Technical Report No. 16-09

Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2016

by

Alvin G. Ott and Parker T. Bradley

December 2016

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

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

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

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

TECHNICAL REPORT NO. 16-09

ARCTIC GRAYLING AND BURBOT STUDIES AT THE FORT KNOX MINE, 2016

By

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December, 2016

Cover: Pond D Outlet in the Developed Wetlands, October 7, 2016. Photograph by Parker T. Bradley

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Acknowledgements

We thank Fairbanks Gold Mining Inc. (FGMI) (Bartly Kleven, Mark Huffington, Jennifer Pyecha, and Dave Stewart) for their continued support of our work to monitor fish and wildlife resources in the water supply reservoir, tributaries, and developed wetlands. Bartly Kleven and Mark Huffington (FGMI) provided constructive review of our report.

Executive Summary

Water Quality

●Dissolved oxygen (DO) concentrations were measured in late March 2016 and for the second consecutive year DO concentrations were some of the highest seen since sampling began in 1998. Higher DO concentrations appear to be directly related to the discharge of non-contact mine water to the water supply reservoir (page 12).

Arctic Grayling Stilling Basin

●No fish sampling was conducted in 2016.

Arctic Grayling Water Supply Reservoir

●In spring 2016, Arctic grayling spawning probably began around April 29 when peak water temperatures reached 4.0ºC and by May 4 (when sampling ended), 23% of the females handled had completed spawning (page 23).

●The spring 2015 population estimate for Arctic grayling ≥ 200 mm FL was 5,947 fish (95% CI 5,111 to 6,783 fish) (page 24).

●Some recruitment of Arctic grayling was observed in spring 2016, 89 new fish between 200 and 245 mm FL were captured and tagged (page 25).

●The highest average annual growth by size class occurred in 2014 and the lowest in 2015 (page 26).

Burbot Water Supply Reservoir

●In spring 2016, 60 burbot that ranged from 125 to 900 mm TL were captured in the developed wetlands. Twenty three of those fish were larger than 400 mm TL and 6 had been initially captured in spring 2015 (page 27).

●The estimated population of large burbot (≥ 400 mm) in the WSR was 92 (95% CI 46-138) for spring 2015 (page 29).

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located in the headwaters of the Fish Creek drainage about 25 km northeast of Fairbanks, Alaska (Figure 1). The project included an open-pit mine, mill, tailings impoundment, water supply reservoir (WSR), and related facilities. Construction of the WSR dam and spillway was completed in July 1996. In 2007, permits were issued for the construction, operation, and closure of a valley fill heap leach facility located in Walter Creek upstream of the tailings pond. In 2016, ore was processed through the mill as well as through the Walter Creek valley fill heap leach. Exploration drilling continued in the vicinity of the existing open pit.

Figure 1. Aerial photograph of the Fort Knox Gold Mine WSR, tailings facility and pit – water supply reservoir in lower part of photo and the tailings dam and impoundment in the upper Fish Creek valley, photograph provided by FGMI.

Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of some disturbed habitats has been rapid. Wetland construction between the tailings dam and the WSR began in summer 1998. A channel connecting Ponds D and E was rebuilt in summer 2001.

In-channel excavation, drainage rock placement, and channel reconstruction work to mitigate aufeis in Last Chance Creek was conducted in fall 2001 and again in fall 2008. Repair work on dikes separating Ponds D and E and the channel connecting the ponds was completed in summer 2002. Buell and Moody (2005) provided recommendations for additional work to enhance fish and wildlife habitats between the tailings dam and WSR.

Ponding of water for the WSR began in November 1995. Water surface elevation varied in 1996 and 1997 due to water use and winter seepage below the freshwater dam. The WSR reached the projected maximum water surface elevation of 1,021 feet on September 29, 1998, after a major rainfall event. When full, the WSR contains about 3,363 acre-feet (1.1 billion gallons) of water. Water levels have remained fairly constant since 1998, except in the winter in certain years when large amounts were removed (Table 1). In late April 2016 there was surface flow over the spillway. No removal of water during winter (October 1 to April 30) occurred in 2015/2016.

In spring 2015, FGMI initiated a discharge of non-contact water from dewatering wells around the open pit. The discharge was authorized by a permit issued by the Alaska Department of Environmental Conservation. The discharge began in mid-March and has been continuous except for a few shutdowns. The water from the discharge appeared to have a beneficial effect by increasing the dissolved oxygen in the WSR in late winter.

A chronology of events from 2011 to 2016 with emphasis on biological factors is presented in Appendix 1. The chronology for previous years (1992 to 2010) can be found in ADF&G Technical Report No. 10-5, "*Arctic grayling and burbot studies at the Fort Knox Mine, 2010*" (Ott and Morris, 2010).

Table 1. Winter (October 1 to April 30) water use from the WSR, 1997 to 2016.

Year (October 1 to April 30)		Acre-Feet of Water Removed		Percent of Water Removed
1997/1998		660		19.6
1998/1999		605		18.0
1999/2000		577		17.2
2000/2001		1,464		43.5
2001/2002		320		9.5
2002/2003		337		10.0
2003/2004		279		8.3
2004/2005		716		21.3
2005/2006		659		19.6
2006/2007		299		8.9
2007/2008		1,176		35.0
2008/2009		817		24.3
2009/2010		1,167		34.7
2010/2011		187		5.6
2011/2012		59		1.8
2012/2013		1,837		54.6
2013/2014		1,399		41.6
2014/2015		104		3.1
2015/2016		0		0

Fish research prior to construction of the Fort Knox mine and related facilities began in 1992 and water quality sampling started in summer 1997. Technical Reports are listed in Appendix 2.

Populations of Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) exist in the WSR, and both Arctic grayling and burbot inhabit the stilling basin below the WSR. Arctic grayling spawning occurs predominantly in the wetland complex between the WSR and the tailings dam. Burbot spawning as documented by using radio telemetry likely occurs in Solo Bay where Solo Creek enters the WSR. Recruitment of Arctic grayling to the stilling basin is from the WSR, but no tagged burbot from the WSR have been caught in the stilling basin. This report summarizes fish and water quality data collected during 2016 and discusses these findings in relation to previous work.

Methods

Water Quality

In 2016, water quality sampling was conducted on March 29 and 31 when the WSR was ice covered (Figure 2). Temperature (^{o}C), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance (*u*S/cm), oxidation reduction potential (ORP), and depth (m) were measured with a Hydrolab® Minisonde®5 water quality multiprobe connected to a Surveyor® 4 digital display unit. The multiprobe sensors were calibrated to suggested specifications prior to use. The LDO sensor was calibrated using a saturated air method. Conductivity, ORP, and pH sensors were calibrated with fresh standard solutions. Winter water quality measurements were made at 1 m depth intervals from the surface to the bottom.

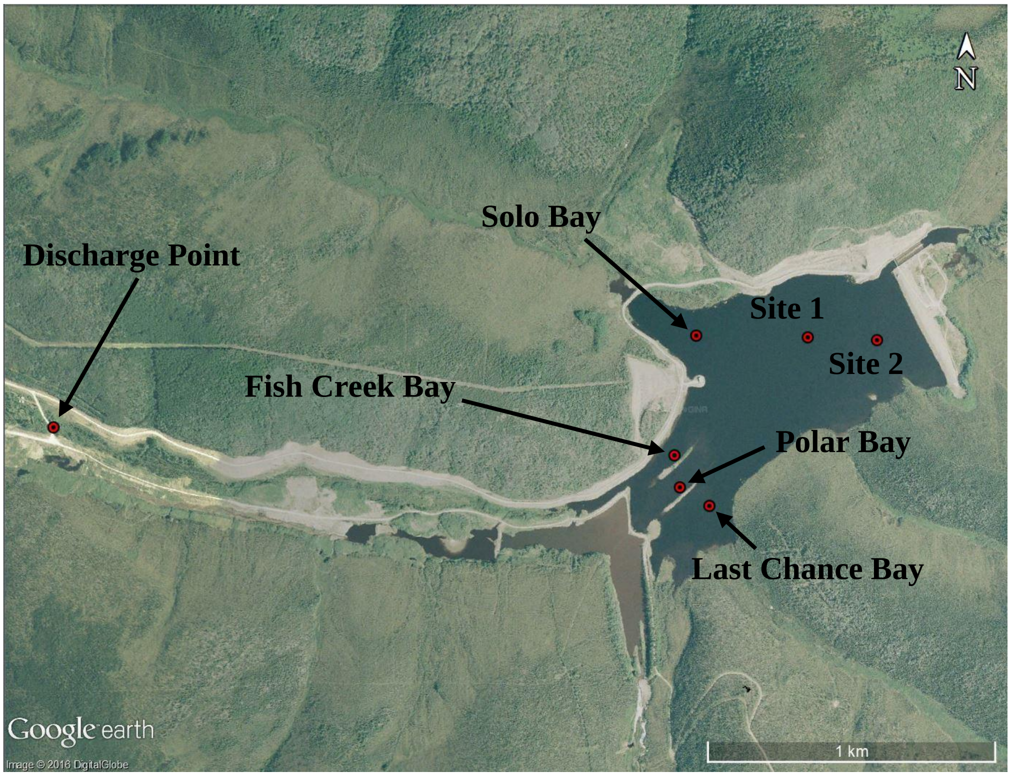

Figure 2. Map of Fort Knox Water Supply Reservoir water quality sample sites, March 29 and 31, 2016. All sites were sampled except for the discharge point.

Temperature probes were placed in the Pond F outlet channel and in the outlet of the old Fish Creek channel downstream of the discharge point. Additional temperature probes were put at the point of discharge, and in the water supply reservoir in Solo Creek Bay, Fish Creek Bay, and Last Chance Bay. The temperature probes were pulled on October 7, 2016.

Fish

Fish sampling methods included visual observations, fyke nets, angling, and hoop traps. Two fyke nets were set in the developed wetlands. A fyke net was set on April 25 at the mouth of Fish Creek, and the second was placed in the outlet of Pond F above the culvert on April 26. Both fyke nets were pulled on May 4 when an adequate number of fish had been captured for the population estimate. In early October, hoop traps were set along the shoreline to fish for burbot.

Arctic grayling were measured to fork length (nearest mm), inspected for tags and spawning condition, and released. Burbot were measured to total length (nearest mm), inspected for tags, and released. Un-tagged Arctic grayling ≥ 200 mm and burbot ≥ 300 mm were marked with a numbered Floy® T-bar internal anchor tag. Abundance of Arctic grayling and burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

Results and Discussion

Water Supply Reservoir, Water Quality

Water quality data were collected prior to breakup on March 29 and 31, 2016 (Appendix 3). Average ice thickness on the WSR was about 1 m. The water surface elevation was at the ice surface across the reservoir with the exception of Last Chance Bay which had about five cm of overflow. Water temperature ranged from 0.13ºC to 2.52ºC and generally increased with depth with minor cooling observed at depths greater than 6 m at Solo Bay, Site 1, Site 2 and at depths deeper than 3 m in Fish Bay (Figure 3). All locations had a similar temperature profile with depth, except for Fish Creek Bay which was much cooler. Based on temperatures taken in the old Fish Creek channel in spring 2015, this likely is a result of the non-contact groundwater discharge which cools as it moves down the valley and is near freezing (0.2°C) at the confluence with Fish Creek.

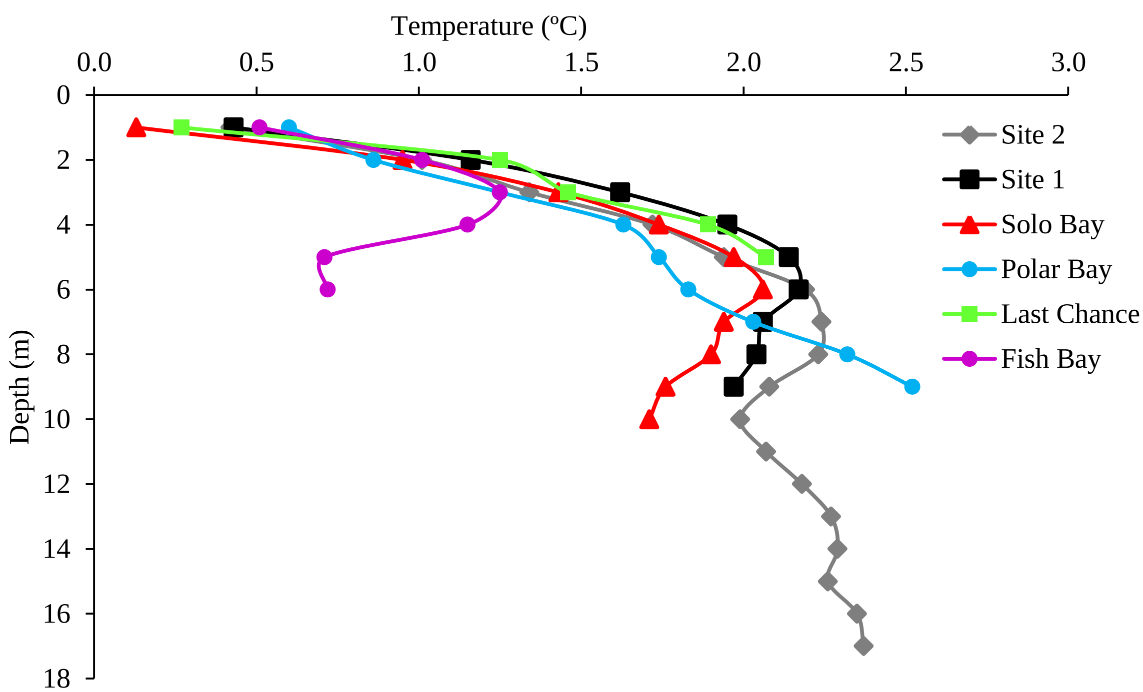

Figure 3. Temperature (°C) profiles, March 29 and 31, 2016

Dissolved oxygen concentrations were high relative to other years, particularly in Fish Creek Bay, Polar Bay, and Last Chance Bay (Figure 4). At these locations, DO concentrations are usually the lowest in the WSR averaging 1.7 to 2.4 mg/L, rarely exceeding 4 mg/L. Fish Creek Bay had the highest DO concentration for the second year in a row averaging 6.75 mg/L followed by Polar Bay at 5.97 mg/L. Similar results for DO were found in 2015 and it was determined the elevated DO concentrations were primarily a result of the non-contact groundwater discharge that began in March 2015.

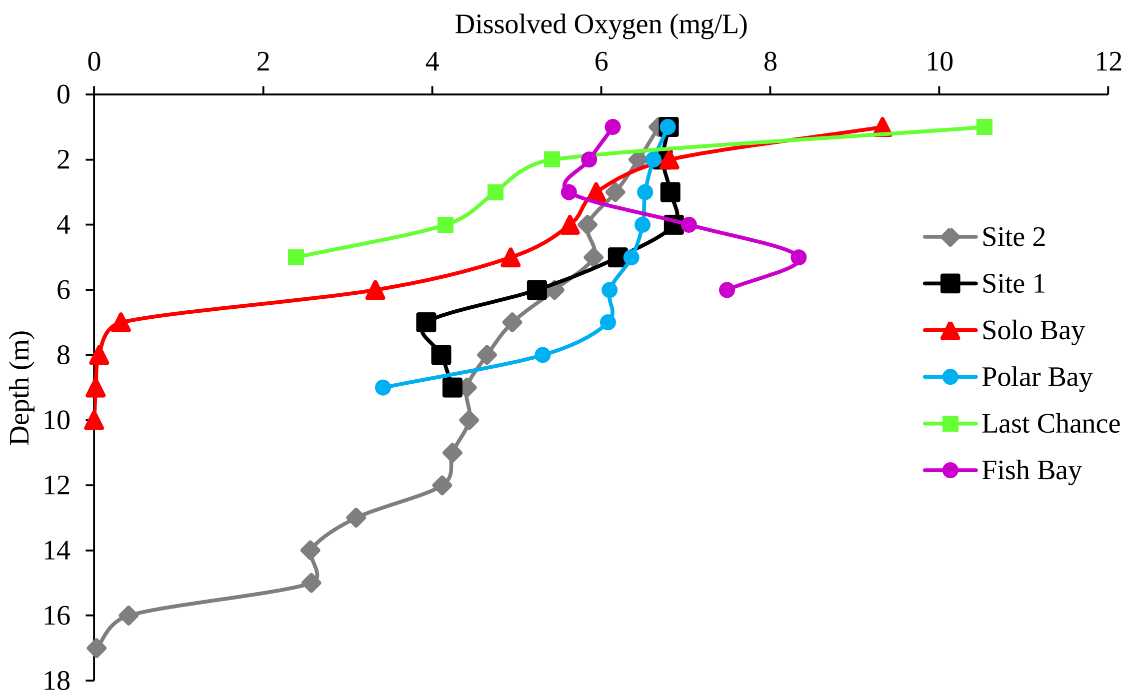

Figure 4. WSR dissolved oxygen (mg/L) profiles, March 29 and 31, 2016.

This discharge continued for the duration of winter 2015/2016 resulting in DO concentrations slightly higher than April 2015 values, particularly at depth. For example, at Site 2 in 2015, DO concentrations above 4 mg/L were maintained to about 7 m in depth while in 2016, DO above 4 mg/L was maintained to 12 m in depth. At all locations, DO concentrations generally decreased with depth, except for Fish Creek Bay which increased with depth. Temperature specific DO saturation followed the same pattern as DO concentrations with exceptionally high levels in the upper WSR.

The pH values ranged from 6.52 at Fish Creek Bay to 8.14 at Site 1. Generally, pH decreased with depth at all sites except for Fish Creek Bay, where it slightly increased with depth (Figure 5).

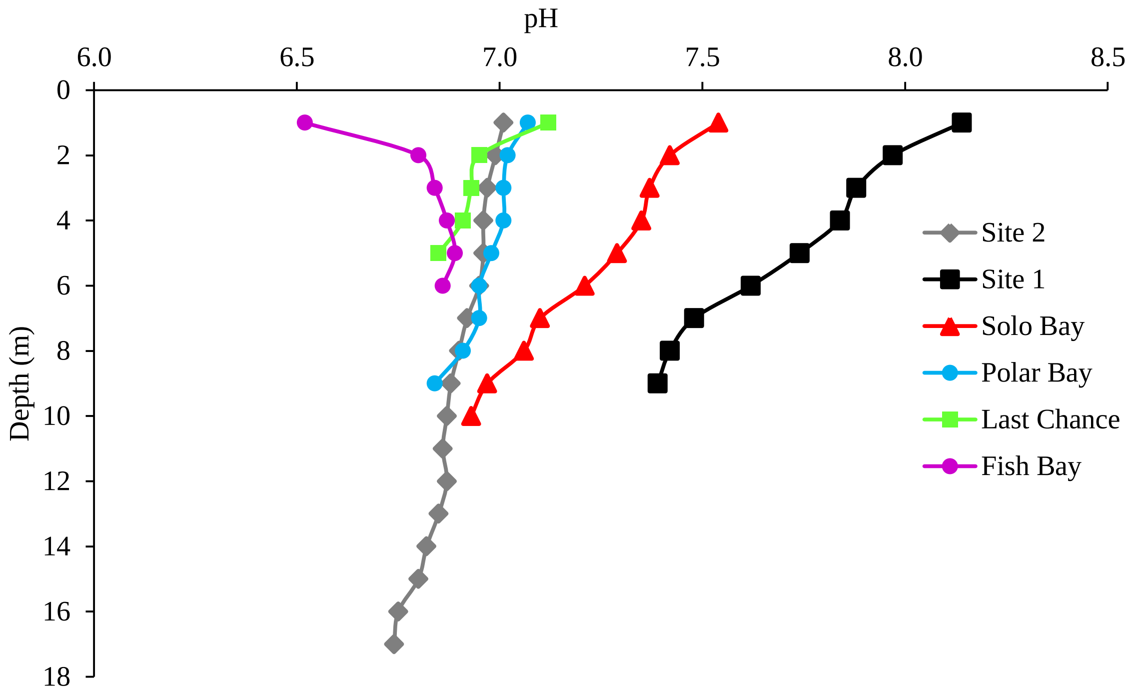

Figure 5. WSR pH profiles, March 29 and 31, 2016.

Specific conductance was similar throughout most of the reservoir in the top 8 m of the water column, at which time it began increasing with depth (Figure 6). In contrast, specific conductance in Fish Creek Bay began increasing after 3 m in depth.

Oxidation reduction potential (ORP) was similar at most sites, except for Site 1 which contained the lowest average ORP (Figure 7). Values were nearly consistent with depth in the upper layers, but began to decrease drastically at depths at or near anoxic conditions.

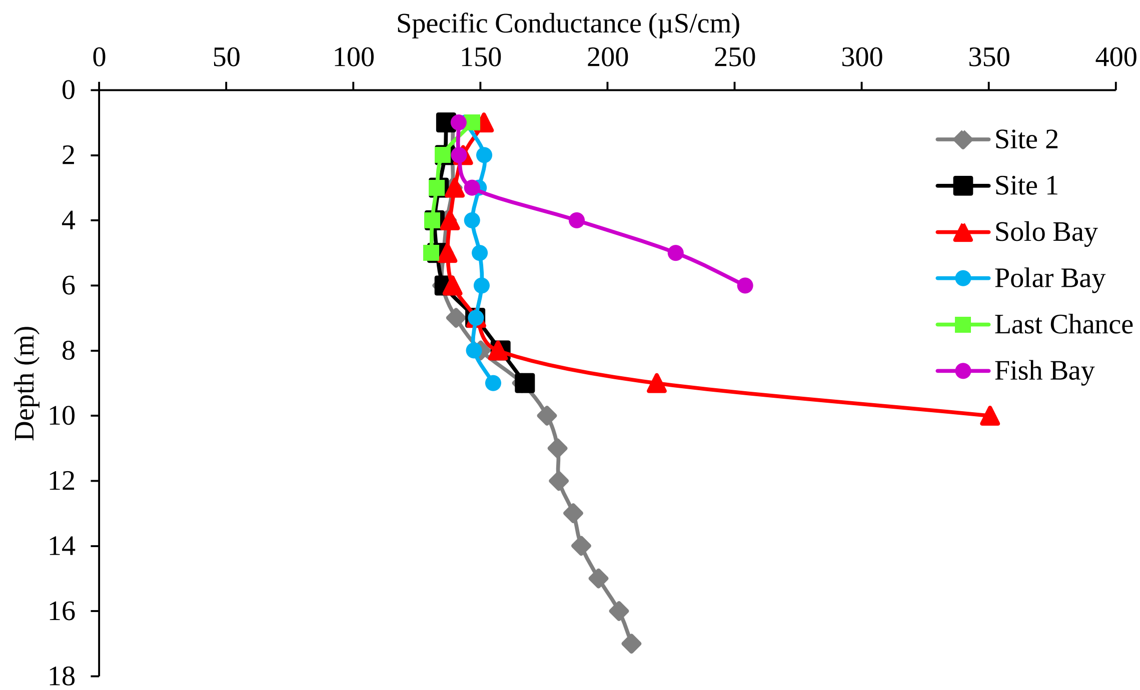

Figure 6. WSR specific conductance (uS/cm) profiles, March 29 and 31, 2016.

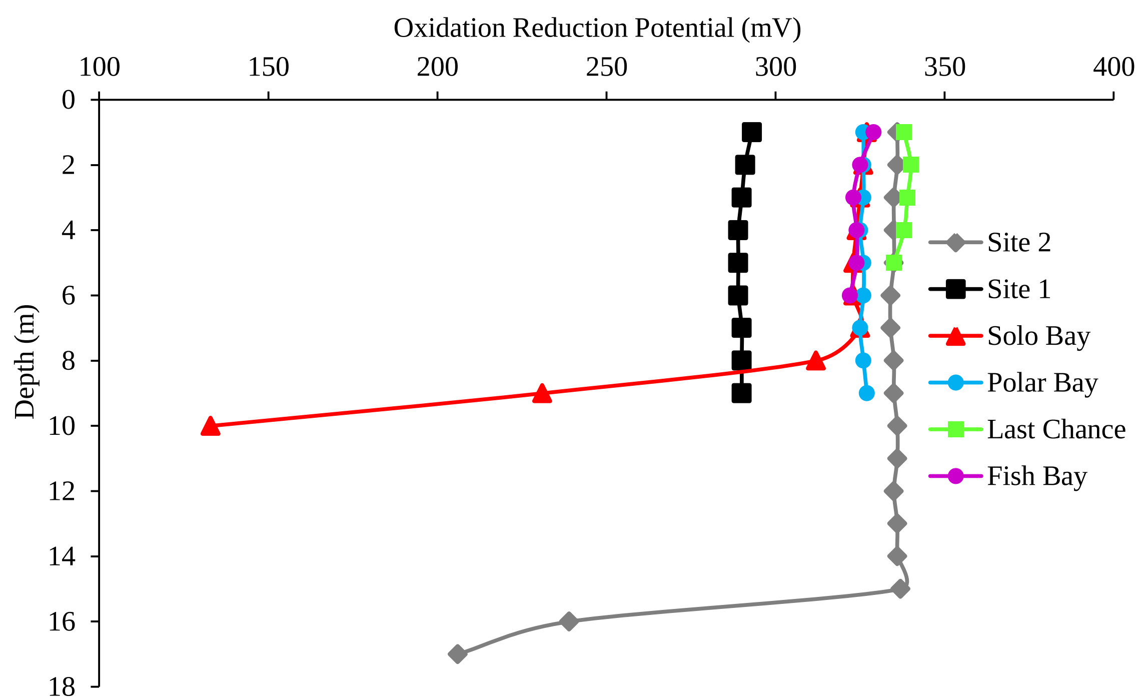

Figure 7. WSR oxidation reduction potential (mV) profiles, March 29 and 31, 2016.

Average winter water column DO at Site 2 was above the 14 year average and the highest on record (Figure 8). This is likely a result of the near continual discharge of non-contact ground water into the Fish Creek Valley about 2 km upstream from the WSR (Figure 2).

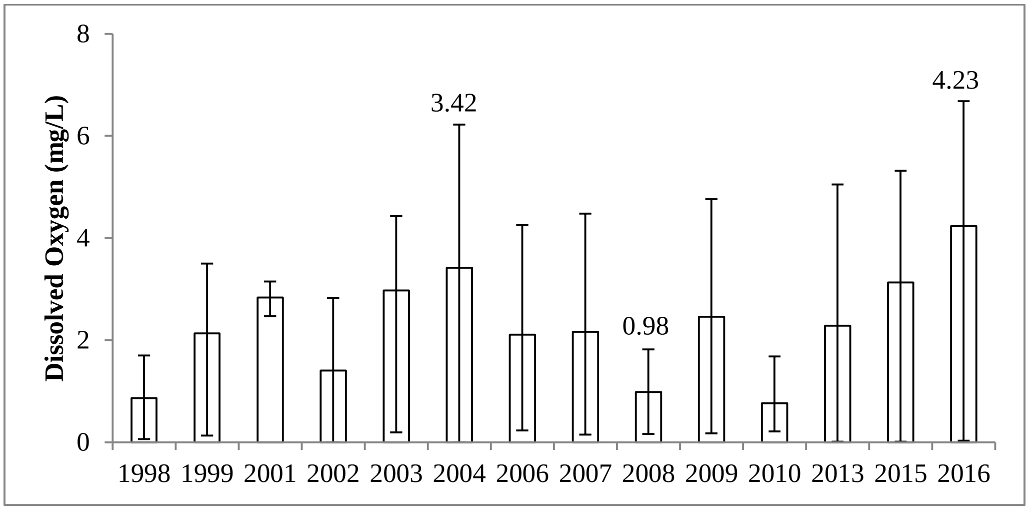

Figure 8. Average, maximum, and minimum dissolved oxygen at Site 2 during late winter.

The DO concentrations in late winter of 2015 and 2016 were much higher than those recorded in 2013 (Figure 9). This dramatic increase in DO concentrations probably is due to the discharge of non-contact water to the Fish Creek valley upstream of the WSR.

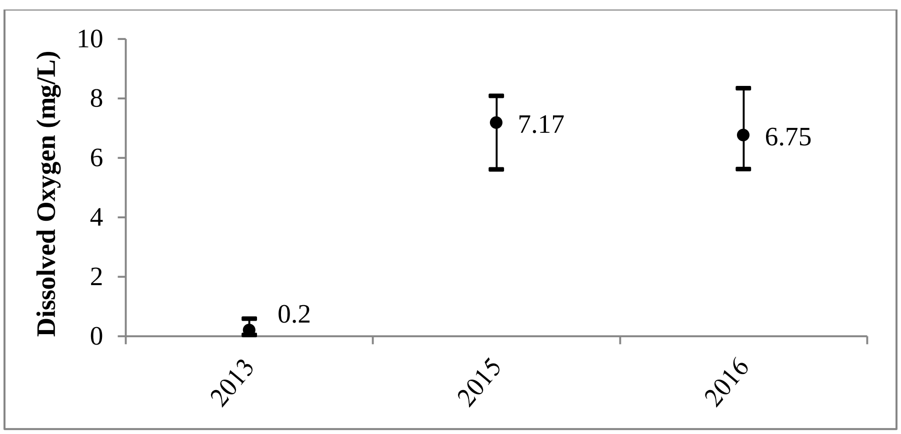

Figure 9. Average, maximum, and minimum dissolved oxygen in Fish Creek Bay during late winter.

Water temperatures were highly variable from April through October 2016 (Figure 10). Generally, while discharge was occurring in June and July, water temperatures were highest near the confluence with Fish Creek. After the discharge was turned off from late July through early September, water temperatures were warmer near the point of discharge.

When the temperature loggers were retrieved in October, it was discovered the discharge water goes subsurface about 0.5 km from the point of discharge and the lower temperature logger had been dewatered. When comparing the temperature data from the lower temperature logger to the air temperature data records from the Fairbanks International Airport, it appears that the lower temperature logger became exposed to the air, or extremely shallow water, around August 5, shortly after the discharge was turned off. It appears to have remained dry even after the discharge was turned back on.

In contrast, the upper temperature logger (near the point of discharge) was placed in a pool and remained submerged, therefore providing a more accurate record of discharge temperatures.

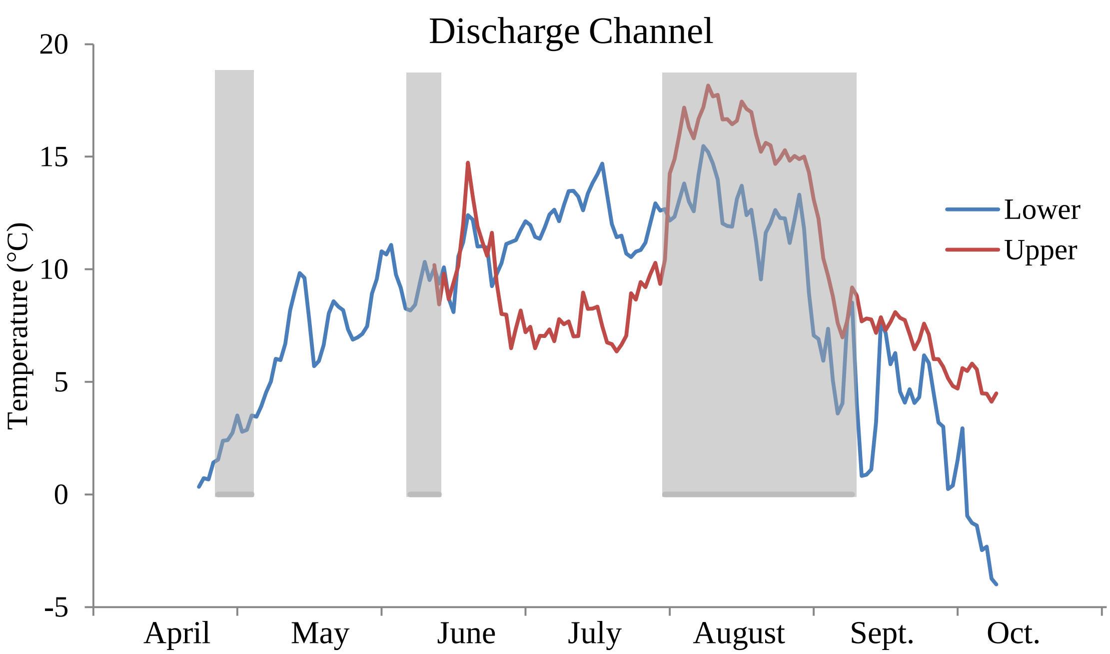

Figure 10. Average daily water temperature (°C) in the discharge channel at the upper end at the point of discharge (red) and the lower end just before its confluence with Fish Creek (blue). Gray shaded boxes indicate periods of time when discharge was not occurring.

Water temperatures in Fish Creek, Solo Creek, and Last Chance bays all showed the same general pattern (Figures 11, 12, and 13). The depth in Fish Creek Bay was relatively shallow (about 2 m), so only two temperature loggers were deployed – one on the surface and one on the bottom. Solo and Last Chance bays were deeper and had temperature loggers positioned at the bottom, middle, and top of the water column. Highest water temperatures occurred on July 16, following a week of very warm air temperatures. Air temperature decreased drastically on July 17 and caused a sharp decrease in water temperature at all sites. Surface water temperatures tracked closely with air temperatures, and beginning early September, water temperatures began steadily decreasing until logger retrieval. In Solo Creek and Last Chance bays, water temperatures were very similar throughout the water column beginning early September.

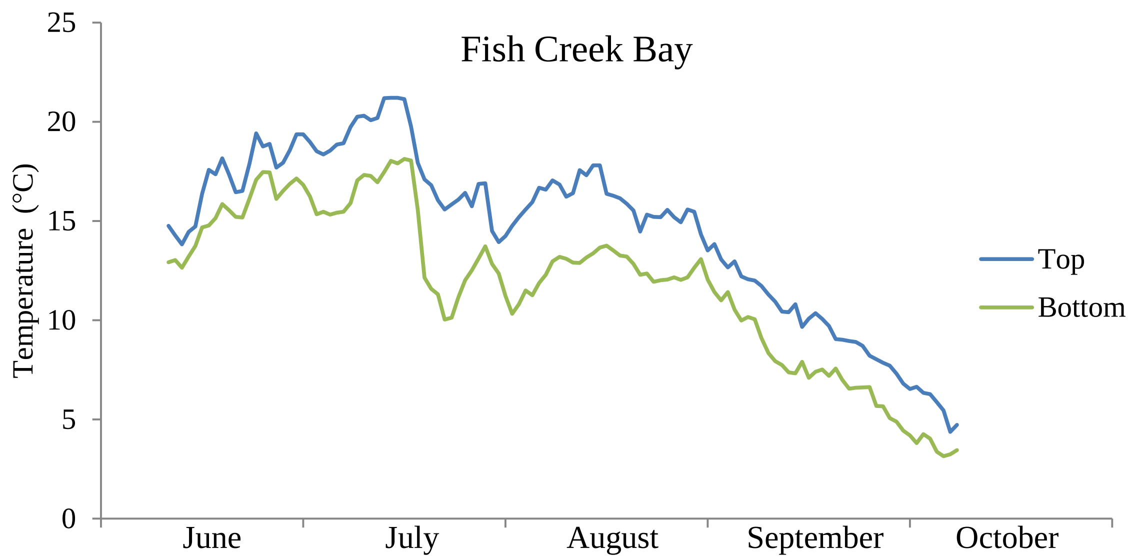

Figure 11. Average daily water temperature (ºC) in Fish Creek Bay June 11 through October 6, 2016 in the top (blue) and bottom (green) of the water column.

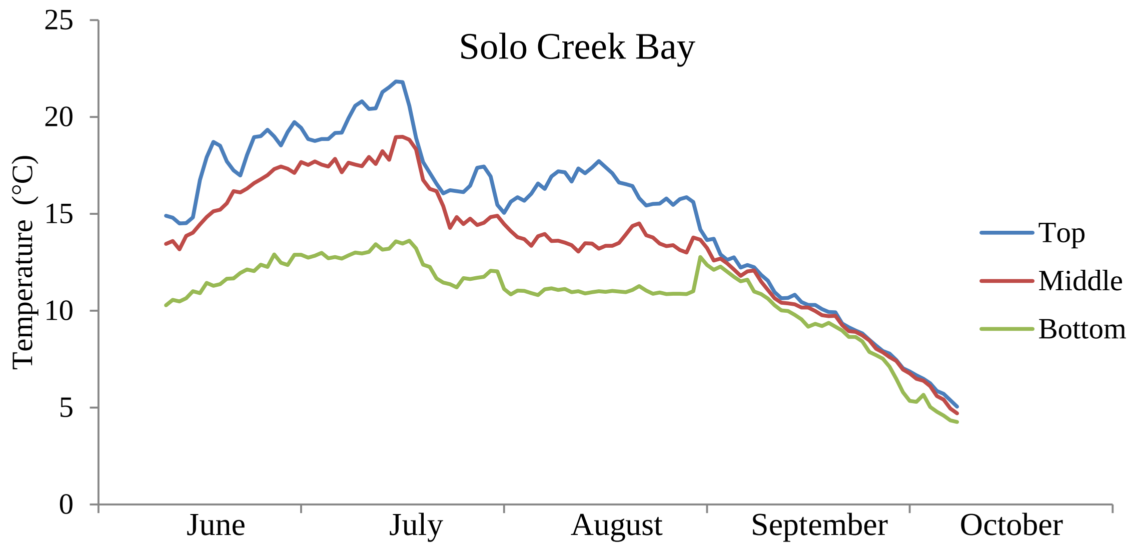

Figure 12. Average daily water temperature (ºC) in Solo Creek Bay June 11 through October 6, 2016 in the top (blue), middle (red), and bottom (green) of the water column.

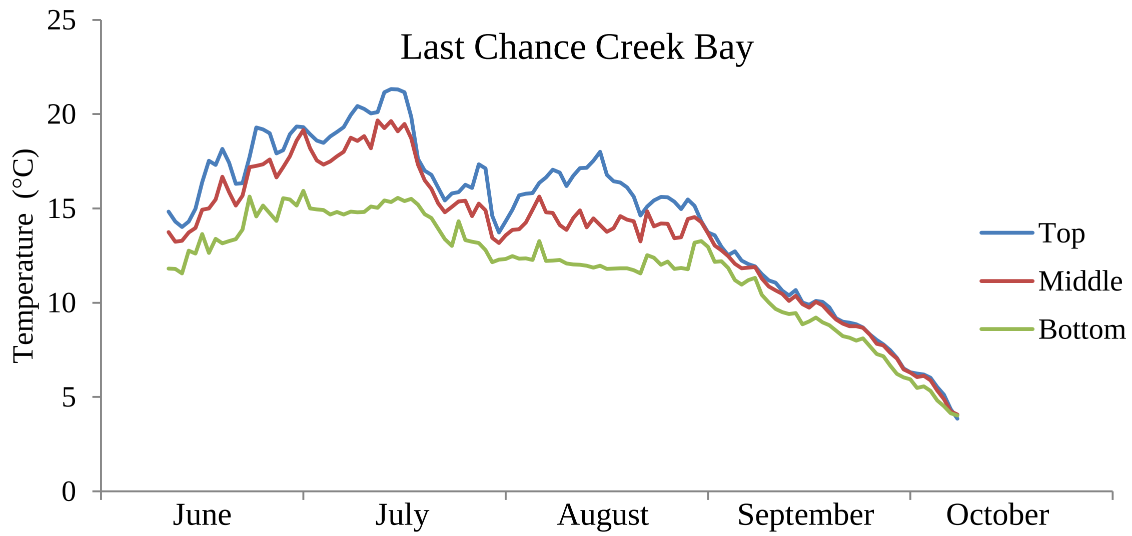

Figure 13. Average daily water temperature (ºC) in Last Chance Creek Bay June 11 through October 6, 2016 in the top (blue), middle (red), and bottom (green) of the water column.

Stilling Basin, Arctic Grayling

The stilling basin, located immediately downstream of the WSR spillway, is fed by groundwater, seepage flow, and surface flow (Figure 14). A narrow notch in the spillway was designed to accommodate surface water discharge from the WSR during winter without forming aufeis. Aufeis in the spillway has never been observed since it was constructed. In spring 2016, water was flowing over the spillway. Fish sampling in the stilling basin was not conducted during summer 2016.

Figure 14. Stilling basin on March 29, 2016 (photo by Parker Bradley).

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. However, fish were concentrated in flooded mine cuts in Last Chance Creek. The population appeared stunted: fish larger than 220 mm were rare; average annual growth was 9 mm; and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning was limited to inlets and outlets of the flooded mine cuts and upper Last Chance Creek. Flooding of the WSR inundated the inlets and outlets of mine cuts, thus eliminating this spawning habitat. Since flooding of the WSR, aufeis in Last Chance Creek has been substantial. Since 1998, successful spawning by Arctic grayling in Last Chance Creek has only been observed in 2004 and 2005.

Very few fry were captured or observed (< 10 fish) from 1996 through 1998 in the WSR and Last Chance Creek. In spring 1999, FGMI constructed an outlet channel to connect the developed wetland complex with the WSR (Figure 15). The outlet channel was constructed to bypass a perched pipe and provide fish access to potential spawning and rearing habitat in the wetland complex.

Figure 15. Pond F outlet channel downstream of the road crossing in late June 2010 (Photo by ADF&G).

Arctic grayling have successfully spawned in the wetland complex every year since 1999. However, in 2002, 2006, and 2007, substantial aufeis and resultant cold water temperatures in the wetland complex, in addition to beaver dams, limited the availability of, and access to, spawning habitat. In recent years, aufeis buildup has been relatively minor and more effective beaver management has been implemented.

Arctic Grayling Spawning (Timing, Temperature, and Fry Presence)

In spring 2016, two fyke nets were deployed in the developed wetlands. Aufeis in the wetland complex was minimal and beaver dams in Pond F outlet had not been rebuilt. A small beaver dam had been built in the outlet of Pond D, but that was removed by hand and was not rebuilt. Arctic grayling had access to most of the wetland complex for spawning in spring 2016.

Sampling ended and both fyke nets were removed on May 4 when an adequate number of fish had been captured for the population estimate. On May 4, 2016, 70% of the females were ripe and 23% were spent. The wetland complex ponds and the WSR were still 70% ice covered.

Catch rates (fish/hour) in the lower fyke net peaked on May 2 with 331 Arctic grayling being captured over a 45 hour period (Figure 16). The lower catch on April 27 was due to a small hole in the cod end of the fyke net which allowed fish to escape.

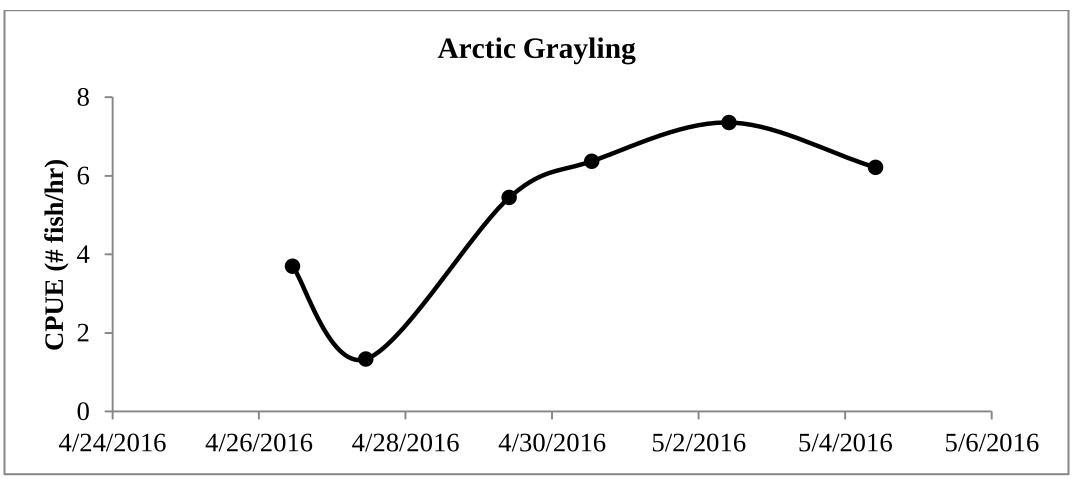

Figure 16. Arctic grayling catch per unit of effort (# fish/hr) in the lower fyke net in the Pond F outlet channel.

Very few Arctic grayling were caught in the Pond F fyke net. Based on that observation; we concluded fyke nets were deployed before most of the fish had entered the wetland complex and the majority of fish likely spawned downstream of the Pond F outlet (between the two fyke nets).

In spring 2016, Arctic grayling spawning probably began around April 29 when peak water temperatures reached 3.5°C. By May 4 (when sampling ended), 23% of the females handled were spawned out (Figure 17). Spring temperatures in Pond F outlet from 2010 to 2016 are presented in Figure 18. 2016 was warmest spring since 2010, while 2013 was the coldest – almost one full month of difference.

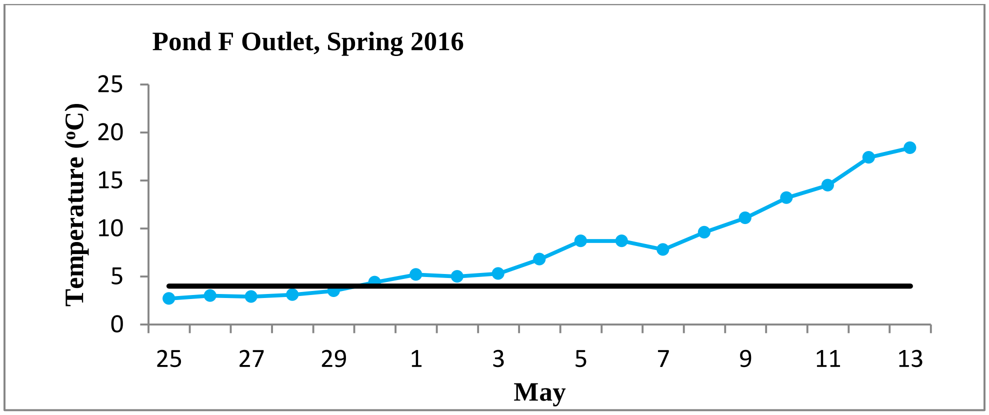

Figure 17. Peak daily water temperatures in Pond F outlet channel in spring 2016.

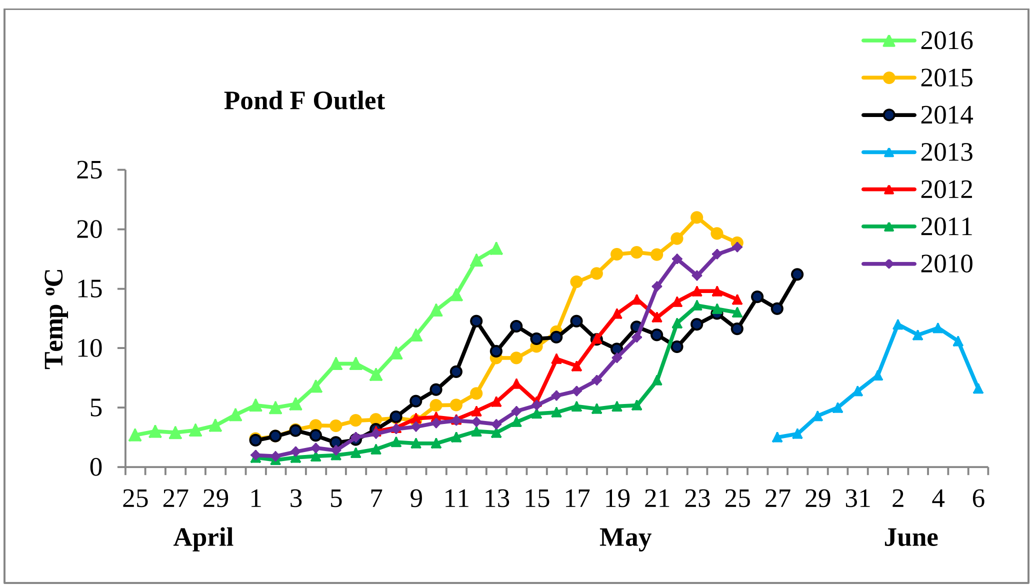

Figure 18. Peak daily water temperatures in Pond F outlet channel in spring 2010 to 2016.

Arctic Grayling Catches and Metrics

The abundance of Arctic grayling was estimated in the WSR using spring 2015 as the mark event and spring 2016 as the recapture event. In spring 2015, there were 780 marks when newly tagged and recaptured fish were combined. In spring 2016, 1,050 Arctic grayling ≥ 245 mm were captured, and of those, 137 were recaptures. For the 2015 estimated Arctic grayling population, length frequency distributions from 2015 and 2016 were compared to eliminate those fish handled in 2016 that would have been too small (< 200 mm) to mark in spring 2015. We had an additional 89 fish caught that were < 245 mm long and these fish were not included in the population estimate.

The spring 2015 population estimate for Arctic grayling ≥ 200 mm long was 5,947 fish (95% CI 5,111 to 6,783 fish) (Figure 19 and Appendix 4). The population has been relatively stable for the last five years.

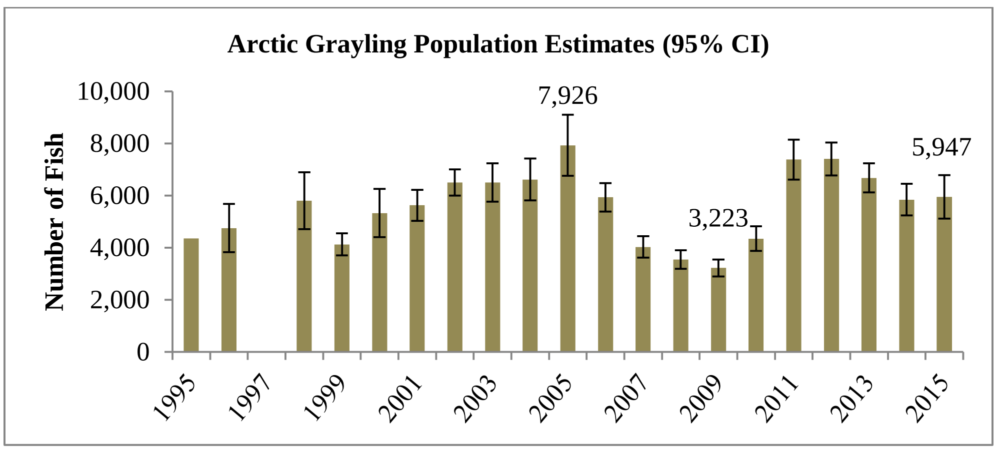

Figure 19. Estimates of the Arctic grayling population (fish ≥200 mm) in the WSR, with 95% Confidence Intervals.

Substantial recruitment events were observed in the spring of 2004, 2010, and 2014 (Figure 20). A substantial recruitment event was defined as >300 fish encountered during a recapture sampling event that were not available for tagging based on size during the mark sampling event (typically fish between 200 and 240 mm).

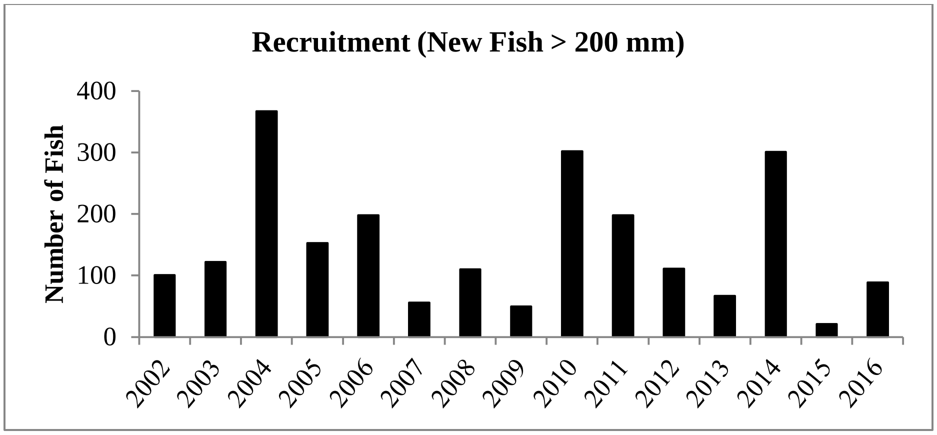

Figure 20. Number of new fish ≥ 200 mm that entered the population but would have been too small to mark in the previous year (based on growth of marked fish).

The length frequency distribution of Arctic grayling captured in 2015 by angling and with a fyke net is presented in Figure 21. The fyke net is set in the spring at the mouth of the creek to target mature Arctic grayling moving upstream to spawning habitats. Thus the catch of small fish (i.e., non-spawners) in some years is low and may not be representative of how many small fish are present in the WSR. The length frequency distribution of Arctic grayling in 1995 also is presented in Figure 21 for comparison. The 1995 data set were obtained before construction of the freshwater dam and reflects the stunted condition of the population at that time. The current population is composed of much larger fish.

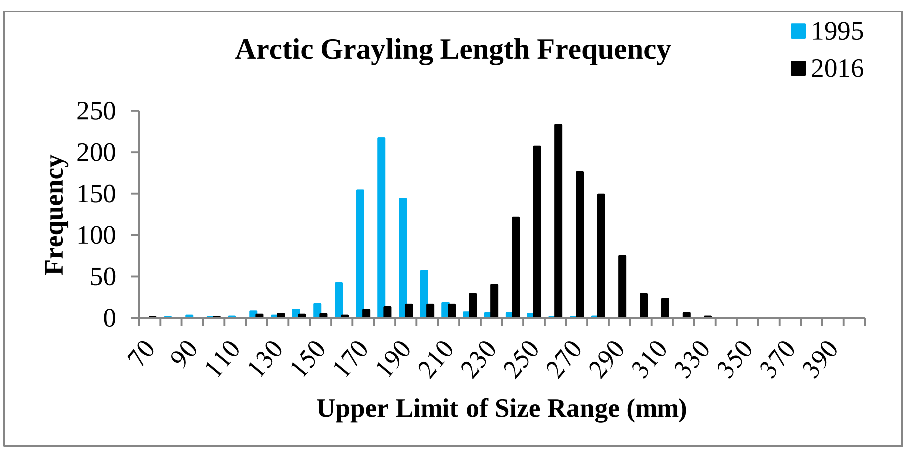

Figure 21. Length frequency distribution of Arctic grayling in 1995 and in 2016.

Average growth of Arctic grayling prior to development of the WSR ranged from 3 to 17 mm per year (Figure 22 and Appendix 5). After the WSR was flooded in 1995, annual growth for fish increased substantially. Average growth in summer 2014 was higher than in 2013. From 2009 to 2015, the highest growth rates were observed in 2009 and 2014 and the lowest growth rates occurred in 2015. The lower growth rates observed in summer 2015 may be related to warmer water temperatures in the WSR due to the discharge of non-contact water from the mine.

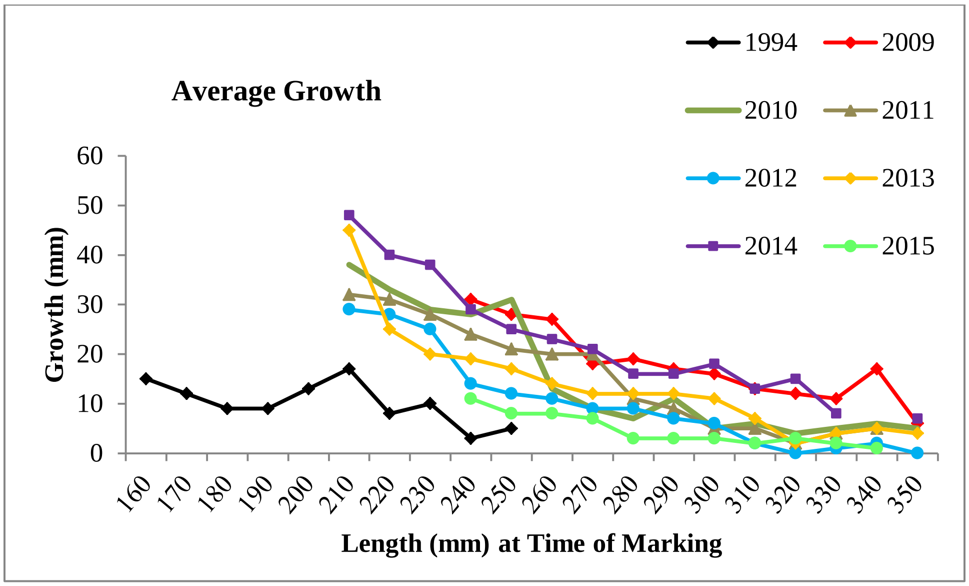

Figure 22. Average growth of marked Arctic grayling before the WSR (1994) and from 2009 to 2015.

Water Supply Reservoir, Burbot

In spring 2016, burbot were caught in fyke nets (n = 60) in the wetland complex (Figure 23). Twenty three of the burbot were ≥ 400 mm long. Burbot ranged in size from 125 to 900 mm.

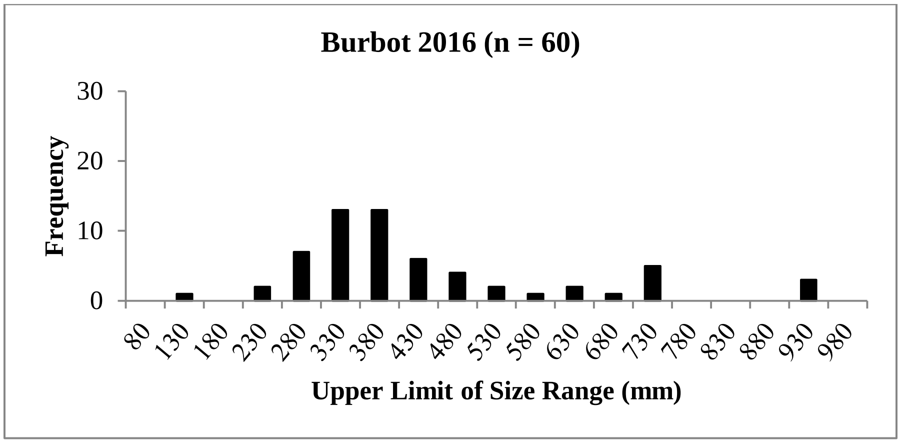

Figure 23. Length frequency of burbot (n=60) in the developed wetlands in spring 2016.

In fall 2016, burbot were captured in hoop traps in the WSR. Twenty six burbot (ranging from 200 to 630 mm) were caught in 10 hoop traps deployed for three days (Figure 24).

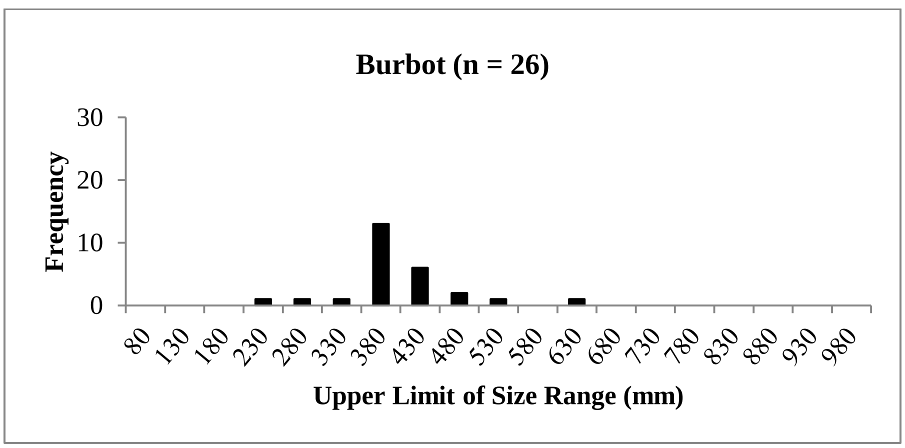

Figure 24. Length frequency of burbot (n=26) in the WSR in fall 2016.

The catch per unit of effort for hoop traps (number of burbot per hoop trap/24 hrs) fished in the WSR remains low as compared with higher catches that occurred following the flooding of the reservoir (Figure 25). Catches of smaller burbot were highest in 1998 (7.2 fish/day), but decreased quickly and have remained low since 2002.

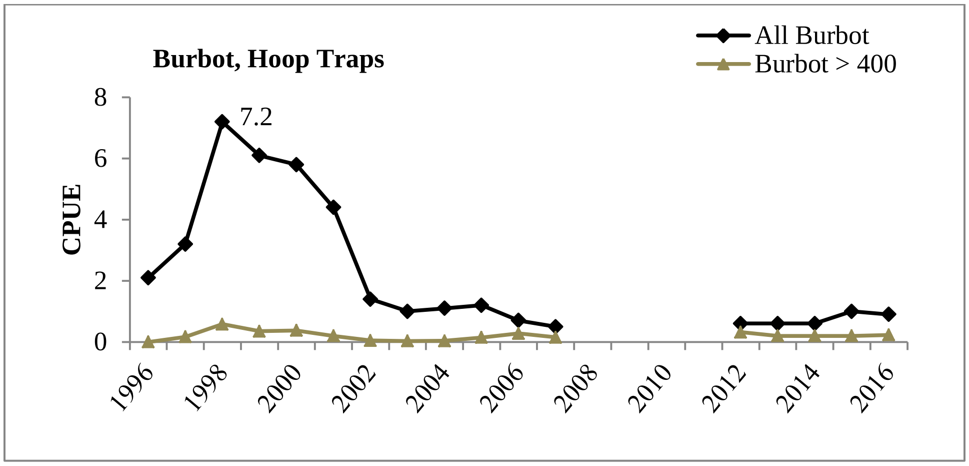

Figure 25. Catch per unit of effort (fish/trap day) of burbot in the WSR from 1996 to 2016.

Catches of large burbot (≥ 400 mm) followed a similar pattern with catches increasing after the WSR was flooded, then decreased for several years, but have been stable the last five years (Figure 26).

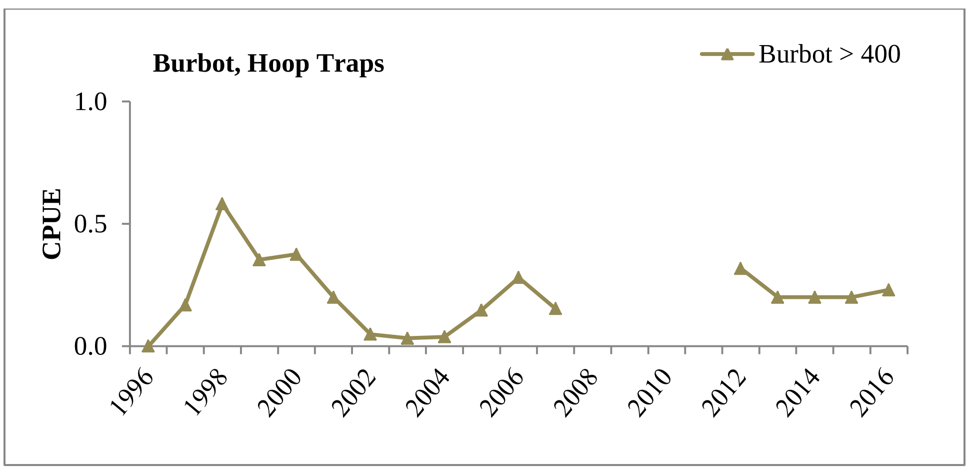

Figure 26. Catch per unit of effort (fish/trap day) of large burbot (≥400 mm) in the WSR from 1996 to 2015.

In spring 2015, we marked or recaptured 26 total burbot ≥400 mm. 23 were new fish and 6 were recaptures from spring 2015. The estimated population of large burbot for spring 2015 was 92 fish (95% CI 45-138 fish) (Figure 27, Appendix 6).

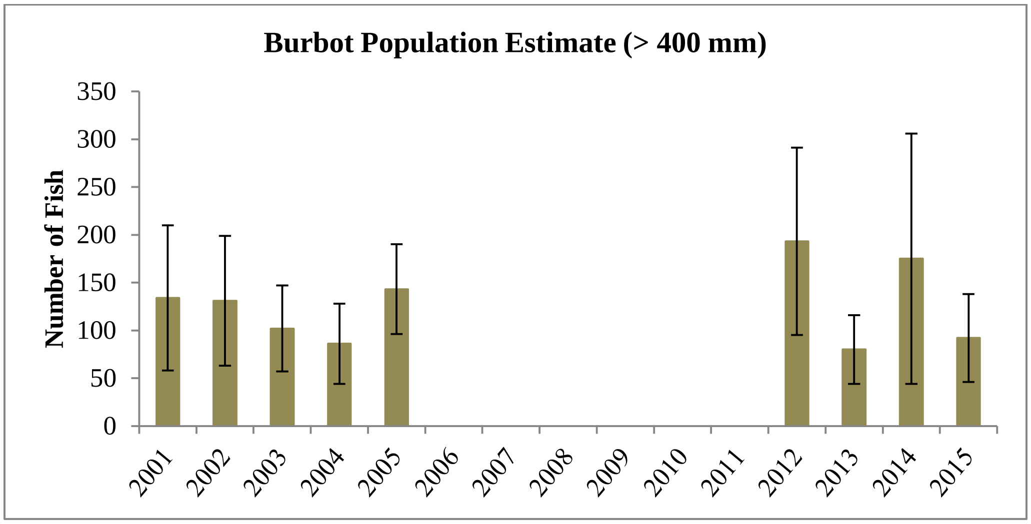

Figure 27. Burbot (≥400 mm) population estimates in the WSR.

Growth rates of burbot from 2013, 2014, and 2015 are shown in Figure 28. Growth is from tagged fish marked or seen in the previous year and recaptured in the following spring. Growth is highly variable, but in general growth rates appeared to be greater in 2015.

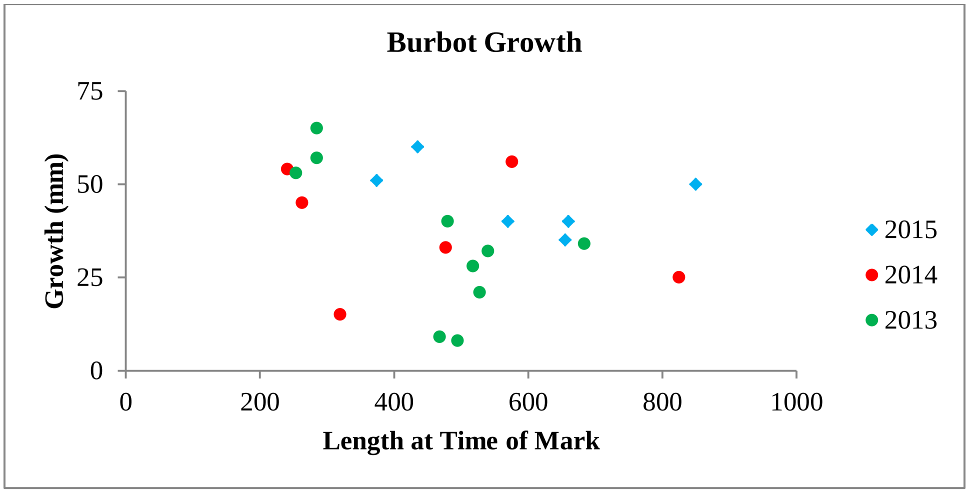

Figure 28. Growth of marked burbot in the WSR.

Conclusion

Populations of Arctic grayling and burbot have been established in the Fort Knox WSR. The post-mining goal for the Arctic grayling population was set at 800 to 1,600 fish $\geq$ 200 mm (FGMI 1993). Our spring 2015 estimated population for Arctic grayling $\geq$ 200 mm was 5,947 fish which is a slight increase from the estimated 2014 population. A goal for the burbot population was not set prior to construction, but a small population of fish larger than 400 mm is present in the WSR.

We plan to continue to work cooperatively with FGMI to collect data on fish resources and water quality in the WSR and to implement rehabilitation projects designed to increase fish and aquatic habitat values and terrestrial habitats. Active management of beaver populations within the developed wetlands and WSR appears to remain a critical component to the productive capacity of the wetland complex for Arctic grayling.

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Appendix 1. A Summary of Mine Development with Emphasis on Biological Factors

2011

- on February 9, 2011, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. We identified several possible fish and wildlife enhancement projects originally recommended by Buell and Moody (2005).
- on March 4, 2011, the ACOE issued a permit (POA-1992-574-M19) authorizing construction of the modified dam raise and expansion of the Tailings Storage Facility (TSF).
- in April and May several Plan of Operations amendments were issued by ADNR for work associated with the TSF, waste rock dumps, powerline, topsoil storage, and dewatering.
- on May 2, 2011, ADF&G provided input to ADNR on the reclamation and closure plan for Fort Knox. Emphasis was on maintaining the existing developed wetland complex downstream of the TSF.
- our spring sample event for Arctic grayling and burbot ran from May 9 to 24. We caught 1,194 Arctic grayling and 117 burbot in a fyke net set in the WSR.
- the estimated spring 2010 Arctic grayling population was 4,346 fish > 200 mm long and was an increase from the 2009 estimate of 3,223. Recruitment of new fish in spring 2011 was strong with 198 new fish < 230 mm marked.
- Arctic grayling spawned in the wetland complex from Pond D downstream. Beavers had not rebuilt the dams in the wetland complex.
- a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2011 – one chick was seen in August. An active raven nest was observed on the rock cut near the freshwater dam.
- water began flowing over the spillway on May 27, water had not reached the spillway since winter 2009/2010.
- on June 2, 2011, ADF&G provided written comments on the Ft. Knox and True North environmental audit proposals.
- on July 19, 2011, FGMI pumped about 10,440 gallons of water from the "801 Pond" downstream – environmental staff were notified and pumping was immediately stopped – water from the "801 Pond" is supposed to be pumped back into sump below the TSF
- on August 4, 2011, ADNR informed us of planned changes at Fort Knox including expansion of the heap leach facility from 160 to 300 million tons, the need for a ADEC permit to discharge non-contact water, and the long-term need for a permit and water treatment plant for closure.

Appendix 1 (continued)

2011

●on September 13, 2011, ADNR approved the drilling of two monitoring wells in the headwaters of Victoria Creek. The purpose of these monitoring wells is to ensure water in Victoria Creek is not impacted by the increased elevation of tailings in the Pearl Creek drainage.

●on September 28, 2011, we met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

2012

●our spring sample event (Arctic grayling and burbot) began on May 7 and ended on May 30. The estimated spring 2011 Arctic grayling population was 7,378 fish $\geq$ 200 mm long which was an increase of 3,032 from the 2010 estimate. Recruitment of new fish in spring 2012 was strong with 111 new fish < 230 mm marked.

●we caught 140 burbot (175 to 950 mm long) in spring 2012 in hoop traps and fyke nets.

●Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2012. Beavers had not rebuilt the dams in the wetland complex.

●a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2012.

●water was flowing over the spillway when we began sampling in the spring of 2012 – water was still overflowing in late October.

●on July 13, 2012, ADF&G provided input to ADEC on the APDES draft permit for discharge of non-contact water. The discharge point has been changed to the old Fish Creek channel just downstream of Ponds A and B. The ADEC permit was issued on August 15, 2012.

●on September 27, 2012, ADF&G confirmed that a culvert in the road down the Fish Creek valley had been removed. In our trip report to FGMI, we recommended some additional civil work to ensure that the discharge water stays on the north side of the valley.

2013

●on February 20, 2013, FGMI received a Notice of Violation from the ACOE for the unauthorized discharge of fill material into 0.28 acres of wetlands

●on March 1, 2013, ADF&G informed FGMI that their 2012 Annual Report was extremely well done and FGMI's report was distributed to all habitat offices in the state

●on March 11, 2013, the ACOE issued an After-the-Fact authorization covering the 0.28 acres of wetland fill

Appendix 1 (continued)

2013

●on April 25, 2013, water quality data (temperature, dissolved oxygen, etc.) were collected in the WSR under ice cover

●on May 4, 2013, the ADNR transmitted comments on the December 2012 reclamation and closure plan

●our spring sample event (Arctic grayling and burbot) began on May 20 and ended on June 10. The estimated spring 2012 Arctic grayling population was 7,404 fish $\geq$200 mm long. Recruitment of new fish in spring 2013 was strong with 114 new fish <230 mm marked

●we caught 96 burbot (89 to 697 mm long) in spring 2013 in hoop traps and fyke nets

●Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2013. Beavers had rebuilt the dams in the wetland complex, but the dams were notched to allow fish passage

●a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2013

●water was not flowing over the spillway when we began sampling, but by May 27 water had begun to flow out of the WSR and over the spillway

●on June 25, 2013, we observed Arctic grayling fry (numerous) in the upper portion of Channel C, very few fry were observed in Pond F and the Pond F outlet

●on October 14, 2013, ADF&G submitted comments on the Fort Knox 2013 reclamation plan – eight recommendations were made

●on November 27, 2013, ADF&G distributed the Fork Knox technical report for work done in 2013

2014

●in early April emails were exchanged to determine when Fish Creek was removed from the list of impaired waterbodies – it was listed on the 1992 list but was removed from the 1994 listing because FGMI had bought out all the existing placer operations and was planning on building the freshwater dam

●in mid-April, 2014, the decision was made to not collect winter water quality due to unsafe ice conditions and overflow

●in spring 2014, we fished a fyke net in the developed wetlands just upstream of the WSR from April 29 until May 9 and then again from May 12 to 15. Arctic grayling spawned throughout the wetland complex in spring 2014 –the only beaver dam present was in the upper end of C Channel

●Our estimated population of Arctic grayling (> 200 mm) for spring 2013 was 6,675 – a slight reduction from the 2011 and 2012 estimates

●Our estimated population of large burbot ($\geq$ 400 mm) for spring 2013 was 80 – a substantial reduction from the spring 2012 estimate of 193

●on September 29, 2014, FGMI notified state agencies that the new Environmental Manager was Bartly Kleven

Appendix 1 (continued)

2014

●on September 4, 2014, we were notified that the road across Solo Creek had failed – FGMI will determine a proper fix – this is the second time the road has failed at the culvert crossing

●on September 26, 2014, the developed wetlands and lower Last Chance Creek were inspected, no beaver dams were observed in Ponds D and F and in lower Last Chance Creek (dams had been removed by FGMI during summer)

●in October FGMI and ADFG discussed a draft design for the Solo Creek culvert replacement, conducted a field inspection, and are continuing discussions to decide what remedial work will be done

●on October 28, 2014, ADF&G distributed the Fork Knox technical report for work done in 2014

●on November 12, 2014, FGMI submitted a permit application to replace the Solo Creek culvert. ADF&G had several questions regarding the culvert design specifications and FGMI addressed these questions and a permit was issued on November 20, 2014 to install the new 10 foot diameter pipe

2015

●on March 2, 2015, we conducted a field visit to observe the discharge point for non-contact mine water to the old Fish Creek channel which except for breakup and periods of heavy rain is dry

●FGMI initiated the discharge of non-contact water (about 250 gallons per minute) in mid-March and the discharge has been continuous except for a few shutdowns. The discharge was authorized by a permit issued by the ADEC

●on April 8 and 9, we collected water quality data in the WSR which was ice covered, high DO concentrations were found in Fish Creek Bay

●on April 17, we collected water quality data in the old Fish Creek channel downstream from where the non-contact mine water was being discharged and found very high DOs in the water – leading us to conclude that the discharge of non-contact mine water resulted in increased DOs in the WSR

●in early May, we field inspected the culvert replacement in Solo Creek and concluded that it had been installed in accordance with the Fish Habitat Permit

●in spring 2015, we fished a fyke net in the developed wetlands just upstream of the WSR from May 4 to 8 and then again from May 10 to 13. Arctic grayling spawned throughout the wetland complex in spring 2015

●our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2014 was 5,841 – a slight reduction from the 2011 and 2012 estimates

●our estimated population of large burbot ($\geq$ 400 mm) for spring 2014 was 175 – a substantial increase from the spring 2013, but with a large 95% CI

●on June 19 and July 23, we collected Arctic grayling fry in the wetland complex, average size on June 19 was 29.7 mm and on July 23 it was 57.3 mm

Appendix 1 (concluded)

2015

●on June 19, we inspected the Last Chance culvert in the Gil Causeway, material at the east end of the pipe has slumped and the road was blocked with cones and flagging
●on October 28, 2015, ADF&G distributed the Fork Knox technical report for work done in 2015

2016

●on March 29 and 31, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998. Average winter water column dissolved oxygen at Site 2 (middle of the WSR) was the highest on record and likely the result of the near continuous discharge of non-contact water into the old Fish Creek channel just upstream of the wetland complex
●in spring 2016, we fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from April 25 to May 4. Based on the fyke net catches, most of Arctic grayling spawned in the wetland complex downstream of Pond F
●our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2015 was 5,947 – a slight increase from the 2014 estimate
●our estimated population of large burbot ($\geq$ 400 mm) for spring 2015 was 92 - a substantial decrease from spring 2014
●in early October hoop traps fished in the WSR captured 26 burbot ranging in size from 200 to 630 mm long
●on October 12, we met with ADEC and FGMI to discuss plans to design and install a new water treatment plant just downstream of the tailings dam with an estimated discharge of 2,000 to 6,000 gallons per minute
●on October 28, we were notified by FGMI that beaver dams at Pond D outlet and downstream of Pond F had been removed
●on December 21, ADF&G sent a summary of our meeting on the new water treatment plant to FGMI

Appendix 2. ADF&G Technical Reports

Technical Reports (Weber Scannell and Ott 1993, Weber Scannell and Ott 1994, Ott et al. 1995, Ott and Weber Scannell 1996, Ott and Townsend 1997, Ott and Weber Scannell 1998, Ott and Morris 1999, Ott and Morris 2000, Ott and Morris 2001, Ott and Morris 2002a and b, Ott and Morris 2003, Ott and Morris 2005a and, b, Ott and Morris 2006, Ott and Morris 2007, Ott and Morris 2009a and b, Ott and Morris 2010, Ott and Morris 2011, Ott et al. 2012, Ott et al. 2013, Ott et al. 2014, and Ott et al. 2015) summarizing field work can be found on the Alaska Department of Fish and Game, Division of Habitat's Web Page:

http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main

Appendix 3. Water Quality Data, March 2016

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (*u* S/cm)	pH	ORP
12 (Fish Creek Bay)	3/31/2016	1	0.51	42.7	6.14	141.4	6.52	329
		2	1.01	41.4	5.86	141.6	6.8	325
		3	1.25	40.0	5.62	146.8	6.84	323
		4	1.15	49.9	7.04	187.9	6.87	324
		5	0.71	58.6	8.34	226.9	6.89	324
		5.5	0.72	52.7	7.49	254.2	6.86	322
2 (WSR near Dam)	3/31/2016	1	0.42	46.3	6.68	139.2	7.01	336
		2	1.01	45.5	6.44	139.0	6.99	336
		3	1.34	43.9	6.17	139.0	6.97	335
		4	1.72	42.1	5.84	136.8	6.96	335
		5	1.94	42.8	5.91	135.5	6.96	335
		6	2.19	39.8	5.45	135.0	6.95	334
		7	2.24	36.1	4.95	140.4	6.92	334
		8	2.23	34.0	4.65	150.2	6.90	335
		9	2.08	32.1	4.41	166.4	6.88	335
		10	1.99	32.3	4.44	176.2	6.87	336
		11	2.07	30.8	4.24	180.4	6.86	336
		12	2.18	30.1	4.12	180.9	6.87	335
		13	2.27	22.7	3.10	186.5	6.85	336
		14	2.29	18.8	2.56	189.7	6.82	336
		15	2.26	18.8	2.57	196.5	6.80	337
		16	2.35	3.0	0.41	204.5	6.75	239
		17	2.37	0.3	0.03	209.5	6.74	206
1 (Middle WSR)	3/29/2016	1	0.43	47.3	6.80	136.5	8.14	293
		2	1.16	47.8	6.73	136.0	7.97	291
		3	1.62	49.0	6.82	133.6	7.88	290
		4	1.95	49.8	6.86	132.0	7.84	289
		5	2.14	45.0	6.20	133.0	7.74	289
		6	2.17	38.2	5.24	135.9	7.62	289
		7	2.06	28.6	3.93	148.0	7.48	290
		8	2.04	29.9	4.11	157.9	7.42	290
		9	1.97	30.8	4.24	167.5	7.39	290

Appendix 3. concluded

				% Saturation	Dissolved			
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity		
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH	ORP
3 (Solo Bay)	3/29/2016	1	0.13	64.4	9.33	151.4	7.54	327
		2	0.95	48.0	6.81	143.2	7.42	326
		3	1.43	42.4	5.94	139.9	7.37	325
		4	1.74	40.5	5.63	138.0	7.35	324
		5	1.97	35.8	4.93	137.1	7.29	323
		6	2.06	24.2	3.33	139.1	7.21	323
		7	1.94	2.3	0.32	148.4	7.10	325
		8	1.90	0.4	0.06	156.9	7.06	312
		9	1.76	0.1	0.02	219.4	6.97	231
		10	1.71	0.0	0.00	350.5	6.93	133
11 (Polar Bay)	3/31/2016	1	0.60	47.4	6.79	144.3	7.07	326
		2	0.86	46.5	6.62	151.5	7.02	326
		3	1.25	46.4	6.52	149.4	7.01	326
		4	1.63	46.7	6.49	146.8	7.01	325
		5	1.74	45.8	6.36	149.7	6.98	326
		6	1.83	41.1	6.10	150.5	6.95	326
		7	2.03	44.2	6.08	148.2	6.95	325
		8	2.32	38.9	5.31	147.5	6.91	326
		9	2.52	25.2	3.42	155.0	6.84	327
7 (Lower Last Chance Bay)	3/31/2016	1	0.27	72.9	10.54	146.8	7.12	338
		2	1.25	38.5	5.42	135.1	6.95	340
		3	1.46	34.0	4.75	132.8	6.93	339
		4	1.89	30.1	4.16	131.0	6.91	338
		5	2.07	17.4	2.39	130.7	6.85	335

Appendix 4. Arctic Grayling Population Estimates in the WSR.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	4,358	
1996[2]	150	4,748	3,824-5,672
1996[3]	150	3,475	2,552-4,398
1998[4]	200	5,800	4,705-6,895
1999[4]	200	4,123	3,698-4,548
2000[4]	200	5,326	4,400-6,253
2001[4]	200	5,623	5,030-6,217
2002[4]	200	6,503	6,001-7,005
2003[4]	200	6,495	5,760-7,231
2004[4]	200	6,614	5,808-7,420
2005[4]	200	7,926	6,759-9,094
2006[4]	200	5,930	5,382-6,478
2007[4]	200	4,027	3,620-4,433
2008[4]	200	3,545	3,191-3,900
2009[4]	200	3,223	2,896-3,550
2010[4]	200	4,346	3,870-4,823
2011[4]	200	7,378	6,616-8,141
2012[4]	200	7,404	6,775-8,033
2013[4]	200	6,675	6,217-7,333
2014[4]	200	5,841	5,235-6,446
2015[4]	200	5,947	5,111-6,783

[1]We used estimates from the ponds and creeks for the Arctic grayling population; a confidence interval was not applicable to the data set.

[2]The 1996 estimate was made with a capture and recapture event in summer 1996.

[3]Gear type for the population estimate was a boat-mounted electroshocker with both capture and recapture events in fall 1996.

[4]The 1998 through 2014 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

Appendix 5. Arctic Grayling Growth in the WSR.

2015 to 2016 growth grayling (n=137)				
Upper Limit (mm) and Sample Size	Average (mm)	Maximum (mm)	Minimum (mm)	n
210				0
220				0
230				0
240	11	15	7	4
250	8	14	4	9
260	8	19	0	19
270	7	14	0	21
280	3	7	0	29
290	3	15	0	21
300	3	12	0	20
310	2	5	0	7
320	3	10	0	4
330	2	2	2	1
340	1	2	0	2
350				0

Appendix 6. Burbot Population Estimates in the WSR.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
2001	400	134	58-210
2002	400	131	63-199
2003	400	102	57-147
2004	400	86	44-128
2005	400	143	96-191
2012	400	193	95-290
2013	400	80	44-117
2014	400	175	44-305
2015	400	92	45-138