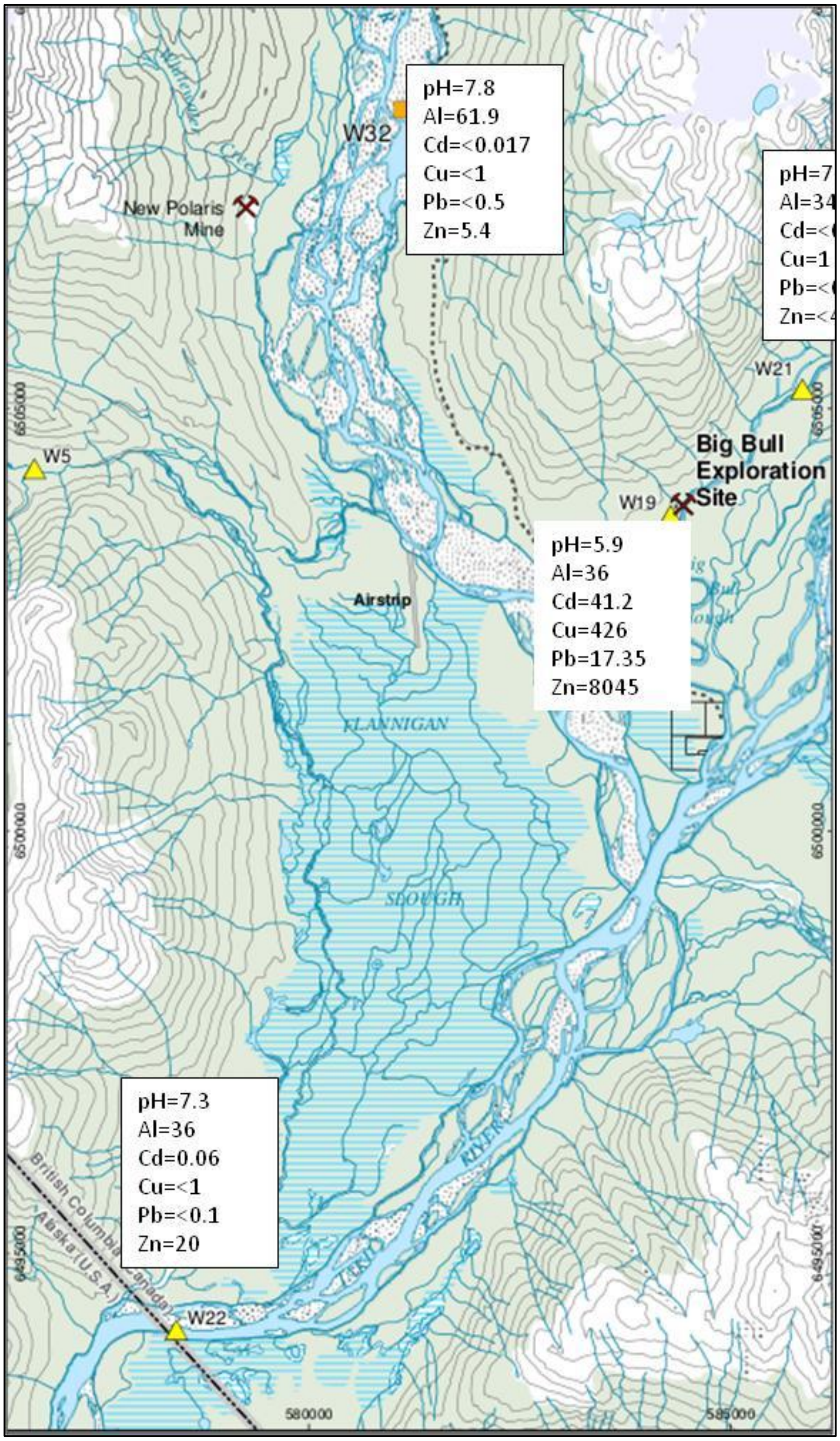

Figure 15.–Median concentrations of dissolved metals (μg/L) and pH downstream of the Tulsequah Chief Mine and in the Taku River.
Source: Map adapted from Gartner Lee 2007c.

Taku River

The Taku River was sampled in four locations:

- W21 – Taku River upstream of Big Bull Slough and Tulsequah River confluence
- W22 – Taku River downstream of the Tulsequah River confluence at the BC/Alaska Border
- W19 – Discharge from Big Bull Mine
- USGS gauging station below W22

The Taku River, upstream of the Tulsequah River, had circumneutral pH and conductivity ranging from 110 to 282 µS/cm. Mehling (2001) reported that conductivity was substantially higher in winter than summer; although not discussed in their document, higher conductivity in winter conditions likely results from higher proportions of subsurface flows and ionic exclusion from freezing. Likewise, higher turbidity and sediment loads occur during ice-free months.

Site W21, Taku River upstream of Big Bull Slough

Water quality in the Taku River upstream of Big Bull Slough (W21) had fairly low concentrations of dissolved Cd, Cu, Pb and Zn (Figures 15 and 16), especially when compared with sites in the Tulsequah River. Dissolved Al was somewhat elevated. Concentrations of total metals frequently were elevated and exceeded WQG (Figure 17): 21% of dissolved Al samples were higher than WQG, 32% of total Cu, 68% of total Fe and 28% of total Zn. For example, when metals concentrations are compared with USEPA WQC (which are based on dissolved forms), only 8% of the samples exceed the acute criterion for Cu, 0% for Fe and 4% for Zn.

As in the Tulsequah River upstream of mining, the Taku River upstream of Big Bull Slough had concentrations of total metals that were substantially higher than dissolved metals (Figure 18). Differences in concentrations of total and dissolved metals (Figure 18) suggest that most of the metals are associated with sediments.

W19, Taku River at Big Bull Slough

Water quality in Big Bull Slough at W19 had lower pH and substantially higher concentrations of dissolved (Figure 15) and total metals than the Taku River sites. Sampling site W19 monitors concentrated flows from the existing adit; samples from this site contribute to the water quality of the Taku River. However, flows from the adit are low—about 1 L/sec (~ 0.03 cfs); therefore, metals loading to the Taku River from this site is low.

W22, Taku River downstream of Tulsequah Confluence

Total and dissolved metals measured in the Taku River downstream of the Tulsequah confluence (Site W22) were not consistently higher in summer (Figures 19 and 20). However, as with water quality at Site W10 in the upstream Tulsequah River, the water samples were collected too infrequently to detect seasonal changes or increases that may be due to glacial outburst floods.

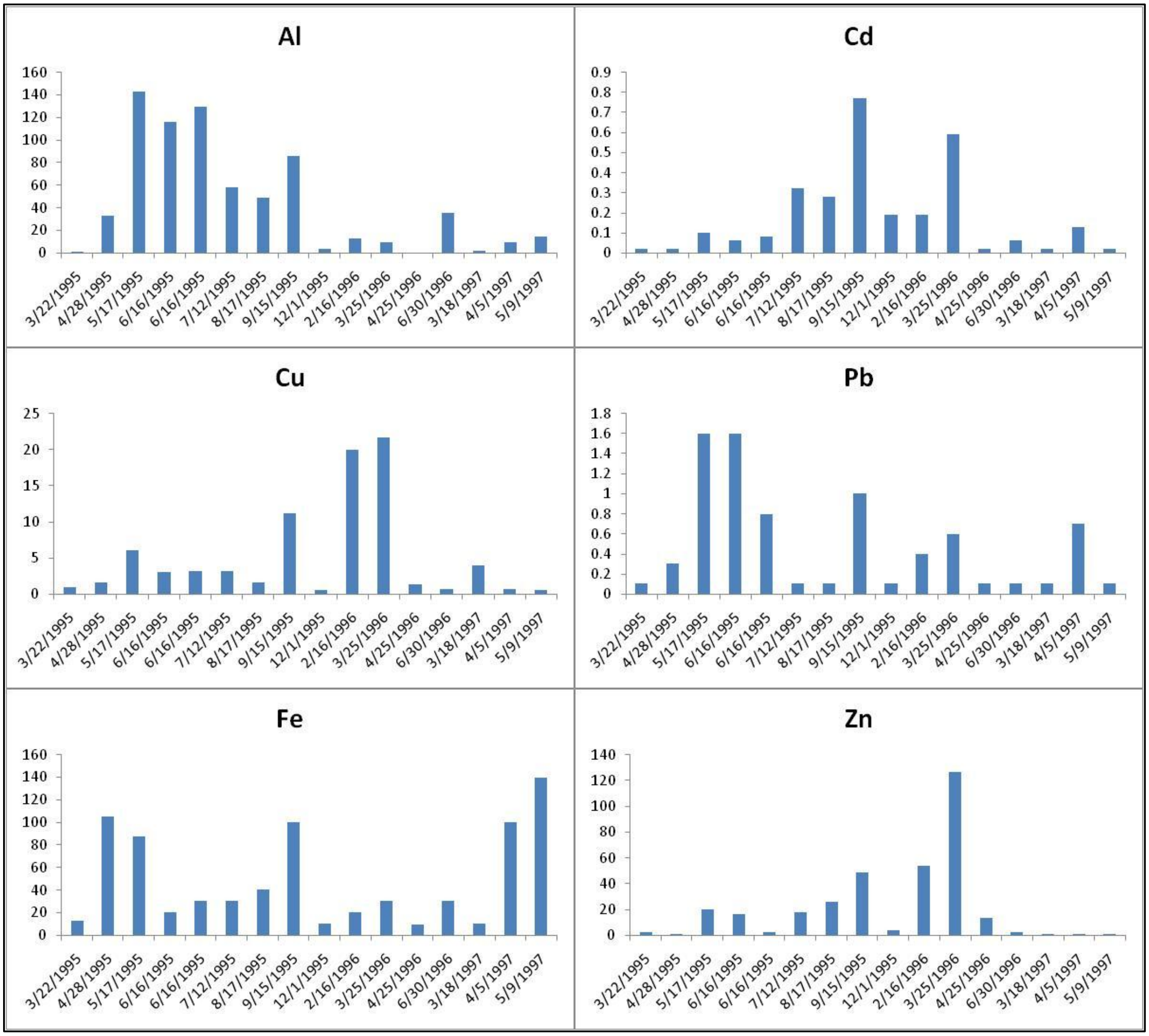

Figure 16.–Concentrations of dissolved metals at Site W21, Taku River upstream of Big Bull Slough.

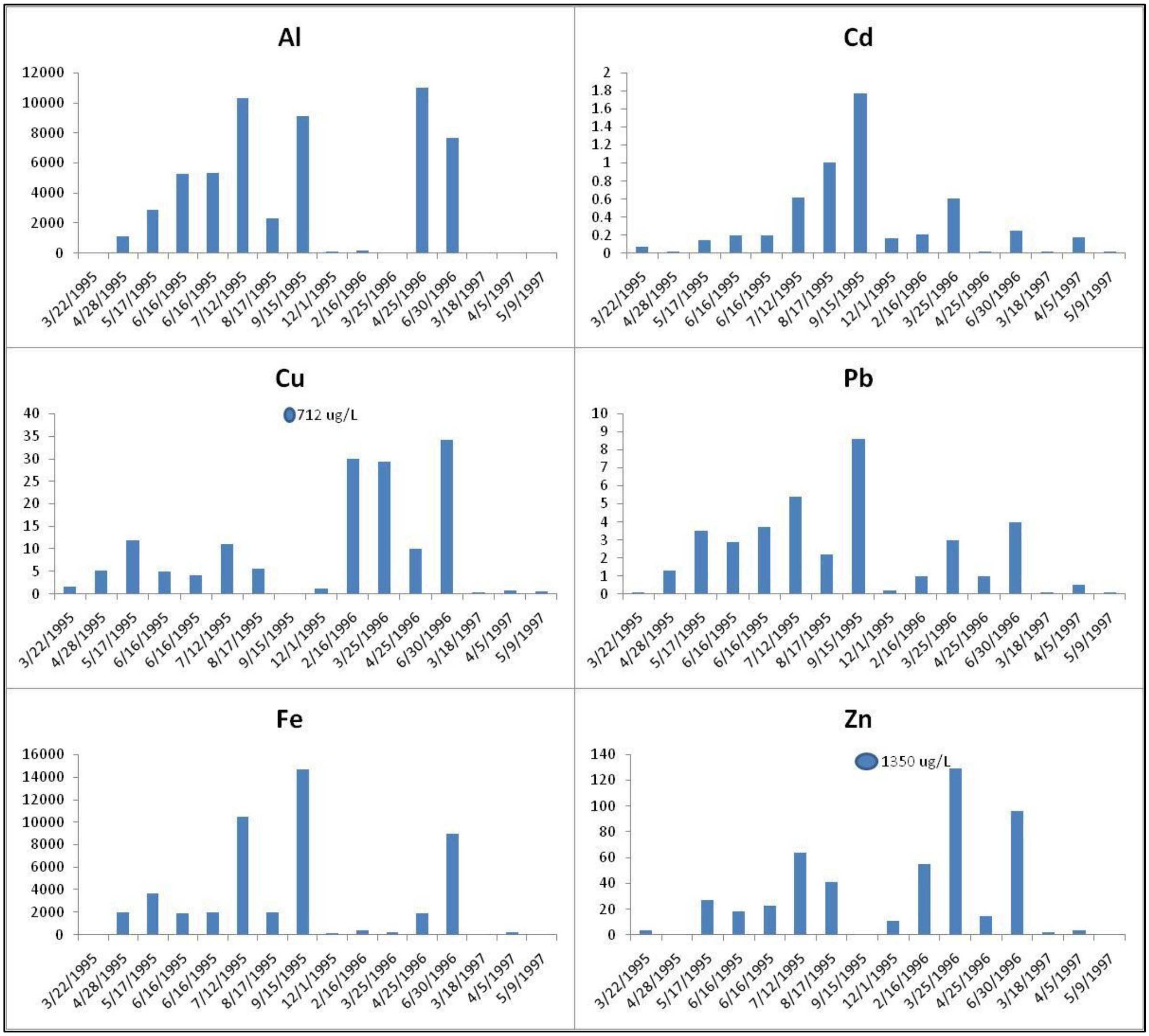

Figure 17.–Concentrations of total metals at Site W21, Taku River upstream of Big Bull Slough.

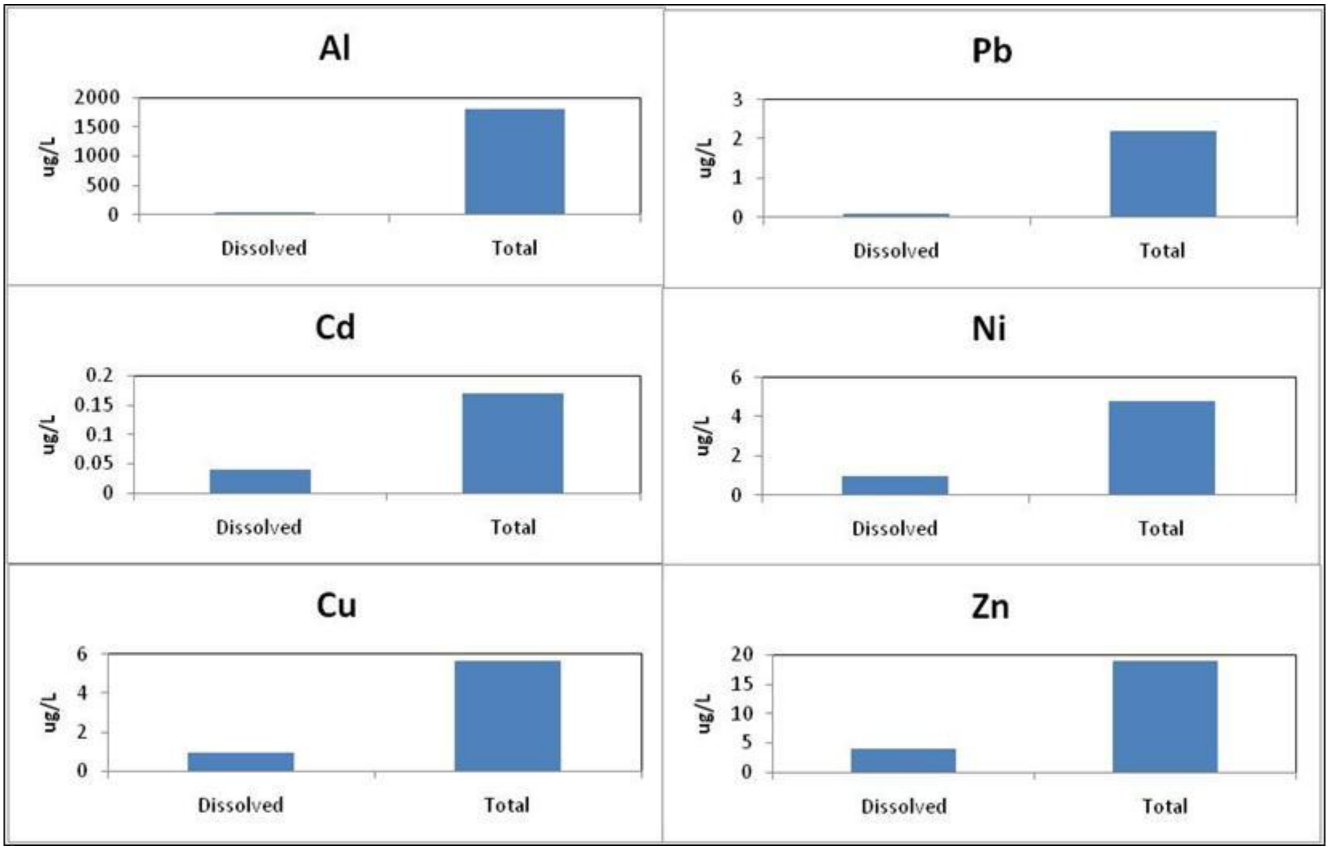

Figure 18.–Median concentrations of dissolved and total metals (µg/L), Site W21, Taku River upstream of Big Bull Slough.

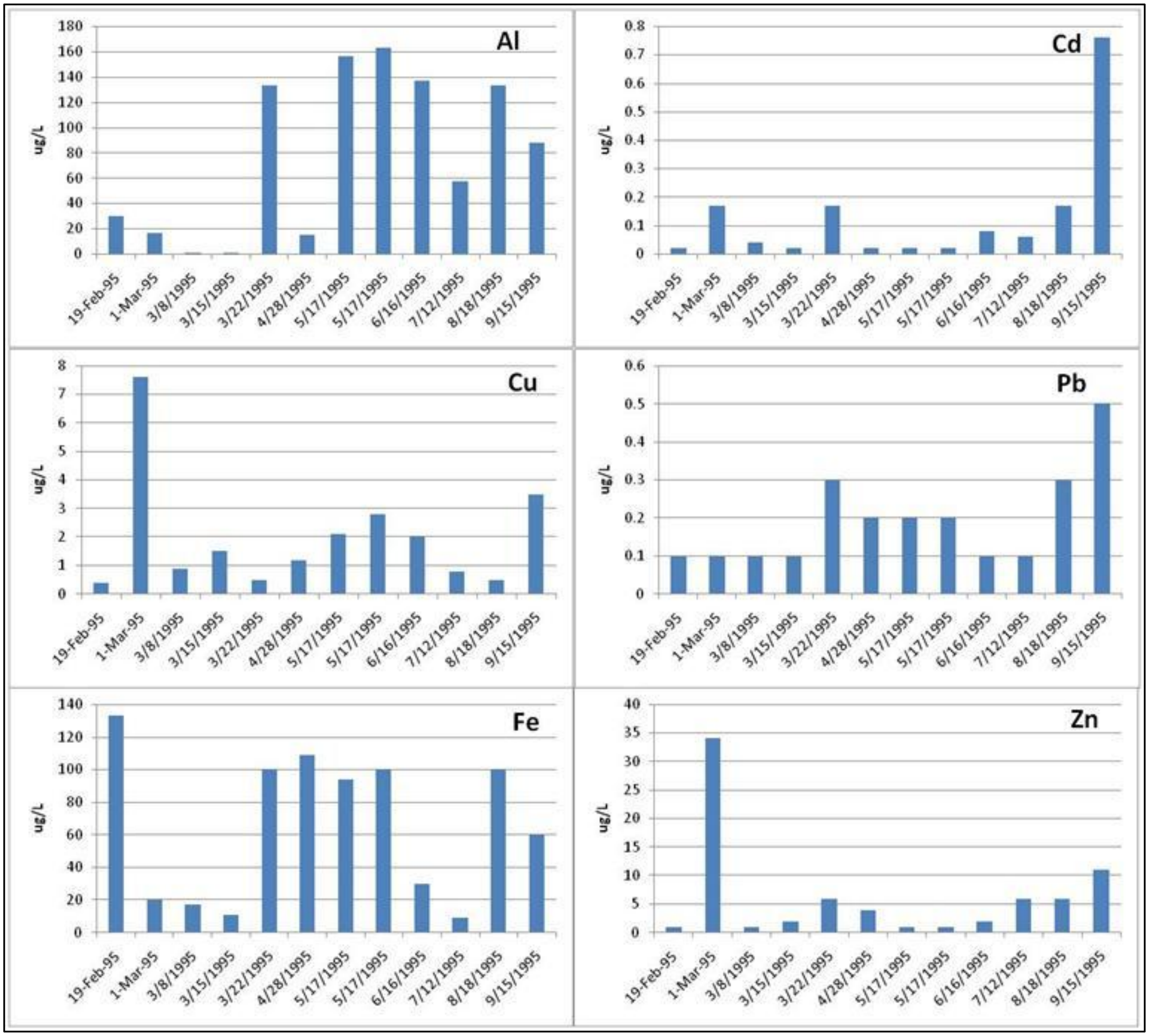

Figure 19.–Concentrations of dissolved metals in the Taku River downstream of the Tulsequah Confluence, Site W22, 1995.

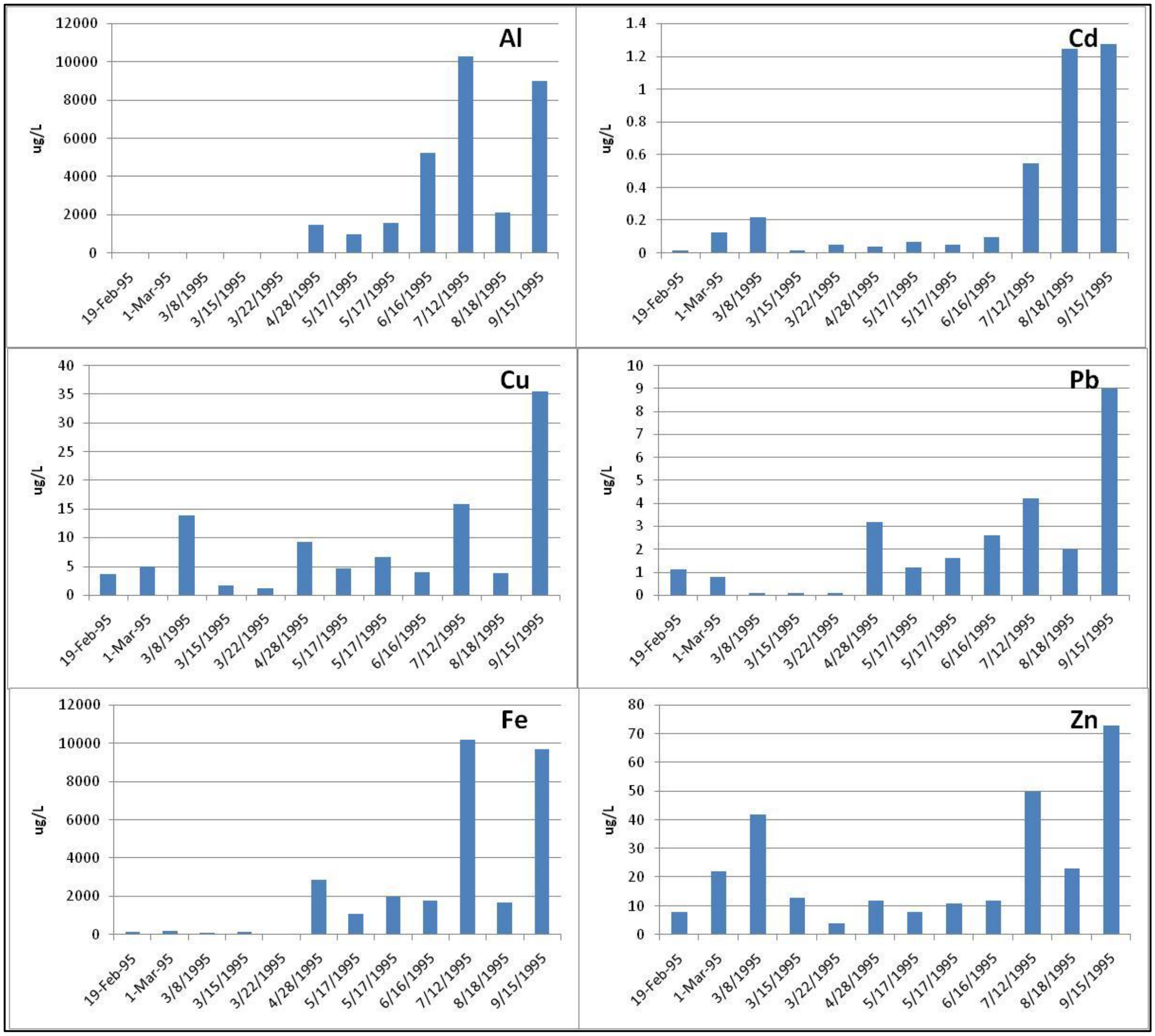

Figure 20.–Concentrations of total metals in the Taku River downstream of the Tulsequah Confluence, Site W22.

Comparisons Among Sites

Median, maximum and minimum concentrations of dissolved (Figure 21) and total (Figure 22) metals were compared among the following sites: Site W10, Tulsequah River upstream of mining; W32, Tulsequah River near the confluence with the Taku River; W21, Taku River upstream of Tulsequah confluence; and W22, Taku River downstream of Tulsequah confluence. The Tulsequah River upstream of mining (W10) had the highest maximum concentrations of dissolved Al, Fe and Ni and highest maximum concentration of total Al. Maximum concentrations of both total and dissolved concentrations of Cd, Cu and Zn were highest in the Taku River, both at Site W21 (upstream of the Tulsequah confluence) and Site W22 (downstream of the Tulsequah confluence). Median concentrations of Cd, As, Cu, Fe, Ni and Zn were similar among sites.

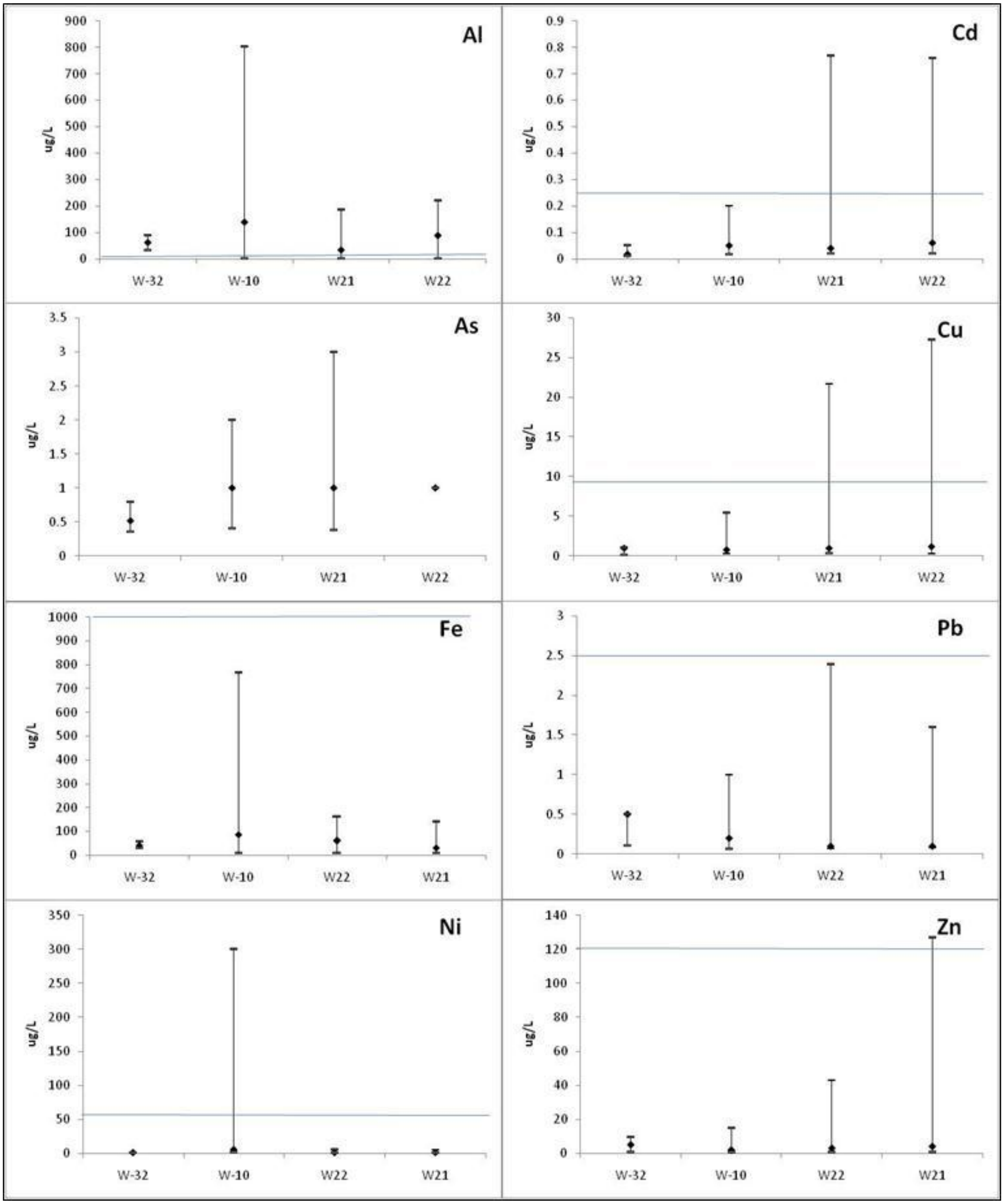

Figure 21.–Median, maximum and minimum concentrations of dissolved metals at Site W10, Tulsequah River upstream of mining; W32, Tulsequah River near the confluence with the Taku River; W21, Taku River upstream of Big Bull Slough on Taku River; and W22, Taku River downstream of Tulsequah confluence.

Note: The blue line is the USEPA water quality criterion for chronic exposure.
Note: The chronic limit for As is 190 µg/L.

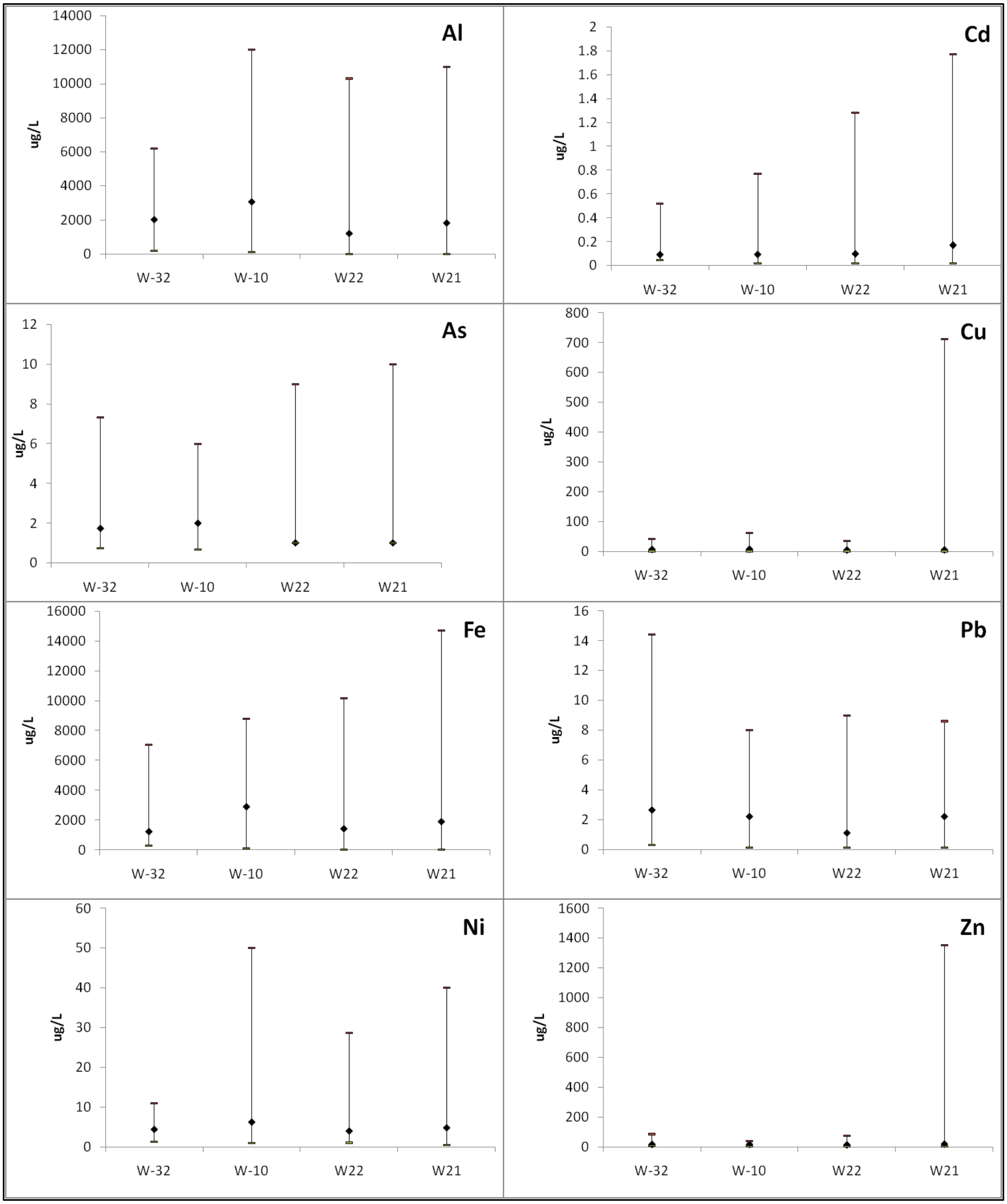

Figure 22.–Median, maximum and minimum concentrations of total metals at Site W10, Tulsequah River upstream of mining; W32, Tulsequah River near the confluence with the Taku River; W21, Taku River upstream of Big Bull Slough on the Taku River; and W22, Taku River downstream of Tulsequah confluence.

Concentrations of total metals were substantially higher than dissolved for most of the metals measured. However, sample analysis for Cd, Mo, Ni and Se frequently used method detection limits that were too high to make meaningful comparisons with water quality criteria or guidelines.

Both Mehling (2001) and Lough and Sharpe (2003) found that upstream metals loadings cannot be summed to accurately estimate loadings in downstream sites. Frequently, upstream metals concentrations predict downstream concentrations that were 2 to 5 times higher than the concentrations measured at the downstream Taku River site (W22). Mehling (2001) listed several reasons for the discrepancy between predicted and measured metals concentrations, including the location of upstream Taku River Site W21 in a side-channel that does not adequately represent conditions of the Taku River.

RECOMMENDATIONS FOR FUTURE WATER QUALITY SAMPLING

Permanent water quality and flow monitoring sites should be established. Each permanent site should be located where water in the entire cross section of stream is mixed. If complete mixing cannot be found, a sample integrator should be used to collect a representative water sample. Site W21, in particular, appears to sample a side channel of the Taku River, not the entire river. Sampling sites W11 and W18, located below mining in the Tulsequah River, are not adequately mixed and do not represent water quality conditions of the river below mining.

At a minimum, permanent water monitoring sites should include discharge from the mine, including possible discharges from adits (if they are not sufficiently captured) and discharge from tailings impoundments and water treatment plants. An upstream site on both the Taku and Tulsequah River would represent background conditions. Sites downstream of the mine should include the Tulsequah River downstream of mining and the Taku River downstream of the Tulsequah confluence. Permanent water quality monitoring sites should be established after the mine plan is developed because it may be necessary to include additional sites to capture water from the different mining activities.

Water samples should be collected with sufficient frequency to detect seasonal changes and effects of glacial outburst floods. The list of analytes could be substantially trimmed from the previous water quality sampling. Elements that are not known to be part of the mineralization or have consistently been reported below the laboratory method detection limit should be considered for elimination from water quality monitoring.

FISH RESOURCES

TAKU RIVER WATERSHED

There have been numerous fisheries studies conducted in the Taku River downstream of the U.S./Canada border. Many of these studies document important habitat characteristics for spawning and rearing and present estimates of fish numbers. Studies conducted in the Tulsequah River show the presence of many species of fish and provide some information on habitats. Many of these studies are discussed below and maps of the general distribution of different fish species are presented.

According to Rescan (1997), the Taku River is one of the more important transboundary rivers crossing between BC and Alaska. It supports a diverse mix of fish species and large runs of commercial salmon species fished both by Canadian and American Native, commercial, subsistence and sport fishers. Gartner Lee (2007a) reported 21 different fish species from the Taku River drainage (Table 2). The majority of salmon spawn above the Tulsequah-Taku confluence (Eiler 1991, Andel 2004); however, the lower river provides critical rearing areas for juvenile salmon and some spawning habitats (Figures 23 and 24). Downstream rearing habitats are especially important during winter months. Coho, chum and sockeye salmon are prevalent in the channels, marshes and ponds of Flannigan Slough, near the Tulsequah-Taku confluence on the Canadian side to the border (Andel 2004).

Bull trout and Dolly Varden are blue-listed by the Province of BC's Conservation Data Center, meaning they are either an endangered or threatened species.

Fish Distribution

The British Columbia Fisheries Inventory database (FISS 2011) documents the presence of fish in the Taku River and tributaries (Figure 23). The polygons added to the maps show some of the areas of concentrations of specific fish species.

The Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fish (Johnson and Blanche 2011, Figure 24) has documented chum, coho, Chinook, pink, and sockeye salmon, cutthroat and steelhead trout and Dolly Varden char in the Taku River to the U.S./Canada border. Spawning and rearing of these species occurs throughout the downstream reaches and in many of the tributaries (Figure 24). The Catalog is a regulatory document for Alaska with jurisdiction to the border with Canada; the document does not imply that fish distribution ends at the border.

Reports on Species of Fish

A number of reports were reviewed that document specific information on fish presence, spawning and rearing in the Tulsequah and Taku River drainages. These studies also provide some information on habitat preferences and timing for spawning and outmigration.

Eulachon

Flory (2008) sampled eulachon embryonic outdrift from the Taku River to estimate locations for spawning and the relative spawning density at different sites. Flory also reported that the Alaska Department of Fish and Game (ADF&G) had documented eulachon spawning as far upstream as Big Bull Slough, although migration this far upstream occurred only during exceptionally large runs. According to Flory, the majority of eulachon spawn in the lower Taku River, but spawning may extend upstream as far as Twin Glacier Lake. Few embryonic eulachon are found in the upstream sites. Eulachon likely spawn in the Taku River in mid- to late April; embryonic egg and larval outdrift begins during the middle of May, peaks during the first week of June and declines by mid-June.

Chum Salmon

Andel (2004) radio-tagged 168 chum salmon to determine their spawning distribution in the Taku River Drainage in 2004. The majority of fish (94%) spawned in the Taku River mainstem between the Tulsequah and Inklin confluences (Figure 23). The chum salmon were most concentrated in braided channels on the west side of the Taku River in areas of groundwater upwelling and alluvial fans. No chum salmon were relocated in the Taku River below the U.S. border or in the Tulsequah, Inklin, or Nakina Rivers. Several fish were found in Yellow Bluff, Chunk, Tuskwa, Shustahini and Yonakina sloughs.

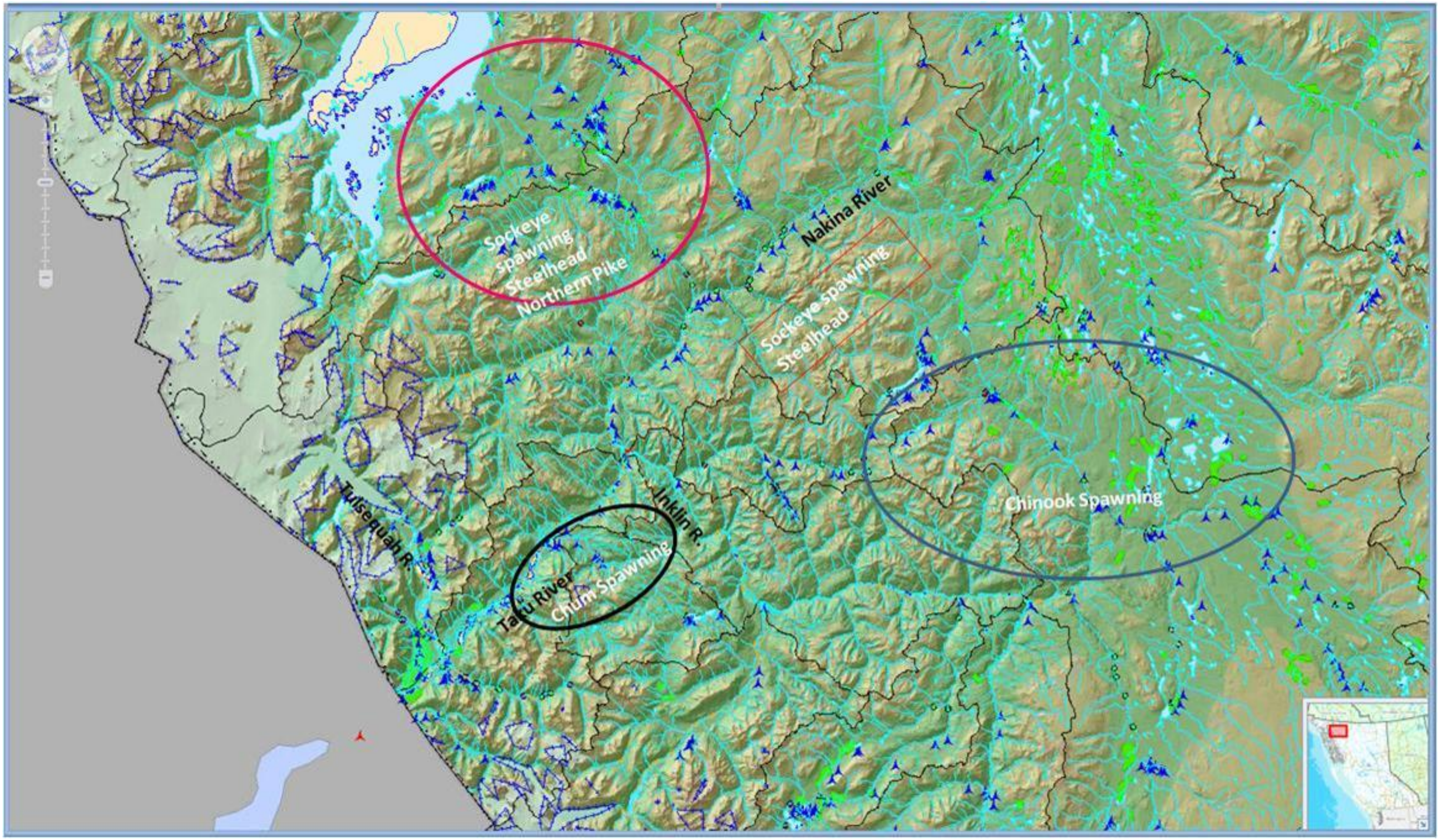

Figure 23.–Documented presence of salmonid fish in the Taku River and tributaries. Each blue symbol represents a fish observation. Ovals show general areas of concentrated spawning or occurrence.
Source: Map and data from Ministry of the Environment, British Columbia, Canada

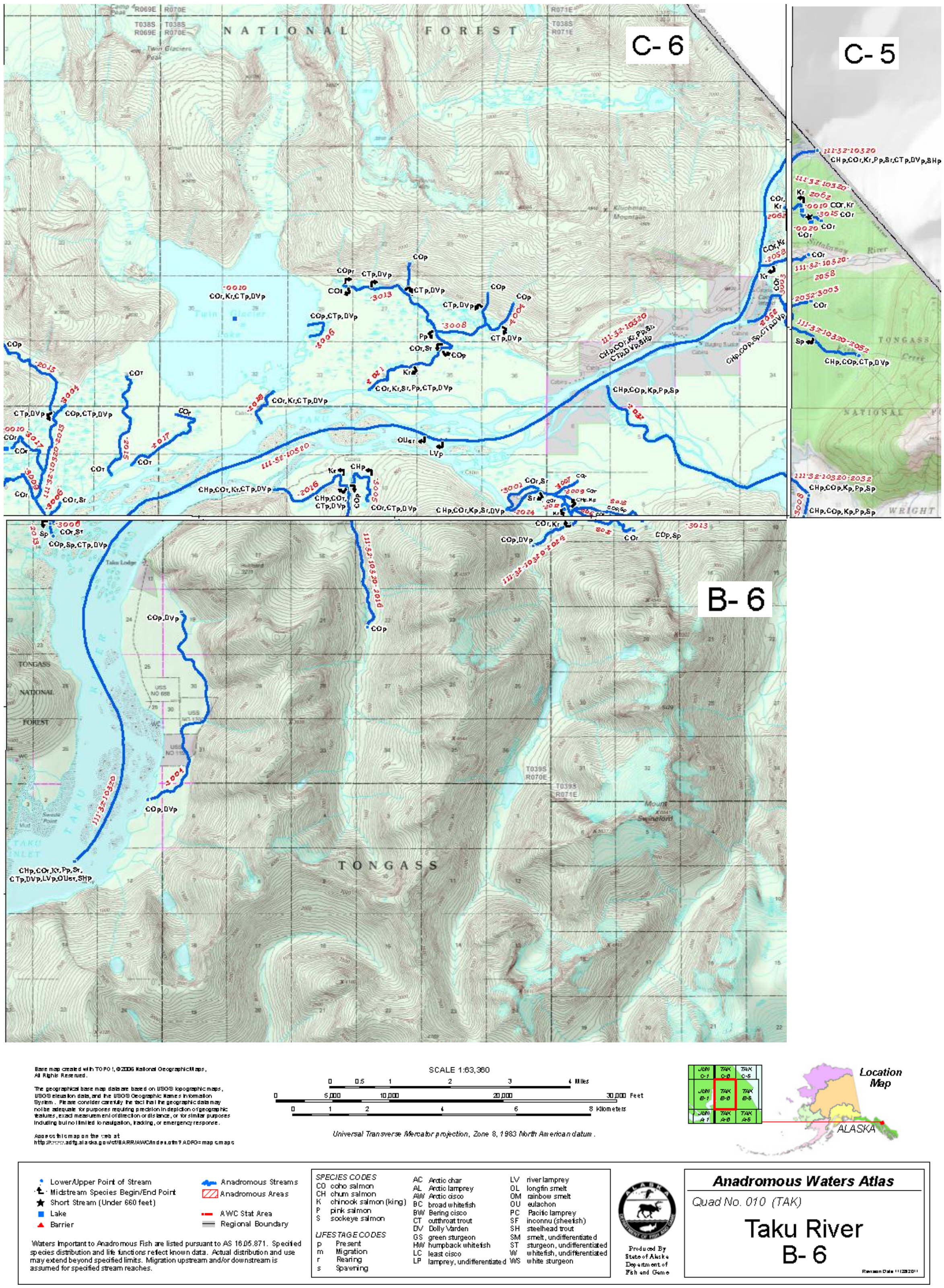

Figure 24.–Documented spawning, rearing and migration of anadromous fish in the Taku River and tributaries.

Source: Map from Alaska Department of Fish & Game, Anadromous Waters Atlas (Johnson, 2011).

There are two spawning populations of chum salmon in the Taku River drainage (Andel 2004). The earlier run spawns from July to September and the fall run spawns from September to November. Fall chum spawning is most prevalent in areas with upwelling groundwater. Eiler et al. (1988) reported chum salmon spawning along the Taku River in King Salmon Flats and, to a lesser extent, near Yellow Bluff and in Flannigan Slough.

Der Hovanisian and Geiger (2005) reported that the harvest of Taku River fall chum salmon dropped from an average of 54,000 fish in the 1970s and 1980s to around 4,200 fish over the past 10 years. While no specific cause for the decline has been identified, Heinl (2005) suggested factors such as natural changes in spawning habitats, overfishing, interactions with other species of fish and interactions with the increased production of hatchery fish.

Chinook Salmon

ADF&G conducted many studies on Chinook salmon harvests and escapement in the Taku River. Few studies discussed precise locations for spawning and rearing or descriptions of habitats where fish were likely found. Their studies, however, do provide information on the general distribution of fish throughout the watershed.

McPherson et al. (2004) presented an average run size for Chinook salmon in the Taku River drainage (from 1979 to 2005) of 50,369 adult fish. Through the mid-1970s and the 1980s, the Taku River Chinook population had low numbers of wild fish (McPherson et al. 2000) and the commercial and sport fisheries were restricted. The commercial fishery in the ocean was closed from 1975 to 2004; however, the drift net fishery above the Canadian border continued. Considerable research was carried out and spawning escapement goals were set. McPherson (2004) reported that escapement has consistently met or exceeded the goal each year since 1985 (except for 1999 when escapement was estimated at 19,734 fish). According to McPherson (2004), total returns of Chinook salmon were too low to allow commercial fishing.

Boyce et al. (2006) tagged adult returning Chinook salmon in the Taku River at Canyon Island. Although the objective of their study was to estimate the escapement, they noted that the Chinook run continued from May through August. Jones et al. (2010) reported a slightly earlier Chinook salmon run: adults usually return in late April and spawn from late July through September. The majority of juveniles leave the system as one-year-old fish and rear in the marine environment for one to five years with most spending two to four years in the ocean before returning to spawn.

Chinook salmon spawn throughout the Taku River watershed with the majority of reported spawning in clear water tributaries upstream of the Tulsequah River (Eiler et al. 1991). Armstrong and Hermans (n.d.) identified the upper reaches of the Taku River drainage as the most important area for Chinook salmon spawning. This region included Tseta Creek, Nahlin River and Dudidontu River (Figure 25).

Murphy et al. (1987) reported that juvenile Chinook salmon in the Taku drainage preferred mostly river-channel habitats, especially in side sloughs and backwaters. The highest densities were found in channel edges with abundant riparian vegetation. In contrast, sockeye and coho salmon juvenile were most abundant in upland sloughs and beaver ponds.

Juvenile Chinook salmon showed a preference for river habitats with mean velocities of 3 to 15 cm/s and were most concentrated in sloughs and channel edges, small tributaries and tributary mouths (Murphy et al. 1989). Murphy et al. reported that juvenile Chinook were mostly absent from beaver ponds and upland sloughs.

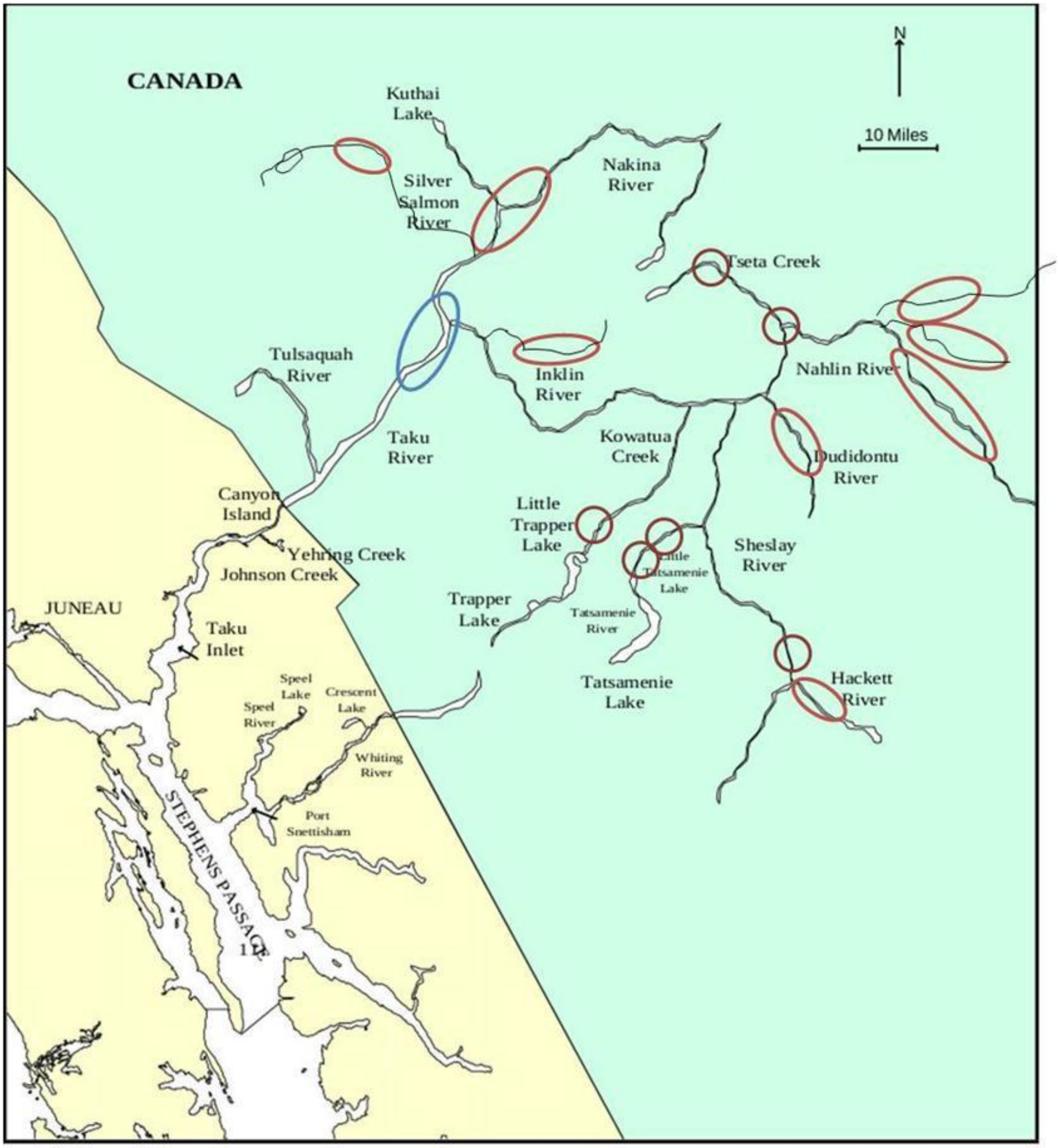

Figure 25.–Chinook salmon spawning areas identified by Eiler et al. 1991.
Source: Map adapted from Andel 2004.
Note: Red ovals are documented spawning areas, blue ovals are possible spawning areas.

Sockeye Salmon

According to Kelley and Frenette (Scott Kelley and Brian Frenette, Division of Commercial Fisheries biologists, ADF&G, Douglas; November 5, 2007, Tulsequah Chief Mine Air Cushion Barge Transportation System, memorandum) the average total run size for sockeye salmon in the Taku River from about 1997 to 2007 was 246,000 adults.

Sockeye salmon spawn throughout the Taku River drainage; spawning has been documented near Big Bull Slough upstream to many of the smaller tributaries (Figure 26). Gustafson et al. (1997) identified numerous sloughs and tributaries to the Taku River as important for sockeye salmon spawning or rearing: mainstem Taku River, Chum Salmon Slough, Shuunk Mountain Slough, Coffee Slough, Fish Creek, Hanatka Slough, South Fork Slough, Shustahini Slough, Tuskwa Slough, Yonakina Slough, Hackett River, Nahlin River, Nakina River, Tatsamenie River and Yehring Creek. Numerous sockeye spawn in the headwaters of the Nakina River and near Kuthai Lake (Andel 2004). Eiler et al. (1992) reported that most of the sockeye salmon returning to the Taku River do not depend on lakes and that riverine sockeye salmon make up a major portion of the run.

Eiler et al. (1992) used radio telemetry to identify sockeye salmon spawning areas in the Taku River. The authors reported that the majority of sockeye salmon spawned in mainstem habitats, including side channels, back channels, sloughs, and upwelling basins. They found 42% of the tagged fish returning to the Taku River mainstem, 17% to the Nakina River and 4% to other rivers. The remaining 37% spawn in or near the major lakes found near the headwaters of the Taku watershed (Little Trapper, Tatsamenie, King Salmon and Kuthai Lakes, Figure 26).

Lorenz and Eiler (1989) also conducted radio telemetry studies of spawning sockeye salmon. They noted the importance of upwelling groundwater in the mainstem of the river: upwelling groundwater was detected in nearly 60% of the sites sampled in mainstem areas. Spawning sites with upwelling groundwater had lower water velocities and more variable substrate compositions than sites without upwelling groundwater.

Heifetz (1987) identified different habitat types in the Taku River downstream of the U.S./Canada Border and determined approximately 38% of rearing sockeye use sloughs and beaver ponds. The extensive braided channels with lower water velocities also provided important rearing habitats.

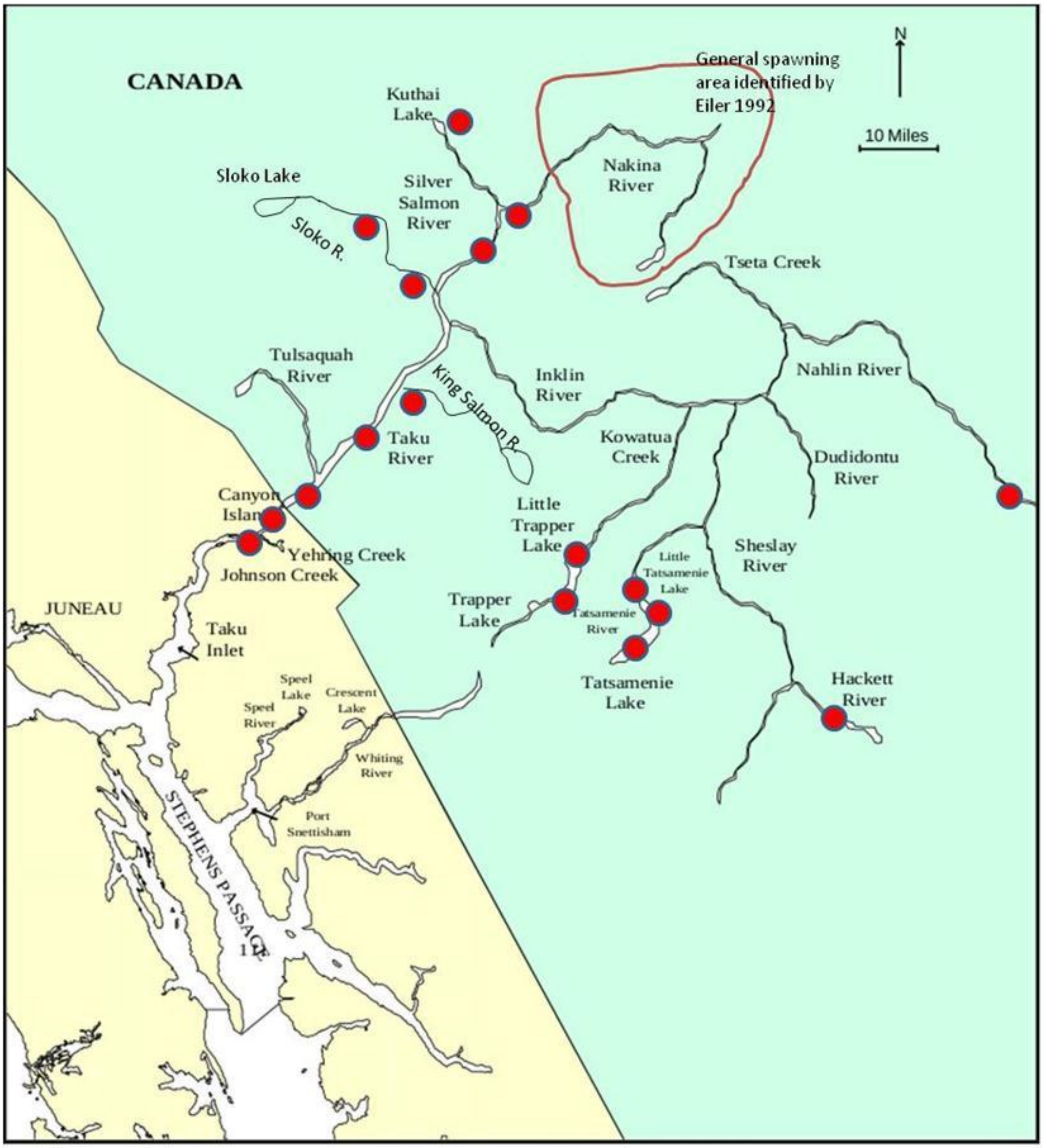

Figure 26.–Sockeye salmon spawning areas identified by Eiler et al. 1988 and 1992.

Source: Map adapted from Andel 2004.

Coho Salmon

Edie (2000) reported excellent coho salmon habitat in the upper portions of the Taku Watershed between the outlet of Kuthai lake and the downstream end of the Kuthai Lake wetlands (Figure 27). Downstream of the wetlands, habitat in Silver Salmon River was limited by steep gradient. McPherson and Bernard (1996) estimated that 22% of Taku River coho salmon spawn downstream of the U.S./Canada Border. Elliott and Bernard (1994) also noted coho salmon rearing in Yehring Creek, Nahlin River, Tatsamenie Lake and the lower Taku River.

Eiler (1995) noted that most coho salmon return to the Taku River drainage in fall, although there is a small run earlier in the summer. In a study of satellite tracking of radio tagged salmon, Eiler found coho spawning in the Inklin River and Tatsatua Creek.

Coho salmon in the Taku Drainage spawn in a variety of habitats (Sandercock 1991), including small headwater streams, side channels and main channels of large rivers. Eiler et al., as reported in Yanusz (2000), estimated that 22% of the coho stock spawning in the Taku River spawn below the U.S./Canada border, with the remaining 78% spawning upstream of the Tulsequah confluence. Shaul et al. (2003) stated that coho salmon escapement above Canyon Island (i.e., near or above the U.S./Canada border) ranged from an estimated 39,500 to 219,600 between 1987 and 1992.

Pink Salmon

Pink salmon spawning has been documented in the Tulsequah River and near the upper tributaries of the Inklin and Nakina Rivers (TRTFN 2000). McGregor and Clark (1988) identified the Nakina River as the principal pink salmon spawning tributary in the Taku River drainage in the Taku River watershed. They calculated a population estimate of 585,915 pink salmon, but did not discuss spawning habitats or life history of this fish species.

Steelhead Trout

The anadromous form of the rainbow trout spawn in early spring before migrating back out to sea. Steelhead have been documented throughout the Taku Watershed, especially in the upstream tributaries near Kuthai Lake (refer to Figure 27 for location, TRTFN 2000, Andel 2004).

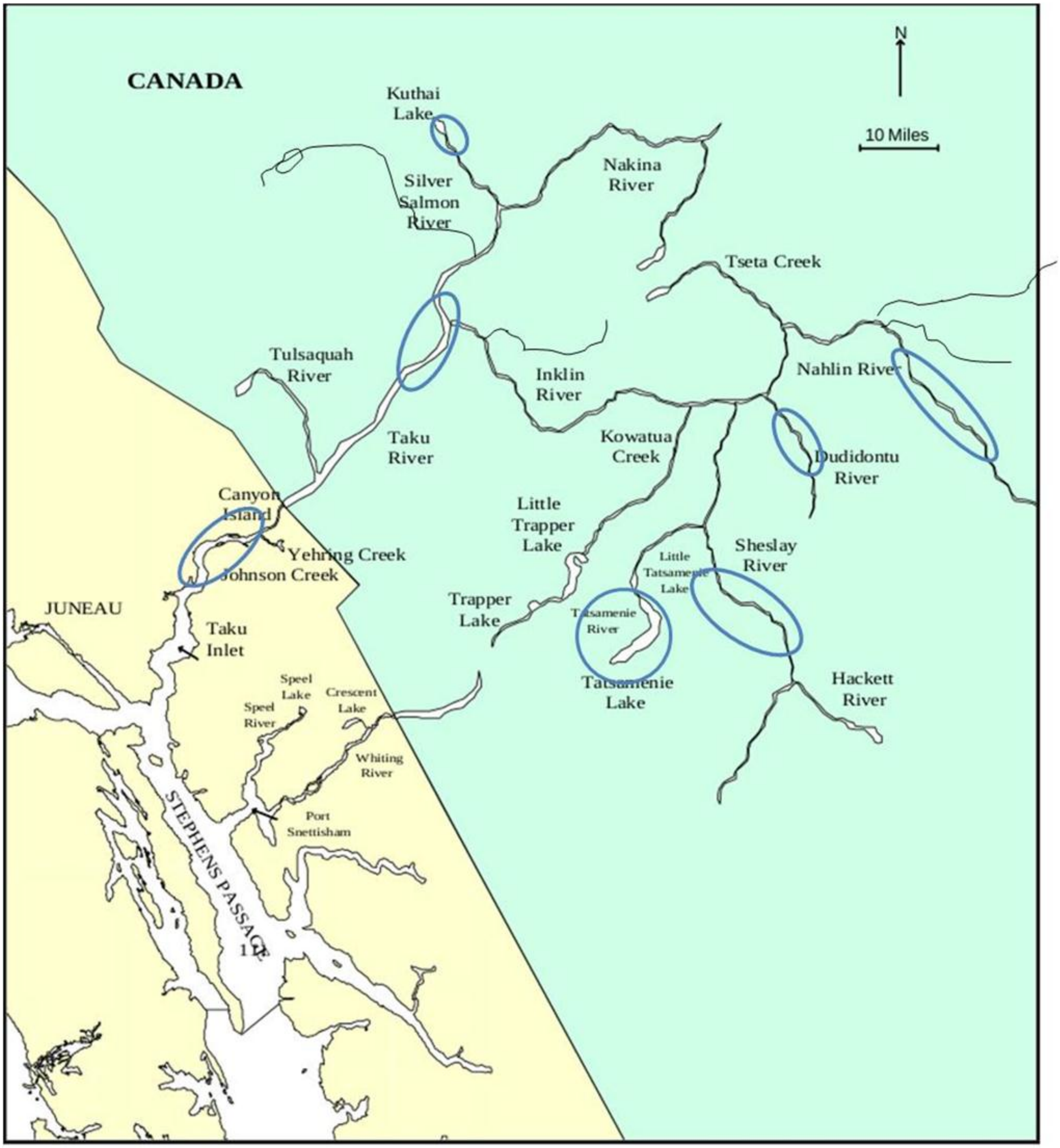

Figure 27.–Reported concentrations of coho salmon juveniles and smolts (delineated by ellipse) in the Taku River drainage.

Source: Map adapted from Andel 2004.

TULSEQUAH RIVER

The Tulsequah River mainstem provides important spawning habitat for sockeye, coho and chum salmon. Several studies have sampled the Tulsequah River for fish. The Ministry of the Environment for British Columbia has documented Dolly Varden throughout the Tulsequah River upstream to the glaciers (Figure 28). Fish studies by Taku River Tlingit First Nation (TRTFN) reported Dolly Varden, bull trout and coho salmon juveniles widely distributed in the river from the airstrip to the mouth (Figure 29). Studies found more widespread use of the Tulsequah River by fish than earlier reports (Gartner Lee 2008b). According to TRTFN, the Tulsequah River provides high value fish habitat throughout the flood plain. There is overwintering habitat critical to coho salmon and Dolly Varden char.

Fish sampling was conducted by Rescan (1997) in August of 1994 and June of 1995. Fish sampling methods included electrofishing, minnow trapping and seining. Rescan (2007) identified 10 fish species from the Tulsequah River Drainage (Table 3).

Table 3.– Fish species reported from Tulsequah River Drainage.

Common name	Scientific name
Dolly Varden char	*S. malma*
Coho Salmon	*O. kisutch*
Sockeye Salmon	*O. nerka*
Chinook Salmon	*O. tshawytscha*
Round Whitefish	*O. keta*
Coastrange Sculpin	*P. cylindraceum*
Sculpin	Species not identified
Slimy Sculpin	*C. cognatus*
Stickleback	Species not identified
Steelhead Trout	*O. mykiss*

The Tulsequah River contains a range of spawning and rearing habitat associated with mainstream margins, side channels and clearwater side channels (Gartner Lee 2007a). The highest value habitats for salmonid spawning and rearing are found in the clearwater channels along the river margins and occasionally appear in the middle of the flood plain. Likely, these side channels are fed by ground and surface water from the valley sides. The clearwater segments that appear in the middle of the flood plain (generally found downstream of the mine site) are likely fed by subsurface flows welling into the river. Although these clear water channels are frequently flooded with glacial river water, they provide relatively stable salmonid rearing habitat (Gartner Lee 2007a).

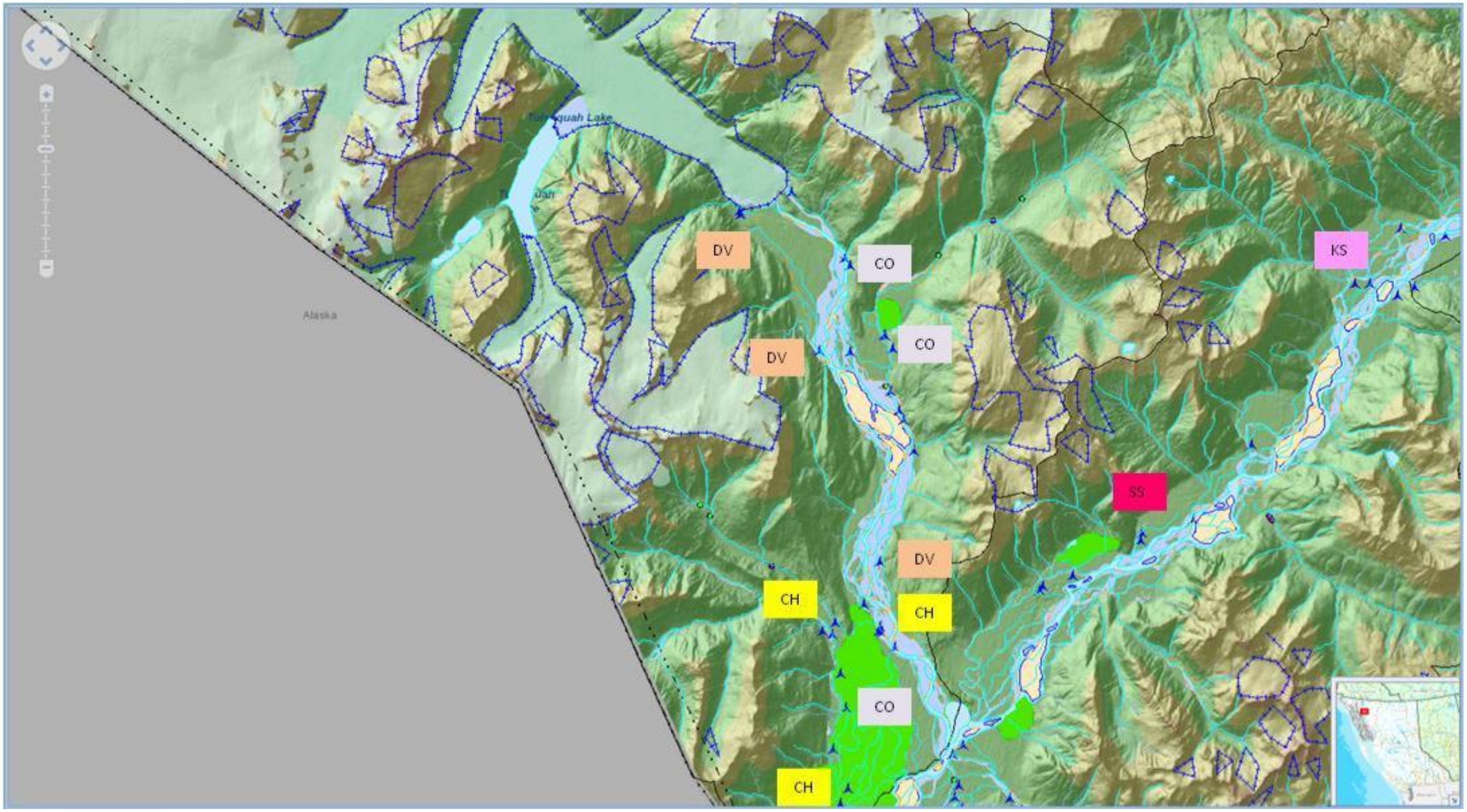

Figure 28.–Distribution of salmonid fish in the Tulsequah River and Taku River near Big Bull Slough.

Source: Map and data from Ministry of the Environment, British Columbia, Canada.
Note: CH = chum salmon, DV = Dolly Varden, CO = coho salmon, KS = King (or Chinook) salmon, SS = sockeye salmon.

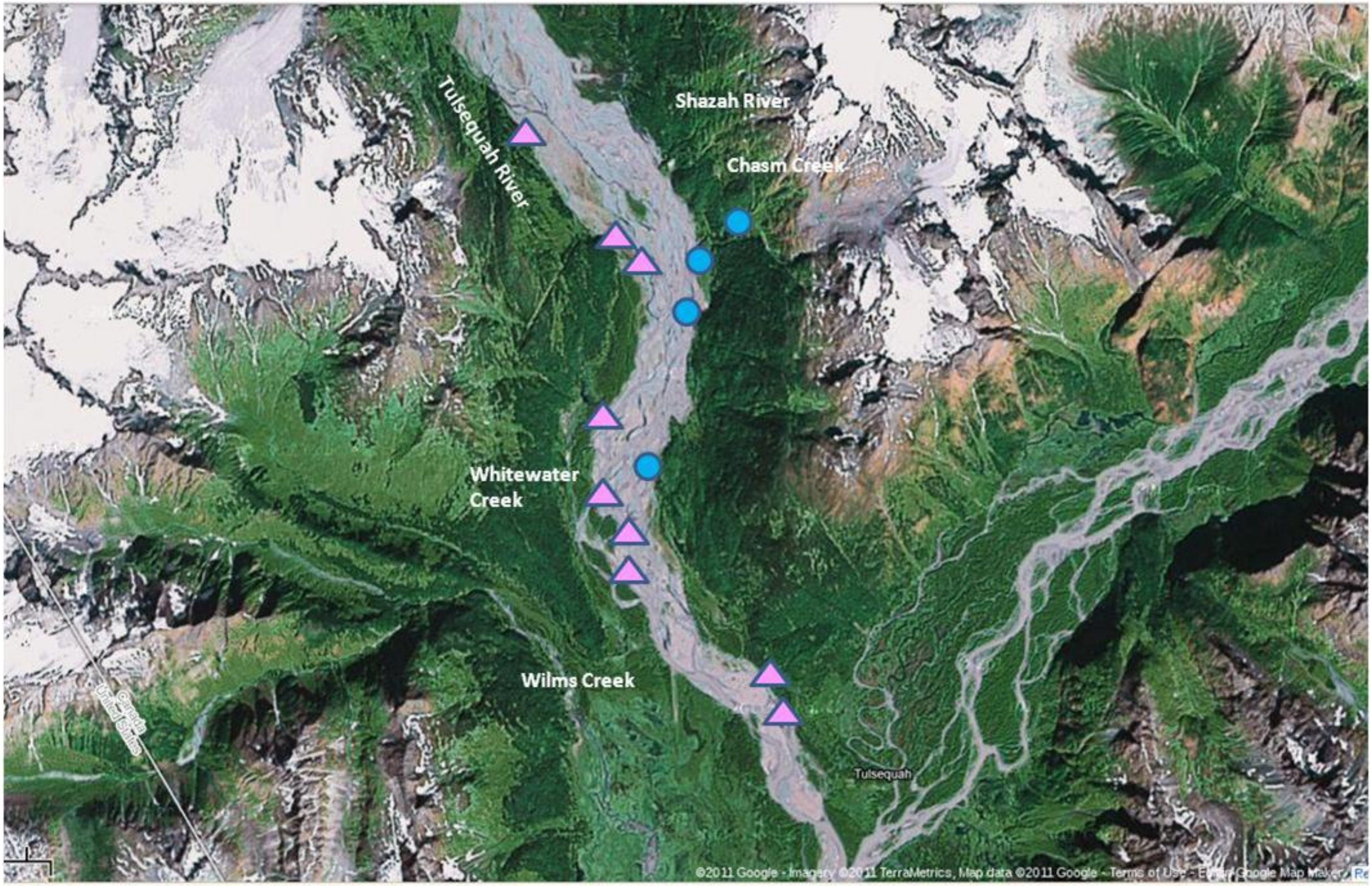

Figure 29.–Fish sampling in the Tulsequah River conducted by TRTFN.

Source: Map adapted from Google Maps, data from TRTFN.
Note: Pink triangle represents coho salmon, blue circle represents Dolly Varden/bull trout.

METALS CONCENTRATIONS IN FISH TISSUES

In 2002, a cooperative research team from BC Ministry of the Environment, U.S. Fish and Wildlife Service and ADF&G collected juvenile coho salmon and Dolly Varden to determine whole body concentrations of Al, Sb, As, Ba, Be, Bi, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Ni, K, Se, Ag, Na, Sr, Te, Tl, Sn, Ti, V, Zn and Zr. In 2011, ADF&G Division of Habitat collected additional juvenile coho salmon and Dolly Varden to determine whole body metals concentrations. Data from both sampling efforts are being analyzed and will be presented in an ADF&G technical report (Hitselberger 2012).

WILDLIFE POPULATIONS

Gartner Lee (2008a) conducted a study of potential effects from mine development on the distribution, use, and availability of high value foraging habitats for different species in the lower Taku and Tulsequah watersheds. Their study examined potential effects to grizzly and black bears, moose, wolf, fisher, waterfowl, shorebirds, trumpeter swan, forest nesting birds, amphibians, raptors and rare plants. The potential effects focused on the then-proposed barge transportation system but included some effects from mine construction and operation.

Gartner Lee reported that most of the seasonal high value habitats were associated with floodplain, estuary, wetland and lower elevation forest habitats in the lower Taku and Tulsequah watersheds. Their study areas extended from Taku Inlet upstream to Big Bull Slough and the Tulsequah River and focused on effects from the proposed barge transportation system. Edie (2000) described wildlife inventory data in the general area of the Tulsequah Chief Mine and proposed access roads that had been collected up to the date of their report. Although the information they reported was based on surveys done before 2000, the information does provide an overview of wildlife and habitat use in the project areas. Their information is summarized below, by species.

Mountain Goats

Edie (2000) reported that more than 140 goats were confirmed to live in the Taku/Tulsequah drainage during summer. Surveys during winter months located only 23 goats in the Taku/Tulsequah area. According to Edie, goats preferred lower elevations and southerly aspects in locations with forage and escape terrain during winter months. Edie also cited that poor visibility reduced winter counts. Moderate to high capability goat winter range was found scattered throughout steeper mountain terrain. Edie stated that surveys conducted during winter suggest that more than 200 goats live along the proposed road corridor. The authors further noted that although seasonal migration patterns have not been identified, it appears there is local movements of goats "between lower elevations and (often) south aspects in winter and higher elevations and additional or other aspects during other seasons."

Mountain Sheep

Mountain sheep are found only drier interior portion of the project area, more or less north of the Silver Salmon/Nakina confluence (Edie, 2000, reference Figure 22 for locations of these rivers). Edie reported that 1998 surveys found more than mountain sheep in that area, with an estimated 47 rams and 30 kids per 100 ewes. Mountain sheep habitat was centered on areas of alpine and subalpine vegetation communities providing grass, sedge and herb forage, usually with escape terrain nearby. Winter habitats are usually windswept ridges where access to grasses and herbs is maintained by removal of snow by wind.

Moose

Twenty-one moose were counted in the Tulsequah Project Area (Edie 2000). The best moose winter range was located along the Taku mainstem and in low elevations.

Edie described two somewhat distinct moose populations in the general project area: a coastal population along the Taku River and the lower Nakina and Sloko Rivers and a more interior population in areas north of the Nakina and Sloko Rivers (Refer to Figure 22 for locations of the rivers). In February 2000, the coastal population was conservatively estimated to include at least 250 animals, with 98 bulls and 23 calves per 100 cows. The coastal population uses alluvial habitats along the major river systems throughout the year. In contrast, the interior population appears to migrate between higher elevation summer ranges and lower elevation winter ranges in most years, depending on snow depth (Edie 2000).

Caribou

Edie (2000) reported that only four caribou were observed in 1996 surveys and limited caribou sign was observed in 1997. The best caribou winter range was found on low elevation alluvial soils with terrestrial lichen and on windswept ridges at higher elevations.

Grizzly and Black Bears

Grizzly bears tended to be found in valley bottoms; black bears are more frequently found at higher elevations on avalanche slopes. Grizzly dens were usually excavated in the lower alpine zone on steep southerly exposures. Grizzly dens were found in steep terrain near tree line along the proposed access road route. Fewer grizzly bears and less sign was found in the access road area than in the Taku/Tulsequah area. Black bears were common in forested habitats in the access road area. Sightings of bears and dens was unavoidably biased toward open habitats with better visibility. Grizzly sign was more common than black bear sign on most transects and was more common along Taku and Nakina Rivers than in Tulsequah watershed.

As reported in Edie (2000), 30-day surveys of grizzly bear presence and habitat use within 500 m of the proposed road alignments was conducted.[1] The authors recommended changes to the then-proposed road alignment and that a vegetative screen between the road alignment and bear foraging areas be maintained. The reports also recommended changes in road alignments to maintain natural hydrologic patterns. Habitats most often considered threatened were feeding areas in sedge meadows, avalanche chutes and berry-producing forest.

Furbearers

Edie reported that in the Taku/Tulsequah drainage and along the proposed access road, red squirrels, ermine and marten were the most abundant furbearers. Wolf tracks were common in the area of the proposed access road.

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[1] Francis, S. R. and M. Gallagher, Tulsequah grizzly bear patch habitat assessment, unpublished report, 1998. Available from Phyllis Weber Scannell, 1235 Schodack Landing Road, Schodack Landing, NY 12156.

Waterfowl

Edie reported that 12–21 Trumpeter Swans, 41–130 Canada Geese and 140–163 ducks were counted during aerial surveys in the Taku/Tulsequah drainage. Trumpeter swan nesting was confirmed in 1994–1996 surveys. Nesting geese were common.

Raptors

Eighteen bald eagle nests were found in the Taku/Tulsequah area, about half were reported as apparently active, although a later survey found in 1995 found only three active nests. Two red-tailed hawk nests were found.

Rescan (1997) conducted surveys of Golden Eagle nests in cliff habitats in proposed road alignment areas. They found eight golden eagle nests were found, none of which were apparently active.

Forest Nesting Birds

The most commonly reported forest birds (Edie 2000) were yellow-rumped warbler, ruby-crowned kinglet, varied thrush, pine siskin, dark-eyed junco, blue grouse, red-breasted sapsucker and American robin.

CURRENT STATUS OF MINING & INFORMATION NEEDS

MINE PLAN OF OPERATIONS

In 2010, Chieftain Metals purchased the mining claims and began an exploration program. To date, there is no plan of operations for the mine. A mining plan, when developed, should comprise detailed descriptions of the proposed mine operation, including:

- Transportation of equipment and personnel and for shipping ore. Transportation of ore, including loading facilities, wheel washing and other measures to prevent ore spillage and contamination.
- Siting of mine facilities, including tailings ponds, waste rock storage areas, concentrate storage area.
- Mill operations, including a description of the process for concentrating ore.
- Chemical and fuel storage and Spill Prevention and Contingency Plans.
- Personnel housing, including handling of domestic waste (sewage, garbage).
- Water treatment plant. Processes that will be used, anticipated concentrations of metals and TDS, anticipated discharge volumes and predicted mass loadings.
- Monitoring plans for seepage from tailings ponds, waste rock storage areas, etc. Monitoring likely will include a series of wells, and possibly a pump-back system.
- Predictions for acid rock generation and measures that will be put in place during mining to minimize future seepage from the mine.
- Plans for future closure of the mine.

After the Mine Plan of Operations is developed, an environmental assessment plan should be developed that identifies potential effects to fish and wildlife and their habitats from specific components of the mine (as listed above). In addition, the assessment should include cumulative effects of the Tulsequah Chief, New Polaris and Big Bull mines on fish and wildlife habitats and water quality. The previous studies described in this report serve as a starting point for future environmental effects monitoring.

REMAINING ISSUES

Critical issues that must be addressed are transportation, acid rock drainage, control of point and nonpoint pollution and developing the mine for future closure.

Transportation

In December 2011, Chieftain Metals revised the road alignment[2] with input from TRTFN. The new alignment reduced the road length from 156 to 122 km and avoided the Nakina heritage trail, an important heritage value of the TRTFN, and Blue Canyon, a high-value TRTFN traditional use area and caribou habitat

Stantec[2] identified the following improvements over the previous road alignment:

- Complete avoidance of the TRTFN Nakina Heritage trail, an important cultural and traditional use value feature for the TRTFN.
- Complete avoidance of the Blue Canyon area traversed by the existing access road alignment in the Wilson and Spruce Creek valleys east of Atlin: a high-value traditional use area for the TRTFN and high value caribou habitat for the Atlin woodland caribou herd.
- Elimination of 34 km of new road construction.
- A reduction of 24 to 25 bridge crossings and up to 495 m of bridge length, particularly for the high value fish habitat in the Silver Salmon River drainage and tributaries.
- Less potential impact upon high value salmon habitat by a reduction of length of road that crosses areas of high surface soil erosion risk that could pose potential hazard of sediment input into areas of high value salmon habitat.
- Reduced potential impact to spawning and escapement of salmon juveniles by moving the road alignment away from Kuthai Lake.
- Reduction in overall risk to grizzly bear and caribou populations.
- Near elimination of potential tenure conflicts with placer mining interests in the Wilson, Spruce and Pine creek drainages.

Acid Rock Drainage

Acid rock drainage and leaching of metals to adjacent waterways has been a long-term problem at mine since the Taku/Tulsequah drainage. According to the Society for Atlin's Sustainable Economic Initiatives (2005), acid rock drainage at the Tulsequah Chief Mine has occurred since the mine was first abandoned in the 1950s. The acid is generated by old waste rock and broken

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[2] Stantec Consulting Ltd. Tulsequah Chief mine—revised access road alignment. Unpublished 2011 project description to determine federal and provincial environmental assessment requirements.

ore piled near and within underground openings and the discharge contains elevated Cu, Zn, Pb, Cd and As. Petition No. 95B estimated a metals leaching rate of 15 tons per year into the Tulsequah River.

In their November 2007 document, Gartner Lee (2007b) described test results that indicated most waste rock to be potentially acid generating. This waste rock resulted from previous mining and exploration and is currently located at the 5200 and 5400 level portals. Gartner Lee proposed that all waste rock would be relocated to a historic potentially acid generating waste site. Their study points out the need for a detailed sampling program to identify all areas of historic acid generating and potentially acid generating rock. The issue of long-term stability of the mine and plans to minimize acid rock drainage must be addressed in the Mine Plan of Operations.

Mine Closure

The Mine Plan of Operations should include plans for reclamation and adequate bonding. The plan should provide detailed information for reclaiming all access roads, waste rock dumps, mill and other facilities and for stabilizing the ore body. Mines in the Taku/Tulsequah drainage should be designed to avoid long-term (or perpetual) water treatment. The mine plan should include descriptions of how exposed ore will be treated to minimize acid rock drainage and metals input to streams and wetlands.

LONG-TERM ENVIRONMENTAL MONITORING OF THE TAKU AND TULSEQUAH RIVER MINES

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 closeout. 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. Usually environmental monitoring is designed to detect changes from baseline, or preproject, conditions. The Tulsequah Chief Mine has been producing acid rock drainage and contributing metals to the Tulsequah River since the 1950s; therefore, comparisons with pre-project conditions are not possible.

ADF&G has designed and conducted biomonitoring at a number of mine 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 (Ott et al. 2010). ADF&G's long-term biomonitoring projects are designed with the following features.

- Establish sample sites for long-term monitoring.
- Monitor 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.

RECOMMENDED SAMPLING METHODS

Identification of Sample Sites

Permanent sampling sites should be established at the onset of the monitoring program. Sites 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 samples should be collected and tested to establish that mixing is complete; usually samples of conductivity are sufficient.

Water Quality and Quantity

Sample all inputs from the mine, including discharges from water treatment plants, tailings ponds and mine drainage. Water monitoring should include both volume (discharge) and concentrations of metals.

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 should be defined from baseline sampling; metals that consistently fell below the method reporting limit could be eliminated unless they are known to be part of the ore deposit. Stream gauges should be installed at all water sampling sites (where possible) and measurements of stream flow recorded at the times water samples are collected.

Water samples should be collected according to Standard Methods (APHA 1992 or later) or similar established standard method in pre-cleaned bottles and preserved with a preservative appropriate for the type of sample or analysis. 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

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 and laboratory methods and quality assurance/quality control procedures are described by Ott et al. (2010).

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. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (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. Sampling should be done according to Ott et al. (2010) or similar methods.

The sampling schedule for benthic invertebrates can be adjusted to maximize information; for example, samples could be collected once 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

Tissue sampling should be done on either whole body juvenile fish or discreet tissues of resident fish. Results from early sampling may result in modifications of laboratory analysis—if specific metals are consistently below the method reporting limits, they should be considered for elimination in future samples. ADF&G (Ott et al. 2010) described methods for collecting and processing both juvenile and adult fish for tissue analysis.

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 fyke nets. Because of possible damage to fish vertebrae, electrofishing is 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 in terms of timing, gear and effort.

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 notable increase in metals concentrations in fish tissues. Protection of downstream environments requires that agency and mining company officials can take corrective actions quickly.

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