Technical Report No. 22-04

Fish and Water Quality Monitoring at the Fort Knox Mine, 2021

by

Chad E. Bear

April 2022

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

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. 22-04

FISH AND WATER QUALITY MONITORING AT THE FORT KNOX MINE, 2021

By

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April 2022

Cover: Fyke Net in North Fork Fish Creek near the Fort Knox water supply reservoir, May 13, 2021.
Drone photography by Chad Bear.

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Acknowledgements

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Executive Summary

Water Quality

Dissolved oxygen (DO) concentrations were measured in the water supply reservoir (WSR) in April 2021. For the seventh consecutive year, DO concentrations were among the highest since sampling began in 1998. Higher DO concentrations appear to be directly related to the discharge of reverse osmosis (RO) water from mine operations into the Fish Creek wetlands complex just downstream of the tailing's impoundment dam.

During 2021 RO water discharge continued and was mostly confined to North Fork Fish Creek drainage before combining with Fish Creek and entering the WSR. The input of warm (6.0°C) RO water raised the North Fork Fish Creek water temperature to 4.53°C on April 15, 2021, compared to 0.98°C in Fish Creek, which receives no direct input of RO water.

Arctic Grayling in the Water Supply Reservoir

Sampling for Arctic graying was conducted from April 30 – May 12, 2021, as fish moved from the WSR into the developed wetlands for spawning. The catch per unit of effort (CPUE) varied between April 30 and May 12 and peaked on May 4 before beginning to decline. Spawning condition of females were initially low at 16% ripe on May 3 but quickly rose to 100% ripe by May 6 as water temperatures increased during the spring thaw.

Recruitment has been variable among the sampling years, with a slight increase observed between 2020 and 2021. During the 2020 sampling event 3,865 juvenile Arctic grayling were captured with an average size of 101 mm. These age-1 Arctic grayling demonstrated good success and survival from the 2019 spawning event but are not included in the 2020 recruitment estimate. During the 2021 sampling, 433 age-2 Arctic grayling were captured between 130 and 240 mm showing survival of the thousands of age-1 Arctic grayling observed in 2020. Of these, 70 were $\geq$200 mm and qualify as 2021 recruitment.

The spring 2020 population estimate for Arctic grayling $\geq$ 200 mm fork length (FL) was 3,632 fish (95% CI: 3,301 to 3,963 fish).

Burbot in the Water Supply Reservoir

Burbot residing in the WSR and Fish Creek wetlands were captured during the 2021 spring Arctic grayling fyke netting event. However unseasonably cold temperatures during September 2021 iced over the WSR before the fall burbot sampling with hoop traps could be conducted. During the 2021 spring sampling event, 48 burbot were captured in Fish Creek and North Fork Fish Creek fyke nets. Six of these were $\geq$ 300 mm and tagged with a unique numbered Floy tag. Because the fall burbot sampling event was not conducted, a population estimate for 2020 could not be made.

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located about 25 km northeast of Fairbanks, Alaska in the headwaters of the Fish Creek drainage that flows into the Chena River. The project includes an open pit mine, mill, tailings impoundment, two valley heap leaches, fresh water supply reservoir (WSR), and related facilities (Figure 1). Construction of the WSR dam and spillway was completed in July 1996. In 2021 improvements were made to the Gil Haul Road and causeway. FGMI broke ground on the Gil Expansion Project in the fall and began hauling ore eight miles to the Fort Knox mill.

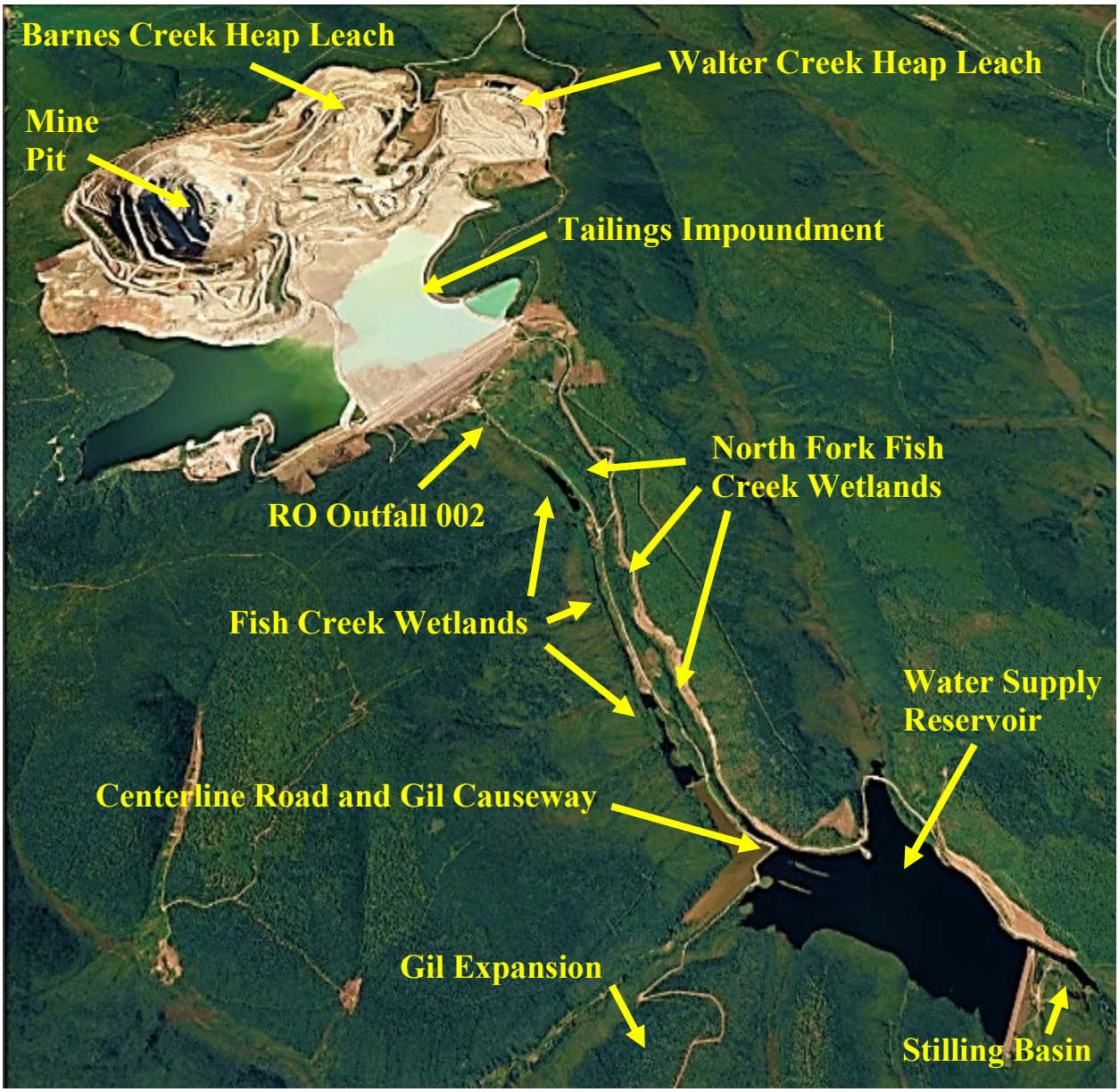

Figure 1. Fort Knox gold mine and associated facilities.

The WSR was constructed to be the primary water supply for mining activities and mill operations at Fort Knox. When full, the WSR contains about 3,363 acre-feet (1.1 billion gallons) of water (Figure 2). Water levels have remained mostly constant since 1998, except during winter in certain years when large amounts were removed for mining processes. Since 2015, operational water needs have been satisfied from mine pit and tailings impoundment dewatering wells and no water has been utilized from the WSR (Table 1). In 2021, during reconstruction and upgrading of the Gil Haul Road, the pipeline from the WSR to the Tailing Storage Facility (TSF) was disconnected. Discharge water from mine operations Reverse Osmosis (RO) facilities now add thousands of acre-feet of water to the WSR annually (Table 2).

Figure 2. Fort Knox Water Supply Reservoir (WSR) May 2021.

Spawning populations of Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) exist in the WSR, and smaller populations of both Arctic grayling and burbot inhabit the Stilling Basin below the WSR spillway. Arctic grayling spawning occurs predominantly in the wetland complex between the WSR and the tailings dam (Figure 1). Burbot spawning, as documented by radio telemetry, likely occurs in Solo Bay where Solo Creek enters the WSR (Ott *et.al*, 2013). Arctic grayling recruit into the stilling basin over the WSR spillway. Burbot recruitment into the stilling basin by passage over the spillway was documented in 2019 when two burbot tagged in the WSR were captured in the stilling basin during sampling (Bear, 2019).

Table 1.Winter (October 1 to April 30) water use from the WSR, 1997 to 2021.

Year (Oct 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
2015-2021		0		0

In spring 2015, FGMI initiated the discharge of non-contact water from dewatering wells around the open pit combined with mine operations water treated by Reverse Osmosis (RO) filtration into upper Fish Creek. The discharge was authorized by permits issued by the Alaska Department of Environmental Conservation (ADEC). During 2019 FGMI brought two additional RO facilities (RO2 and RO3) online and began discharging from Outfall 002 on January 15, 2019 (Figure 3). Water discharge through the RO systems has been generally increasing since 2015. During 2021 8,752 acre-feet of RO water was discharged into Fish Creek (Table 2). This influx of RO water is most likely the reason for increased dissolved oxygen (DO) concentrations in the WSR starting in 2015 as documented in the late winter water quality sampling (Figure 16).

Table 2. Total Reverse Osmosis (RO) water discharge from Outfall 001 and 002 into Fish Creek, 2015 - 2021.

Year (Jan 1 to Dec 31)	Acre-Feet of RO Water Discharged from Outfall 001 and 002
2015	163
2016	461
2017	618
2018	806
2019	6,681
2020	9,663
2021	8,752

Figure 3. Outfall 002 showing RO water discharge of up to 3,000 gpm into North Fork Fish Creek, April 15, 2021.

Discharge water from Outfall 002 enters the drainage upstream from Pond AB (Figure 3). Water would typically flow through Pond AB and exit through a culvert below centerline road and be diverted into North Creek before entering Fish Creek between Pond F and the WSR. During the summer of 2019 Fort Knox lowered the centerline road culvert and installed a beaver diversion fence on the upriver end of the culvert (Figure 4). On April 15, 2021, the diversion fence had some woody debris but most of Pond AB water was flowing through the culvert and into North Fork Fish Creek. Approximately 10 percent of the water flows from Pond AB's natural outlet and into Fish Creek (Figure 5). This overflow RO water may warm Fish Creek water slightly, but also provides flow and oxygen rich water to the system during the winter.

Figure 4. Beaver diversion fence installed at Pond AB culverts, April 15, 2021.

Figure 5. Approximately 10% of RO water exiting Pond AB's natural outlet into Fish Creek, April 15, 2021.

The WSR outlet spillway had substantial aufeis built up during the 2020 / 2021 winter similar to the 2019/2020 winter (Figure 6). Cold winter temperatures combined with the RO discharge water entering the drainage resulted in sheet flow across the spillway which created ice. The aufeis was contained within the spillway walls. Aufeis appeared to be 8 to 9 feet thick near the lower end of the spillway and was within two feet of the top of the spillway walls. Water was flowing under the ice in the center channel during the April 15, 2021 winter water quality sampling and no water was flowing on top of the ice.

Fort Knox initiated a WSR water drawdown on June 4, 2021, to perform required spillway inspections. A relief valve was opened lowering the WSR water level about 4 vertical feet by June 7 and drying the spillway (Figure 7). After inspections were complete the relief valve was closed on June 9 and the WSR began to refill to normal levels. A second drawdown to perform repairs was initiated on August 2. Contractors replaced sealant between the concrete slabs, cleaned organic debris, and repaired a crack near the upper portion of the spillway. Repairs were delayed by COVID and contractor availability. Repairs were completed on September 29 and the relief valve was closed refilling the WSR to normal levels by October 15.

Figure 6. Spillway at outlet of Water Supply Reservoir on April 15, 2021.

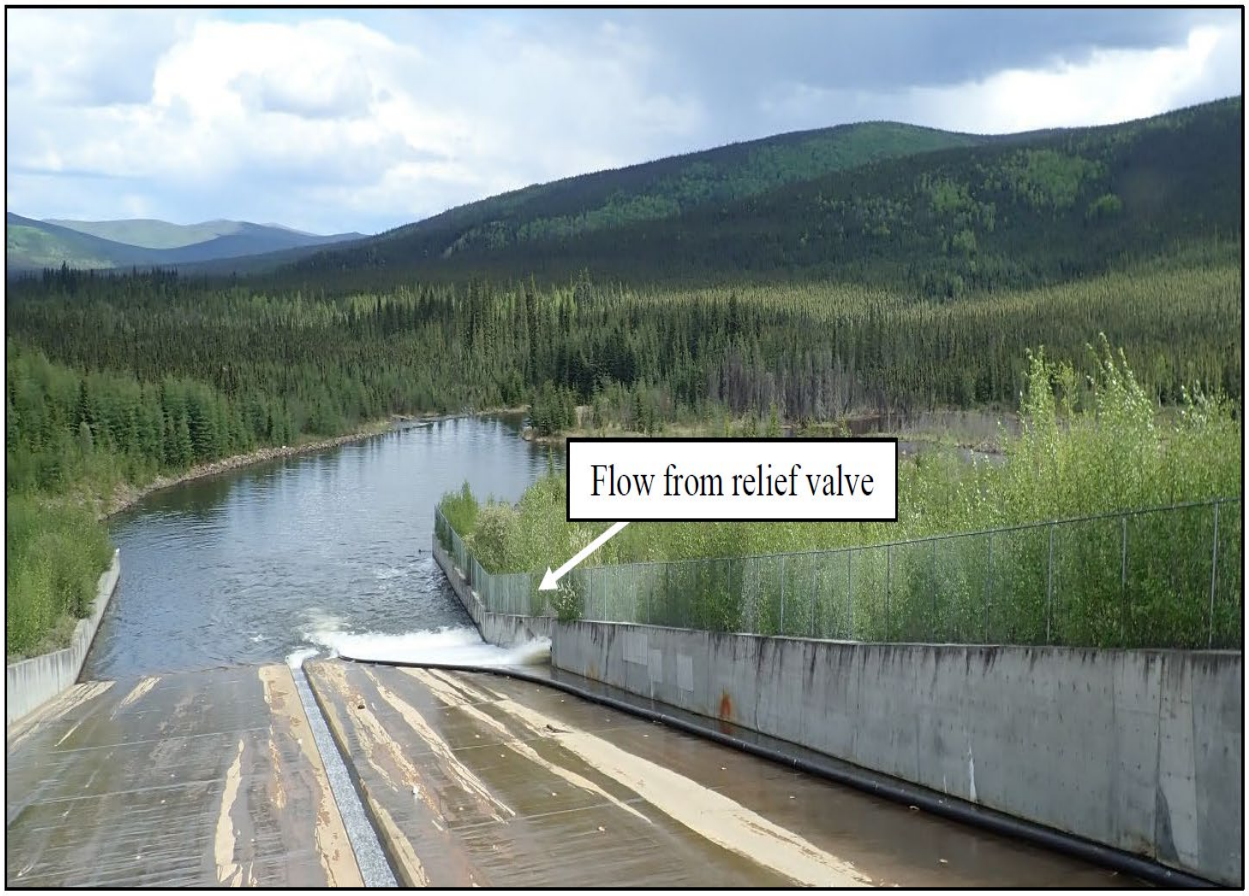

Figure 7. WSR relief valve open into spillway on June 4, 2021.

Fort Knox's rehabilitation of the disturbed fish and wildlife habitats have been concurrent with permit requirements, to the extent practicable, and natural revegetation of some areas has been rapid. The Fish Creek wetland complex was increased in size and available fish habitat in 2019 when discharged RO water was diverted into the channel on the north side of Centerline Road (Figure 8). The substantial increase of water to the drainage flooded many low-lying areas creating small ponds. This resulted in 7.9 acres of new wetlands during establishment of the North Fork Fish Creek channel. Arctic grayling adapted quickly to new spawning and rearing areas and during the April 2021 fish sampling event a fyke placed in North Fork Fish Creek captured numerous Arctic grayling moving upstream to utilize the newly available wetlands.

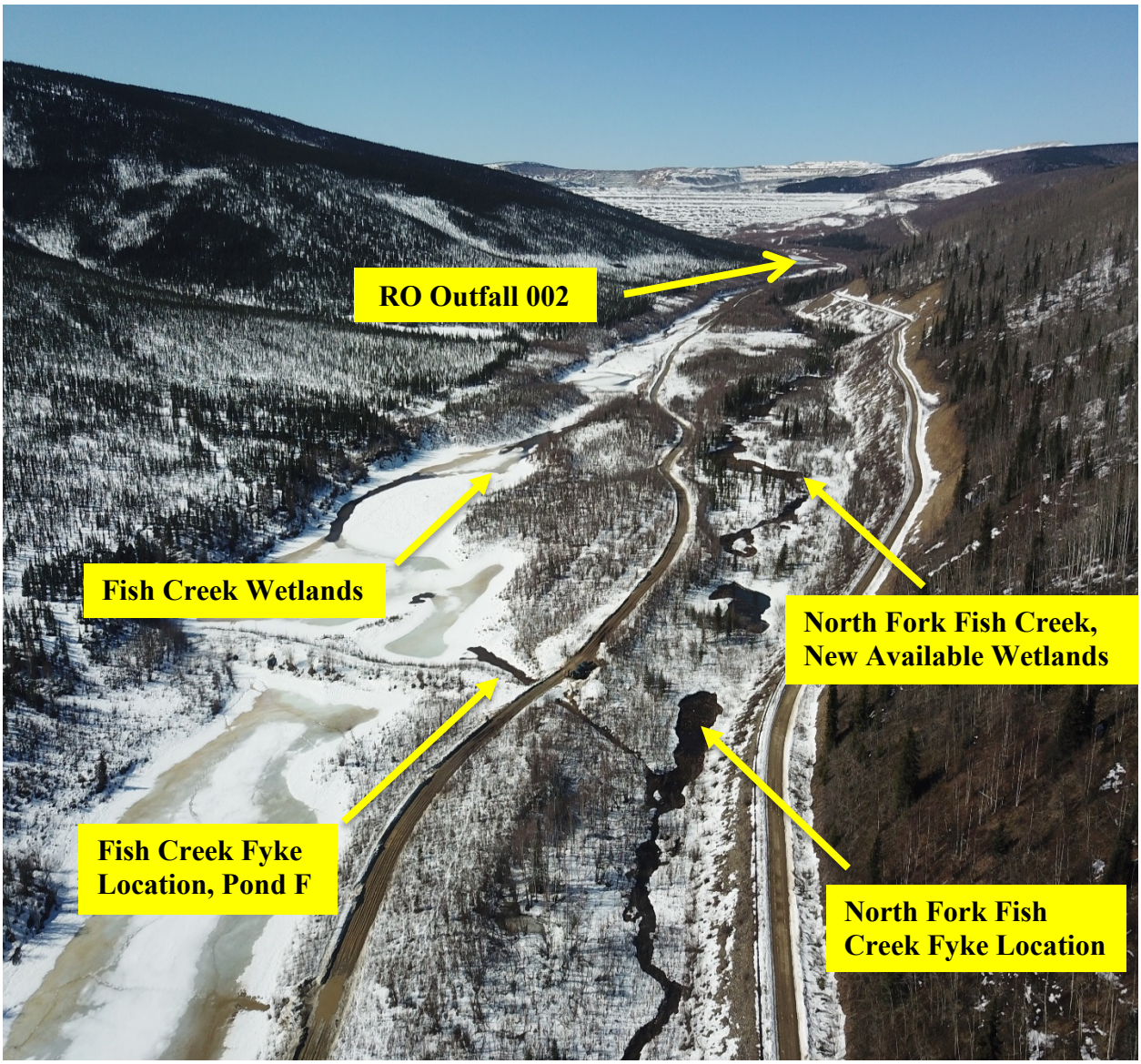

Figure 8. Fish Creek Wetlands (Left) and North Fork Fish Creek Wetlands (Right) April 15, 2021.

Fish monitoring has been performed annually at the Fort Knox mine and related facilities since 1992 and water quality sampling since 1997. This report summarizes fish and water quality data collected during 2021 and discusses these findings in relation to previous work. A chronology of events from 2011 to 2021, with emphasis on biological factors, is presented in Appendix 1. The chronology for the 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). All ADF&G Technical Reports summarizing biomonitoring activities at Fort Knox can be found on the Alaska Department of Fish and Game - Habitat Section website.

Methods

Water Quality

Water quality sampling was conducted on April 15, 2021, when the WSR was ice covered. Six sites in the WSR have been sampled annually since 1998 with two new sites in the wetland complex included starting in 2018 (Figure 9). Measurements of Fish Creek and North Fork Fish Creek were taken to document the effect of increased RO water discharged from Outfall 001 and 002 into the wetlands complex. Vertical profiles of water temperature (°C), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance (µS/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. Measurements were taken at 1-meter intervals from just below the ice surface to the bottom of the reservoir at the six WSR sample sites and at 1-meter depth in the two wetlands complex sites. The multiprobe sensors were calibrated in the ADF&G lab prior to field sampling and DO was additionally calibrated on site just prior to data collection. Two Hobo temperature loggers were deployed, one in Fish Creek at the Pond F outlet, one in North Fork Fish Creek below RO Outfall 002 discharge water influence (Figure 9).

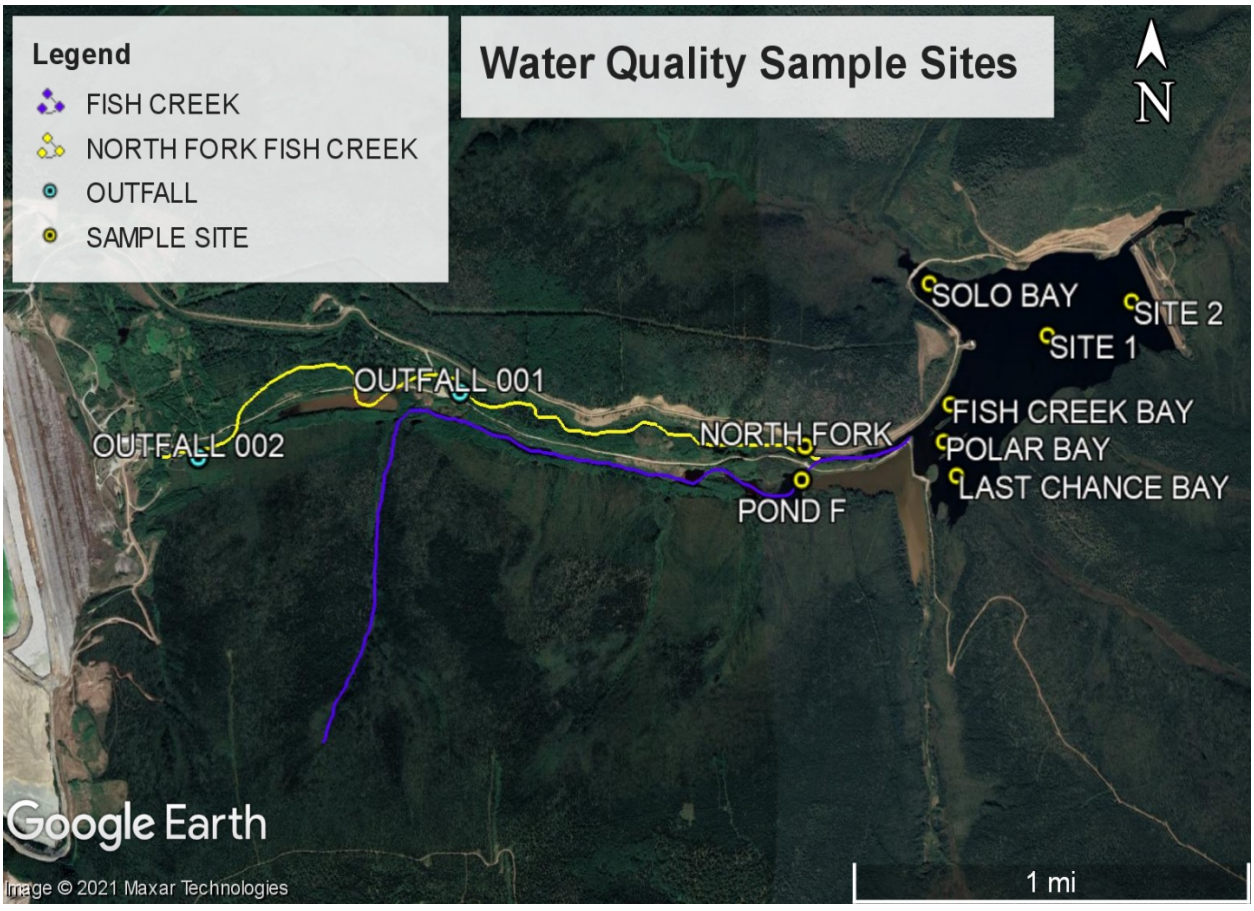

Figure 9. Fort Knox Water Supply Reservoir water quality sample sites, April 10, 2021

Fish

Fish sampling methods included fyke nets, hoop traps, angling, and visual observations. On April 30, 2021, one fyke net was set in Fish Creek near the Pond F outlet (Figure 10). A second fyke net was placed in North Fork Fish Creek to determine if Arctic grayling were recruiting into the new available wetland habitat. Fyke nets were fished in the same locations without being moved until May 12. The fyke nets were checked every 1 to 2 days and fished effectively for the sampling period. Burbot are typically sampled annually in the fall using hoop traps (Figure 11) and the WSR population estimated. During fall 2021 an early cold snap in late September froze over the WSR before sampling started.

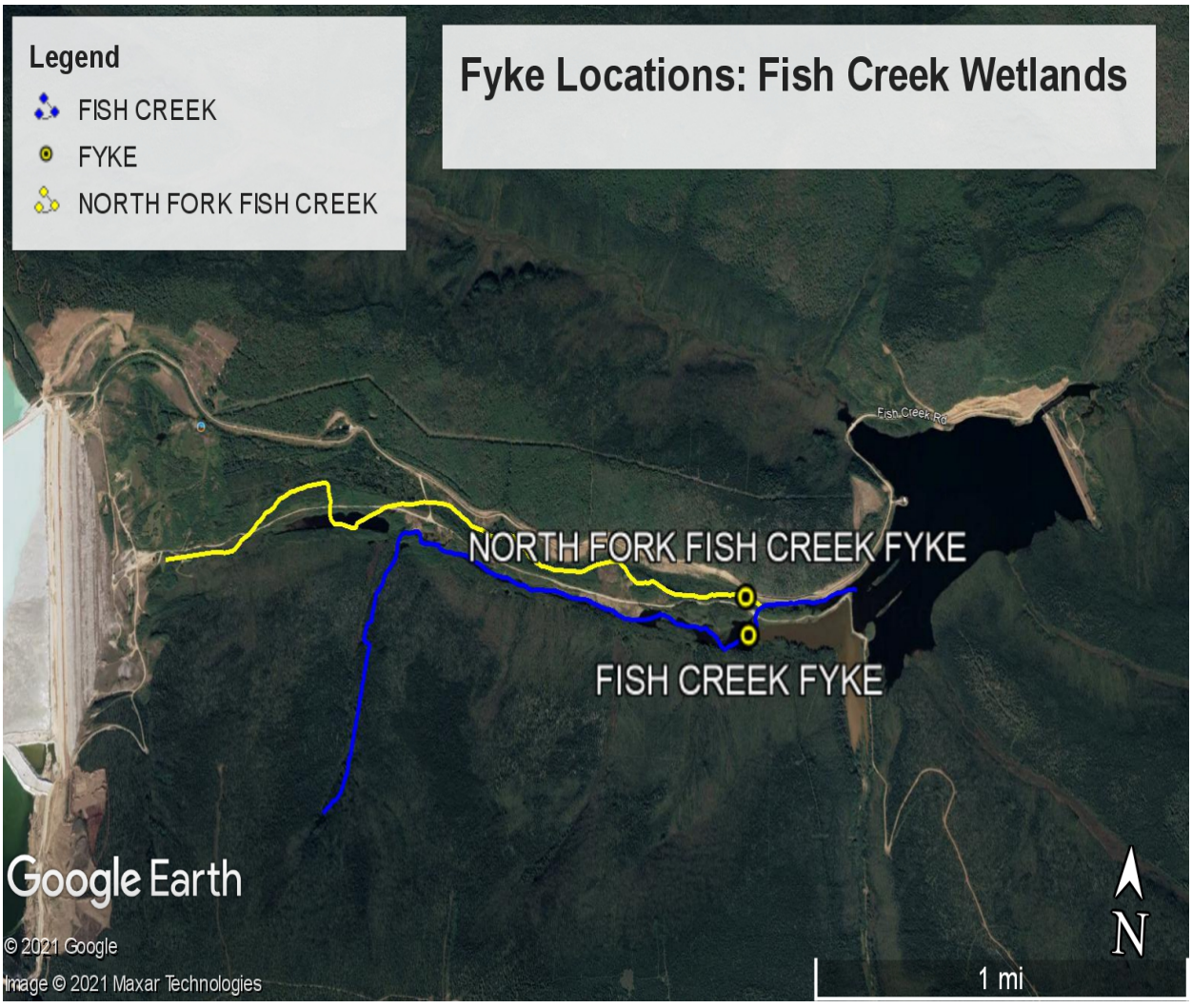

Figure 10. 2021 Fish Creek Wetlands Fyke Locations.

Arctic grayling were measured to fork length (FL, nearest mm), inspected for tags and spawning condition, and released. Burbot were caught in the spring fyke nets and 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).

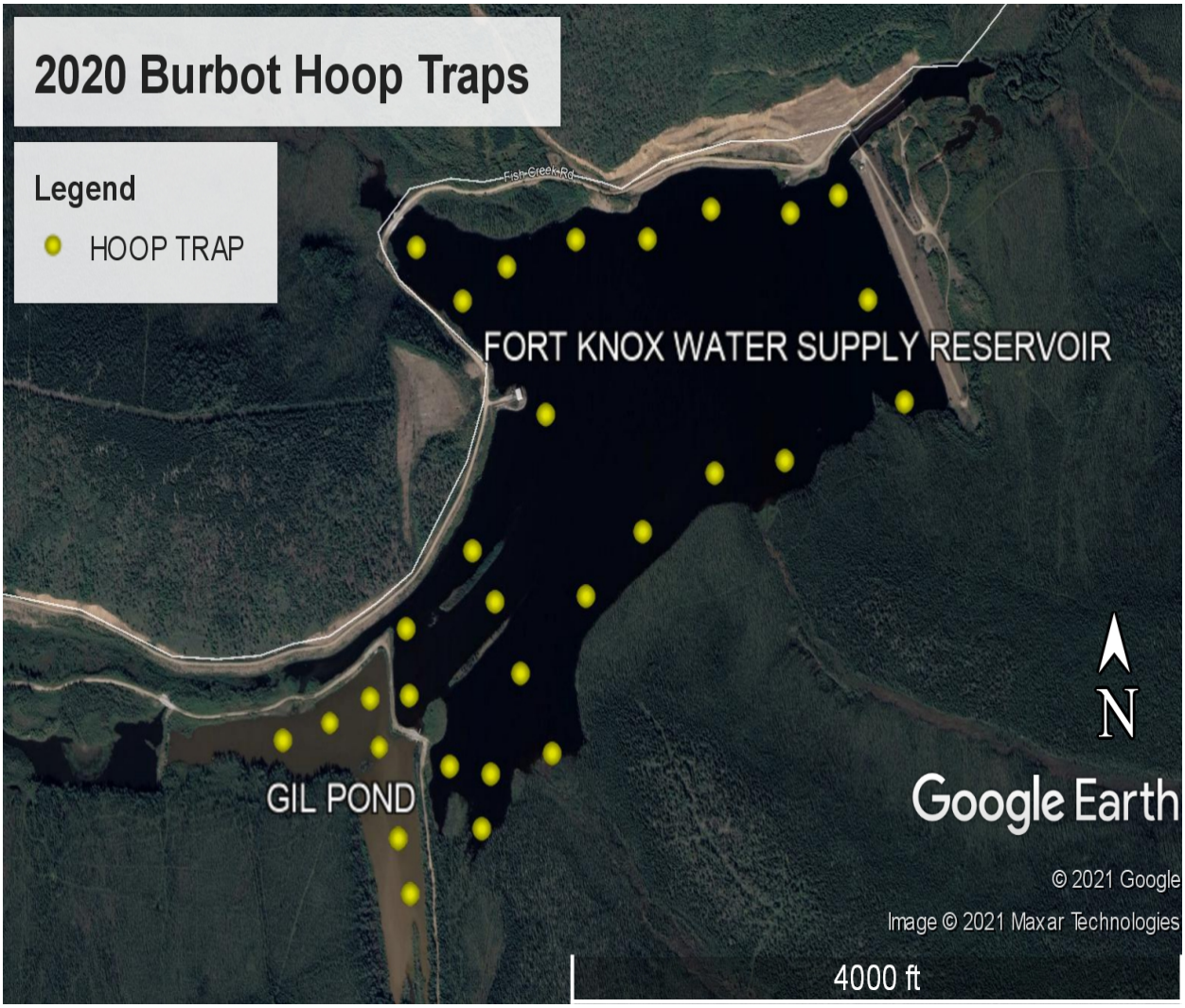

Figure 11. Typical burbot hoop trap locations in the WSR and Gil Pond.

Results and Discussion

Water Quality, Water Supply Reservoir

Water quality data were collected on April 15, 2021 (Appendix 2). Ice thickness on the WSR was slightly less than 1 m at each of the six annual sampling location. There was six inches of slushy snow and up to one foot of overflow on top of the WSR ice near Last Chance Creek (Figure 12). This overflow water may have influenced the water quality at the one-meter depth sample from mixing while drilling the test holes, but not the remainder of the water column (Figure 13). The majority of Fish Creek was frozen with very little exposed flowing water. North Fork Fish Creek had sections of open water but also sections with overflow and glaciated ice in the streambed. The annual cumulative snowfall between September 1 and April 10 at the Fairbanks International Airport was ~145.2 cm (~57 in) in 2021. The water temperature of Fish Creek at Pond F was 0.98°C and the outlet channel was partly open. North Fork Fish Creek was 4.53°C taken at open water near its confluence with Fish Creek (Figure 14).

Figure 12. Six inches of overflow and two feet of snow covering WSR ice, April 15, 2021.

Figure 12. Drilling sample holes with six inches of overflow above WSR ice April 15, 2021.

Figure 13. Water quality sampling in North Fork Fish Creek open water above confluence with Fish Creek April 15, 2021.

WSR water temperatures recorded in 2021 ranged from 0.20°C to 3.01°C (Figure 15). The minimum temperature of 0.20°C was recorded in Site 2, just below the ice surface. The maximum temperature of 3.01°C was recorded in Polar Bay at nine meters depth, just above the reservoir bottom. Temperature at all six sample sites steadily increased with water depth. The water temperature profiles at each site are similar when compared to previous years starting in 2015 with the introduction of RO discharge water into the Fish Creek drainage.

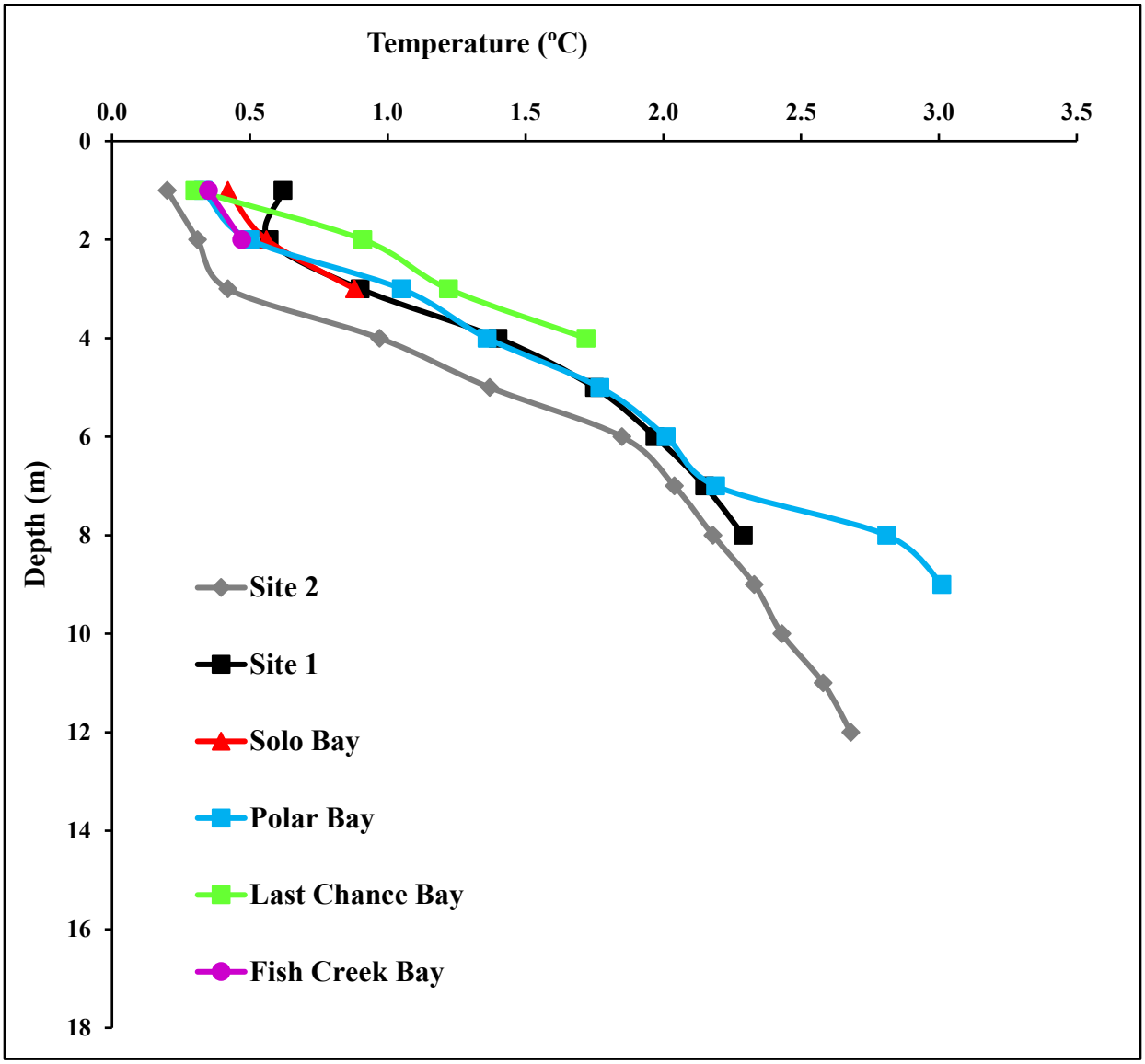

Figure 14. Fort Knox WSR water temperature profiles, April 15, 2021.

Dissolved oxygen (DO) is essential for the survival of fish, aquatic invertebrates, and aquatic plants. Solo Bay had the highest recorded dissolved oxygen (DO) at 8.95 mg/L followed by Site 1 at 7.92 mg/L (Figure 16). These maximums are higher than years prior to 2015 and likely are a result of the non-contact water discharge that began in March 2015 at Outfall 001. On January 15, 2019, Fort Knox began discharging up to 3,000 gpm from a second and third RO water treatment plant into Fish Creek at Outfall 002. RO water discharges from Outfall 002 flows downgradient through Pond AB and North Fork Fish Creek before combining with Fish Creek and entering the WSR. Fish Creek Bay had the highest water column average DO concentration (8.03 mg/L) for the seventh year in a row followed by Solo Bay at 7.60 mg/L. At all six WSR samples sites DO was very consistent between the surface and bottom readings showing very little stratification or reduced DO near the bottom of the reservoir. The difference in DO concentration observed in Last Chance Bay is likely due to it not being directly mixed by the water entering the WSR from Fish Creek.

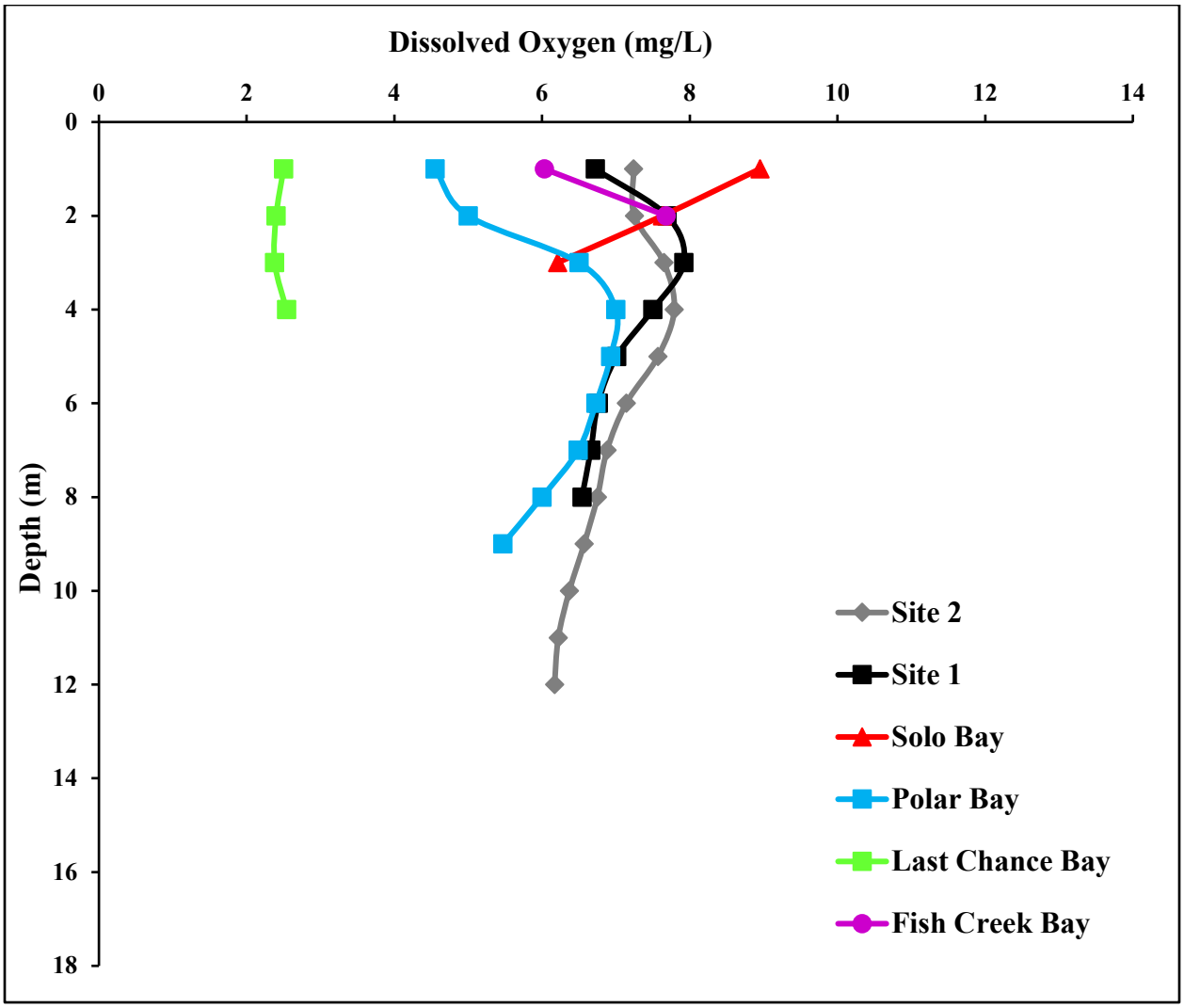

Figure 15. Fort Knox WSR dissolved oxygen (DO) (mg/L) profiles, April 15, 2021.

Temperature specific dissolved oxygen percent saturation DO (%) values were relatively consistent between the surface and bottom in 2021 (Figure 17). WSR water is well mixed with very little stratification or reduced DO near the lowest readings at 12 meters of depth. Percent DO follow the same pattern as DO (mg/L). At three of the sites DO (%) was between 30 to 50 percent at the surface, increased as it neared four to six meters, then reduced to close to its starting values as it approached the reservoir bottom. DO may still be anoxic in the deepest parts of the reservoir between 12 and 18 meters near Site 2. Overflow deeper than we could travel through was present near the freshwater dam near Site 2 and we did not reach the exact same location for Site 2 annually sampled. With increased water volume entering the WSR from the combined RO discharges into Fish Creek, the water is well mixed with more consistent DO concentrations among five of the six sites. Last Chance Bay had the lowest average DO for the third year in a row and as previously noted, it is not directly mixed by the water entering the WSR from Fish Creek.

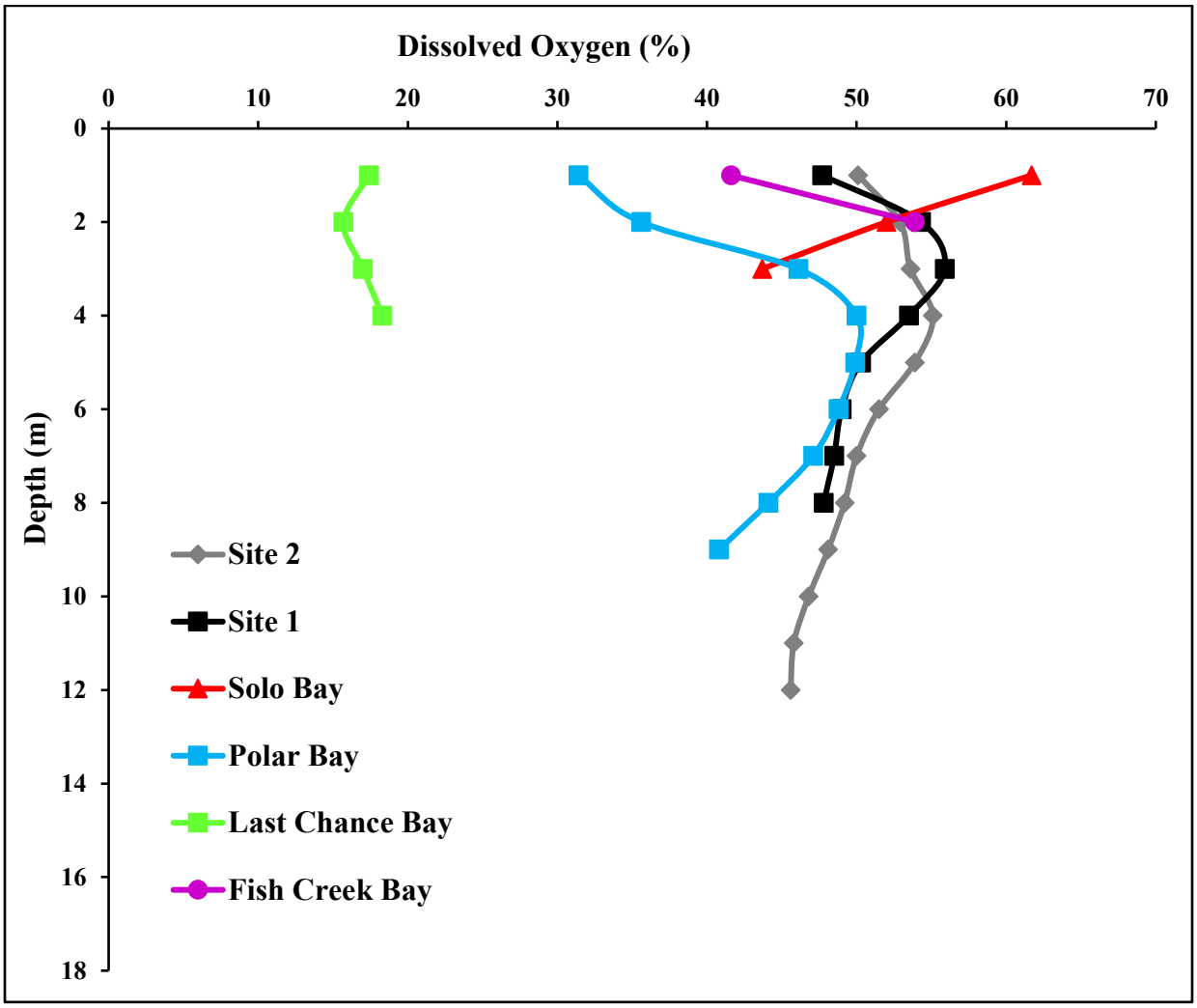

Figure 16. Fort Knox WSR dissolved oxygen (% saturation) profiles, April 15, 2021.

Average winter water column dissolved oxygen DO (mg/L), recorded at Site 2 in 2021 was above the 18-year running average and higher than all previous years sampled since 1998 (Figure 18). Polar Bay recorded a very similar average DO (%) to readings starting in 2015 (Figure 19). This likely is a result of the continual discharge of RO water into the Fish Creek drainage entering the WSR. The RO water mixes with the WSR water but may have plumes of highly oxygenated water in different sections of the reservoir at different times. The 2020 total input of 9,663 acre-feet of RO water is three times the total volume of the WSR water of about 3,363 acre-feet. The input of oxygen rich water into Fish Creek has substantially raised the DO in the WSR since 2015.

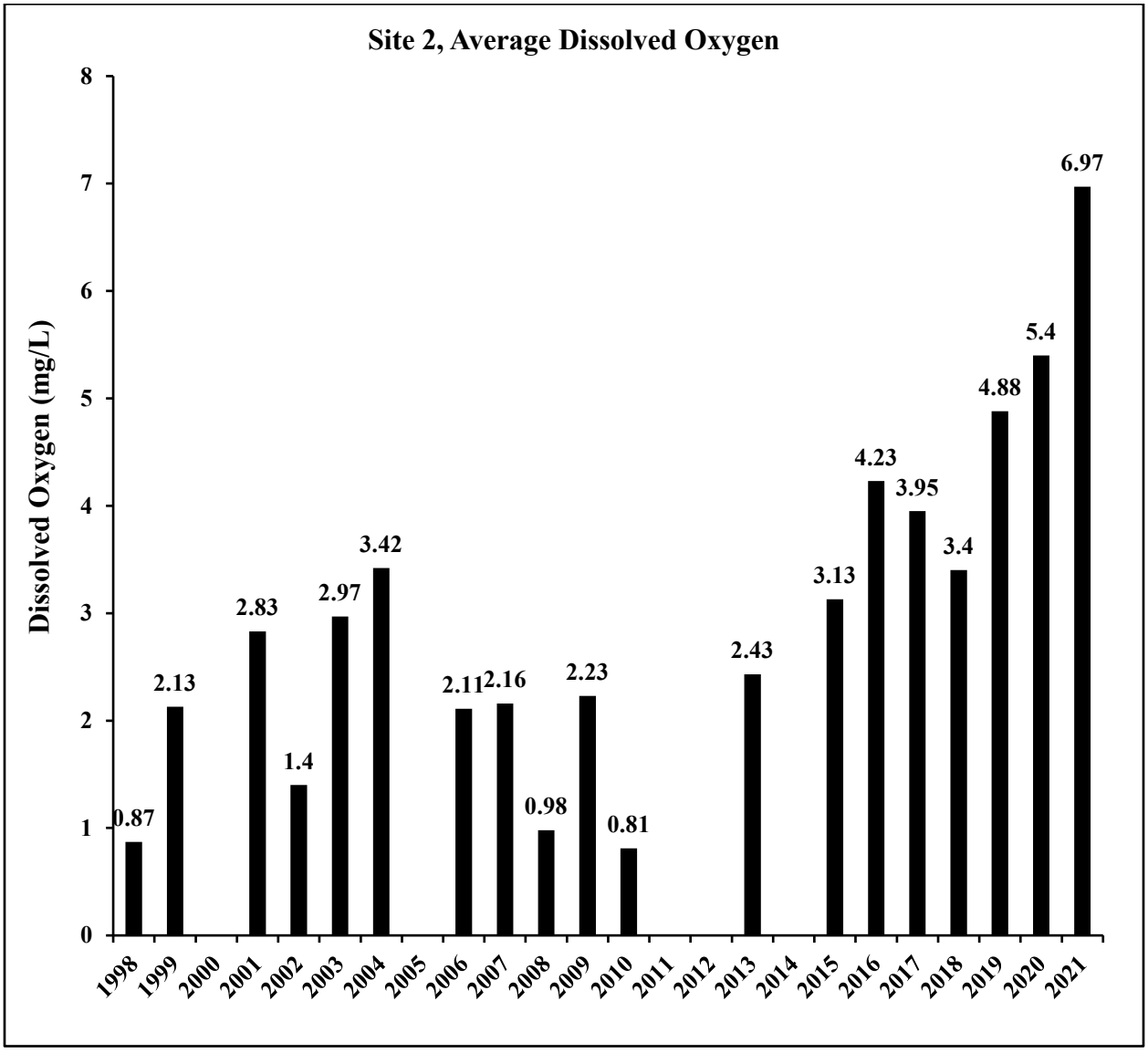

Figure 17. Average water column dissolved oxygen (mg/L) at Site 2, 1998 – 2021.

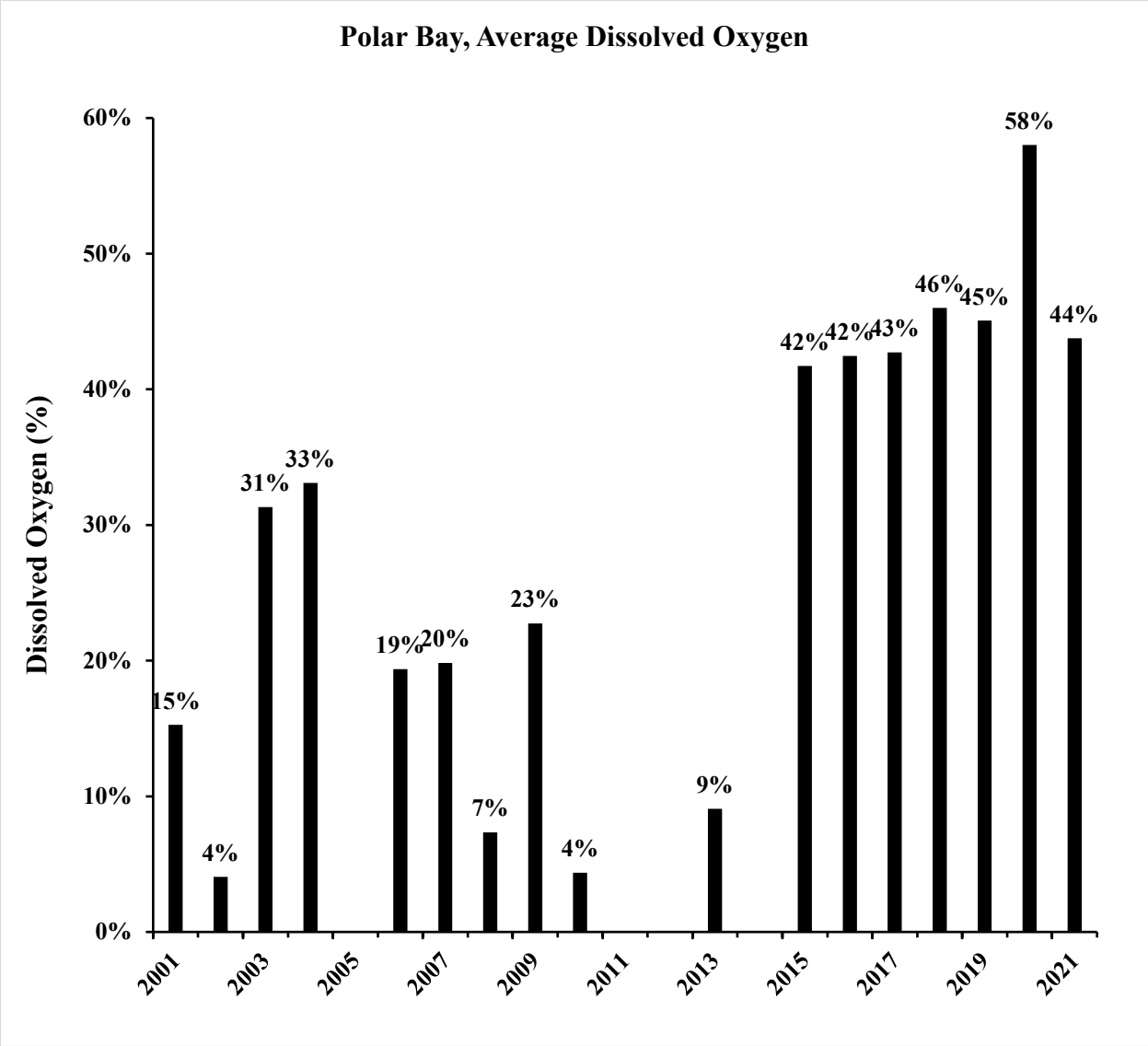

Figure 18. Average water column dissolved oxygen (% Saturation) Polar Bay, 2001–2021.

The pH of water has many effects on the plants, invertebrates, and fish in a water body, and has the potential to affect reproduction, recruitment, growth, and general health of fish. The WSR water pH in 2021 was relatively similar compared to prior years at all six sample sites (Figure 20). At most sites, the pH remained between 6.9 and 7.4 at all depths measured. All WSR pH readings were in the acceptable range, between 5.5 and 7.5 for freshwater fish including Arctic grayling and burbot.

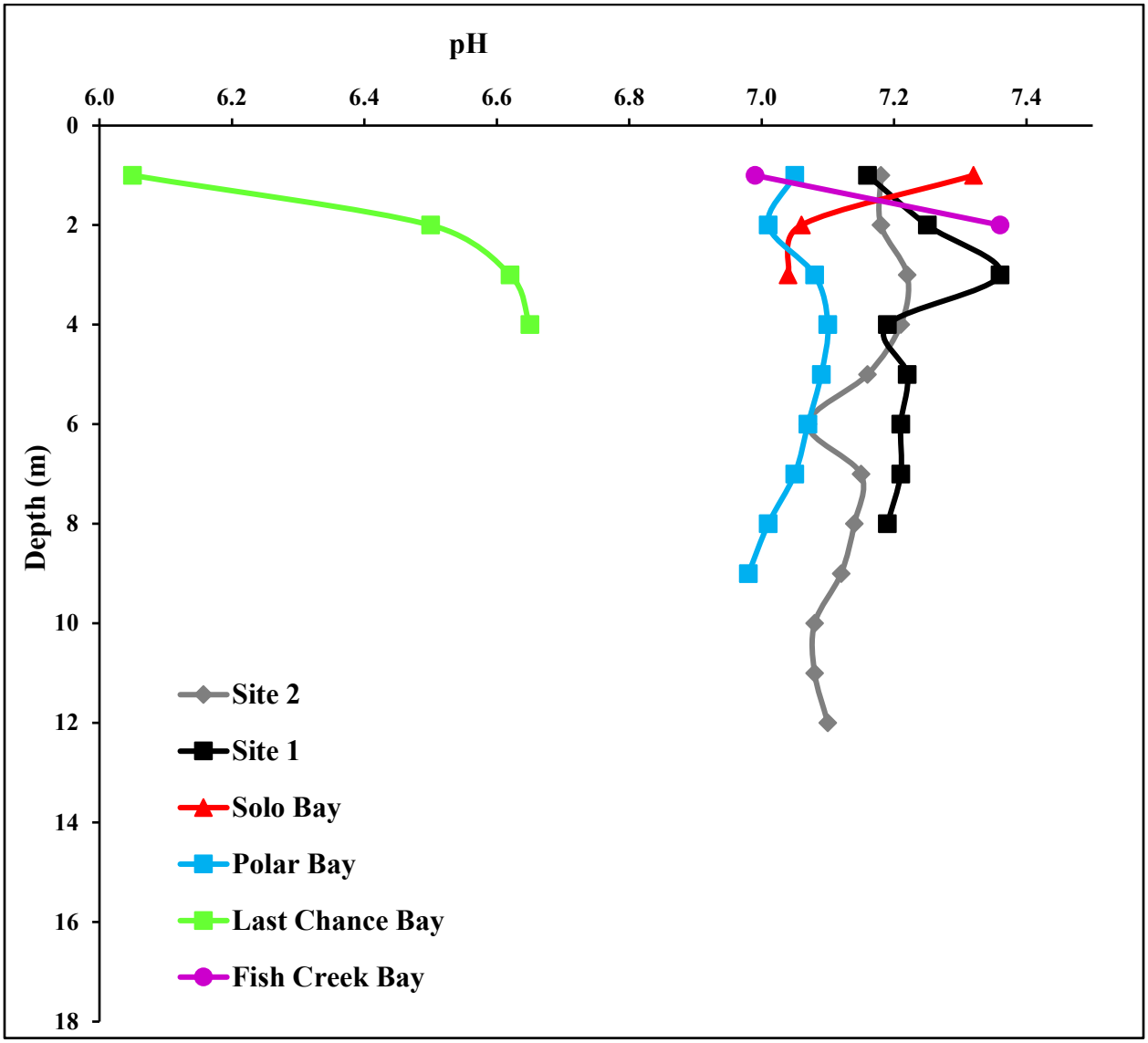

Figure 19. Fort Knox WSR water column pH profiles, April 15, 2021.

Specific conductance is the measure of how well water can conduct an electrical current and increases with increasing amounts and mobility of positively or negatively charged ions and can be used as an indicator of water quality. Specific conductance was similar among all six sites throughout the reservoir (Figure 21). Values generally increased with water depth as minerals sink from the surface and settle near the bottom. The water in the WSR appears to be mixed with similar measurements at all six sample sites. The one-meter reading, just below the ice surface, may be influenced by melt water mixing with WSR water while drilling the test hole. The 2021 average from all six sites combined is 374.3 µS/cm and higher than the 2020 average of 178.0 µS/cm and 2019 average of 143.0 µS/cm. The specific conductance also is higher than the 2015 to 2019 averages showing an increase in the number of dissolved solids such as chloride, nitrate, phosphate, sodium, magnesium, calcium, and iron present in the WSR water.

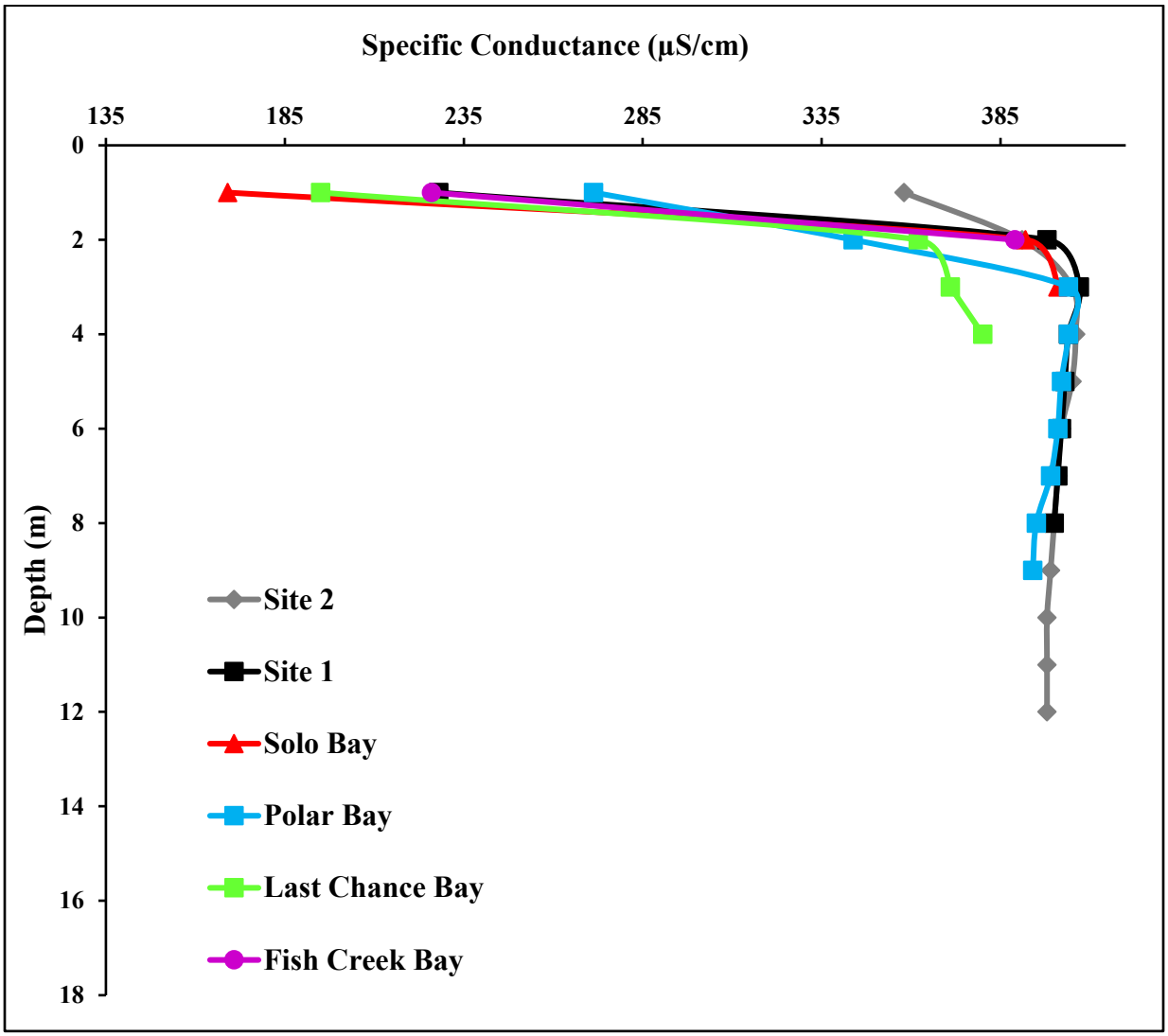

Figure 20. Fort Knox WSR specific conductivity (µS/cm) profiles, April 15, 2021.

Oxidation reduction potential (ORP) measures the ability of a lake or river system to break down waste products, such as contaminants and/or dead organic material. ORP was consistent among all six sample sites ranging between 415 mV to 456 mV (Figure 22). The 2021 average of 432.5 mV is similar to previous years. Values were uniform throughout the water column until near the bottom of the reservoir where ORP decreased.

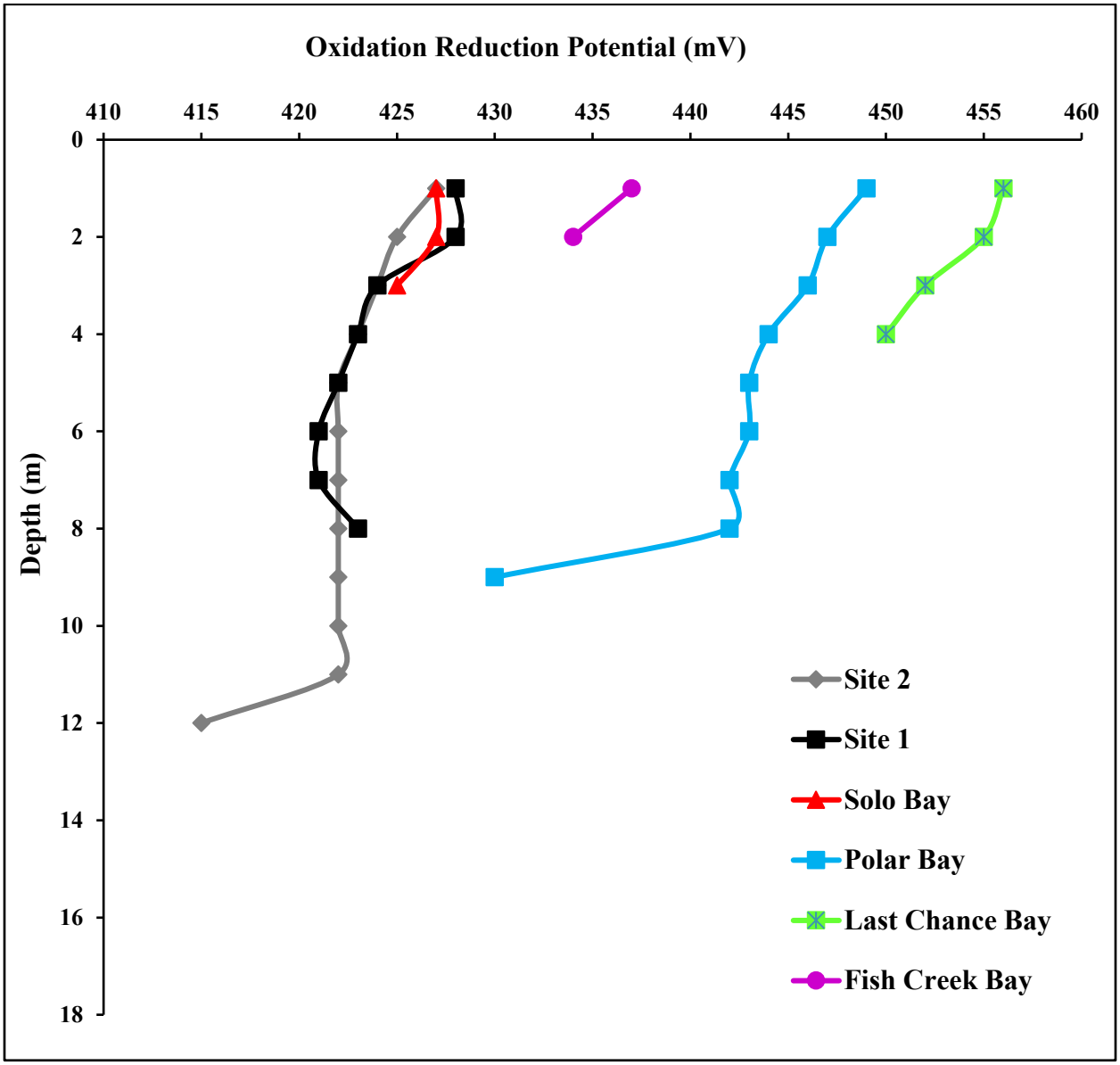

Figure 21. WSR oxidation reduction potential (mV) profiles, April 15, 2021.

Water Quality: Fish Creek, North Fork Fish Creek

Water quality data were again collected at two sample sites that were first sampled in 2019: Fish Creek at Pond F and North Fork Fish Creek downstream of Outfall 002 (Figure 9). On April 15,

2021, water temperature in North Fork Fish Creek was 4.53°C and higher compared to the water temperature in Fish Creek of 0.98°C and the six WSR sample sites, where average temperatures ranged from 0.62 – 1.67°C (Figure 23). Typically, the temperature in the two forks of Fish Creek is similar; however, the influence of warmer RO water discharged from Outfalls 001 and 002 raised the water temperature in North Fork Fish Creek. In comparison, during the 2019 sampling RO water was flowing into Fish Creek because of a beaver dam blocking the Pond AB culvert and Fish Creek water was warmer than North Fork Fish Creek.

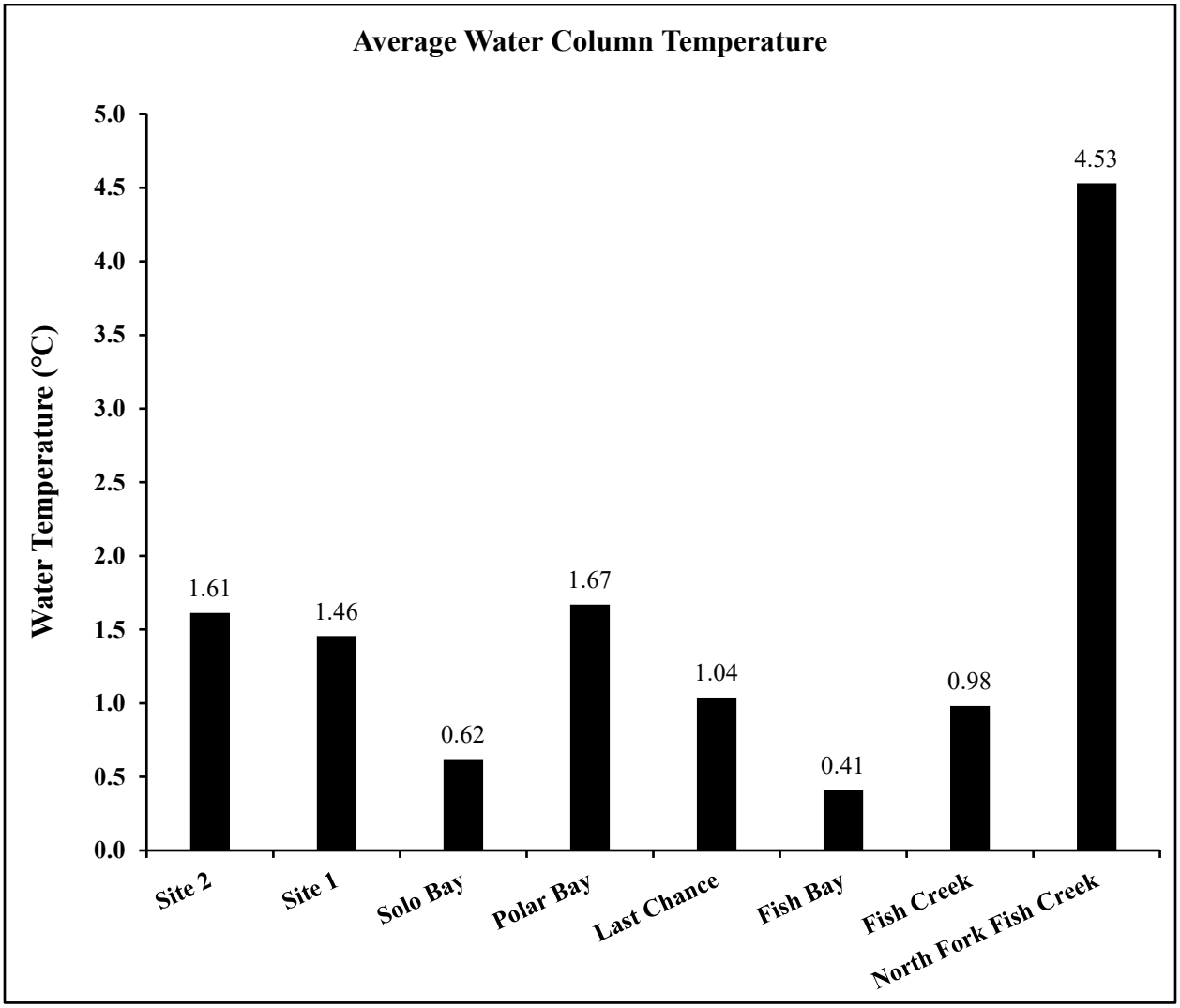

Figure 22. Average water column temperature in the WSR, Fish Creek and North Fork Fish Creek, April 15, 2021.

The DO in North Fork Fish Creek and Fish Creek was higher when compared to the average DO in the six WSR sample sites (Figure 24). RO water discharged from Outfalls 001 and 002 is high in DO and has contributed to the rise in measured WSR DO since 2015. Most of the RO water discharged from outfall 002 flows though Pond AB and into North Fork Fish Creek. On Aril 15,

2021, about 10 percent discharged RO water was flowing out of Pond AB's natural outlet and into Fish Creek despite no culvert blockage from beaver activity. This RO water combined with natural hydraulic agitation during movement contributed to its higher DO concentration.

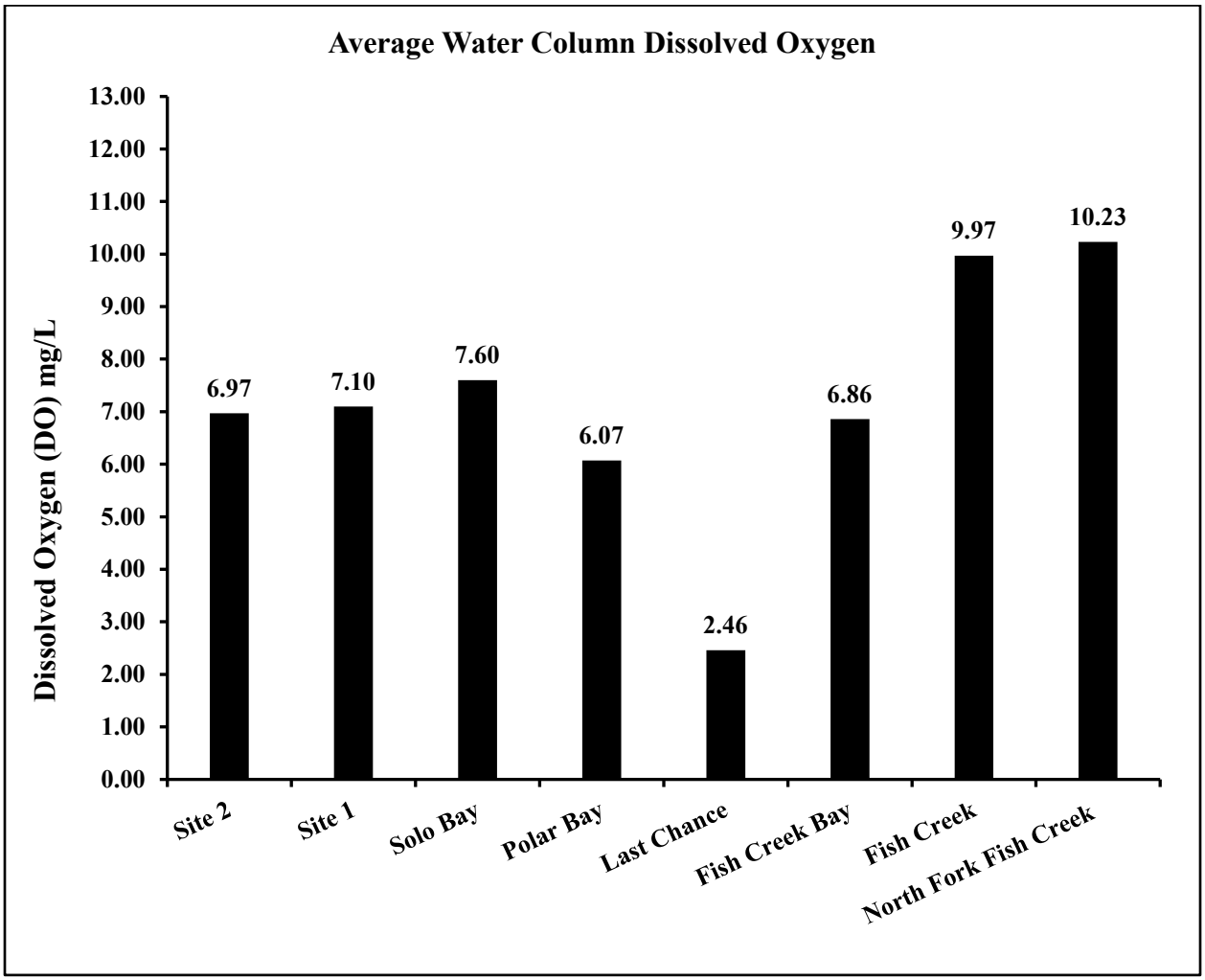

Figure 23. Average water column dissolved oxygen in the WSR, Fish Creek and North Fork Fish Creek, April 15, 2021.

The RO water discharged from Outfall 002 is mixed with non-contact ground water from de-watering wells that adds minerals and raises the specific conductance before it is discharged into the Fish Creek drainage. The percentage of non-contact ground water can vary during RO water processing. North Fork Fish Creek specific conductance measurements were taken downstream of Outfall 002 and had the highest recorded values for the WSR and Fish Creek (Figure 25). During the 2019 sampling North Fork Fish Creek's specific conductance was the highest measured during sampling at 187.3 µS/cm and was the lowest in 2020 at 124.0 µS/cm (Figure 26).

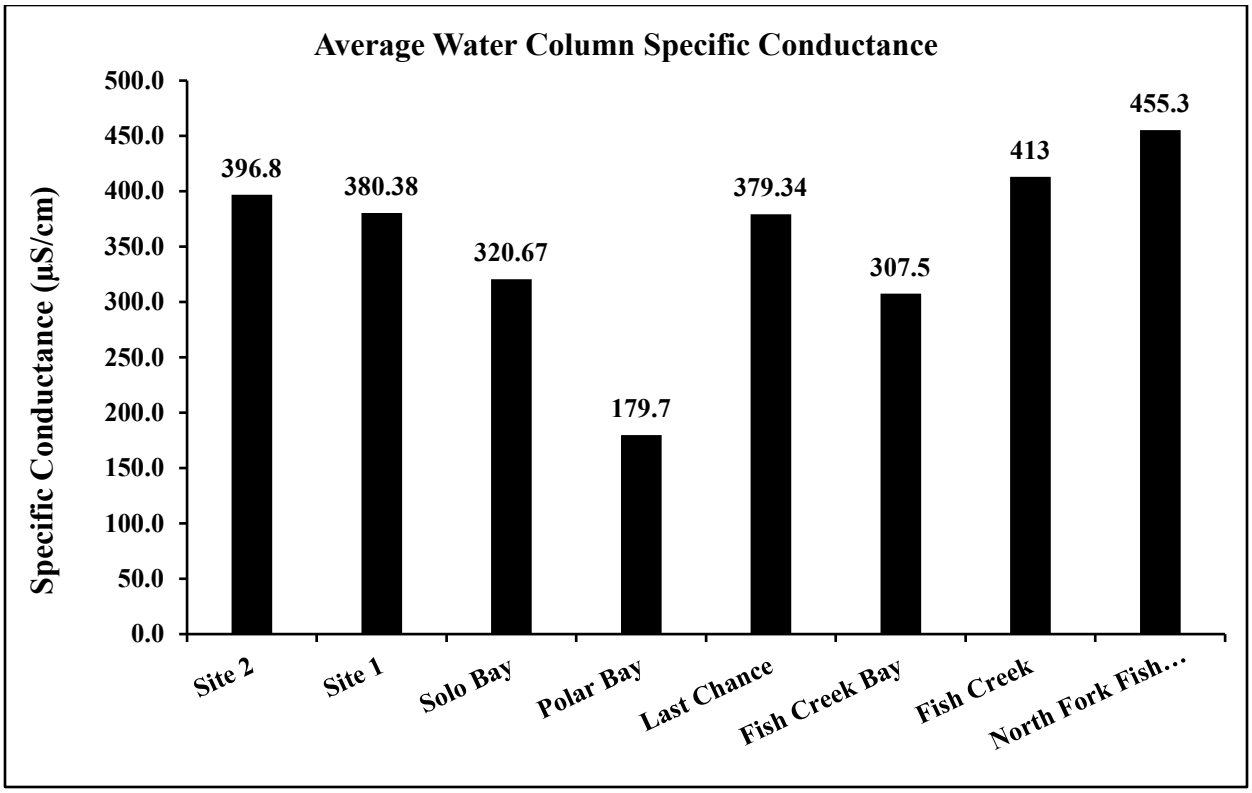

Figure 24. Average water column specific conductance in the WSR, Fish Creek and North Fork Fish Creek, April 15, 2021.

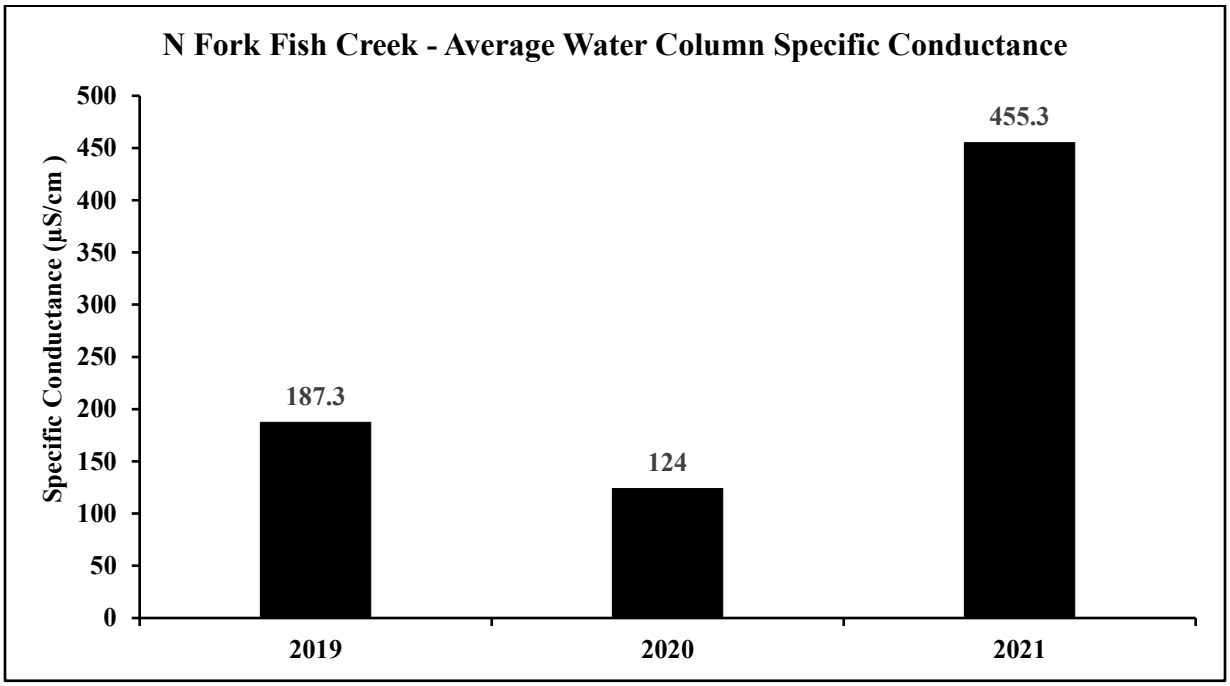

Figure 25. Average water column specific conductance in North Fork Fish Creek, April 15, 2021.

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. However, these 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 averaging 148 mm for males and 165 mm for females (Al Ott, Unpublished Data). 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.

After completion of the freshwater dam, very few Arctic grayling 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. The outlet channel was constructed to bypass a perched pipe and provide fish access to potential spawning and rearing habitat in the wetland complex.

Arctic grayling have successfully spawned in the wetland complex every year since 1999 (Figure 27). However, in 2002, 2006, and 2007, substantial aufeis and resultant cold-water temperatures in the wetland complex, in addition to beaver dams, limited the access and availability of spawning habitat. In recent years, aufeis buildup has been relatively minor and more effective beaver management has been implemented, including the annual removal of dams throughout the wetland complex by Fort Knox and ADF&G staff.

Figure 26. Male Arctic grayling in Fish Creek Pond F outlet, May 2021.

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

In winter 2020/2021, aufeis in Fish Creek was minimal. North Fork Fish Creek had substantial aufeis and formed glaciers of frozen overflow two to three feet deep throughout the drainage. A channel with open water was flowing on April 15, 2021, from the discharged warm RO water from outfall 002. Beaver dams throughout the lower wetlands complex and Pond D and F outlets had been rebuilt during fall of 2020 (Figure 28). Fort Knox staff were successful in removing several resident beavers from Fish Creek during the summer of 2020 to maintain fish passage, but the remaining beavers had reestablished many of the dams in the drainage. Arctic grayling had access to the Fish Creek wetland complex (Ponds D, E, and F) during most of the summer of 2021, but access was limited by a 3-meter-tall beaver dam in the channel connecting Pond D and the Horseshoe Ponds. (Figure 29). No Arctic grayling were observed upstream of this dam during the two weeks of sampling in spring 2021. In North Fork Fish Creek, a series of six or more smaller dams were creating partial obstructions to fish and creating ponds between Pond AB and it's confluence with Fish Creek (Figure 30).

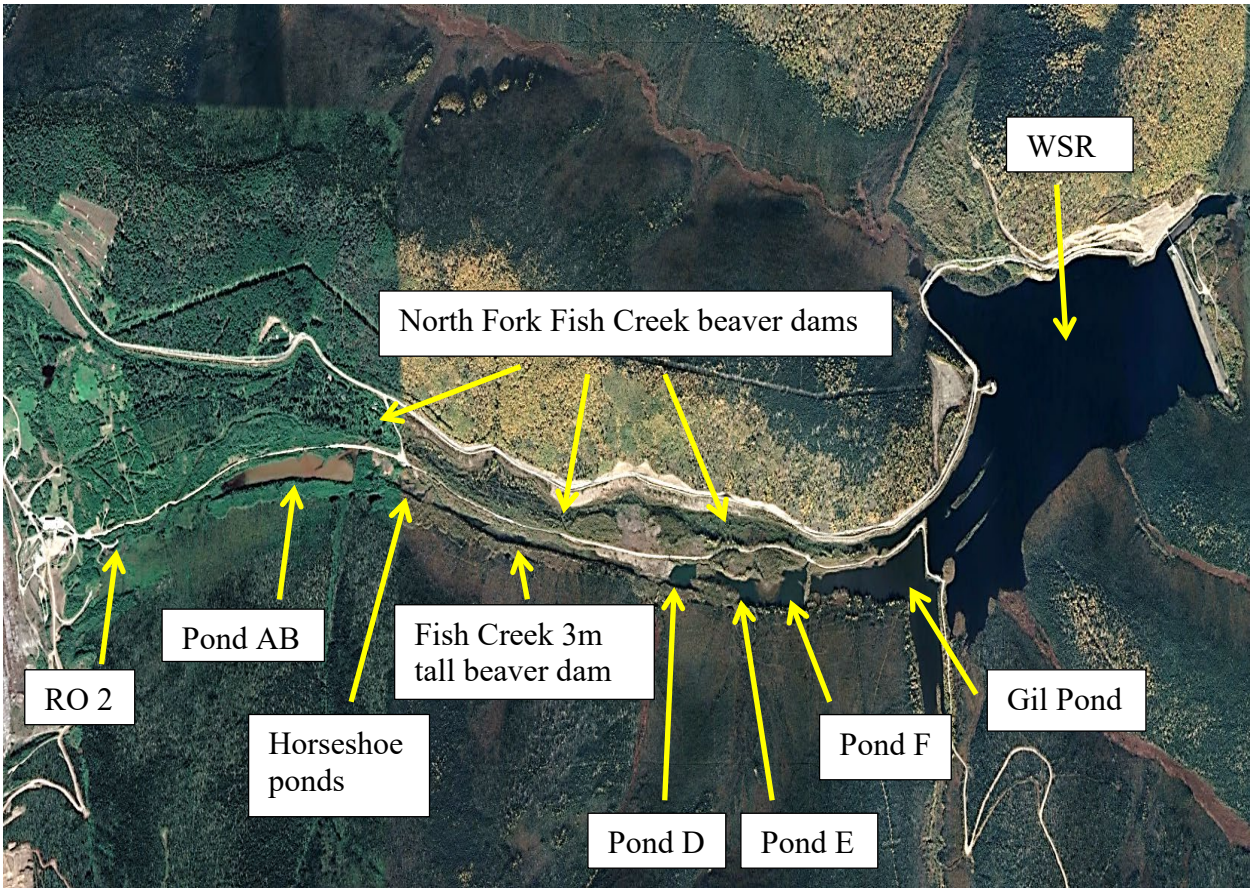

Figure 27. Fish Creek wetland features including 2021 beaver dam locations.

Figure 28. A beaver dam (about 3 m high) formed in the channel below Horseshoe Ponds that was an obstacle to the upstream movement of fish, April 30, 2021.

Figure 29. Beaver dams in North Fork Fish Creek limiting fish movement, May 12, 2021.

On April 15, during the late winter WSR water quality sampling, water temperature of North Fork Fish Creek was already 4.53°C and above the ideal spawning conditions for Arctic grayling (4.0°C). Fish Creek at the Pond F outlet was colder at 0.98°C. North Fork Fish Creek was partially open and flowing, most of Fish Creek and Pond F was frozen over including the outlet. Conditions were determined to be appropriate to begin fyke netting Arctic grayling on April 30. This start date was six days later than sampling began in 2020.

Fyke nets were set in Fish Creek at the Pond F outlet (Figure 31) and North Fork Fish Creek (Figure 32) on April 30. Both fyke nets were fished in the same locations without being moved for the duration of the sample period. Beginning on May 3, the fyke nets were checked daily until they were removed on May 12 as water became too warm for sampling to continue. Capture efficiency declined in the North Fork Fish Creek fyke net on May 7 when a new channel thawed around the fyke, which allowed fish to avoid capture. Both fyke nets fished effectively for the remainder of the sampling days.

Figure 30. Fish Creek Pond F fyke net and open water, April 30, 2021.

Figure 31. North Fork Fish Creek fyke net and open water, April 30, 2021.

The 2021 Fish Creek daily peak water temperature taken at the Pond F outlet was similar when compared to previous years during similar timing (Figure 33). Fish Creek water temperature was 0.14°C on April 16 from natural spring melt water entering the drainage. The Fish Creek daily peak water temperature and timing were like 2019 but dissimilar to 2020 when all discharged RO water was diverted into Fish Creek stabilizing water temperatures (Figure 33). North Fork Fish Creek water temperature data collection began on April 30 and was warmer at 5.91°C compared to Fish Creek temperature of 3.46°C (Figure 34). The warmer water temperature resulted from the up to 3,000 gpm discharge of RO water from Outfall 002. The large volume of warm water dilutes the influx of cold spring melt water thereby keeping North Fork Fish Creek warmer than Fish Creek (Figure 34). Fyke netting started on April 30 as water temperatures were suitable for Arctic grayling movement and spawning.

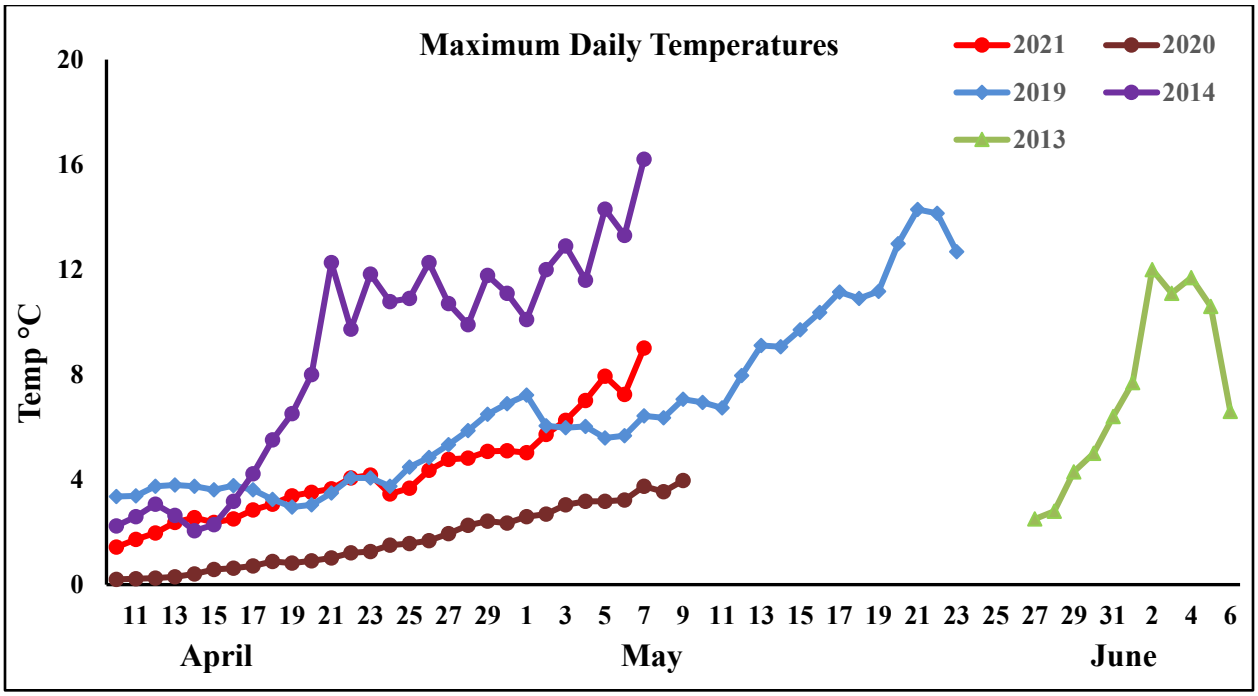

Figure 32. Fish Creek at Pond F daily water temperature maximums; select years for reference.

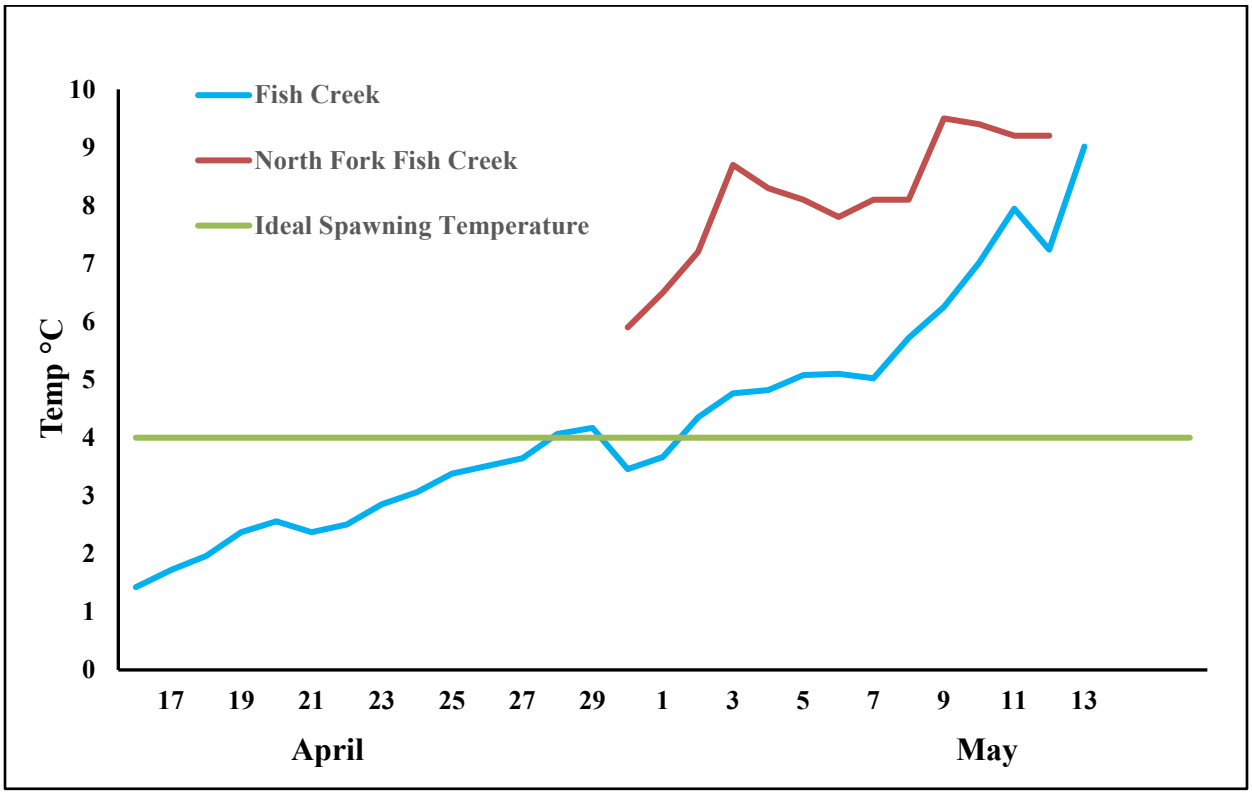

Figure 33. Fish Creek and North Fork Fish Creek daily peak water temperature, April 16 – May 13, 2021.

From April 30 to May 12, all fish caught in the fyke nets were handled with the majority being Arctic grayling. Burbot were also captured. The Arctic grayling catch per unit of effort (CPUE) in Fish Creek varied during the first few days of sampling and peaked at 3.91 fish/hour on May 7 (Figure 35). The North Fork Fish Creek fyke net CPUE initially increased then dropped to a lower catch rate. North Fork Fish Creek CPUE reached a high of 3.87 fish/hour on May 4 and catch rates declined in part due to a previously frozen channel that thawed around the fyke net allowing fish an alternate route. Water temperatures were warmer in North Fork Fish Creek, 5.9°C on April 30 compared to 3.5°C in Fish Creek. The fyke nets were pulled on May 12 as the target sample size of 1,000 Arctic grayling had been reached.

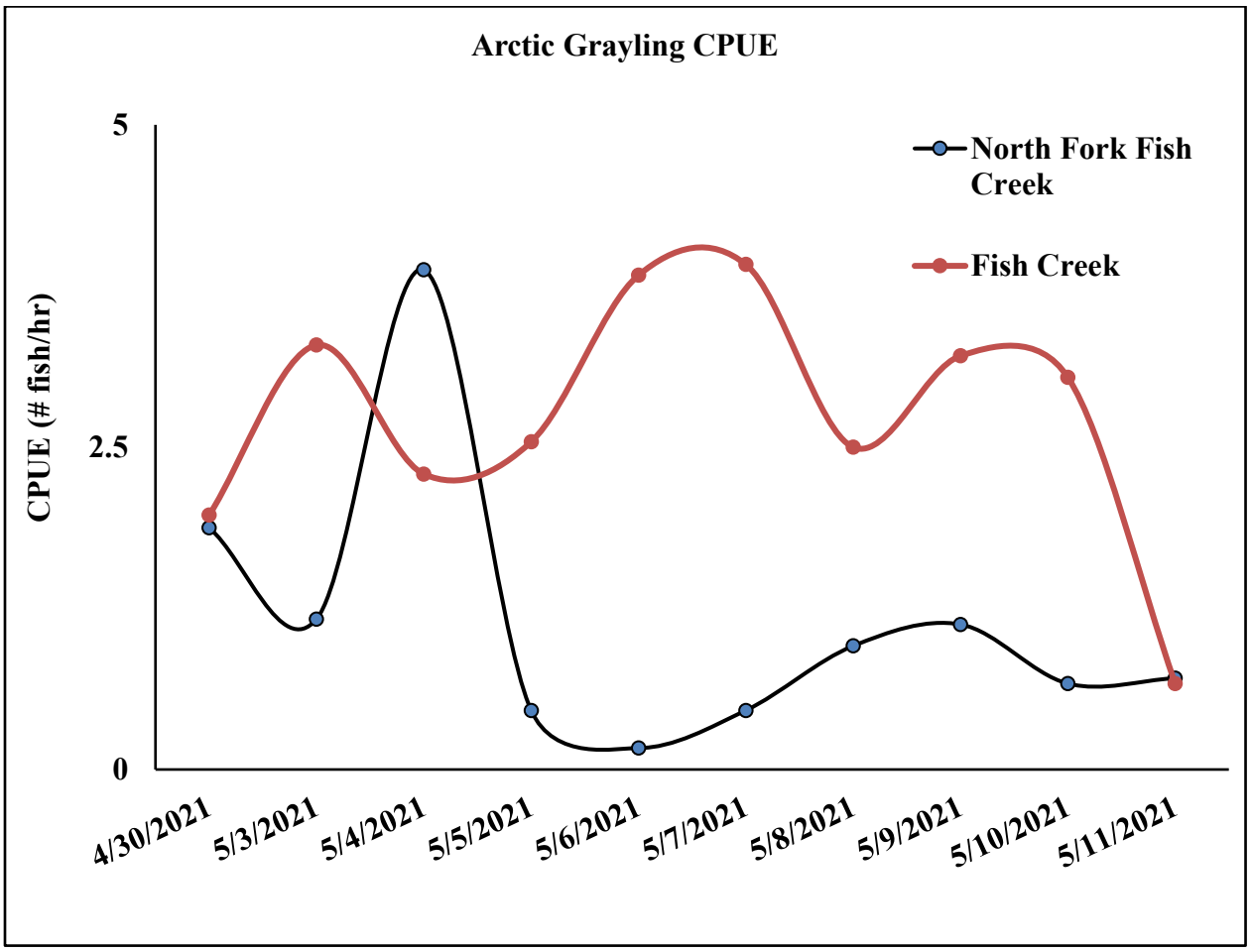

Figure 34. Arctic grayling catch per unit of effort (CPUE) in #fish/hr at the Pond F and North Fork Fish Creek fyke nets in the wetlands complex, 2021.

Female Arctic grayling were categorized as not ripe, ripe, or spent, based on their spawning condition (Figure 36). On the first day of fish capture (May 3), 84% of the female Arctic grayling were categorized as not ripe. The number of not ripe females decreased throughout the sampling period to 7% on May 11. On May 3, 16% of the female Arctic graying were classified as ripe. The number of ripe females increased to 100% on May 6 and remained high until sampling concluded. No fish were classified as spent during the first two days of sampling and 31% of females were spent on May 9. Sampling was conducted during the same time frame as 2020 but water temperatures were warmer in 2021.

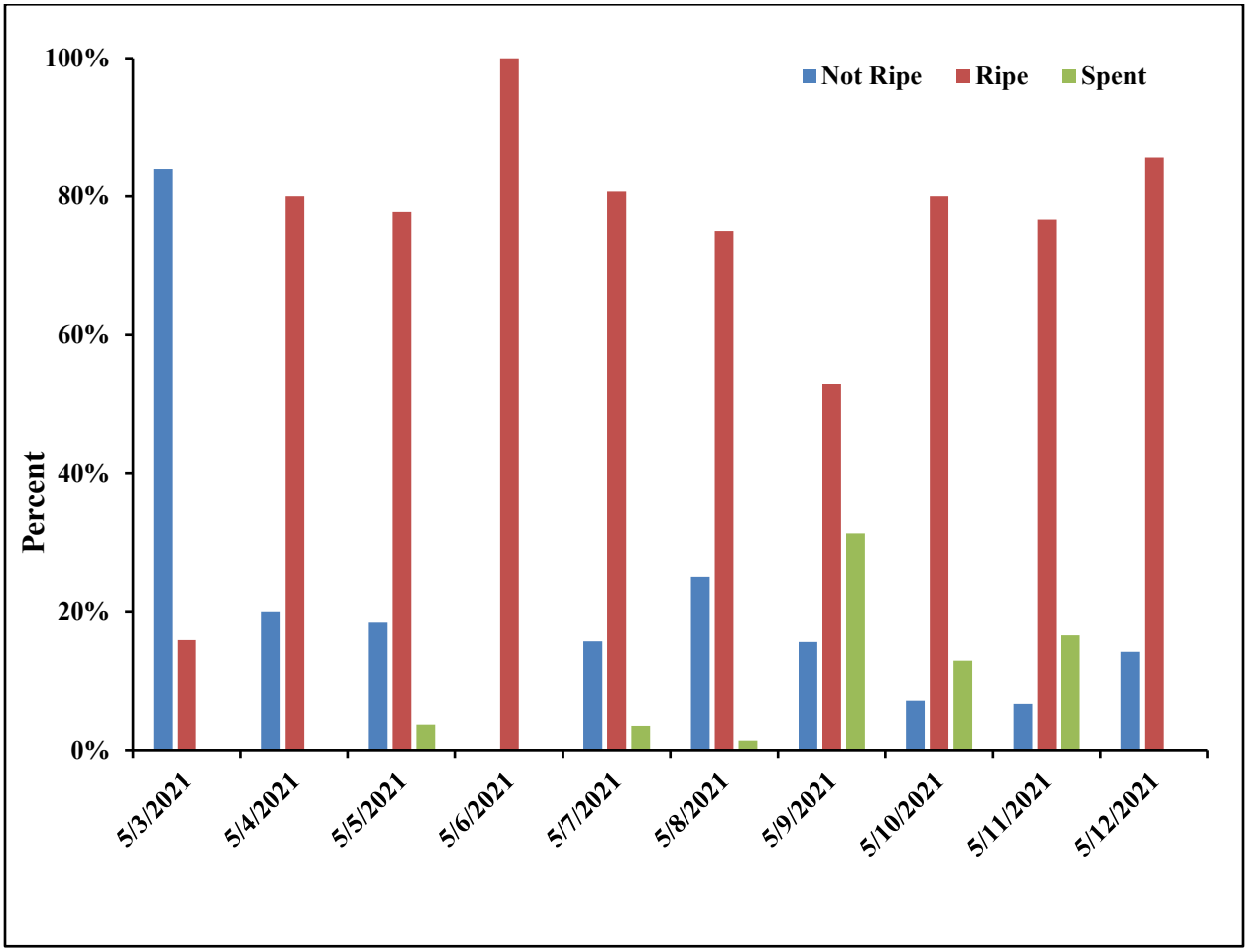

Figure 35. Spawning condition of Arctic grayling females categorized as: not ripe, ripe or spent, 2021.

Arctic Grayling Catches and Metrics

The spring 2020 population abundance estimate for Arctic grayling ≥ 200 mm was 3,632 fish with a 95% CI of 3,301 to 3,963 fish (Figure 37). The population has declined since 2017 but is anticipated to increase in the future with the substantial number of age-2 Arctic grayling seen during the spring 2021 sampling event.

The 2020 population abundance estimate of Arctic grayling in the WSR was calculated using spring 2020 as the mark event and spring 2021 as the recapture event. During the spring of 2021 1,038 Arctic grayling ≥ 235 mm were captured, of those 291 were recaptures from the spring 2020 tagging event. For the 2020 population estimate, Arctic grayling population length frequency distributions from 2020 and 2021 were compared to eliminate those fish handled in 2021 that would have been too small (< 200 mm) to mark in spring 2020, 70 fish met this criterion and were not included in the population estimate.

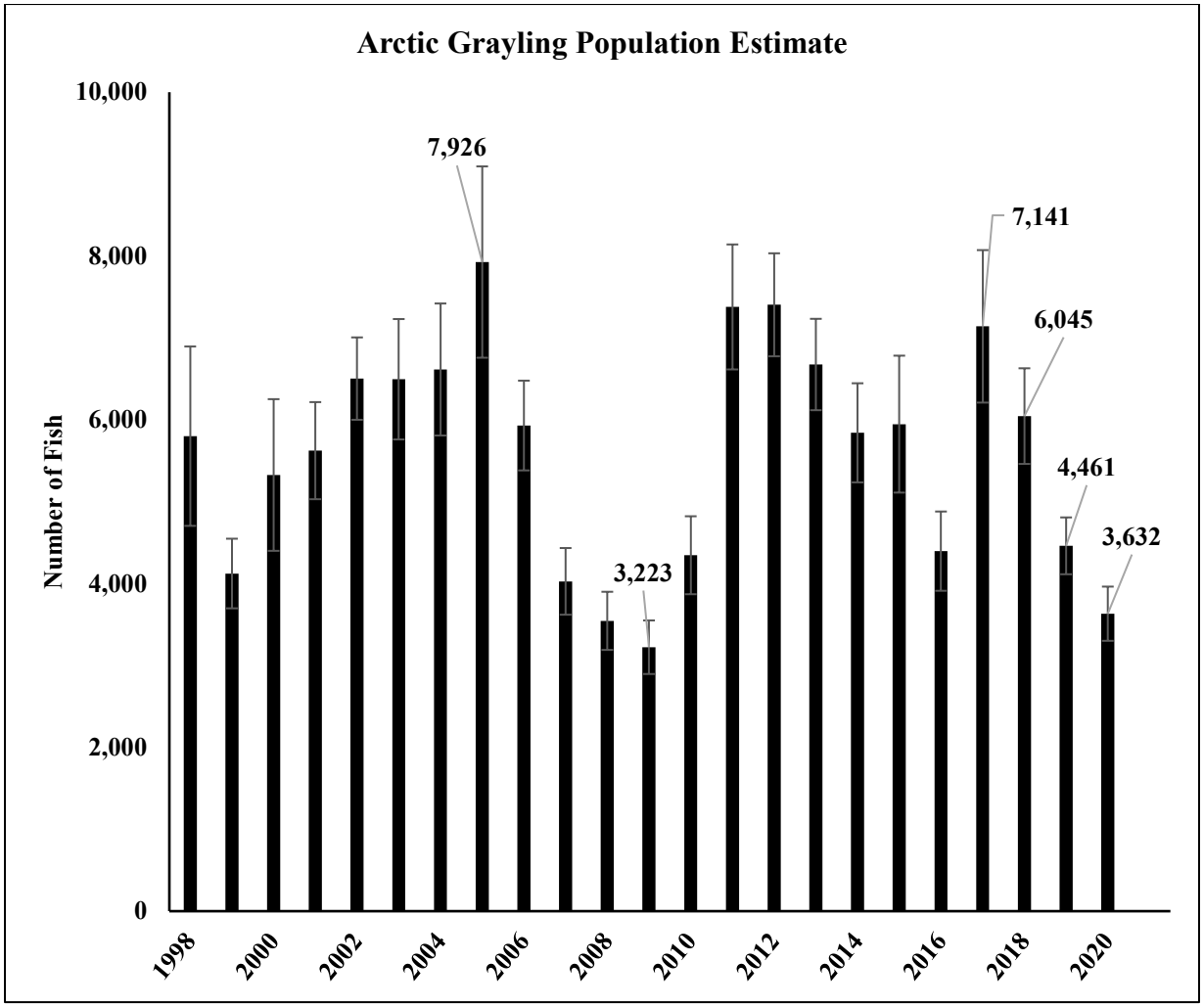

Figure 36. Estimates of the Arctic grayling population in the wetlands and WSR with 95% confidence intervals, 1998 – 2020.

Arctic grayling recruitment, as defined as the number of new fish ≥ 200 mm that entered the population but would have been too small to mark in the previous year (upper limit of size based on growth of marked fish – generally about 235 mm) is variable among the sampling years, but was highest in 2017 and declined in 2018, 2019, and 2020 (Figure 38). Substantial recruitment was observed in the spring of 2004, 2010, 2014, and 2017. A substantial recruitment event was

defined as > 300 fish encountered during a recapture sampling event that were not available for tagging based on size at the mark event (typically fish between 200 and 240 mm). During the 2020 sampling event there were 3,865 age-1 Arctic grayling captured indicating that there was good spawning success and survival from the 2019 spawning event. During the 2021 sampling, 595 age-1 and age-2 Arctic Grayling were captured but thousands more were observed in the brushy creek and pools in North Fork Fish Creek. These fish were not included in the recruitment estimate (Figures 34 and 40).

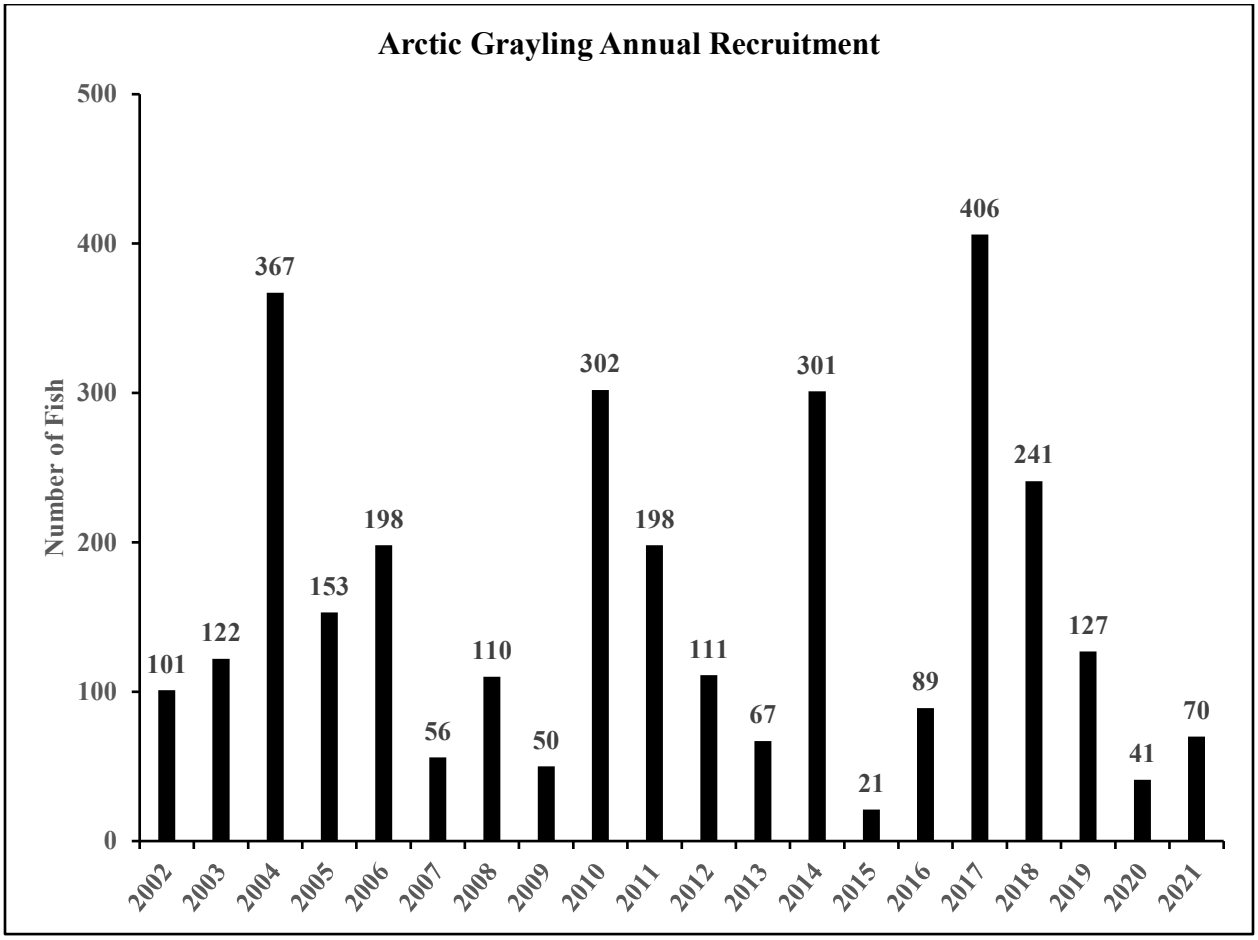

Figure 37. Arctic grayling annual recruitment in Fort Knox wetlands complex, 2002-2021.

Figure 38. Age-1 and age-2 juvenile Arctic grayling captured in Fish Creek, May 5, 2021.

Figure 39. Juvenile Arctic grayling (age-1) observed in North Fork Fish Creek, May 5, 2021.

Average growth of Arctic grayling prior to the development of the WSR ranged from 3 to 17 mm per year (Figure 41). Average growth in each size class has increased since the construction of the WSR in 1994. The highest annual average growth in most size classes occurred in 2014, and the lowest occurred in 2015. Most notable in 2020 was the increase of the average growth rate of large grayling ≥ 300 mm. For example, Arctic grayling between 300 and 310 mm grew an average of 16 mm in 2020 compared to 11 mm in 2019, 3 mm in 2018 and 6 mm in 2017. Higher growth rates seem to occur at lower population levels. The increased growth of large Arctic grayling ≥ 300 mm corresponds to the decrease in recruitment and total population of Arctic grayling in the WSR since 2017.

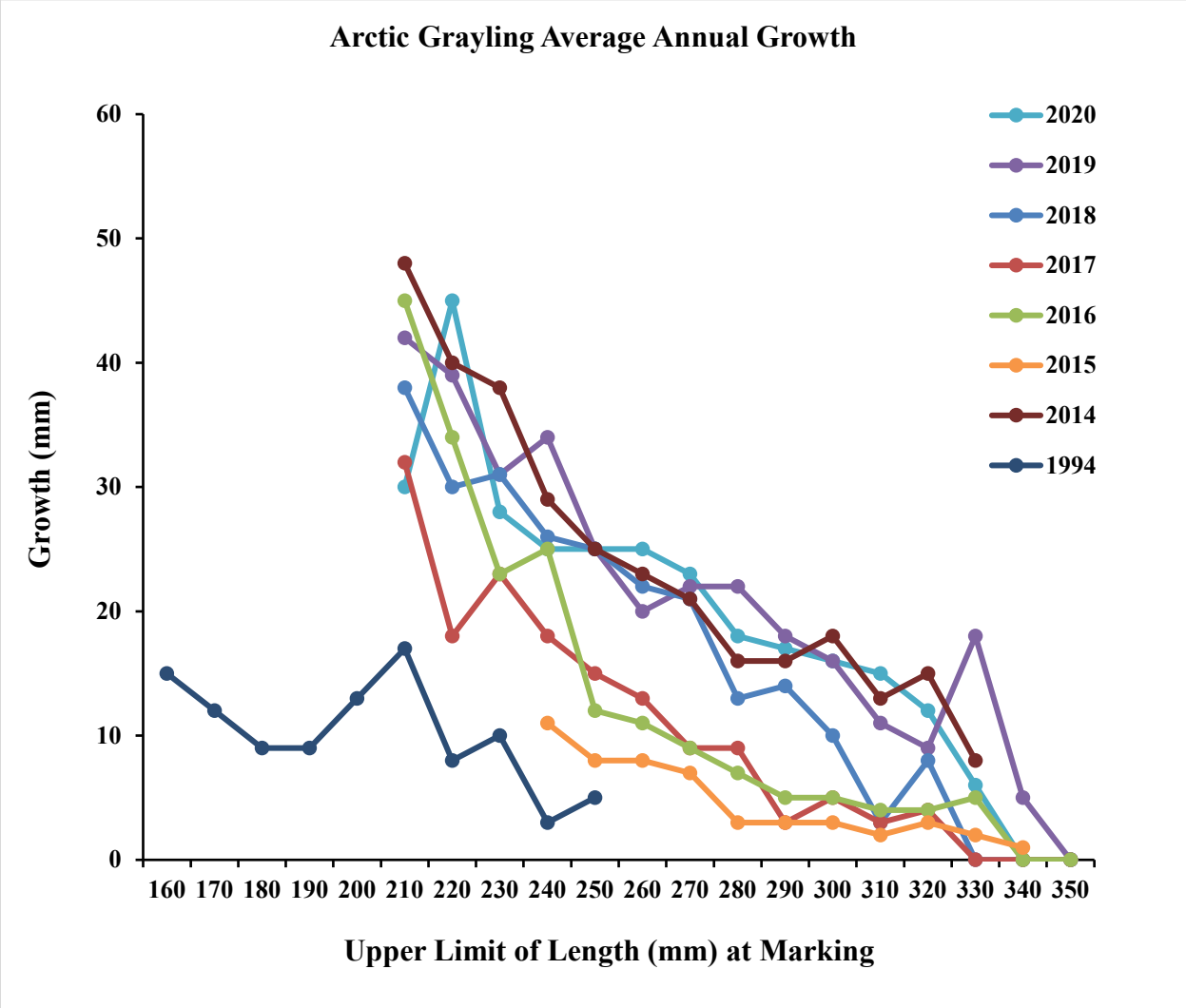

Figure 40. Average annual growth of Arctic grayling by size group in the WSR in selected years including baseline (before WSR) in 1994.

The 2021 length frequency distribution of Arctic grayling caught in the wetlands complex is presented in Figure 42. Data from 1995 are included for comparison to the length of Arctic grayling before the construction of the WSR. The 1995 data set was obtained before construction of the freshwater dam and reflects the stunted condition of the population at that time. During the 2020 sampling, 3,865 small Arctic grayling were captured <130 mm (Figure 43). A subsample of 425 of these small Arctic grayling were measured and found to have an average length of 101 mm. Very few Arctic grayling were captured in the 130 to 240 mm size range during 2020. During the 2021 sampling 488 grayling were captured between 130 and 240 mm showing survival of thousands of small Arctic grayling observed in 2020. Thousands of juvenile Arctic grayling were observed but not captured in the North Fork Fish Creek wetlands upriver of the fyke location in spring 2021. These Arctic grayling moved into the creek before fyke netting began on April 30, 2021.

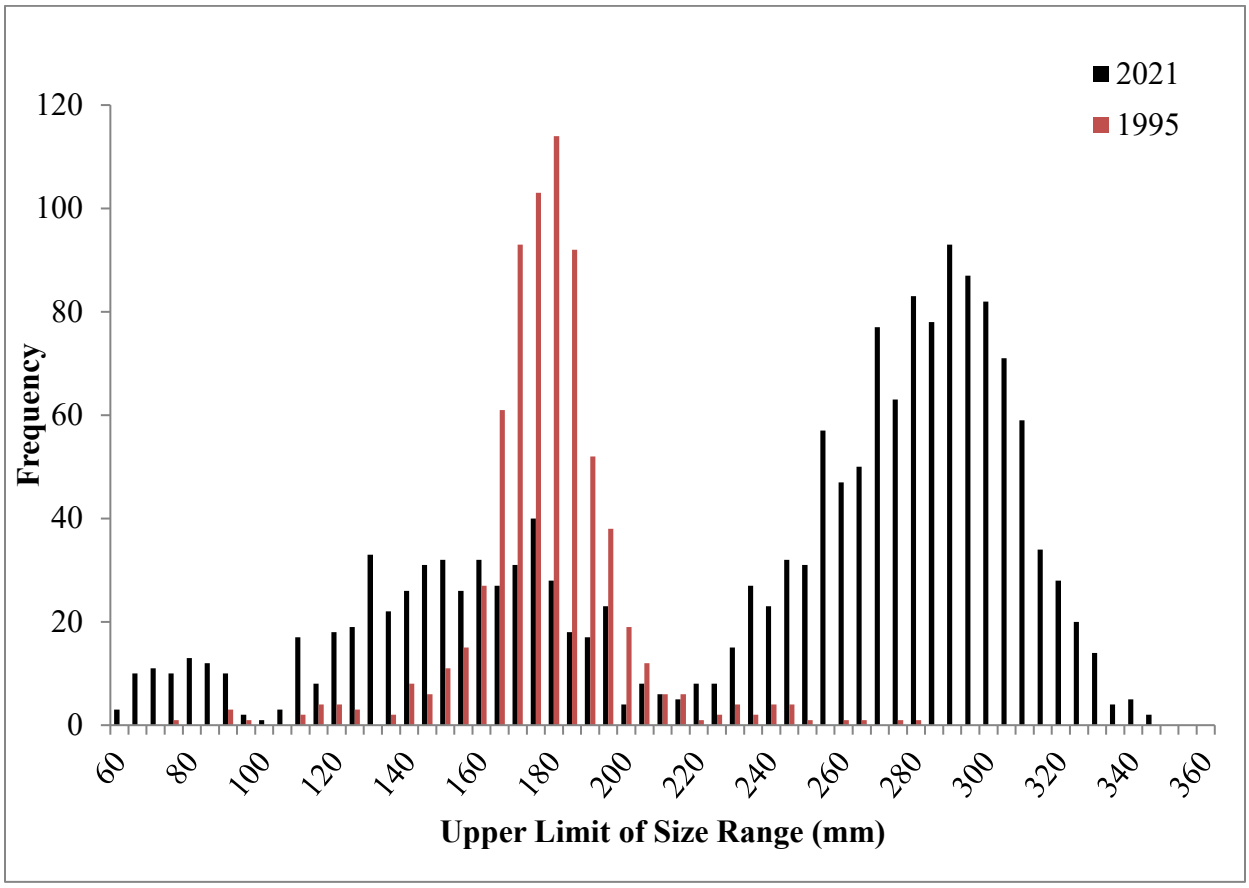

Figure 41. Length frequency distribution of Arctic grayling captured in spring 2021 and 1995.

Figure 42. One of the individuals from the subsample of 425 juvenile Arctic grayling captured in Fish Creek May 9, 2020.

Water Supply Reservoir, Burbot

During the spring 2021 fyke netting 48 burbot were captured in Fish Creek and North Fork Fish Creek. Six of these were ≥ 300 mm and tagged with a unique numbered floy tag. Forty-two were < 300 mm and were measured and released without being tagged. No burbot were captured that had been previously tagged during past year's Fish Creek or WSR burbot sampling.

Typically fall burbot sampling with hoop traps would occur during late September or early October in the WSR. During September 2021 an early cold snap formed ice on the WSR and prevented sampling. There were not enough mark and recaptured burbot during 2021 field work to generate a 2020 WSR burbot population estimate.

Burbot populations in the WSR and Fish Creek wetlands have been relatively stable during the past eight years. The most recent population estimate for burbot ≥ 400 mm was 203 fish (95% CI: 142 to 264 fish) in 2019.

Conclusion

Populations of Arctic grayling and burbot have been established and remain in the Fort Knox WSR. The post-mining population goal for the Arctic grayling in the WSR was set at 800 to 1,600 fish $\geq$ 200 mm. The spring 2020 population estimate of 3,632 fish $\geq$ 200 mm (95% CI: 3,301 to 3,963) was a decrease from the estimated 2019 population of 4,461 fish but still well above the post-mining population goal. A post-mining population goal was not established for the burbot within the WSR, however a small population of fish larger than 400 mm remains present. In 2019 that population was estimated to be 203 fish.

ADF&G plans 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 appears to remain a critical component to ensure Arctic grayling have access to spawning areas within the developed wetlands. The WSR remains a critical component to the productive capacity of the wetland complex by providing overwintering and rearing habitat for both Arctic grayling and burbot.

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

2011

- February 9, 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).
- March 4, the ACOE issued a permit (POA-1992-574-M19) authorizing construction of the modified dam raise and expansion of the Tailings Storage Facility (TSF).
- 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.
- May 2, 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.
- A constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring – 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.
- June 2, ADF&G provided written comments on the Fort Knox and True North environmental audit proposals.
- July 19, 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.
- August 4, 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.
- September 13, 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.
- September 28, we met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

Appendix 1 (continued)

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 ≥ 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.
- July 13, 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.
- September 27, 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

- February 20, FGMI received a Notice of Violation from the ACOE for the unauthorized discharge of fill material into 0.28 acres of wetlands.
- March 1, 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.
- March 11, the ACOE issued an After-the-Fact authorization covering the 0.28 acres of wetland fill.
- April 25, water quality data (temperature, dissolved oxygen, etc.) were collected in the WSR under ice cover.
- May 4, 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 ≥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.

Appendix 1 (continued)

- 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.
- June 25, 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.
- October 14, ADF&G submitted comments on the Fort Knox 2013 reclamation plan – eight recommendations were made.
- November 27, 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 on the 1992 list but was removed from the 1994 list because FGMI had bought out all the existing placer operations and was planning on building the freshwater dam.
- April 2014, the decision was made not to 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.
- September 29, FGMI notified state agencies that the new Environmental Manager was Bartly Kleven.
- September 4, 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.
- September 26, 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).

Appendix 1 (Continued)

- October FGMI and ADF&G discussed a draft design for the Solo Creek culvert replacement, conducted a field inspection, and continued discussions to decide what remedial work will be done.
- October 28, ADF&G distributed the Fork Knox technical report for work done in 2014.
- November 12, 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

- March 2, we conducted a field visit to observe the discharge point for non-contact mine water to the old Fish Creek channel, which is dry, except for breakup and periods of heavy rain.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- October 28, ADF&G distributed the Fork Knox technical report for work done in 2015.

Appendix 1 (continued)

2016

- 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 (≥ 200 mm) for spring 2015 was 5,947 – a slight increase from the 2014 estimate.
- Our estimated population of large burbot (≥ 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.
- 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.
- October 28, we were notified by FGMI that beaver dams at Pond D outlet and downstream of Pond F had been removed.
- December 21, ADF&G sent a summary of our meeting on the new water treatment plant to FGMI.

2017

- April 12 and 19, 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 above the 15 year running average and the second highest on record, behind 2016.
- In spring 2017, we fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from early May to May 18. Based on the fyke net catches and observations, most Arctic grayling spawned in the wetland complex downstream of Pond F.
- About 100 Arctic grayling adults were moved from the Pond F fyke net and released into Pond D upstream of a barrier. These fish successfully spawned in Pond D as fry were captured on June 29.

Appendix 1 (continued)

- Our estimated population of Arctic grayling (≥ 200 mm) for spring 2016 was 4,396, a decrease of about 1,500 fish from 2015.
- May 26, ADEC issued Waste Management Permit 2014DB002 (Modification #1).
- May 26, ADNR issued a permit amendment for the construction of the Barnes Creek heap leach.
- July 19, ADNR issued a Certificate of Approval to construct a dam for the Barnes Creek heap leach (#AK00315).
- October 12, a site visit was conducted to check on the status of beaver dams in the wetland complex that had been removed recently by FGMI.
- October 24, historic information was provided to FGMI on the status of Fish Creek and why it was taken off the impaired waterbody list in 1994.
- December 12, FGMI, ADF&G, ADNR, and ADEC met to discuss alternatives for tailings disposal, closure configuration for the tailing dam at elevation 1557, and a new water treatment plant.
- December 13, FGMI acquired a new parcel of land that contains an estimated 2.1 million ounces of gold.

2018

- March 14, ADNR approved a POA amendment request to replace the power line trail.
- April 3, 5, and 6, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998.
- May 3-May 14, two fyke nets were fished in the developed wetlands just upstream of the WSR and in Pond F.
- Our estimated population of Arctic grayling (≥200mm) for Spring 2017 was 7,141, which is an increase of 2,745 over 2016.
- Our estimated population of large burbot (≥400 mm) was 201 fish, which is an increase of 82 fish over 2016.
- October 9, 2018, the Pond D beaver dam was removed to allow the downstream movement of grayling into the WSR.

2019

- January 15, Fort Knox began the discharge of up to 3000 gpm of Reverse Osmosis (RO) from Outfall 002 into Fish Creek.
- February 20, environmental compliance and management systems audit performed by SRK Consulting found FGMI to be in compliance with all State of Alaska permitting requirements.

Appendix 1 (continued)

- April 3, FGMI requested modification 16 to Plan of Operations (POO) for clearing/grubbing of 15.5 acres of land to stockpile subbase for the Barns Creek Heap Leach facility.
- Between January 15 and April 10, a beaver blocked the Centerline Road culvert between Pond AB and North Creek diverting the 3000 gpm of RO water from Outfall 002 into Fish Creek instead of North Fork Fish Creek.
- April 10, water quality data were collected as six sites in the WSR, and three new sites in Fish Creek. Average dissolved oxygen (DO) at Site 2, (Middle of the WSR) was higher that all previous year's data. Fish Creek sites had higher water temperature (6.0 °C) compared to WSR sites.
- April 12 to May 03, we set one fyke net in Fish Creek near the Pond F outlet to capture Arctic grayling and burbot moving into the developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for spring of 2018 was 6,045 fish with a 95% CI of 5,461 to 6,629 fish.
- June 15, FGMI received a Fish Habitat Permit to lower Centerline Road culvert to improve flow of RO water from Pond AB into North Creek.
- June 25 to 27, we captured seventy-one Arctic grayling from 160-315 mm FL and nine burbot from 320 – 615 mm tail length in the stilling basin. Bathymetric measurements were taken in the stilling basin and WSR seepage pond.
- August 27 to 29, WSR water level lowered 1.70 vertical feet for required spillway structural inspection. Water discharged through stilling basin into lower Fish Creek.
- September 25 to October 9, we fished twenty-one hoop traps in the WSR and captured 124 burbot for the 2018 population estimate.
- Our estimated population of large burbot (≥400 mm) for spring of 2018 was 402 fish (95% CI: 190 to 613 fish).

2020

- Fort Knox continued discharge of RO water from outfall 002 into Fish Creek drainage. Outfall 001 not operated in 2020. Outfall 002 discharged 9,663 acre-feet of RO water.
- Majority of discharged RO water confined to North Fork Fish Creek before combining with Fish Creek and entering the WSR.
- March 2020, FGMI implemented Covid-19 precautions in response to 2020 pandemic when working on FGMI property. ADF&G Habitat Section deployed HOBO temperature loggers on March 31.
- April 10, water quality data were collected at six sites in the WSR and two sites in Fish Creek. Average dissolved oxygen at Site 2 (middle of the WSR) was higher than all previous year's data.

Appendix 1 (continued)

- April 10, water temperature in North Fork Fish Creek 3.01°C from warm RO discharge water compared to 0.23°C in Fish Creek from natural spring thawing.
- From April 24 to May 9 ADF&G sampling with two fyke nets placed in Fish Creek and North Fork Fish Creek to capture Arctic grayling and burbot moving into developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for Spring of 2019 was 4,461 fish with a 95% CI from 4,4114 to 4,808 fish.
- September 29 to October 9, twenty-six hoop traps were set in the WSR and six in Gil Pond. 123 burbot were captured and used for the 2019 population estimate.
- The 2019 populations estimate of large burbot (≥ 400 mm) is 203 fish with a 95% CI from 142 to 264 fish.
- October 2020, Fort Knox began hauling ore to Barns Creek Heap Leach (BCHL) and began leaching processes.
- November 20, Barns Creek Heap Leach (BCHL) was issued Certificate of Approval to Operate for Stage 1 by ADNR Dam Safety.

2021

- Fort Knox continued discharge of RO water from outfall 002 into Fish Creek drainage. Outfall 001 not operated in 2021. Outfall 002 discharged 8,752 acre-feet of RO water.
- Majority of discharged RO water confined to North Fork Fish Creek before combining with Fish Creek and entering the WSR.
- April 13, ADF&G Habitat Section collected water quality data at five gravel pit sites in lower Fish Creek below Fairbanks Creek as part of the Gil Expansion base line survey work.
- April 15, ADF&G Habitat Section deployed HOBO temperature loggers into upper Fish Creek and North Fork Fish Creek.
- April 15, water quality data were collected at six sites in the WSR and two sites in Fish Creek. Average dissolved oxygen at Site 2 (middle of the WSR) was higher than all previous year's data.
- April 15, water temperature in North Fork Fish Creek 4.63 °C from warm RO discharge water compared to 0.98 °C in Fish Creek from natural spring thawing.
- From April 30 to May 12 ADF&G spring sampling with two fyke nets placed in Fish Creek and North Fork Fish Creek to capture Arctic grayling and burbot moving into developed wetlands.
- Estimated population of Arctic grayling (≥ 200 mm) for Spring of 2020 was 3,632 fish with a 95% CI of 3,301 to 3,963 fish.

Appendix 1 (continued)

- From April 30 to May 12, 48 burbot were captured in the Fish Creek and North Fork Fish Creek fyke nets. Six of these were $\geq$ 300 mm and tagged with a unique numbered floy tags. No burbot were captured that had been previously tagged during past year's wetlands or WSR burbot sampling.
- June 4, Fort Knox initiated a WSR water drawdown to perform a required spillway inspection. Relief valve was closed on June 9 and WSR water levels returned to normal.
- July – September, Gil Haul Road improvements cross Fish Creek and Gil Causeway. Four culverts in Fish Creek extended under FH15-III-0218-A1, FH15-III-0219-A1, FH18-III-0039-A1 and FH21-III-0076.
- August 2, Fort Knox initiated a WSR water drawdown to perform spillway repairs. Construction was delayed due to COVID and contractor availability. Repairs were completed on September 29 and the relief valve was closed refilling the WSR.
- Fresh water supply line from WSR to Tailings Storage Facility (TSF) removed during Gil Haul Road improvements.
- September, groundbreaking ceremony for Gil expansion.

Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 15, 2021.

Site Number (Name)	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (µ S/cm)	pH	ORP
1 (Middle WSR)	1	0.62	47.7	6.72	228	7.16	428
	2	0.57	54.3	7.69	398	7.25	428
	3	0.9	55.9	7.92	407	7.36	424
	4	1.4	53.5	7.5	404	7.19	423
	5	1.75	50.3	7.01	403	7.22	422
	6	1.97	49	6.76	402	7.21	421
	7	2.15	48.5	6.66	401	7.21	421
	8	2.29	47.8	6.54	400	7.19	423
2 (WSR Near Dam)	1	0.20	50.1	7.24	358.0	7.18	427.00
	2	0.31	52.9	7.25	391.0	7.18	425.0
	3	0.42	53.6	7.65	405.0	7.22	424.0
	4	0.97	55.1	7.79	406.0	7.21	423.0
	5	1.37	53.9	7.57	405.0	7.16	422.0
	6	1.85	51.5	7.14	402.0	7.07	422.0
	7	2.04	50.0	6.88	401.0	7.15	422.0
	8	2.18	49.2	6.75	400.0	7.14	422.0
	9	2.33	48.1	6.57	399.0	7.12	422.0
	10	2.43	46.8	6.37	398.0	7.08	422.0
	11	2.58	45.8	6.22	398.0	7.08	422.0
	12	2.68	45.6	6.17	398.0	7.10	415.0
3 (Solo Bay)	1	0.42	61.7	8.95	169.0	7.32	427
	2	0.56	52.0	7.63	392.0	7.06	427
	3	0.88	43.7	6.21	401.0	7.04	425
7 (Last Chance Bay)	1	0.30	17.4	2.50	195.0	6.05	456
	2	0.91	15.7	2.40	362.0	6.50	455
	3	1.22	17.0	2.38	371.0	6.62	452
	4	1.72	18.3	2.54	380.0	6.65	450
11 (Polar Bay)	1	0.33	31.4	4.55	271.3	7.05	449
	2	0.50	35.6	5.00	343.8	7.01	447
	3	1.05	46.1	6.50	404.0	7.08	446
	4	1.36	50.0	7.00	404.0	7.10	444
	5	1.77	49.9	6.93	402.0	7.09	443
	6	2.01	48.8	6.73	401.0	7.07	443
	7	2.19	47.1	6.49	399.0	7.05	442
	8	2.81	44.1	6.00	395.0	7.01	442
	9	3.01	40.8	5.47	394.0	6.98	430
12 (Fish Creek Bay)	1	0.35	41.6	6.03	226.0	6.99	437.00
	2	0.47	53.9	7.68	389.0	7.56	434.00

Appendix 3. Population estimates of Arctic Grayling ≥ 200 mm in the Fort Knox Water Supply Reservoir (WSR), 1995-2020.

Year	[1]	Population Estimate	95% Confidence Interval
1995	[2]	4,358	
1996	[3]	4,748	3,824 - 5,672
1996	[4]	3.475	2,552 - 4,398
1998		5,800	4,705 - 6,895
1999		4,123	3,698 - 4,548
2000		5,326	4,400 - 6,253
2001		5,623	5,030 - 6,217
2002		6,503	6,001 - 7,005
2003		6,495	5,760 - 7,231
2004		6,614	5,808 - 7,420
2005		7,926	6,759 - 9,094
2006		5,930	5,382 - 6,478
2007		4,027	3,620 - 4,433
2008		3,545	3,191 - 3,900
2009		3,223	2,896 - 3,550
2010		4,346	3,870 - 4,823
2011		7,378	6,616 - 8,141
2012		7,404	6,775 - 8,033
2013		6,675	6,217 - 7,333
2014		5,841	5,235 - 6,446
2015		5,947	5,111 - 6,783
2016		4,396	3,913 - 4,880
2017		7,141	6,176 - 8,018
2018		6,045	5,461 - 6,629
2019		4,461	4,114 - 4,808
2020		3,632	3,301-3,963

[1]Population estimates from 1995-1996 include fish ≥ 150 mm, in all other years fish ≥ 200 mm.

[2]In 1995, we used estimates from the ponds and creeks for the Arctic grayling population; a confidence interval was not applicable to the data set.

[3]The 1996 estimate was made with a capture and recapture event in summer 1996 using fyke nets.

[4]In 1996, Arctic grayling were captured with a boat-mounted electro shocker for both the capture and recapture events in fall 1996 by Sport Fish Division.

[5]Starting in 1998 through 2017 the population estimates were made using a mark event in the spring of the year of the estimate, and the recapture event in spring of the following year.

Appendix 4. Arctic Grayling Growth in the WSR, 2020-2021.

Upper Limit (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Sample Size
210	30	30	30	1
220	45	49	41	2
230	28	28	28	1
240	25	42	0	7
250	25	57	2	19
260	25	43	10	31
270	23	64	1	51
280	18	37	0	65
290	17	33	4	53
300	16	29	0	29
310	15	34	0	23
320	12	19	0	8
330	6	6	6	1
340	0	0	0	0
350	0	0	0	0

Appendix 5. Population Estimate of Burbot (≥ 400mm) in the Fort Knox Water Supply Reservoir (WSR), 2001-2020.

Year	Population Estimate	95% Confidence Interval
2001	134	58 - 210
2002	131	63 - 199
2003	102	57 - 147
2004	86	44 - 128
2005	143	96 - 191
2006-2011	No Population Estimates Performed	
2012	193	95 - 290
2013	80	44 - 117
2014	175	44 - 305
2015	92	46 - 138
2016	119	65 - 173
2017	201	124 - 278
2018	402	190 - 613
2019	203	142 - 364
2020	No Population Estimate Performed	