Technical Report No. 12-02

Aquatic Biomonitoring at Red Dog Mine, 2011
National Pollution Discharge Elimination System
Permit No. AK-003865-2

by Alvin G. Ott and William A. Morris

North Fork Red Dog Creek, Radio-Tag Arctic Grayling, Spring 2011
Photograph by Janett Rounds

March 2012

Alaska Department of Fish and Game
Division of Habitat

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Randall W. Bates
Director
Division of Habitat
Alaska Department of Fish and Game

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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Acknowledgements

We thank Teck for their financial and logistical support for the 2011 aquatic biomonitoring work. We specifically acknowledge the assistance provided by Mr. Jeff Clark, Mr. Wayne Hall, Mr. John Martinisko, Mr. Chris Eckert, Mr. Andy Willman, Mr. Joseph Diehl III, Mr. Dennis Sheldon, Mr. Chris Menefee, Ms Karen Conitz, and Mr. Robert Napier.

Ms. Laura Jacobs and Mr. Brad Wendling with the Division of Habitat, Alaska Department of Fish and Game (ADF&G) and Mr. Brendan Scanlon with Sport Fish Division (ADF&G) provided assistance with laboratory work. Mr. Fred DeCicco (Fisheries Services and Supplies) and Mr. Brendan Scanlon conducted the fall Dolly Varden (*Salvelinus malma*) and chum salmon (*Oncorhynchus keta*) aerial surveys, collected the fall sample of adult Dolly Varden from the Wulik River, and conducted radio tag aerial surveys for Arctic grayling (*Thymallus arcticus*). Mr. Brad Wendling participated in the July sampling event for aquatic invertebrates and periphyton, and conducted an aerial survey of radio-tagged Arctic grayling.

Dr. Phyllis Weber Scannell (Scannell Technical Services) updated our long-term water quality data base with 2011 data. Ms. Nora Foster (NRF Taxonomic Services) was responsible for sorting and identification of aquatic invertebrates collected with drift nets. Mr. Jack Winters and Mr. Robert Napier provided constructive review of our report.

Executive Summary

●Median metals concentrations (Pb, Zn, Al, Cd) in Mainstem Red Dog Creek are consistently lower when compared with pre-mining data. Baseline data for Se and Ni are not available, but Se and Ni have increased in recent years. The pH and total dissolved solids (TDS) in Mainstem Red Dog Creek are higher than pre-mining. The higher pH and TDS are directly related to the water treatment process. When Mainstem Red Dog Creek is compared with reference sites (Buddy and North Fork Red Dog creeks), Cd, Pb, and Zn concentrations are consistently higher. Se concentrations do not show a pattern.

●Algal biomass, as estimated by chlorophyll-a concentration, is sampled each year at nine sites. Generally, chlorophyll-a concentrations are highest in North Fork Red Dog, Bons, and Buddy creeks and lower in Middle Fork Red Dog, Mainstem Red Dog, and Ikalukrok creeks. In 2011, chlorophyll-a concentrations also were high in Ikalukrok Creek. Chlorophyll-a concentrations track with changes in metals concentrations in Ikalukrok Creek at control site Station 9 just upstream of the mouth of Mainstem Red Dog Creek.

●Aquatic invertebrate densities are used as a measure of stream productivity. In 2011, the highest aquatic invertebrate density was found in Buddy Creek below the falls. Densities were higher in North Fork Red Dog, Bons (upstream of Bons Pond), Buddy (above road and below falls) and Ikalukrok (upstream site) creeks than in Mainstem Red Dog, Middle Fork Red Dog, and Ikalukrok creeks. These data are consistent with previous sampling results, demonstrating a pattern of higher densities occurring in the Bons and Buddy Creek drainages and in North Fork Red Dog Creek. Ephemeroptera, Plecoptera, and Tricoptera (EPT) densities have remained consistent among years, while Chironomidae densities have increased. In 2011, taxa richness was the highest measured since 2004 in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks.

●Juvenile Dolly Varden are collected each year from Mainstem Red Dog, Buddy, and Anxiety Ridge creeks, and are analyzed for whole body metal concentrations. There is less variation among the three sample sites for Se than there is for Cd, Pb, Zn, and Hg. Whole body metals concentrations in fish from each sample site exhibit a creek specific signature. Median Cd, Pb, and Zn tissue concentrations are highest in Mainstem Red Dog Creek. Se is similar at all three sites. Hg concentrations consistently are higher in Anxiety Ridge Creek. Finally, Cd and Zn are higher in Buddy Creek than they are in Anxiety Ridge Creek.

●Kidney, liver, ovary, testes, and muscle from adult Dolly Varden captured in the Wulik River during spring and fall 2011 were sampled for Cd, Cu, Pb, Se, Zn, and Hg. None of the analytes measured have been found to concentrate in muscle tissue. Various metals do concentrate in specific tissues: Cd in kidney, Cu in liver, Pb in gill, Se in kidney and ovary, Zn in ovary, and Hg in kidney. It is unlikely that tissue metals concentrations or changes could be related to events at the Red Dog Mine since large Dolly Varden attain their growth in the marine environment.

●The number of overwintering Dolly Varden is estimated each fall in the Wulik River. From 2005 to 2011, the number of fish overwintering in the Wulik River has exhibited a decreasing trend. Aerial surveys prior to mine development found that over 90% of

overwintering Dolly Varden in the Wulik River were located below the mouth of Ikalukrok Creek. Surveys post mining demonstrate the same distribution. Two surveys were done in fall 2011 to assess if fish were returning later in the fall. On September 25, 2011, DeCicco estimated 15,591 Dolly Varden and on October 6, 2011, he estimated 62,612.

●Annual aerial surveys assess the distribution of chum salmon in Ikalukrok Creek. Aerial counts of adult chum salmon after mine development in 1990 and 1991 were much lower than those reported in baseline studies. The highest estimated number of chum salmon was 4,185 in 2006. In fall 2011, we estimated 1,507 chum salmon in Ikalukrok Creek.

●With almost 20 years of sampling for juvenile Dolly Varden in streams near the Red Dog Mine, we have developed the following conclusions: abundance is higher in the upper reaches of each sampled stream; peak use occurs from late July to late August; and decreasing fall water temperatures and high water events likely trigger outmigration. In 2011, juvenile Dolly Varden were caught in all sample reaches, with the highest catch per unit of effort (77) in Buddy Creek. Juvenile Dolly Varden continue to use Mainstem Red Dog Creek for rearing.

●The Arctic grayling spring migration into North Fork Red Dog Creek was monitored in spring 2011. We caught 140 Arctic grayling in a fyke net in North Fork Red Dog Creek. Spawning was judged to be substantially complete by June 9 in Mainstem Red Dog Creek. Few fry (4 to 10) were observed in Mainstem Red Dog and North Fork Red Dog creeks in late August.

●A seasonal migration/habitat use by Arctic grayling study, using radio telemetry, was initiated in spring 2011. Fifteen adult Arctic grayling were implanted with radio transmitters in North Fork Red Dog Creek. Radio tracking surveys were flown in June, July, September, October, and November. Arctic grayling distributed throughout the Ikalukrok Creek drainage after spawning, then concentrated in lower Ikalukrok Creek in a reach used by chum salmon spawners in late summer/early fall, and by early winter 73% of the live fish with working radio tags were in the Wulik River between the mouth of Ikalukrok Creek to a point several km downstream of the mouth of Tutak Creek.

●The Arctic grayling population in Bons Pond in 2010 was an estimated 1,767 fish $\geq$ 200 mm long. The 2010 population was similar to 2008 and 2009, but still lower than previous estimates and the peak estimate of 6,189 fish in 2004. Arctic grayling spawned in Bons Creek and in the outlet channel from Bons Pond in spring 2011. Arctic grayling fry were caught in drift nets in Bons Creek in July, 2011.

●Pre-mining slimy sculpin (*Cottus cognatus*) abundance is unknown. Baseline reports indicated that this species was numerous in the Ikalukrok Creek drainage, but uncommon in the Red Dog Creek drainage. In most years, we catch slimy sculpin in the spring in North Fork Red Dog Creek and in minnow buckets in Mainstem Red Dog Creek during the summer. In 2011, our catch per unit of effort in Mainstem Red Dog Creek was 0.5 sculpin per 10 trap days.

Introduction

The Red Dog zinc (Zn) and lead (Pb) deposit is located in northwestern Alaska, about 130 km north of Kotzebue and 75 km inland from the Chukchi Sea coast (Figure 1). Mine operations, facilities, surrounding vegetation, and wildlife are described in Weber Scannell and Ott (1998). A chronology of development and operations at the Red Dog Mine is presented in Appendix 1. Aquatic resources in the Wulik River drainage are described in Weber Scannell et al. 2000.

Aquatic biomonitoring has occurred annually since 1995 and has included periphyton, aquatic invertebrate, and fish sampling, including tissue and whole body metals analyses for Dolly Varden (*Salvelinus malma*) and spawning season monitoring for Arctic grayling (*Thymallus arcticus*). On January 8, 2010, the US Environmental Protection Agency (EPA) issued National Pollution Discharge Elimination System Permit No. AK-003865-2 (NPDES Permit) to Teck Alaska Incorporated (Teck) to allow discharge of up to 2.418 billion gallons of treated effluent per year. The NPDES Permit required a bioassessment program that included periphyton, aquatic invertebrates, and fish in selected streams near the Red Dog Mine (Table 1). The bioassessment program became fully effective and enforceable on March 31, 2010.

Table 1. Location of NPDES Sample Sites and Factors Measured.

Sample Site	Factors Measured
North Fork Red Dog Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use
Mainstem Red Dog Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use
Ikalukrok Creek	Periphyton (chlorophyll-a concentrations) Aquatic Invertebrates (taxonomic richness and abundance) Fish Presence and Use

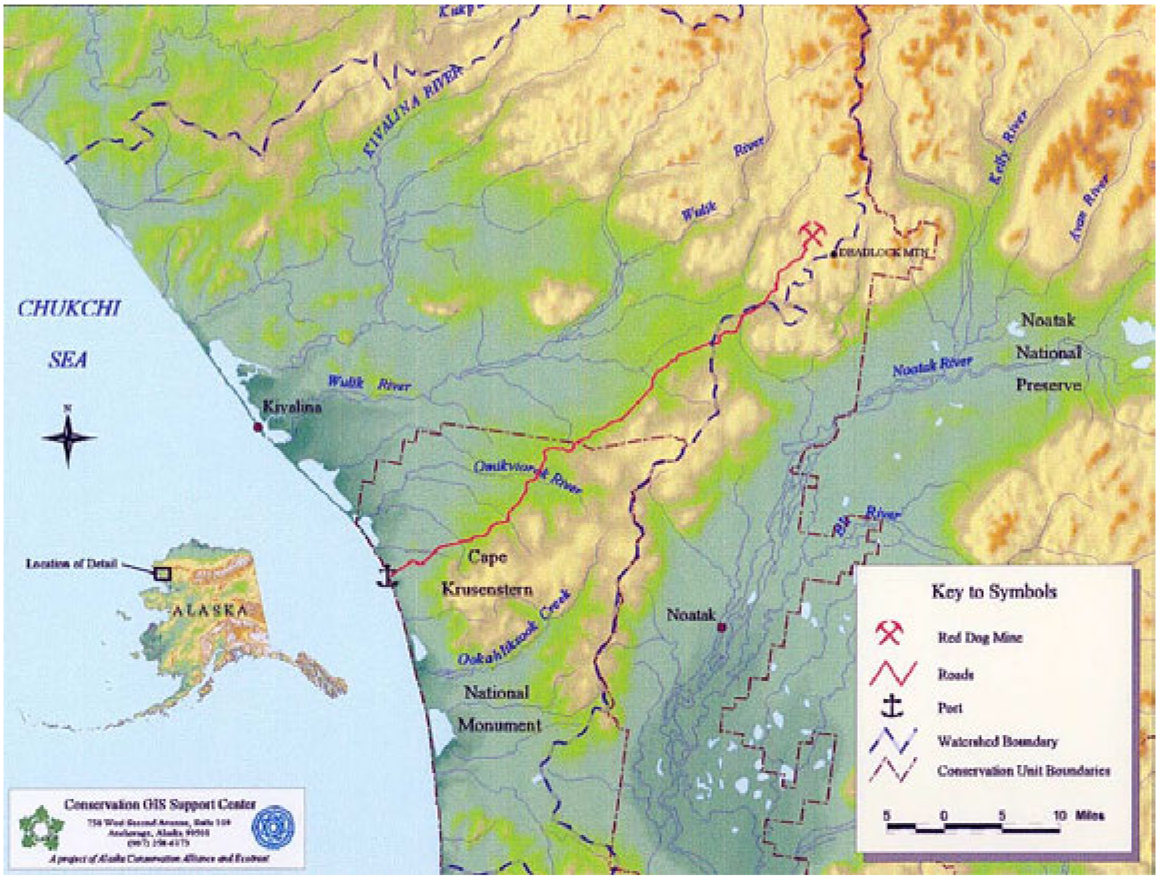

Figure 1. Location of the Red Dog Mine in northwestern Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, Alaska.

On December 2, 2009, the Alaska Department of Environmental Conservation (ADEC) issued Waste Management Permit No. 0132-BA002 for the Red Dog Mine that included a condition that Teck adhere to the requirements of the monitoring plan submitted by Teck in May 2009. The Alaska Department of Fish and Game (ADF&G) submitted Technical Report #10-04 titled "Methods for Aquatic Life Monitoring to Satisfy Requirements of 2010 NPDES Permit, Red Dog Mine Site (Revision #1)" in April 2010 to satisfy conditions in the EPA and ADEC permits. Teck's May 2009 monitoring plan includes sample sites, sampling frequency, and parameters for all aquatic sites, including those required by the NPDES Permit (Table 2).

Table 2. Location of Sample Sites and Factors Measured.

Location	NPDES/ADEC	Location Description	Sampling Frequency	Parameters
Wulik River	ADEC	Kivalina Lagoon upstream to about 10 km upstream of the mouth of Ikalukrok Creek (where the canyon starts)	1/year	Fall aerial surveys for overwintering Dolly Varden
Ikalukrok Creek	ADEC	Lower Ikalukrok Creek to mouth of Dudd Creek	1/year	Fall aerial surveys for adult chum salmon
Station 9	NPDES/ADEC	Ikalukrok Creek upstream of confluence with Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
Station 160	ADEC	Lower Ikalukrok Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
Station 20	ADEC	Middle Fork Red Dog Creek upstream on confluence wit	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Station 10	NPDES/ADEC	Mouth of Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Station 12	NPDES/ADEC	North Fork Red Dog Creek	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Record of spawning activity (Arctic grayling)
			Periodic	Capture/mark Arctic grayling
Buddy Creek	ADEC	Below falls, about 1.5 km downstream of Haul Road	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
			1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Buddy 221	ADEC	Buddy Creek, above road	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Bons 220	ADEC	Bons Creek, below pond	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Bons Above Pond	ADEC	Above pond	1/year	Periphyton (as chlorophyll-a concentrations)
			1/year	Aquatic invertebrates (monitored for taxonomic richness, abundance, and density)
Anxiety Ridge Creek	ADEC	below DMTS road	1/year	Fish presence and use
			1/year	Juvenile Dolly Varden metals in tissue (Zn, Pb, Se, Hg, and Cd)
Evaingiknuk Creek	ADEC	East of DMTS road	1/year	Fish presence and use
Bons Reservoir	ADEC	Above reservoir spillway	1/year	Juvenile Arctic grayling metals in tissue (Zn, Pb, Se, Hg, and Cd)
			1/year	Arctic grayling population estimate

Teck's monitoring plan is incorporated by reference into the Alaska Department of Natural Resources Reclamation Plan Approval (F20099958) dated December 2, 2009. On March 10, 2010, the U.S. Department of Army issued permit POA-1984-12-M45 to Teck which authorized development of the Aqqaluk Pit. Our report presents data collected during summer 2011 and where applicable, we compare these data with previous years.

Structure of Report

Water quality, periphyton standing crop, and aquatic invertebrate data are presented in the first three sections of our report. Metals concentration data for juvenile Dolly Varden and Arctic grayling collected from small streams and Bons Pond, and adult Dolly Varden collected from the Wulik River are then presented. Aerial survey estimates of overwintering Dolly Varden in the Wulik River and chum salmon (*Oncorhynchus keta*) spawners in Ikalukrok Creek are covered next. Finally, biological monitoring data for Dolly Varden juveniles, Arctic grayling, and slimy sculpin (*Cottus cognatus*) are presented.

Location of Sample Sites

Biomonitoring is conducted in streams adjacent to and downstream from the Red Dog Mine as required under the EPA NPDES Permit No. AK-003865-2 (Tables 1 and 2 and Figures 2 and 3), and by condition in the ADEC Waste Management Permit and the ADNR Reclamation Plan Approval. Monitoring sites include the Red Dog Creek drainage, Ikalukrok Creek, Bons and Buddy Creek drainage, Anxiety Ridge Creek, and Evaingiknuk Creek.

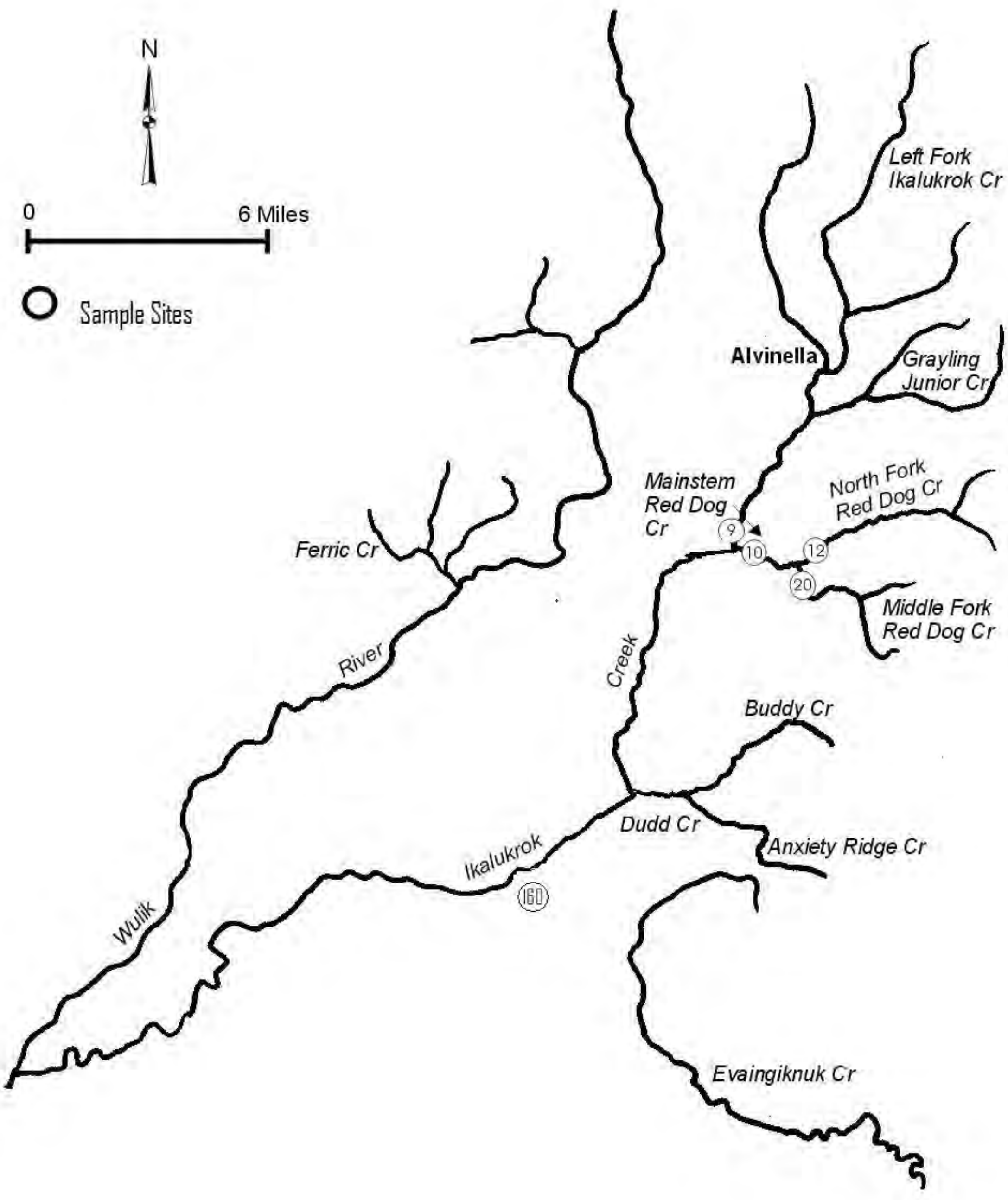

Figure 2. Location of sample sites (Station # on Figure) in the Ikalukrok Creek and Noatak River drainages.

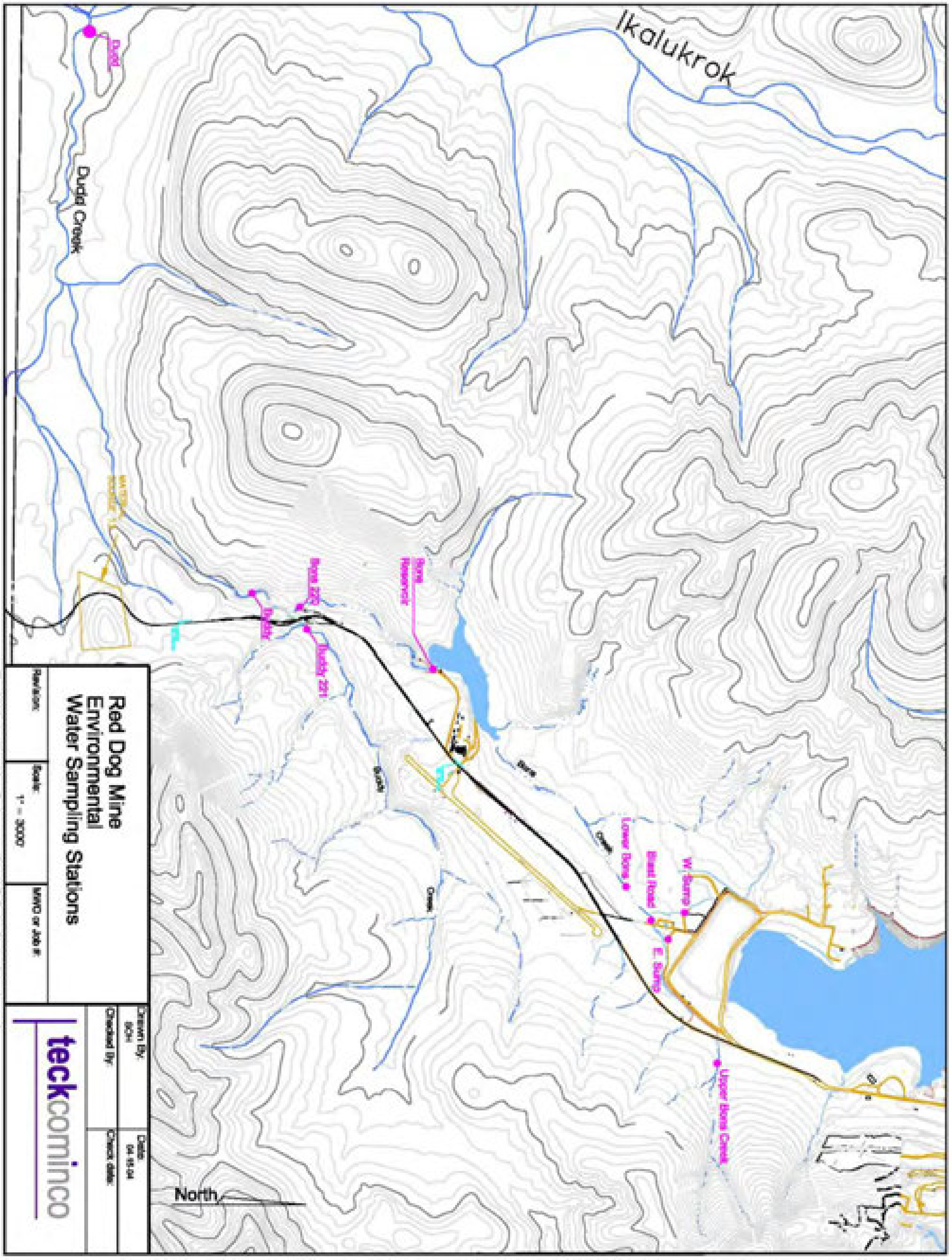

Figure 3. Bons and Buddy creeks and Bons Pond (map provided by Teck).

Description of Streams

All streams in the study area are in the Wulik River drainage, except for Evaingiknuk Creek, which is in the Noatak River drainage. Station numbers correspond either to those used by Dames and Moore (1983) during baseline work or to the current water quality program being conducted by Teck. Water quality and fish data collected during baseline studies (1979 to 1982) represent pre-mining conditions. Comparisons of existing conditions relative to baseline data should take into account that we have many years of data during mining and only a short time frame of baseline data.

Methods

All methods used for the Red Dog Mine aquatic biomonitoring study are described by ADF&G (2010) in Technical Report No. 10-04 titled "Methods for Aquatic Life Monitoring to Satisfy Requirements of 2010 NPDES Permit, Red Dog Mine Site (Revision #1)."

The method detection limit (MDL) in 2000 for copper (Cu), lead (Pb), and selenium (Se) was 50, 20, and 50 *u*g/L, respectively, for a portion of the samples early in the ice-free season. MDL's were changed part way through summer 2000 for Cu, Pb, and Se to 1, 2, and 1 *u*g/L respectively. Because of the high MDLs used in early 2000, water quality data for these samples are not presented. Water quality data presented in our report are for "total recoverable." All water quality data are provided by Teck. The number of water quality samples taken each year varies with the permit condition requirements, but for most analytes, samples are collected twice each month with a sample size of 9 to 13 per year per site. Baseline water quality pre-mining presented in the report were collected from 1979 to 1982.

The abundance of Arctic grayling was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951),

$$\hat{N}_c = \left\{ \frac{(n_1+1)(n_2+1)}{(m_2+1)} \right\} - 1,$$

where $\hat{N}_c$ = estimated population, n_1=fish marked in first capture event, n_2=fish captured during recapture event, and m_2=fish captured during recapture event that were marked in the capture event. Variance was calculated as: (Seber 1982)

$$\operatorname{var}(\hat{N}_c) = \left\{ \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \right\}.$$

95% CI for the population estimate was calculated as

$$95\% C.I. = N_c \pm (1.960)\sqrt{\hat{\operatorname{var}}(\hat{N}_c)}.$$

Radio tags (15) were implanted into adult Arctic grayling in North Fork Red Dog Creek in spring 2011. Fish were selected for transmitter implantation based on their size and condition. Generally, transmitter weight is kept between 1 and 3% of body weight. Review of Arctic grayling length:weight relationship curves suggested that fish over 350 mm fork length (fl) should exceed the necessary weight to ensure the proper fish mass to transmitter mass was achieved. However, space within the peritoneal cavity was the more restrictive metric for implanting transmitters in Arctic grayling and only fish longer than 370 mm fl were selected to receive a radio tag. Only fish appearing healthy and relatively unstressed were selected and all fish were caught with a fyke net.

Fish selected to receive a transmitter were placed in a tub containing an anesthetic solution (10% clove oil extract/90% pure ethanol) and water from the sampling site at a concentration of 20 ppm clove oil extract. Concentrations of the anesthetic were adjusted upwards as needed by adding additional clove oil solution. Fish were held in the anesthetic until they reached the desired state of anesthesia, which was evidenced by loss of equilibrium, loss of swimming response and a flaccid body. Throughout the surgical procedure either water or anesthetic solution was continually applied to moisten the gills and maintain the proper level of anesthesia. Just prior to completion of the surgical procedure, water was applied to the gills to begin recovery. Fish were removed from the anesthetic bath and placed ventral side up in a surgical trough lined with a moist towel. A 3 to 4 cm long (1.5 inch) incision was made on the ventral side of the fish into the peritoneal cavity. A transmitter was then inserted into the cavity with the antenna end facing towards the tail. The antenna was routed out of the body cavity behind the pelvic girdle by inserting a needle into the incision and orienting the guide to the desired antenna exit point. A small horse catheter was inserted through the body wall using the guide to protect internal organs from the catheter needle. The antenna was threaded through the catheter and out of the body. The catheter and needle guide were removed and the incision closed with 2 or 3 sutures. The incision area was dabbed with sterile gauze and surgical glue was applied to the incision area to provide a closed incision to aid in initial healing of the wound. Fish were then placed in a recovery tub filled with fresh water from North Fork Red Dog Creek. Once equilibrium had been regained, fish were released in the vicinity of the capture site. Total time for the surgical procedure is about 3 minutes per fish. Time required to get the fish anesthesized and for recovery after surgery varies among individual fish, but total time usually is somewhere from 10 to 12 minutes.

Results and Discussion

Water Quality

We will focus on several key sites including Mainstem Red Dog Creek. Water quality data collected in Mainstem Red Dog Creek prior to 2010 are from Station 10, located near the mouth of the creek (Figure 4). Data in 2010 and 2011 were collected at Station 151 located about 2 km upstream from Station 10, but below the mixing zone in Mainstem Red Dog Creek. There are no defined drainages entering Mainstem Red Dog Creek between these two water quality stations. Station 151 replaced Station 10 effective in spring 2010. Mainstem Red Dog Creek is directly affected by the mine wastewater effluent and by water from the clean water bypass. North Fork Red Dog Creek is a reference site with no direct effects from the mine.

Figure 4. Mainstem Red Dog Creek at Station 10 in July 2005.

Teck continued to maintain the mine's clean water bypass system which picks up non-mining impacted water from Sulfur, Shelly, Connie, Rachael, and Middle Fork Red Dog creeks. This water is moved through the active mine area, including Aqqaluk, to its original channel via a combination of culverts and lined open ditch. Pb and Zn concentrations at Station 151/10, downstream of the clean water bypass system, indicate that both of these elements are lower now than pre-mining, with the exception of several maximum Pb concentrations in some years. Median Pb and Zn concentrations remain consistently lower than pre-mining (Figures 5 and 6).

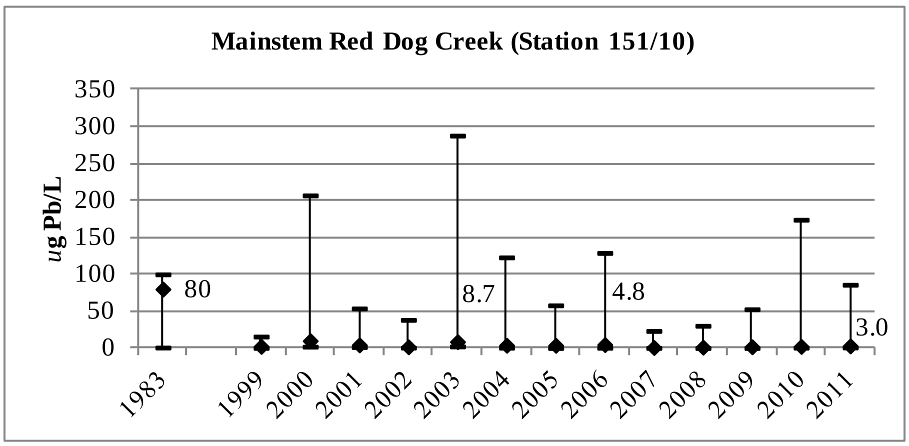

Figure 5. Median, maximum, and minimum Pb concentrations at Station 151/10 (selected median values shown).

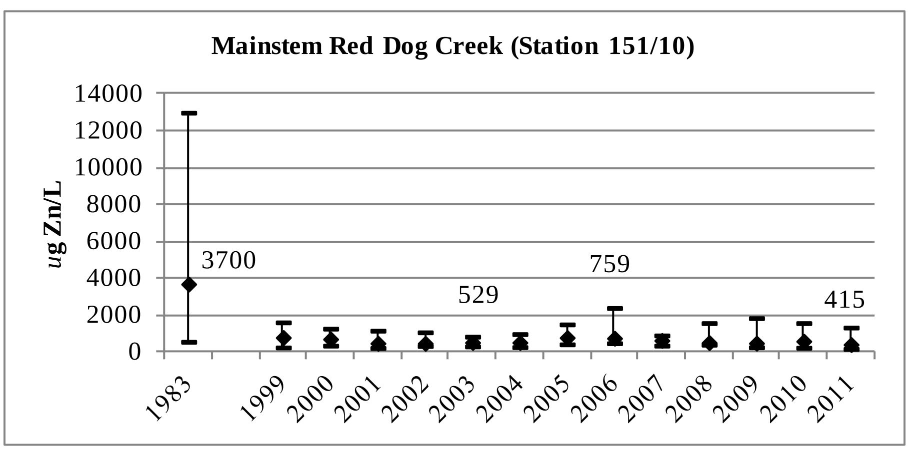

Figure 6. Median, maximum, and minimum Zn concentrations at Station 151/10 (selected median values shown).

We continue to evaluate water quality data collected in Mainstem Red Dog Creek as part of the ongoing aquatic biomonitoring program. Median Al concentrations at Station 10/151 continue to be lower than pre-mining (Figure 7) and there is a decreasing trend over time for Al concentrations (Figure 7). Cd concentrations also are lower than pre-mining conditions (Figure 8). The median Cd concentration in 1983 was 28 *u*g/L and in summer 2011 it was 3.0 *u*g/L (Figure 8). Maximum Cd concentrations from 1999 to 2011 are slightly more than the median concentration in 1983 and in most years (10 out of 13) the maximum Cd concentration is below the 1983 median.

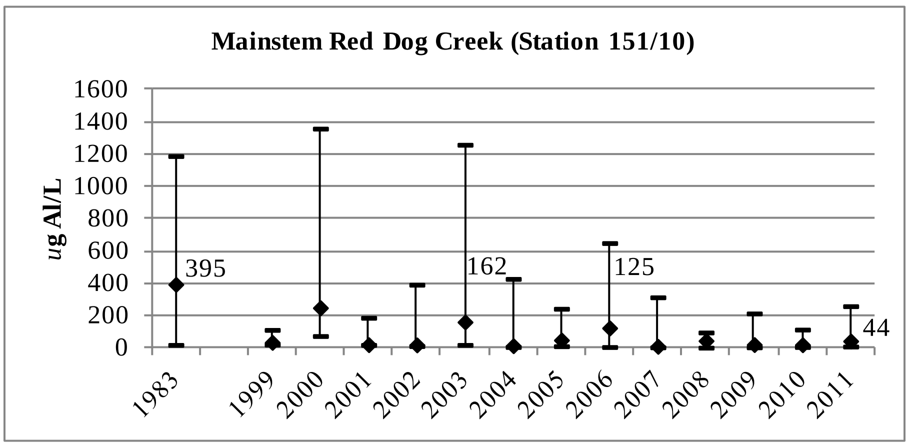

Figure 7. Median, maximum, and minimum Al concentrations at Station 151/10 (selected median values shown).

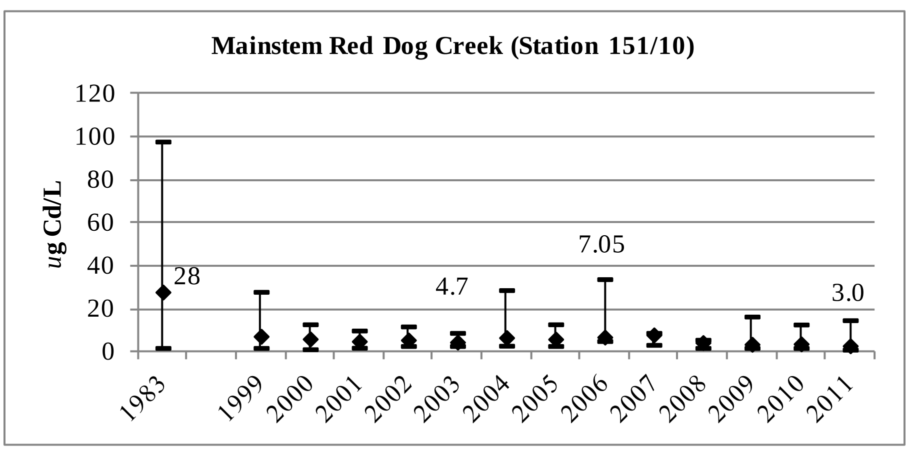

Figure 8. Median, maximum, and minimum Cd concentrations at Station 151/10 (selected median values shown).

Pre-mining data for Se are not available. Se concentrations in Mainstem Red Dog Creek have remained similar from 2001 to 2007, but have been higher in recent years (2008 to 2011) (Figure 9). The highest median Se concentration was 2.8 *u*g/L in 2011.

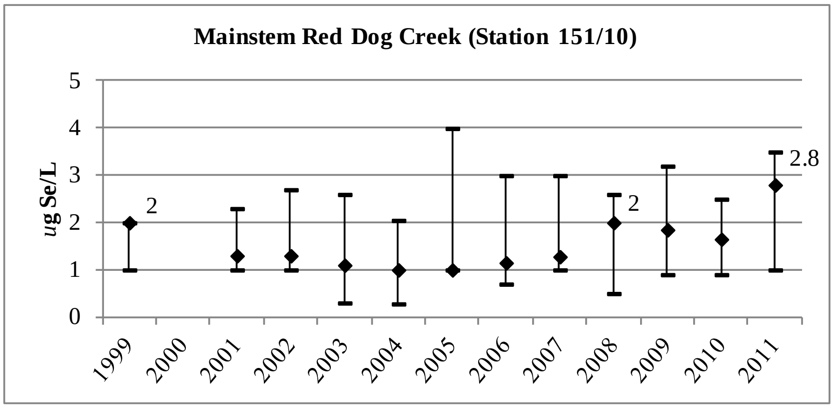

Figure 9. Median, maximum, and minimum Se concentrations at Station 151/10 (selected median values shown).

Pre-mining data for Ni are not available. Ni concentrations at Station 151/10 have risen since 2005 (Figure 10). Higher median Ni concentrations were observed first in 2006 (19.1 *u*g/L). The primary source of Ni to the clean water bypass system in previous years has been Rachael Creek (Ott and Morris 2010).

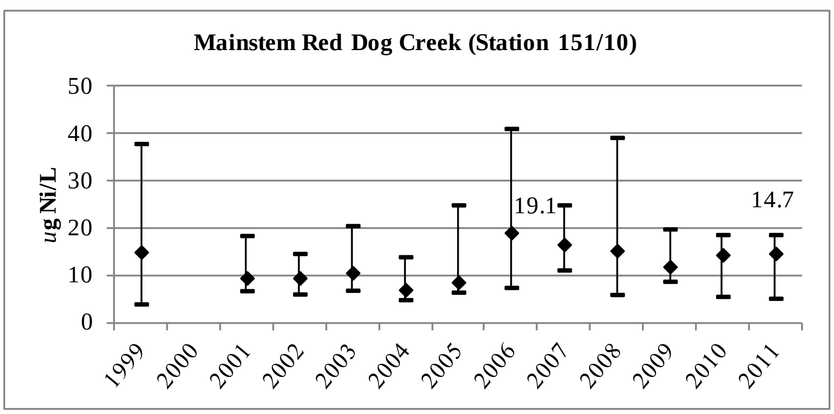

Figure 10. Median, maximum, and minimum Ni concentrations at Station 151/10 (selected median values shown).

The pH at Station 151/10 is higher than pre-mining (Figure 11). The pH is slightly more basic and has only dropped below 6 once in 2011. The 1990 data set is during mining, but prior to construction of the clean water bypass system. The clean water bypass system was built prior to spring breakup in 1991.

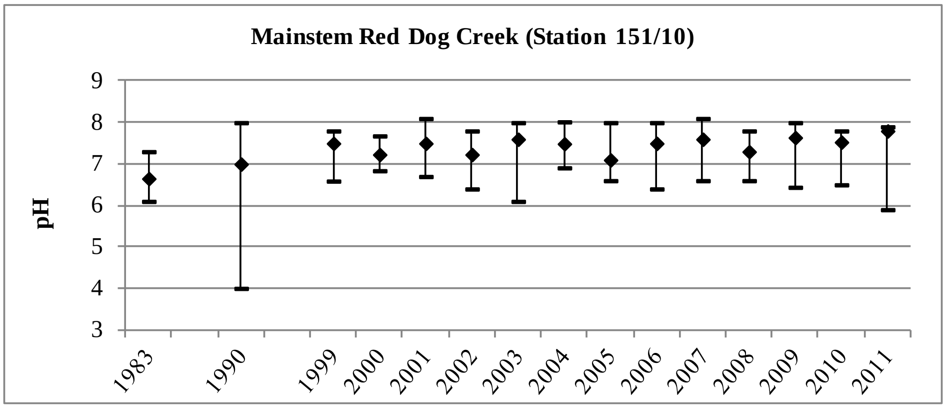

Figure 11. Median, maximum, and minimum pH values at Station 151/10.

Total dissolved solids (TDS) in Mainstem Red Dog Creek are higher than pre-mining (Figure 12). TDS is directly related to high concentrations in the treated wastewater discharge at Outfall 001. $Ca(OH)_2$ is added to precipitate and collect metals from the tailing water as metal hydroxides prior to discharge. Sulfates released in this process along with the Ca result in the elevated TDS concentrations. TDS concentrations in Mainstem Red Dog Creek in summer 2011 never exceeded 1,500 mg/L standard applied at Station 151.

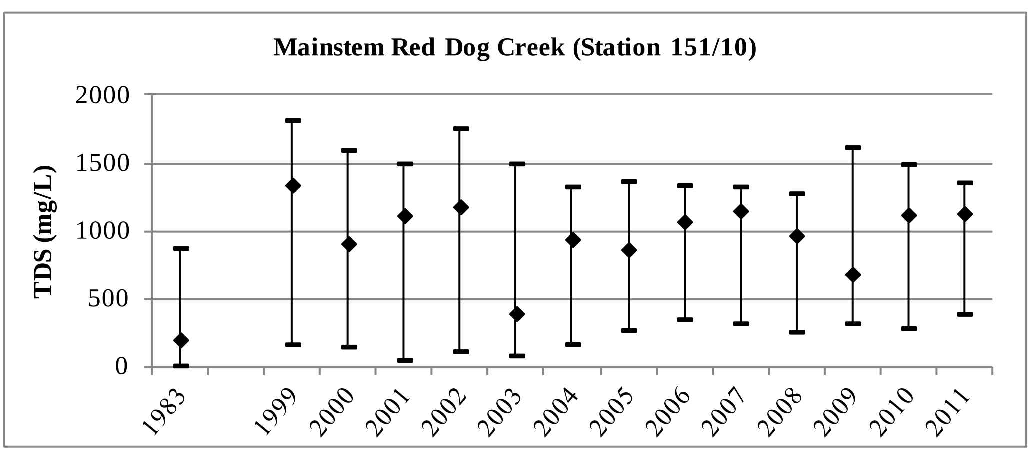

Figure 12. Median, maximum, and minimum TDS concentrations at Station 151/10.

We compare Cd, Pb, Se, and Zn concentrations in Mainstem Red Dog Creek (Station 151/10) with those found in North Fork Red Dog Creek (Station 12) and in Buddy Creek (below the confluence of Bons and Buddy creeks). The sites in North Fork Red Dog and Buddy creeks were selected because they are reference sites with no direct effects from the mine process or discharge. Mainstem Red Dog Creek is directly downstream of the mine clean water bypass and wastewater effluent discharge at Outfall 001. Buddy Creek also is a reference site, but with the potential to be affected by the road, airport, waste rock dump, Bons Pond, and is down gradient from the backdam on the south end of the tailing pond. Cd, Pb, Se, and Zn were selected for comparison because they are analyzed for whole body concentrations in juvenile Arctic grayling and Dolly Varden.

Cd, Pb, and Zn median concentrations are highest in Mainstem Red Dog Creek (Figures 13, 14, and 15). In the two reference sites, Cd and Zn concentrations are stable over the sampling period from 2000 to 2011. Pb concentrations demonstrate more variability, but still are consistently lower in North Fork Red Dog and Buddy creeks. Since 2007, median Cd and Zn concentrations in Mainstem Red Dog Creek have exhibited a decrease while Pb has increased.

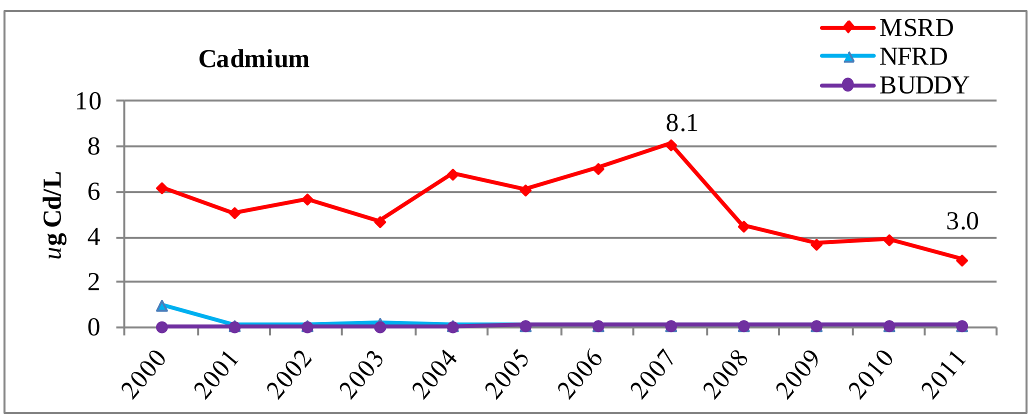

Figure 13. Median Cd concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2011).

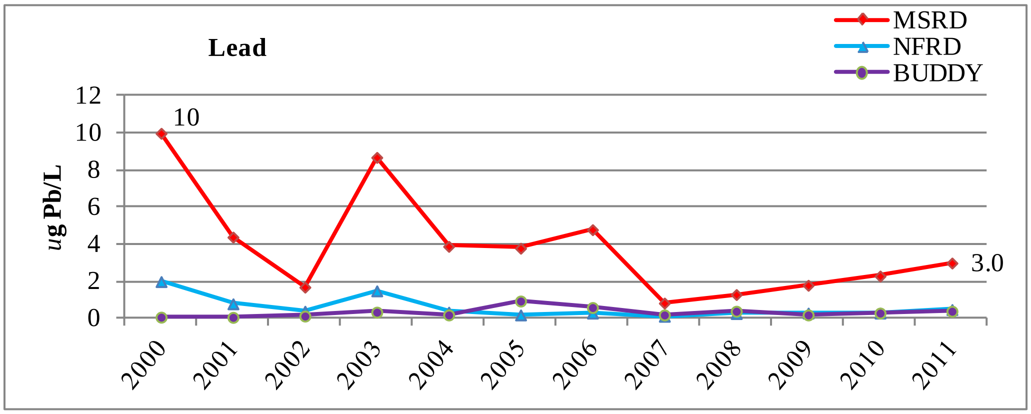

Figure 14. Median Pb concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2011).

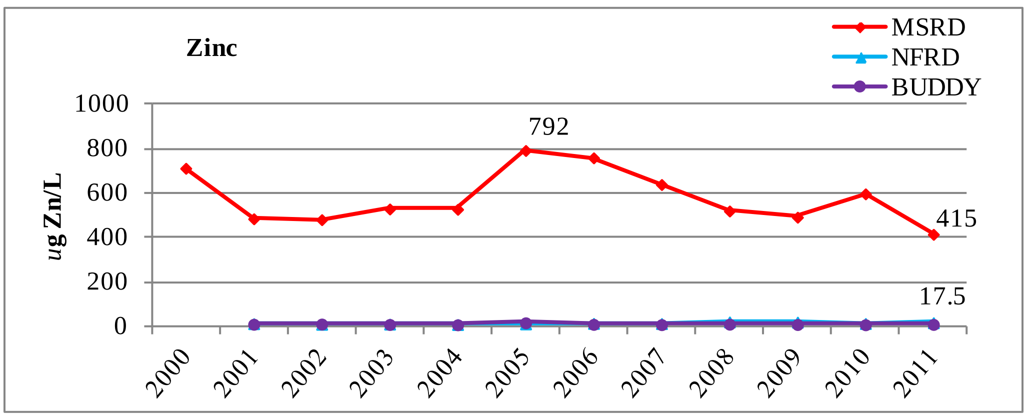

Figure 15. Median Zn concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2011).

Median Se concentrations in Mainstem Red Dog Creek are lower than in Buddy Creek but the same or slightly higher than in North Fork Red Dog Creek (Figure 16). The differences among these sites are not great as most median Se concentrations range from 1 *u*g/L (the detection limit) to 2.5 *u*g/L.

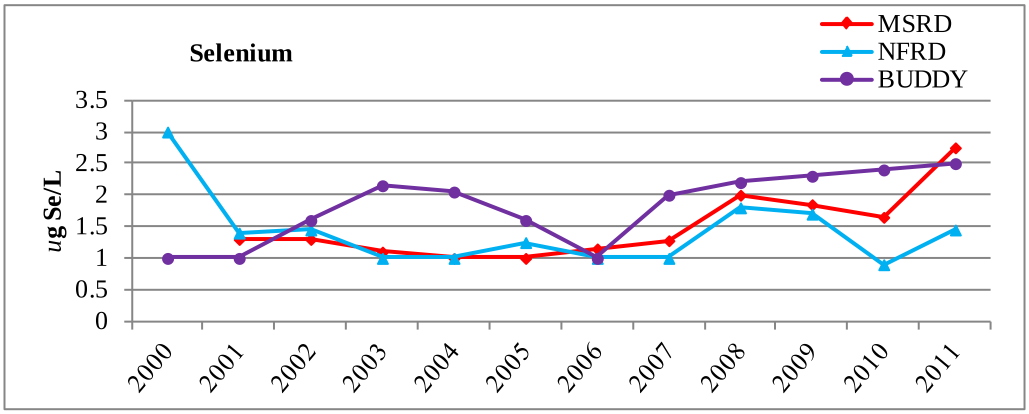

Figure 16. Median Se concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy Creeks (2000 to 2011).

Periphyton Standing Crop

Algal biomass samples, periphyton or attached microalgae are collected each year (2011 data, Appendix 2). Under the new program initiated in 2010, sampling occurred at nine sites (Table 2). Periphyton samples are processed in the laboratory and standing crop determined as mg/m^2 chlorophyll-a. Chlorophyll-a concentrations in 2011 were highest in Bons Creek (14.8 mg/m^2) below Bons Pond, and lowest in Middle Fork Red Dog Creek (0.5 mg/m^2) (Figure 17). Periphyton standing crops are higher in the Buddy and Bons Creek and North Fork Red Dog Creek drainages as compared to typical concentrations in Ikalukrok and Mainstem Red Dog creeks, consistent with the pattern observed in previous years. However, in 2011, chlorophyll-a concentrations also were high at reference Station 9 in Ikalukrok Creek (upstream of Red Dog Creek).

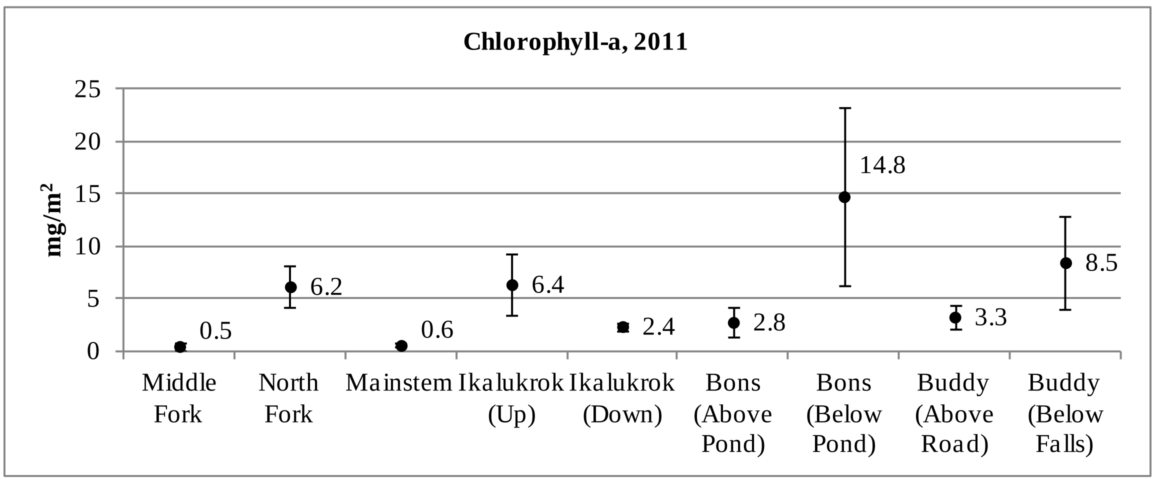

Figure 17. Average concentration of chlorophyll-a (plus and minus one SD).

Average chlorophyll-a concentrations in Mainstem Red Dog Creek from 2004 through 2011 varied from a low of 0.3 in 2007 to a high of 10.1 mg/m^2 in 2004 (Figure 18). In 2011, the average chlorophyll-a concentration was 0.6 mg/m^2. In North Fork Red Dog and Buddy creeks, the average chlorophyll-a concentration in 2011 was 6.2 and 8.5 mg/m^2 (Figures 19 and 20). Generally, periphyton standing crop is highest in Buddy Creek. Chlorophyll-a concentrations are similar in North Fork Red Dog and Mainstem Red Dog creeks with the exception of 2004, 2007, and 2011. Periphyton standing crop was much higher in North Fork than in Mainstem Red Dog Creek in 2007 and 2011.

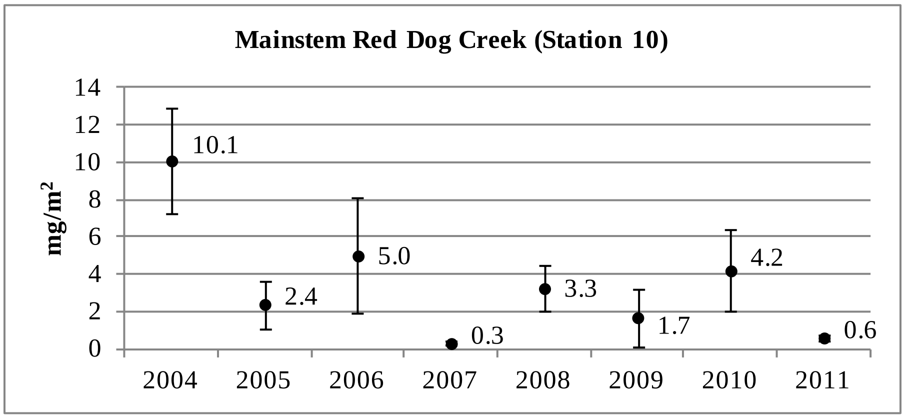

Figure 18. Average concentration of chlorophyll-a (plus and minus one SD).

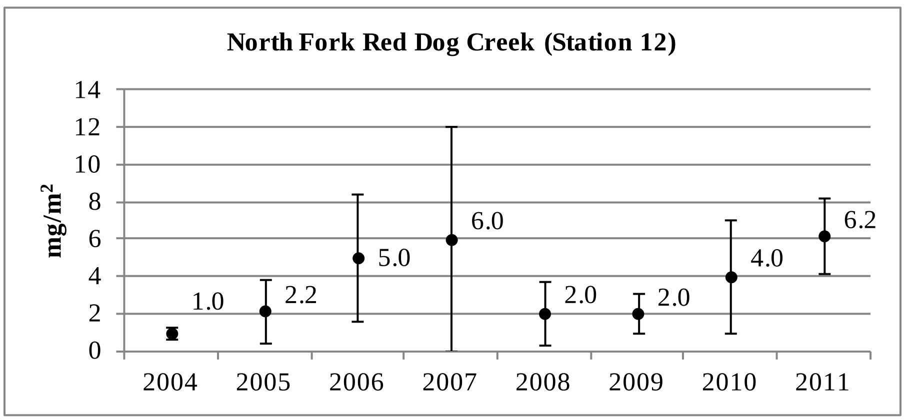

Figure 19. Average concentration of chlorophyll-a (plus and minus one SD)

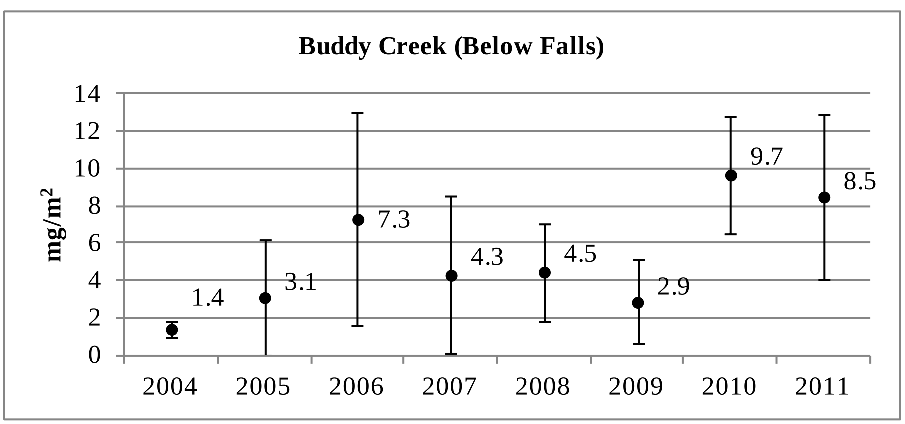

Figure 20. Average concentration of chlorophyll-a (plus and minus one SD).

Periphyton standing crop tracks closely with elevated Zn and Cd in Ikalukrok Creek at Station 9 which is just upstream of the mouth of Mainstem Red Dog Creek. Water quality at this site is not affected by water from the Red Dog Mine facility, but is affected by natural mineral seeps located upstream and along Ikalukrok Creek (Ott and Morris, 2007). Chlorophyll-a concentrations are higher when the Zn and Cd concentrations are lower (Figures 21 and 22). One of the major sources of Zn and Cd to Ikalukrok Creek is the Cub Creek seep (Figure 23).

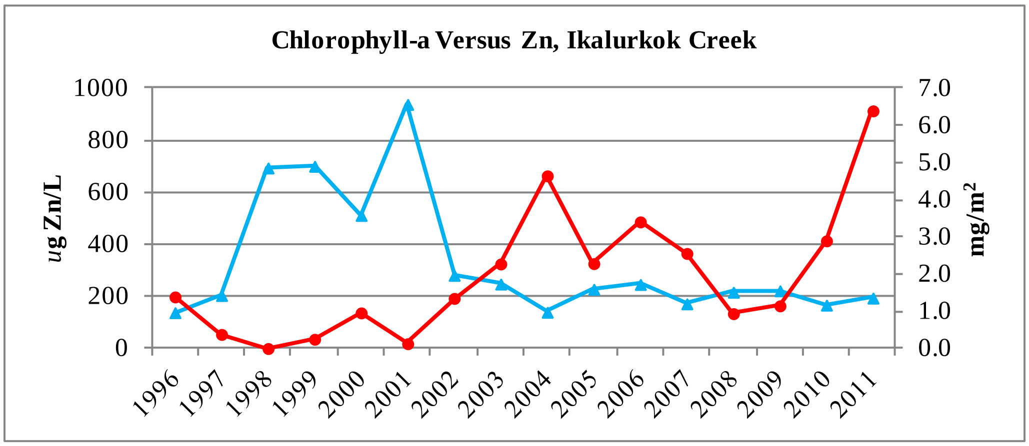

Figure 21. Chlorophyll-a concentrations versus Zn in Ikalukrok Creek (red line is chlorophyll and blue line is metal).

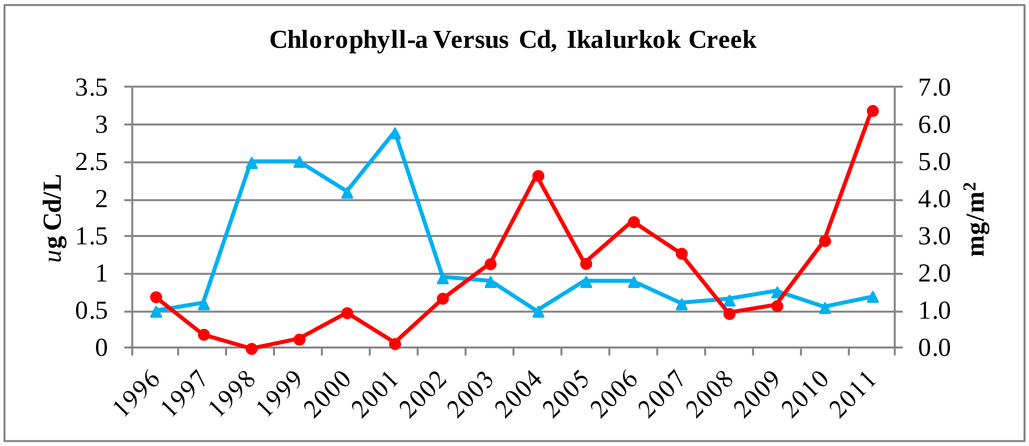

Figure 22. Chlorophyll-a concentrations versus Cd in Ikalukrok Creek (red line is chlorophyll and blue line is metal).

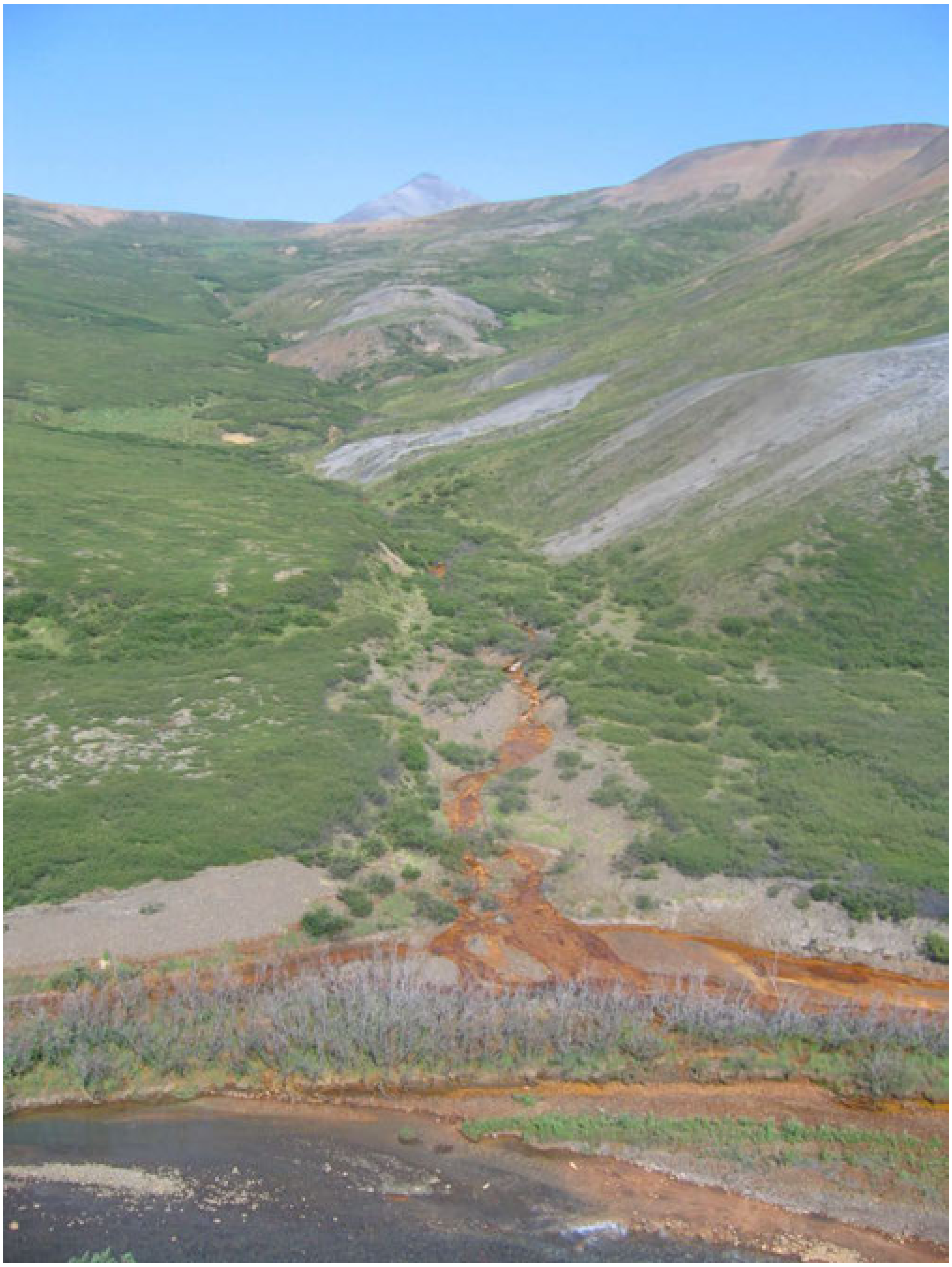

Figure 23. Ikalukrok Creek at the Cub Creek seep about 10 km upstream of the mouth of Mainstem Red Dog Creek – note iron staining in and along the edge of Cub Creek with noticeable effects to Ikalukrok Creek.

Aquatic Invertebrates

Aquatic invertebrate samples are collected annually using drift nets (Appendix 3). In 2011, all nine sites were sampled in mid-July (July 14 to 16). This was about 10 days later than the usual sample period. Flows were moderate without any rainfall events of any magnitude during the sampling effort.

In 2011, the density of aquatic invertebrates was highest (20.1/m^3) in Buddy Creek below the falls and was lowest (3.0/m^3) in Middle Fork Red Dog Creek (Figure 24) (Appendix 3). These data continue to follow the same general pattern with higher densities occurring in the Bons and Buddy Creek drainages and in North Fork Red Dog Creek. Densities are lower in Middle Fork Red Dog, Mainstem Red Dog, and Ikalukrok creeks. Of interest was a large catch of ostracods in Buddy Creek below the falls – average number per drift net was 509 (SD = 119). The ostracods in Buddy Creek are part of the invertebrate drift from Bons Pond.

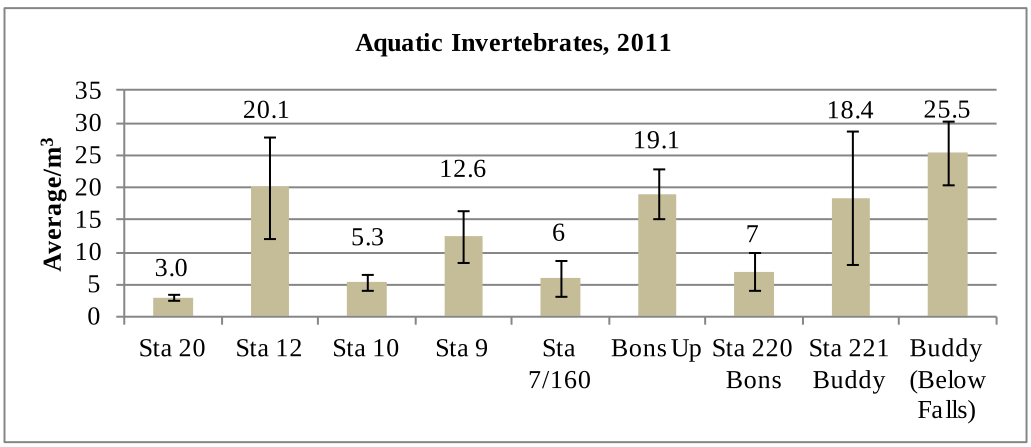

Figure 24. Aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

The average aquatic invertebrate densities vary among the sample years. Densities in North Fork Red Dog Creek generally are higher than in Mainstem Red Dog Creek (Figures 25 and 26). In most years, the highest densities are found in Buddy Creek below the falls (Figure 27). There appears to be an increase in aquatic invertebrate densities since 2005 in North Fork Red Dog Creek and, though less consistently, in Mainstem Red Dog Creek.

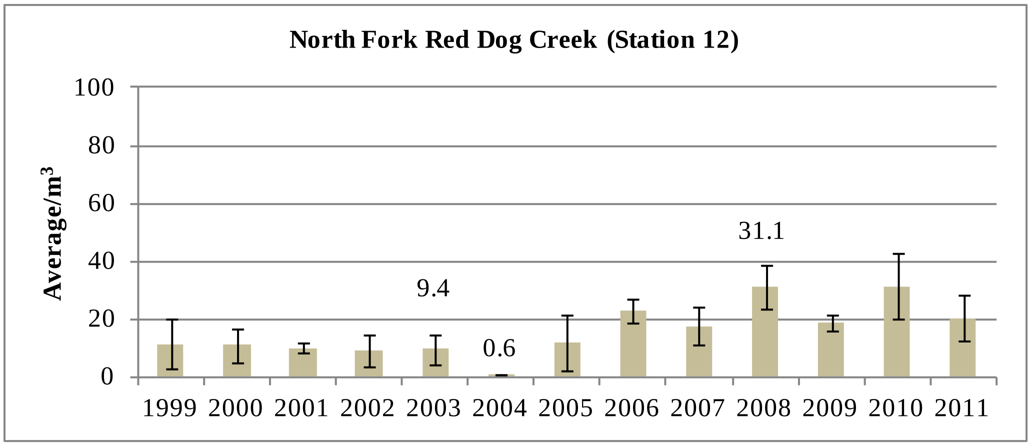

Figure 25. North Fork Red Dog Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

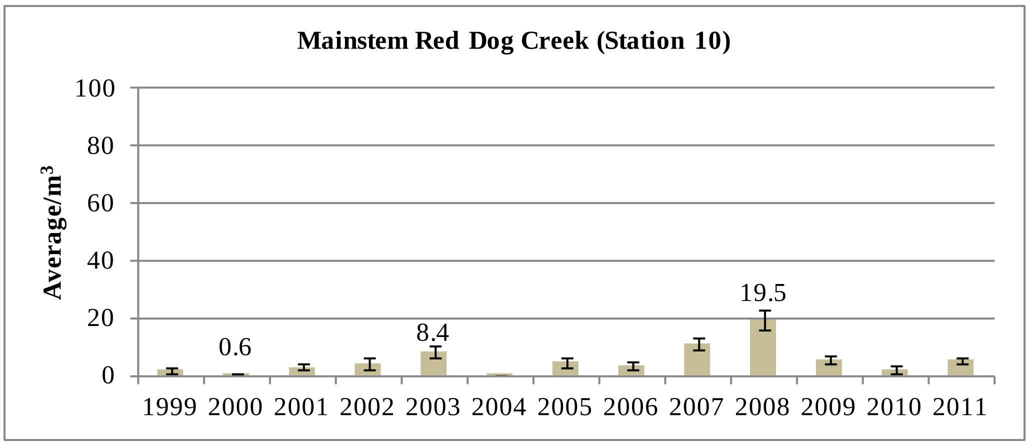

Figure 26. Mainstem Red Dog Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

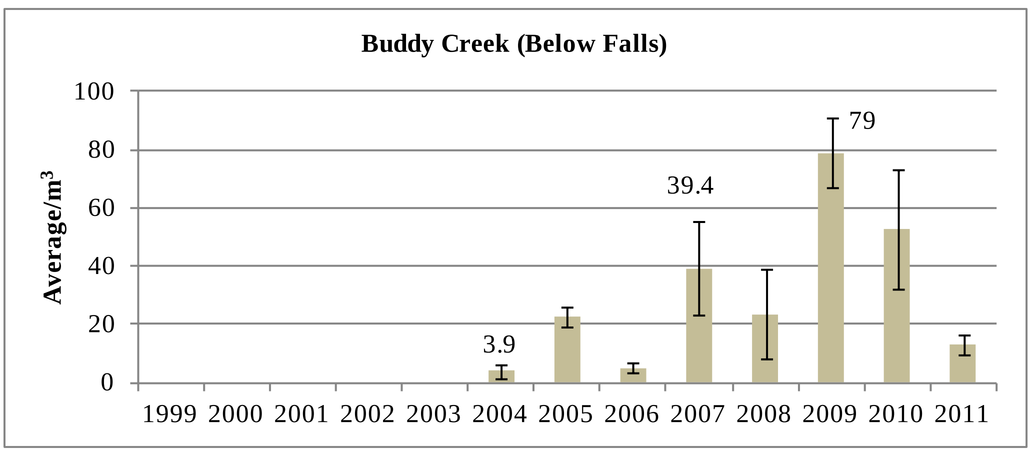

Figure 27. Buddy Creek aquatic invertebrate densities (average plus and minus one SD). Selected average values shown.

The percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) and the percent Chironomidae for all sample sites in 2011 are presented in Figure 28. All sites, except for Buddy Creek above the road, were dominated by Chironomidae in 2011. Trichoptera are not common in our samples and are not a substantial contributor to EPT. Although some Trichoptera were present in 2011, the percent of EPT was zero. The aquatic systems in the Red Dog Mine area are dominated by Chironomidae which is one of the primary food items of the fish species using these creeks.

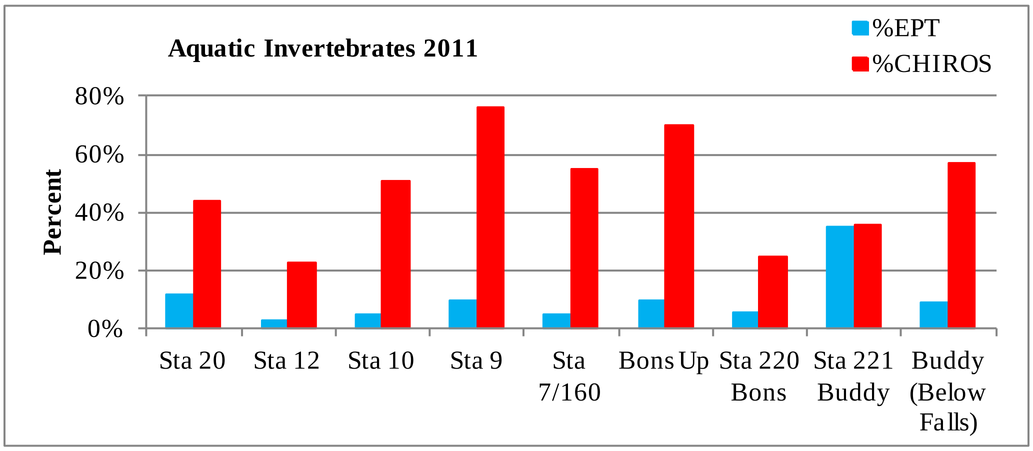

Figure 28. Percent Chironomidae and EPT in the aquatic invertebrate sample sites in July 2011.

Since 2004, there is a trend for a decrease in the percent EPT in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks (Figure 29). The trend exists at each of these sample sites so it reflects an area wide shift in the aquatic invertebrate community. Both North Fork Red Dog and Buddy creeks are considered reference sites whereas Mainstem Red Dog Creek at Station 10 is directly affected by waters from the clean water bypass system and the treated wastewater discharge.

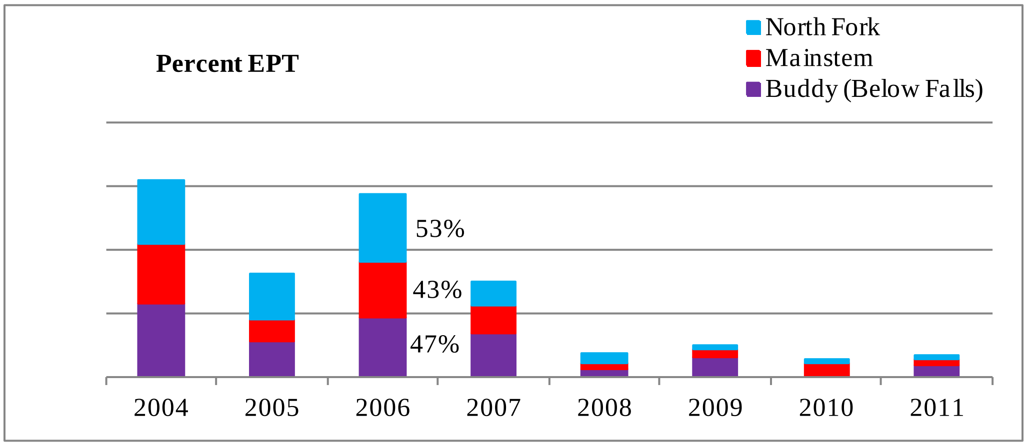

Figure 29. Percent EPT from 2004 to 2011. Values shown for 2006.

The percent Chironomidae in the aquatic invertebrate samples was higher from 2007 to 2011 than in the previous three years of sampling (Figure 30).

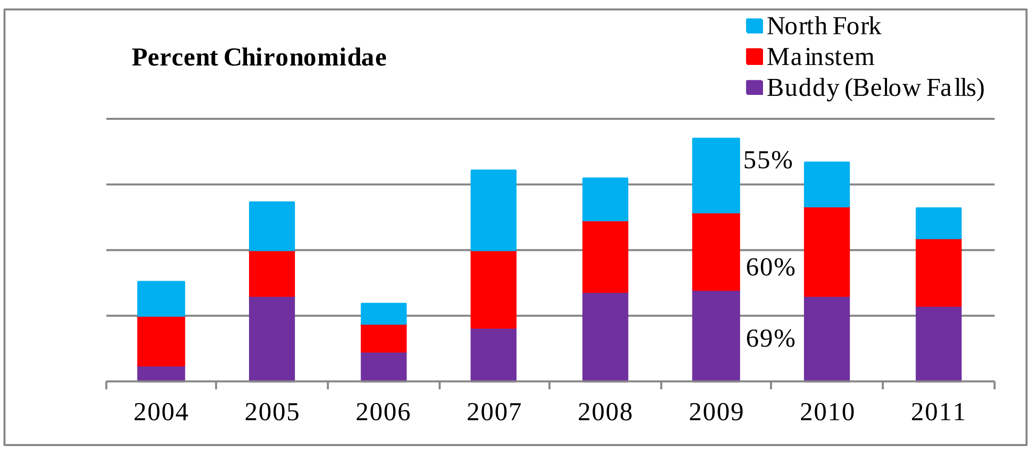

Figure 30. Percent Chironomidae from 2004 to 2011. Values shown for 2009.

We looked at the density of EPT in Mainstem Red Dog, North Fork Red Dog, and Buddy creeks (below falls) to determine if there has been an actual decrease in the numbers of EPT (Figure 31). Densities of EPT generally are higher in North Fork Red Dog Creek than in Mainstem Red Dog Creek and they are highly variable in Buddy Creek (below falls). The highest densities observed in North Fork Red Dog, Mainstem Red Dog, and

Buddy creeks were 2.45, 0.48, and 2.39/m^3, respectively. We conclude that there is no downward trend in EPT densities, but rather an increase in Chironomidae densities.

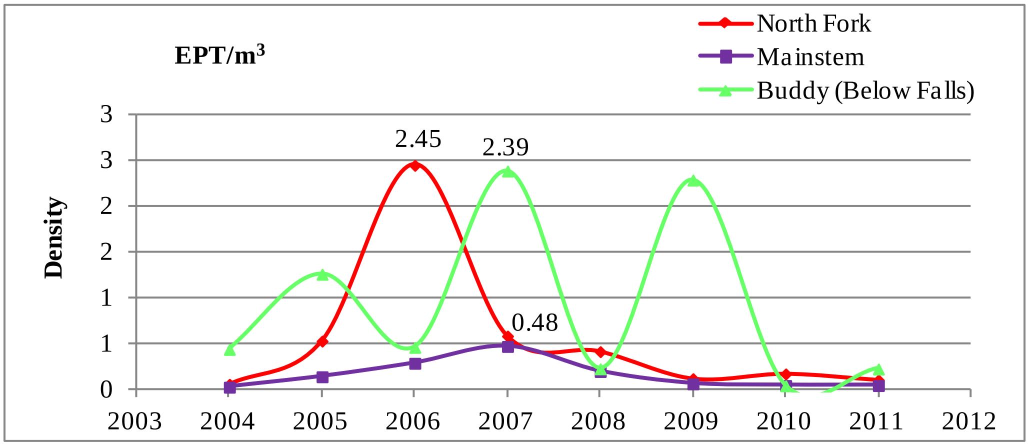

Figure 31. EPT/m3 in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks from 2004 to 2011 (selected peak densities for each sample site are shown).

We compared taxa richness for the three sites in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks (Figure 32). Taxa richness was highest in 2011 and was the lowest in 2010. Overall taxa richness is similar in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks.

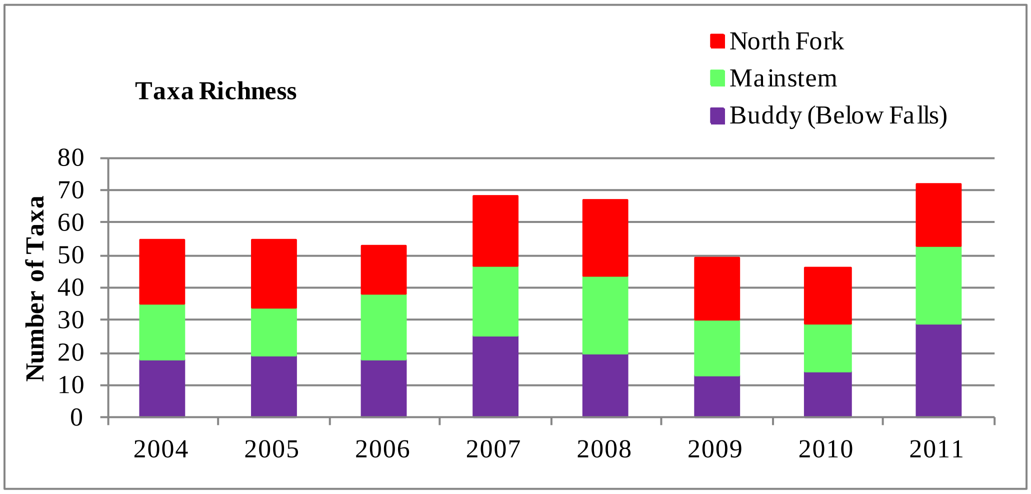

Figure 32. Aquatic invertebrate taxa richness in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks.

Metals Concentrations in Juvenile Dolly Varden and Arctic Grayling

We sample juvenile Dolly Varden and Arctic grayling to determine whole body concentrations of selected metals. The purpose of this effort is: (1) to determine if differences exist in metals concentrations in fish among the sample sites that can be linked with background water quality; and (2) to track change over time. Juvenile Dolly Varden were selected as the target species because of their wide distribution in the Red Dog area streams, their presence in Mainstem Red Dog Creek, their residence in freshwater for two to four years before smolting, and their rearing in the sample sites only during the ice-free season. Juvenile Arctic grayling were added after we successfully established a self-sustaining population in Bons Pond. Arctic grayling captured in Bons Pond have been in the pond upstream of the freshwater dam their entire life and therefore serve as a good indicator of year round water quality conditions and change over time.

Ott and Morris (2004) found no relationship between fish length and whole body concentrations of selected metals for pre-smolt sized Dolly Varden. To minimize age-related variability, we targeted juvenile Dolly Varden from 90 to 140 mm (likely 2 and 3 year old fish), and collected all samples in August after fish have been there for, presumable six to 10 weeks. Fish larger than 140 mm were excluded because they could be resident fish and may be much older than the fish from 90 to 140 mm long. Fish < 90 mm long were not kept, because the laboratory prefers a sample quantity of at least 5 g.

In prior years, we selected juvenile Arctic grayling that were between 140 and 220 mm long to minimize age variability. In 2010, we refined the sample effort to include only fish between 150 and 200 mm long. Our preferred sample size for Dolly Varden and Arctic grayling is 15 each year, recognizing that in some years we do not achieve this goal. Whole body metal concentrations (Cd, Pb, Se, Zn, and Hg) for Dolly Varden collected in 2011 are presented in Appendix 4. Fifteen juvenile Dolly Varden were retained from Anxiety Ridge and Buddy creeks and 12 from Mainstem Red Dog Creek. Adequate numbers of Arctic grayling in the selected size range were not caught in spring 2011 in Bons Creek.

Whole body Cd concentrations (median value) were consistently higher in fish collected from Mainstem Red Dog Creek and consistently lowest in Anxiety Ridge Creek (Figure 33). No trends of increasing or decreasing Cd concentrations have been observed from 2005 to 2011 other than a period of decrease from 2006 to 2009 for Mainstem Red Dog Creek. Cd concentrations in water samples from Mainstem Red Dog Creek reflect in part this decrease (Figure 34). The water quality data and the whole body concentrations of Cd in juvenile Dolly Varden, with some exceptions, track with each other.

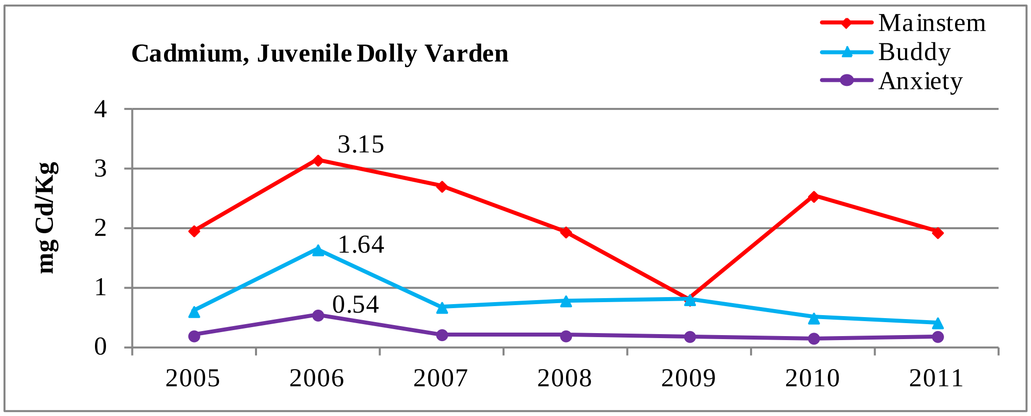

Figure 33. Median Cd whole body concentrations in juvenile Dolly Varden from 2005 to 2010.

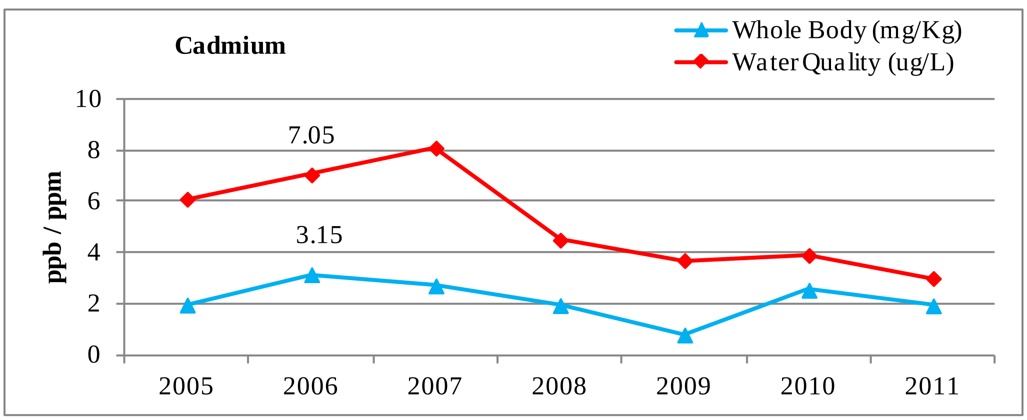

Figure 34. Median Cd concentrations in whole body juvenile Dolly Varden (parts per million) and in the water (parts per billion) from Mainstem Red Dog Creek.

Whole body Pb concentrations (median value) were highest each year in Mainstem Red Dog Creek (Figure 35). Pb concentrations from 2005 to 2011 in Buddy and Anxiety Ridge creeks were consistently low and show no trend. Pb concentrations in juvenile Dolly Varden in Mainstem Red Dog Creek were highest in 2010 and 2011. Pb concentrations in the water in Mainstem Red Dog Creek have increased from 2007 to 2011, but there does not appear to be direct relationship between whole body Pb in fish and the concentrations in water (Figure 36).

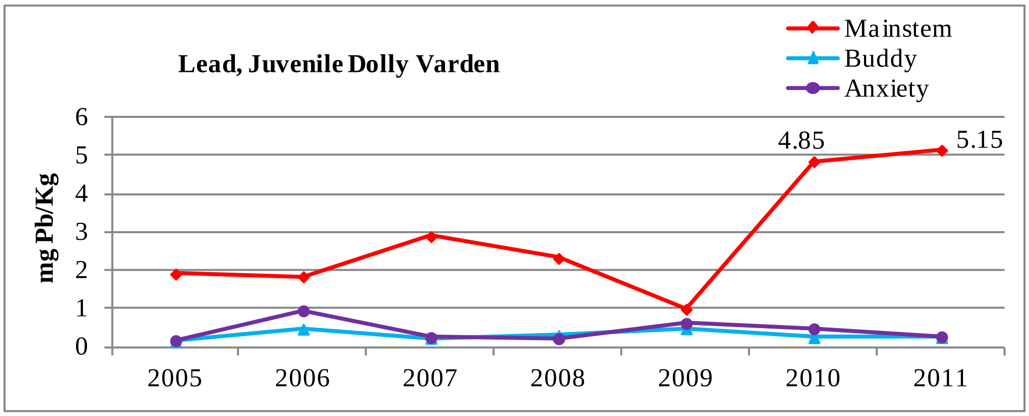

Figure 35. Median Pb whole body concentrations in juvenile Dolly Varden from 2005 to 2010.

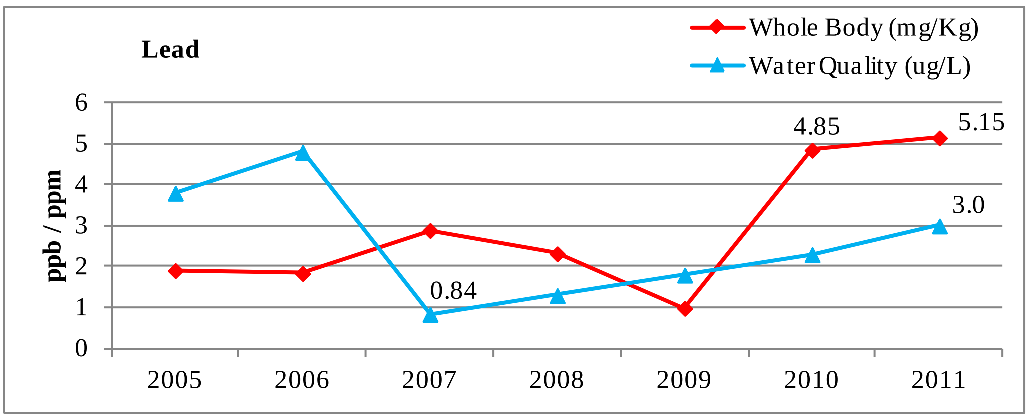

Figure 36. Median Pb concentrations in whole body juvenile Dolly Varden (parts per million) and in the water (parts per billion) from Mainstem Red Dog Creek.

Se concentrations in Buddy Creek are higher than in Anxiety Ridge Creek (Figure 37). Se concentrations in Mainstem Red Dog Creek are sometimes higher than Buddy and Anxiety Ridge creeks, but in 2009 they were lower. Major differences in Se do not exist among these three sample sites. There does not appear to be any correlation between Se concentrations in the water and in juvenile Dolly Varden (Figure 38). The highest median Se concentration in the fish was in 2005 (8.8 mg/Kg) when the Se concentrations in water were at the detection limit of 1 *u*g/L.

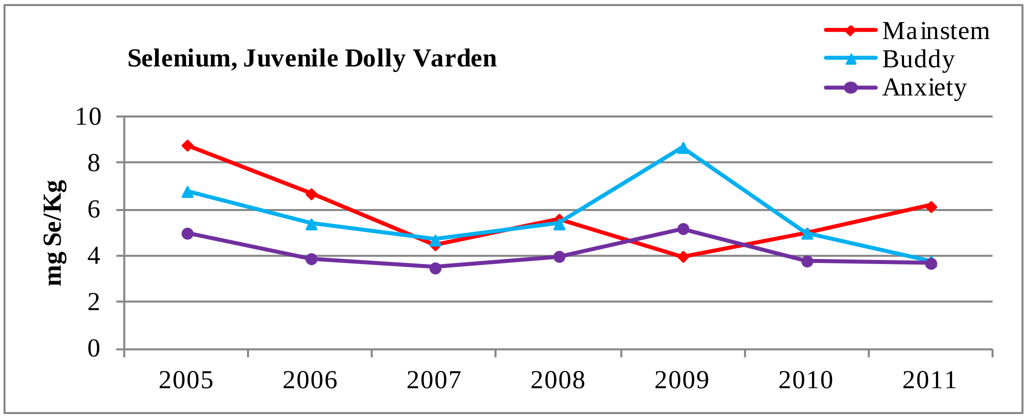

Figure 37. Median Se whole body concentrations in juvenile Dolly Varden from 2005 to 2010.

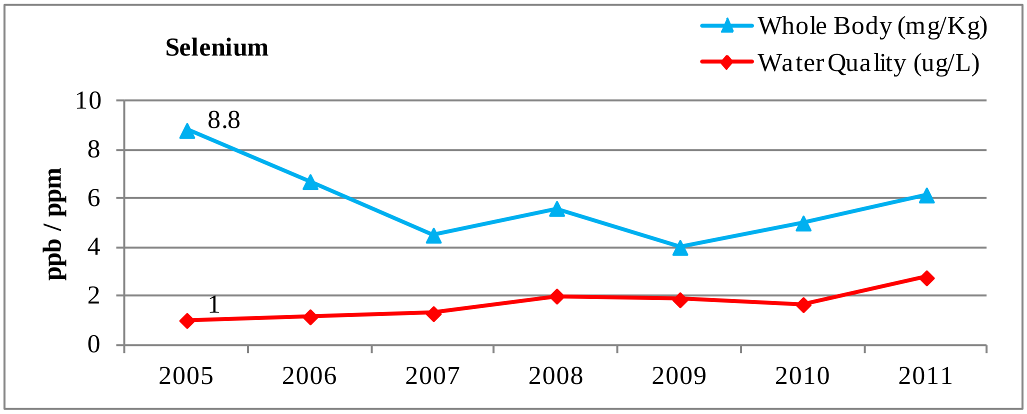

Figure 38. Median Se concentrations in whole body juvenile Dolly Varden (parts per million) and in the water (parts per billion) from Mainstem Red Dog Creek.

Zn whole body concentrations (median value) are highest in Mainstem Red Dog Creek (Figure 39). Concentrations of Zn generally are higher in Buddy Creek than in Anxiety Ridge Creek. There is no apparent trend with time for Zn except for a decreasing trend for Dolly Varden caught in Mainstem Red Dog Creek. The median Zn concentrations in Mainstem Red Dog Creek generally have decreased and median whole body Zn concentrations since 2007 have also decreased (Figure 40).

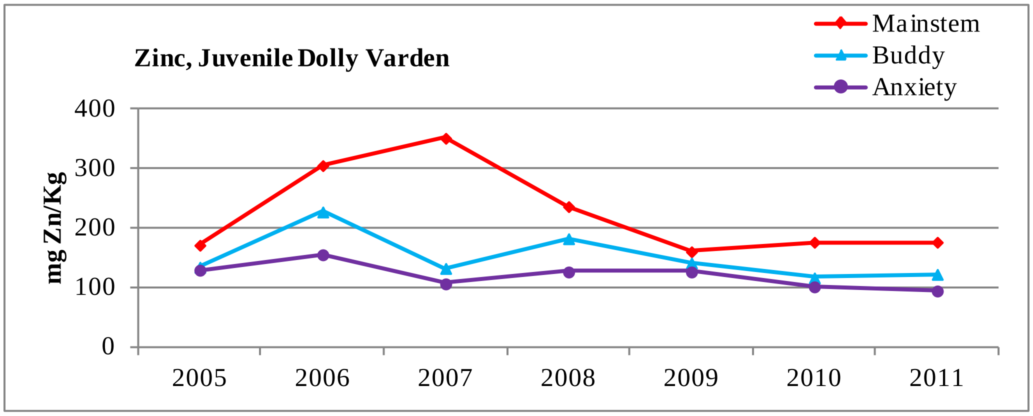

Figure 39. Median Zn whole body concentrations in juvenile Dolly Varden from 2005 to 2010.

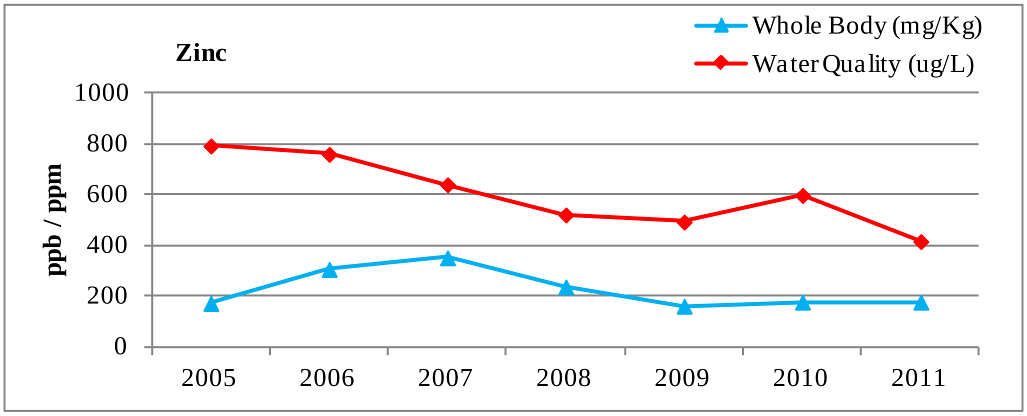

Figure 40. Median Se concentrations in whole body juvenile Dolly Varden (parts per million) and in the water (parts per billion) from Mainstem Red Dog Creek.

Median whole body Hg concentrations generally are low (< 0.1 mg/Kg dry weight) and in many instances at the detection limit of 0.02 mg/Kg. However, in contrast with whole body Cd, Pb, and Zn concentrations which are highest in Mainstem Red Dog Creek, Hg is highest every year in Anxiety Ridge Creek (Figure 41).

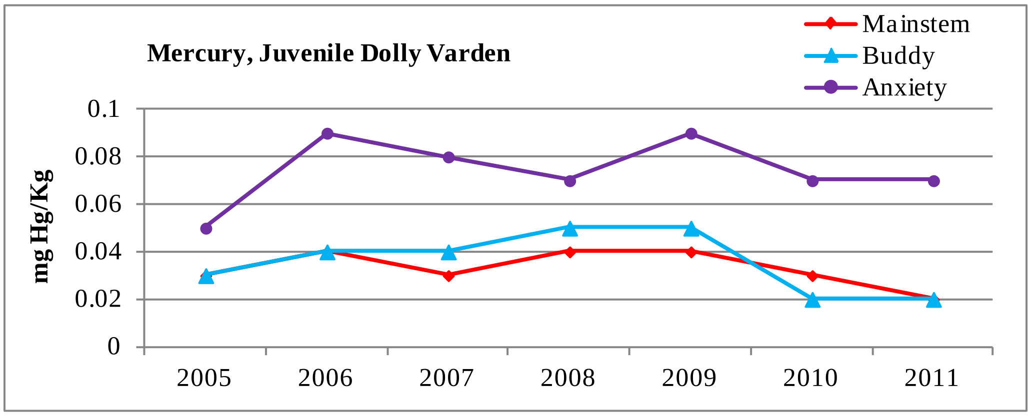

Figure 41. Median Hg whole body concentrations in juvenile Dolly Varden from 2005 to 2010.

In summary, whole body metals concentrations in juvenile Dolly Varden seem to have their own unique signature at each sample site/creek. Cd, Pb, and Zn median concentrations are highest in Mainstem Red Dog Creek. Se is similar at all three sites. Hg concentrations consistently are higher in Anxiety Ridge Creek. Finally, Cd and Zn are higher in Dolly Varden caught in Buddy Creek than they are in Dolly Varden caught in Anxiety Ridge Creek.

Arctic grayling were not retained for whole body metals analyses in 2011 – only three were caught in spring 2011 that met our size criteria of 150 to 200 mm long. Ott and Morris (2011) reported that Cd, Pb, and Se concentrations (median value) in Bons Pond Arctic grayling have remained unchanged over time, but there appeared to be an increase in Zn concentrations between 2004 and 2007. Median Hg concentrations are near the detection limit of 0.02 mg/Kg, but have increased since 2004.

Metals Concentrations in Adult Dolly Varden

Since 1990, we have sampled adult Dolly Varden from the Wulik River (Station 2) near Tutak Creek for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle tissue (Weber Scannell et al. 2000). In 1997, we added Se and in 1998 we started sampling reproductive tissue, when available in adequate mass. In 2003, we added Hg and Ca to the analytes being tested. From 2004 through 2009, Dolly Varden tissues were analyzed for Al, Cd, Cu, Pb, Se, Zn, and Hg. In 2010, we made several modifications based on previous results, including deleting Al from the analytes and eliminating gill tissue. The extremely high variability of Al in gill tissue was the reason for the change. The sample size for each spring and fall sample period has been six fish, except for the fall 2002 sample, when only five fish were caught.

The purpose of sampling adult Dolly Varden for metals concentrations is to monitor the long-term condition of fish over the life of the mine, to identify changes in tissue metals concentrations that may be related to mine activities and to provide a database for use by other professionals. The most likely benefits of this sampling program are long-term monitoring and use of these data by other professionals. It is highly unlikely that tissue metals concentrations or changes in adult fish could be related to events at the Red Dog Mine, since Dolly Varden attain their growth while in the marine environment. All laboratory work has been done with Level III Quality Assurance. Metals data for 2011 are presented in Appendix 5.

Metals are known to concentrate preferentially in certain organs; however, the relationship of organ concentration to ambient environmental concentrations is unknown. Concentrations of metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals concentrations vary with exposure to freshwater and marine environments. None of the analytes we measure appear concentrate in muscle tissue.

Analyte concentration in various tissues is summarized below and in Figures 42 through 53: Two figures are presented for each analyte – one for all fish handled from 1999 to 2011 and the second for fish caught in spring and fall, 2011.

- ●Cd concentrates in kidney tissue (Figures 42 and 43)
- ●Cu concentrates in liver tissue and eggs (Figure 44 and 45);
- ●Pb does not concentrate in any specific tissue (Figures 46 and 47);
- ●Se concentrates in kidney and eggs (Figures 48 and 49);
- ●Zn concentrates in eggs (Figures 50 and 51); and
- ●Hg concentrates in kidney tissue (Figures 52 and 53).

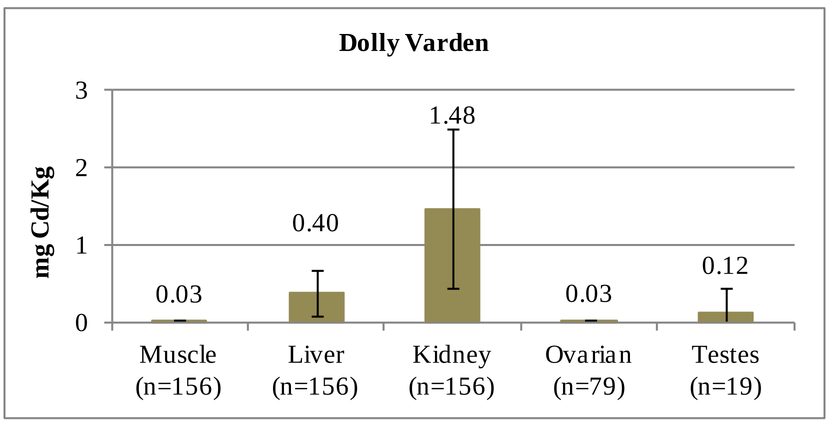

Figure 42. Average Cd concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

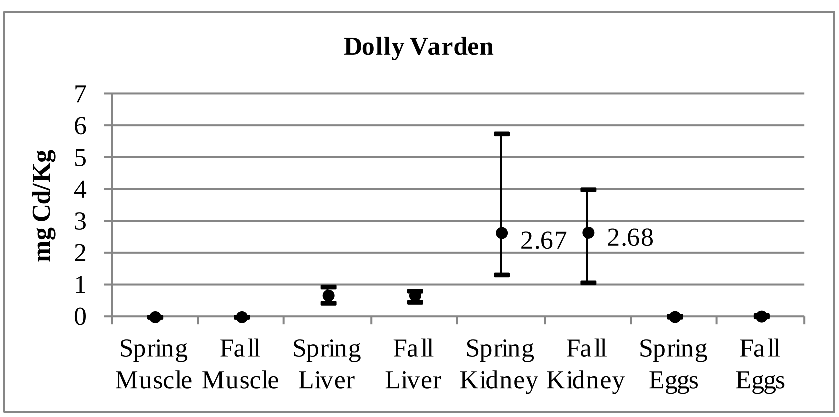

Figure 43. Median, maximum, and minimum Cd concentrations in Dolly Varden caught in spring and fall, 2011.

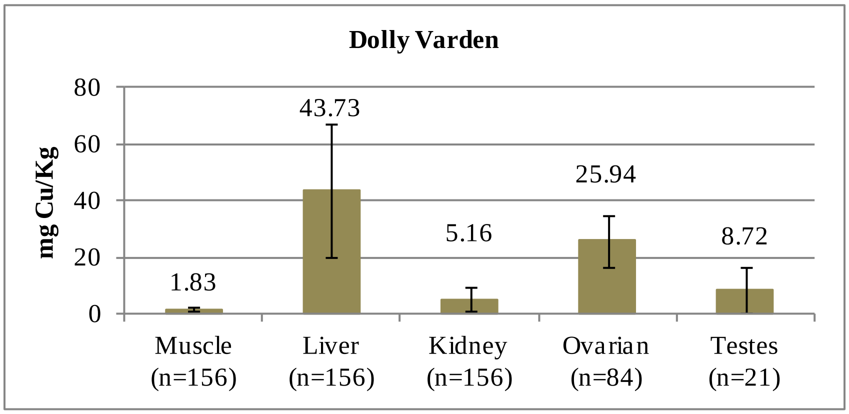

Figure 44. Average Cu concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

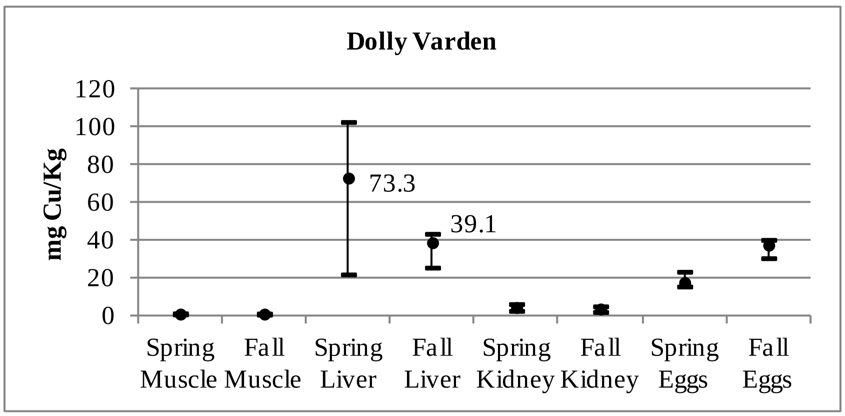

Figure 45. Median, maximum, and minimum Cu concentrations in Dolly Varden caught in spring and fall, 2011.

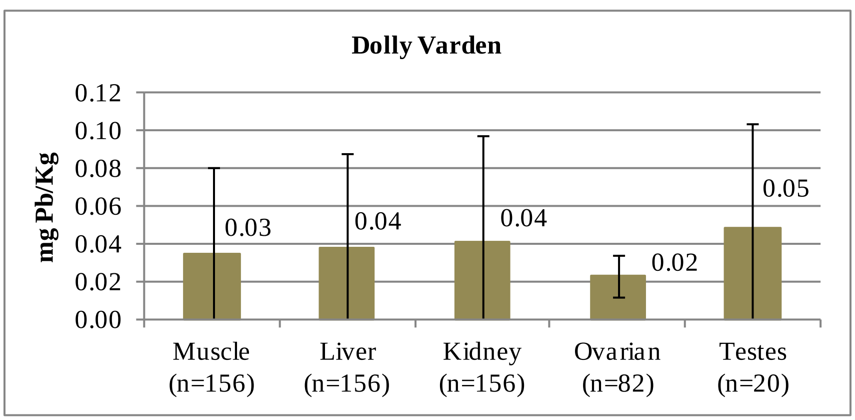

Figure 46. Average Pb concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

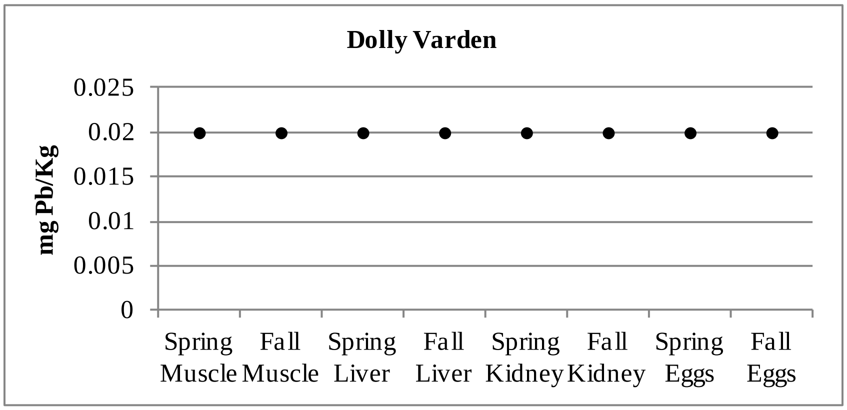

Figure 47. Median, maximum, and minimum Pb concentrations in Dolly Varden caught in spring and fall, 2011 (all were at the detection limit).

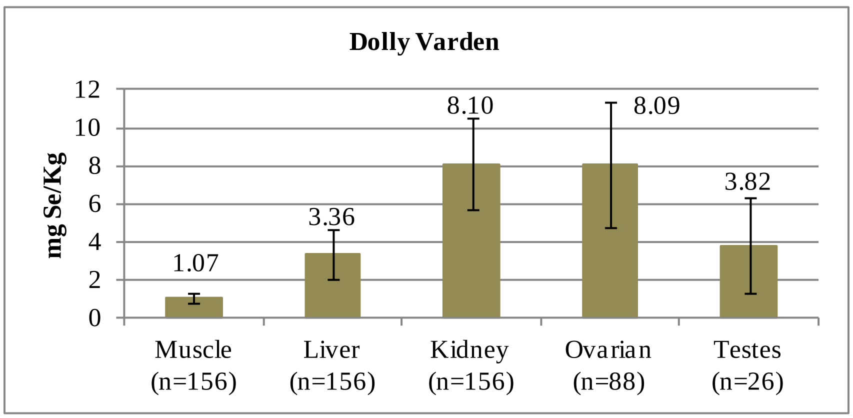

Figure 48. Average Se concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

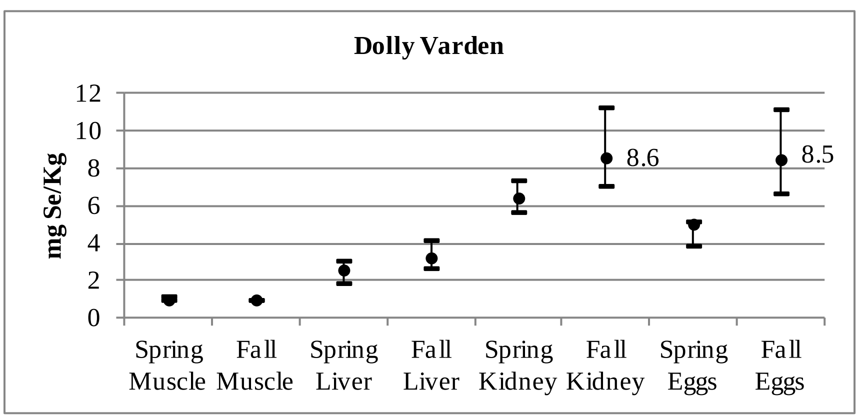

Figure 49. Median, maximum, and minimum Se concentrations in Dolly Varden caught in spring and fall, 2011.

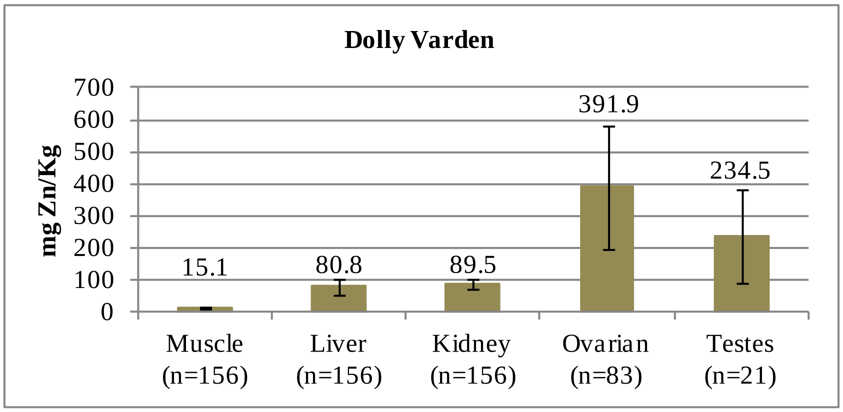

Figure 50. Average Zn concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

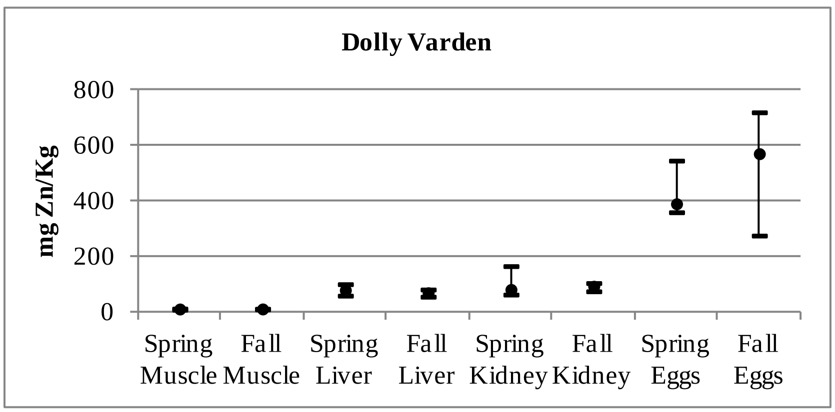

Figure 51. Median, maximum, and minimum Zn concentrations in Dolly Varden caught in spring and fall, 2011.

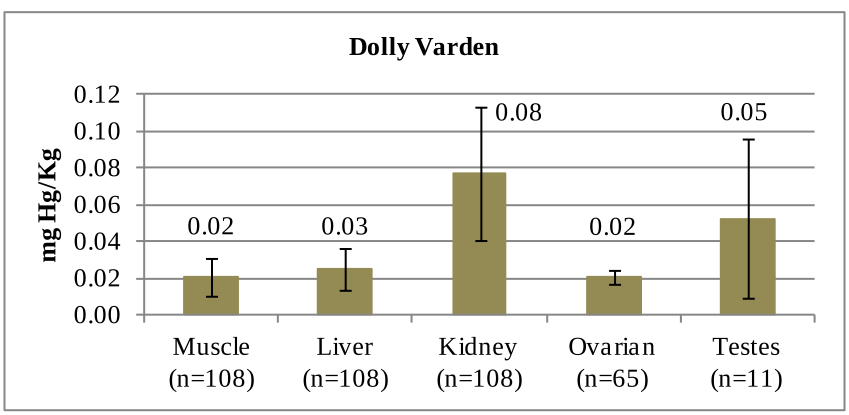

Figure 52. Average Hg concentrations (plus and minus 1 SD) in Dolly Varden (1999-2011).

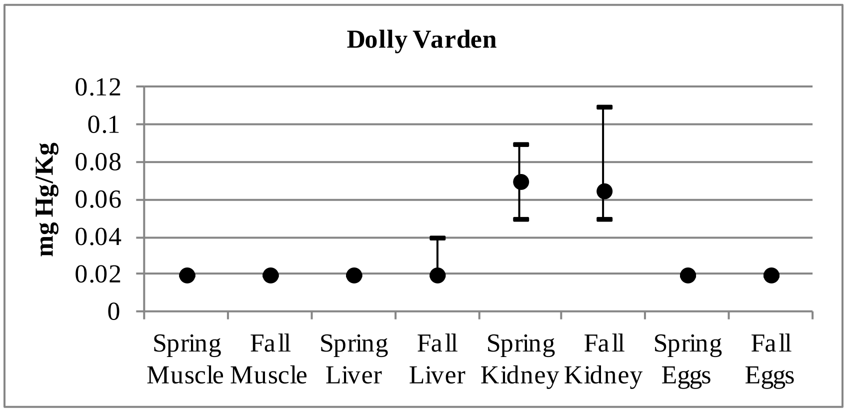

Figure 53. Median, maximum, and minimum Hg concentrations in Dolly Varden caught in spring and fall, 2011.

None of the analytes sampled concentrate in the muscle tissue of the Dolly Varden (Figure 54). Cd, Pb, Se, and Hg are at or very near the detection limit and many of the individual sample points are less than the detection limit. Sample sizes for each analyte are 156 fish, except for Hg where the sample size was 108.

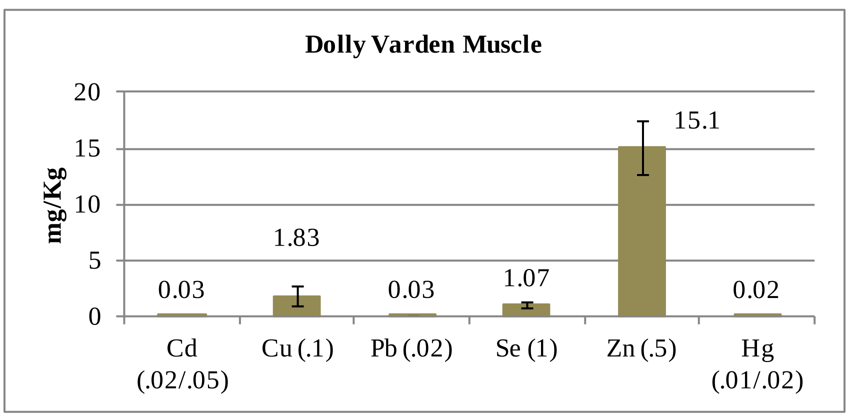

Figure 54. Average concentrations (plus and minus 1 SD) in Dolly Varden muscle (1999-2011). Note, detection limits shown in parenthesis.

Dolly Varden, Overwintering

Two aerial surveys to estimate the number of overwintering Dolly Varden in the Wulik River were conducted in 2011, one on September 25 and one on October 6, 2011. Surveys were conducted with a R-44 helicopter provided by Teck (DeCicco 2011). The second survey was conducted as late as possible to document Dolly Varden moving into the Wulik River late in the fall. Conditions were ideal during both surveys except for floating slush ice in parts of the Wulik River during the October survey and increased turbidity from a tundra slump located several km downstream of Driver's Camp that affected water color for about 6 km. Counts began about 1.6 km upstream of Kivalina Lagoon.

Late September estimates of Dolly Varden have decreased annually since 2005 and reached their lowest in recent years in 2010. We hypothesized that, similar to some recent salmon migrations in the Arctic, Dolly Varden may be delaying their migration until later in the fall and that the aerial survey may need to be conducted later in the season. Dolly Varden in the Wulik River were estimated at 15,591 on September 25, 2011 and 62,612 on October 6, 2011 (DeCicco 2011, Figure 55, and Appendix 6). A large number of Dolly Varden had entered the Wulik River between surveys. DeCicco reported that in 2011, October 6 was the last day a survey could have been made as the Wulik River was flowing ice pans and slush ice on October 7. We will continue to do two surveys, one in late September when river conditions are most likely to provide good visibility for counts and then a second survey timed for as late in the year as possible.

The number of Dolly Varden estimated in the fall in the Wulik River varies annually. Survey results in October 2011 found that 99% of the fish observed were downstream of the mouth of Ikalukrok Creek. Only in 2004 has the percentage of fish below Ikalukrok Creek been less than 90%. Continued use of this section of the Wulik River by the majority of overwintering Dolly Varden suggests that conditions have not changed to alter the distribution of these fish.

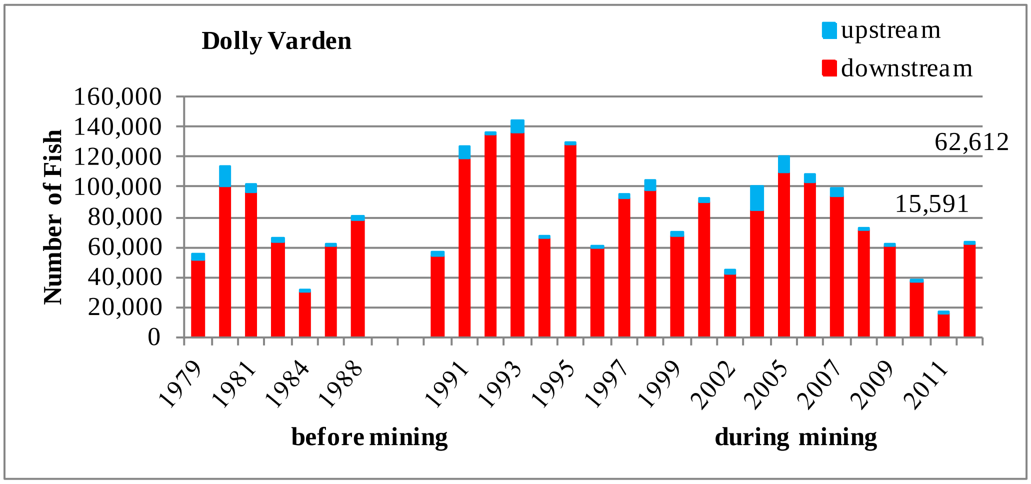

Figure 55. Estimated Dolly Varden in the Wulik River just prior to freezeup.

Chum Salmon, Spawning

ADF&G conducts annual aerial surveys to assess the distribution of adult chum salmon in Ikalukrok Creek from its confluence with the Wulik River upstream to Dudd Creek (Table 3 and Appendix 7). In fall 2011, we flew a survey using a R-44 helicopter. Survey conditions on September 25, 2011, were nearly ideal with clear weather and very light winds. An estimated 1,507 chum salmon (live plus carcasses) and 825 Dolly Varden were observed in Ikalukrok Creek (DeCicco 2011). The survey was conducted late in the chum salmon spawning cycle and we assume numbers would have been higher in mid to late August.

Our estimated chum salmon return to Ikalukrok Creek in 2011 was at least 1,507 fish. We have observed good returns of chum salmon for the last 6 years. Our highest count since mining began at Red Dog was in 2006, when we estimated 4,185 chum salmon.

All chum salmon observed were below Station 160 on Ikalukrok Creek, the furthest downstream location at which instream TDS limits apply (from July 25 through the end of the discharge season). Counts of chum salmon in Ikalukrok Creek in 1990 and 1991 (mine discharge began in 1989) were lower than reported in baseline studies. Surveys began again in 1995, with the highest count made in fall 2006. The numbers of returning chum salmon in recent years are a good indication that the population has recovered from the early 1990s.

Table 3. Number of chum salmon adults in Ikalukrok Creek.

Survey Date	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August September 1982	353 to 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990c
August 1986	1,985	DeCicco 1990c
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 16, 1995	49	Townsend and Lunderstadt 1995
August 1995	300 to 400	DeCicco 1995
August 11, 1996	180	Townsend and Hemming 1996
August 12, 1997	730 to 780	Ott and Simpers 1997
1998	no survey	
August 9, 1999	75	Ott and Morris 1999
2000	no survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco 2001a
August 5, 2002	890	Ott and Townsend 2002
August 11, 2003	218	Townsend and Ingalls 2003
August 26, 2004	405	Townsend and Conley 2004
August 29, 2005	350	Thompson 2005
August 14, 2006	4,185	Ott and Timothy 2006
August 11, 2007	1,408 and 1,998	Ott and Townsend 2007
August 6, 2008	3,820	Ott and Jacobs 2008
July 31, 2009	100	Ott and Benkert 2009
September 25, 2009	2,051	DeCicco 2009
September 24, 2010	1,358	DeCicco 2010
September 26, 2011	1,507	DeCicco 2011

Dolly Varden, Juveniles

Limited pre-mining juvenile Dolly Varden distribution and use data are available for streams in the Red Dog Mine area. Houghton and Hilgert (1983) identified Anxiety Ridge Creek as the most productive system in the project area. They also reported finding only one Dolly Varden in the North Fork Red Dog Creek drainage and presumed that it was a resident fish. Surveys along Mainstem Red Dog Creek reported either few fish or no fish, and in some cases mortalities of small juvenile Dolly Varden and Arctic grayling fry (EVS Consultants Ltd and Ott Water Engineers 1983, Ward and Olson 1980).

We have sampled for juvenile Dolly Varden in streams in the Red Dog Mine area since 1990. We added new sample sites and increased the number of minnow traps (10) per sample reach in 1992. Under the new program that began in 2010, we sample eight sites with 10 minnow traps per sample reach with about 24 hr of effort in early-to-mid August (Table 4, Appendix 8). Seven of these sites are unchanged since 1992 and the new Station 160 corresponds to Station 7 – instead of being immediately downstream of Dudd Creek, it is now located about 7 km downstream.

Table 4. Location of juvenile Dolly Varden sample sites.

Site Name	Station No.	Year Sampling Started
Evaingiknuk Creek		1990
Anxiety Ridge Creek		1990
Buddy Creek		1996
North Fork Red Dog Creek	12	1993
Mainstem Red Dog Creek	151	1995
Mainstem Red Dog Creek	10	1996
Ikalukrok Creek above Mainstem	9	1996
Ikalukrok Creek below Dudd	7/160	1990

Minnow traps are the preferred sampling gear for juvenile Dolly Varden because they are very effective for this species and the age classes present, the gear is suitable for sample areas in large to small streams, the effort is uniform across sample sites, variability due to sampler-induced bias is reduced, and there is seldom fish mortality. Juvenile Dolly Varden generally are the most numerous fish species present and are distributed most widely in the sample area. Our objective is to assess numbers of fish using streams over time and to sample juvenile Dolly Varden for whole body metal analyses from selected streams. Data relevant to whole body metal analyses of juvenile Dolly Varden were presented in a previous section of this report.

Dolly Varden Catches and Metrics

The relative abundance of juvenile Dolly Varden varies considerably among sample years (Appendix 9); however, the relative catches among the sample sites follow similar patterns. Generally, the CPUE (total number of fish for ten traps for 24 hr) in Anxiety Ridge and Buddy creeks is higher than at the other sample reaches (Figure 56). In 2011, the CPUE was highest in Buddy Creek and catches were similar in Anxiety Ridge and Lower Ikalukrok creeks.

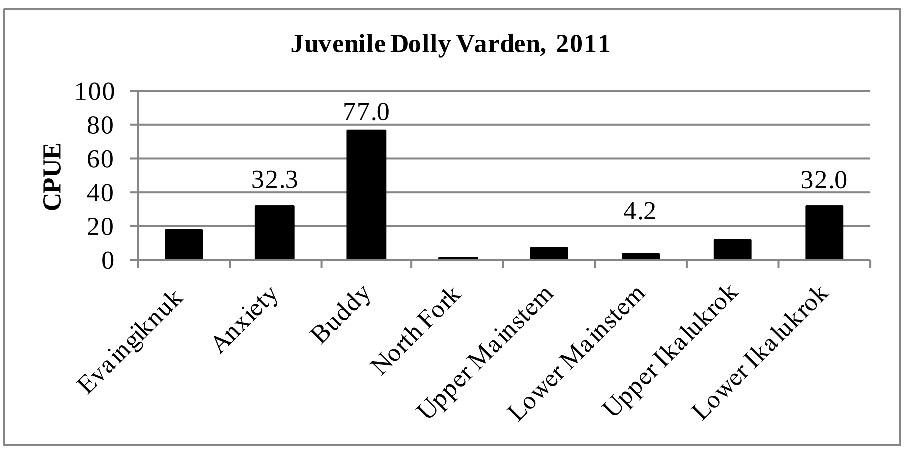

Figure 56. CPUE for juvenile Dolly Varden in the Red Dog Mine sample reaches. Upper Mainstem is a sample reach at Station 151, while Lower Mainstem is a sample reach at Station 10.

Natural environmental conditions such as the duration of breakup, patterns and magnitude of rainfall, ambient air temperatures, and the strength of the age 1 cohort affect distribution of juveniles and relative abundance. Probably the most important factor is the strength of the age 1 cohort which is directly related to numbers of spawners, spawning success, and survival the previous winter. The CPUE for juvenile Dolly Varden in Anxiety Ridge and Buddy creeks from 1997 to 2011 reflects this high degree of variability among sample years (Figure 57). The highest CPUE for Buddy Creek was 306 fish/reach in 1999 and the lowest was 5.1 fish/reach in 2006. The CPUE for Anxiety Ridge Creek also was high in 1999 and low in 2006.

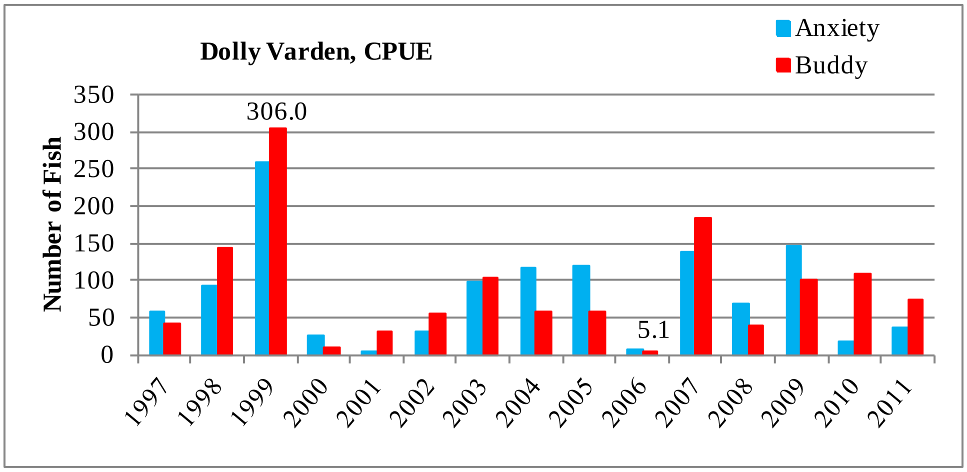

Figure 57. CPUE (total number of fish in ten traps per day) of juvenile Dolly Varden in Anxiety Ridge and Buddy creeks in late July to early August.

The CPUE for lower Mainstem Red Dog Creek from 1997 to 2011 is presented in Figure 58. The highest CPUE was 73.3 fish/reach in 1999 and one of the lowest CPUEs was 2.5 fish/reach in 2006. This same pattern was found for Anxiety Ridge and Buddy creeks. Catches since 2000 in lower Mainstem Red Dog Creek have been low, but relatively consistent. Only in 2004 did we not catch any juvenile Dolly Varden in lower Mainstem Red Dog Creek.

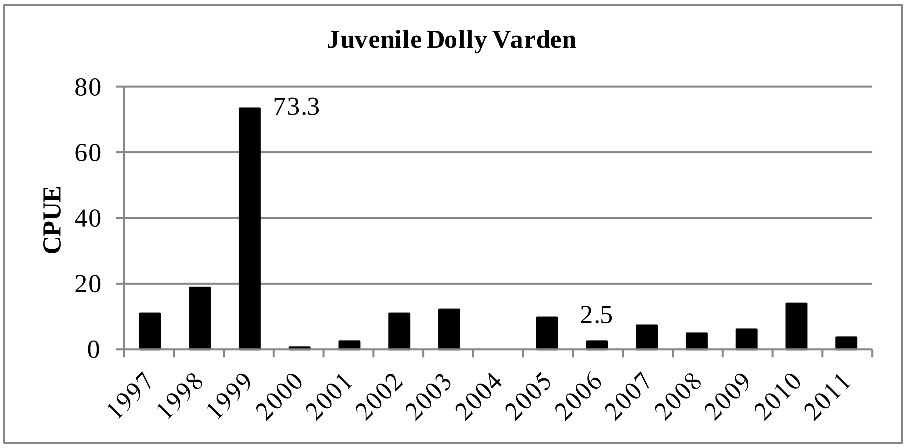

Figure 58. CPUE for juvenile Dolly Varden in the lower Mainstem Red Dog Creek sample reach.

Evaingiknuk Creek is a tributary to the Noatak River and serves as a reference site. The juvenile Dolly Varden using this creek are present earlier in the sample year and there is a mixture of resident fish with an anadromous component. The CPUE in Evaingiknuk Creek varies like the samples reaches in the Ikalukrok Creek drainage (Figure 59). However, high catches in Evaingiknuk Creek do not necessarily follow the same pattern in the Ikalukrok Creek drainage.

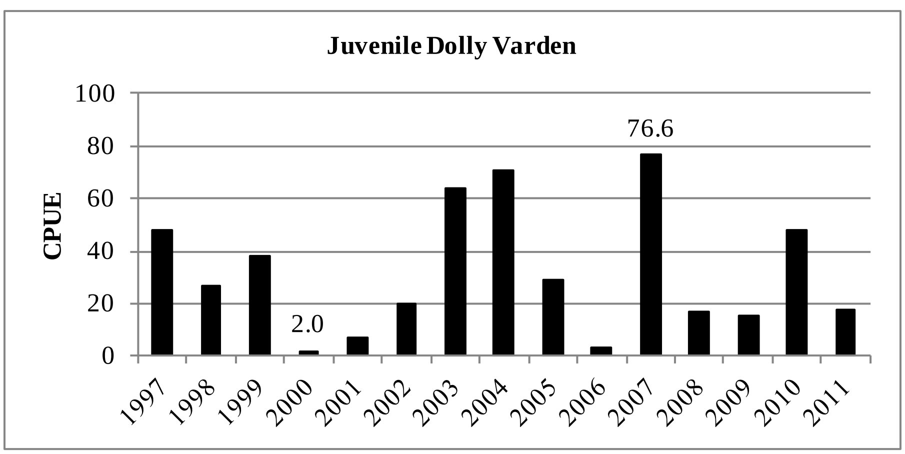

Figure 59. CPUE for juvenile Dolly Varden in Evaingiknuk Creek, a Noatak River tributary.

Length frequency distributions for 2009, 2010, and 2011 are presented in Figures 60, 61, and 62. Small Dolly Varden (< 70 mm) have been represented in our catches in both 2009 and 2011, but were absent in 2010. Dolly Varden less than 70 mm long in late July to mid-August probably are age 0 fry (Houghton and Hilgert 1983, DeCicco 1985). Dolly Varden spend several years in freshwater before their migration (i.e., smolting) to the marine environment at age 2 or 3 (DeCicco 1990a). Most of the juvenile Dolly Varden present in 2009 that were 110 mm or larger probably smolted and thus would not be present in the 2010 catches.

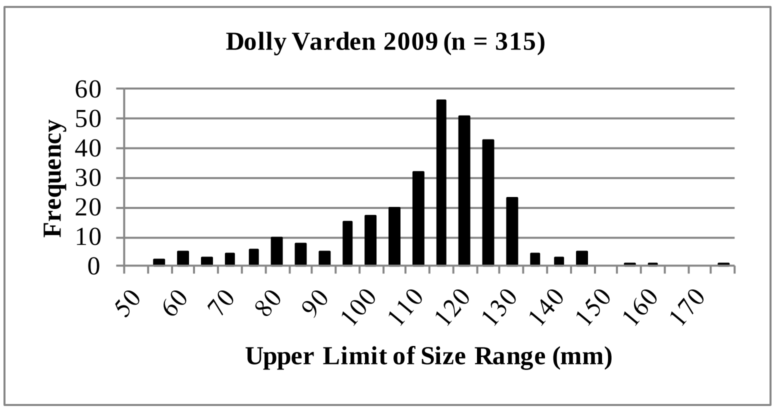

Figure 60. Length frequency distribution of juvenile Dolly Varden in the Ikalukrok Creek drainage in 2009.

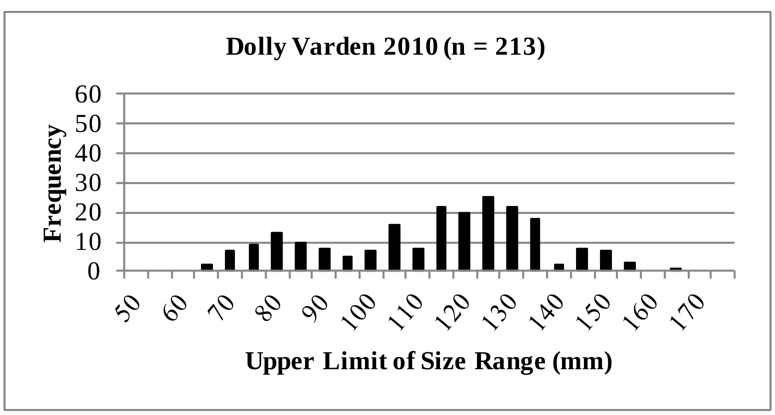

Figure 61. Length frequency distribution of juvenile Dolly Varden in the Ikalukrok Creek drainage in 2010.

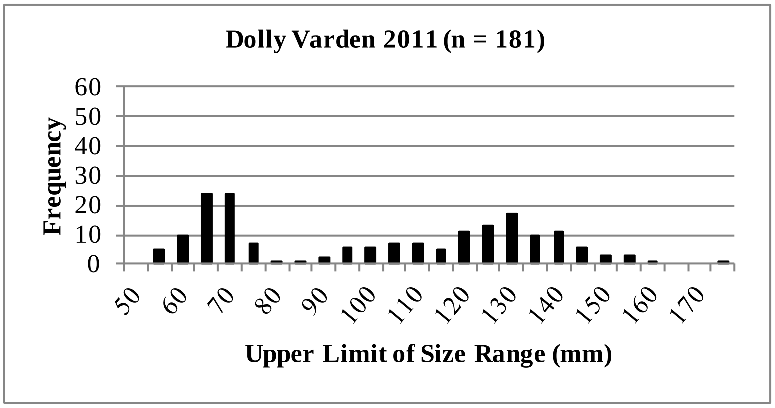

Figure 62. Length frequency distribution of juvenile Dolly Varden in the Ikalukrok Creek drainage in 2011.

Each spring during breakup we fish fyke nets in North Fork Red Dog Creek to capture Arctic grayling, but we also catch resident Dolly Varden and slimy sculpin. In spring 2011, we caught 16 Dolly Varden that averaged 183 mm long (Figure 63). Most of these fish were presumed to be stream resident (non-anadromous) fish due to size (larger than smolts), obvious parr marks, and distinct orange/pink dots. Use of North Fork Red Dog Creek by resident Dolly Varden varies among the sample years.

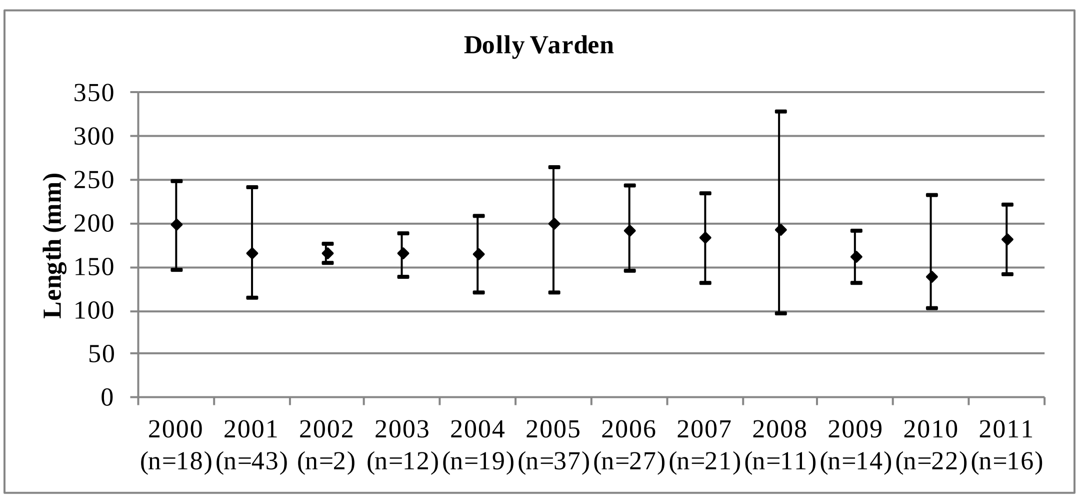

Figure 63. Dolly Varden caught in fyke nets fished in North Fork Red Dog Creek in spring during the Arctic grayling spawning run.

Arctic Grayling, Red Dog Creek Drainage

Before mine development, Arctic grayling adults migrated through Mainstem Red Dog Creek in spring when flows were high and metals concentrations were low (Ward and Olsen 1980, EVS and Ott Water Engineers 1983, and Houghton and Hilgert 1983). Arctic grayling moved through Mainstem Red Dog Creek to spawn in North Fork Red Dog Creek. None of these reports indicated that Arctic grayling spawned in Mainstem Red Dog Creek. Arctic grayling fry reared in North Fork Red Dog Creek and were displaced downstream by high-water events or outmigrated as water temperatures cooled in the fall. Before Red Dog Mine operations, very few juvenile Arctic grayling were observed in North Fork Red Dog Creek. Fry mortalities were reported in Mainstem Red Dog Creek by EVS Consultants and Ott Water Engineers (1983) and Ward and Olsen (1980). Since 1994, we have documented Arctic grayling use of Mainstem Red Dog Creek and have not observed any fish mortalities (Appendix 10).

Arctic Grayling Spawning

We have monitored Arctic grayling spawning during spring in North Fork Red Dog and Mainstem Red Dog creeks since 2001. The purpose of this sampling effort is to document when spawning has been substantially completed in Mainstem Red Dog Creek. Water temperature is the most likely factor determining spawning time, emergence of fry, first year growth, and survival. High flows during or immediately following spawning can have a negative effect on fry survival (Clark 1991).

Discharge volume and quality from the wastewater treatment facility at Red Dog are regulated to meet permit conditions. From 2001 to 2007, TDS concentrations were regulated to be less than 500 mg/L at Station 151 (Station 10) during Arctic grayling spawning. During that time frame, monitoring of Arctic grayling spawning was performed to determine when spawning was substantially completed, thus allowing Teck to increase the TDS concentrations to 1,500 mg/L for the remainder of the ice-free season.

A TDS site-specific criterion (SSC) of 1,500 mg/L during Arctic grayling spawning was issued by ADEC and became effective on February 15, 2006. The US Environmental Protection Agency (EPA) approved the 1,500 mg/L TDS SSC on April 21, 2006. The SSC developed by ADEC was based on field and laboratory studies conducted with Arctic grayling at the Red Dog Mine site (Brix and Grosell 2005). Teck regulates the wastewater discharge to ensure that TDS concentrations do not exceed the ADEC and EPA approved TDS limit of 1,500 mg/L at Station 151.

In 2011, fyke nets and angling were used to capture Arctic grayling moving into North Fork Red Dog Creek. We checked North Fork Red Dog Creek on June 1 and flows were high and aufeis about 2 m thick extended out over the thalweg. We set a fyke net upstream of the aufeis field on June 2, but this net never fished effectively. On June 4, 2011, a larger fyke net (≈ 1 m frame) was set on the north bank of the creek, but the wing did not extend to the thalweg because of aufeis and high flows (Figure 64). In contrast, water levels were extremely low in spring (late May/early June) 2010 (Figure 64).

Figure 64. Fyke net in North Fork Red Dog Creek on June 6, 2011 (left photo) and fyke nets in North Fork Red Dog Creek on June 3, 2010 (right photo).

As aufeis melted and flows decreased we kept extending the wing and by June 7, 2011, we had the construction fence wing across the thalweg. Fyke nets were fished until the morning of June 11. Fyke nets are checked twice each day, around 0800 and 1800 hr.

On June 10 we caught 6 Arctic grayling with 2 hr of angling in Mainstem Red Dog Creek. We caught 140 Arctic grayling in North Fork Red Dog Creek in the large fyke net. Catches were fairly consistent with an increase at the end when we started catching juvenile Arctic grayling (Figure 65).

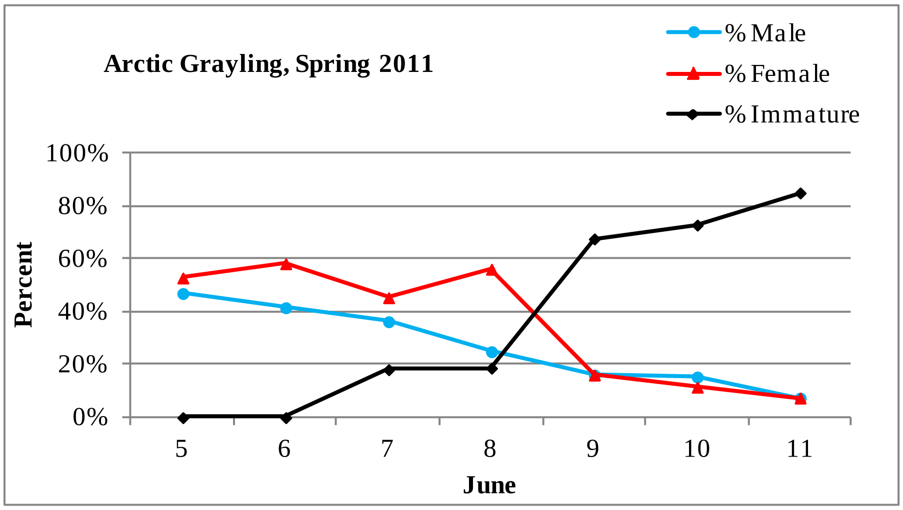

Figure 65. Percent male, female, and immature Arctic grayling in fyke net catches in North Fork Red Dog Creek in June 2011.

On June 5, 2011, about 50% of females captured were ripe. As sampling continued, the percentage of ripe females increased and by June 10, all of the females handled were spent (Figure 66).

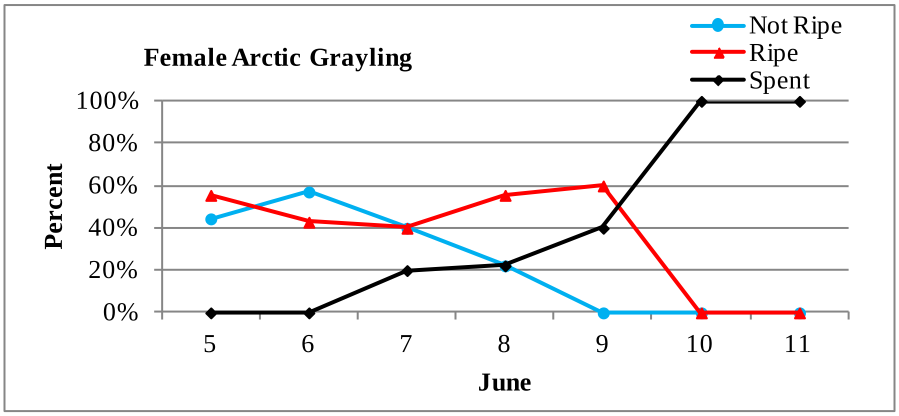

Figure 66. Percent not ripe, ripe, and spent Arctic grayling females caught in North Fork Red Dog and Mainstem Red Dog creeks in June 2011.

Based on these data, it appears that spawning was substantially complete in Mainstem Red Dog Creek by June 9. Spawning probably started in North Fork Red Dog Creek on June 10 as peak water temperatures first exceeded 4.0°C (Figure 67). Water temperatures were, on the average, 2.3°C higher in Mainstem Red Dog Creek.

Middle Fork and North Fork of Red Dog Creek join to form Mainstem Red Dog Creek immediately downstream of the fish barrier in Middle Fork Red Dog Creek. Substantial aufeis exists in North Fork Red Dog Creek, but not in Middle Fork Red Dog Creek. The increased water temperatures in Mainstem Red Dog Creek as compared with North Fork Red Dog Creek appear to be related to the lack of aufeis in Middle Fork Red Dog Creek. The absence of aufeis in Middle Fork Red Dog Creek probably is because all winter surface and ground water are collected in the mine sump drainage and moved to the tailing impoundment.

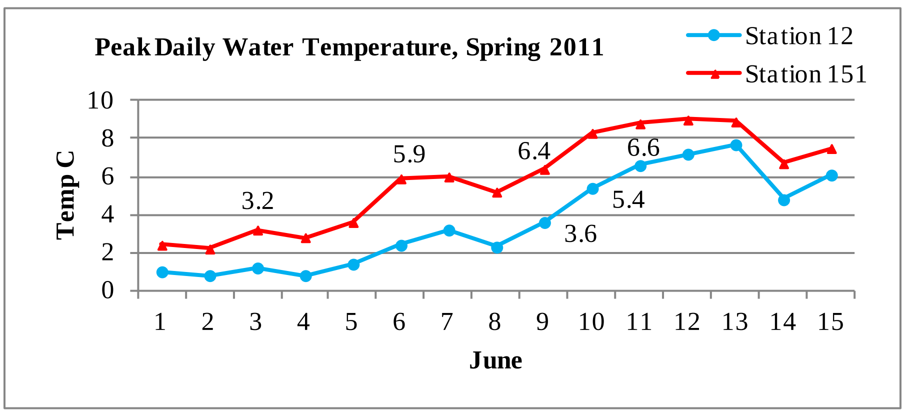

Figure 67. Peak daily water temperatures in North Fork Red Dog (Station 12) and Mainstem Red Dog (Station 151) creeks in June 2011.

The earliest spawning was judged to be substantially complete was May 29 in 2010 (Table 5). In both 2001 and 2006, spawning was not completed until June 15 (Table 5). Limited spawning could start at 3°C, but most likely does not start until temperatures reach 4°C. For comparison, data collected at Ft. Knox in spring 2010 did confirm that some Arctic grayling spawned in the wetland complex before peak temperatures reached 4°C (Ott and Morris 2010).

Table 5. Summary of Arctic grayling spawning in Mainstem Red Dog Creek.

Year	Date When Limited Spawning Started (3°C)	Date When Spawning Complete (Condition of Females)	Number of Days Peak Temperatures Exceeded 4°C[1]
2001	June 6	June 15	6
2002	May 29	June 8	8
2003	June 7	June 14	6
2004	May 25	May 31	4
2005	May 27	June 6	9
2006	May 30	June 15	10
2007	May 26	June 3	8
2008	June 1	June 9	9
2009	June 8	June 13	4
2010[2]	May 21	May 29	6
2011	June 6	June 9	4

[1]Does not include the day spawning was judged to be complete since the fyke net is worked in the early morning prior to peak temperatures on that day.

[2]The date spawning was judged to be substantially complete was based solely on the water temperature data collected in spring 2010.

Arctic Grayling Fry

In 2011, spawning success in the Red Dog Creek drainage probably was low due to a late breakup. Spawning probably did not start until June 6, 2011, in Mainstem Red Dog Creek and probably not until June 10, 2011, in North Fork Red Dog Creek. In mid-July 2011, Arctic grayling fry were not observed in North Fork Red Dog or Mainstem Red Dog creeks; however, one fry was collected in Mainstem Red Dog Creek in a drift net. In late August, 2011, a few Arctic grayling fry (< 10 fish) were observed in backwater areas and along the margins in both North Fork Red Dog and Mainstem Red Dog creeks.

Arctic Grayling Catches and Metrics

Catches of Arctic grayling in the fyke net fished in North Fork Red Dog Creek were fairly consistent and increased near the end of sampling as more juvenile Arctic grayling entered the creek (Figure 68).

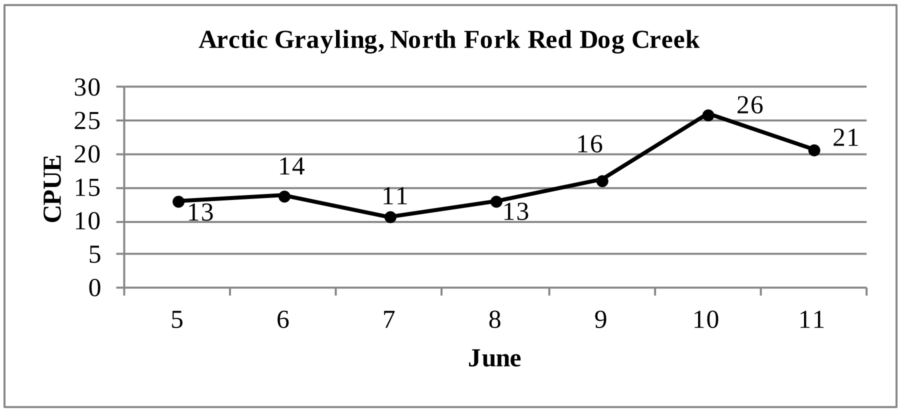

Figure 68. Catch per unit of effort (fish/fyke net day) of Arctic grayling in North Fork Red Dog Creek in June 2011.

In spring 2011, excluding fish captured more than once, we handled 145 Arctic grayling in North Fork Red Dog Creek, including five caught by angling in Mainstem Red Dog Creek (Figure 69). Recruitment of immature fish was strong in 2011.

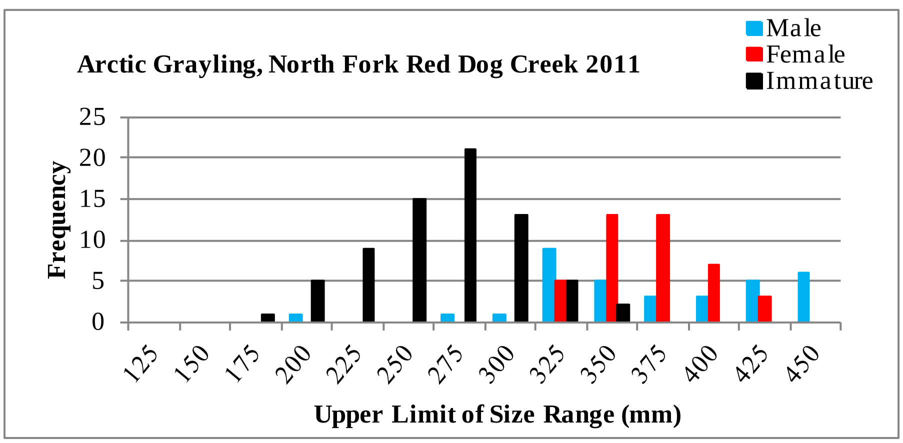

Figure 69. Length frequency distribution of Arctic grayling in June 2011.

The catch per unit of effort (CPUE) for immature Arctic grayling in North Fork Red Dog Creek was 9.7 in 2011 and has ranged from 3.4 in 2002 to 25.2 in 2007 over the course of our research (Figure 70). These data are for the fyke net that is set to capture upstream moving fish with the exception of 2010 when due to extremely low water two fyke nets were fished (one upstream and one downstream). Recruitment of immature Arctic grayling has been strong the last five years.

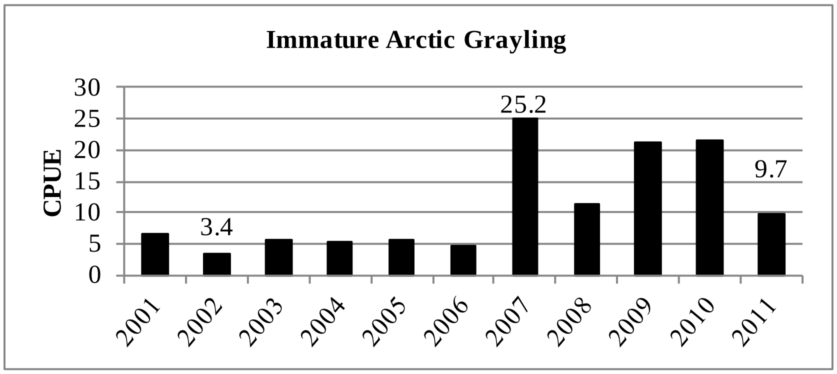

Figure 70. Catch per unit of effort (fish per day) of immature Arctic grayling in North Fork Red Dog Creek in spring 2001 to 2011.

The CPUE for mature Arctic grayling in North Fork Red Dog Creek is presented in Figure 71. These data are for the large fyke net only. The CPUE is fairly consistent for mature fish among sample years with the exception of 2006 (2.7 fish/day) and 2007 (35.2 fish/day).

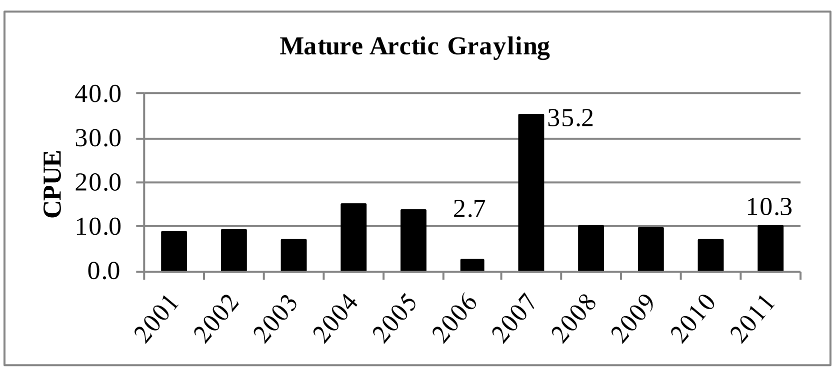

Figure 71. Catch per unit of effort (fish per day) of mature Arctic grayling in North Fork Red Dog Creek in spring 2001 to 2011.

A portion of the recruitment is attributable to Arctic grayling leaving Bons Pond, entering the Ikalukrok Creek drainage, and then returning to North Fork Red Dog Creek in the spring. Bons Pond Arctic grayling were first captured in North Fork Red Dog Creek in spring 2005. Arctic grayling marked in spring 2010 and recaptured in spring 2011 demonstrate higher growth rates for the immature than the mature fish (Figure 72).

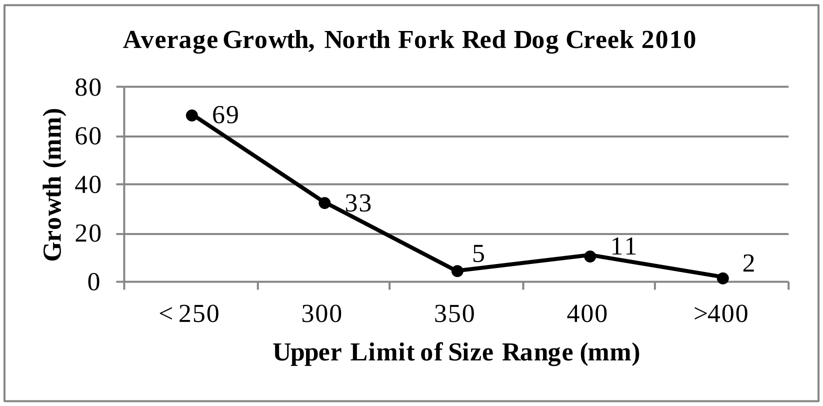

Figure 72. Average growth of Arctic grayling in 2010 in North Fork Red Dog Creek.

Growth rates for a selected size range of Arctic grayling in North Fork Red Dog Creek were compared among sample years. Growth rates for this size class of Arctic grayling have been fairly consistent from 2004 to 2010 (Figure 73).

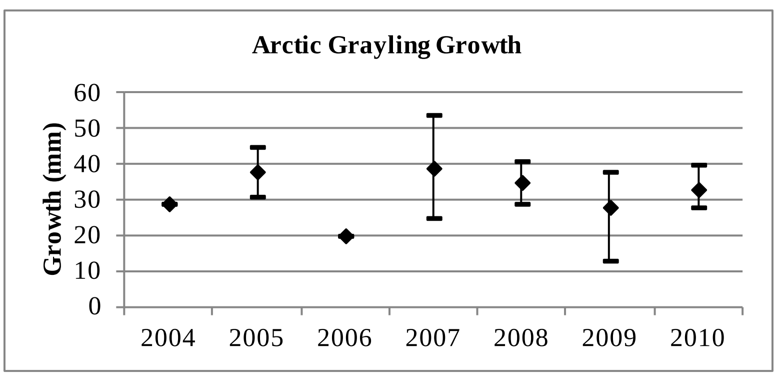

Figure 73. Average, maximum, and minimum growth of Arctic grayling in North Fork Red Dog Creek for fish between 250 and < 300 mm long when marked.

In 2010, we caught 243 Arctic grayling > 200 mm long of which 14 were recaptured in spring 2011. Of all the fish captured in 2011, 21 were smaller than 240 mm long. Based on a comparison of the 2010 and 2011 length frequency distributions we determined that fish < 240 mm in 2011 would not have been large enough to mark in spring 2010. Considering only fish > 240 mm, a total of 114 fish were captured for the purpose of estimating the 2010 population. The estimated 2010 North Fork Red Dog Creek Arctic grayling population was 1,870 fish (SD = 828) (Figure 74). The 95% confidence intervals for the 2008 and 2009 estimates are tighter than for the 2003, 2004, and 2010 estimates. The population of Arctic grayling in North Fork Red Dog Creek, pre-mining, is not known.

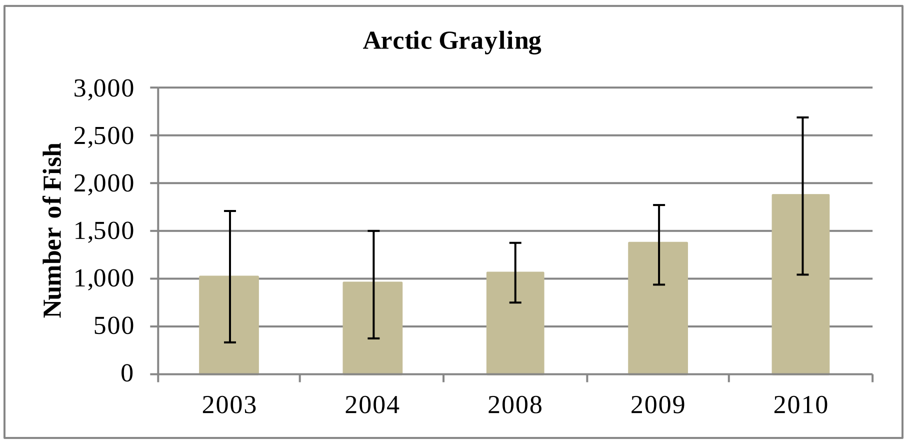

Figure 74. The estimated Arctic grayling population (+ SD) in North Fork Red Dog Creek for fish > 200 mm long.

Arctic Grayling Seasonal Migration

We initiated an Arctic grayling seasonal migration and habitat use study using radio telemetry. The goal of the study was primarily to identify overwintering areas used by the North Fork Red Dog Creek Arctic grayling spawning population. Secondary goals of the project were to monitor movement and migration patterns of the radio tagged population during summer and also during the spring migration. Radio tracking surveys were flown in June, July, September, October, and November, 2011.

Between June 5 and June 11, 2011, 14 Arctic grayling captured in North Fork Red Dog Creek were successfully implanted with Lotek ® MCFT2-3BM coded radio tags. Only large adult males and spent females were radio-tagged (Table 6). These fish were relocated in North Fork Red Dog and Mainstem Red Dog creeks during the same time frame. Several of the adults were in Mainstem Red Dog Creek downstream of Station 151 and in North Fork Red Dog Creek in the reach that parallels the gas field access road, with the exception of one female (Code 53) upstream of the first major tributary from the north.

Table 6. Radio-tagged Arctic grayling in North Fork Red Dog Creek

Frequency	Code	Fork Length (mm)	Sex	Comments
	41	413	Male	
	42	371	Female	
	43	404	Male	
	44	378	Male	
	45	422	Male	
	46	430	Male	
	47	442	Male	weak signal initially, assumed to quit functioning, not found in July, September, October, or November
	48	374	Female	
	49	435	Male	
	50	418	Male	
	51	415	Male	
	52	381	Male	
	53	370	Female	
	54	433	Male	
	55	372	Male	

Aerial surveys to relocate these radio-tagged Arctic grayling were conducted on July 17 (Figure 75), September 26 (Figure 76), October 7 (Figure 77), and November 5 (Figure 78). We found 13 of the fish on July 17 and 14 on September 26, October 7, and November 5.

On July 17, the radio-tagged Arctic grayling were distributed throughout the Ikalukrok Creek drainage (Figure 75) with six in North Fork Red Dog Creek, one in Grayling Junior Creek, one in upper Ikalukrok Creek (just below an impassable falls), two in Ikalukrok Creek between Mainstem Red Dog and Dudd creeks, and three in lower

Ikalukrok Creek. The three fish in lower Ikalukrok Creek were in the reach where most of the chum salmon spawn. Seagulls were seen on several gravel bars in this reach and we assume that some chum salmon already were present.

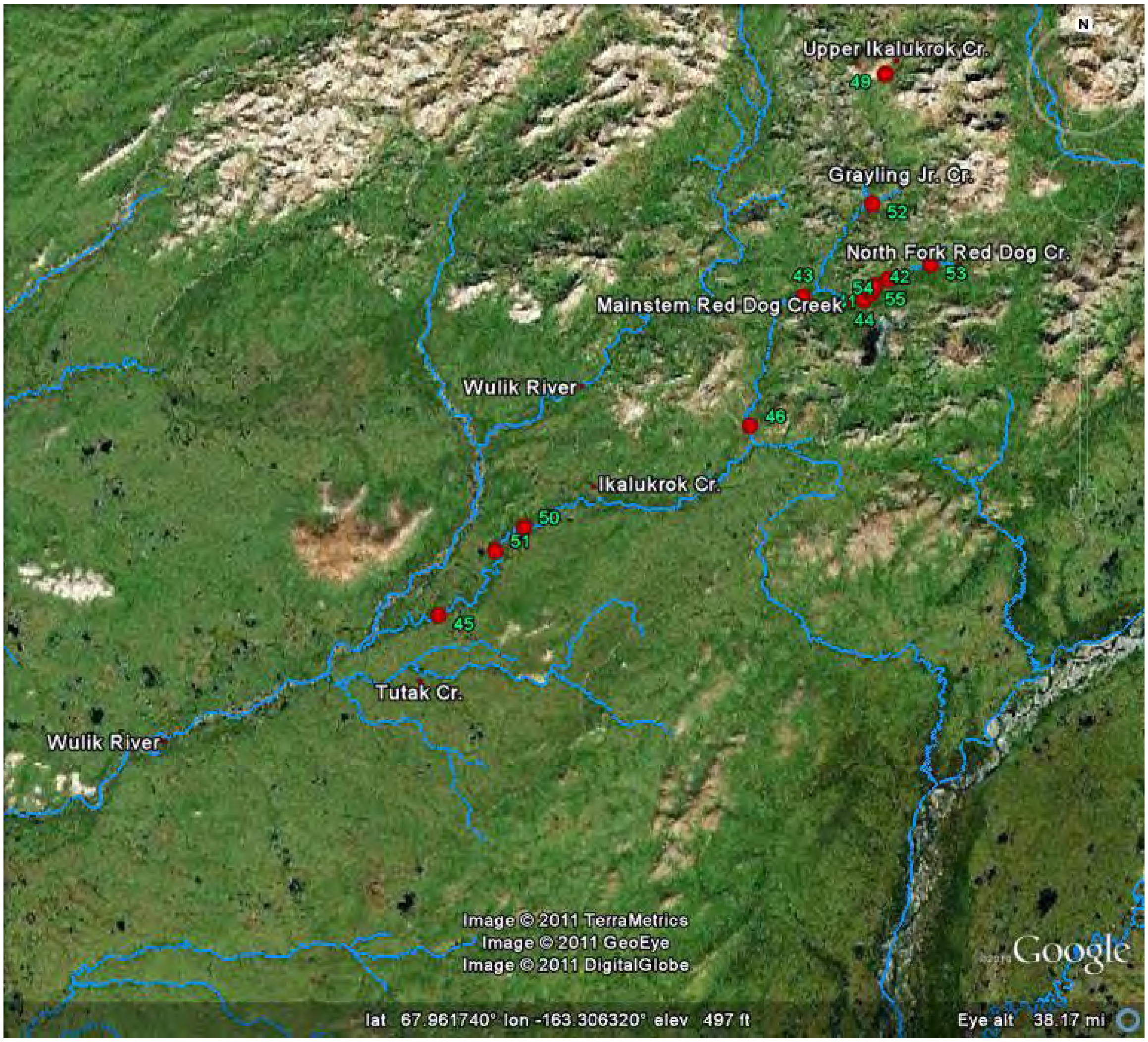

Figure 75. Radio tagged Arctic grayling on July 17, 2011.

On September 26, two Arctic grayling were still in North Fork Red Dog Creek, one was in Grayling Junior Creek (different fish from the one found in July), three were in the Wulik River near the mouth of Ikalukrok Creek, and eight were in Ikalukrok Creek in the chum salmon spawning reach (Figure 76).

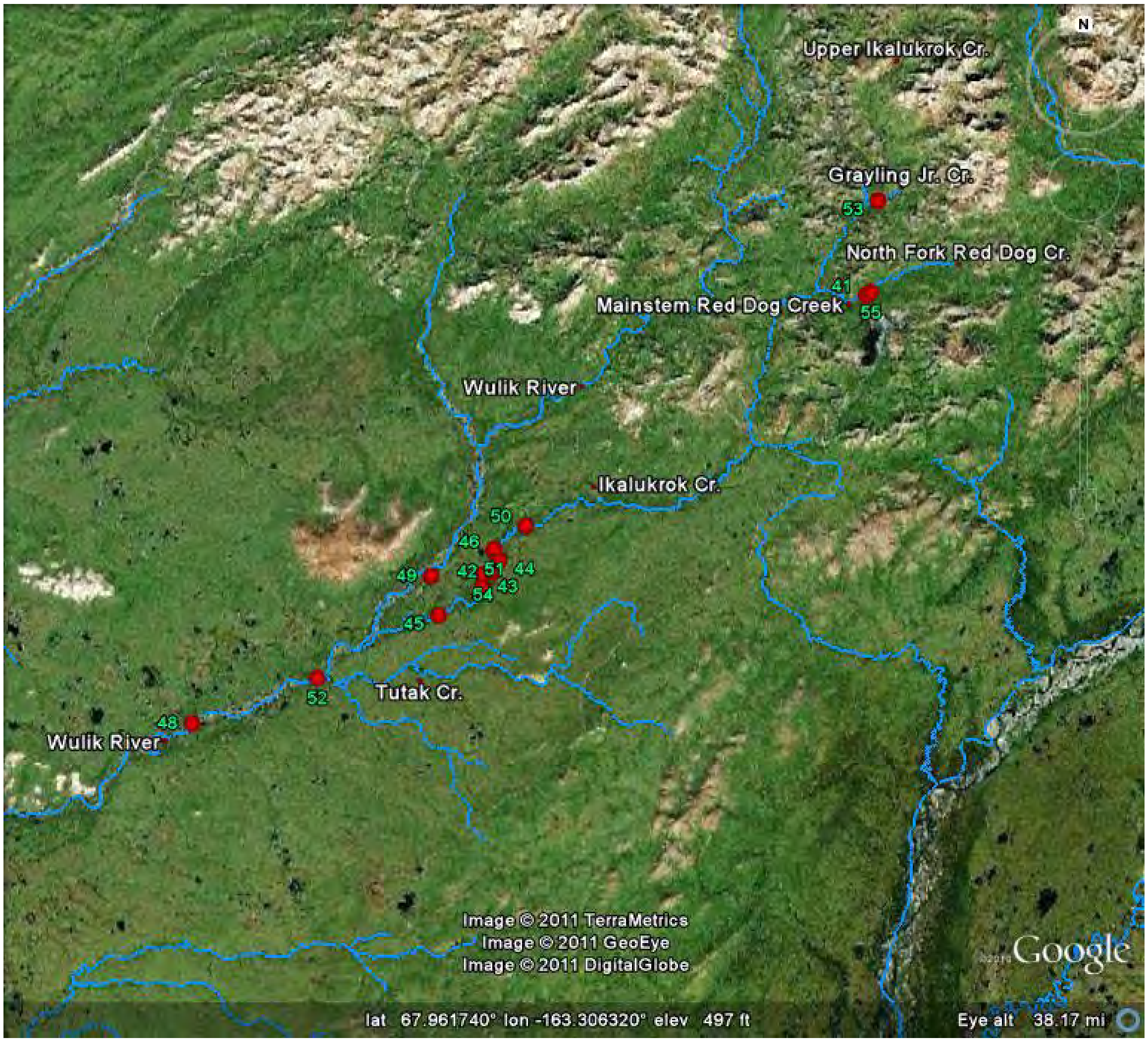

Figure 76. Radio tagged Arctic grayling on September 26, 2011.

On October 7, two Arctic grayling were in North Fork Red Dog Creek and one in Grayling Junior Creek. Three of the fish were in the Wulik River and eight were in lower Ikalukrok Creek (Figure 77).

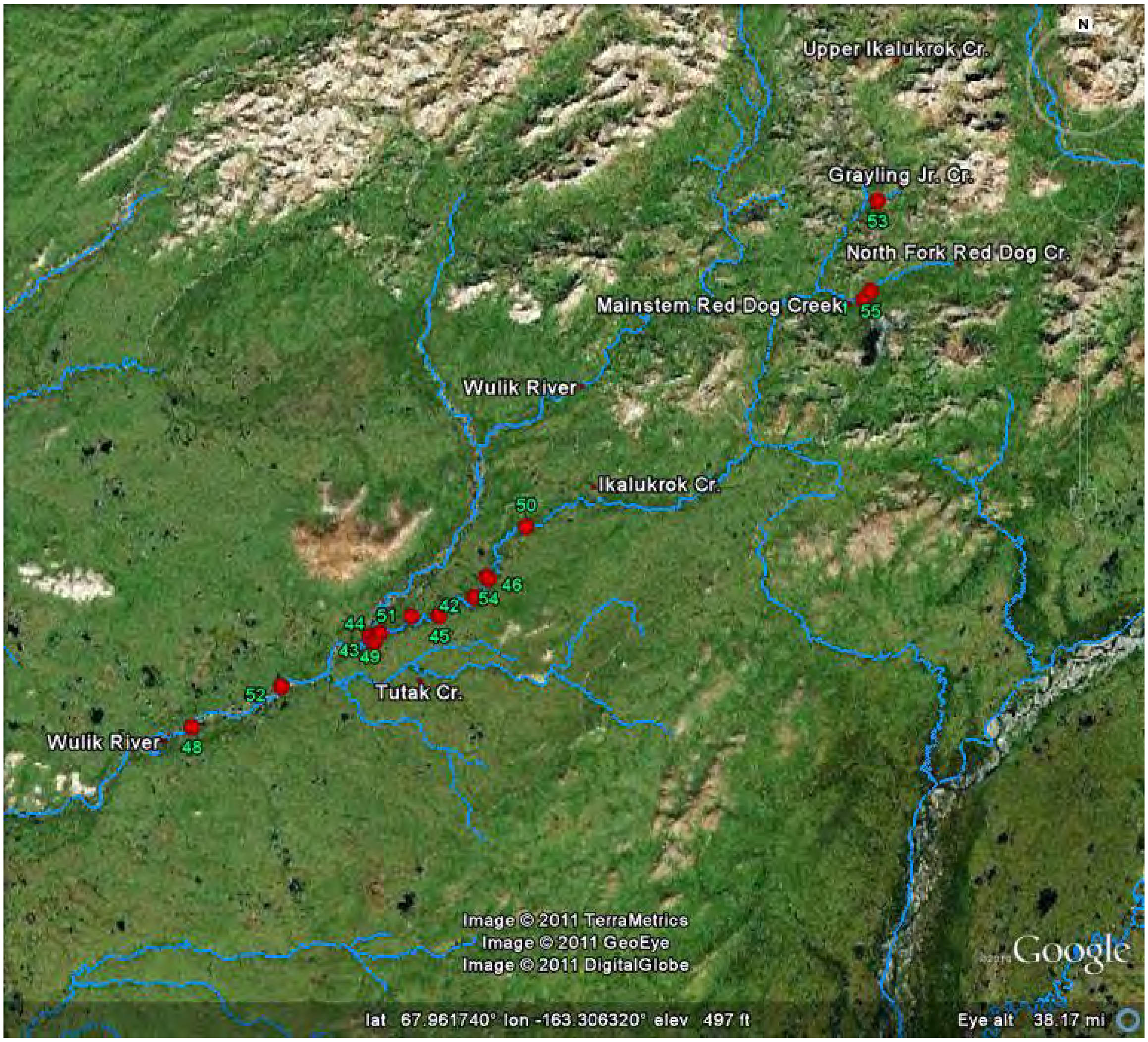

Figure 77. Radio tagged Arctic grayling on October 7, 2011.

On November 5, 2011, we relocated 14 radio tagged Arctic grayling (Figure 78). Two fish were in North Fork Red Dog Creek in the vicinity of the Gas Well Road in about the same location as in the October 7 survey. Another fish was relocated just below the falls in Grayling Junior Creek at the same location as in the October 7 survey. These 3 fish are assumed to be dead. If they are not dead, it is almost certain they will not survive the winter. Two Arctic grayling were relocated in lower Ikalukrok Creek, and the remaining nine were relocated in the Wulik River between the mouth of Ikalukrok Creek and 14 km downstream from the mouth of Ikalukrok Creek.

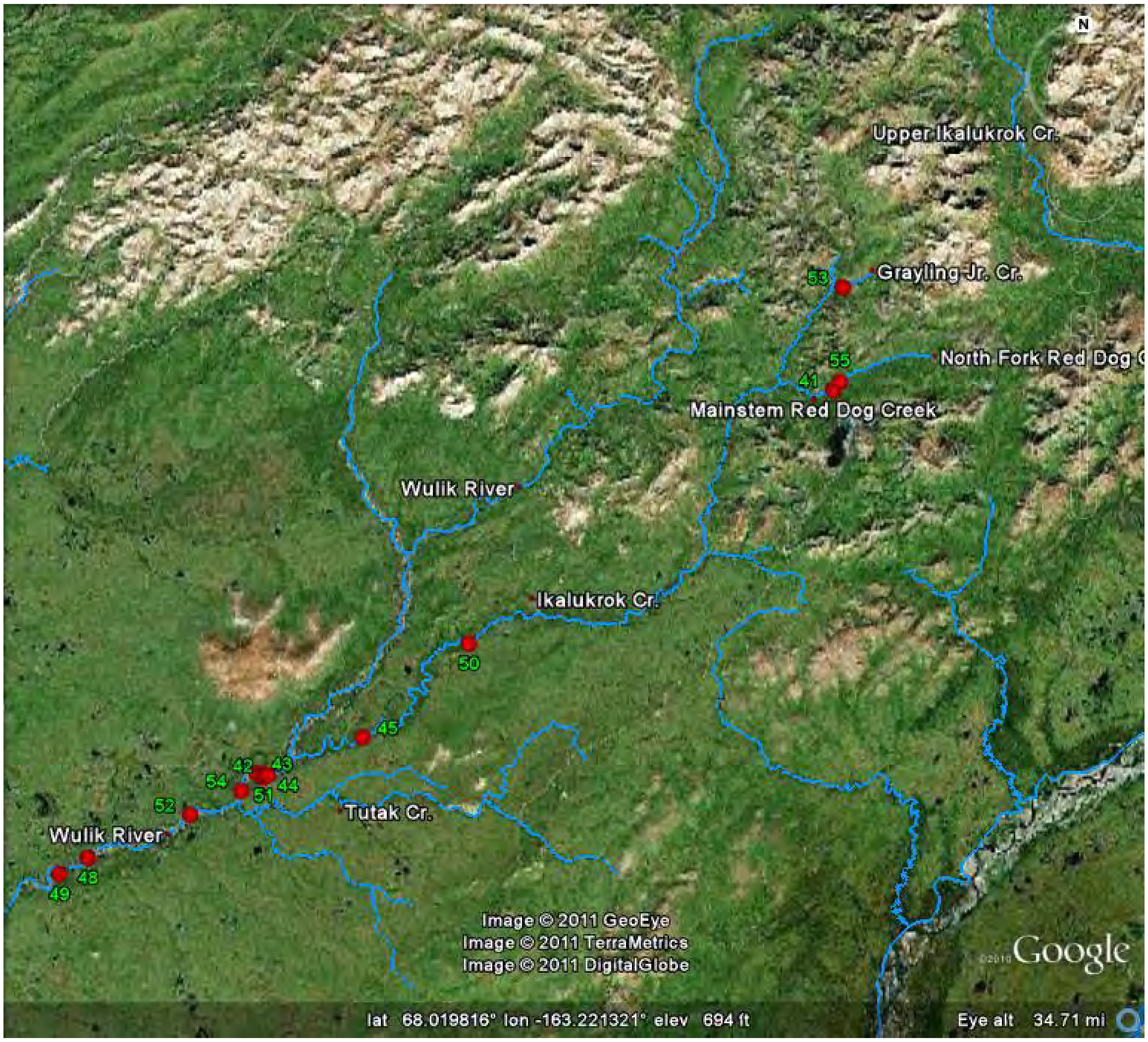

Figure 78. Radio tagged Arctic grayling on November 5, 2011.

Generally, Arctic grayling radio tagged in North Fork Red Dog Creek in early June, 2011, dispersed throughout Ikalukrok and North Fork Red Dog creeks post spawning. However, by September, most fish were in lower Ikalukrok Creek within a known chum salmon spawning area. Nine radio tagged Arctic grayling were relocated in lower Ikalukrok Creek in early October. By November 5, 2011, only two Arctic grayling were in lower Ikalukrok Creek – the rest were in the Wulik River. The majority of Arctic grayling radio tagged in North Fork Red Dog Creek appear to be overwintering in the

Wulik River. Figure 79 shows all relocations of radio tagged fish from July, September, October, and November 2011. On November 5 the Wulik River was substantially frozen (Figure 80).

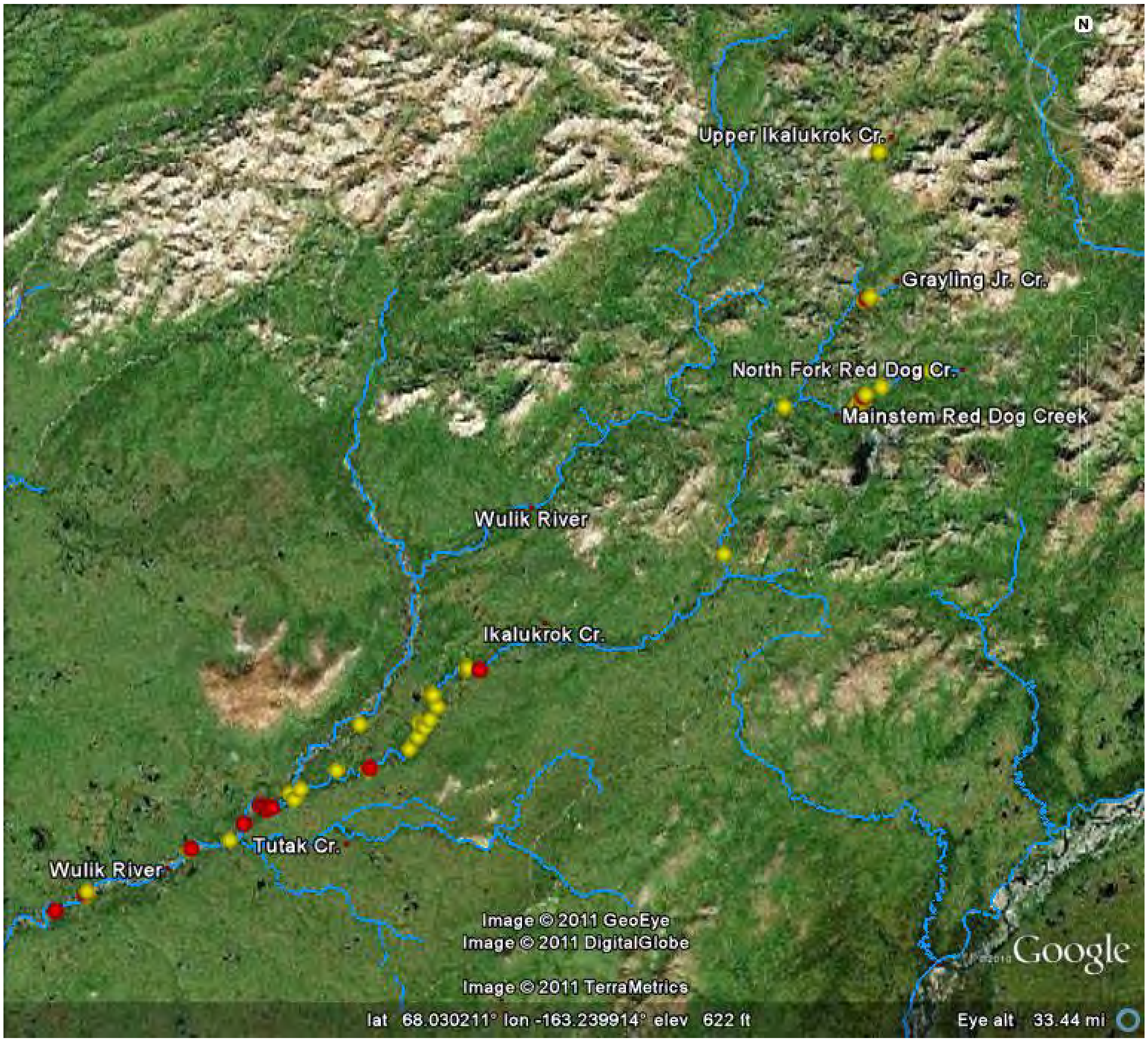

Figure 79. Map of radio tagged Arctic grayling relocations from July, September, October, and November, 2011. July through October relocations are in yellow and November relocations are in red.

Figure 80. The Wulik River looking at the confluence of Tutak Creek on November 5, 2011.

Arctic Grayling, Bons Pond

Bons Pond, is an impoundment created by construction of an earthen dam. The dam was built in 1987/1988 to provide potable and make-up water for operational activities. Prior to construction of the dam, there were no fish present in Bons Creek due to a series of impassable waterfalls and chutes in bedrock about 1 km downstream of the dam.

The Arctic grayling population in Bons Pond is the result of a fish transplant conducted in 1994 and 1995 (Ott and Townsend 2003). The 1994 transplant fish from North Fork Red Dog Creek ranged in size from 158 to 325 mm long (n=102, average 235, SD = 34) and included 5 large Arctic grayling from Ikalukrok Creek (350 to 425 mm long, average 376, SD =32). In 1995, about 200 fry were caught in North Fork Red Dog Creek and transported to Bons Pond. Bons Creek flows out of the pond via a channel excavated in bedrock. Bons Creek flows over a 20 m high falls into the creek – there is no upstream fish passage (Figure 81).

Figure 81. Outlet of Bons Pond into Bons Creek – Arctic grayling leaving Bons Pond go over the falls and into Bons Creek and some of these fish are recaptured in North Fork Red Dog Creek during the spring sample event.

Sampling conducted in 1996 and 1997 indicated that the transplant probably was not successful as we were unable to catch or observe any fish in Bons Pond. In summers 1995 to 1997, 12 of the marked Arctic grayling from Bons Pond were recaptured in North Fork Red Dog Creek. However, in 2001 and 2002, Arctic grayling juveniles were observed in Bons Creek immediately downstream of the blast road. In summer 2003, fish sampling was initiated in Bons Pond to determine the extent of fish use. The estimated Arctic grayling population in 2003 was 6,773 fish $\geq$ 200 mm long (Ott and Townsend 2003).

Since 2003, we have sampled Bons Pond and Bons Creek in the spring, with additional sampling later in the ice-free season to increase the number of marked fish. Spawning has been observed in Bons Creek and in the outlet of Bons Pond. Our current program in Bons Pond includes a mark/recapture study to estimate the population size and the collection of 15 juvenile Arctic grayling for whole body metals analyses.

Bons Creek, upstream of Bons Pond, is about 1 to 2 m wide with depths from 0.3 to 1 m. In our sample reach, located about 200 m upstream of Bons Pond, the substrate consists of gravel in riffles, with fine sediments and organics in the pools. Bons Creek is incised with streambanks vegetated with willows and sedges. Thermal and hydraulic erosion downstream of the diversion ditch placed to bypass non-mining impacted surface waters around the waste rock stockpile, located between the tailing back dam and Bons Creek, contributes seasonally to the sediment and organic load in the creek. Most of the drainage area upstream of our sample site is in ice-rich permafrost with thermal erosion and sediment/organic input varying with seasonal conditions. Generally, there is a high input of sediments and organics to Bons Creek, particularly during rainfall events.

Arctic Grayling Fry

In 2011, spawning success in Bons Pond and Bons Creek should have been low due to a late breakup. Fry were not observed in mid-July; however, we caught 2 fry in Bons Creek in the drift nets. We also made observations in Bons Pond outlet in late August and did not see any juvenile or fry Arctic grayling.

Arctic Grayling Catches and Metrics

On June 2, 2011, we set a fyke net in Bons Creek, about 200 m upstream of Bons Pond (Figure 82). We also sampled fish by angling in Bons Creek and Bons Pond. The catch of Arctic grayling (including recaptures) by angling was 10.4 fish/hour. The fyke net was fished from June 2 to 10 and was checked periodically. Our CPUE (fish/day) in the Bons Creek fyke net ranged from a low of 10 on June 4, 2011, to a high of 127 on June 7, 2011 (Figure 83).

Figure 82. Fyke net in Bons Creek in spring 2011. The off color water seen is indicative of the sediment and organic load in this creek.

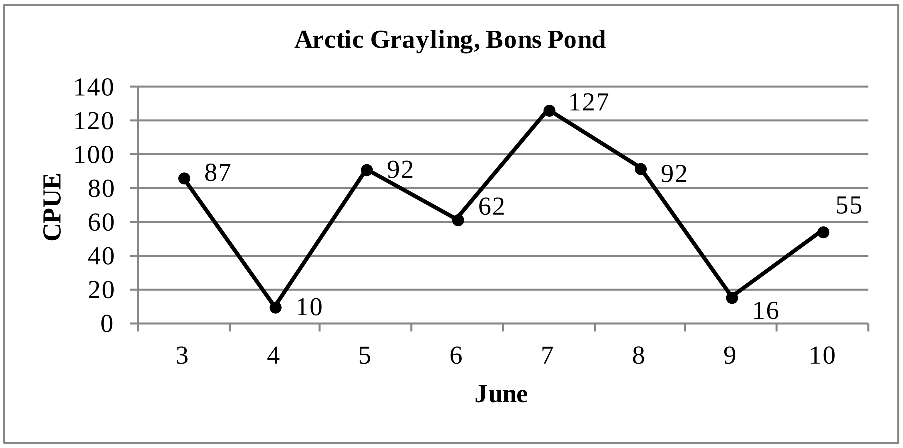

Figure 83. Catch per unit of effort (fish/day) in Bons Creek in a fyke net in June 2011.

We caught 474 Arctic grayling in Bons Creek and Bons Pond (does not include fish handled more than once). Most of the Arctic grayling (425) were caught in the fyke net, and 49 were caught by angling. Most Arctic grayling $\geq$ 250 mm in Bons Pond are mature. In contrast, Arctic grayling from North Fork Red Dog Creek are not mature until 350 mm (Figure 84).

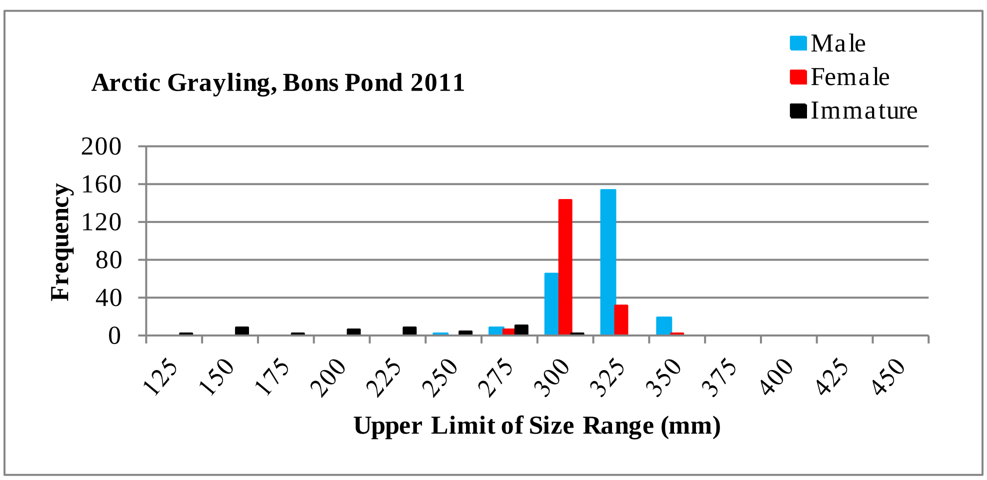

Figure 84. Length frequency distribution of Arctic grayling in Bons Pond in spring 2011.

The current population in Bons Pond consists of mature fish with limited numbers of juveniles suggesting limited spawning success and/or survival and low recruitment. In spring 2011, we caught 44 immature Arctic grayling. We only caught four Arctic grayling between 150 and 180 mm and thus decided to not retain a sample for whole body metal analyses.

Growth rates (spring to spring) were low and even the smallest fish did not exceed 11 mm annual growth (Figure 85). Growth rates for fish from Bons Pond are much less than for comparable sized fish from North Fork Red Dog Creek.

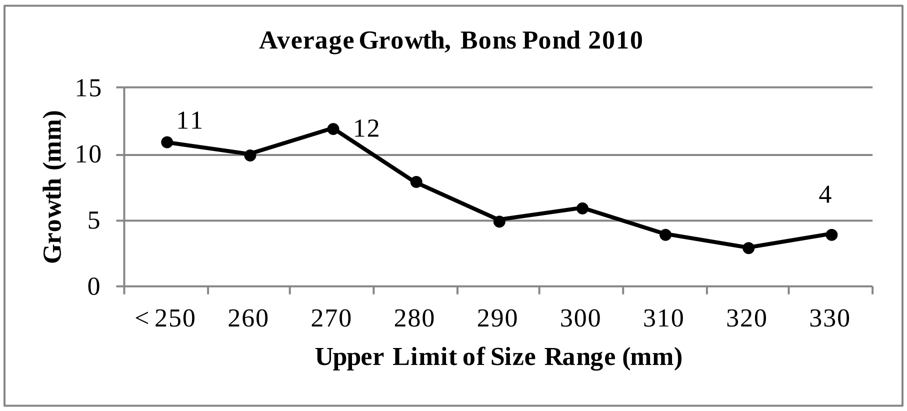

Figure 85. Individual growth of Arctic grayling from spring 2010 to spring 2011 in Bons Pond.

We estimated the Arctic grayling population in Bons Pond using 2010 as the mark event and spring 2011 as the recapture event. We had 381 marked fish seen in summer 2010. In spring 2011, we caught 448 Arctic grayling of which 96 were recaptures (fish observed in summer 2010). Our estimated Arctic grayling population is 1,767 fish $\geq$ 200 mm long (SD = 268 fish). The population estimates show a strong decreasing trend since the 2004 peak of 6,189 fish (Figure 86). However, estimates for 2008, 2009, and 2010 are similar indicating the population has stabilized or reached its low point somewhere around 2,000 individuals $\geq$200 mm.

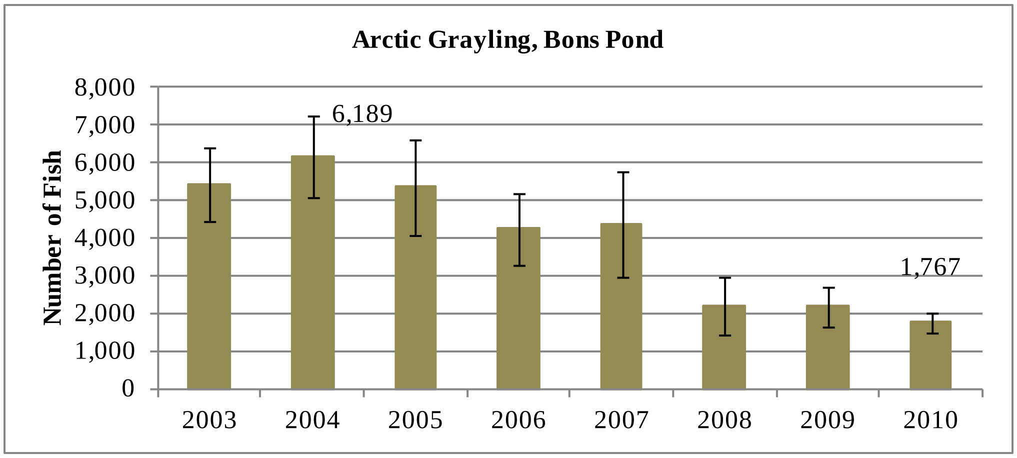

Figure 86. Estimated Arctic grayling population (± SD) in Bons Pond for fish ≥ 200 mm long.

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none were observed or caught in the Red Dog Creek drainage. In 1995, we caught slimy sculpin in Mainstem Red Dog and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Slimy sculpin are infrequently caught in the Red Dog Creek drainage; however, we did catch three large slimy sculpin (133, 129, and 132 mm) in spring 2008 and 4 large slimy sculpin (132, 134, 136, and 142 mm) in spring 2009 in the North Fork Red Dog Creek fyke net. In spring 2010, we caught one slimy sculpin (88 mm) in North Fork Red Dog Creek and in spring 2011 no slimy sculpin were captured.

The minnow trap catch per unit of effort (CPUE is for 10 traps for one sample period of 24 hr) since 1997 is presented in Figure 87 for Mainstem Red Dog Creek in the vicinity of Station 10. There is no apparent trend with CPUE varying from 0 to a high of 5 slimy sculpin in fall 2009.

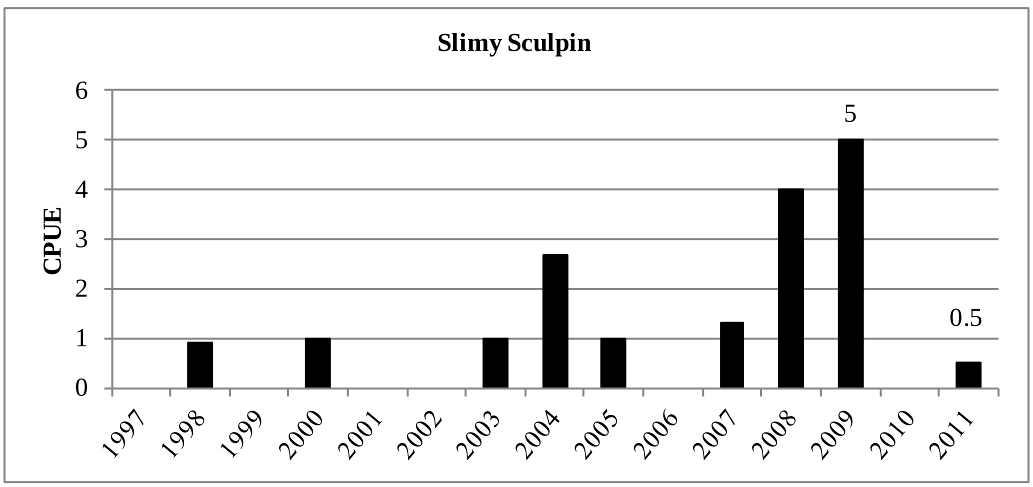

Figure 87. Slimy sculpin caught in Mainstem Red Dog Creek at the sample reach in the vicinity of Station 10 near the mouth of the creek.

In 2010, we moved our minnow trap sample reach from Station 7 in Ikalukrok Creek (just below Dudd Creek) to Ikalukrok Creek just upstream of Station 160. The new sample site in Ikalukrok Creek is similar to Station 7 in that there are multiple channels in this reach of Ikalukrok Creek. The CPUE has varied from a low of 0 to a high of 21.8 in

2003 and 2004 (Figure 88). Catches of slimy sculpin generally are higher in Ikalukrok Creek than in the other sample reaches, particularly in Ikalukrok near the mouth of Dudd Creek. These data are consistent with findings by Houghton and Hilgert in the early1980s prior to development of the Red Dog Mine when they reported slimy sculpin to be numerous in Ikalukrok Creek but not in the Red Dog Creek drainage.

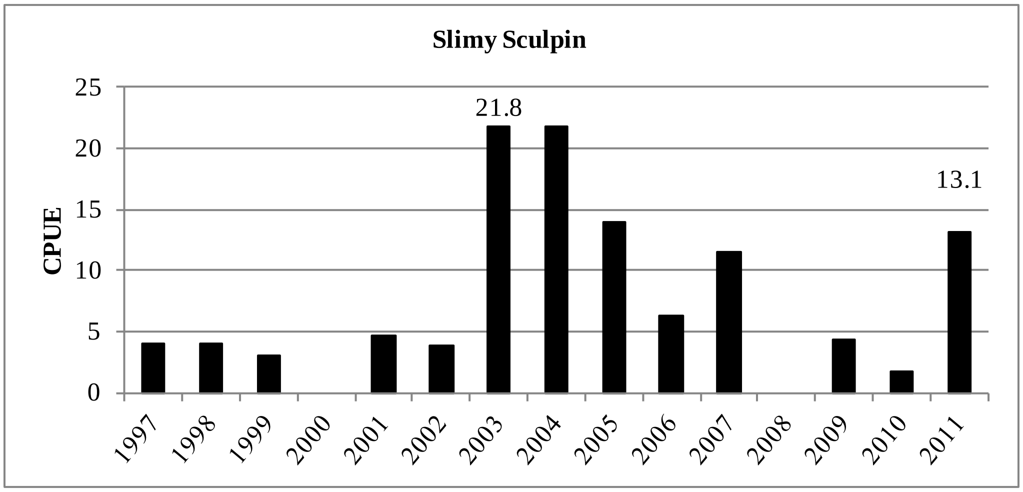

Figure 88. Slimy sculpin caught in Ikalukrok Creek at Station 7 (1997 to 2009) and Station 160 (2010 to 2011).

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Appendix 1. Summary of Mine Development and Operations

1982

●Baseline studies initiated, Cominco agreement with NANA finalized

1983

●EIS process initiated, alternatives for mine and road to port site identified

1984

●Stream surveys conducted along proposed road by private consultant

1985

●Permit applications prepared for regulatory agencies
●Implementation of wastewater treatment plant deferred to ADEC by ADF&G
●Wastewater discharge limited to summer
●Potential for acid rock drainage and metals mobilization not recognized

1986

●ADEC solid waste permit and bonding not required
●ADEC permit preceded solid waste regulations
●AIDEA bonds to build road and port site issued

1987

●Construction of road began, budget request to AIDEA prepared by ADF&G
●Reimbursement agreement for logistics with ADF&G to monitor construction made by AIDEA

1988

●Ore body developed
●Road and port site construction began
●Notice of Violation issued to AIDEA by ADF&G for failed road crossing bypasses
●Uniform Summons and Complaint issued for illegal water removal
●AIDEA provided funding to ADF&G for monitoring
●Rehabilitation plans for streams developed and implemented

Appendix 1 (continued)

1989

●Agreement to close-out old solid waste site finalized with Cominco
●Civil work on ore body and surface water drainage control begun
●Complaints about water quality in Ikalukrok Creek received
●Tailing dam becomes full, Cominco's request to siphon untreated water over the dam denied by State
●Elevated metals concentrations identified by red precipitation, were observed in Ikalukrok Creek below the mine
●Winter discharge of treated water authorized by State
●State regulatory agencies and Cominco in disagreement over whether metals exceeded background conditions

1990

●Biomonitoring of fish populations proposed and initiated by ADF&G
●Dead fish from the Wulik River were discovered by the public
●ADF&G sampling indicated very few fish remaining in Ikalukrok Creek
●Installation of sumps and pumps by Cominco prevented metals-laden water from entering Red Dog Creek
●Baseline and current water quality data reviewed by ADF&G
●Clean water bypass system requested by ADF&G
●Zinc levels in Ikalukrok Creek exceeded 40 mg/L
●State regulatory agencies and Cominco in disagreement over cause and extent of water quality problems
●Compliance Order by Consent for water quality violations affecting anadromous fish issued by ADEC
●Notice of Violation for water quality violations affecting anadromous fish issued by ADF&G
●Cominco directed to design and construct a clean water bypass system
●Perceived impairment to the subsistence fishery initiated involvement by the community of Kivalina

1991

●Clean water bypass system designed by Cominco, approved by state agencies
●ADF&G fisheries study funded by Cominco
●Clean water bypass system built
●Clean water bypass system repaired
●Improvements to water quality were documented

Appendix 1 (continued)

1992

- ●Fish study continued
- ●Water quality improvements to downstream receiving water continued
- ●Increasing water volume in tailing impoundment continued
- ●Water from dirty water collection system entering tailing impoundment increased volume
- ●Water treatment plant modifications made

1993

- ●Fish study continued
- ●Sand filters to remove particulate zinc installed

1994

- ●Fish study continued
- ●Use attainability studies of several streams initiated for reclassification
- ●Water treatment capacity increased by thickening tank conversion
- ●Wastewater discharge increased from 7.5 cfs to 23 cfs
- ●Ore processing capability expanded by Cominco
- ●107 juvenile and adult Arctic grayling transplanted from North Fork Red Dog Creek to Bons Pond in late June
- ●79 juvenile Dolly Varden transplanted from Anxiety Ridge Creek to Bons Pond in late June

1995

- ●Fish study expanded to include other aquatic biota
- ●Work on stream reclassification and site-specific criteria continued by ADF&G
- ●Metals concentrations in the clean water bypass system increased; contributing sources were identified: Hilltop Creek (Zn), Shelly Creek (Cd), and Rachel Creek (Al)
- ●Clean water bypass system extended to collect water from Hilltop Creek
- ●Reserves were doubled after exploration drilling located more ore
- ●Possible metals contamination in Bons Creek identified by ADF&G
- ●About 200 Arctic grayling fry (40 to 45 mm) were moved from North Fork Red Dog Creek to Bons Pond in August

1996

- ●Public notice for stream reclassification sent out
- ●Bons Creek water samples from above and below the Kivalina shale dump collected
- ●Fish and aquatic biota study continued

Appendix 1 (continued)

1997

●Stream reclassification incorporated into regulation (18 AAC 70.50)
●Fish barrier constructed across Middle Fork Red Dog Creek
●Water bypass around the Kivalina shale dump and interceptor trench at the head of the tailing impoundment built
●Gray-white precipitate observed in Middle Fork Red Dog Creek
●Heavy red staining and precipitate seen in Ikalukrok Creek; originated from seep near headwaters of Ikalukrok Creek, located upstream of mining activity
●Laboratory experiments of TDS on egg fertilization and early egg development initiated
●Fish and aquatic biota studies continue
●US EPA brings enforcement action for water quality violations; Cominco initiates Supplemental Environmental Projects
●Two-year aquatic community study in upper Ikalukrok Creek, above and below the Red Dog Mine discharge initiated by ADF&G
●Ground water monitoring wells installed and monitored below tailing dam by Cominco

1998

●Wet fertilization studies to test effects of TDS on fish embryos continued
●Draft 401 certification for a new NPDES permit prepared by ADEC and reviewed by ADF&G
●Discussed extension of the clean water bypass system up Shelly and Connie Creeks to ensure bypass of clean water and collection of seepage water from newly disturbed areas
●Heavy red staining in headwaters of Ikalukrok Creek, originating from seep in headwaters of Ikalukrok Creek, upstream of mining activity, staining extends downstream about 30 km
●Site-specific criteria for Zn in Mainstem Red Dog and Ikalukrok Creeks approved by EPA
●Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
●Plans to increase port site capacity for direct loading of ships released to public
●NPDES permit (AK-003865-2) issued by US EPA became effective August 28, 1998 and was certified by ADEC (Certificate of Reasonable Assurance)
●Two-year aquatic community study completed
●Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

Appendix 1 (continued)

1999

●Two-year drilling program (Shelly and Connie Creeks) proposed
●New station 7 on Ikalukrok Creek established by Cominco, USGS, and ADF&G
●Fish and aquatic biota study expanded to upper North Fork Red Dog, Ikalukrok, and Ferric creeks
●Biomonitoring and USGS gauging work proposals submitted to Cominco
●Study of periphyton communities exposed to different concentrations of TDS in Mainstem Red Dog Creek done by ADF&G and Cominco Alaska Inc.
●Request to increase TDS for periphyton colonization experiment not approved
●Effects to Ikalukrok Creek from Alvinella Creek seepage water continued to below Dudd Creek mouth
●Arctic grayling females in ripe spawning condition collected from North Fork Red Dog Creek for selenium analysis of livers and ovaries

2000

●Effects to Ikalukrok Creek from Cub Creek seep continued; red stain and precipitate observed several km below mouth of Mainstem Red Dog Creek
●North Fork Red Dog Creek silty at breakup, previously not observed
●Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall observed
●Civil work performed in Connie Creek to isolate surface from subsurface flows and bypass flow through disturbed areas
●Effectiveness of pump back system at the Kivalina rock dump verified by presence of juvenile Arctic grayling in creek immediately south of dump
●Site-specific criteria for TDS requested by Cominco
●Biomonitoring study continued
●Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect begun

Appendix 1 (continued)

2001

●Effects to Ikalukrok Creek from Cub Creek seep continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
●North Fork Red Dog Creek, siltation (natural) less than in summer 2000
●Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall
●Water quality was monitored in Shelley, Rachel, Connie, and Middle Fork Red Dog creeks upstream and downstream of surface disturbance, catch-box and pipeline (about 430 m) placed in Shelley Creek to move water pass disturbance
●Juvenile Arctic grayling observed in Bons Creek just south of the Kivalina rock dump, pump-back system working based on fish use
●Fish weir repairs made during 2000, no problems observed in 2001
●Stream survey of cross drainage structures made along the Delong Mountains Transportation System, some minor work at some crossings identified
●Site-specific criteria for TDS still being worked, data on Arctic grayling spawning/water temperature collected in North Fork Red Dog and Mainstem Red Dog creeks, supplemental data gathered at the Ft. Knox mine
●Studies expanded to include the Delong Mountains Transportation System based on a National Park Service report that metals concentrations adjacent to road were elevated, water sites established upstream and downstream of road and sampled by Teck Cominco, juvenile Dolly Varden samples collected in Omikviorok River and Aufeis Creek, vegetation sampling started by Teck Cominco
●New haul trucks brought on site, hard-covered trucks to minimize loss of zinc and lead concentrates during transport
●Exploratory drilling (ore and shallow gas) continued, focus on North Fork Red Dog Creek and Wulik River basins near Anarraaq and Lik, including west of the Wulik River, another ore prospect found northwest of Anarraaq, shallow gas results promising
●State and Teck Cominco agree to start the state's large mine team to work on issues, key issue identified was development of a solid waste permit with bonding for the tailing dam, other issues include site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
●Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect continued for the second field season, four new sites added (tributaries on west side of Wulik in the area of the Lik Deposit and potential shallow gas development)

Appendix 1 (continued)

2002

●Effects to Ikalukrok Creek from Cub Creek seep continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek

●North Fork Red Dog Creek, siltation minor during summer 2002

●Minor precipitate in Middle Fork Red Dog Creek below effluent outfall

●Fish weir operating as designed

●Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox

●Pit expansion continues to the north of the clean-water bypass system, road crossing added for access

●A bypass was installed for Connie Creek during winter 2001/2002. The bypass captures the upstream creek and carries the water in a pipe to the clean-water bypass system

●The bypass system for Shelly Creek was modified during summer 2002 to correct an overflow problem that occurred during breakup (the overflow water was captured in the pit and did not affect downstream waters). The modification involved adding a lined ditch to contain overflowing clean water and direct the water to the clean-water bypass system

●Juvenile Dolly Varden collected at eight sites located upstream and downstream of the Delong Mountains Regional Transportation System, whole body metals analyses for Cd, Pb, Se, and Zn

●Site-specific criteria for total dissolved solids is still being worked

●State and Teck Cominco continue to work on key issues, e.g., solid waste permit with bonding for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)

●Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect and shallow gas exploration

●Arctic grayling adults remained in North Fork Red Dog Creek through early August, only the second time since 1992 that most of the adults stayed in the creek during summer, most years adults outmigrate shortly after spawning in spring

●Arctic grayling adults present in Buddy Creek just below the falls, about 50 adult fish in sample reach (0.3 km) in early July, all gone by early August

●About 50 to 60 adult Dolly Varden in Ikalukrok Creek at mouth of Dudd Creek from early July through late August

●Effluent discharge ceased on October 5, 2002, to allow time to winterize the water treatment plant

Appendix 1 (continued)

2003

●Effects to Ikalukrok Creek from Cub Creek seep continued but were much less than seen in the last two to three years

●North Fork Red Dog Creek, natural siltation throughout most of the summer was minor in summer 2003

●Minor precipitate in Middle Fork Red Dog Creek below effluent outfall

●Fish weir operating as designed

●Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox

●Site-specific criteria for total dissolved solids was finalized

●USEPA modified the NPDES effective August 22, 2003, to incorporate the ADEC Site Specific Criteria and mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks with conditions that ensure total dissolved solids are at or below 500 mg/L during Arctic grayling spawning in Mainstem Red Dog Creek and during chum salmon and Dolly Varden spawning in Ikalukrok Creek, the modified permit was appealed by the Kivalina Relocation Planning Committee

●State and Teck Cominco continue to work on key issues, e.g., solid waste permit with financial assurance for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)

●Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adult Arctic grayling seen in the Ikalukrok Creek drainage was the lowest seen since aerial surveys were begun in the late 1990s

●Arctic grayling population estimate was completed for Bons Pond the site of a fish transplant made in 1994 and 1995, estimated population in the reservoir was 6,773

●Modification to Shelly Creek bypass ditch completed, a better designed and constructed lined ditch was built and commissioned in August, 2003

●A permanent lined ditch was constructed parallel to the Connie Creek diversion pipeline to avoid spring freeze-up issues

●A permanent monitoring station was established at the end of the mixing zone in Mainstem Red Dog Creek, the location designation is Station 151, and is fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system

●Station 150, at the end of the mixing zone in Ikalukrok Creek, was fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system

Appendix 1 (continued)

2004

●Wastewater discharge began on May 20, ended on September 26, total discharge about one billion gallons
●Effects to Ikalukrok Creek from Cub Creek seep continued but were minor
●North Fork Red Dog Creek, natural siltation minor during ice-free season
●Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
●Fish weir operating as designed
●Arctic grayling spawning/water temperature data collected, Arctic grayling from North Fork Red Dog Creek used for TDS fertilization experiment
●State and Teck Cominco continued to work on key issues associated with the solid waste permit and closure plan for the mine
●Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adults seen in Ikalukrok Creek drainage remained low as in summer 2003
●Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2003 was 6,773 and for summer 2004 was 5,739
●Chinook salmon juveniles were documented for the first time in Ikalukrok Creek, near Dudd Creek, and in Anxiety Ridge Creek
●Age-1 Arctic grayling were caught in minnow traps fished in Ikalukrok, Mainstem, and Buddy creeks, since age-1 fish are seldom captured in minnow traps this may indicate good survival of fry spawned in spring 2003
●Red Dog Creek diversion (clean water ditch) was realigned to the west side of the pit. Realigned configuration is a combination of large diameter culvert and open lined ditch

2005

●Wastewater discharge began on May 10, 2005, ended on October 6, 2005, total discharge about 1.501 billion gallons
●Major precipitate observed on streambed in Middle Fork Red Dog Creek below effluent outfall in July and August, precipitates (gray colored) evident for at least 1 km downstream of effluent outfall
●Fish weir operating as designed
●Effects to Ikalukrok Creek from Cub Creek seep substantially greater than seen for past several years, water opaque and streambed coated with red precipitate at confluence with Mainstem Red Dog Creek, TCAK water sample from Cub Creek seep with a pH of 3.3
●Arctic grayling spawning/water temperature data collected, Arctic grayling from North Fork Red Dog Creek used for TDS fertilization experiment
●Attended and participated in a NPDES permit renewal meeting in Seattle with EPA, TCAK, and NANA, identified and discussed key issues

Appendix 1 (continued)

2005

- ●Red Dog Creek diversion (clean water ditch) mine engineering drawings (r4) were provided by TCAK showing the culverts and lined ditch that carry water from tributaries and Middle Fork Red Dog Creek through the pit area
- ●Recommendations for changes to the Red Dog biomonitoring program based on field data collection and analyses since 1999 were made for possible incorporation into the renewed NPDES permit or ADEC's solid waste permit for the tailing impoundment
- ●TCAK distributed the 2005 draft report on Arctic grayling fertilization studies that concluded TDS concentrations at or below 1,500 mg/L at Station 10 in Mainstem Red Dog Creek would provide for proper protection of Arctic grayling in the Red Dog Creek drainage, OHMP supported these findings in a letter to Pete McGee (ADEC) dated August 17, 2005
- ●Dr. Weber Scannell prepared comments on fish tissue data (Dolly Varden from Wulik and Kivalina rivers) collected by Maniilaq Association and compared these data with existing information from other sources in both Alaska and nationwide
- ●OHMP prepared a summary report (letter to Jim Kulas dated August 23, 2005) on temperature/spawning data collected for Arctic grayling in Mainstem Red Dog and North Fork Red Dog creeks from 2001 through 2005, a recommendation for determining start and completion of spawning based on temperature was developed for Mainstem Red Dog Creek
- ●State and TCAK continued to work on key issues associated with the solid waste permit and closure plan for the mine ADEC
- ●Wastewater Treatment Plant (WTP) #3 began operations in late summer 2005 to treat mine sump water and drainage from waste rock dumps prior to placement of these waters into the tailing impoundment; purpose is to improve water quality in tailing impoundment over time
- ●Exploratory drilling and flow testing for gas in North Fork Red Dog Creek basin was conducted, access road and pads inspected, corrugated pipes installed to provide cross drainage, no evidence of erosion noted along road to and connecting the drill pads
- ●A road was constructed to Station 151 (end of mixing zone in Mainstem Red Dog Creek
- ●Work to expand and relocate the water treatment plant sand filters was initiated
- ●Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2003 was 6,773 - for summer 2004 was 5,739 – and for summer 2005 was 5,356

Appendix 1 (continued)

2006

●ADEC amended the site-specific criteria (SSC) for TDS in Mainstem Red Dog Creek, the 500 mg/L limit during Arctic grayling spawning was removed and replaced with a 1,500 mg/L limit on February 15, 2006, and EPA approved the new SSC in April 2006

●North Fork Red Dog Creek, extensive areas of aufeis existed, turbidity and organic debris high due to erosion and thermal degradation, in several reaches flow was not in stream channel due to aufeis

●Arctic grayling spawning/water temperature data collected, early spring warming followed by cold weather, adult Arctic grayling entered North Fork Red Dog Creek in late May and due to cold water temperatures abandoned spawning and outmigrated from the creek in mid-June

●Four Arctic grayling captured in North Fork Red Dog Creek in spring 2006 were fish that had been marked in Bons Pond

●Review of ADEC's draft 401 certification to the renewal of the NPDES was completed and we provided a letter of support (March 10, 2006) to ADEC, including our concurrence with ADEC's decision to not require Whole Effluent Toxicity (WET) limits

●Effects to Ikalukrok Creek from Cub Creek seep continued, but were minor

●Major precipitate observed on streambed in Middle Fork Red Dog Creek below effluent outfall in August, precipitates (orange colored) evident for at least 1 km downstream of effluent outfall and precipitates continued upstream through the clean water bypass to Connie and Rachel creeks

●Fish weir operating as designed

●Work continued on the design for the Red Dog tailing backdam, the dam will be located on the south side of the tailing pond and will be constructed of earth fill with a concrete/soil aggregate/bentonite cutoff wall, the dam will be constructed to a final height of 986 ft., construction anticipated during 2006 and 2007

●In July, windrows of dead capelin were documented at the Port Site, die off after spawning is normal, only a small percentage survive spawning

●Total count of chum salmon in Ikalukrok Creek on August 16 was 4,185, the highest number reported since 1990

●In 2006, slightly elevated Zn concentrations persisted and TCAK initiated a field investigation comprised of sampling along the clean water bypass, although not definitive, results indicated that the Mine Sump might have been the source of increased Zn concentrations, modifications were made in operational procedures to ensure containment of contaminated waters in the Mine Sump

●Bons Pond (the site of a fish transplant made in 1994 and 1995), estimated Arctic grayling population for summer 2006 was 4,249

Appendix 1 (continued)

2007

●ADEC issued the Certificate of Reasonable Assurance for NPDES Permit AK-003865-2 on February 12, 2007. EPA issued the proposed NPDES permit for the Red Dog Mine discharge on March 7, 2007. Both actions were appealed and on September 28, 2007, EPA signed the NPDES Permit withdrawal. EPA intends to reissue the NPDES Permit upon completion of the Supplemental EIS for Aqqaluk Extension. In the interim, TCAK will operate under the 1998 NPDES Permit
●OHMP completed Technical Report No. 07-04 which summarized aquatic biomonitoring in Bons and Buddy creeks from 2004 to 2006. OHMP recommended that aquatic biomonitoring at four sites in Bons and Buddy Creeks and field work to estimate the Arctic grayling population in Bons Pond continue
●On May 17, 2007, ADNR issued the Certificate of Approval to Construct a Dam Red Dog Back Dam (AK00303)
●On May 24, we notified EPA that open flow existed in North Fork and Mainstem Red Dog creeks. TCAK received written permission from EPA to begin discharge from Outfall 001 and discharge was initiated on May 25
●Two fyke nets were fished in North Fork Red Dog Creek in spring 2007 to determine when Arctic grayling spawning was finished. Based on net catches, observed spawning activity in Mainstem Red Dog Creek, outmigration of mature fish from Mainstem Red Dog Creek as observed on June 3, and the lack of any spawning activity in Mainstem Red Dog Creek on June 3, OHMP determined that spawning was completed on June 2
●On June 6, EPA notified TCAK that the TDS load in Mainstem Red Dog Creek could be increased to 1,500 mg/L due to the fact that Arctic grayling spawning was complete
●Seven Arctic grayling captured in North Fork Red Dog Creek in spring 2007 were fish that had been marked in Bons Pond. Recruitment of Arctic grayling to North Fork Red Dog Creek from the Bons Pond population is occurring
●Fish weir, on Middle Fork Red Dog Creek, is operating as designed
●Arctic grayling spawning success, as determined by presence of fry, was very good in 2007 due to early spawning, low water following spawning for most of the summer, and warm water temperatures. Numerous fry were seen in North Fork Red Dog, Mainstem Red Dog, Ikalukrok, and Bons creeks. Arctic grayling fry in mid-August average 64 mm long (n = 26, 58 to 71 mm, SD = 3.1)
●Middle Fork Red Dog Creek contained an orange, tan colored precipitate that extended both above and below the waste water discharge point and was visible downstream to the fish weir

Appendix 1 (continued)

2007

●Our two estimates for adult chum salmon in Ikalukrok Creek (downstream of Station 160) were 1,408 and 1,998 along with about 100 adult Dolly Varden and 8 Chinook salmon

●Work on a Supplemental EIS for the Aqqaluk Extension project began with a draft scoping document in August, public meetings in early October, and draft alternatives scoping in December

●TCAK continued to make improvements to the mine's clean water bypass system. In October, galvanized culvert was installed replacing sections of HDPE lined ditch in Middle Fork Red Dog Creek upstream of Shelly Creek and continued upstream to the Rachel Creek confluence. In addition, the section of HDPE lined ditch in Connie Creek was converted to culvert as well

Appendix 1 (continued)

2008

●Work on the SEIS for the Aqqaluk Extension continued during 2008. Input via the State's LMPT coordinator was made periodically with emphasis on the alternatives being considered, the aquatic biology background section, and the monitoring plan for both the Red Dog and Bons/Buddy Creek drainages
●On May 5, 2008, we distributed copies of our technical report titled "Aquatic biomonitoring at Red Dog Mine, 2007 National Pollution Discharge Elimination System Permit No. AK-003865-2" covering work done in summer 2007
●On May 13, 2008, we notified ADEC that based on information provided by TCAK that open water flow existed in North Fork Red Dog, Mainstem Red Dog, and Ikalukrok creeks and that wastewater discharge could commence under the conditions of state and federal permits
●On May 28, 2008, TCAK reported to EPA that TDS on May 16 exceeded the permit limits in effect at the time of the discharge
●In spring 2008, Kivalina residents and NANA collected a number of adult Dolly Varden in the Wulik River and planned to have the fish analyzed for metals by Columbia Analytical Lab. Input regarding sampling protocol for adult Dolly Varden was provided to TCAK and NANA on June 6
●June 24, 2008, we reported to TCAK the successful completion of spring work on Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks and Bons Creek/Bons Pond. In spring 2008, we had at least three age classes of immature fish present in our North Fork Red Dog Creek sample and 18% of these recaptures were fish originally marked in Bons Pond. Our estimated population of Arctic grayling in Bons Pond for summer 2007 was 4,363 fish ≥ 200 mm
●On July 9, 2008, we participated in a teleconference with TCAK and Tetra Tech (contractor for the Aqqaluk SEIS) to discuss the potential impacts to Mainstem Red Dog Creek if the wastewater discharge was moved to the ocean. A short narrative describing possible changes to Mainstem Red Dog Creek was prepared and distributed
●On July 16, 2008, ADF&G sent a letter to TCAK that summarized results of our early July field work when we sampled periphyton, aquatic invertebrates, and fish at the NPDES and ADEC sample sites
●In early August, 2008, ADF&G Commissioner Denby Lloyd spent several days at Red Dog that included a briefing, tour of mine facilities, and an overflight of the project area including Ikalukrok Creek, Wulik River, Port Site, and the haul road from the port to the mine

Appendix 1 (continued)

2008

●On August 13, 2008, ADF&G sent to TCAK a summary of fish work done in early August. Using a helicopter, we estimated 3,820 chum salmon in Ikalukrok Creek on August 6 – one of our highest counts since surveys began in 1990
●On August 21, 2008, ADF&G sent to TCAK a summary of Arctic grayling spawning in Mainstem Red Dog and North Fork Red Dog creeks that covered from 2001 to 2008. The report includes a temperature-based criterion for determining when the majority of Arctic grayling spawning in Mainstem Red Dog Creek is substantially complete
●On September 3, 2008, a settlement was reached between all five plaintiffs residents of Kivalina and TECK on a lawsuit that alleged violations of the mine's NPDES permit. On October 23, 2008, a Consent Decree was entered with the Department of Justice as required under a CWA lawsuit. Principle to the agreement was a commitment (barring certain requirements) by TECK to design, permit and construct a pipeline to carry treated mine effluent to the ocean
●TCAK prepared and submitted on August 26, 2008, a draft Fugitive Dust Risk Management Plan
●On October 3, 2008, ADF&G sent by letter to TCAK results of the fall Dolly Varden overwintering survey in the Wulik River. Overall the count of Dolly Varden was lower than in the recent past; however, it was noted that very few small fish (first year migrants) were present. More chum salmon (16,215) were seen from Sivu to Driver's Camp – more chum salmon than have been seen before
●TCAK prepared and submitted a draft monitoring plan for state agency review in early November 2008. The objective is to develop one comprehensive monitoring plan for all state and federal permits pertaining to the mine site as defined by the ambient air boundary. In November and December, we provided input to the States LMPT on the monitoring plan which when completed will be incorporated by reference into the 401 Certification and the ADEC Waste Management Permit
●Adult Dolly Varden and juvenile Dolly Varden for selected metals analyses were prepared and sent to Columbia Analytical Laboratory in mid-November
●November 24, 2008, the SEIS for Red Dog Aqqaluk Extension was released by EPA for public review
●On December 22, 2008, we received a CD for the Red Dog Mine Closure and Reclamation Plan – the final draft for agency review. The closure and reclamation plan are the result of over six years of work by TCAK in consultation with state and federal agencies and the public

Appendix 1 (continued)

2009

●Continued to review and provide comments on the SEIS for the Red Dog Aqqaluk Extension project with emphasis on the monitoring plan prepared by Teck that covers both the Bons/Buddy Creek and Red Dog Creek drainages
●During 2009, Teck continued construction of the back dam/cutoff wall and the next raise of the main dam
●On February 10, 2009, the National Park Service issued a news release that they had released a report titled "Assessment of Metals Exposure and Sub-Lethal Effects in Voles and Small Birds Captured Near the Delong Mountain Regional Transportation System Road, Cape Krusenstern National Monument, Alaska, 2006"
●On February 12, 2009, we received notification that the legal company name for Red Dog was now changed to Teck Alaska Incorporated and in simple form will be known as Teck
●On May 1, 2009, ADF&G distributed copies of the report titled "Aquatic Biomonitoring at Red Dog Mine, 2008 National Pollution Discharge Elimination System Permit No. AK-003865-2"
●On May 5, 2009, ADF&G by email stated that we have no objection to Teck beginning the discharge of treated water to Middle Fork Red Dog Creek
●On May 6, 2009, ADF&G provided written input to ADEC on Teck's Monitoring Plan
●Several field inspections of the fish weir on Middle Fork Red Dog Creek were made by ADF&G - the weir was operating in compliance with the Fish Habitat Permit
●In early June, ADF&G monitored the Arctic grayling spawning run in Mainstem Red Dog and North Fork Red Dog creeks. Six adult Dolly Varden were collected in the Wulik River near Tutak Creek by Teck
●In early July we successfully completed collection of periphyton, aquatic invertebrates and fish at all NPDES required sample sites as well as 4 sites located in the Bons/Buddy Creek drainages
●Due to extremely low flows, Teck ceased the discharge at Outfall 001 from July 22 around 0600 hr to August 2 around 1400 hr. In our sample reach at Station 151 in Mainstem Red Dog Creek, we observed hundreds of Arctic grayling fry and caught 7 juvenile Dolly Varden in minnow traps. At Station 10 in Mainstem Red Dog Creek we observed several Arctic grayling fry and two adults and caught 6 juvenile Dolly Varden and 5 slimy sculpin. The Arctic grayling fry observed were actively feeding and showed no sign of stress. These results were obtained from July 29 to 31, 2009, and represent conditions in the creek without water from the wastewater discharge

Appendix 1 (continued)

2009

- ●On August 19, 2009, we reported to Teck the successful completion of spring work on Arctic grayling in North Fork Red Dog and Mainstem Red Dog creeks and Bons Creek/Bons Pond. In spring 2009, we again saw strong recruitment of Arctic grayling to North Fork Red Dog Creek and 13% of these recaptures were fish originally marked in Bons Pond. Our estimated population of Arctic grayling in Bons Pond for summer 2008 was 2,216 ≥200 mm – a fairly substantial decrease from the summer 2007 estimate of 4,363
- ●Provided to Teck via email on September 3 the protocols that should be used to handle a fish for pathological work
- ●On September 25, 2009, Mr. Fred DeCicco (Fisheries Services and Supplies) and Mr. Brendon Scanlon (ADF&G) conducted aerial surveys for Dolly Varden in the Wulik River and chum salmon in Ikalukrok Creek
- ●On November 24, 2009, ADF&G transmitted to Teck by letter a summary of Arctic grayling spawning in Mainstem Red Dog and North Fork Red Dog creeks (2001 through 2009)
- ●On December 2, 2009, ADNR issued the Reclamation Plan Approval for the Red Dog Mine and ADEC issued Waste Management Permit No. 0132-BA002 for the Red Dog Mine. Both actions are subject to appeal by third parties
- ●On December 15, 2009, the ADEC issued the Certificate of Reasonable Assurance for the NPDES Permit AK-003865-2 to regulate the discharge of treated wastewater and stormwater from Red Dog Mine

Appendix 1 (continued)

2010

●On January 8, 2010, the EPA issued NPDES Permit No. AK-003865-2. The permit shall become effective on March 1, 2010
●On January 14, 2010, two nonprofit law firms, representing local tribes and environmental groups, filed an appeal of the state's 401 certification, asserting that certain provisions do not comply with the Clean Water Act
●On February 15, 2010, the same two nonprofit law firms filed a petition for review of the EPA permit with the Environmental Appeals Board. In a letter dated February 26, 2010, EPA stayed several contested conditions of NPDES Permit No. AK-003865-2
●On March 11, 2010, the US Department of the Army issued permit POA-1984-12-M45 to Teck which would authorize development of the Aqqaluk Pit at the Red Dog Mine
●On March 17, 2010, EPA Region 10 withdrew conditions from the 2010 NPDES Permit No. AK-003865-2, including: Part IA.1, Table 1 effluent limits for lead (monthly average limit), selenium (daily maximum limit), zinc, and weak acid dissociable (WAD) cyanide, and; Part IA.7.a – effluent limitations for Total Dissolved Solids (TDS). Those permit conditions not withdrawn, which include the entire permit except the conditions identified above, became fully effective and enforceable on March 31, 2010. As a result of this withdrawal, the following conditions in the 1998 NPDES Permit No. AK003865-2 remain in effect until further agency action: Part IA.1 – effluent limitations for lead (monthly average limit), selenium (daily maximum limit), zinc, TDS, and total cyanide
●On May 20, 2010, Teck announced plans to proceed with development of Aqqaluk
●In early June, ADF&G monitored the Arctic grayling spring spawning migration in the Red Dog Creek drainage and in Bons Pond – strong recruitment of immature Arctic grayling was seen in North Fork Red Dog Creek
●On June 14, 2010, ADNR responded to a Legislative Research Services request for information on what happened at Red Dog during the past – ADF&G provided input on the request including a copy of Appendix 1 (chronology of events)
●In early July, we collected periphyton and aquatic invertebrate samples at all sites, except Bons Creek where there was no surface flow present
●On July 12, 2010, ADF&G sent a letter to Teck that included a document titled "Comparison of adult Dolly Varden (*Salvelinus malma*) tissue metals concentrations from fish caught in 2008 in the Wulik River Kivalina, Alaska." The document compares metals concentrations between fish collected by Kivalina and those collected by ADF&G
●We estimated the Arctic grayling population (fish $\geq$200 mm) in North Fork Red Dog Creek in spring 2009 at 1,368 fish (SD = 418) based on the 2010 recapture event

Appendix 1 (continued)

2010

- We estimated the Arctic grayling population (fish $\geq$200 mm) in Bons Pond in spring 2009 at 2,180 (SD = 539) based on the 2010 recapture event
- On September 24, 2010, Mr. Fred DeCicco (Fisheries Services and Supplies) and Mr. Brendon Scanlon (ADF&G) conducted aerial surveys for Dolly Varden in the Wulik River and chum salmon in Ikalukrok Creek – they also estimated 548 adult Dolly Varden in Ikalukrok Creek
- An Arctic grayling tagged in North Fork Red Dog Creek was recaptured by an sport fisherman in the Wulik River due west of the mine and near the Lik Deposit on August 15, 2010
- Seasonal discharge from Outfall 001 was initiated on May 6 and terminated on September 22, 2010

Appendix 1 (continued)

2011

- Technical Report No. 11-01 titled "Aquatic biomonitoring at Red Dog Mine, 2010 National Pollution Discharge Elimination System Permit (NPDES) No. AK-003865-2" was submitted to EPA and ADEC on February 2, 2011
- In mid-February, Teck approved funding to support a radio telemetry project on Arctic grayling in North Fork Red Dog Creek
- On March 11, 2011, ADNR approved modifications (fertilizer rates and composition, use of wild native seeds) to the Reclamation Plan
- On March 30, 2011, ADNR approved modifications to the waste rock segregation criteria as submitted by Teck
- Reports were received from hunters in April of a foul odor up the Wulik River and Teck responded by sending out an inspection crew – they went to Jakes seep along Ikalukrok Creek – the seep was active with a fair amount of gas being released and the odor was very noticeable downwind
- On May 8, 2011, Teck notified EPA (by letter) of plans to utilize Waste Treatment Plant (WTP1) in parallel with WTP2 in order to facilitate more efficient treatment of tailings impoundment (reclaim) water
- On May 15, 2011, Teck notified EPA (by letter) that the discharge through Outfall 001 was initiated at about 0830 – seasonal discharge was terminated on September 24, 2011
- On June 6, 2011, Teck sent a letter to ADF&G summarizing work conducted to clear bridges and culverts of snow and ice along the Port Road prior

Appendix 1 (concluded)

2011

●On June 13, 2011, Teck notified EPA by letter of an exceedance in TDS collected at Outfall 001 on May 17 – Teck also indicated that they continue to be in compliance with TDS at Station 151
●In early June, ADF&G monitored the Arctic grayling spring spawning migration in the Red Dog Creek drainage and in Bons Pond – strong recruitment of immature Arctic grayling was seen in North Fork Red Dog Creek
●On June 2, 7 adult Dolly Varden were captured and retained for metals analyses of selected tissues
●15 mature Arctic grayling were surgically implanted with radio transmitters between June 5 and 11 – all fish were caught and tagged in North Fork Red Dog Creek
●Arctic grayling with radio transmitters were relocated in July, September, October and November – initially they distributed throughout the Ikalukrok Creek drainage but by fall most were in lower Ikalukrok Creek in a reach used by chum salmon for spawning – on the last survey in early November most of the fish were in the Wulik River between the mouth of Ikalukrok Creek to a location several km downstream of the mouth of Tutak Creek
●In mid-July, periphyton and aquatic invertebrate samples were collected at all the NPDES and ADEC sites
●In late August, 2011, juvenile Dolly Varden sampling was conducted and 42 fish were retained for whole body metals analyses
●On September 27, 7 adult Dolly Varden were captured and retained for metals analyses of selected tissues and an aerial survey of chum salmon spawners in Ikalukrok Creek was conducted on September 25 – 1,507 chum salmon (live and dead) were counted
●Two aerial surveys of Dolly Varden in the Wulik River were flown (September 26 and October 6). The first survey found 16,916 Dolly Varden, but on October 6 DeCicco estimated 64,499 Dolly Varden – a substantial increase from the earlier survey

Appendix 2. Periphyton Standing Crop

2011 Chloro Results - Red Dog		IDL = 0.10 mg/m^2	Linear Check Maximum = 49.67mg/m^2									
		EDL = 0.10 mg/m^2						Phaeo Corrected				
			Date	Date	Vial	**Chl a**	**Below Instrument**	**Chl a**	**664/665**	Chl b	Chl c	
Daily	Site/Volume (liters)	Station /Site	Collected	Analyzed	Chl a	**mg/m2**	**Detection Limit**	**mg/m2**	**Ratio**	mg/m2	mg/m2	**Notes**
Vial #							**(0.10 mg/m^2)**					
							OR					
							Above Linear Check					
							(49.67 mg/m^2)					
1	BLANK	BLANK		12/06/11	0.00	0.00	**Below Detection**					
2	Buddy Above Road	STA 221	July 2011	12/06/11	0.46	1.84		**1.82**	1.71	0.36	0.12	
3	Buddy Above Road	STA 221	July 2011	12/06/11	0.60	2.41		**2.24**	1.64	0.63	0.12	
4	Buddy Above Road	STA 221	July 2011	12/06/11	1.10	4.42		**4.17**	1.67	0.04	0.46	
5	Buddy Above Road	STA 221	July 2011	12/06/11	0.34	1.35		**1.28**	1.67	0.28	0.12	
6	Buddy Above Road	STA 221	July 2011	12/06/11	1.09	4.36		**4.06**	1.64	0.80	0.09	
7	Buddy Above Road	STA 221	July 2011	12/06/11	1.02	4.10		**3.63**	1.60	0.69	0.12	
8	Buddy Above Road	STA 221	July 2011	12/06/11	1.16	4.66		**4.38**	1.65	1.11	0.25	
9	Buddy Above Road	STA 221	July 2011	12/06/11	0.86	3.43		**3.20**	1.67	0.00	0.36	
10	Buddy Above Road	STA 221	July 2011	12/06/11	1.06	4.25		**3.95**	1.65	0.45	0.26	
11	Buddy Above Road	STA 221	July 2011	12/06/11	1.58	6.34		**5.13**	1.52	1.27	0.13	
12	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.11	0.45		**0.43**	1.67	0.01	0.04	
13	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.14	0.55		**0.53**	1.71	0.00	0.02	
14	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.24	0.95		**0.85**	1.62	0.09	0.04	
15	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.11	0.45		**0.43**	1.67	0.00	0.14	
16	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.54	1.08		**0.91**	1.55	0.16	0.25	
17	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.10	0.40		**0.43**	1.80	0.11	0.11	
18	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.19	0.39		**0.32**	1.55	0.00	0.06	
19	Mainstem Red Dog	STA 10	July 2011	12/06/11	0.17	0.67		**0.64**	1.67	0.14	0.11	
22	Bons Below Pond	STA 220	July 2011	12/06/11	1.83	7.32		**6.73**	1.64	0.31	0.38	
23	Bons Below Pond	STA 220	July 2011	12/06/11	2.08	8.31		**6.73**	1.52	1.11	0.13	
24	Bons Below Pond	STA 220	July 2011	12/06/11	3.15	12.60		**11.85**	1.66	1.60	0.55	
25	Bons Below Pond	STA 220	July 2011	12/06/11	5.33	21.33		**17.41**	1.52	4.41	0.36	
26	Bons Below Pond	STA 220	July 2011	12/06/11	3.11	12.43		**11.32**	1.63	0.80	0.72	
27	Bons Below Pond	STA 220	July 2011	12/06/11	5.83	23.33		**21.47**	1.64	3.25	0.93	
28	Bons Below Pond	STA 220	July 2011	12/06/11	7.26	29.05		**26.59**	1.63	4.91	0.82	
29	Bons Below Pond	STA 220	July 2011	12/06/11	5.07	20.29		**17.52**	1.57	3.73	0.49	
30	Bons Below Pond	STA 220	July 2011	12/06/11	7.07	28.30		**26.27**	1.65	2.18	1.26	
32	Bons Below Pond	STA 220	July 2011	12/06/11	0.51	2.06		**2.03**	1.73	0.00	0.12	
31	BLANK	BLANK			0.00	0.00	**Below Detection**					
9 Double	Buddy us Road DBL	STA 221 DBL	July 2011	12/06/11	0.87	3.47		**3.42**	1.73	0.00	0.42	
1	BLANK	BLANK		12/07/11	0.00	0.00	**Below Detection**					
2	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	4.33	17.33		**16.34**	1.68	0.00	1.81	
3	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	1.67	6.67		**6.19**	1.66	0.00	0.78	
4	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	1.40	5.62		**5.34**	1.68	0.00	0.63	
5	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	3.51	14.03		**13.14**	1.66	0.14	1.32	
6	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	1.59	6.36		**5.98**	1.67	0.00	0.63	
7	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	3.06	12.24		**11.64**	1.69	0.00	1.09	
8	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	3.62	14.47		**11.53**	1.51	2.29	0.35	
9	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	0.73	2.92		**2.67**	1.64	0.00	0.33	
10	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	1.17	4.67		**4.17**	1.61	0.41	0.24	
11	Buddy Below Falls	Buddy blw Falls	July 2011	12/07/11	2.12	8.46		**7.90**	1.67	0.00	0.93	

Appendix 2 (concluded)

Daily Vial #	Site/Volume (liters)	Station /Site	Date Collected	Date Analyzed	Vial Chl a	Chl a mg/m2	Below Instrument Detection Limit (0.10 mg/m^2)	Chl a mg/m2	664/665 Ratio	Chl b mg/m2	Chl c mg/m2	Notes
12	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.65	2.60		**2.35**	1.63	0.00	0.31	
13	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.66	2.65		**2.56**	1.71	0.00	0.24	
14	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.65	2.61		**2.46**	1.68	0.00	0.27	
15	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.51	2.06		**2.03**	1.73	0.00	0.22	
16	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.52	2.06		**2.03**	1.73	0.00	0.15	
17	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.86	3.43		**3.31**	1.70	0.00	0.39	
18	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.57	2.29		**2.14**	1.67	0.00	0.25	
19	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.53	2.10		**2.03**	1.70	0.00	0.21	
20	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.75	3.02		**2.88**	1.69	0.00	0.32	
21	Ikalukrok Below Dudd	STA 160	July 2011	12/07/11	0.57	2.29		**2.14**	1.67	0.00	0.28	
22	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.07	0.27		**0.21**	1.50	0.03	0.00	
23	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.40	1.62		**1.50**	1.64	0.32	0.02	
24	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.09	0.36		**0.43**	2.00	0.06	0.05	
25	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.12	0.50		**0.43**	1.57	0.08	0.00	
26	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.23	0.90		**0.85**	1.67	0.11	0.05	
27	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.07	0.27		**0.32**	2.00	0.02	0.10	
28	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.14	0.54		**0.53**	1.71	0.05	0.00	
29	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.06	0.22		**0.21**	1.67	0.05	0.00	
30	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.12	0.50		**0.43**	1.57	0.08	0.00	
31	Middle Fork Red Dog	STA 20	July 2011	12/07/11	0.06	0.22		**0.21**	1.67	0.05	0.00	
32	BLANK	BLANK	July 2011	12/07/11	0.00	0.00	**Below Detection**					
13 Double	Ikalukrok ds Dudd DBL	STA 160 DBL	July 2011	12/07/11	0.69	2.74		**2.67**	1.71	0.00	0.39	
1	BLANK	BLANK		12/08/11	0.00	0.00	**Below Detection**					
2	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	1.14	4.56		**4.38**	1.69	0.00	0.34	
3	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	1.42	5.67		**5.23**	1.65	0.00	0.52	
4	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.08	8.32		**7.80**	1.67	0.00	0.66	
5	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	0.75	3.01		**2.78**	1.65	0.00	0.29	
6	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.37	9.47		**8.86**	1.67	0.00	0.70	
7	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	0.33	1.32		**1.07**	1.53	0.00	0.15	
8	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.08	8.32		**7.80**	1.67	0.00	0.76	
9	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.81	11.24		**10.47**	1.66	0.00	0.99	
10	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.10	8.42		**7.90**	1.67	0.00	0.55	
11	Ikalukrok Above Mainstem	STA 9	July 2011	12/08/11	2.07	8.28		**7.58**	1.65	0.00	0.70	
12	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.71	3.11		**2.94**	1.68	0.06	0.13	
13	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.59	2.38		**2.24**	1.68	0.00	0.11	
14	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	1.51	6.04		**5.55**	1.63	1.02	0.13	
15	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.44	1.77		**1.71**	1.70	0.09	0.06	
16	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	1.26	5.05		**4.81**	1.67	0.77	0.26	
17	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.55	2.19		**2.03**	1.66	0.05	0.04	
18	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.51	2.04		**1.92**	1.67	0.10	0.16	
19	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.94	3.74		**3.42**	1.64	0.00	0.22	
20	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.32	1.28		**1.17**	1.65	0.00	0.09	
21	Lower Bons Above Pond	Lower Bons blw WRD	July 2011	12/08/11	0.45	1.82		**1.71**	1.67	0.03	0.35	
22	North Fork Red Dog	STA 12	July 2011	12/08/11	2.54	10.16		**9.72**	1.69	0.00	0.90	
23	North Fork Red Dog	STA 12	July 2011	12/08/11	1.59	6.36		**5.98**	1.67	0.37	0.38	
24	North Fork Red Dog	STA 12	July 2011	12/08/11	1.61	6.44		**5.98**	1.66	0.00	0.45	
25	North Fork Red Dog	STA 12	July 2011	12/08/11	0.79	3.16		**3.10**	1.73	0.00	0.27	
26	North Fork Red Dog	STA 12	July 2011	12/08/11	1.92	7.69		**7.37**	1.70	0.00	0.61	
27	North Fork Red Dog	STA 12	July 2011	12/08/11	1.62	6.48		**6.09**	1.67	0.00	0.61	
28	North Fork Red Dog	STA 12	July 2011	12/08/11	1.30	5.19		**4.81**	1.65	0.16	0.26	
29	North Fork Red Dog	STA 12	July 2011	12/08/11	1.25	4.99		**4.70**	1.68	0.00	0.48	
30	North Fork Red Dog	STA 12	July 2011	12/08/11	2.30	9.19		**8.76**	1.69	0.00	0.90	
31	North Fork Red Dog	STA 12	July 2011	12/08/11	1.54	6.17		**5.55**	1.63	0.00	0.55	
32	BLANK	BLANK		12/08/11	0.01	0.04	**Below Detection**					
22 double	North Fork Red Dog DBL	STA 12 DBL	July 2011	12/08/11	2.54	10.15		**9.72**	1.69	0.00	1.04	

Appendix 3. Aquatic Invertebrate Drift Samples

Middle Fork Red Dog Creek, Station 20, Drift Samples Invertebrates													
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	15	15	19	15	28	23	20	16	26	25	15	15	25
												\	
Tot. Ephemeroptera	9	0	17	4	6	44	41	7	23	29	16	1	30
Tot. Plecoptera	3	5	43	20	34	38	28	9	11	13	4	0	20
Tot. Trichoptera	0	0	0	0	0	0	1	0	1	1	1	0	1
Total Aq. Diptera	104	40	153	121	449	28	92	6	80	72	45	103	197
Misc.Aq.sp	9	17	73	17	55	46	177	5	82	52	38	10	181
% Ephemeroptera	8%	0%	6%	2%	1%	28%	12%	26%	12%	17%	15%	1%	7%
% Plecoptera	3%	7%	15%	13%	7%	24%	8%	35%	6%	8%	4%	0%	5%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
% Aq. Diptera	83%	64%	53%	75%	83%	18%	27%	22%	41%	43%	43%	90%	46%
% other	7%	28%	26%	10%	10%	29%	52%	18%	42%	31%	37%	9%	42%
% EPT	10%	8%	21%	15%	7%	52%	21%	60%	18%	25%	20%	1%	12%
% Chironomidae	80%	36%	51%	73%	73%	16%	24%	15%	35%	39%	38%	86%	44%
% Dominant Aquatic Taxon	46%	36%	31%	43%	48%	30%	42%	37%	22%	22%	37%	75%	28%
Volume of water (m3)	378	551	933	310	702	880	302	296	384	249	285	78	733
average water/net	76	110	187	62	140	176	60	59	77	50	57	16	147
StDev of water volume	24	26	89	14	38	91	26	9	52	8	11	9	28
Estimated total inverts/m3 water	2.92	0.6	1.7	6.2	6.6	1.1	19.4	0.6	7.4	16.2	23.2	10.1	4.7
Estimated aquatic inverts/m3 water	1.7	0.6	1.5	2.6	3.9	0.9	5.6	0.4	2.6	3.4	1.8	7.3	2.9
average inv/m3	3.2	0.6	1.8	6.1	6.4	1.2	19.5	0.6	10.5	16.3	24.1	11.7	4.7
average aq. Invertebrates/m3 water	1.8	0.57	1.64	2.59	3.74	0.95	5.33	0.45	3.53	3.39	1.8	8.2	3
Stdev of aq. Inv. Den.	1.3	0.21	0.38	0.58	1.07	0.27	0.97	0.21	1.86	0.7	0.25	3.2	0.4
Total aquatic invertebrates	627	309	1431	810	2719	783	1694	133	980	835	523	573	2145
Total. terrestrial invertebrates	477	10	185	1115	1889	170	4158	59	1875	3210	6096	218	1290
Total invertebrates	1104	319	1616	1925	4608	953	5852	192	2855	4045	6619	791	3435
% Sample aquatic	57%	97%	89%	42%	59%	82%	29%	69%	34%	21%	8%	72%	62%
% Sample terrestrial	43%	3%	11%	58%	41%	18%	71%	31%	66%	79%	92%	28%	38%
Average # aquatic inverts / net	125	62	286	162	544	157	339	27	196	167	105	115	429
stdev aq inv/net	59	20	111	56	242	69	178	11	20	35	30	51	86
Average # terr. inverts / net	95	2	37	223	378	34	832	12	375	642	1219	44	258
Average # inverts / net	221	64	323	385	922	191	1170	38	571	809	1324	158	687
stdev inv/net	68	21	127	156	376	85	532	13	55	191	259	74	206
Total Larval Arctic Grayling/site	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

North Fork Red Dog Creek, Station 12, Drift Samples Invertebrates													
Date:	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	13	13	18	16	26	20	21	15	21	23	19	17	19
Tot. Ephemeroptera	67	14	20	170	194	38	198	882	163	57	66	26	79
Tot. Plecoptera	23	94	117	40	64	5	5	19	11	77	18	4	22
Tot. Trichoptera	4	6	6	0	4	0	0	0	1	4	1	3	11
Total Aq. Diptera	700	314	1134	116	716	27	333	755	641	1574	2113	1092	3245
Misc.Aq.sp	30	69	226	43	188	17	39	32	135	320	251	140	536
% Ephemeroptera	8%	3%	1%	46%	16%	44%	34%	52%	17%	3%	3%	2%	2%
% Plecoptera	3%	19%	8%	11%	6%	5%	1%	1%	1%	4%	1%	0%	1%
% Trichoptera	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	85%	63%	75%	31%	62%	31%	58%	45%	67%	77%	86%	86%	83%
% other	4%	14%	15%	12%	16%	19%	7%	2%	14%	16%	10%	11%	14%
% EPT	11%	23%	9%	57%	23%	50%	35%	53%	18%	7%	3%	3%	3%
% Chironomidae	54%	36%	57%	22%	27%	25%	36%	14%	61%	32%	55%	33%	23%
% Dominant Aquatic Taxon	45%	32%	43%	46%	35%	48%	34%	44%	36%	45%	43%	54%	61%
Volume of water (m3)	559	221	747	226	672	672	380	368	297	329	681	187	1015
average water/net	112	44	149	45	134	134	76	74	59	66	136	37	203
StDev of water volume	80	12	54	23	37	64	54	10	24	20	45	22	49
Estimated total inverts/m3 water	9.2	11.8	10.2	13.5	9.3	0.9	12.4	23.6	18.3	33.2	28	37.4	20.2
Estimated aquatic inverts/m3 water	7.4	11.2	10	8.1	8.7	0.6	7.6	23	16	30.9	18	33.8	19.2
average inv/m3	14.2	11.5	10.2	15	10	0.8	16.3	23.5	19.9	33.5	28.1	35.3	21.2
average aq. Invertebrates/m3 water	11.4	10.9	10	9.1	9.4	0.6	11.8	22.8	17.5	31.1	18.4	31.3	20.1
Stdev of aq. Inv. Den.	8.3	5.7	1.5	5.3	5.2	0.2	9.4	3.9	6.6	7.8	2.83	11.6	7.9
Total aquatic invertebrates	4120	2486	7509	1839	5827	435	2875	8442	4750	10159	12242	6324	19465
Total. terrestrial invertebrates	1044	129	117	1211	426	159	1833	248	670	745	6843	677	1070
Total invertebrates	5164	2615	7626	3050	6254	594	4708	8691	5420	10904	19085	7000	20535
% Sample aquatic	80%	95%	98%	60%	93%	73%	61%	97%	88%	93%	64%	90%	95%
% Sample terrestrial	20%	5%	2%	40%	7%	27%	39%	3%	12%	7%	36%	10%	5%
Average # aquatic inverts / net	824	497	1502	368	1165	87	575	1688	950	2032	2448	1265	3893
stdev aq inv/net	138	352	545	161	409	60	278	448	265	802	764	977	1286
Average # terr. inverts / net	209	26	23	242	85	32	367	50	134	149	1369	135	214
Average # inverts / net	1033	523	1525	610	1251	119	942	1738	1084	2181	3817	1400	4107
stdev inv/net	274	339	560	188	434	97	587	447	308	848	1480	1048	1378
Total Larval Arctic Grayling/site	1	3	1	0	0	0	0	0	9	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Mainstem Red Dog Creek, Station 10, Drift Samples Invertebrates													
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	11	7	19	12	21	17	15	20	22	24	17	15	24
Tot. Ephemeroptera	2	0	6	14	313	24	54	77	56	25	10	1	16
Tot. Plecoptera	35	16	34	30	292	16	36	45	144	50	15	6	27
Tot. Trichoptera	0	1	3	0	1	0	7	0	1	3	1	0	4
Total Aq. Diptera	182	20	676	129	438	37	396	87	558	1301	347	57	708
Misc.Aq.sp	3	2	82	8	58	9	82	73	141	106	49	10	271
% Ephemeroptera	1%	1%	1%	8%	28%	28%	9%	27%	6%	2%	2%	2%	2%
% Plecoptera	16%	41%	4%	17%	27%	18%	6%	16%	16%	3%	4%	8%	3%
% Trichoptera	0%	3%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	82%	52%	84%	71%	40%	43%	69%	31%	62%	88%	82%	76%	69%
% other	1%	4%	10%	4%	5%	11%	14%	26%	16%	7%	12%	14%	26%
% EPT	17%	44%	5%	25%	55%	47%	17%	43%	22%	5%	6%	10%	5%
% Chironomidae	69%	25%	79%	62%	24%	39%	36%	22%	60%	55%	60%	68%	51%
% Dominant Aquatic Taxon	61%	42%	64%	52%	29%	30%	33%	23%	42%	52%	43%	55%	38%
Volume of water (m3)	869	356	1323	255	688	1239	665	417	422	384	378	139	966
average water/net	174	71	265	51	138	248	133	83	84	77	76	28	193
StDev of water volume	122	27	56	15	39	54	65	13	20	10	24	16	17
Estimated total inverts/m3 water	1.4	0.6	3.1	3.8	8.2	0.5	7.5	4.8	13.5	22.6	9.2	4.1	6.7
Estimated aquatic inverts/m3 water	1.3	0.5	3	3.6	8	0.3	4.3	3.4	10.7	19.4	5.6	2.7	5.3
average inv/m3	1.9	0.7	3.2	4.2	8.6	0.5	8.2	5	14	22.8	8.8	3.2	6.6
average aq. inverts/m3 water	1.8	0.6	3.1	4	8.4	0.4	4.6	3.5	11.1	19.5	5.3	2.1	5.3
Stdev of aq. Inv. Den.	1.3	0.3	0.8	2.1	1.9	0	1.6	1.4	2.3	3.6	1.4	1.4	1.3
Total aquatic invertebrates	1111	192	4003	910	5503	427	2875	1410	4497	7427	2109	370	5125
Total. terrestrial invertebrates	136	21	121	49	121	173	2119	609	1218	1252	1351	205	1311
Total invertebrates	1247	213	4123	959	5624	600	4993	2018	5715	8679	3461	575	6437
% Sample aquatic	89%	90%	97%	95%	98%	71%	58%	70%	79%	86%	61%	64%	80%
% Sample terrestrial	11%	10%	3%	5%	2%	29%	42%	30%	21%	14%	39%	36%	20%
Average # aquatic inverts / net	222	38	801	182	1101	85	575	282	899	1485	422	74	1025
stdev aq inv/net	126	25	182	47	152	16	311	66	83	227	242	76	315
Average # terr. inverts / net	27	4	24	10	24	35	424	122	244	250	270	41	262
Average # inverts / net	249	43	825	192	1125	120	999	404	1143	1736	692	115	1287
stdev inv/net	153	27	171	51	152	25	529	69	111	218	358	116	355
Total Larval Arctic Grayling/site	5	5	0	2	1	0	0	0	0	45	2	0	1
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Ikalukrok Creek, Station 9, Drift Samples Invertebrates													
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	8	9	15	13	21	16	13	18	20	20	24	14	19
Tot. Ephemeroptera	11	63	267	213	138	208	571	67	225	122	151	4	129
Tot. Plecoptera	17	13	159	24	54	30	189	57	98	64	21	4	62
Tot. Trichoptera	0	0	0	0	0	0	1	0	1	0	0	0	3
Total Aq. Diptera	10	58	1252	285	485	196	185	56	217	193	370	167	1625
Misc.Aq.sp	9	8	56	5	23	23	23	25	24	162	125	10	113
% Ephemeroptera	24%	44%	15%	40%	19%	45%	59%	33%	40%	23%	23%	2%	7%
% Plecoptera	36%	9%	9%	5%	8%	7%	19%	28%	17%	12%	3%	2%	3%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	22%	41%	72%	54%	70%	43%	19%	27%	39%	36%	56%	90%	84%
% other	19%	6%	3%	1%	3%	5%	2%	12%	4%	30%	19%	5%	6%
% EPT	60%	54%	25%	45%	27%	52%	79%	60%	57%	34%	26%	4%	10%
% Chironomidae	21%	39%	69%	52%	65%	25%	15%	18%	35%	28%	31%	49%	76%
% Dominant Aquatic Taxon	32%	45%	65%	44%	57%	36%	37%	24%	35%	20%	24%	44%	63%
Volume of water (m3)	260	478	833	575	450	2772	555	352	382	390	601	265	792
average water/net	52	96	167	115	90	554	111	70	76	78	120	53	158
StDev of water volume	25	16	106	29	23	161	12	16	23	22	46	19	28
Estimated total inverts/m3 water	1.5	1.6	10.7	4.9	8.7	1.4	11.4	3.8	9	11.3	8.4	3.8	13.9
Estimated aquatic inverts/m3 water	0.9	1.5	10.4	4.6	7.8	0.8	8.7	2.9	7.4	6.9	5.5	3.5	12.2
average inv/m3	1.6	1.6	12	5	8.9	1.4	11.4	3.9	9.5	13.7	8.4	4	14.3
average aq inverts/m3 water	1	1.5	11.7	4.7	7.9	0.9	8.7	3	7.9	8.3	5.5	3.7	12.6
Stdev of aq. inv. Den.	0.6	0.3	4.6	0.8	1	0.1	1.7	1.2	2.5	6.2	1.3	0.8	4
Total aquatic invertebrates	232	714	8668	2635	3497	2288	4848	1028	2822	2707	3330	926	9662
Total. terrestrial invertebrates	159	66	220	168	403	1507	1482	325	606	1704	1741	92	1377
Total invertebrates	391	780	8888	2803	3900	3795	6330	1353	3427	4410	5071	1018	11039
% Sample aquatic	59%	92%	98%	94%	90%	60%	77%	76%	82%	61%	66%	91%	88%
% Sample terrestrial	41%	8%	2%	6%	10%	40%	23%	24%	18%	39%	34%	9%	12%
Average # aquatic inverts / net	46	143	1734	527	699	458	970	206	564	541	666	185	1932
stdev aq inv/net	26	46	822	102	115	90	255	81	120	266	347	63	516
Average # terr. inverts / net	32	13	44	34	81	301	296	65	121	341	348	18	275
Average # inverts / net	78	156	1778	561	780	759	1266	271	685	882	1014	204	2208
stdev inv/net	51	50	849	99	110	158	296	94	173	424	491	65	581
Total Larval Arctic Grayling/site	1	1	0	0	0	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	1	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Ikalukrok Creek below Dudd Creek Station 7, and Station 160 starting in 2010 under new permit													
Year Sampled	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	10	12	18	9	18	24	18	22	18	24	19	14	19
Tot. Ephemeroptera	1	4	138	12	59	23	152	114	126	17	33	4	38
Tot. Plecoptera	9	102	43	12	37	8	4	29	21	21	8	2	6
Tot. Trichoptera	0	1	1	0	1	2	0	2	1	1	0	0	0
Total Aq. Diptera	38	319	262	111	1054	95	529	323	1356	1335	1558	371	867
Misc.Aq.sp	3	105	22	2	36	44	8	83	187	119	28	92	61
% Ephemeroptera	1%	1%	30%	8%	5%	13%	22%	21%	7%	1%	2%	1%	4%
% Plecoptera	17%	19%	9%	8%	3%	4%	1%	5%	1%	1%	1%	0%	1%
% Trichoptera	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	75%	60%	56%	81%	89%	55%	76%	59%	80%	89%	96%	79%	89%
% other	7%	20%	5%	1%	3%	26%	1%	15%	11%	8%	2%	20%	6%
% EPT	18%	20%	39%	17%	8%	19%	22%	26%	9%	3%	3%	1%	5%
% Chironomidae	66%	39%	51%	36%	22%	43%	59%	43%	68%	18%	14%	29%	55%
% Dominant Aquatic Taxon	63%	39%	46%	46%	67%	31%	38%	27%	58%	71%	82%	50%	36%
Volume of water (m3)	190	513	617	359	866	1182	303	617	502	491	659	1236	801
average water/net	38	103	123	72	173	236	61	123	100	98	132	247	160
StDev of water volume	23	54	40	23	19	114	14	35	33	56	46	101	29
Estimated total inverts/m3 water	1.8	5.7	3.9	2.2	7.2	1	15.3	5.2	23.1	17.7	13.6	2.4	6.4
Estimated aquatic inverts/m3 water	1.3	5.2	3.8	1.9	6.9	0.7	11.4	4.5	16.9	15.2	12.3	1.9	6.1
average inv/m3	2.5	6	4.1	2.3	7.3	1	15.4	5.6	26.1	17.9	14.1	2.3	6.4
average aq inverts/m3 water	1.7	5.4	4	2	7	0.8	11.4	4.9	18.8	15.6	13	1.8	6
StDev of aq. Inv. Density	1	1.3	1	0.8	1.5	0.1	3.4	2	7.6	1.8	2.7	0.6	2.9
Total aquatic invertebrates	253	2657	2335	684	5940	857	3465	2759	8455	7466	8136	2347	4860
Total. terrestrial invertebrates	90	291	54	114	291	279	1181	428	3112	1224	791	574	252
Total invertebrates	343	2948	2389	798	6232	1136	4646	3187	11567	8689	8927	2920	5112
% Sample aquatic	74%	90%	98%	86%	95%	75%	75%	87%	73%	86%	91%	80%	95%
% Sample terrestrial	26%	10%	2%	14%	5%	25%	25%	13%	27%	14%	9%	20%	5%
Average # aquatic inverts / net	51	531	467	137	1188	171	693	552	1691	1493	1627	469	972
stdev aq inv/net	27	309	64	56	167	63	292	111	209	842	421	308	502
Average # terr. inverts / net	18	58	11	23	58	56	236	86	622	245	158	115	50
Average # inverts / net	69	590	478	160	1246	227	929	637	2313	1738	1785	584	1022
stdev inv/net	29	328	66	53	167	84	352	130	276	1012	487	386	533
Total Larval Arctic Grayling/site	0	2	0	14	1	0	0	0	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	1	0	0	1	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	7	0	0	0	0	0	0	0

Appendix 3 (continued)

Bons Creek below Blast Road, upstream of Bons Pond								
Year Sampled	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	17	23	16	14	19	14	11	20
Tot. Ephemeroptera	3	15	7	6	6	9	3	67
Tot. Plecoptera	1	1	1	1	3	1	0	1
Tot. Trichoptera	0	0	0	0	0	0	0	0
Total Aq. Diptera	39	82	23	367	347	251	46	507
Misc.Aq.sp	7	66	10	56	114	17	8	86
% Ephemeroptera	6%	9%	17%	1%	1%	6%	5%	10%
% Plecoptera	2%	1%	2%	0%	1%	3%	0%	0%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	77%	50%	56%	86%	74%	0%	81%	77%
% other	14%	40%	25%	13%	24%	90%	14%	13%
% EPT	8%	10%	19%	2%	2%	4%	5%	10%
% Chironomidae	68%	27%	43%	72%	20%	81%	75%	70%
% Dominant Aquatic Taxon	60%	38%	38%	50%	53%	76%	61%	48%
Volume of water (m3)	349	104	68	86	79	87	16	176
average water/net	70	21	14	17	16	17	3	35
StDev of water volume	10	11	3	3	8	12	1	7
Estimated total inverts/m3 water	1.3	23	4.6	31.5	55.4	25.7	21.8	21.3
Estimated aquatic inverts/m3 water	0.7	7.9	3.1	24.8	29.9	16.1	17.9	18.8
average inv/m3	1.3	23	4.6	31.5	57.6	31.8	20.2	21.5
average aq inverts/m3 water	0.7	9.6	3.2	25	30.4	19	16.1	19.1
StDev of aq. Inv. Density	0.5	4.9	1.3	8.4	4.6	8.5	9.5	3.9
Total aquatic invertebrates	251	823	208	2147	2354	1392	283	3302
Total. terrestrial invertebrates	209	1564	105	574	2012	834	63	450
Total invertebrates	460	2387	313	2721	4365	2226	346	3752
% Sample aquatic	55%	34%	66%	79%	54%	63%	82%	88%
% Sample terrestrial	45%	66%	34%	21%	46%	37%	18%	12%
Average # aquatic inverts / net	50	165	42	429	471	278	57	660
stdev aq inv/net	40	58	14	154	218	135	43	141
Average # terr. inverts / net	42	313	21	115	402	167	13	90
Average # inverts / net	92	477	63	544	873	445	69	750
stdev inv/net	79	336	17	207	428	169	48	187
Total Larval Arctic Grayling/site	0	10	0	78	0	0	0	3
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Buddy Creek (Station 221), upstream of haul road								
Year Sampled	2004	2005	2006	2007	2008	2009	2010	2011
Total aquatic taxa	20	20	19	23	22	17	17	23
Tot. Ephemeroptera	2042	232	515	385	110	18	25	409
Tot. Plecoptera	20	18	28	130	86	30	3	48
Tot. Trichoptera	0	1	0	1	0	1	2	1
Total Aq. Diptera	195	423	476	965	1632	489	654	715
Misc.Aq.sp	25	47	84	98	204	73	69	147
% Ephemeroptera	89%	32%	47%	24%	5%	3%	3%	31%
% Plecoptera	1%	3%	3%	8%	4%	5%	0%	4%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	9%	59%	43%	61%	80%	80%	87%	54%
% other	1%	32%	8%	6%	10%	12%	9%	11%
% EPT	90%	35%	49%	33%	10%	8%	4%	35%
% Chironomidae	5%	38%	25%	43%	39%	39%	81%	36%
% Dominant Aquatic Taxon	89%	28%	44%	24%	41%	41%	62%	32%
Volume of water (m3)	771	235	600	242	489	318	183	437
average water/net	154	47	120	48	98	64	37	87
StDev of water volume	146	18	65	30	18	34	16	46
Estimated total inverts/m3 water	16.2	22	11.5	39.7	24.6	19	31	15.7
Estimated aquatic inverts/m3 water	14.8	15.3	9.2	32.7	20.8	9.6	20.6	15.1
average inv/m3	20.1	22	11.5	47	25	22.3	35.4	19.2
average aq inverts/m3 water	18.1	17.2	9.3	38.9	21	11.1	25.1	18.4
StDev of aq. Inv. Density	10.1	7.5	2.1	16.1	4.2	4.7	16.8	10.3
Total aquatic invertebrates	11414	3607	5515	7892	10161	3050	3767	6593
Total. terrestrial invertebrates	1074	1572	1404	1698	1900	2971	1897	289
Total invertebrates	12488	5179	6918	9590	12061	6021	5664	6882
% Sample aquatic	91%	70%	80%	82%	84%	51%	67%	96%
% Sample terrestrial	9%	30%	20%	18%	16%	49%	33%	4%
Average # aquatic inverts / net	2283	721	1103	1578	2032	610	753	1319
stdev aq inv/net	1459	176	575	555	391	144	410	642
Average # terr. inverts / net	215	314	281	340	380	594	379	58
Average # inverts / net	2498	1036	1384	1918	2412	1204	1133	1376
stdev inv/net	1540	323	752	683	394	380	852	670
Total Larval Arctic Grayling/site	0	0	0	1	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0

Appendix 3 (continued)

Bons Creek (Station 220), just upstream of confluence with Buddy Creek											
Year Sampled	2004	2005	2006a	2006b	2007a	2007b	2008a	2008b	2009	2010c	2011
Total aquatic taxa	20	18	17	19	16	17	19	20	19		27
Tot. Ephemeroptera	7	51	17	17	95	95	63	63	130		12
Tot. Plecoptera	3	5	8	8	8	8	29	29	7		14
Tot. Trichoptera	1	1	0	0	4	4	4	4	0		2
Total Aq. Diptera	48	63	122	122	1391	1391	2112	2112	1044		260
Misc.Aq.sp	3	8	241	5255	34	1590	134	1322	95		191
% Ephemeroptera	11%	40%	4%	0%	6%	3%	3%	2%	10%		2%
% Plecoptera	5%	4%	2%	0%	1%	0%	1%	1%	1%		3%
% Trichoptera	2%	1%	0%	0%	0%	0%	0%	0%	0%		0%
% Aq. Diptera	77%	50%	31%	2%	91%	45%	90%	60%	82%		54%
% other	5%	40%	62%	97%	2%	51%	6%	37%	7%		40%
% EPT	18%	44%	7%	0%	7%	3%	4%	3%	11%		6%
% Chironomidae	46%	43%	30%	2%	35%	17%	72%	48%	50%		25%
% Dominant Aquatic Taxon	45%	43%	53%	89%	56%	50%	67%	48%	45%		29%
Volume of water (m^3)	698	76	612	612	150	150	317	317	216		409
average water/net	140	15	122	122	30	30	63	63	43		82
StDev of water volume	59	7	44	44	21	21	20	20	12		47
Estimated total inverts/m^3 water	0.8	11.2	5.0	46.0	63.7	115.6	41.7	60.5	36.2		6.3
Estimated aquatic inverts/m^3 water	0.4	8.4	3.2	44.2	51.1	103.0	37.0	55.8	29.6		5.9
average inv/m^3	0.9	11.2	5.0	46.0	130.0	222.4	42.3	61.4	35.2		7.6
average aq inverts/m^3 water	0.4	8.1	3.3	46.4	107.4	199.8	37.8	56.8	28.6		7
StDev of aq. Inv. Density	0.2	2.2	0.8	21.5	136.8	232.8	11.0	11.0	12.4		3
Total aquatic invertebrates	312	636	1943	27013	7654	15436	11706	17648	6375		2393
Total. terrestrial invertebrates	273	217	1143	1143	1892	1892	1494	1494	1427		198
Total invertebrates	585	853	3086	28156	9546	17328	13200	19142	7802		2591
% Sample aquatic	53%	75%	63%	96%	80%	89%	89%	92%	82%		92%
% Sample terrestrial	47%	25%	37%	4%	20%	11%	11%	8%	18%		8%
Average # aquatic inverts / net	62	127	389	5403	1531	3087	2341	3530	1275		479
stdev aq inv/net	56	66	108	2101	854	2008	766	993	833		188
Average # terr. inverts / net	55	43	229	229	378	378	299	299	285		40
Average # inverts / net	117	171	617	5631	1909	3466	2640	3828	1560		518
stdev inv/net	59	88	239	2183	1108	2288	872	1098	992		197
Total Larval Arctic Grayling/site	0	0	0	0	1	1	0	0	0		0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0		0
Total Larval Dolly Varden/site	0	0	0	0	0	0	0	0	0		0
2006a is without Daphniids and 2006b is with Daphniids											
2007a is without Ostracods and 2007b is with Ostracods											
2008a is without Ostracods and 2008b is with Ostracods											
2010c site not sampled, no flowing water											

Appendix 3 (concluded)

Buddy Creek (below falls), downstream of the canyon and haul road										
Year Sampled	2004	2005	2006a	2006b	2007	2008	2009	2010	2011a	2011b
Total aquatic taxa	18	19	16	18	25	20	13	14	28	29
Tot. Ephemeroptera	578	328	253	253	1316	124	776	6	139	139
Tot. Plecoptera	9	12	32	32	92	21	18	0	30	30
Tot. Trichoptera	1	2	0	0	7	2	0	0	3	3
Total Aq. Diptera	363	855	199	199	2284	2011	4424	1478	1525	1525
Misc.Aq.sp	71	19	125	2461	444	206	153	56	230	1773
% Ephemeroptera	57%	27%	42%	9%	32%	5%	14%	0%	7%	4%
% Plecoptera	1%	1%	5%	1%	2%	1%	0%	0%	2%	1%
% Trichoptera	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
% Aq. Diptera	35%	70%	33%	7%	55%	85%	82%	96%	79%	44%
% other	7%	2%	21%	84%	11%	9%	3%	4%	12%	51%
% EPT	58%	28%	47%	10%	34%	6%	15%	0%	9%	5%
% Chironomidae	11%	64%	22%	4%	40%	67%	69%	65%	57%	32%
% Dominant Aquatic Taxon	56%	43%	33%	69%	30%	46%	50%	50%	44%	44%
Volume of water (m3)	1326	271	612	612	593	633	347	128	741	741
average water/net	265	54	122	122	119	127	69	26	148	148
StDev of water volume	160	12	29	29	63	57	19	15	23	23
Estimated total inverts/m3 water	4.5	35.9	7.3	26.4	42.4	20.8	81.5	87.5	15.8	26.2
Estimated aquatic inverts/m3 water	3.9	22.5	5	24.1	34.9	18.7	77.4	60.3	13	23.4
average inv/m3	4.4	35.9	7.3	26.4	47.5	26.4	83.4	73.3	15.9	26.4
average aq inverts/m3 water	3.9	22.6	5	24.8	39.4	23.6	79	52.5	13	25.5
StDev of aq. Inv. Density	2.2	3.3	1.6	9.7	16	15.3	11.9	20.6	3.3	4.9
Total aquatic invertebrates	5109	6085	3041	14723	20713	11820	26860	7706	9639	17358
Total. terrestrial invertebrates	876	3645	1400	1400	4439	1320	1431	3479	2091	2091
Total invertebrates	5985	9730	4441	16123	25152	13140	28291	11185	11730	19448
% Sample aquatic	85%	63%	68%	91%	82%	90%	95%	69%	82%	89%
% Sample terrestrial	15%	37%	32%	9%	18%	10%	5%	31%	18%	11%
Average # aquatic inverts / net	1022	1217	608	2945	4143	2364	5372	1541	1928	3472
stdev aq inv/net	744	279	222	1201	1812	352	1247	1322	567	787
Average # terr. inverts / net	175	729	280	280	888	264	286	696	418	418
Average # inverts / net	1197	1946	888	3225	5030	2628	5658	2237	2346	3890
stdev inv/net	893	494	322	1224	2337	432	1244	2327	761	922
Total Larval Arctic Grayling/site	0	0	0	0	1	0	0	0	0	0
Total Larval Slimy Sculpin/site	0	0	0	0	0	0	0	0	0	0
Total Larval Dolly Varden/site	0	1	0	0	0	0	0	0	0	0
2006a is without Daphniids and 2006b is with Daphniids										
2011a is without Ostracods and 2011b is with Ostracods										

Appendix 4. Juvenile Dolly Varden Whole Body Metal Concentrations, 2011

								Method		200.8		200.8		7471B		7010		200.8	
								analyte		Cd		Pb		Hg		Se		Zn	
	Sample			Date	Fish	Length	Weight			total		total		total		total		total	%
Collector	Number	Stream	Site	Collected	Spp	(mm)	(g)	MRL		0.02		0.02		0.02		1		0.5	Solids
ADF&G	082711AXDVJ01	Anxiety Ridge	at Haul Road	8/27/2011	DV	138	27.5	Juvenile		0.19		0.16		0.07		3.5		96.2	27.3
ADF&G	082711AXDVJ02	Anxiety Ridge	at Haul Road	8/27/2011	DV	103	11	Juvenile		0.14		0.22		0.07		3.8		96.4	27
ADF&G	082711AXDVJ03	Anxiety Ridge	at Haul Road	8/27/2011	DV	118	15	Juvenile		0.13		0.47		0.08		3.4		98.7	25.3
ADF&G	082711AXDVJ04	Anxiety Ridge	at Haul Road	8/27/2011	DV	138	26.5	Juvenile		0.18		0.46		0.06		3.7		93.8	24.3
ADF&G	082711AXDVJ05	Anxiety Ridge	at Haul Road	8/27/2011	DV	127	20	Juvenile		0.22		0.18		0.06		3.1		78	26.6
ADF&G	082711AXDVJ06	Anxiety Ridge	at Haul Road	8/27/2011	DV	125	18	Juvenile		0.2		1.24		0.06		3.8		107	25.3
ADF&G	082711AXDVJ07	Anxiety Ridge	at Haul Road	8/27/2011	DV	131	23	Juvenile		0.14		0.88		0.07		3.3		82.8	25.2
ADF&G	082711AXDVJ08	Anxiety Ridge	at Haul Road	8/27/2011	DV	112	12	Juvenile		0.39		0.09		0.04		4.8		77.7	26.9
ADF&G	082711AXDVJ09	Anxiety Ridge	at Haul Road	8/27/2011	DV	110	12.5	Juvenile		0.1		0.27		0.07		3.7		88	27.1
ADF&G	082711AXDVJ10	Anxiety Ridge	at Haul Road	8/27/2011	DV	130	18.5	Juvenile		0.33		0.06		0.04		5.6		87.8	25.5
ADF&G	082711AXDVJ11	Anxiety Ridge	at Haul Road	8/27/2011	DV	140	24.5	Juvenile		0.23		2.12		0.04		4.2		105	25.1
ADF&G	082711AXDVJ12	Anxiety Ridge	at Haul Road	8/27/2011	DV	136	25	Juvenile		0.51		0.41		0.05		5.5		85.3	27.5
ADF&G	082711AXDVJ13	Anxiety Ridge	at Haul Road	8/27/2011	DV	130	19.5	Juvenile		0.17		0.3		0.07		4.2		129	25.4
ADF&G	082711AXDVJ14	Anxiety Ridge	at Haul Road	8/27/2011	DV	95	9	Juvenile		0.09		0.1		0.07		2.9		86	24.5
ADF&G	082711AXDVJ15	Anxiety Ridge	at Haul Road	8/27/2011	DV	94	8	Juvenile		0.08		0.12		0.07		3.3		95.2	25.5
ADF&G	082711BUDVJ01	Buddy	D/S Road	8/27/2010	DV	128	21	Juvenile		0.37		0.25		0.02		3.8		118	29
ADF&G	082711BUDVJ02	Buddy	D/S Road	8/27/2010	DV	124	18	Juvenile		0.52		0.25		0.02		4.1		126	27.5
ADF&G	082711BUDVJ03	Buddy	D/S Road	8/27/2010	DV	137	23	Juvenile		0.3		0.3		0.02		4.6		122	26.8
ADF&G	082711BUDVJ04	Buddy	D/S Road	8/27/2010	DV	129	21.5	Juvenile		0.44		0.39		0.02		3.3		113	26.8
ADF&G	082711BUDVJ05	Buddy	D/S Road	8/27/2010	DV	122	18.5	Juvenile		0.24		0.14		0.02		3.5		93.2	27.1
ADF&G	082711BUDVJ06	Buddy	D/S Road	8/27/2010	DV	106	15	Juvenile		0.35		0.43		0.02		3		113	26.5
ADF&G	082711BUDVJ07	Buddy	D/S Road	8/27/2010	DV	140	25.5	Juvenile		0.3		0.22		0.02		3.9		101	26.7
ADF&G	082711BUDVJ08	Buddy	D/S Road	8/27/2010	DV	124	19.5	Juvenile		0.41		0.16		0.03		3.4		93.6	27.8
ADF&G	082711BUDVJ09	Buddy	D/S Road	8/27/2010	DV	127	20	Juvenile		1.27		0.94		0.03		4.6		154	25.2
ADF&G	082711BUDVJ10	Buddy	D/S Road	8/27/2010	DV	100	10.5	Juvenile		0.75		0.23	<	0.03		4.4		147	24.8
ADF&G	082711BUDVJ11	Buddy	D/S Road	8/27/2010	DV	128	19.5	Juvenile		0.21		0.55		0.02		3.4		103	26.6
ADF&G	082711BUDVJ12	Buddy	D/S Road	8/27/2010	DV	128	19.5	Juvenile		0.48		0.21		0.02		4.2		133	26.2
ADF&G	082711BUDVJ13	Buddy	D/S Road	8/27/2010	DV	109	12	Juvenile		0.75		0.26		0.03		3.8		143	25.4
ADF&G	082711BUDVJ14	Buddy	D/S Road	8/27/2010	DV	126	18.5	Juvenile		0.27		1.06		0.03		3.2		122	27.8
ADF&G	082711BUDVJ15	Buddy	D/S Road	8/27/2010	DV	105	11.5	Juvenile		0.61		0.12		0.02		3.6		130	25.8
ADF&G	082711MSRDDVJ01	Red Dog	Mainstem	8/27/2011	DV	134	23	Juvenile		1.93		5.74		0.02		10.1		159	23.6
ADF&G	082711MSRDDVJ02	Red Dog	Mainstem	8/29/2011	DV	132	22.5	Juvenile		1.92		2.72	<	0.02		7.4		189	25.5
ADF&G	082711MSRDDVJ03	Red Dog	Mainstem	8/29/2011	DV	93	9	Juvenile		3.39		12.9	<	0.03		7.3		258	25.3
ADF&G	082711MSRDDVJ04	Red Dog	Mainstem	8/29/2011	DV	122	16.5	Juvenile		1.59		6.82		0.02		5.8		182	25
ADF&G	082711MSRDDVJ05	Red Dog	Mainstem	8/29/2011	DV	110	14.5	Juvenile		1.41		6.07		0.02		6.5		176	25.3
ADF&G	082711MSRDDVJ06	Red Dog	Mainstem	8/27/2011	DV	102	10.5	Juvenile		1		1.22	<	0.02		3.2		171	27.3
ADF&G	082711MSRDDVJ07	Red Dog	Mainstem	8/27/2011	DV	103	12	Juvenile		1.83		0.85		0.02		3.8		173	25.4
ADF&G	082711MSRDDVJ08	Red Dog	Mainstem	8/27/2011	DV	127	18.5	Juvenile		1.46		4.63		0.03		3.1		170	24.6
ADF&G	082711MSRDDVJ09	Red Dog	Mainstem	8/27/2011	DV	109	11.5	Juvenile		2.16		1.54		0.04		5.2		149	23.7
ADF&G	082711MSRDDVJ10	Red Dog	Mainstem	8/27/2011	DV	124	14	Juvenile		2.89		1.19		0.03		5.3		253	22.9
ADF&G	082711MSRDDVJ11	Red Dog	Mainstem	8/29/2011	DV	134	24.5	Juvenile		2.76		7.69		0.02		10.3		175	26.6
ADF&G	082711MSRDDVJ12	Red Dog	Mainstem	8/29/2011	DV	136	25.5	Juvenile		1.94		5.66		0.02		10.8		211	25.4

Appendix 5. Dolly Varden Metals Data, 2011

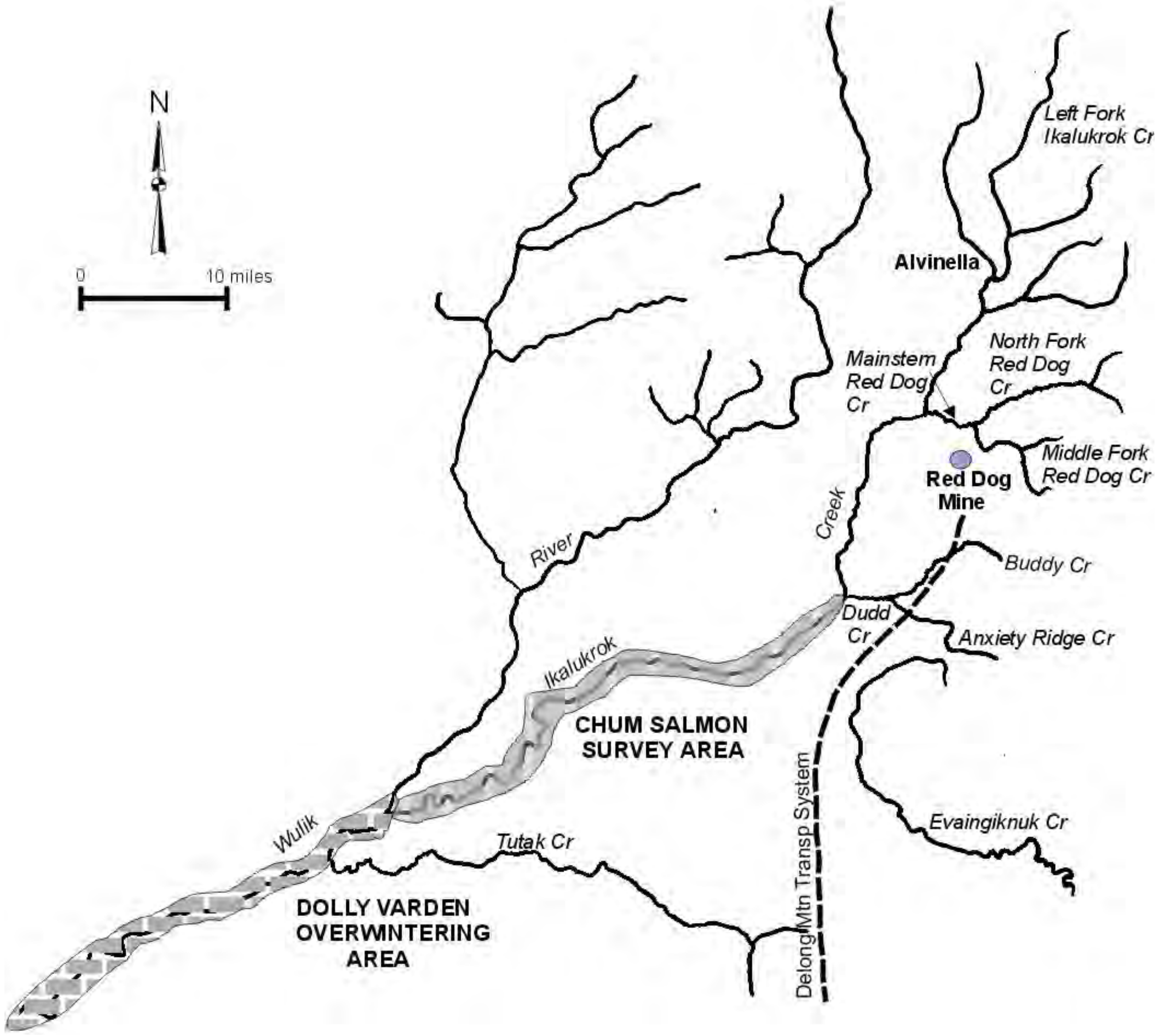
	Sample		Fish	Sex	Weight	Length	Age	Age	Total		Cd		Cu		Pb		Se		Zn		Hg	%
Tissue	Identification	Location	Species		(g)	(mm)	Fresh	Salt	Age		(mg/Kg)		(mg/Kg)		(mg/Kg)		(mg/Kg)		(mg/Kg)		(mg/Kg)	Solids
Kidney	060211WUDVA1	Wulik	DV	F	2525	600					1.35		6.5	<	0.02		6.4		74.5		0.08	25.3
Kidney	060211WUDVA2	Wulik	DV	F	2164	600					3.06		4.6	<	0.02		6.4		96.7		0.06	22.3
Kidney	060211WUDVA3	Wulik	DV	F	2974	616					3.05		3	<	0.02		5.7		65.5		0.08	23.3
Kidney	060211WUDVA4	Wulik	DV	F	1713	525					2.29		4.9	<	0.02		7.3		69.7		0.05	25.0
Kidney	060211WUDVA5	Wulik	DV	M	1517	538					5.79		6.6	<	0.02		7.4		168		0.06	20.3
Kidney	060211WUDVA6	Wulik	DV	M	2222	619					2.21		4.3	<	0.02		6.5		93.4		0.09	23.7
Kidney					Duplicate of Fish #1						3.19		13.3	<	0.02		6.8		89.1		0.10	22.4
Kidney	092711WUDVA1	Wulik	DV	M	1434	508					2.44		4.1	<	0.02		11.3		104		0.06	24.2
Kidney	092711WUDVA2	Wulik	DV	F	1701	538					1.65		3.9	<	0.02		9.1		91.7		0.05	21.6
Kidney	092711WUDVA3	Wulik	DV	F	2387	624					4.03		5.4	<	0.02		8.7		107		0.06	25.7
Kidney	092711WUDVA4	Wulik	DV	F	2770	622					1.1		2.4	<	0.02		8.5		77.3		0.07	28.2
Kidney	092711WUDVA5	Wulik	DV	F	2608	604					3.65		3.5	<	0.02		7.5		89.5		0.08	26.7
Kidney	092711WUDVA6	Wulik	DV	F	1701	554					2.91		4.9	<	0.02		7.1		99.4		0.11	25.2
Kidney			DV		Duplicate of Fish #4						2.87		3.3	<	0.02		10.2		82.0		0.09	24.0
Liver	060211WUDVA1	Wulik	DV	F	2525	600					0.62		103	<	0.02		1.9		80.7		0.02	36.2
Liver	060211WUDVA2	Wulik	DV	F	2164	600					0.97		86.8	<	0.02		2.7		103		0.02	32.4
Liver	060211WUDVA3	Wulik	DV	F	2974	616					0.72		22.3	<	0.02		2.5		61.6		0.02	35.3
Liver	060211WUDVA4	Wulik	DV	F	1713	525					0.46		69.1	<	0.02		3.1		82.8	<	0.02	33.6
Liver	060211WUDVA5	Wulik	DV	M	1517	538					0.83		77.5	<	0.02		2.8		98.9		0.02	38.1
Liver	060211WUDVA6	Wulik	DV	M	2222	619					0.68		44.6	<	0.02		2.0		65.6		0.02	41.6
Liver			DV		Duplicate of Fish #1						0.62		91.0	<	0.02		1.9		76.2	<	0.02	38.1
Liver	092711WUDVA1	Wulik	DV	M	1434	508					0.49		39.2	<	0.02		4.2		70.8		0.03	46.5
Liver	092711WUDVA2	Wulik	DV	F	1701	538					0.49		31.1	<	0.02		4.2		73.4	<	0.02	39.1
Liver	092711WUDVA3	Wulik	DV	F	2387	624					0.84		43.8	<	0.02		3.2		74.3	<	0.02	50.1
Liver	092711WUDVA4	Wulik	DV	F	2770	622					0.78		25.9	<	0.02		2.8		57.8		0.02	50.2
Liver	092711WUDVA5	Wulik	DV	F	2608	604					0.78		39.0	<	0.02		2.7		68.2	<	0.02	51.4
Liver	092711WUDVA6	Wulik	DV	F	1701	554					0.63		42.8	<	0.02		3.3		83.8		0.04	42.5
Liver			DV		Duplicate of Fish #4						0.72		23.0	<	0.02		2.5		56.8	<	0.02	52.0
Muscle	060211WUDVA1	Wulik	DV	F	2525	600				<	0.02		1.2	<	0.02	<	1.0		11	<	0.02	31.7
Muscle	060211WUDVA2	Wulik	DV	F	2164	600				<	0.02		1.7	<	0.02	<	1.0		15.1	<	0.02	29.7
Muscle	060211WUDVA3	Wulik	DV	F	2974	616				<	0.02		1.3	<	0.02		1.2		14.2	<	0.02	27.7
Muscle	060211WUDVA4	Wulik	DV	F	1713	525				<	0.02		1.3	<	0.02	<	1.0		13.2	<	0.02	28.6
Muscle	060211WUDVA5	Wulik	DV	M	1517	538				<	0.02		1.4	<	0.02		1.1		13.8	<	0.02	27.2
Muscle	060211WUDVA6	Wulik	DV	M	2222	619				<	0.02		1.1	<	0.02	<	1.0		13.0	<	0.02	29.4
Muscle			DV		Duplicate of Fish #1					<	0.02		1.2	<	0.02	<	1.0		14.3	<	0.02	33.9
Muscle	092711WUDVA1	Wulik	DV	M	1434	508				<	0.02		1.6	<	0.02	<	1.0		12.9	<	0.02	35.7
Muscle	092711WUDVA2	Wulik	DV	F	1701	538				<	0.02		1.4	<	0.02	<	1.0		13.7	<	0.02	32.0
Muscle	092711WUDVA3	Wulik	DV	F	2387	624				<	0.02		1.0	<	0.02	<	1.0		13.7	<	0.02	32.3
Muscle	092711WUDVA4	Wulik	DV	F	2770	622				<	0.02		1.2	<	0.02	<	1.0		14.5	<	0.02	31.7
Muscle	092711WUDVA5	Wulik	DV	F	2608	604				<	0.02		1.4	<	0.02	<	1.0		12.4	<	0.02	33.5
Muscle	092711WUDVA6	Wulik	DV	F	1701	554				<	0.02		1.2	<	0.02	<	1.0		14.5	<	0.02	30.6
Muscle			DV		Duplicate of Fish #4					<	0.02		1.3	<	0.02	<	1.0		12.7	<	0.02	35.5
Reproductive	060211WUDVA1	Wulik	DV	F	2525	600					0.03		18.1	<	0.02		3.9		362	<	0.02	31.5
Reproductive	060211WUDVA2	Wulik	DV	F	2164	600					0.02		23.7	<	0.02		5.2		548	<	0.02	27.6
Reproductive	060211WUDVA3	Wulik	DV	F	2974	616					0.05		17.9	<	0.02		5.1		416	<	0.02	26.6
Reproductive	060211WUDVA4	Wulik	DV	F	1713	525				<	0.02		15.9	<	0.02		5.0		369	<	0.02	29.3
Reproductive			DV		Duplicate of Fish #1						0.02		17.4	<	0.02		4.1		435	<	0.02	31.1
Reproductive	092711WUDVA2	Wulik	DV	F	1701	538					0.03		37.8	<	0.02		10.0		644	<	0.02	22.2
Reproductive	092711WUDVA3	Wulik	DV	F	2387	624					0.04		31.8	<	0.02		6.7		533	<	0.02	22.3
Reproductive	092711WUDVA4	Wulik	DV	F	2770	622					0.04		30.9	<	0.02		8.5		722	<	0.02	22.2
Reproductive	092711WUDVA5	Wulik	DV	F	2608	604					0.07		40.6	<	0.02		11.2		573	<	0.02	21.9
Reproductive	092711WUDVA6	Wulik	DV	F	1701	554					0.05		39.7		0.02		6.8		278	<	0.02	23.8
Reproductive			DV		Duplicate of Fish #4						0.05		29.9	<	0.02		8.4		639	<	0.02	22.5

Appendix 6. Dolly Varden Aerial Surveys

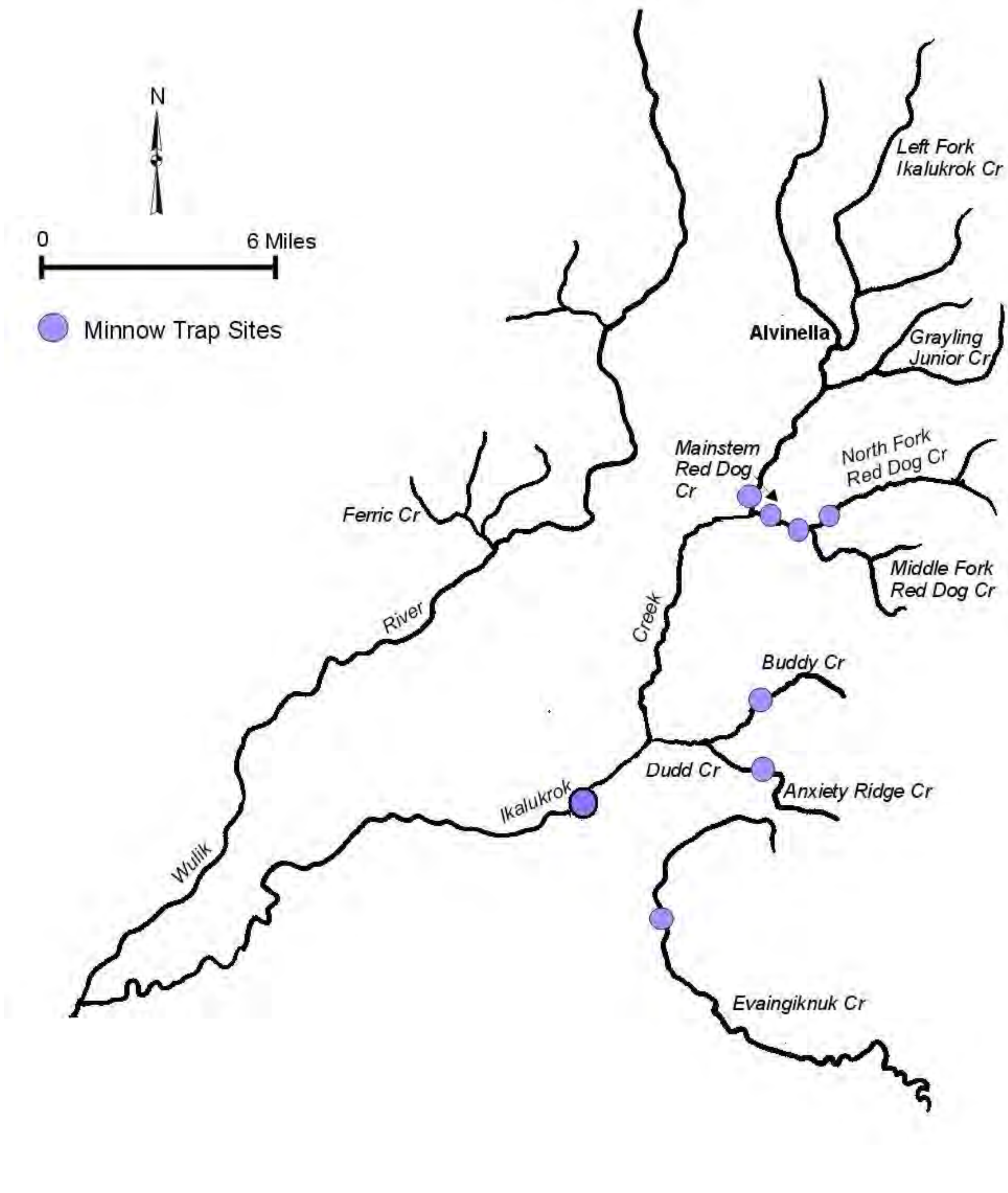
Estimated number of overwintering Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989, 1991-1999, 2001-2002, and 2004-2011.

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1,500	78,644	80,144	98
During Mining				
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2004	16,486	84,320	100,806	84
2005	10,645	110,203	120,848	91
2006	4,758	103,594	108,352	96
2007	5,503	93,808	99,311	94
2008	271	71,222	71,493	99
2009	122	60,876	60,998	99
2010	70	36,248	36,318	99
2011 (September)	500	15,591	16,091	97
2011 (October)	637	62,612	63,249	99
The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm				
was 76,892 (DeCicco 1990b)				
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm				
was 361,599 (DeCicco 1996c)				
Fall 2000 aerial survey was not made due to weather.				
Fall 2003 aerial survey was not made due to weather.				

Appendix 7. Dolly Varden and Chum Salmon Survey Areas



Appendix 8. Juvenile Dolly Varden Sampling Sites



Appendix 9. Juvenile Dolly Varden Catches

Number of Dolly Varden Caught in Late-July/Early August with ten minnow traps per sample site															
Sample Site Description	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Evaingiknuk (Noatak Tributary)	54	27	38	2	7	20	64	71	29	4	67	21	16	48	36
Anxiety Ridge	68	94	271	27	6	33	98	116	121	8	115	75	147	18	43
Buddy	48	154	306	11	34	57	104	59	59	5	183	43	100	115	77
North Fork Red Dog Creek (Sta 12)	0	12	17	1	1	1	0	1	8	0	1	0	3	6	2
Mainstem (below North Fork) (Sta 151)	14	70	86	13	9	12	2	2	6	8	2	13	7	13	7
Mainstem (Station 10)	10	21	66	1	3	12	12	0	10	3	6	5	6	14	8
Ikalukrok Creek (below Dudd)(Sta 7/160)	13	51	55	31	6	17	17	27	36	2	25	7	30	10	32
Ikalukrok Creek (above Mainstem)(Sta 9)	3	44	41	5	2	18	3	12	0	5	7	3	11	37	12
Total Catch Dolly Varden	210	473	880	91	68	170	300	288	269	35	406	167	320	261	217

Appendix 10. Arctic Grayling, Mainstem Red Dog Creek

Observations and catches of Arctic grayling in Mainstem Red Dog Creek below the confluence of North Fork Red Dog and Middle Fork Red Dog creeks since 1994.

7/27/94 – visual, two adults just below North Fork

6/29/95 – angling, one adult just below North Fork
7/17/95 – angling, two adults near rock bluff 0.8 km below North Fork
7/20/95 – visual, one adult near rock bluff 0.8 km below North Fork
8/11/95 – visual, fry (about 30) below North Fork
8/14/95 – angling, 11 adults marked and released, rock bluff 0.8 km below North Fork

6/19/96 – visual, one adult near Station 10
7/15/96 – angling, seven adults marked and released near Station 10
8/11/96 – visual, fry in shallow eddies at mouth of Mainstem
8/12/96 – visual, fry near rock bluff 0.8 km below North Fork

6/25/97 – visual, two adults at rock bluff 0.8 km below North Fork
6/25/97 – drift net, fry caught at Station 10, 13-15 mm long
6/26/97 – angling, 15 adults marked and released near Station 10
6/27/97 – visual, fry numerous at Station 10
8/10/97 – visual, fry in backwaters
9/29/97 – minnow traps, seven fry caught near Station 10

6/10/98 – visual, no fish seen between North Fork mouth and rock bluff 0.8 km downstream
6/28/98 – visual, one adult feeding at rock bluff (0.8 km below North Fork)

5/29/99 – angling, three adults caught just below North Fork mouth
5/30/99 – fyke net, 32 adults caught about 100 m below North Fork mouth
7/8-9/99 – angling, two adults captured, marked, and released near Station 10
7/8-9/99 – visual, 12 adults and some fry near Station 10
7/8-9/99 – visual, two adults at rock bluff (0.8 km below North Fork)
8/9-10/99 – visual, numerous fry in backwaters and along stream margins

Appendix 10 (continued)

6/11-12/00 – fyke net, adults captured, marked, and released 7/28/00 – visual, several fry in backwaters and along stream margins, not numerous
7/5/00 – visual, two adults feeding at rock bluff (0.8 km below North Fork), juvenile observed
7/6/00 – visual, walked most of creek, tagged three adults near Station 10, most pools held one to three adults

6/15-18/01 – visual, walked creek to check for spawners in proposed mixing zone, none observed, one adult seen feeding at rock bluff (about 0.8 km below North Fork)
6/17/01 – angling, 11 adults marked and released near Station 10, all females spent
7/29-31/01 – visual, very few fry seen (about 20 mm), late breakup, cold temperatures resulted in late spawning

5/31/02 – fyke net, seven adults marked and released near Station 10
6/1/02 – fyke net, 31 adults marked and released near Station 10
6/2/02 – fyke net, eight adults marked and released near Station 10
6/3/02 – fyke net, three adults marked and released near Station 10
6/4/02 – fyke net, three adults and three juveniles marked and released near Station 10
6/7/02 – angling, 10 adults and three juveniles marked and released near Station 10, most of the females were spent
7/27/02 – visual, few fry (<10) seen
7/28/02 – visual, adults present near Station 10, three to four per pool

6/11/03 – aerial, 48 adults, two spawning pairs seen
6/12/03 – visual, ten adults, three active spawning pairs observed near Station 10
6/14/03 – angling, eight adults, one spent male near Station 10
7/7/03 – visual, fry in backwaters near Station 10, one group of 30
7/8/03 – visual, ten adults near Station 10
9/7/03 – visual, two adults and five fry near Station 151

5/25/04 – visual, two adult males near Station 10
5/26/04 – fyke net, four adults near Station 10
7/7/04 – visual, fry common near Station 151
7/7/04 – angling, two adults (333, 325 mm) near Station 151
7/8/04 – visual, fry in all backwaters near Station 10
7/8/04 – angling, three adults (373, 297, 356 mm) near Station 10

Appendix 10 (continued)

6/5/05 – aerial, observed 30 adult Arctic grayling, only two sets paired
6/25 and 26/05 – Houghton reported catching about 60 fish in Mainstem between mouth and North Fork Red Dog Creek
7/4/05 – visual, 8 adults and fry (about 70) observed near Station 10
7/28/05 – visual, small numbers of fry in backwaters near Station 10

6/13/06 – visual, five adult Arctic grayling seen in Mainstem near Station 10
6/16/06 – angling, caught 8 Arctic grayling (260 – 355 mm long) in Mainstem just below mouth of North Fork

6/1/07 – visual, several adult male and female Arctic grayling seen near Station 151
6/2/07 – visual, numerous Arctic grayling spawning at 3rd bend downstream of Station 151 in area of cobbles to gravelly sand
6/3/07 – visual, groups of 4 to 5 adults moving downstream in Station 10 area, caught several spent females, fish obviously moving out of Mainstem
7/1/07 – visual, observed large number of fry in side channels and backwaters near Station 10 and three adult Arctic grayling feeding on drift
7/3/07 – visual, observed one adult Arctic grayling at Station 151 and several fry along stream margins
8/9/07 – visual, observed two adult Arctic grayling at Station 151 and saw 35 fry along stream margins, one group of about 25
8/10/07 – visual, observed quite of few Arctic grayling fry in vicinity of Station 10 and caught fry in minnow traps (n = 10, 59 to 68 mm, average 64.1, SD = 2.8)

6/608 – visual, observed one Arctic grayling near Station 151
6/9/08 – visual and angling, walked Station 151 downstream for about 1.6 km and caught one Arctic grayling (363 mm)
6/10/08 – visual and angling, caught 5 Arctic grayling (325 – 425 mm long) just upstream of Station 10, four males and one partially spent female – saw about six fish that we did not catch
7/3/08 – visual, saw one adult Arctic grayling near Station 10
7/4/08 – visual, fry common along stream margins near Station 10, very small (about 15 mm long)
7/4/08 – minnow traps, caught one 67 mm Arctic grayling near Station 151
8/3/08 – minnow traps, caught one 82 mm Arctic grayling near Station 151

Appendix 10 (concluded)

6/13/09 – caught one 408 mm Arctic grayling in Mainstem Red Dog Creek at first rock bluff below North Fork Red Dog Creek
7/2/09 – observed one adult Arctic grayling near Station 151
7/3/09 – observed 8 adult Arctic grayling in pools just upstream of Station 10
7/29/09 – saw large numbers of Arctic grayling fry virtually everywhere in our sample reach in Mainstem Red Dog Creek upstream of Station 151
7/30/09 – observed a few Arctic grayling fry in Mainstem Red Dog Creek near Station 10

7/3/10 – observed fry at Station 10, fry numerous and schools of 5 to 20 seen everywhere we looked
8/15/10 – observed moderate numbers of Arctic grayling fry just upstream of Station 151
8/15/10 – saw two adult Arctic grayling just upstream of Station 10
8/15/10 – observed moderate numbers of Arctic grayling fry upstream and downstream of Station 10

6/7/2011 – one male Arctic grayling (Code #49 – radiotag) relocated in Mainstem Red Dog Creek along with many other adult Arctic grayling near first bluff below Station 151
6/10/2011 – caught 6 Arctic grayling in Mainstem Red Dog Creek between the mouth of North Fork Red Dog Creek and Station 151
6/11/2011 – two male Arctic grayling (Code 50 and 54 – radiotag) relocated in Mainstem Red Dog Creek downstream of Station 151
7/17/2011 – aerial survey to relocate radio-tagged Arctic grayling, 13 of 15 fish found – none were in Mainstem Red Dog Creek
8/28/2011 – observed several Arctic grayling fry in Mainstem Red Dog Creek just upstream of Station 151, fry were in backwaters and in a side channel

Appendix 11. Arctic Grayling Fry, North Fork Red Dog Creek

Year	Relative Abundance of Fry	Comments
1992	high	100's of fry, late July
1993	low	Few fry in early August, high water
1994	low	High water after spawning probably displaced fry
1995	low	Fry small (<25 mm) in mid-July
1996	high	Schools of 50 to 200 fry common
1997	high	Average size of fry was 10 mm greater than in 1996
1998	low	Cold water, late breakup, high water after spawning
1999	high	Low flows, warm water after spawning, schools of 50 to 100 fry common
2000	low	Cold water, late breakup, spawning 90% done June 13/14, fry small (<25 mm) and rare in mid-July
2001	low	Cold water, late breakup, spawning 90% done June 19, fry small (<25 mm) and rare in mid-July
2002	low	High flows, spawning 90% done June 8, fry small (<35 mm) in early August and rare, more fry seen in Ikalukrok Creek in early July, probably displaced by high water
2003	low	Cold water, late breakup, spawning 90% done June 14, fry small (<25 mm) and rare in early August
2004	low	Early breakup, spawning 90% done by May 31, fry (<30 mm) on July 10
2005	low	Spawning 90% done by June 7, fry present in early July, several groups of 25 to 30 observed to high water
2006	low	Spawning partially abandoned due to cold water temperatures, no fry observed in early August, July surveys not possible due to high water
2007	high	Spawning 90% done by June 3, followed by low water with very little rainfall until mid-August, fry numerous, hundreds seen in shallow water along stream margin, fry averaged 64 mm in early August

Appendix 11 (concluded)

Year	Relative Abundance of Fry	Comments
2008	low	Spawning 90% done by June 9, most fish probably spawned in Mainstem Red Dog Creek, no fry seen along stream margins
2009	low	Most fish probably spawned in Mainstem Red Dog Creek, breakup late, very few fry seen in July or August, fry observed in the reach just upstream of Station 151 indicate some spawning success in North Fork Red Dog Creek
2010	moderate	Breakup early, water flows low, moderate numbers of fry seen in North Fork Red Dog Creek in July, grayling fry caught in minnow buckets on August 16
2011	low	Spawning probably began on June 9, 2011 – no fry were seen in July and in late August a few fry (less than 5) were observed in backwaters