Technical Report No. 12-10

Aquatic Studies at Kensington Gold Mine, 2012

by

Jackie Timothy and Katrina M. Kanouse

with Southeast Region Habitat Staff

February 2013

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, and Special Publications. 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)

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. 12-10

AQUATIC STUDIES AT KENSINGTON GOLD MINE, 2012

by
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Cover: Clockwise from bottom left hand corner: periphyton sample; benthic macroinvertebrates from the Orders Plecoptera (stonefly), Ephemeroptera (mayfly) and Trichoptera (caddisfly); juvenile Dolly Varden char, and; anadromous fish barrier at Johnson Creek.

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ACKNOWLEDGEMENTS

The Alaska Department of Fish and Game thanks Coeur Alaska Inc. Kensington Gold Mine for financially supporting the aquatic studies program. Kevin Eppers, Pete Strow, and staff provided logistical support and water quality information.

Alaska Department of Fish and Game Division of Habitat biologists assisted with this year's effort, including Greg Albrecht, Benjamin Brewster, Matt Kern, Tally Teal, Tess Quinn, Gordon Willson-Naranjo, and Johnny Zutz. John Hudson provided macroinvertebrate quality assurance and control. Division of Sport Fish biometrician Dan Reed provided biometric review and Dr. Al Ott provided technical review. Habitat biologist Nicole Legere edited the draft report and Amy Carroll of the Commercial Fisheries Division prepared the report for publication. Thank you all so very much.

EXECUTIVE SUMMARY

The Alaska Department of Fish and Game (ADF&G) Division of Habitat (Habitat) completes the aquatic resource monitoring the U.S. Forest Service (USFS) and the Alaska Department of Environmental Conservation (DEC) require for Coeur Alaska Inc.'s (Coeur) Kensington Gold Mine. This partnership provides Habitat the opportunity to gather and review aquatic information and identify, assess, and resolve issues at the Kensington Gold Mine as they arise.

During 2011, the first year we completed aquatic studies, we observed the physiochemical habitat characteristics of each sample site are distinct and saw less value in comparisons amongst drainages and more value in comparisons at each sampling location between years. In 2012, we focused on evaluating stream health by assessing biotic assemblages in relation to the physical and chemical constituents within a drainage section. This process will continue over the long term. These are complex relationships with inherent high variability.

Weather is a factor we consider when we analyze the aquatic study data. The National Weather Service reports that November 2012 was the seventh consecutive month that Juneau experienced air temperatures below normal. The cooler temperatures contributed to a decrease in algal biomass in our annual July samples at all sample sites except in Upper Slate Creek where we observed a slightly greater density. The cooler temperatures and above normal precipitation in 2012 also effectively controlled the algae growing in the tailing treatment facility (TTF) so the filters in the TTF wastewater treatment plant did not clog.

Coeur's environmental staff agreed we could continue sampling periphyton quarterly in Lower, East Fork and Upper Slate Creek during 2012 and beyond. Should warmer temperatures and decreased precipitation in future years result in an algal bloom in the TTF as happened in 2011, we will have periphyton community composition and biomass data across seasons and drainage sections to compare. These data will be useful should Coeur need to treat the TTF with an algaecide. Of interest is there are no significant differences between the mean ranks of July 2011 and July 2012 chlorophyll *a* densities in samples collected in East Fork Slate Creek, meaning algal biomass is about the same both years downstream of the TTF.

The Lower Slate Creek benthic macroinvertebrate sample site is a shallow, wide riffle with no defined thalweg. We find it difficult to select suitable sampling locations and we record more chironomids (midges) in Lower Slate Creek than any other Kensington Gold Mine sampling site. Though we tried to replicate the 2005–2010 sampling reach of the previous contractor (Flory 2011), we are not confident we sampled the exact reach in 2011 and 2012. In 2013, we will collect six additional benthic macroinvertebrate samples at riffle habitats upstream where it appears there are better opportunities for sampling. If we find the EPT taxa in previously documented proportions, we will establish a new long-term benthic macroinvertebrate sampling site in Lower Slate Creek.

The concentrations of the metallic elements cadmium, copper, lead, mercury, nickel, silver, and zinc, and the semimetallic element arsenic, are higher in East Fork Slate Creek stream sediments than in those of Upper Slate or Lower Slate Creeks. Cadmium and zinc concentrations are about an order of magnitude higher and unlike the aforementioned metals, do not naturally occur above NOAA sediment recommendations[a] for freshwater ecosystems (Buchman 2008; MacDonald et al.

[a] These are guidelines, not federal or state standards.

2000) at Upper Slate Creek, suggesting input somewhere between the sampling stations in Upper Slate Creek and East Fork Slate Creek, which includes the TTF, dam and plunge pool.

That said, there are no significant differences in growth or survival of *Chironomus dilutes* or *Hyalella azteca* between the laboratory control sediments and the individual sediment samples in our short-term chronic sediment toxicity tests at any sampling location. We will sample stream sediments in West Fork Slate Creek and Upper Sherman Creek in 2013 and test for metals concentrations to improve our understanding of naturally occurring background conditions.

The phosphorous concentrations measured in the TTF last year are consistent with those found in eutrophic lakes, and this year are consistent with those found in mesotrophic lakes, despite the TTF being situated in the formerly oligotrophic Lower Slate Lake. We theorize a source of phosphorous in the mine tailings is causing algal blooms in the TTF.

We may be starting to see a correlation between phosphorus spikes in the TTF and total dissolved solids[b] (TDS) spikes downstream in East Fork Slate Creek. In 2013, we will review these data with a 2012 schedule of TTF discharge to see if there is a correlation between phosphorus dips when the mill is not operating or when the tailings are directed to the underground paste plant. We have not ruled out natural seeps or the graphitic phyllite seeps at the dam and plunge pool as a metals contributor to East Fork Slate Creek.

In 2013, we will sample Dolly Varden char *Salvelinus malma* in West Fork Slate Creek for whole body metals concentrations for comparison with other Slate Creek drainage sampling locations. These data will help improve our understanding of natural metals concentrations and variability.

In our 2011 report, we stated we would investigate overwintering habitat possibilities in East Fork Slate Creek in 2012, as previous contractors suggested the East Fork Slate Creek Dolly Varden char population might be dependent on Upper Slate Lake migrants. We did not complete the investigation in 2012 as we planned, and have scheduled visits in February 2013.

We attempted, and did not document adult coho salmon returning to Lower Slate Creek, though it makes sense they spawn there given the number of age-0 and 1-year-old juveniles we observe. We viewed adult coho salmon returning to Lower Johnson Creek during snorkel surveys, and will continue to survey Lower Slate Creek by foot and snorkeling in 2013 as we work to document adult coho salmon spawning in the system. We will continue to investigate the presence of age-0 and 1-year-old juvenile coho salmon in Lower Slate Creek during spring 2013.

We reviewed the 2011 data with the 2012 data to ensure accuracy. We found errors in the 2011 periphyton, benthic macroinvertebrate, resident fish, and spawning substrate datasets. We corrected the errors and note corrections that change results in this report. We will continue the practice of revisiting the long-term dataset annually, noting errors and corrections in the subsequent report. Since we provide the report to Coeur by the end of February each year, readers can ensure they are reviewing the most recent issue by checking the February [year] date near the bottom of the cover page.

[b] TDS is a measure of minerals, salts, metals, cations or anions dissolved in water.

INTRODUCTION

The Kensington Gold Mine is located near Berners Bay in Southeast Alaska; about 72.5 km north of Juneau by air and about 56 km south of Haines by air (Figure 1). The site, where mining began near the end of the 19th century, is within the City and Borough of Juneau and the Tongass National Forest (Tetra Tech Inc. et al. 2004a,b). The mine is owned and operated by Coeur Alaska, Inc. under the Coeur d'Alene Corporation out of Coeur d'Alene, Idaho.

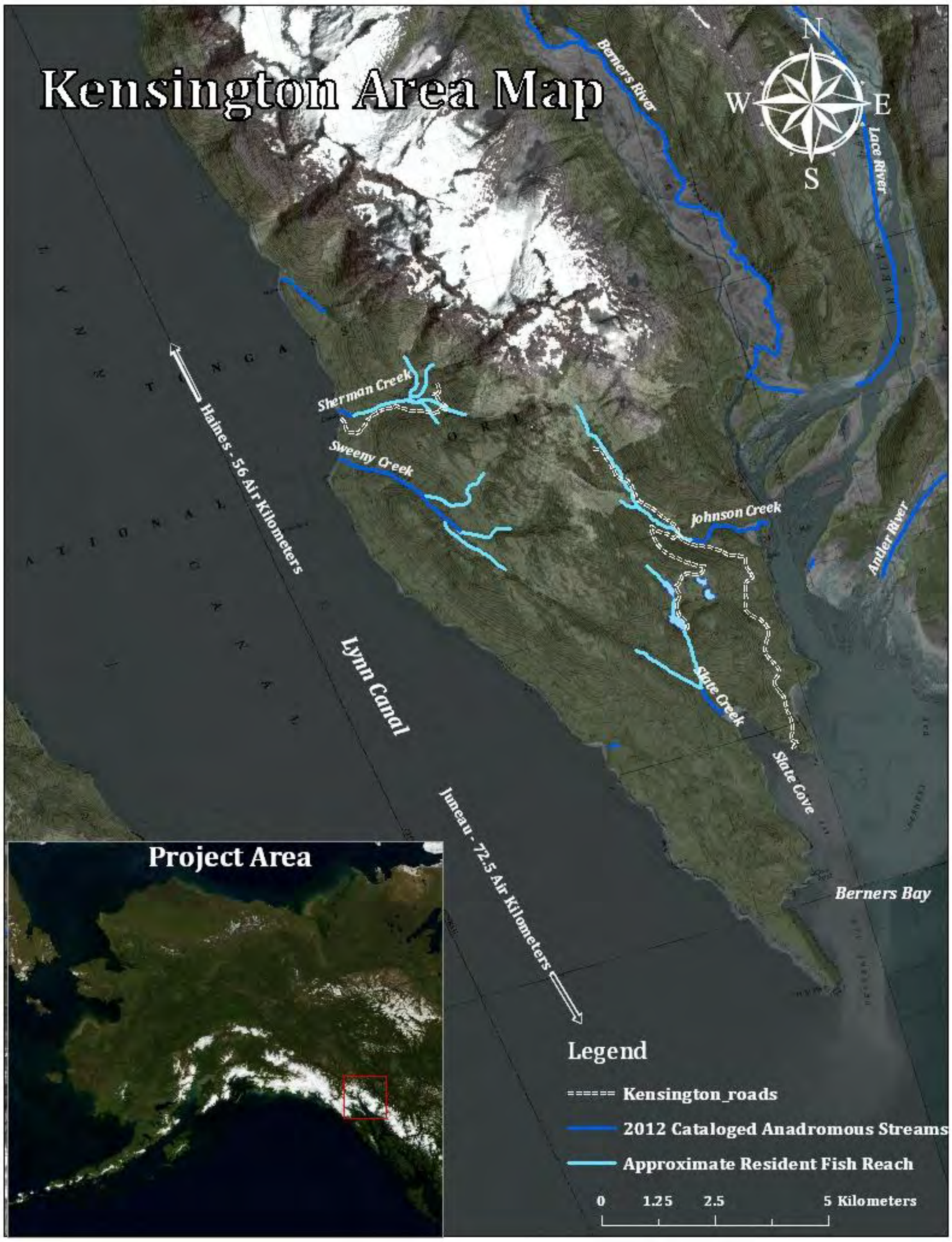

Figure 1.–Kensington Gold Mine area map.

Figure 2.–Kensington Gold Mine infrastructure.

Mine infrastructure is located in three drainages that support anadromous fish (Figure 2):

- The TTF in the Slate Creek drainage;
- The camp and mill facilities in the Johnson Creek drainage, and;
- The mine water treatment facility in the Sherman Creek drainage.

The Kensington and Jualin adits were connected in July 2007, making travel through the ore body between the Johnson and Sherman Creek drainages possible. The mine began production on June 24, 2010 and produces gold concentrate that is exported for processing. Tailings are disposed as slurry from the mill through a pipeline into the TTF. Under ADF&G's authorities at Alaska Statute (AS) 16.05.841 and 16.05.871, Habitat permits a dam and stream diversion in the Slate Creek drainage that allows Dolly Varden char to bypass the TTF and move downstream into East Fork Slate Creek. Habitat permits activities in two other waterbodies where Kensington Gold Mine activities occur, including an infiltration gallery and bridges at Johnson Creek, and bridges over tributaries to Sherman Creek (Timothy and Kanouse 2012, Appendix B).

Contractors gathered aquatic data for the Kensington Gold Mine from the late 1980s through 2005 that, in part, informed Habitat permit decisions, the USFS Plan of Operations monitoring requirements (Coeur 2005), the Environmental Protection Agency (EPA) National Pollutant Elimination Discharge System (NPDES) Permit No. AK-005057-1 (Timothy & Kanouse 2012, Appendix A), and the DEC Alaska Pollutant Elimination System (APDES) Permit No. AK0050571 (Timothy and Kanouse 2012, Appendix A). Contractor reports include Archipelago Marine Research Ltd. (1991), Dames and Moore (1991), Earthworks Technology, Inc. (2002), EVS Environment Consultants (2000), Flory (1998, 1999, 2000, 2001a, 2001b, 2002, 2004), HDR Alaska, Inc. (2003), Kline Environmental Research, LLC (2001, 2003, 2005), Konopacky Environmental (1992a, 1992b, 1993a, 1993b, 1993c, 1995, 1996a, 1996b, 1996c, 1996d), Pentec Environmental (1990, 1991), and Steffen Robertson and Kirsten Consulting Engineers and Scientists (1997). Monitoring reports include Flory (2006, 2007, 2008, 2009a, 2009b, 2009c, 2009d, 2011) and (Timothy and Kanouse 2012).

Habitat began the aquatic studies for the Kensington Gold Mine in Slate, Johnson, and Sherman Creeks in 2011. The aquatic monitoring requirements at the mine changed in 2011 as DEC assumed responsibility for mine discharge permitting, compliance, and enforcement, previously held by the EPA. The APDES Permit requires periphyton, benthic macroinvertebrate, resident fish and sediment sampling. Overall stream health is assessed by estimates of periphyton community composition and chlorophyll *a* biomass, benthic macroinvertebrate composition and abundance, resident Dolly Varden char abundance, condition, and whole body metals concentrations in the Slate Creek system, sediment metals concentrations, sediment toxicity, and pink salmon spawning substrate quality. Habitat also completes adult salmon counts and the tailing habitability studies the USFS Plan of Operations requires (Coeur 2005).

PURPOSE

The purpose of this technical report is to summarize our 2012 aquatic study data and document the condition of biological communities and sediments in the Slate, Johnson, and Sherman Creek drainages near mine development and operations. This report satisfies the aquatic study requirements of Coeur's USFS approved 2005 Plan of Operations and APDES Permit AK0050571.

STUDY AREA

We sample the locations within the drainages listed in Table 1.

Table 1.–Aquatic studies sample sites in three drainages.

Slate Creek	Johnson Creek	Sherman Creek
Lower Slate Creek	Lower Johnson Creek	Lower Sherman Creek
East Fork Slate Creek	Upper Johnson Creek	
West Fork Slate Creek		
TTF (Lower Slate Lake)		
Upper Slate Creek		

Note: Drainages are located near the Kensington Gold Mine, 2012.

Slate Creek Drainage

Slate Creek (Figure 3) drains a 10.5 km^2 watershed (Coeur 2005) into Slate Cove on the northwest side of Berners Bay. Two waterfalls about 1 km upstream of the mouth prevent upstream anadromous fish passage to the East and West Forks. There are two lakes in this drainage; Lower Slate and Upper Slate Lakes, both upstream of the East Fork. Many of the plants and animals that inhabit lakes differ from those that inhabit rivers, so results of samples taken in Lower Slate and East Fork Slate Creeks below the lakes will differ from those of West Fork Slate and Upper Slate Creeks, Johnson Creek, and Sherman Creek, where lakes are not present.

The Catalog of Waters Important for the Spawning, Rearing, or Migration of Anadromous Fishes (Catalog; Johnson and Blanche 2012) lists Lower Slate Creek (Stream No. 115-20-10030) providing habitat for pink salmon *Oncorhynchus gorbuscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, and eulachon *Thaleichthys pacificus*. Dolly Varden char and cutthroat trout *O. clarkii* are present below the waterfalls. Above the waterfalls, Dolly Varden char are present in East Fork Slate, West Fork Slate and Upper Slate Creeks.

We access Slate Creek by kayak from the Slate Cove dock when conditions permit. During inclement weather, we access the creek hiking along the rocky shoreline, or through the woods to the mouth. Above the waterfalls, East Fork Slate Creek is on river left and West Fork Slate Creek is on river right.[c] The 1 km East Fork Slate Creek reach above the waterfalls, to a plunge pool at the base of an earthen dam that contains the TTF, is a series of steep cascade falls. Upstream of the TTF, a small concrete dam diverts water draining from Upper Slate Lake through a diversion pipeline and into East Fork Slate Creek at the plunge pool, bypassing the TTF. Upper Slate Creek is the inlet creek to Upper Slate Lake and is upstream of current mine operations.

[c] The terms “river right” and “river left” are looking downstream in the direction water is flowing, per USGS convention.

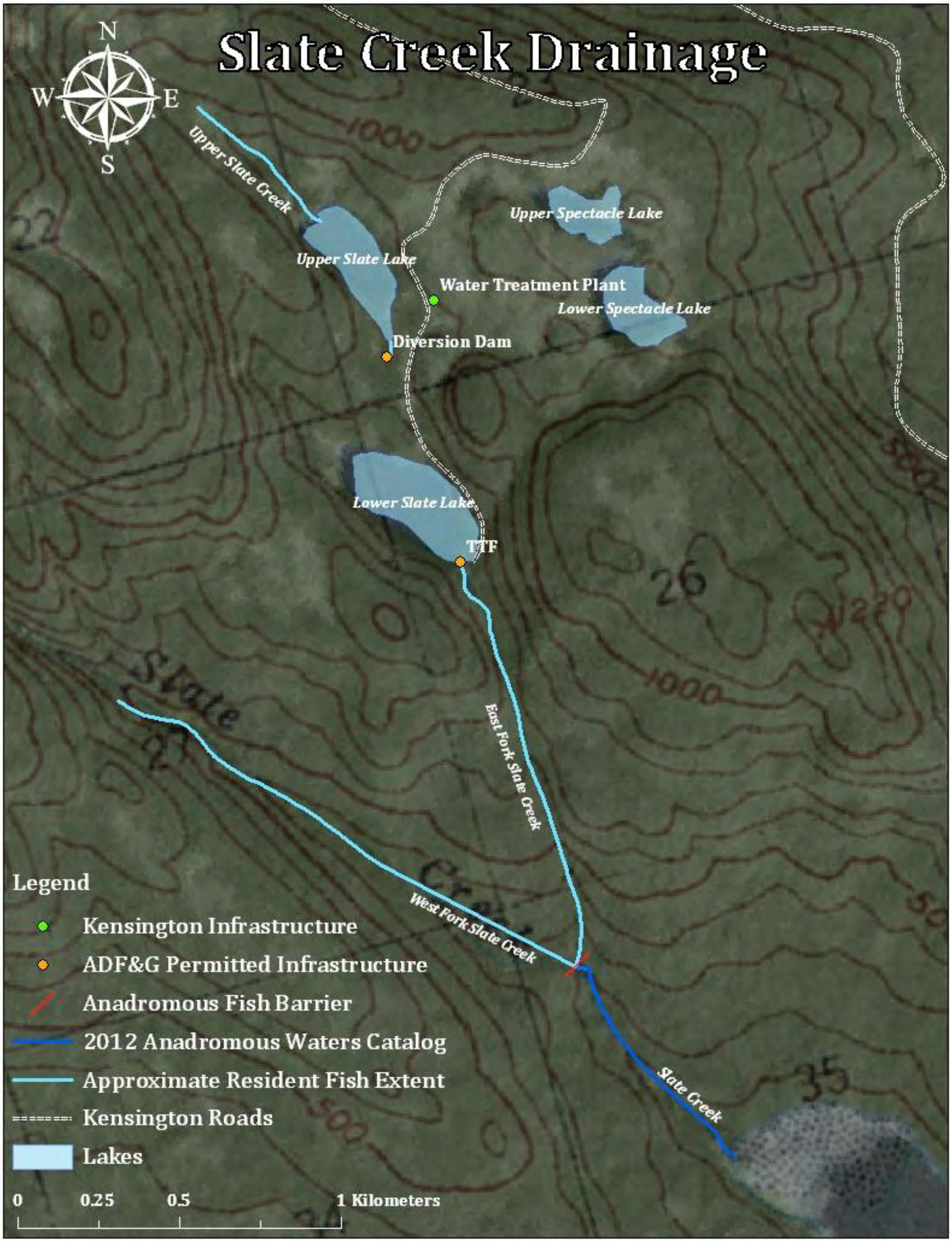

Figure 3.–Slate Creek Drainage.

Johnson Creek Drainage

Johnson Creek (Figure 4) drains a 14.6 km^2 watershed (Coeur 2005) to the north side of Berners Bay. A waterfall about 1.5 km upstream of the mouth prevents anadromous fish passage. The Catalog (Johnson and Blanche 2012) lists Johnson Creek (Stream No. 115-20-10070) providing habitat for pink, chum, and coho salmon. Dolly Varden char and cutthroat trout are present below the waterfall, and Dolly Varden char are present above the waterfall.

Figure 4.–Johnson Creek Drainage.

We access Lower Johnson Creek by hiking downhill from mile 3 of the Jualin road, through the woods and across meadows to the mouth. About 0.5 km above the anadromous barrier, the creek runs beneath the Jualin Road Bridge 1. The Snowslide Gulch tributary is on river right about 1 km upstream of Jualin Road Bridge 1. Further upstream, the creek runs beneath the Jualin Road Bridge 2 with camp facilities, the mill and the Jualin adit on river right. Upper Johnson Creek is between Jualin Road Bridge 2 and the headwaters. An infiltration gallery collects water from Johnson Creek at the mill bench to support the camp. Upper Johnson Creek above the waste rock pile near the Jualin adit to the headwaters is upstream of current mine operations.

Sherman Creek Drainage

Sherman Creek (Figure 5) drains a 10.84 km^2 watershed (Coeur 2005) to the east shore of Lynn Canal. A waterfall about 360 m upstream from the mouth prevents anadromous fish passage. The Catalog (Johnson and Blanche 2012) lists Sherman Creek (Stream No. 115-31-10330) providing habitat for pink, chum and coho salmon. Habitat submitted a nomination to remove coho salmon and correct the 2013 Catalog, since juvenile and adult coho salmon have not been documented in Sherman Creek. Above the waterfall, Dolly Varden char are present.

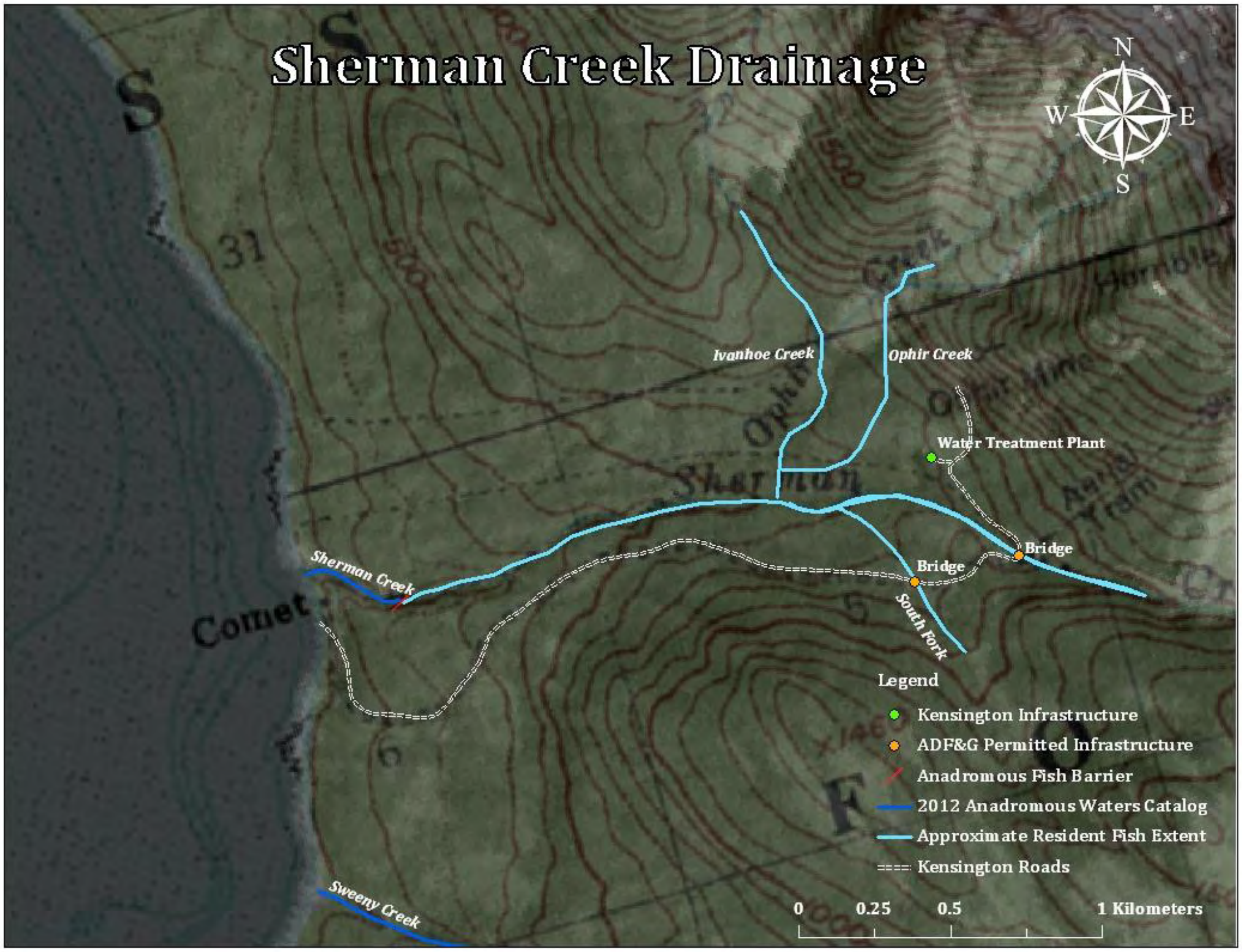

Figure 5.–Sherman Creek Drainage.

We access Sherman Creek by driving underground from the Jualin adit to the Kensington adit and then down the Comet Road to the beach where we walk north about 100 m to the mouth. Middle Sherman Creek is upstream of the waterfall and intercepts Ophir Creek on river right. Upstream of the Sherman and Ophir Creeks confluence, the South Fork of Sherman Creek is on river left. The mine water treatment plant Outfall 001 is upstream of the Sherman and South Fork Creeks confluence. The outfall discharge into Sherman Creek does not require an ADF&G fish passage permit as the discharge does not block fish passage (AS 16.05.841). Upper Sherman Creek above the Comet Road to the headwaters is upstream of current mine operations. The historic 2050 adit and a cabin are in this drainage.

AQUATIC STUDIES

We conduct the Kensington Gold Mine aquatic studies[d] at the frequency specified in the USFS Plan of Operations and DEC APDES Permit (Table 2). We note when we include studies in the Slate Creek drainage (Figure 6) in excess of those required by the USFS or DEC. We show maps of the stream segments and aquatic study sampling stations in Figures 7, 8, & 9. The latitude and longitude of each aquatic study sampling station is listed in Table 3.

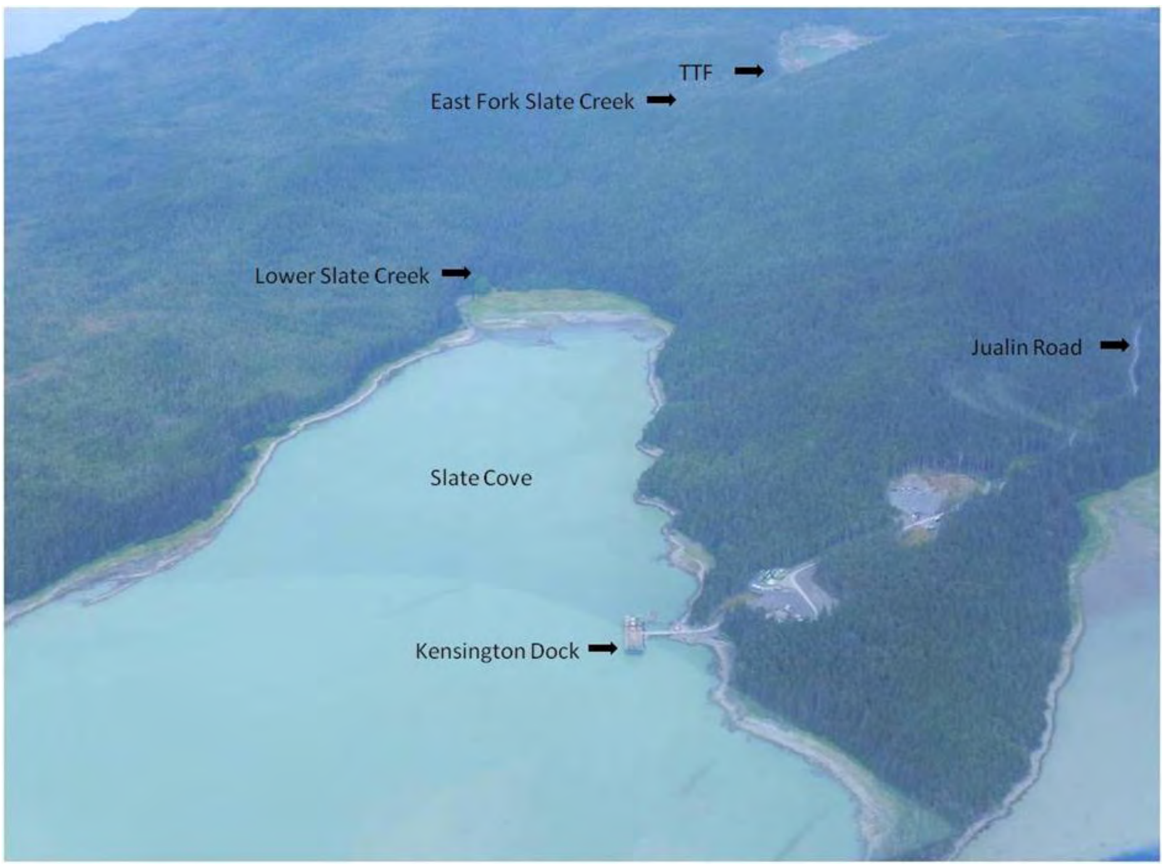

Figure 6.–Aerial view of the Slate Creek Drainage below the TTF.

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[d] For our own information, we use an Extech Exstick II field meter to measure basic water quality at each site during sampling, including temperature and conductivity. We use a Global Water Flow Probe FP101 to measure stream flow. Product names used in the publication are included for completeness but do not constitute product endorsement. The Alaska Department of Fish and Game does not endorse or recommend any specific company or their products.

Table 2.–Aquatic studies sampling frequency.

Location	Location Description	Aquatic Study	Sampling Frequency
Lower Slate Creek	Anadromous, drains to Berners Bay downstream of a 25 m barrier waterfall.	Periphyton biomass and composition	1/year
		Benthic macroinvertebrate composition and abundance	1/year
		Resident fish metals concentrations (Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Sediment metals concentrations and toxicity (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Spawning substrate quality	1/year
		Adult salmon counts	Annually
East Fork Slate Creek	Riffles and cascade falls downstream of the TTF to the barrier waterfall.	Periphyton biomass and composition	1/year
		Benthic macroinvertebrate composition and abundance	1/year
		Resident fish population and condition	1/year
		Resident fish metals concentrations (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Sediment metals concentrations and toxicity (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
West Fork Slate Creek	Reference site, a tributary to Slate Creek located outside of mine influence.	Periphyton biomass and composition	1/year
		Benthic macroinvertebrate composition and abundance	1/year
Upper Slate Creek	Control site located on the north side of upper Slate Lake upstream of mine influence.	Periphyton biomass and composition	1/year
		Benthic macroinvertebrate composition and abundance	1/year
		Resident fish population and condition	1/year
		Resident fish metals concentrations (Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Sediment metals concentrations and toxicity (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
Lower Johnson Creek	Anadromous, drains to Berners Bay below a 30 m barrier waterfall.	Sediment metals concentrations and toxicity (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Adult salmon counts	Annually
Upper Johnson Creek	Adjacent to camp facilities, downstream of the mill bench.	Benthic macroinvertebrate composition and abundance	1/year
Lower Sherman Creek	Anadromous, drains to Lynn Canal below a 15 m barrier waterfall.	Periphyton biomass and composition	1/year
		Benthic macroinvertebrate composition and abundance	1/year
		Sediment metals concentrations and toxicity (Ag, Al, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn)	1/year
		Adult salmon counts	1/year

Note: Requirements of the DEC APDES Permit and USFS Plan of Operations.

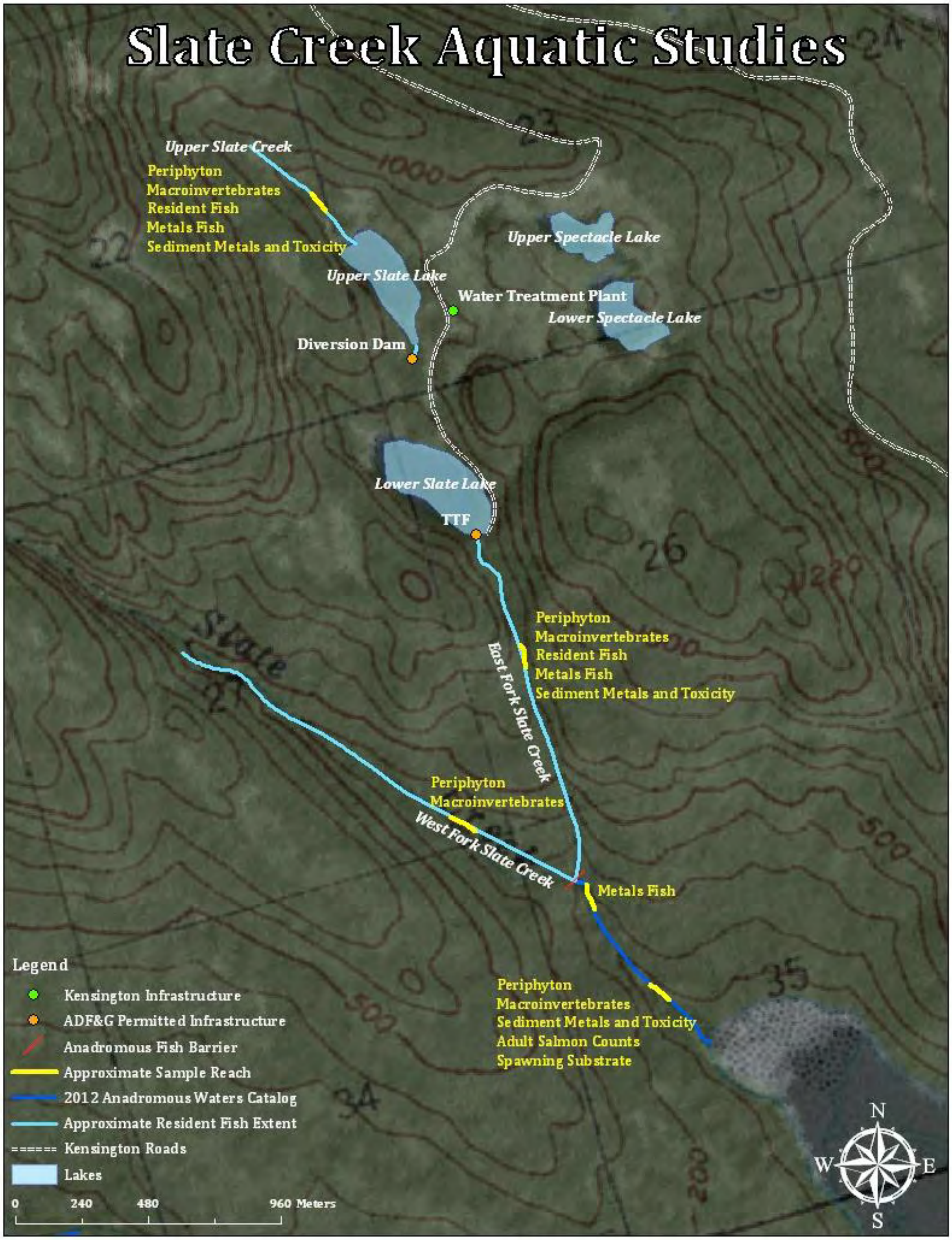

Figure 7.–Slate Creek aquatic studies.

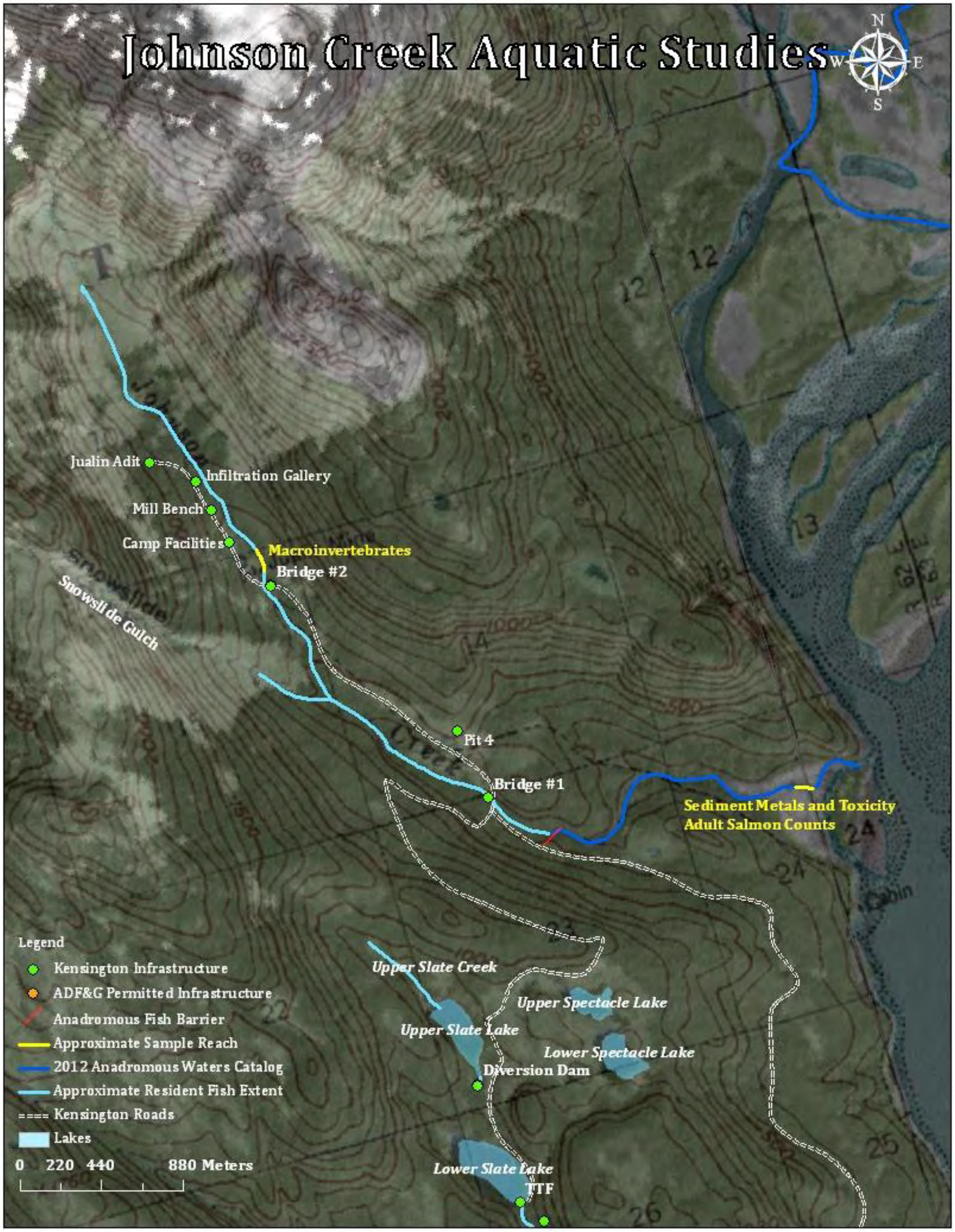

Figure 8.–Johnson Creek aquatic studies.

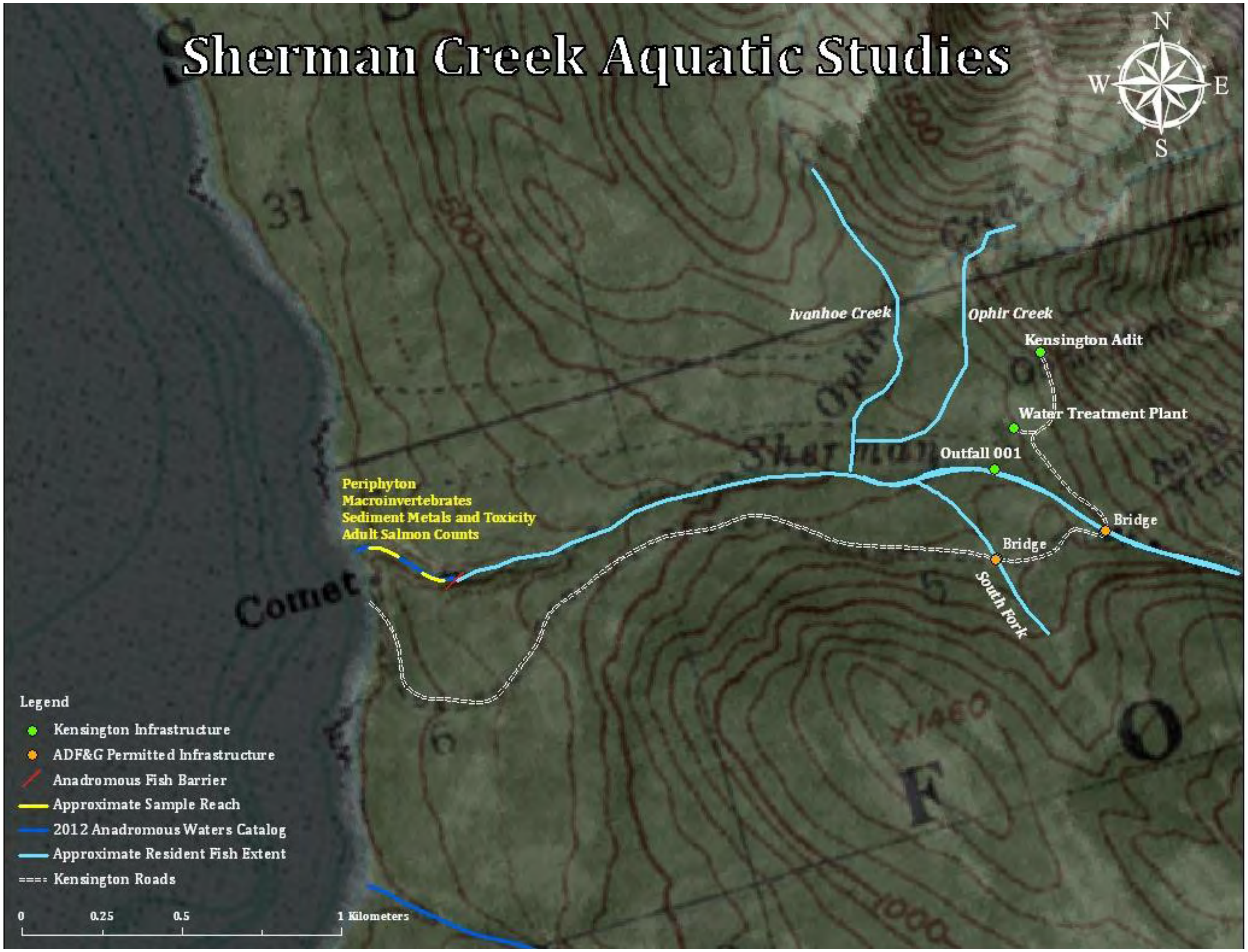

Figure 9.–Sherman Creek aquatic studies.

Table 3.–Latitude and longitude of sampling stations.

Location	Sample Parameter	Latitude	Longitude
Lower Slate Creek	Periphyton	58.7901° N	135.0343° W
	Benthic Macroinvertebrates	58.7901° N	135.0342° W
	Resident Fish Metals	58.7964° N	135.0389° W
	Sediment Metals and Toxicity	58.7920° N	135.0360° W
	Spawning Substrate Sample Point 1	58.7905° N	135.0345° W
	Spawning Substrate Sample Point 2	58.7905° N	135.0345° W
East Fork Slate Creek	Periphyton	58.8046° N	135.0382° W
	Benthic Macroinvertebrates	58.8045° N	135.0381° W
	Resident Fish	58.8040° N	135.0382° W
	Resident Fish Metals	58.8040° N	135.0382° W
	Sediment Metals and Toxicity	58.8053° N	135.0383° W
West Fork Slate Creek	Periphyton	58.7992° N	135.0460° W
	Benthic Macroinvertebrates	58.7995° N	135.0459° W
Upper Slate Creek	Periphyton	58.8191° N	135.0416° W
	Benthic Macroinvertebrates	58.8189° N	135.0415° W
	Resident Fish	58.8199° N	135.0425° W
	Resident Fish Metals	58.8199° N	135.0425° W
	Sediment Metals and Toxicity	58.8189° N	135.0416° W
Lower Johnson Creek	Sediment Metals and Toxicity	58.8235° N	135.0048° W
Upper Johnson Creek	Benthic Macroinvertebrates	58.8407° N	135.0450° W
Lower Sherman Creek	Periphyton Sample Point 1	58.8687° N	135.1414° W
	Periphyton Sample Point 2	58.8672° N	135.1376° W
	Benthic Macroinvertebrates Sample Point 1	58.8688° N	135.1412° W
	Benthic Macroinvertebrates Sample Point 2	58.8674° N	135.1381° W
	Sediment Metals and Toxicity	58.8687° N	135.1413° W

Source: World Geodetic System 84 datum, at Kensington Gold Mine, 2012.

MONITORING SCHEDULE

We document our 2012 aquatic studies data collection schedule in Table 4.

Table 4.–Aquatic studies data collection schedule.

Aquatic Study	Lower Slate	East Fork Slate	West Fork Slate	Upper Slate	Lower Johnson	Upper Johnson	Lower Sherman
Periphyton	2/8/12 5/2/12 7/25/12 10/30/12	2/7/12 4/27/12 7/24/12 10/30/12	7/25/12	2/7/12 4/27/12 7/24/12 10/30/12			7/26/12
Benthic Macroinvertebrates	2/8/12 5/2/12	2/8/12 4/27/12	5/2/12	10/30/12		4/26/12	4/30/12
Resident Fish		8/1/12		4/27/12			
Resident Fish Metals	8/20/12	8/1/12		8/2/12			
Sediment Metals and Toxicity	7/3/12	7/10/12		8/2/12	7/2/12		7/3/12
Adult Salmon Counts	7/16/12– 10/30/12				7/17/12– 11/5/12		7/16/12– 9/18/12
Spawning Substrate Quality	7/9/12			7/2/12			

Note: Data collected by Habitat biologists at Kensington Gold Mine, 2012.

METHODS[e]

PERIPHYTON COMMUNITY COMPOSITION & BIOMASS

Rationale (APDES 1.5.3.5.2)

Periphyton are primary producers whose microcommunites include algae, cyanobacteria, heterotrophic microbes, and detritus attached to the submerged surfaces of aquatic ecosystems. The chlorophyll *a* pigment in periphyton samples provides an estimate of active algal biomass present. Chlorophyll *b* and *c* pigments provide an estimate of the composition of organisms present in addition to those found in chlorophyll *a*. We monitor periphyton community composition and biomass in Lower Slate Creek, East Fork Slate Creek, and Lower Sherman Creek receiving waters downstream of Kensington Gold Mine discharges as a reliable indicator of water quality and to detect changes over time. We monitor periphyton community composition and biomass in the West Fork Slate Creek and Upper Slate Creek reference sites to detect variations due to other natural factors that may include mineral seeps, climate, and stream flow.

Sample Collection and Analysis

We attempt to sample periphyton annually at low flows when there have not been high flows within the previous three weeks. We collect 10[f] smooth, flat, undisturbed, and perennially wetted rocks from a riffle area of submerged cobble in less than 0.45 m of water within each study reach using the collection methods described in Ott et al. (2010). We place a 5 × 5 cm square of high-density foam on each rock and scrub the area around the foam with a toothbrush to remove all attached algae outside the covered area. We rinse the rock by dipping it with foam intact in the stream.

We remove the foam square and scrub the sample area with a rinsed toothbrush over a 1 µm, 47 mm glass fiber filter attached to a vacuum pump. We use stream water in a wash bottle to rinse the loosened periphyton from the rock, the toothbrush, and the inside of the vacuum pump onto the filter. We pump most of the water through the filter then add a few drops[g] of saturated magnesium carbonate ($MgCO_3$) to the filter before we pump the sample dry. This prevents acidification and conversion of chlorophyll to phaeophyton. We remove the dry glass fiber filter, fold it in half with the sample on the inside, and wrap it in a coffee filter to absorb additional water. We place the sample in a sealed, labeled plastic bag with desiccant and store the samples in a light-proof cooler containing frozen gel packs until we can freeze them. Once we return to the office, we keep the samples frozen at –20°C until processing.

We follow U.S. Environmental Protection Agency protocol (1997) for chlorophyll extraction and measurement and instrument detection limit and error.[h] We remove the samples from the freezer, cut them into small pieces, and place them in a centrifuge tube with 10 ml of 90% buffered acetone. We cap the centrifuge tubes and place them in a metal rack, cover them with aluminum foil, and hold them in a refrigerator for not more than 24 hours to extract the chlorophyll. After extraction, we centrifuge the samples for 20 minutes at 1,600 rpm and then read them on a

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[e] We will provide footnotes under each specific aquatic study in the *Results* section when we deviate from the methods described in this section.

[f] We are working with Dan Reed, ADF&G Sport Fish biometrician, to evaluate sample size.

[g] This measurement is not exact as the amount of water used to dilute the magnesium carbonate is not exact and fixes the sample regardless of the concentration and without affecting data integrity.

[h] There are two main deviations from EPA Method 446. Our sample storage may exceed 3.5 weeks. Our filters are cut rather than homogenized due to risk of acetone exposure (Ott et al. 2010).

Shimadzu UV-1800 Spectrophotometer at optical densities (OD) 664 nm, OD 647 nm, and OD 630 nm.[i] We also take a reading at OD 750 nm to correct for turbidity. We use an acetone blank to correct for the solvent. We treat the samples with 80 µ1 of 0.1 N hydrochloric acid to convert chlorophyll to phaeophyton, and then read them again at OD 665 nm and OD 750 nm.

We use Statistix® 9 (Analytical Software. 2008. Statistix 9 User's Manual. Analytical Software, Tallahassee, Florida, http://www.statistix.com/features.html) to conduct the Kruskal-Wallis One-Way Analysis of Variance by ranks test to investigate significant differences ($p \leq 0.05$) in data distribution within sites between sample events (Neter et al. 1990).

Data Presentation

We include a figure of stream flow three weeks prior to field sampling in the East Fork Slate Creek section when the information is available. Discharge data is not available in Johnson or Sherman Creeks.

For each sample site, we provide a table showing sampling dates and chlorophylls *a*, *b*, and *c* mean concentrations (mg/m^2) for the calendar year, present a graph of the mean proportion of chlorophylls *a*, *b*, and *c* for all sampling events, and show algal biomass, estimated by the chlorophyll ***a*** concentration in each sample, for all sampling events. Data are in Appendix A.

BENTHIC MACROINVERTEBRATE COMPOSITION & ABUNDANCE

Rationale (APDES 1.5.3.2)

We sample benthic macroinvertebrates, paying close attention to the proportion of those classified in the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); collectively known as EPT taxa. EPT taxa have limited mobility, a short life cycle, and are sensitive to changes in water quality. We monitor macroinvertebrate community composition and abundance in Lower Slate Creek, East Fork Slate Creek, Upper Johnson Creek, and Lower Sherman Creek annually between March and May after spring breakup and before peak snowmelt to detect changes over time. We monitor West Fork Slate Creek and Upper Slate Creek reference sites to detect variations due to other natural factors.

Sample Collection and Analysis

The APDES Permit requires we evaluate each reach for all areas that contain stream substrate with particles less than 20 cm along the longest axis, and then sample every third or fourth sampling site, until we collect six benthic macroinvertebrate samples. We sample with a Surber stream bottom sampler in riffles and runs representing different velocities (Barbour et al. 1999).

The Surber stream bottom sampler has a $0.093\ m^2$ sample area and a 300-micron mesh net that terminates at the cod end. After setting the frame in the substrate, we scrub rocks within the sample area with a brush and disturb gravels and silt manually, to about 10 cm depth, to dislodge insects into the net.

We remove each macroinvertebrate sample from the cod end of Surber sampler by rinsing the sample into a prelabeled 500 mL plastic bottle with minimum 70% denatured ethanol. We add additional ethanol to each bottle at three parts ethanol to one part sample. Habitat biologists sort macroinvertebrates from debris under dissecting stereoscopes and identify oligochaetes to Order,

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[i] In 2012, our error detection limit for the spectrophotometer was high, potentially due to scratches on the cuvettes. We disposed and replaced the cuvettes in late 2012, and will regularly replace the cuvettes to prevent high detection limits on future readings.

and all others to genus, using Merritt and Cummins (1996) and Stewart and Oswood (2006). We contract externally with an expert in macroinvertebrate identification to provide quality assurance and control and verify our insect identification in 10% of our total samples.

We calculate the density of aquatic macroinvertebrates per square meter by dividing the number of aquatic insects per sample by 0.093 m^2, the Surber sampling area.

The Shannon Diversity (*H*) and Evenness (*E*) Indices are commonly applied measures of diversity (Magurran 1988). We calculate the indices using the following equations:

$$H = -\sum_{i=1}^{S} (P_i \log_{10} P_i)$$

$$E = \frac{H}{\log_{10} S}$$

Where P_i is the number of invertebrates per genus divided by the total number of invertebrates in the sample, and *S* is the number of genera in the sample.[j]

A single insect community has an *H* value of 0 that increases with the insect number (richness) and insect evenness (abundance equality). Aquatic macroinvertebrate density is expressed as the mean number of invertebrates per m^2.

We use Statistix® 9 (Analytical Software 2008) to conduct the Kruskal-Wallis One-Way Analysis of Variance by ranks test to investigate significant differences ($p \leq 0.05$) in data distribution within sites between sample events (Neter et al. 1990).

Data Presentation

We present a figure of macroinvertebrate community composition and abundance by year. Though not required by the APDES permit, we include an additional February 2012 measurement in the Slate Creek figures. The Shannon Indices of Diversity and Evenness are in narrative. Data are in Appendix B.

RESIDENT FISH POPULATION

Rationale (APDES 1.5.3.3)

The APDES Permit requires resident fish population estimates by species and habitat type in 360 m reaches in East Fork Slate and Upper Slate Creeks so that statistical comparisons can be made between years within a reach. We estimate the variability of the data, including minimum detectable differences between samples, and the precision of the 95% confidence interval so that we can refine or revise sampling protocols.

Sample Collection and Analysis

In 2011, we completed habitat surveys in about the same 360 m reaches surveyed by Flory (2011) using the habitat types described in Bisson et al. (1981). Based on the results of those habitat surveys, we selected a 90 m sampling reach representative of the habitat types present. Though Bisson subdivides three main habitat types for precision to detect environmental change,

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[j] Assuming all species are represented in the sample.

we counted the main habitat types—riffles[k], pools[l], and glides[m]. The East Fork and Upper Slate Creeks sample sites are moderate gradient, narrow, shallow, and contained, with East Fork Slate Creek dominated by bedrock and boulder substrate. Channels of this type are stable and habitat features are unlikely to change during the Kensington Gold Mine period of operation. In 2012, we sampled in the representative 90 m reaches selected in 2011.

We sample resident fish populations using a modification[n] of a depletion method developed by the USFS (Bryant 2000). We isolate sample reaches using fine mesh nets and secure them to the stream bottom with large rocks. We saturate the 90 m reaches with 0.635 cm (1/4 in) and 0.317 cm (1/8 in) soft mesh and wire mesh minnow traps baited with whirl packs containing sterilized salmon roe (Magnus et al. 2006).

Biologists begin from the downstream end of each reach setting baited minnow traps opportunistically in all habitat types where water depth and flow allow. We record the habitat type in which each trap is set. We move away from the sampling site so fish are not disturbed while the traps soak for 1.5 h. We retrieve each trap, record the fish in each trap, and then place the fish in an aerated bucket for processing. We remove the spent bait packet, rebait each trap and reset it in the exact same spot, as quickly as possible. We leave the trap for another 1.5 h soak period, and then complete the sequence a third time.

Biologists anesthetize fish in the aerated bucket with clove oil[o], measure FL to the nearest 1 mm, weigh each to the nearest 0.1 g, and record the species (Pollard et al. 1997). Fish are kept in a live well secured in the stream outside the delineated sample reach during the sampling period, and returned to the sample reach after all three passes are complete.

We collect data to meet the assumptions of closure and of equal probability of capture (Lockwood and Schneider 2000) during all three sampling events by ensuring the following.

- Fish emigration and immigration during the sampling period is negligible.
    - Sample reaches are isolated using fine mesh nets having a cork and lead line.
    - The net is secured to the streambed with large rocks along the lead line.

- All fish are equally vulnerable to capture during a pass.
    - Baited minnow traps are set in all habitat types where water depth and flow allow.

- Fish do not become more wary of capture with each pass.
    - Trap numbers and placement remain constant during all three capture events.
    - Instream field crew is limited to two biologists.
    - Field crew completes all three capture events as quickly possible.
    - Field crew does not talk and uses hand signals to convey habitat type for each trap to the data recorder on shore.
    - Field crews move away from sampling sites so fish are not disturbed while the traps soak 1.5 h each capture event.

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[k] Steepest slopes and shallowest depths at flows below bankfull with a poorly defined thalweg.
[l] Deepest areas where water surface slope below bankfull is near zero.
[m] Immediately downstream of pools with negative bed slope and positive water surface slope.
[n] Shorter reaches, more minnow traps and three passes instead of four.
[o] Clove oil (.5 ml/gl) in 2012. We learned we should be diluting the clove oil with ethanol for solubility and will in 2013 (Anderson et al. 1997).

- Collection effort and conditions which affect collection efficiency remain constant.
  - All capture events begin at the downstream end of each reach.
  - Field crew moves upstream setting, retrieving and replacing traps as quickly as possible.
  - Data recorder notes time between capture events in field notebook.
  - Water temperature and clarity are recorded at the beginning of each capture event.
  - For the second and third capture events, the field crew removes the spent bait packet and rebaits and resets each trap in the exact same location.

We estimate resident fish populations using the multiple-pass depletion method developed by Lockwood and Schneider (2000), based on methods developed by Carle and Strub (1978). The repetitive method produces a maximum likelihood estimate (MLE) of fish with a 95% confidence interval.

Let *X* represent an intermediate sum statistic where the total number of passes, *k*, is reduced by the pass number, *i*, and multiplied by the number of fish caught in the pass, C_i,, for each pass,

$$X = \sum_{i=1}^{k} (k - i) C_i$$

Let *T* represent the total number of fish captured in the minnow traps for all passes. Let *n* represent the predicted population of fish, using *T* as the initial value tested. Using *X*, the MLE, *N*, is calculated by repeated estimations of *n*. The MLE is the smallest integer value of *n* greater than or equal to *T* which satisfies[p]:

$$\left[\frac{n+1}{n-T+1}\right] \prod_{i=1}^{k} \left[\frac{kn - X - T + 1 + (k-i)}{kn - X + 2 + (k-i)}\right]_i \leq 1.000$$

The probability of capture, *p*, is given by the total number of fish captured, divided by an equation where the number of passes is multiplied by the MLE and subtracted by the intermediate statistic, *X*,

$$p = \frac{T}{kN - X}$$

The variance of *N*, a measure of variability from the mean, is given by,

$$Variance\ of\ N = \frac{N(N-T)T}{T^2 - N(N-T)\left[\frac{(kp)^2}{(1-p)}\right]}$$

The SE of *N* is calculated by the square root of the variance of *N*, and the 95% confidence interval for the MLE is given by: MLE $\pm$ 2(SE). Because we sample a 90 m reach, we multiply the MLE and 95% confidence interval by four to extrapolate the data to a 360 m sample reach. A

[p] Lockwood and Schneider (2000) suggest the result should be rounded to one decimal place (1.0). We use three decimal places (1.000) which is an option in Carle and Strub (1978).

MLE cannot be generated from samples from small populations if few fish are captured during the three sample events; in these cases, we present the number of fish captured as the result and do not include a MLE. We determine the precision of the estimate by expressing the 95% confidence interval as a percentage of the MLE.

Calculating a MLE using three-pass depletion data relies heavily on equal capture probability among passes (Bryant 2000, Carle and Strub 1968, Lockwood and Schneider 2000). To evaluate equal capture probability, we use the goodness of fit test in White et al. (1982), recommended by Lockwood and Schneider (2000), which follows the χ^2 test form. We first calculate expected numbers of fish captured for each pass ($C_1, C_{2.}, C_3$) using variables previously described

$$E(C_1) = N(1-p)^{i-1}p$$

Then we calculate χ^2,

$$\chi^2 = \frac{[C_1 - E(C_1)]^2}{E(C_1)} + \frac{[C_2 - E(C_2)]^2}{E(C_2)} + \frac{[C_3 - E(C_3)]^2}{E(C_3)}$$

If the goodness of fit test indicates we did not achieve equal capture probability, the MLE will be biased low.

We use Monte-Carlo simulations to assess the power of our three-pass depletion studies to detect changes in abundance of small (N < 200) fish populations. We simulate sampling according to the three-pass depletion design on each years population of fish where the abundance of fish differs by varying degrees, and estimate the abundance of each population using the techniques described in Lockwood and Schneider (2000). We use a Student's *t*-test with two degrees of freedom to test the null hypothesis that both estimates come from populations of equal size, with one degree of freedom associated with each estimate. We evaluate significance at $\alpha = 0.05$, conduct 10,000 simulations of three-pass depletions to evaluate power for probabilities of capture during each sampling pass of 0.30, 0.40, 0.50, 0.60, and 0.70 using the assumptions of the model and estimate the power as the proportion of simulations where the null hypothesis is rejected (Dan Reed, Sport Fish Biometrician, ADF&G, Nome, personal communication).

Data Presentation

We present resident fish population estimates by 360 m reach by year, population estimates by habitat type by 360 m reach by year, and the length frequency of this year's captures in figures. We present resident fish capture data, population estimates by reach by year, population estimates by habitat type by reach by year, precision of the population estimates, and power of the current year population estimates compared to the previous year population estimate in Appendix C.

RESIDENT FISH CONDITION

Rationale (APDES 1.5.3.3.1)

The APDES Permit requires us to compare fish condition by reach and by year in East Fork Slate and Upper Slate Creeks. Age, sex, season, maturation, diet, gut fullness, fat reserve, and muscular development affect fish condition.

Sample Collection and Analysis

We weigh the resident fish captured in our resident fish surveys to the nearest 0.1 g and measure FL to the nearest 1 mm.

We use the lengths and weights to calculate Fulton's condition factor (K) using the equation given in Anderson & Neumann (1996) where the weight of each fish measured in grams (W) is divided by the cubed length of fish (L) measured in millimeters, and the product multiplied by 100,000,

$$K = \frac{W}{L^3} \times 100{,}000$$

Data Presentation

We present the mean condition factor of resident fish in the East Fork Slate Creek and Upper Slate Creek sections, and provide resident fish length, weight, and condition factor data in Appendix C.

Resident Fish Metals Concentrations

Rationale (APDES 1.5.3.4)

The APDES Permit requires us to sample six Dolly Varden char within the size class 90–130 mm for whole body concentrations for the metallic elements aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag) and zinc (Zn), and the semi-metallic element selenium (Se), in Lower Slate, East Fork Slate and Upper Slate Creeks for a total of 18 fish. We recommended DEC choose this sample size as it is the size used for aquatic studies at other mines in Alaska and provides information without being cost prohibitive. The minimum size of 90 mm FL is the minimum amount of tissue (about 5 g) required for the laboratory to conduct the analyses. The maximum size of 130 mm FL improves the likelihood of sampling less than a three year old resident fish in Lower Slate Creek where Dolly Varden char may be anadromous (Balon 1980). In the future, we may be able to examine the relationship of tissue and water quality data to see if changes over time are related to operations or natural variability.

Sample Collection and Analysis

We capture fish in minnow traps baited with sterilized salmon roe, individually package them in clean, prelabeled bags, and measure FL to 1 mm. Samples are immediately stored in a cooler containing gel ice packs, then in a camp freezer until we return to Juneau and weigh the fish in the sealed bags, correcting for bag weight. We freeze the samples at –20°C until we ship them to a private laboratory, where they are individually digested, dried, and analyzed for Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn on a dry-weight basis. The private analytical laboratory provides Tier II quality assurance/quality control validation information for each analyte including matrix spikes, standard reference materials, laboratory calibration data, sample blanks and duplicates.

Data Presentation

We present a figure of whole body metals concentrations for each sample by element in the Lower Slate, East Fork Slate, and Upper Slate Creeks sections. We provide a figure with the 2012 whole body metals concentrations for Lower, East Fork and Upper Slate Creeks, a table with all data, and the laboratory report in Appendix D.

SEDIMENT METALS CONCENTRATIONS

Rationale (APDES 1.5.2)

Sediment metals concentrations are influenced by a variety of factors, including mineralogy, grain size, organic content, and human activity. We sample Lower Slate, East Fork Slate, Upper Slate, Lower Johnson, and Lower Sherman Creeks for the metallic elements Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, and Zn and the semi-metallic elements arsenic (As) and Se.

Sample Collection and Analysis

We collect sediment samples opportunistically in areas with fine sediment deposition, usually along the perimeter of the stream and in shallow eddies. We retain the sediment that passes through a 1.7 mm sieve in a plastic bucket, and transfer the sediment to a 100 mL glass jar the laboratory provides. Between sites, we rinse our sampling equipment in stream water. We store the samples in coolers on ice during transport between the mine and our lab, and store them in our refrigerator until we ship them to a private laboratory for analysis.

Data Presentation

We present sediment metals concentrations for each sample site in a figure. We include tables with Kensington Gold Mine sediment sample compositions, metallic element concentrations, and semi-metallic element concentrations for all six sample sites across years with this year's laboratory report in Appendix E.

SEDIMENT METALS TOXICITY

Rationale (APDES 1.5.2.3)

Sediment is a repository of metals introduced into surface waters. We monitor the toxicity of metals in sediments in the laboratory using *Chironomus dilutus* (midges) and *Hyalella azteca* (amphipods). We sample Lower Slate, East Fork Slate, Upper Slate, Lower Johnson, and Lower Sherman Creeks for the metallic elements Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, and Zn and the semi-metallic elements As and Se. Survival of *Chironomus dilutus* is generally lower than survival of *Hyalella azteca* on all mediums including the laboratory control sand.

Sample Collection and Analysis

We collect sediment samples opportunistically in areas with fine sediment deposition, usually along the perimeter of the stream and in shallow eddies. We retain the sediment that passes through a 1.7 mm sieve in a plastic bucket, and transfer the sediment to a 2 L plastic container the laboratory provides. Between sites, we rinse our sampling equipment in stream water. We store the samples in coolers on ice during transport between the mine and our lab, and store them in our refrigerator until we ship them to a private laboratory for analysis.

The private laboratory tests for short-term chronic toxicity of sediment using the organisms *Chironomus dilutus* and *Hyalella azteca* , and removes debris and large sediment from the sample prior to homogenizing. The laboratory uses eight replicates of sediment for each treatment, and the laboratory control sediment is commercial grade sand.

Data Presentation

We present organism survival and growth for each sample site in the narrative. We provide the laboratory report that lists significant differences ($p \leq 0.05$) between control and individual samples in Appendix E.

SPAWNING SUBSTRATE QUALITY

Rationale (APDES 1.5.3.5.1)

The APDES permit requires annual pink salmon spawning substrate sampling in Lower Slate Creek during July prior to spawning activity. We calculate the geometric mean particle size (d_g), an index of substrate textural composition, for each sample and for each sample site. We monitor spawning substrate quality to detect change over time.

Sample Collection

We collect four replicate samples from two locations in the anadromous portion of Slate Creek using a McNeil sampler, which has a 15 cm basal core diameter and 25 cm core depth. We choose sample sites selecting substrate measuring less than 10 cm, the maximum gravel size used by pink salmon (Lotspeich and Everest 1981; Kondolf and Wolman 1993), where the stream gradient is less than 3% (Valentine, B. E. 2001. Unpublished. Stream substrate quality for salmonids: Guidelines for Sampling, Processing, and Analysis. California Department of Forestry and Fire Protection, Coast Cascade Regional Office, Santa Rosa, CA). We push the McNeil sampler into the substrate until the sample core is buried, then transfer the sediments to a five gallon bucket using a stainless steel scoop. Samples are wet-sieved onsite using sieve sizes 101.6, 50.8, 25.4, 12.7, 6.35, 1.68, 0.42, and 0.15 mm. We measure the contents of each sieve to the nearest 5 mL[q] by the volume of displaced water in 600 mL and 1 L plastic beakers. We transfer the fines that pass through the 0.15 mm sieve to an Imhoff cone and allow them to settle for 10 minutes, then measure the displacement using the Imhoff cone gradations.

Data Presentation

We convert the wet weights to dry weights using standards identified by Zollinger (1981) for the fines that settle in the Imhoff cones. For all others, we convert the wet weights to dry weights using a correction factor derived from Shirazi et. al (1979), assuming a gravel density of 2.6 g/cm^3 previously used by Timothy and Kanouse (2012). We calculate the geometric mean particle size (d_g) using methods developed by Lotspeich and Everest (1981), where the midpoint diameter of particles retained in each sieve (d) is raised to a power equal to the decimal fraction of volume retained by that sieve (w), and multiplied the products of each sieve size to obtain the final product,

$$d_g = d_1^{w1} \times d_2^{w2} \times d_3^{w3} \ldots d_n^{wn}$$

We present a figure that shows the geometric mean particle size calculated for each sample at each sample point and a figure that shows the geometric mean particle size of all samples by year in the Lower Slate Creek results section. Raw data are in Appendix F.

[q] The contents of the 0.15 mm sieve are measured to the nearest 1 mL using an Imhoff cone.

ADULT SALMON COUNTS

Rationale (USFS Plan of Operations)

The USFS Plan of Operations require weekly surveys of adult chum salmon, coho salmon, and pink salmon in Lower Slate, Lower Johnson, and Lower Sherman Creeks throughout the spawning season. We can detect shifts in the distribution of pink salmon spawning activity using the number of adult pink salmon observed in different reaches of each stream system (Daniel Reed, Division of Sport Fish Biometrician, ADF&G, Nome; memorandum, Review of Technical Report No 11-08: Aquatic Studies at Kensington Mine, 2011).

Sample Collection

We conduct foot surveys in the anadromous reaches of Slate and Sherman Creeks once per week, and survey Johnson Creek from a helicopter once per week, verifying survey results three times with foot surveys.

We section each creek to examine the distribution of adult salmon (Timothy and Kanouse 2012). Sherman Creek is sectioned into 50 m reaches, Slate Creek into 100 m reaches, and Johnson Creek by landmarks. We begin surveys at the stream mouth, ending at the anadromous fish barrier.

A team of two biologists wearing polarized sunglasses independently record the number of live fish and carcasses by species during each foot and aerial survey. We use the average of the two biologists' counts to estimate the total number of fish, by species, each survey. We also record weather and flow conditions each survey.

Data Presentation

We present figures of adult pink salmon counts by week and distribution in Lower Slate, Lower Johnson, and Lower Sherman Creeks. We present figures of adult chum salmon counts in Slate and Johnson Creek and adult coho salmon counts in Johnson Creek. Pentec (1990) documented a 1–3 week pink salmon residence time in Sherman Creek, so we divide the total number of adult pink salmon by two (residence time) in all systems to avoid overestimating (Neilson and Geen 1981). We do not adjust chum and coho salmon estimates as we have not identified the residence time of these fish in these stream systems. In Johnson Creek, we use a method developed by Jones et al. (1998) to adjust the adult pink and chum salmon aerial counts by multiplying our mean weekly count by a factor of 2.5, before we adjust for residence time. We also round down intermediate numbers and final numbers to whole numbers for the return estimate calculations. Data are in Appendix G.

RESULTS

SLATE CREEK

Lower Slate Creek

Periphyton Community Composition & Biomass

We collected periphyton samples in Lower Slate Creek at 58.7901°N, 135.0343°W, on July 25, 2012, as required in the APDES permit to sample annually at low stream flow and not within three weeks after peak snowmelt/outfall discharge. In addition we sampled three times, February 8, 2012, May 2, 2012, and October 30, 2012, to investigate the algal bloom in the TTF and changes in algal biomass downstream in East Fork Slate Creek in 2011.

Table 5 shows the average concentrations of chlorophylls *a*, *b*, and *c* (mg/m^2) in Lower Slate Creek samples collected during 2012. The 2011 and 2012 proportion of chlorophylls *a*, *b*, and *c* are shown in Figure 10.

Table 5.–Lower Slate Creek chlorophylls *a*, *b*, and *c* mean densities.

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
February 8, 2012	1.73	0.04	0.13
May 2, 2012	0.96	0.02	0.11
July 25, 2012	2.31	0.05	0.18
October 30, 2012	1.31	0.00	0.16

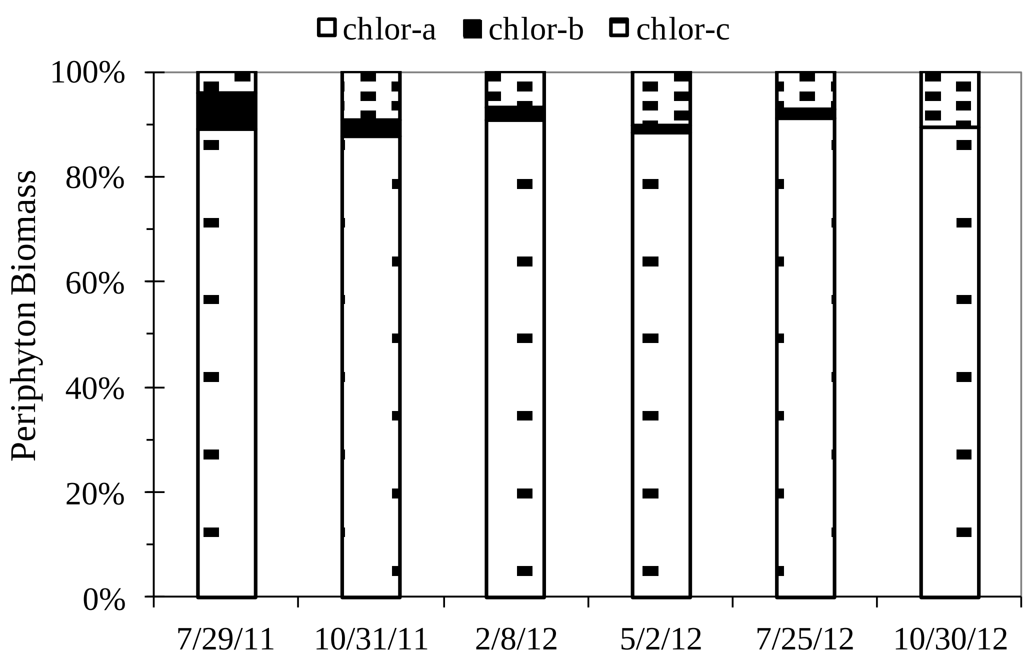

Figure 10.–Lower Slate Creek chlorophylls *a*, *b*, and *c* proportion.

Lower Slate Creek algal biomass, estimated from the chlorophyll *a* concentration in each sample, is shown in Figure 11.

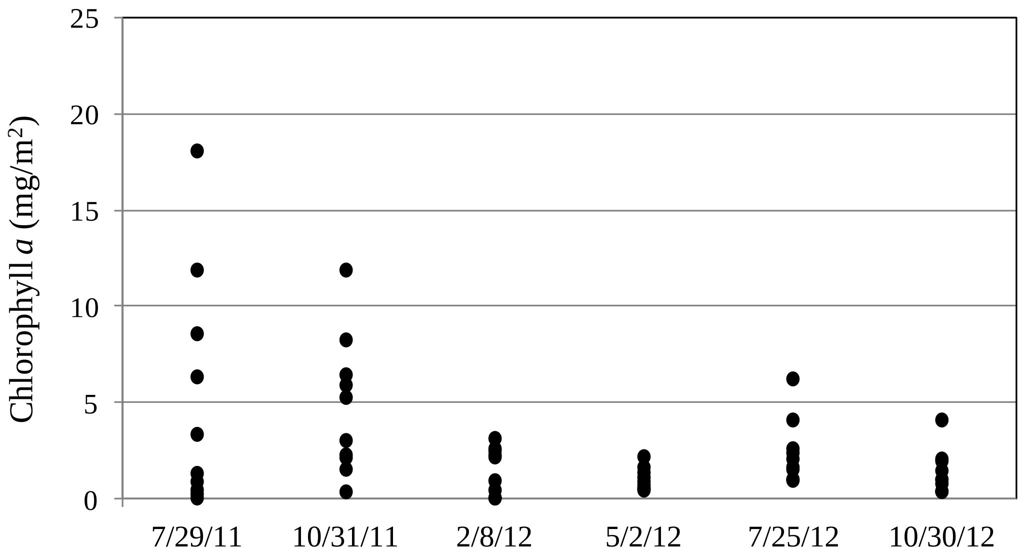

Figure 11.–Lower Slate Creek chlorophyll *a* densities.

Benthic Macroinvertebrate Composition & Abundance

We collected benthic macroinvertebrate samples in Lower Slate Creek at 58.7901°N, 135.0342°W, on February 8, 2012, to document aquatic life downstream of the TTF following the algal bloom in 2011. We collected benthic macroinvertebrate samples in Lower Slate Creek in the same location again on May 2, 2012, as required by the APDES Permit to sample between late March and late May, after spring breakup and before peak snowmelt.

In February, we identified 30 taxa among the 6 samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 2,452 insects, of which 38% are EPT taxa (Figure 12). The Shannon Diversity score is 0.75 and Evenness score is 0.64. The dominant taxa are Diptera: Chironomidae and Annelida: Oligochaeta, each representing about 28% of samples.

In May, we identified 32 taxa among the 6 samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 3,154 insects, of which 38% are EPT taxa (Figure 12). The Shannon Diversity score is 0.69 and Evenness score is 0.58. The dominant taxon is Diptera: Chironomidae, representing about 53% of samples.

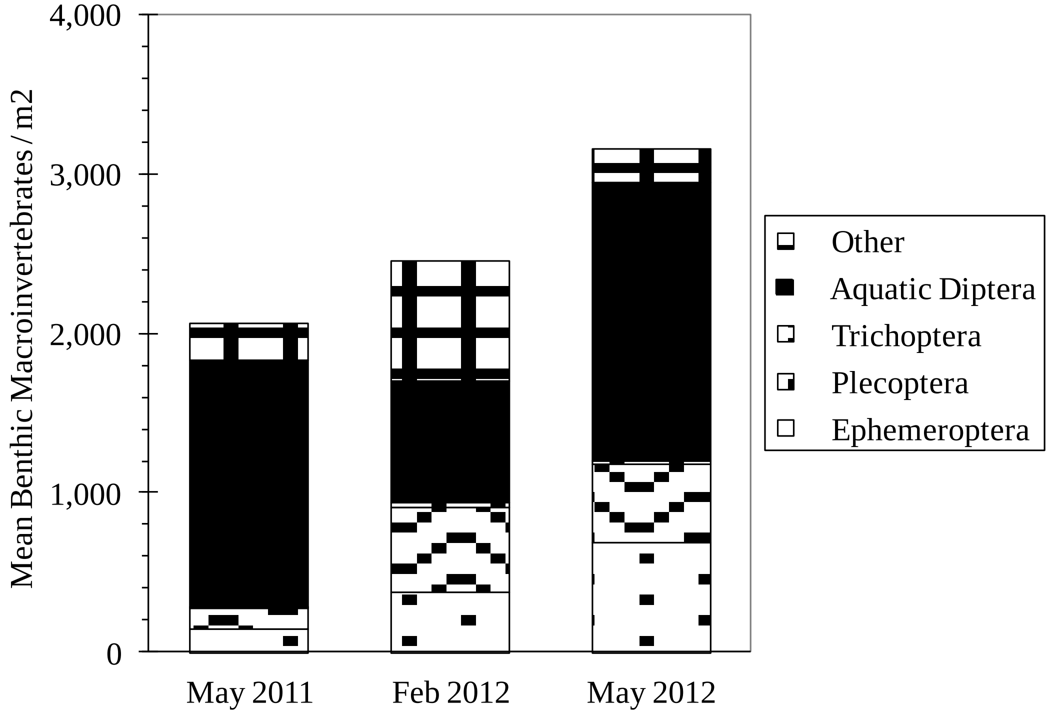

Figure 12.–Lower Slate Creek benthic macroinvertebrates.

Resident Fish Metals Concentrations

We captured six Dolly Varden char in Lower Slate Creek at 58.7964°N, 135.0389°W on August 20, 2012 within 200 m downstream of the waterfall barrier. We shipped the samples to Columbia Analytical in Kent, Washington, for laboratory analyses September 27, 2012 and received the results November 9, 2012. The laboratory processed the fish individually and the concentration for each fish is shown for each element, except for Ag and Ni which are undetected at the method reporting limit in two samples.

Though we present the information from 2011 and 2012 in Figure 13, we won't compare data between years because in 2011 we incorrectly completed the laboratory's chain of custody form and the laboratory homogenized all six fish, giving one concentration for each element. Columbia Analytical reported in 2011 they observed sediment in the bottom of their digestion tube containing the Lower Slate Creek fish samples[r], which may have elevated metals concentrations.

[r] The probable source is sediment the fish ingested.

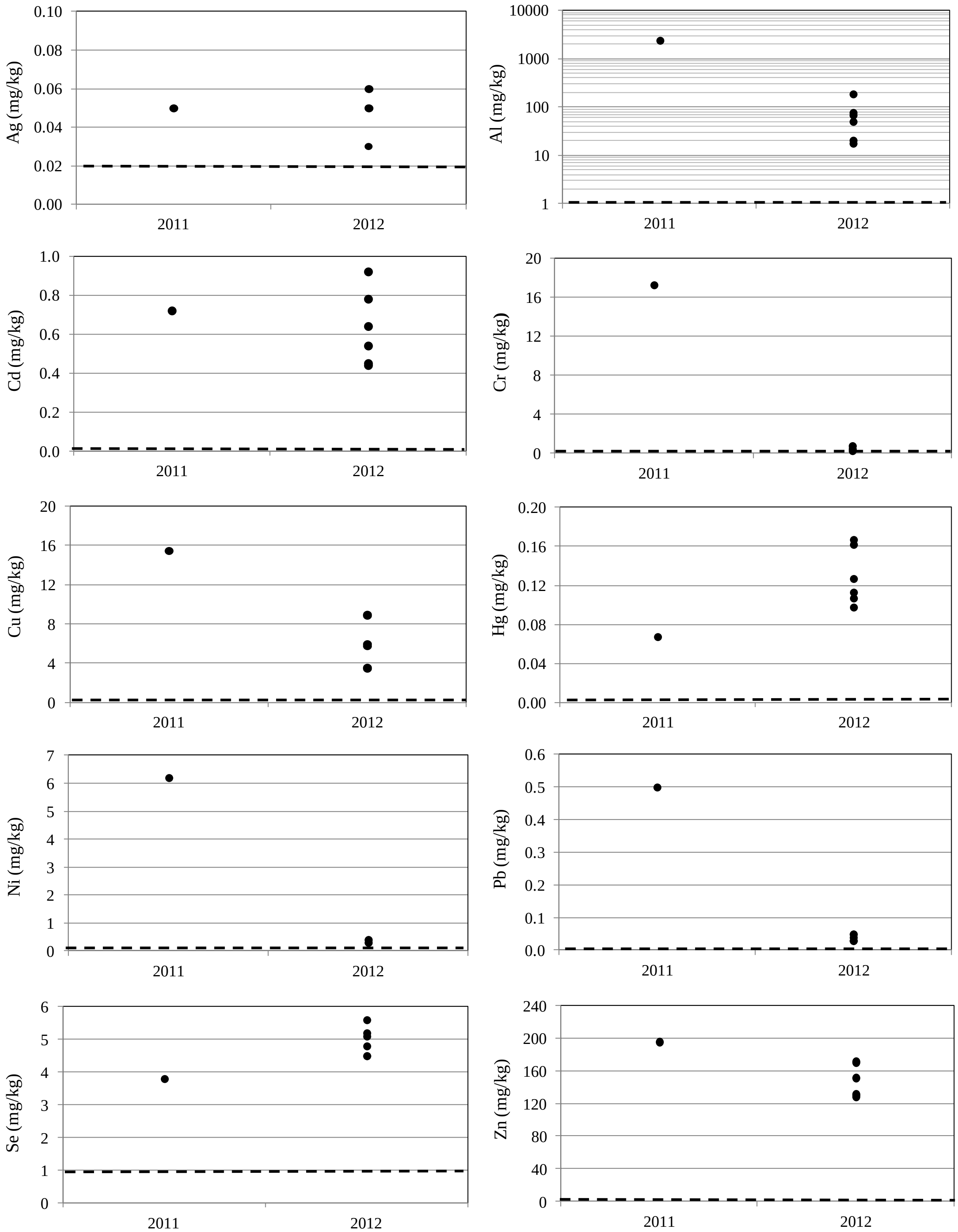

Figure 13.–Lower Slate Creek whole body metals concentrations.

Note: 2011 and 2012, juvenile Dolly Varden char.
Note: Dashed lines represent the method reporting limit, ND indicates the metal was not detected.

Sediment Metals Concentrations

We collected sediments in Lower Slate Creek at 58.7920°N, 135.0360°W on July 3, 2012 and shipped the samples to the AECOM Environmental Toxicology laboratory in Fort Collins, Colorado for analyses on July 19, 2012. We received the laboratory results on September 27, 2012.

Lower Slate Creek sediment metals concentrations are shown in Figure 14. Concentrations are similar to the 2011 results, and to results from sampling during the 2005–2010 period (Flory 2011). We include tables with 2011 and 2012 sediment composition, metals and semi metals data for all sites and the 2012 AECOM laboratory report in Appendix E.

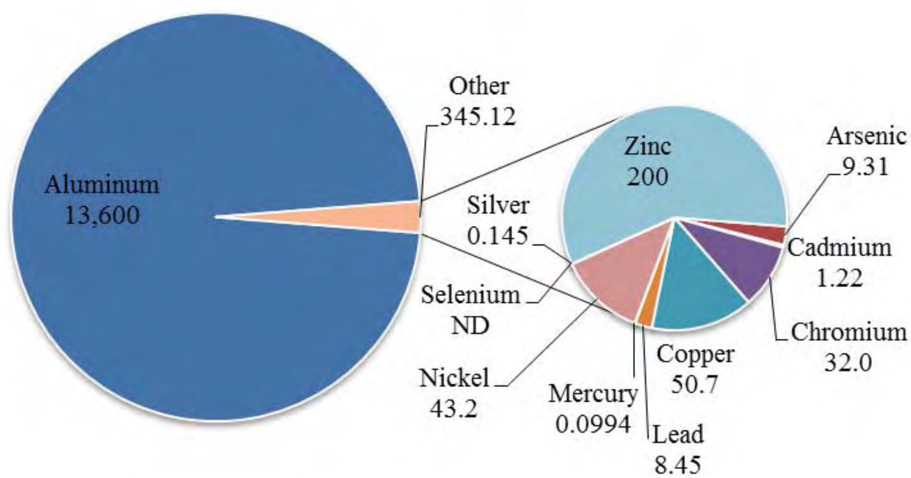

Figure 14.–Lower Slate Creek sediment metals concentrations.

Note: 2012 data presented in parts per million (mg/kg).

Sediment Toxicity

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Lower Slate Creek sediment sample compared to the control. We include the laboratory report that in Appendix E.

Adult Salmon Counts

We surveyed Lower Slate Creek for adult chum salmon and pink salmon between July 16 and September 10, 2012. We did not observe adult salmon during the first two surveys, or during the last survey.

Figure 15 presents our adult pink salmon count for each survey in Lower Slate Creek, and Figure 16 presents the distribution of pink salmon by section. We estimate the 2012 adult pink salmon return at 3,636 fish, the highest estimate in the eight years of monitoring (Flory 2011, Timothy and Kanouse 2012).

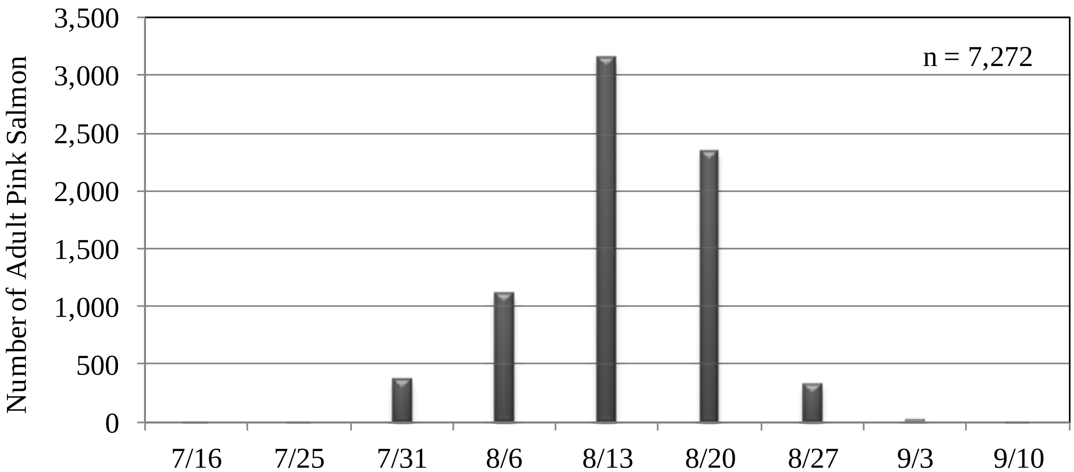

Figure 15.–Lower Slate Creek adult pink salmon counts.

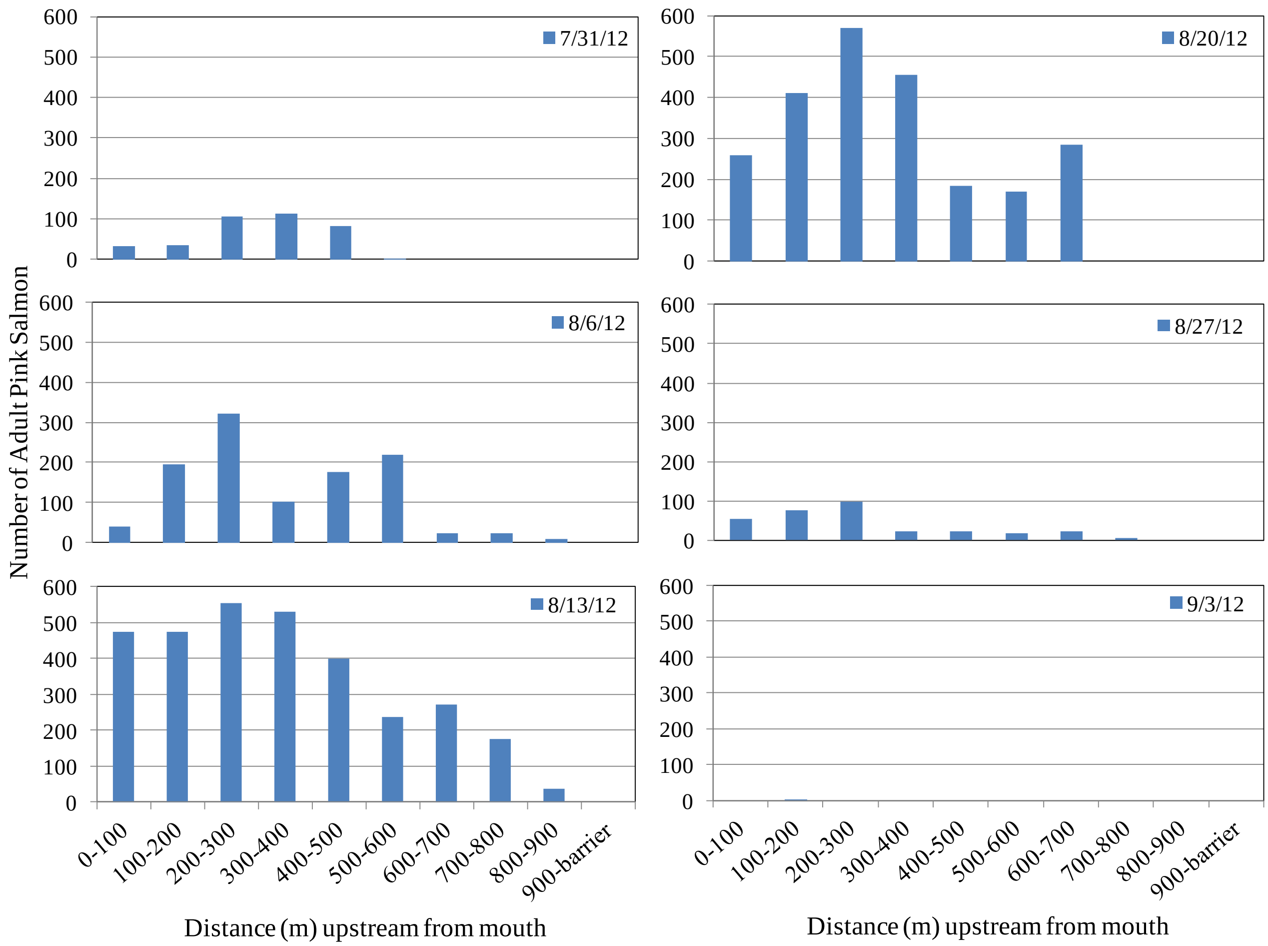

Figure 16.–Lower Slate Creek adult pink salmon distribution.

We observed one live adult chum salmon in Lower Slate Creek on August 15.

We surveyed for adult coho salmon between September 18 and October 30, 2012 and did not document any live fish or carcasses. Since we captured age-0 and 1-year-old juvenile coho salmon during resident fish abundance and distribution studies, we theorize Lower Slate Creek is the natal stream (Timothy and Kanouse 2012). We will continue our investigation of adult coho salmon in this stream during the coho salmon spawning season by foot and snorkel.

Spawning Substrate Quality

Sample Point 1, 58.7905°N, 135.0345°W

Sample Point 2, 58.7916°N, 135.0356°W

We present the geometric mean particle size for each of the four samples collected at Sample Point 1 and each of the four samples collected at Sample Point 2 in Lower Slate Creek on July 9, 2012 in Figure 17 (two sediment samples from Sample Point 2 have the same geometric mean, 11.6 mm).

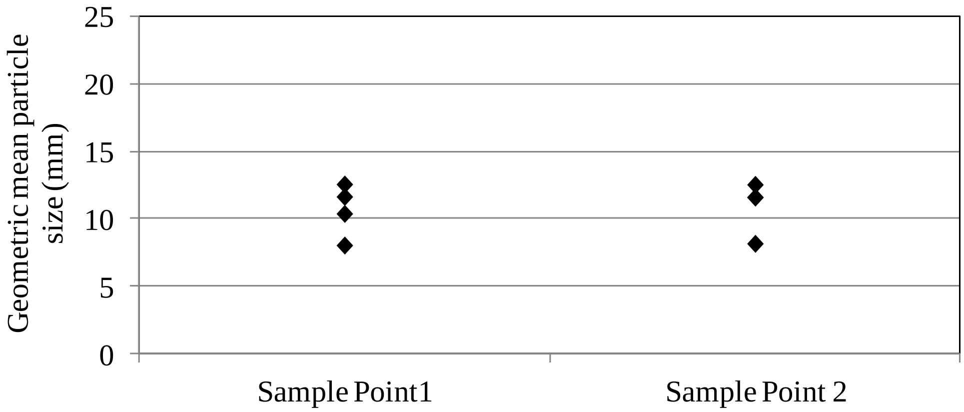

Figure 17.–Lower Slate Creek geometric mean particle sizes by sample and sample point.

In our 2012 Technical Report (Timothy and Kanouse), we reported the geometric mean particle size for substrate samples taken at Lower Slate Creek on August 17, 2011 as 6.54 mm at Sample Point 1, and 9.33 mm at Sample Point 2, and stated the substrate was finer than any year sampled since 2005. While entering the 2012 data, we noticed the formulas we used to calculate the 2011 results contained an error. We corrected the formulas and the results change to an geometric mean particle size for substrate samples taken at Lower Slate Creek on August 17, 2011 is 10.1 mm at Sample Point 1, and 10.9 mm at Sample Point 2 (Figure 17). This remains finer than any year sampled since 2005.

We include the corrected Lower Slate Creek data in Appendix F[s].

The geometric mean particle size for substrate samples taken at Lower Slate Creek on July 9, 2012 is 10.6 mm at Sample Point 1, and 10.9 mm at Sample Point 2 (Figure 18).

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[s] We also include corrected 2011 and new 2012 data for Johnson and Sherman Creeks in Appendix F, but do not summarize it in this technical report as the APDES permit does not require the sampling. Those results are summarized in Brewster, 2012.

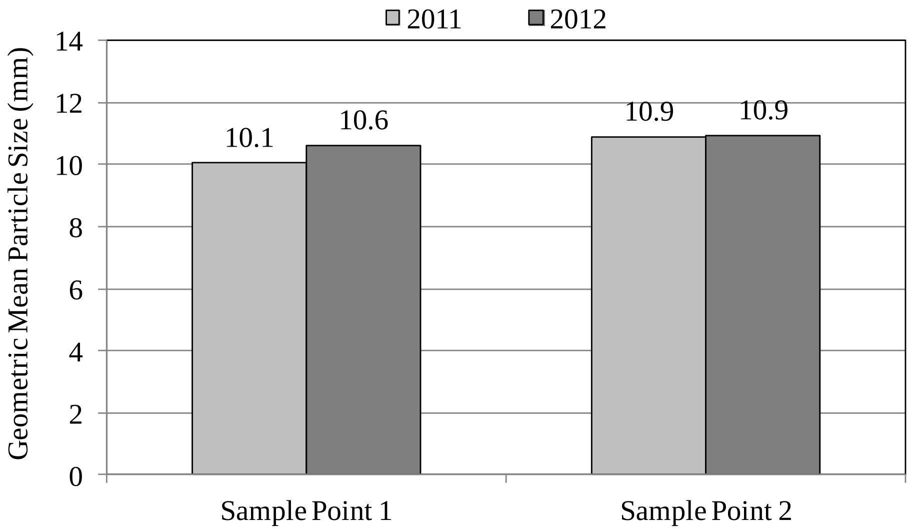

Figure 18.–Lower Slate Creek geometric mean particle size of all samples by year.

East Fork Slate Creek

Upper Slate Lake discharge is intercepted at a dam (Figure 19) and routed through a diversion pipeline around the TTF (Figure 20), discharging into East Fork Slate Creek (Gordon Willson-Naranjo, Division of Habitat Biologist, ADF&G, Douglas; December 12, 2012, memorandum, Kensington Gold Mine: Diversion Pipeline Fish Passage Trip Report). Treated water from the TTF wastewater treatment plant began discharging into East Fork Slate Creek in December 2010. Most sampling in East Fork Slate Creek occurs between 250 m and 300 m downstream of the plunge pool.

Figure 19.–Diversion dam, pipeline, and TTF.

Figure 20.–Approximate diversion pipeline route.

Periphyton Community Composition & Biomass

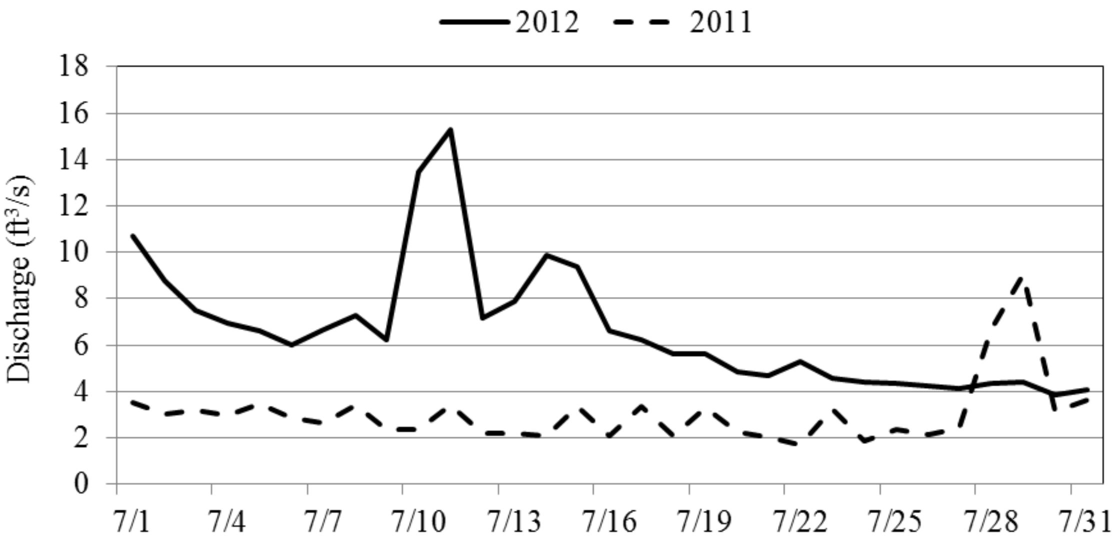

Figure 21.–East Fork Slate Creek discharge, July 2011 and 2012.

Note: Discharge calculated using Parshall Flume flow data and TTF WTP discharge data.

In July 2011, mean daily discharge in East Fork Slate Creek stayed below 4 ft^3/s except on July 29 when it peaked at about 9 ft^3/s during a rainstorm. In July 2012, three weeks prior to periphyton sampling, mean daily discharge stayed above 4 ft^3/s during this same period, except for July 30, when it dipped to 3.8 ft^3/s (Figure 21).

We collected periphyton samples in East Fork Slate Creek at 58.8046°N, 135.0382°W on July 24, 2012. In addition, we sampled three times, February 7, 2012, April 27, 2012, and October 30, 2012, to investigate the algal bloom in the TTF and changes in periphyton biomass in East Fork Slate Creek in 2011.

Table 6 shows the average concentrations of chlorophylls *a*, *b*, and *c* (mg/m^2) in East Fork Slate Creek samples collected during 2012. The 2011 and 2012 proportion of chlorophylls *a*, *b*, and *c* are shown in Figure 22.

Table 6.–East Fork Slate Creek chlorophylls *a*, *b*, and *c* mean densities.

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
February 7, 2012	2.04	0.48	0.05
April 27, 2012	4.87	0.26	0.26
July 24, 2012	5.08	0.57	0.18
October 30, 2012	0.78	0.00	0.06

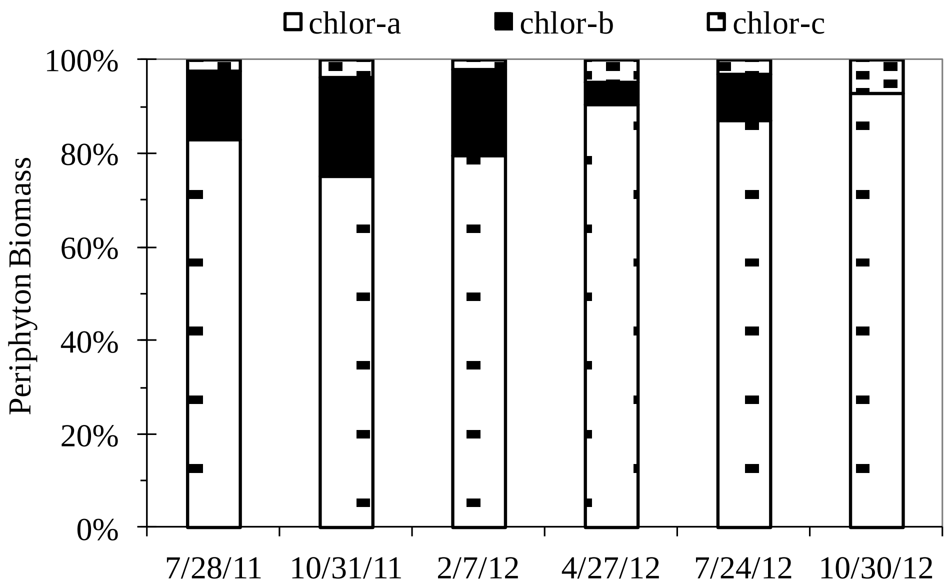

Figure 22.–East Fork Slate Creek chlorophylls *a*, *b*, and *c* proportion.

East Fork Slate Creek algal biomass, estimated from the chlorophyll *a* concentration for each sample, is shown in Figure 23. There are no significant differences between the mean ranks of July 2011 and July 2012 chlorophyll *a* densities in East Fork Slate Creek.

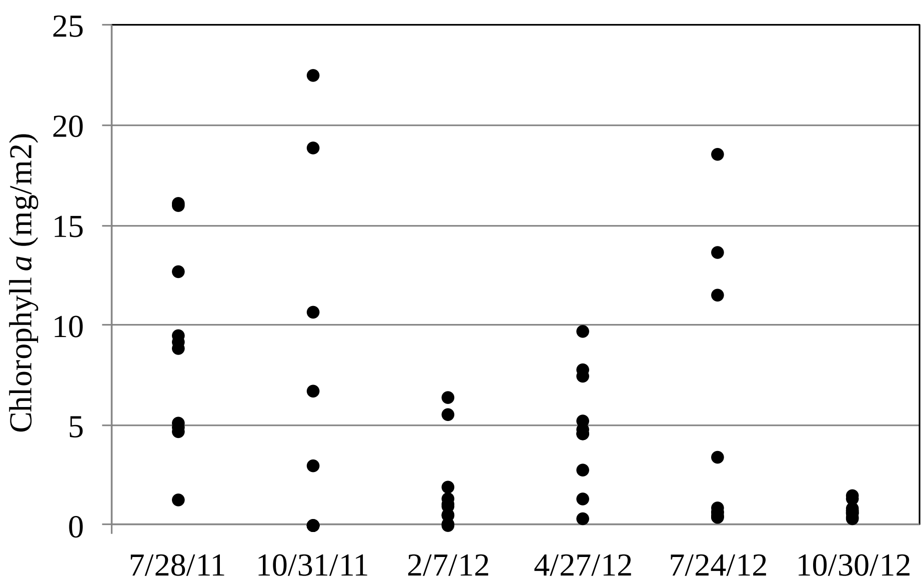

Figure 23.–East Fork Slate Creek chlorophyll *a* densities.

Benthic Macroinvertebrate Composition & Abundance

We collected six benthic macroinvertebrate samples in East Fork Slate Creek at 58.8045°N, 135.0381°W, on February 7, 2012, to investigate the algal bloom in the TTF and the change in algal biomass downstream in East Fork Slate Creek in 2011. We collected six benthic macroinvertebrate samples in Lower Slate Creek in the same location again on April 27, 2012, as required by the APDES Permit to sample between late March and late May, after spring breakup and before peak snowmelt.

In February, we identified 33 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 10,703 insects, of which 22% are EPT taxa (Figure 24). The Shannon Diversity score is 0.73 and Evenness score is 0.57. The dominant taxon is Bivalvia: Sphaeriidae (pea clams), representing about 45% of samples.[t]

In April, we identified 33 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 4,633 insects, of which 23% are EPT taxa (Figure 24). The Shannon Diversity score is 0.78 and the Evenness score is 0.61. The dominant taxon is Bivalvia: Sphaeriidae (pea clams), representing about 45% of samples[u].

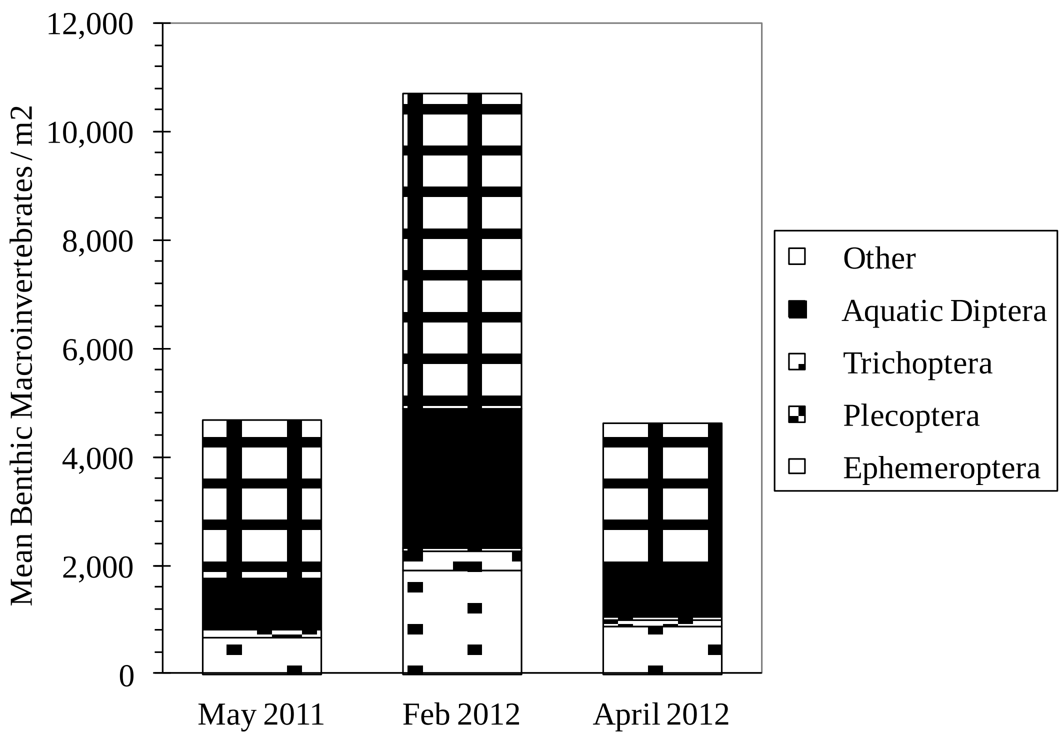

Figure 24.–East Fork Slate Creek benthic macroinvertebrates.

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[t] We do not observe this organism at other sites, except a few occasionally in the Lower Slate Creek samples. When we removed the pea clams from the East Fork Slate Creek February 2012 data set, the estimated mean benthic macroinvertebrate density decreased to 5,880 insects per m^2, percent EPT increased to 40%, and Chironomidae became the dominant taxon representing about 37% of samples.

[u] When we removed the pea clams from the East Fork Slate Creek April 2012 data set, the estimated mean benthic macroinvertebrate density decreased to 2,534 insects per m^2, percent EPT increased to 42%, and Chironomidae became the dominant taxon representing about 28% of samples.

Resident Fish Population & Condition

We sampled East Fork Slate Creek resident fish at 58.8040°N, 135.0382°W on August 1, 2012. We followed the methods described earlier in this report, except that two of our three minnow trapping intervals exceeded the 1.5 hr soak time because of blasting occurring upstream at the dam.

The 2012 Dolly Varden char population estimate for East Fork Slate Creek is 20 fish, half the 2011 estimate (Figure 25). We captured more Dolly Varden char in pools than riffles or glides (Figure 26) and the fish we captured are about the same size (Figure 27). Mean fish condition is 1.08 g/mm^3, about the same as in 2011.

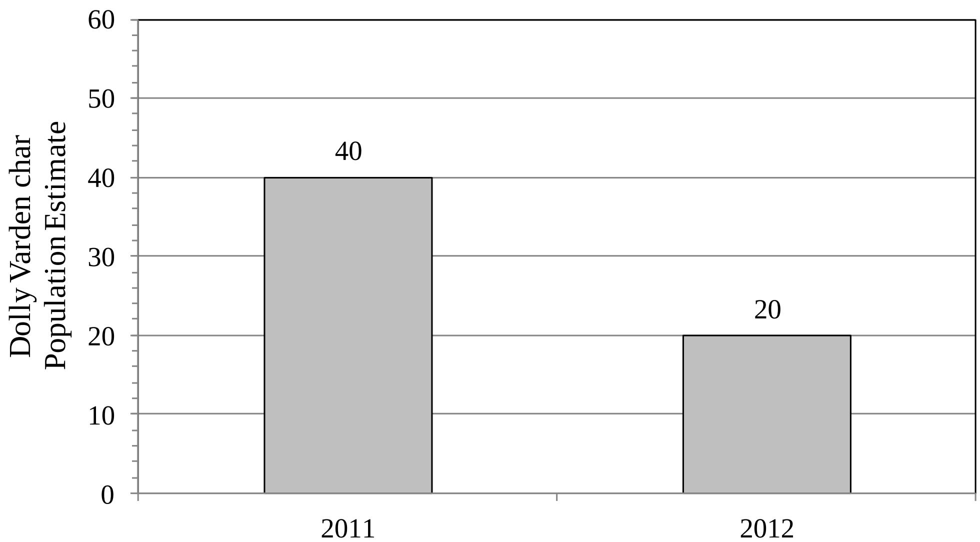

Figure 25.–East Fork Slate Creek resident fish population estimates.

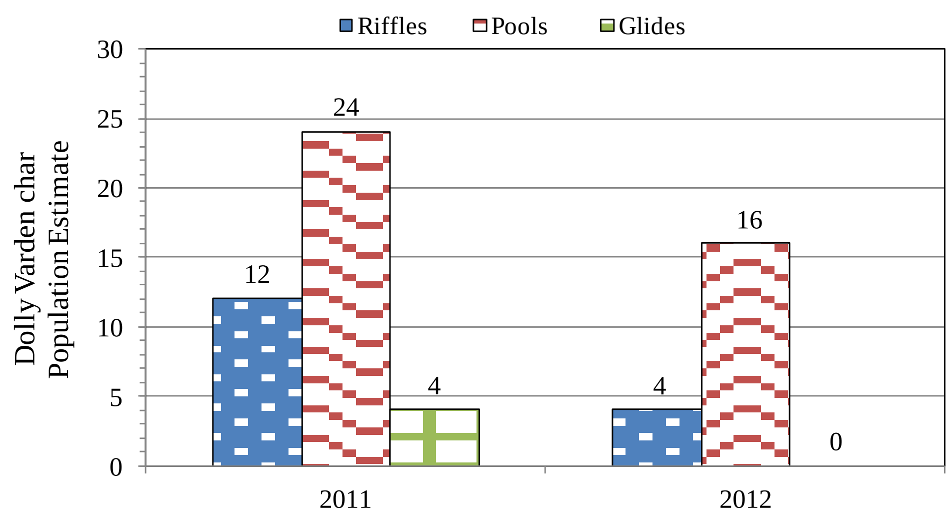

Figure 26.–East Fork Slate Creek resident fish population estimates by habitat type.

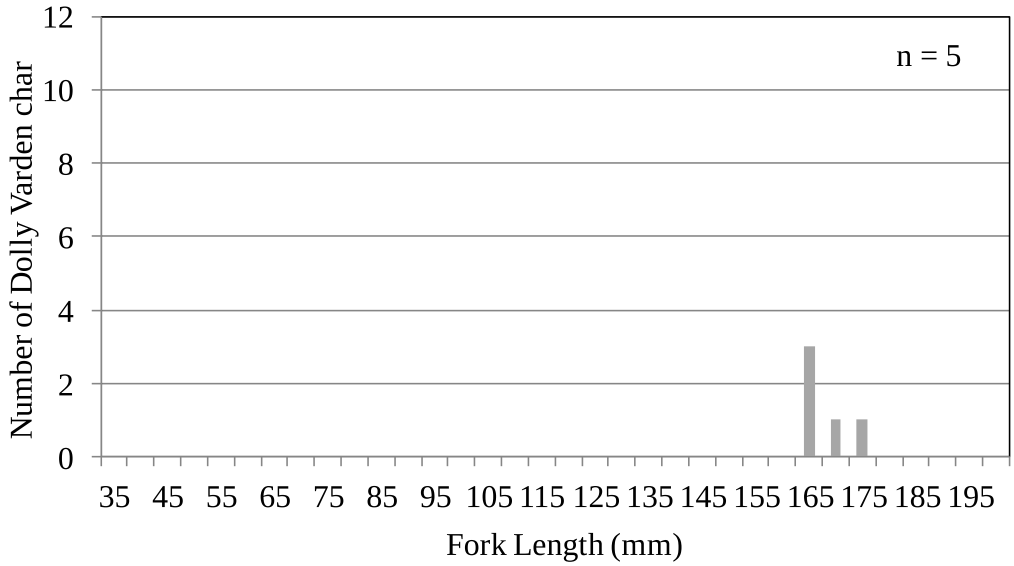

Figure 27.–East Fork Slate Creek resident fish length frequency.

Resident Fish Metals Concentrations

We captured six Dolly Varden char in East Fork Slate Creek at 58.8040°N, 135.0382°W on August 1, 2012. We shipped the fish samples to Columbia Analytical in Kent, Washington, for laboratory analyses September 27, 2012 and received the results November 9, 2012. The laboratory processed the fish individually and the concentration for each fish is shown for each element in Figure 28.

Though we present the information from 2011 and 2012 in the figure below, we won't compare data between years because in 2011 we incorrectly completed the laboratory's chain of custody form and the laboratory homogenized all six fish, giving one concentration for each element.

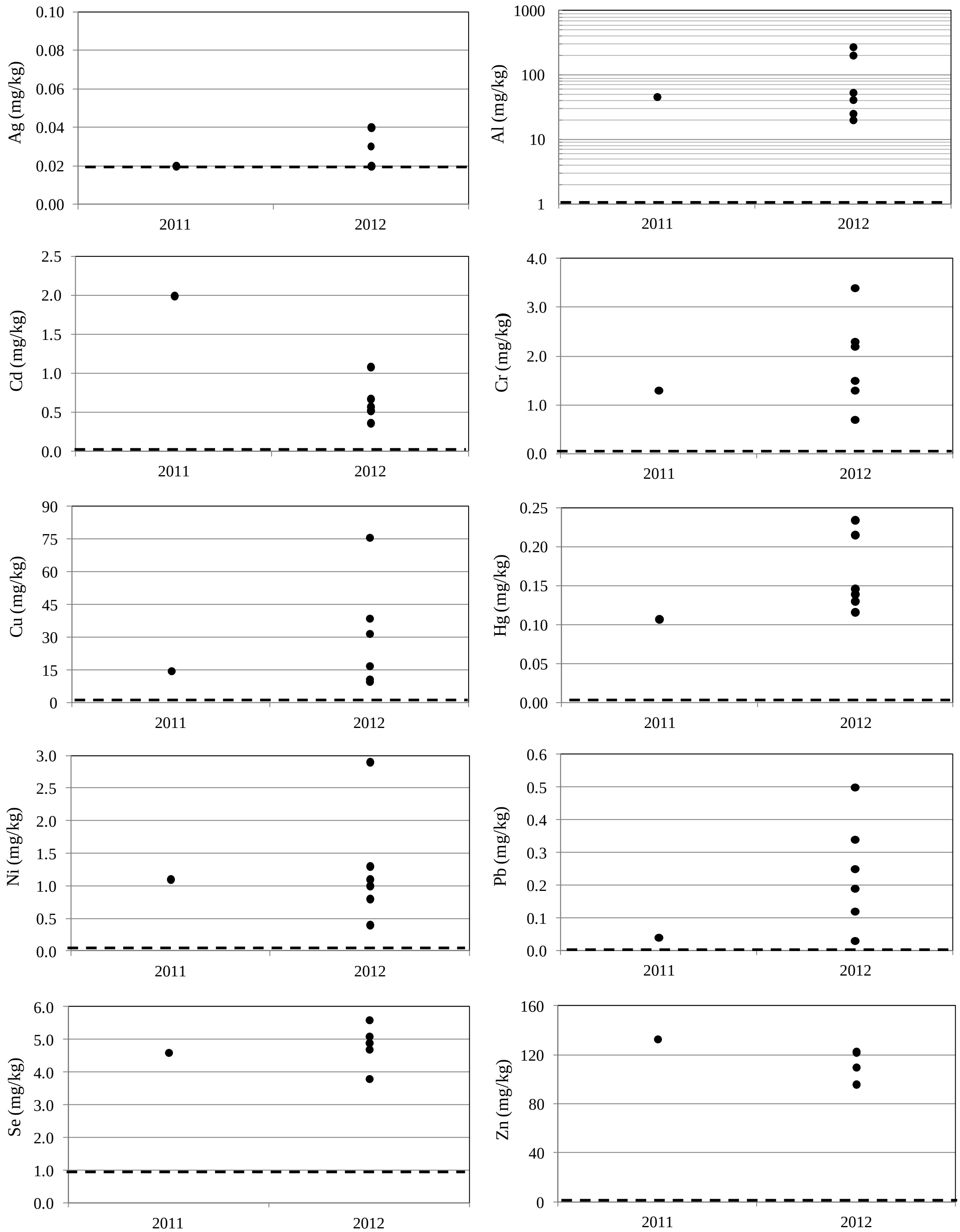

Figure 28.–East Fork Slate Creek whole body metals concentrations.

Note: 2012, juvenile Dolly Varden char.
Note: Dashed lines represent the method reporting limit.

Sediment Metals Concentrations

We collected sediments in East Fork Slate Creek at 58.8053°N, 135.0383°W on July 10, 2012, finding collection more difficult than in 2011. East Fork Slate Creek is characterized as an incised, bedrock canyon with water flow primarily from Upper Slate Lake via the diversion pipeline and the TTF water treatment plant effluent. We collected sediment upstream of the bedrock canyon under large woody debris and in eddies. We shipped the samples to the AECOM Environmental Toxicology laboratory in Fort Collins, Colorado for analyses on July 19, 2012. We received the laboratory results on September 27, 2012.

East Fork Slate Creek concentrations of Ag, Cr, Cu, Hg, Pb, and Zn are greater than in 2011, Cd and Ni concentrations are similar, and Al, As, and Se concentrations are lower. East Fork Slate Creek sediment metals concentrations are shown in Figure 29.

The 2012 East Fork Slate Creek sediment sample is composed of 26% sand, has the greatest percentage of total volatile solids (29%) and total organic carbon (17%), the lowest percentage of total solids (24%), and a similar amount of acid volatile sulfide (1%) compared to the sediment samples collected from our other sampling locations (Ben Brewster, Division of Habitat Biologist, ADF&G, Douglas; September 27, 2012, memorandum, Kensington Spawning Substrate Trip Report). We include tables with 2011 and 2012 sediment composition, metals and semi metals data for all sites and the 2012 AECOM laboratory report in Appendix E.

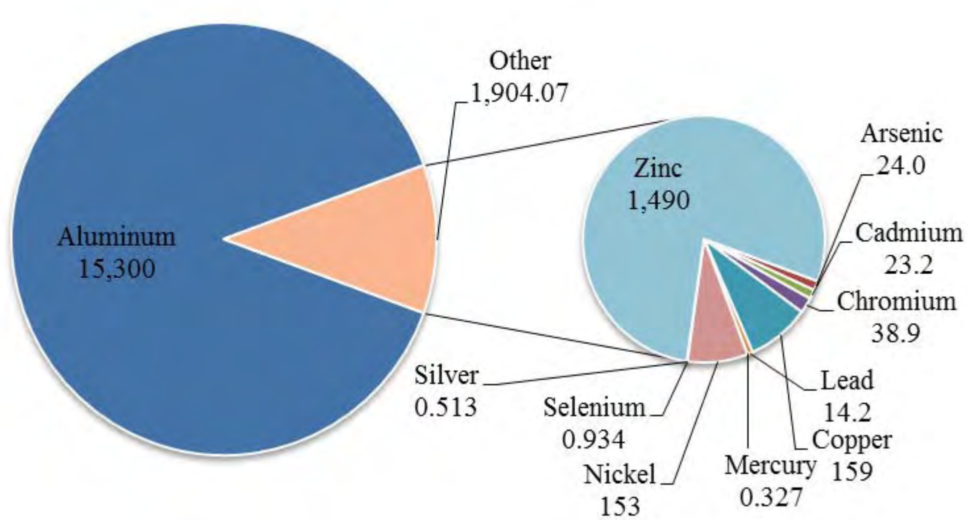

Figure 29.–East Fork Slate Creek sediment metals concentrations.

Note: 2012 data presented in parts per million (mg/kg).

Sediment Toxicity

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the East Fork Slate Creek sediment sample compared to the control. We include the laboratory report in Appendix E.

Aquatic Vegetation Surveys

Tailing discharge to the TTF began June 24, 2010. In July 2011, the TTF was host to an algal bloom. In August 2011, Coeur began water sampling to detect chlorophyll *a* (Figure 30), nitrogen (Figure 31), phosphorus (Figures 32, 33), potassium (Figure 34), sulfur (Figure 35), and total organic carbon (Figure 36), among other parameters, at four locations: 1) upstream of the TTF (Control), 2) in the TTF, 3) the TTF water treatment plant effluent, and 4) downstream of effluent discharge in East Fork Slate Creek (EFSC).

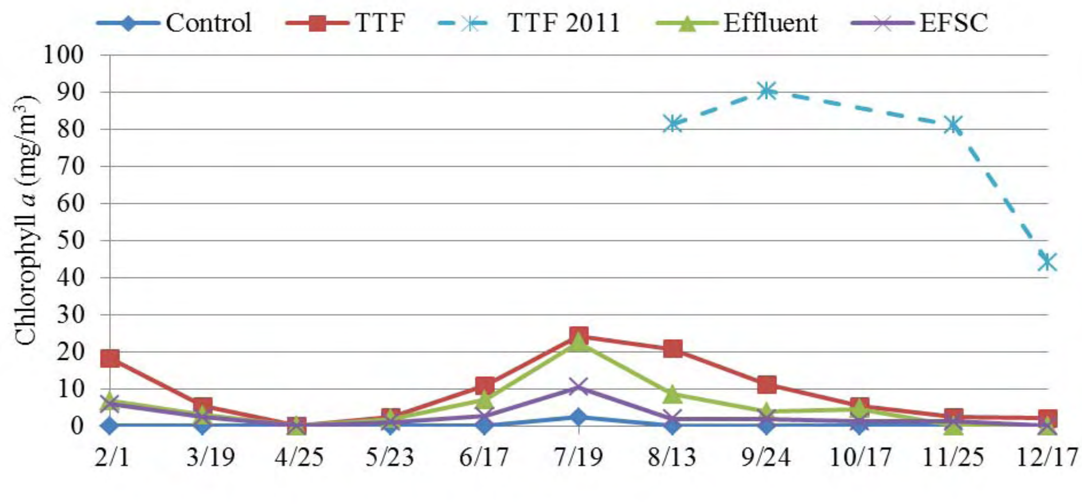

Figure 30.–Chlorophyll *a* parts per billion (mg/m^3) at four stations.

Chlorophyll *a* concentrations in the TTF have decreased from a high of 90 mg/m^3 on September 19, 2011. In 2012, chlorophyll *a* concentrations in the TTF, effluent, and East Fork Slate Creek are generally higher than the control, and follow control trends.

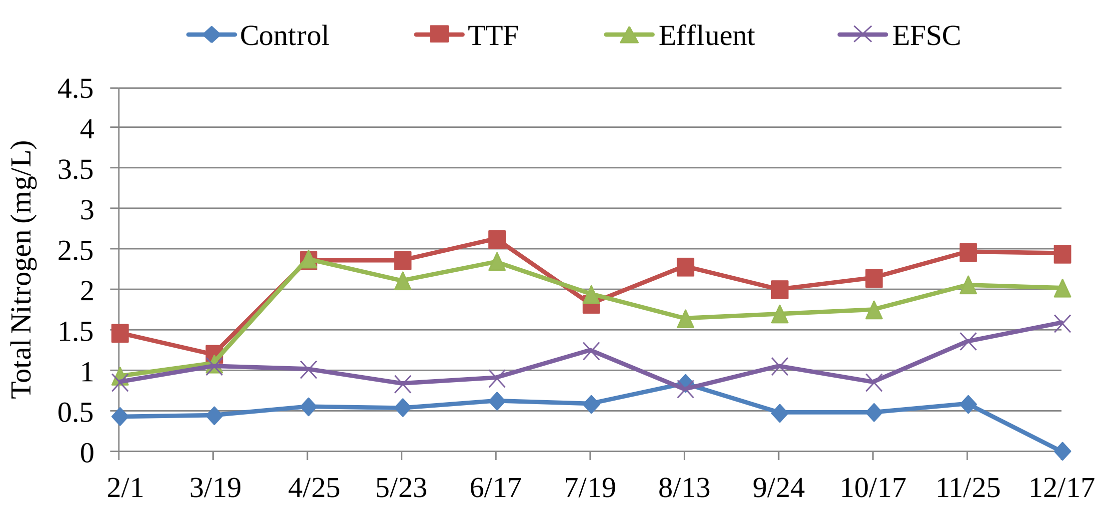

Figure 31.–Total Kjeldahl nitrogen parts per million (mg/L) at four stations.

The nitrogen concentrations are greatest in the TTF and effluent, increasing in East Fork Slate Creek toward the 2012 year end.

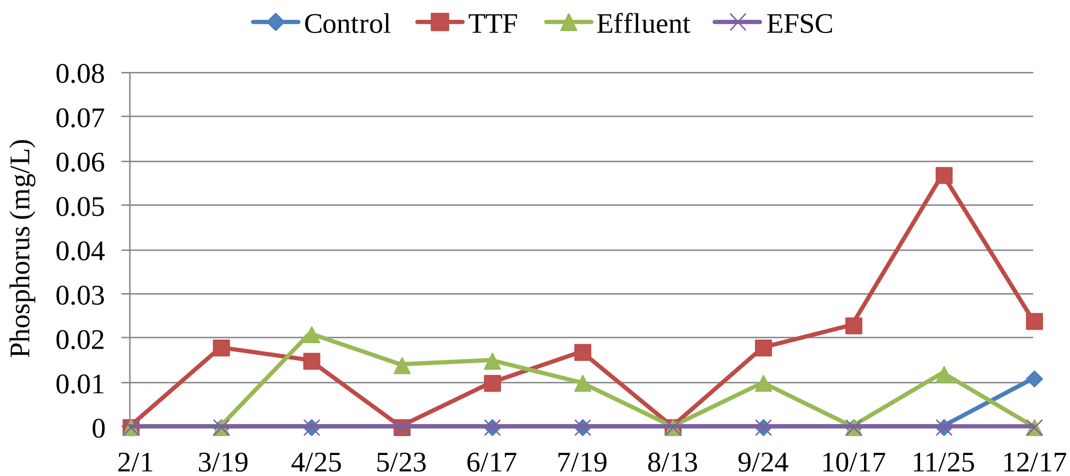

Figure 32.–Total phosphorus parts per million (mg/L) at four stations.

The 2011 phosphorous concentrations in the TTF were consistent with those found in eutrophic[v] lakes, though the TTF is in a formerly oligotrophic[w] lake, suggesting a source of phosphorous in the tailings caused the algal bloom. The erratic phosphorus concentrations in the TTF in 2012 continue to suggest phosphate deposit encounters during mining, with tailing discharge to the TTF. We are investigating a correlation between phosphorus spikes in the TTF and TDS spiking shortly thereafter downstream in East Fork Slate Creek (Figure 33).

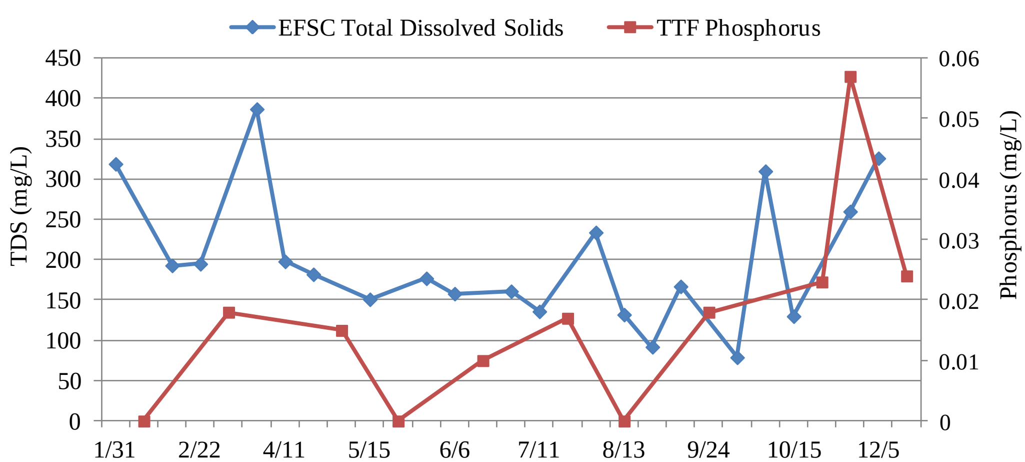

Figure 33.–East Fork Slate Creek TDS and TTF total phosphorus in parts per million (mg/L).

[v] Warm water, high productivity.
[w] Cold water, low productivity.

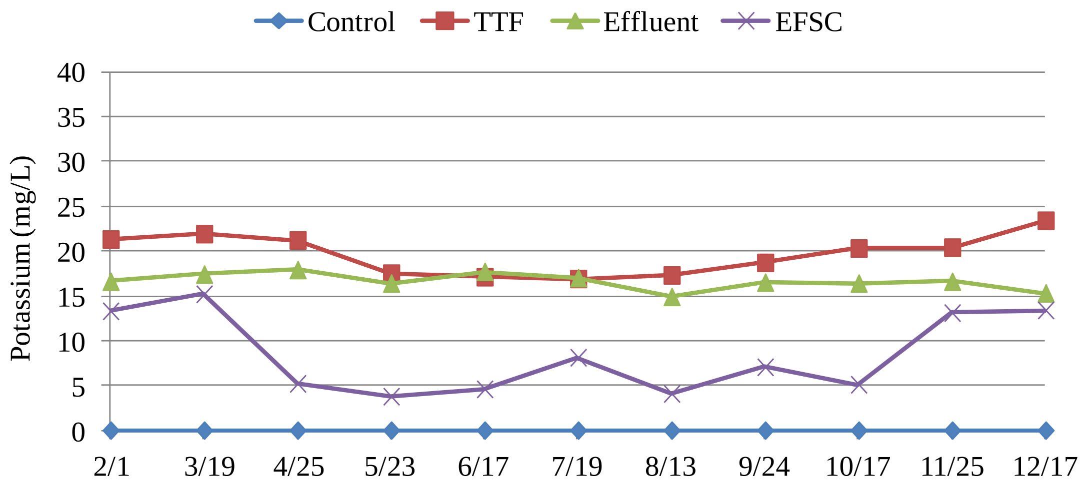

Figure 34.–Total recoverable potassium parts per million (mg/L) at four stations.

Potassium is not detected at the control site in 2012, and is highest in the TTF and in the effluent. East Fork Slate Creek potassium concentrations in 2012 are higher than the control and lower than the TTF and effluent. We continue to watch potassium levels in East Fork Slate Creek, as increases can disrupt the sodium/potassium ratio and become toxic to algae. We assess algal abundance in our periphyton biomass studies and the chlorophyll *a* concentrations in Coeur's water samples.

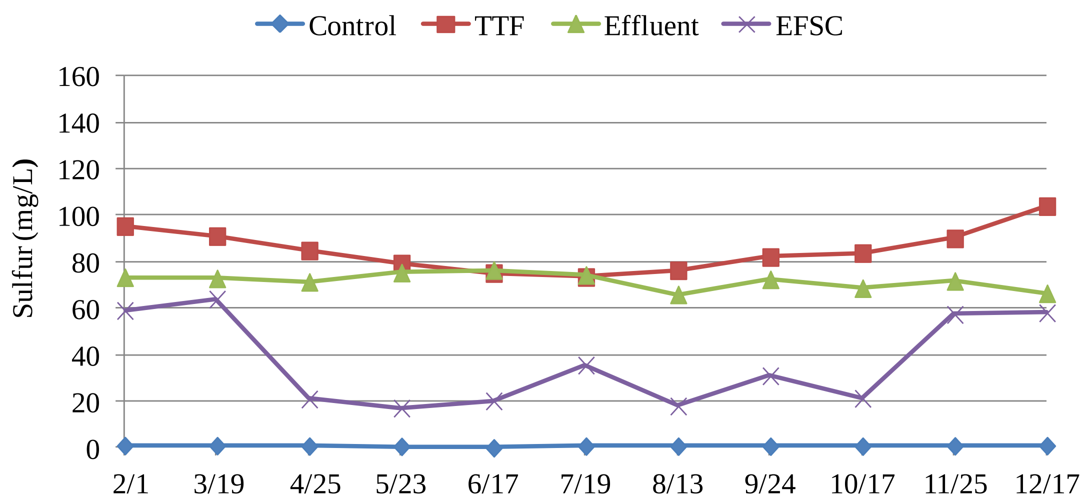

Figure 35.–Total sulfur parts per million (mg/L) at four stations.

Sulfur is present in low concentrations (<1.0 mg/L) upstream of the TTF in 2012, and is highest in the TTF and in the effluent. East Fork Slate Creek sulfur concentrations are higher than the control and lower than the TTF and effluent, and remain within a similar range across years.

Potassium and sulfur are present in potassium amyl xanthate (C5H11OCSSK), used in the milling process. Habitat biologists occasionally smell an odor reminiscent of the mill in East Fork Slate and Lower Slate Creeks. In a conversation with the lead author at the mine site in the spring of 2011, a former Kensington Mine employee suggested the xanthate molecules pass the water treatment facility, move downstream, dissolve in the water column and release the characteristic odor of sulfur into the air (Ron Johnson, Mill Manager, Kensington Gold Mine, Juneau, personal communication).

Sulfur can increase the acidity of water, so we regularly review Couer's monthly water quality data. In 2012, we find that the pH of East Fork Slate Creek water is about 7.5 to 8 throughout the year, within the normal range.

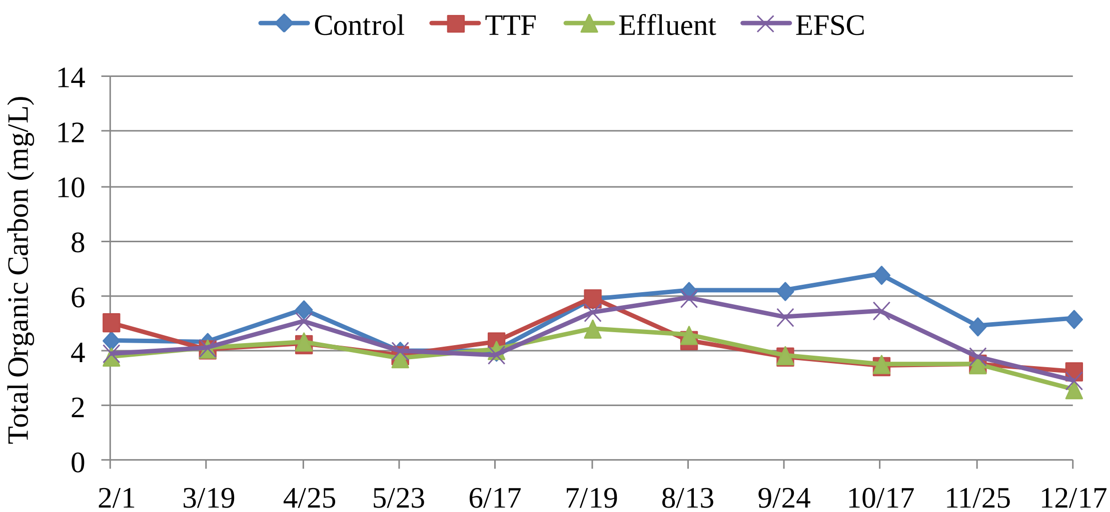

Figure 36.–Total Organic Carbon parts per million (mg/L) at four stations.

The total organic carbon at the control site and East Fork Slate Creek follow a similar trend in 2012 (Figure 36). The rate of vegetative growth depends, among other factors, on temperature and sunshine, both more abundant in 2011 than 2012, resulting in greater decaying natural organic matter in 2011.

West Fork Slate Creek

Periphyton Community Composition & Biomass

We collected periphyton samples in West Fork Slate Creek at 58.7992°N, 135.0460°W on July 25, 2012 (Figure 37). Table 7 shows the average concentration of chlorophylls *a*, *b*, and *c* (mg/m^2) in the sample. The 2011 and 2012 proportion of chlorophylls *a*, *b*, and *c* are shown in Figure 38. West Fork Slate Creek algal biomass, estimated from the chlorophyll *a* concentration in each sample, is shown in Figure 39.

Figure 37.–West Fork Slate Creek periphyton sample taken July 25, 2012.

Table 7.–West Fork Slate Creek chlorophylls *a*, *b*, and *c* mean densities

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
July 25, 2012	1.01 (0.75)	0.00 (0.00)	0.10 (0.08)

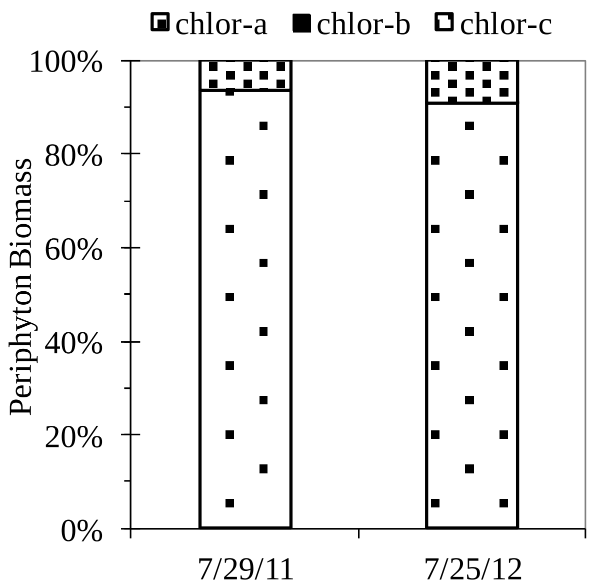

Figure 38.–West Fork Slate Creek chlorophylls *a*, *b*, and *c* proportion

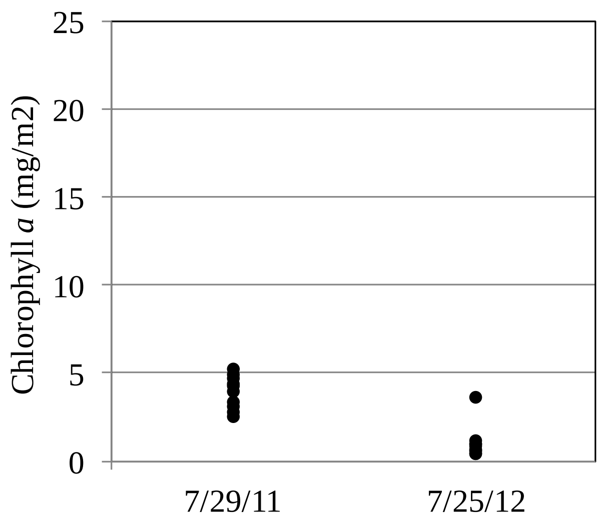

Figure 39.–West Fork Slate Creek chlorophyll *a* densities.

Benthic Macroinvertebrate Composition & Abundance

We collected six macroinvertebrate samples in West Fork Slate Creek at 58.7995°N, 135.0459°W, on May 2, 2012. We identified 31 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 1,819 insects, of which 80% are EPT taxa (Figure 40). The Shannon Diversity score is 0.84 and the Evenness score is 0.71. The dominant taxon is Ephemeroptera: Baetidae, representing 32% of samples. When we compared the benthic macroinvertebrate samples collected in May 2011 and April 2012, we detected significant differences ($p \leq 0.05$) in insect density and the number of taxa per sample between years.

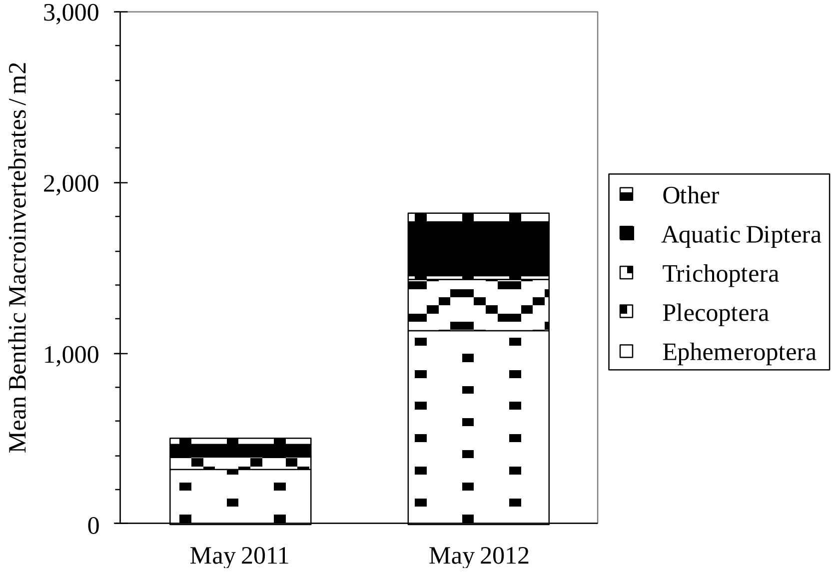

Figure 40.–West Fork Slate Creek benthic macroinvertebrates.

Upper Slate Creek

Periphyton Community Composition & Biomass

We collected 10 periphyton samples in Upper Slate Creek at 58.8191°N, 135.0416°W on July 24, 2012. In addition, we sampled three times, February 7, 2012, April 27, 2012, and October 30, 2012 to investigate the algal bloom in the TTF and the change in periphyton biomass downstream in East Fork Slate Creek in 2011.

Table 8 shows the average concentrations of chlorophylls *a*, *b*, and *c* (mg/m^2) in East Fork Slate Creek samples collected during 2012. The 2011 and 2012 proportion of chlorophylls *a*, *b*, and *c* are shown in Figure 41.

Table 8.–Upper Slate Creek chlorophylls *a*, *b*, and *c* mean densities.

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
February 7, 2012	0.64	0.00	0.04
April 27, 2012	0.70	0.00	0.06
July 24, 2012	1.26	0.00	0.07
October 30, 2012	0.78	0.00	0.06

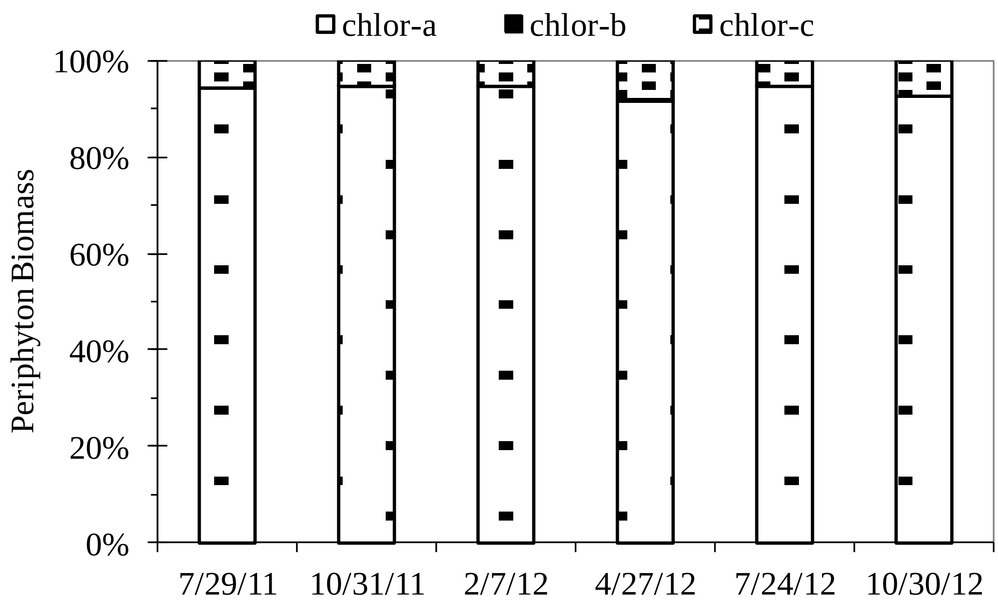

Figure 41.–Upper Slate Creek chlorophylls *a*, *b*, and *c* proportion.

Upper Slate Creek algal biomass, estimated from the chlorophyll *a* concentration in each sample, is shown in Figure 42.

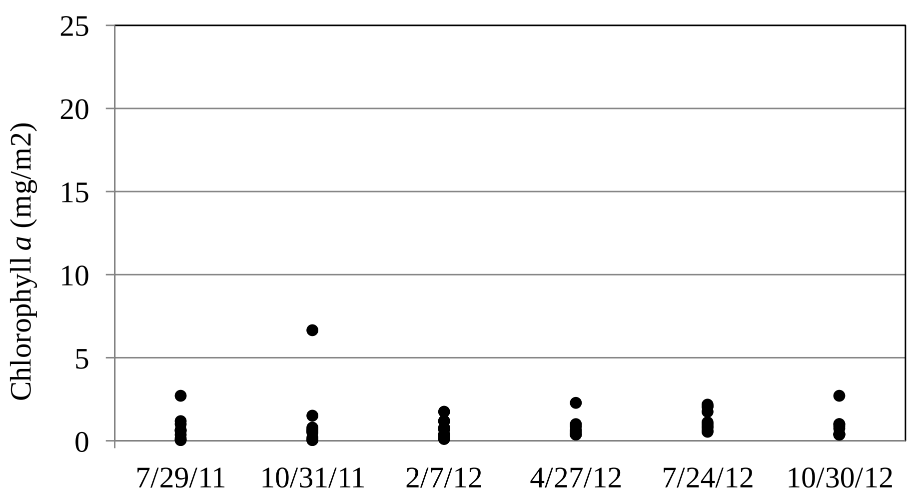

Figure 42.–Upper Slate Creek chlorophyll *a* densities.

Benthic Macroinvertebrate Composition & Abundance

We collected macroinvertebrate samples in Upper Slate Creek at 58.8189º N, 135.0415º W, on April 27, 2012. We identified 39 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 2,256 insects, of which 68% are EPT taxa (Figure 43). The Shannon Diversity score is 1.04 and the Evenness score is 0.79. The dominant taxon is Diptera: Chironomidae, representing about 20% of samples.

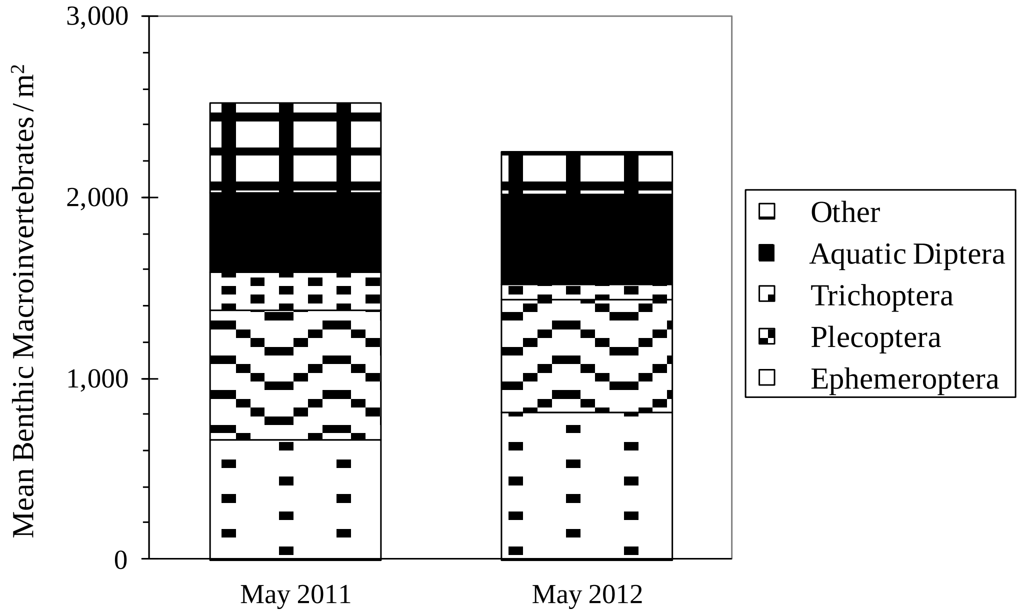

Figure 43.–Upper Slate Creek benthic macroinvertebrates.

Resident Fish Population & Condition

We sampled resident fish in Upper Slate Creek at 58.8199°N, 135.0425°W on August 2, 2012. The 2012 Dolly Varden char population estimate for Upper Slate Creek is 192±32 fish and significantly greater ($p \leq 0.05$) than our 2011 estimate (Figure 44). We captured more Dolly Varden char in pools than riffles or glides (Figure 45) and the fish we captured are from several age classes (Figure 46). Mean fish condition is 0.99 g/mm^3, about the same as fish condition in 2011.

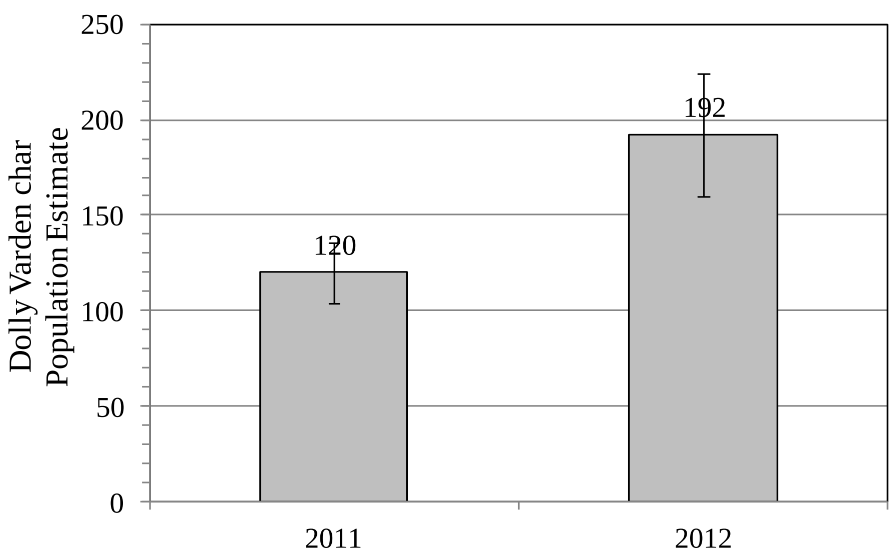

Figure 44.–Upper Slate Creek resident fish population estimates.

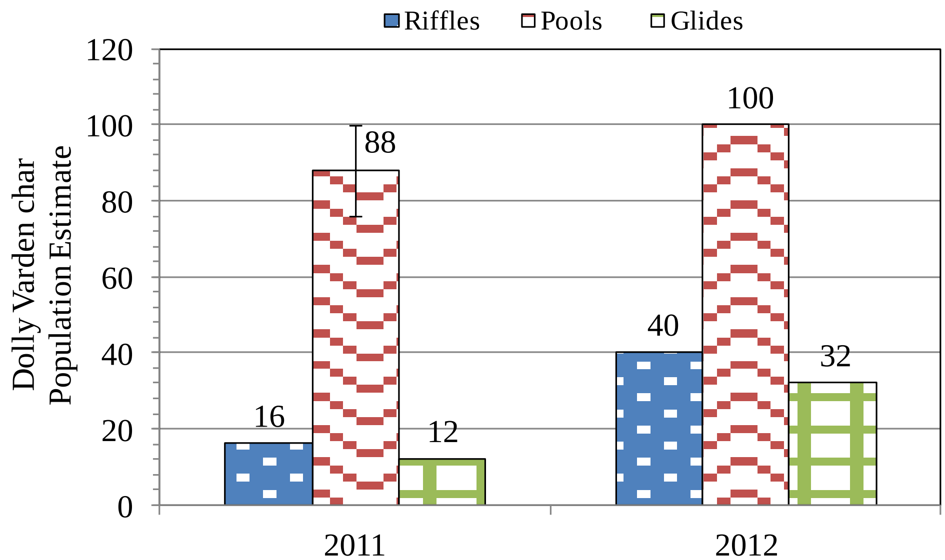

Figure 45.–Upper Slate Creek resident fish population estimates by habitat type.

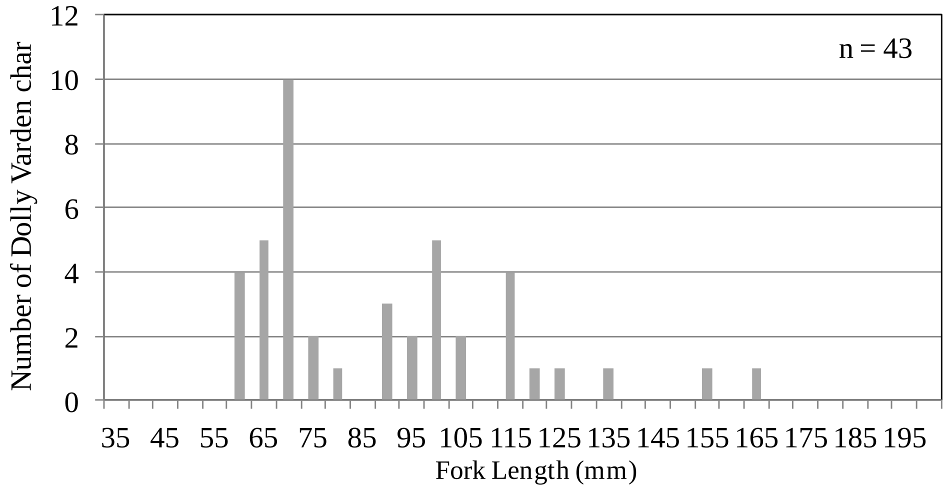

Figure 46.–Upper Slate Creek resident fish length frequency.

Resident Fish Metals Concentrations

We captured six Dolly Varden char in Upper Slate Creek at 58.8199°N, 135.0425°W on August 2, 2012. We shipped the fish samples to Columbia Analytical in Kent, Washington, for laboratory analyses September 27, 2012 and received the results November 9, 2012. The laboratory processed the fish individually and the concentration for each fish is shown for each element in Figure 47, except for Ag, which was undetected at the method reporting limit in five samples and Ni, which was undetected at the method reporting limit in one sample.

Though we present the information from 2011 and 2012 in the figure below, we won't compare data between years because in 2011 we incorrectly completed the laboratory's Chain of Custody form and the laboratory homogenized all six fish, giving just one concentration for each element for all six fish. Columbia Analytical reported they observed sediment in the bottom of their digestion tube containing the 2011 Upper Slate Creek homogenized fish sample[x], which may have increased the concentrations of some elements.

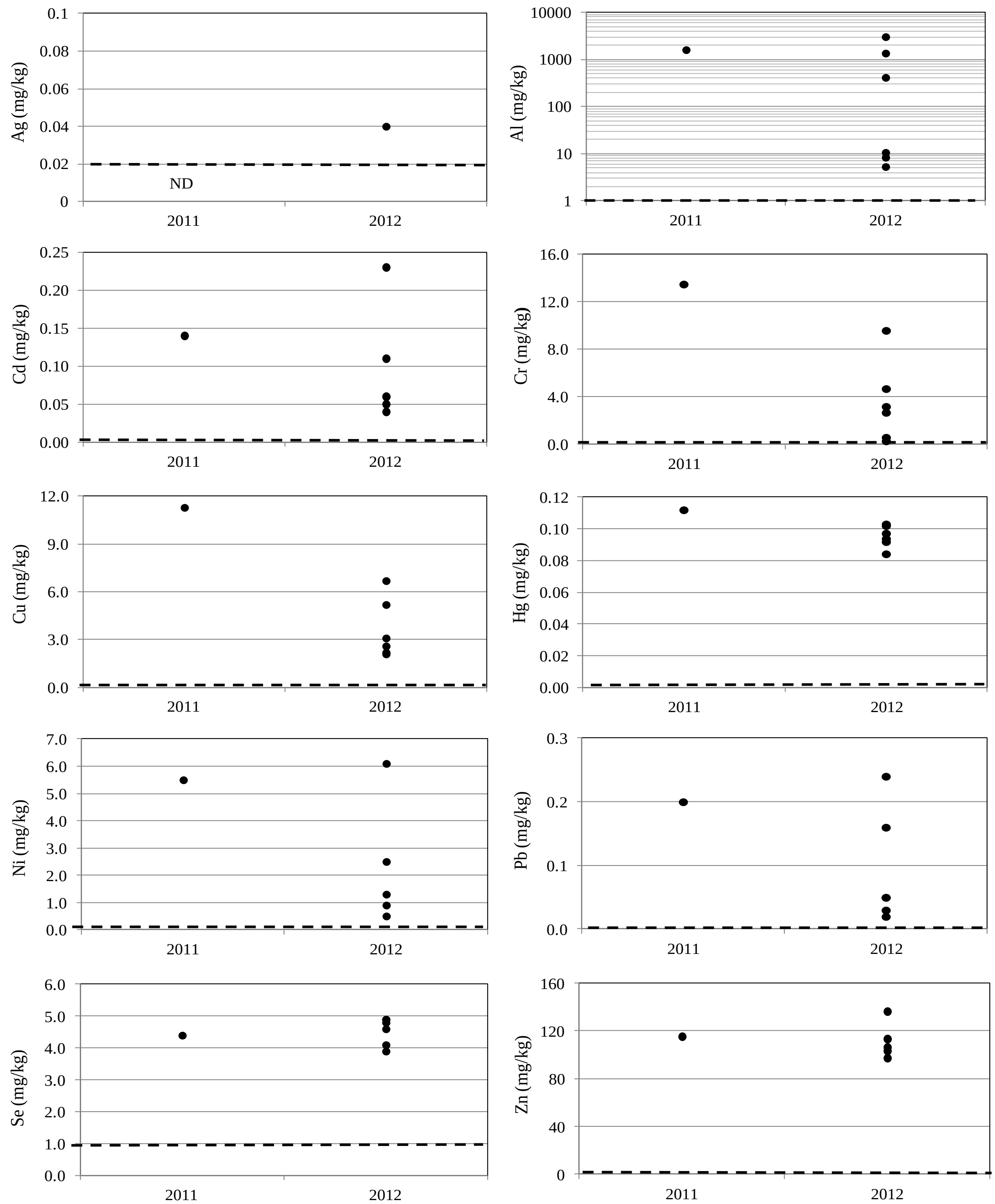

Figure 47.–Upper Slate Creek whole body metals concentrations.

Note: 2012, juvenile Dolly Varden char.
Note: Dashed lines represent the method reporting limit.
Note: ND indicates the metal was not detected at the method reporting limit.

[x] The probable source is sediment the fish ingested.

Sediment Metals Concentrations

We collected sediments in Upper Slate Creek at 58.8189°N, 135.0416°W on July 2, 2012. We shipped the samples to the AECOM Environmental Toxicology laboratory in Fort Collins, Colorado for analyses on July 19, 2012. We received the laboratory results on September 27, 2012.

The Upper Slate Creek Hg concentration is greater in 2012 than 2011 when it was not detected at the method reporting limit (0.0366 mg/kg). Concentrations of the other elements are similar to those in 2011. Upper Slate Creek sediment metals concentrations are shown in Figure 48. We include tables with 2011 and 2012 sediment composition, metals and semi metals data for all sites and the 2012 AECOM laboratory report in Appendix E.

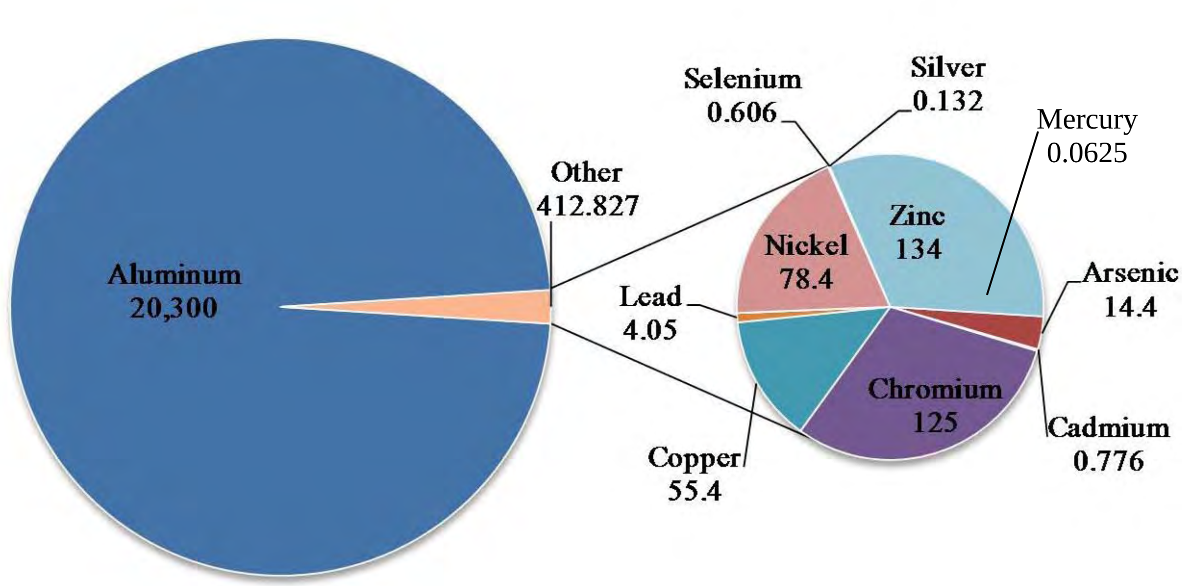

Figure 48.–Upper Slate Creek sediment metals concentrations.

Note: 2012 data presented in parts per million (mg/kg).

Sediment Toxicity

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Upper Slate Creek sediment sample compared to the control. We include the laboratory report in Appendix E.

JOHNSON CREEK

Lower Johnson Creek

Sediment Metals Concentrations

We collected sediments in Lower Johnson Creek at 58.8235°N, 135.0048°W on July 2, 2012. We shipped the samples to the AECOM Environmental Toxicology laboratory in Fort Collins, Colorado for analyses on July 19, 2012. We received the laboratory results on September 27, 2012.

The 2012 Ag concentration is twice that of 2011 though still similar to 2005–2010 (Flory 2011). The concentrations of the other elements are similar to 2011. Lower Johnson Creek sediment metals concentrations are shown in Figure 49. We include tables with 2011 and 2012 sediment composition, metals and semi metals data for all sites and the 2012 AECOM laboratory report in Appendix E.

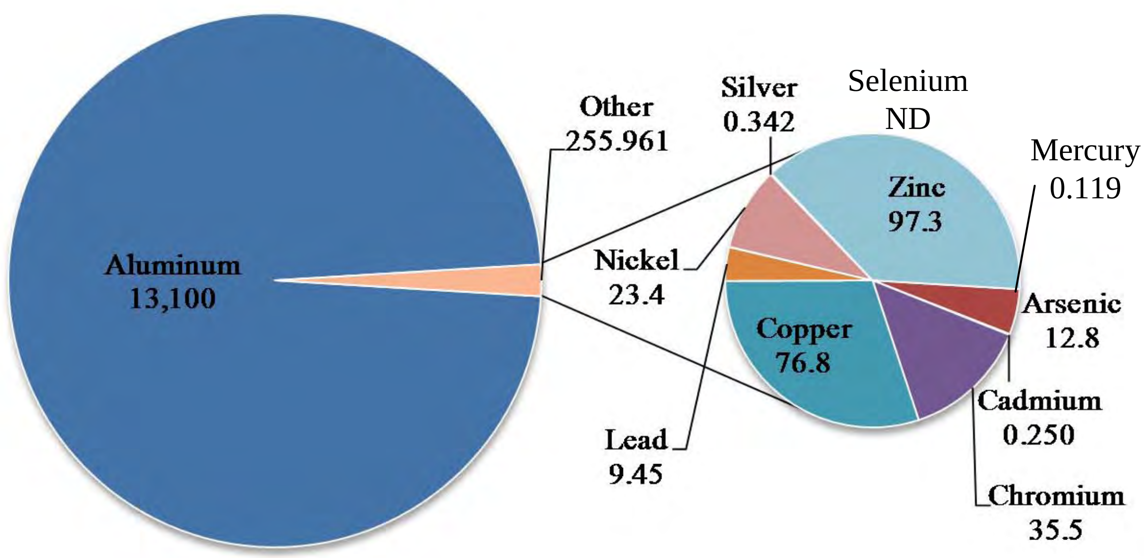

Figure 49.–Lower Johnson Creek sediment metals concentrations.

Note: 2012 data presented in parts per million (mg/kg).

Sediment Toxicity

We collected sediments in Lower Johnson Creek at 58.8235°N, 135.0048°W on July 2, 2012 (Figure 50). There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Lower Johnson Creek sediment sample compared to the control. We include the laboratory report in Appendix E.

Figure 50.–Ben Brewster collects sediment in Lower Johnson Creek.

Adult Salmon Counts

We surveyed Lower Johnson Creek for adult chum salmon and pink salmon between July 17 and September 19, 2012.

Figure 51 presents the adult pink salmon count for each Lower Johnson Creek survey, and Figure 52 presents the weekly distribution of adult pink salmon. The 2012 adult pink salmon estimate is 6,267 fish, similar to the 2006 and 2009 estimates (Flory 2011).

We observed adult chum salmon in the lower and middle portions of the Johnson Creek between July 24 and August 7, and estimate adult chum salmon return at 248 fish, similar to estimates for previous years.

We surveyed Lower Johnson Creek for coho salmon between September 26 and November 5 by foot and by snorkeling on October 23, October 30, and November 5. We observed most adult coho salmon in the middle portion of Lower Johnson Creek between Site 4 and Site 10. We estimate coho salmon at 90 fish, the highest in eight years of monitoring (Flory 2011, Timothy and Kanouse 2011). This is an overestimation as we unknowingly counted adult Dolly Varden char as adult coho salmon prior to snorkeling. We will snorkel deep pools in Lower Johnson Creek each week in 2013 during the coho salmon spawning season to verify Dolly Varden char are not included in the adult coho salmon estimate.

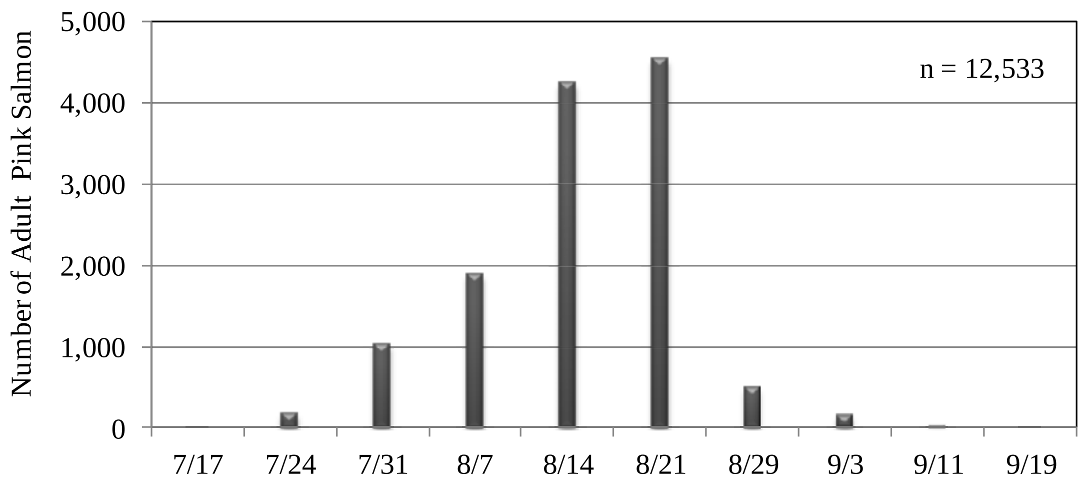

Figure 51.–Lower Johnson Creek adult pink salmon counts.

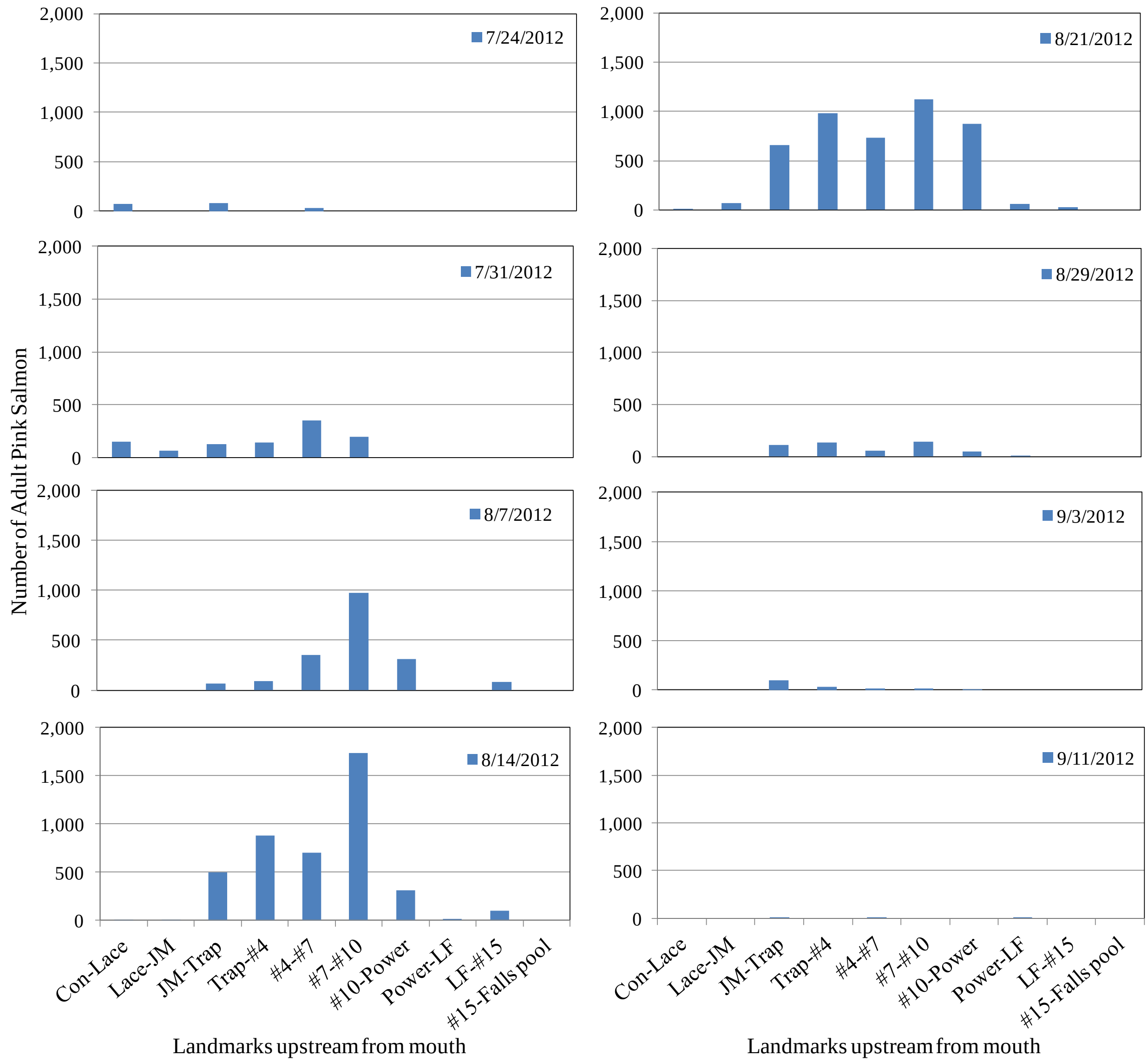

Figure 52.–Lower Johnson Creek adult pink salmon distribution.

Upper Johnson Creek

Benthic Macroinvertebrate Composition & Abundance

We collected macroinvertebrate samples in Upper Johnson Creek at 58.8407°N, 135.0450°W, on April 26, 2012. We identified 28 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 3,968 insects, of which 64% are EPT taxa (Figure 53). The Shannon Diversity score is 0.81 and the Evenness score is 0.68. The dominant taxon is Diptera: Chironomidae, representing about 26% of samples.

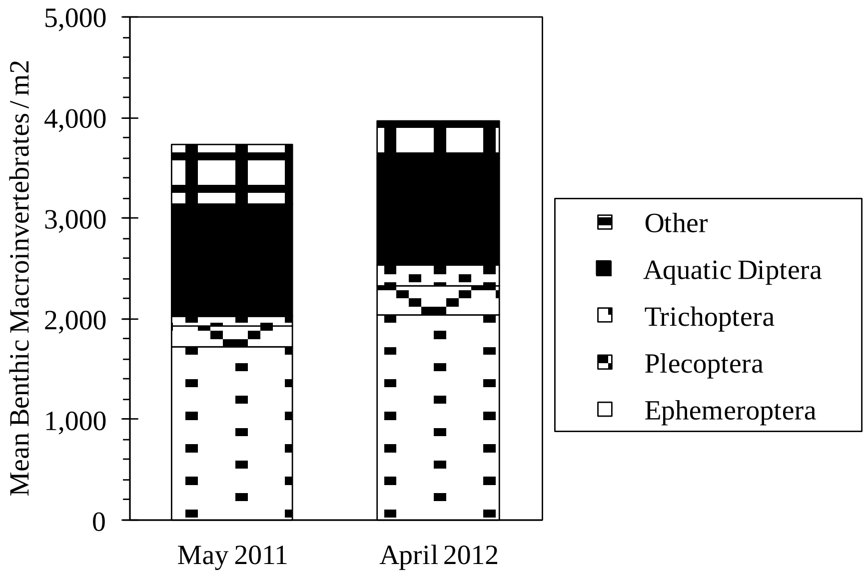

Figure 53.–Upper Johnson Creek benthic macroinvertebrates.

SHERMAN CREEK

Lower Sherman Creek

Periphyton Community Composition & Biomass

We collected periphyton samples in Lower Sherman Creek on July 26, 2012 in two locations; Sample Point 1 at 58.8687°N, 135.1414°W, and Sample Point 2 at 58.8672°N, 135.1376°W. Tables 9 and 10 show the average concentration of chlorophylls *a*, *b*, and *c* (mg/m^2) in the samples. The 2011 and 2012 proportion of chlorophylls *a*, *b*, and *c* are shown in Figures 54 and 55.

Table 9.–Lower Sherman Creek Sample Point 1 chlorophylls *a*, *b*, and *c* mean densities.

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
July 26, 2012	2.54	0.93	0.08

Table 10.–Lower Sherman Creek Sample Point 2 chlorophylls *a*, *b*, and *c* mean densities.

Sample Date	Chlorophyll *a* (mg/m^2)	Chlorophyll *b* (mg/m^2)	Chlorophyll *c* (mg/m^2)
July 26, 2012	0.67	0.01	0.09

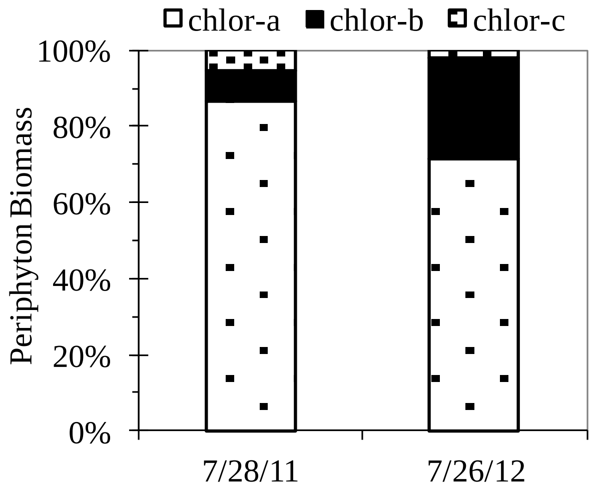

Figure 54.–Lower Sherman Creek Sample Point 1 chlorophylls *a, b,* and *c* proportion.

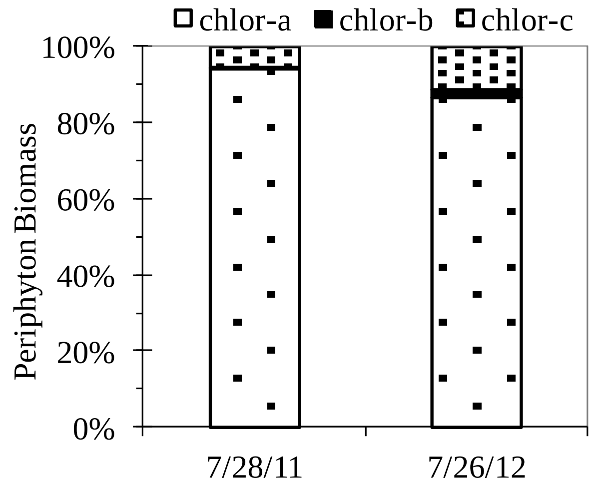

Figure 55.–Lower Sherman Creek Sample Point 2 chlorophylls *a*, *b*, and *c* proportion.

Lower Sherman Creek Sample Points 1 and 2 algal biomass, estimated by the chlorophyll *a* concentration in each sample, is shown in Figures 56 and 57.

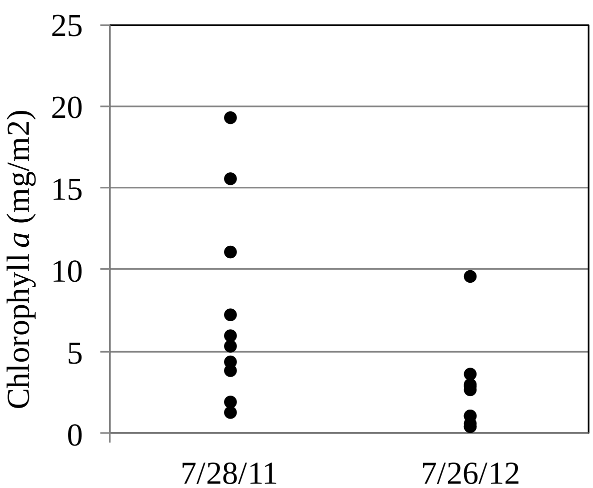

Figure 56.–Lower Sherman Creek Sample Point 1 chlorophyll *a* densities.

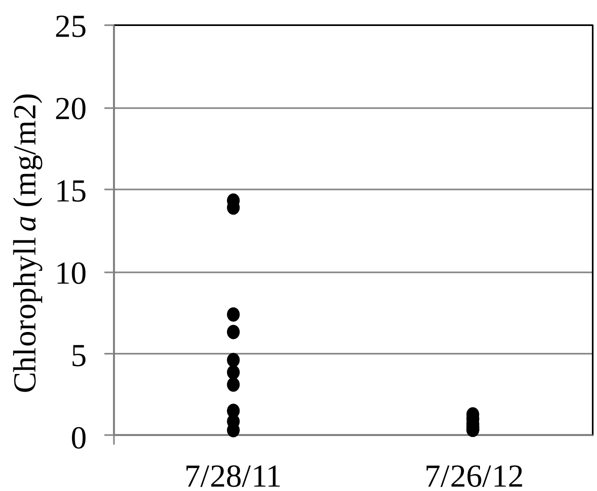

Figure 57.–Lower Sherman Creek Sample Point 2 chlorophyll *a* densities.

Benthic Macroinvertebrate Composition & Abundance

Sherman Creek Sample Point 1

We collected macroinvertebrate samples in Lower Sherman Creek at Sample Point 1, 58.8688°N, 135.1412°W, on April 30, 2012. We identified 31 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 2,733 insects, of which 66% are EPT taxa (Figure 58). The Shannon Diversity score is 0.74 and the Evenness score is 0.62. The dominant taxon is Ephemeroptera: Baetidae, representing 44% of samples.

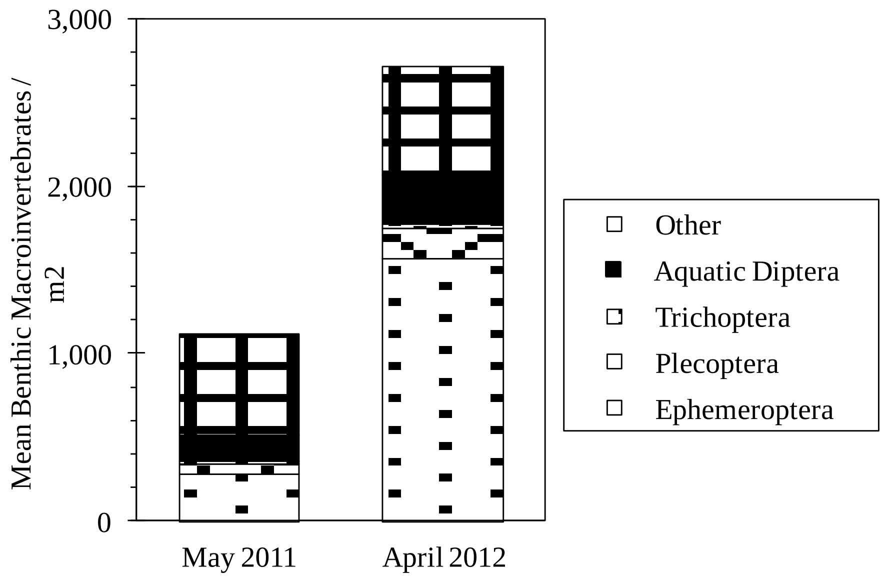

Figure 58.–Lower Sherman Creek Sample Point 1 benthic macroinvertebrates.

Sherman Creek Sample Point 2

We collected macroinvertebrate samples in Lower Sherman Creek at Sample Point 2, 58.8674°N, 135.1381°W, on April 30, 2012. We identified 37 taxa among the six samples, and we estimate the mean number of aquatic benthic macroinvertebrates per m^2 at 2,823 insects, of which 79% are EPT taxa (Figure 59). The Shannon Diversity score is 0.70 and the Evenness score is 0.57. The dominant taxon is Ephemeroptera: Baetidae, representing 57% of samples.

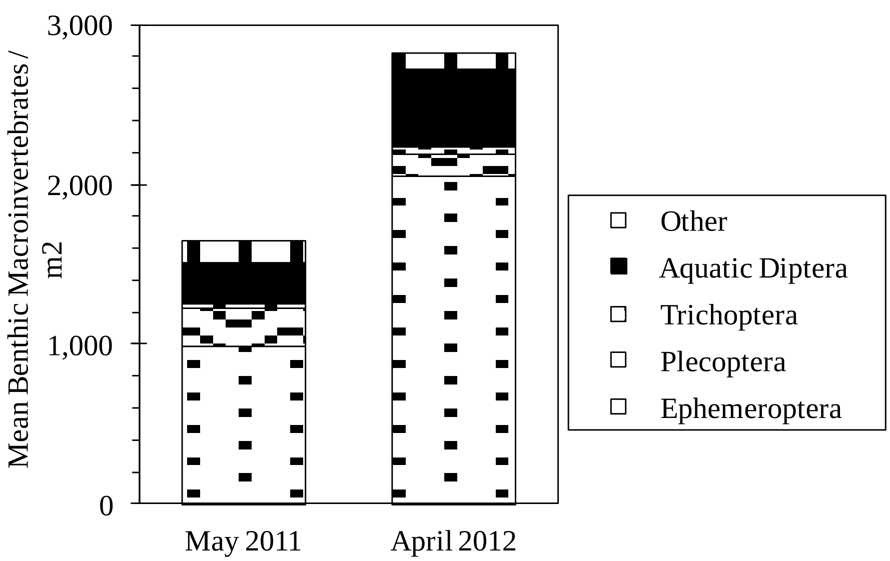

Figure 59.–Lower Sherman Creek Sample Point 2 benthic macroinvertebrates.

Sediment Metals Concentrations

We collected sediments in Lower Sherman Creek at 58.8687°N, 135.1413°W on July 3, 2012. We shipped the samples to the AECOM Environmental Toxicology laboratory in Fort Collins, Colorado for analyses on July 19, 2012. We received the laboratory results on September 27, 2012.

The 2012 Ag concentration is twice that of 2011 though still similar to 2005–2010 (Flory 2011). The concentrations of the other elements are similar to 2011. Lower Sherman Creek sediment metals concentrations are shown in Figure 60. We include tables with 2011 and 2012 sediment composition, metals and semi metals data and the 2012 AECOM laboratory report for Lower Sherman Creek[y] in Appendix E.

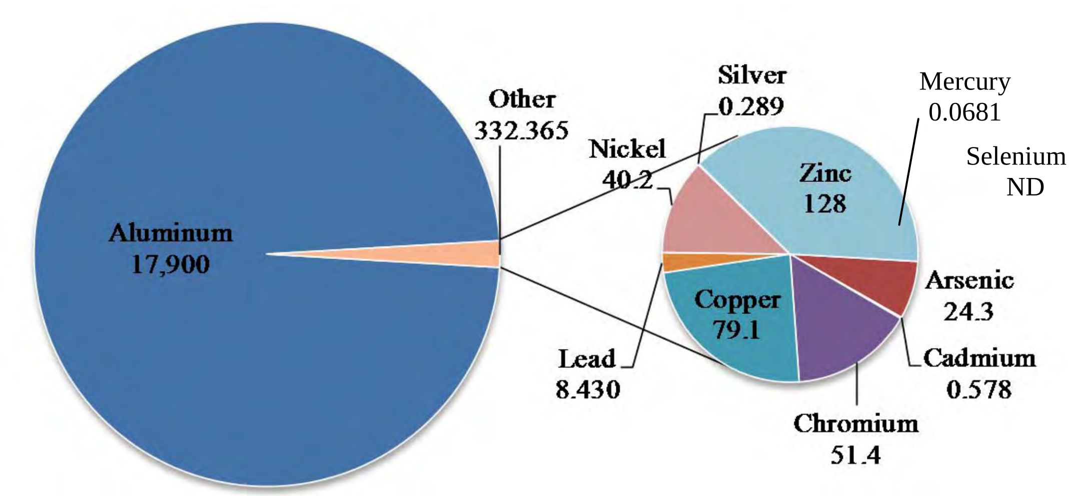

Figure 60.–Lower Sherman Creek sediment metals concentrations.

Note: 2012 data presented in parts per million (mg/kg).

Sediment Toxicity

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Lower Sherman Creek sediment sample compared to the control. We include the laboratory report in Appendix E.

Adult Salmon Counts

We surveyed Lower Sherman Creek for adult chum salmon and pink salmon between July 16 and September 18, 2012.

Figure 61 presents our adult pink salmon count for each survey in Lower Sherman Creek, and Figure 62 presents the distribution of pink salmon by section. We estimate the 2012 adult pink salmon return at 804 fish, less than estimates reported for the previous three years and similar to the 2006 and 2008 estimates (Flory 2011, Timothy and Kanouse 2012).

We did not observe live adult chum and coho salmon or any carcasses.

[y] We also provide this information for Middle Sherman Creek in Appendix E, though the information is not required in the APDES permit.

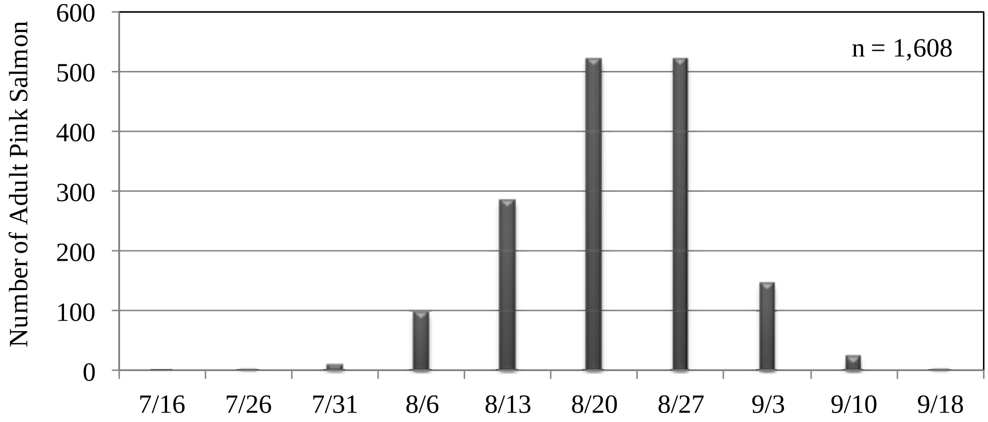

Figure 61.–Lower Sherman Creek adult pink salmon counts.

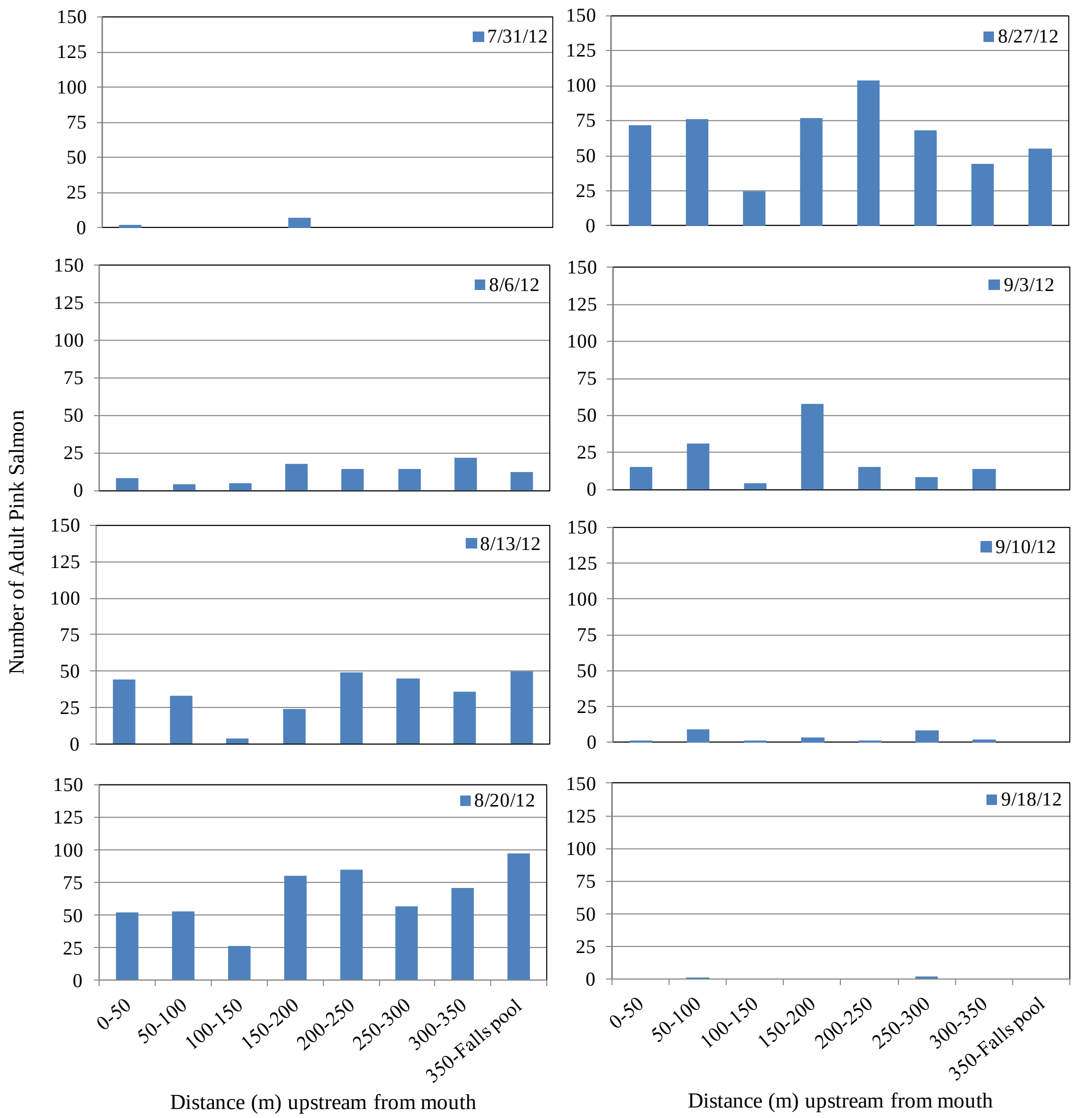

Figure 62.–Lower Sherman Creek adult pink salmon distribution.

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[z] This publication is actually the resident fish survey report.

[aa] This publication is actually the invertebrate tissue analysis.

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[bb] Actually published February 2010.

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