Technical Report No. 25-06

Fish and Water Quality Monitoring at the Fort Knox Mine, 2024

by

Chad E. Bear

April 2025

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. 25-06

FISH AND WATER QUALITY MONITORING AT THE FORT KNOX MINE, 2024

By

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April 2025

Cover: Fort Knox Water Supply Reservoir Spillway and Stilling Basin, August 2024.
Photograph by Chad Bear.

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Executive Summary

Water Quality

In April 2024, dissolved oxygen (DO) concentrations were measured in the Water Supply Reservoir (WSR). For ten consecutive years, winter DO concentrations have been 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, located just downstream of the tailing's impoundment dam.

Throughout 2024, RO water discharged from Outfall 002 continued at a reduced rate of 400 gpm, similar to levels observed in winter of 2023. During the fall of 2023, beavers blocked the Pond AB outlet culverts, diverting discharged RO water into Fish Creek instead of the RO Channel wetlands. On April 15, 2024, the water temperature in Pond AB was 6.5°C, cooling to 3.6°C by the time it reached the Pond F outlet. On April 24, ADF&G staff cleared the Pond AB culverts, restoring water flow into the RO Channel just prior to Arctic grayling spawning.

Arctic Grayling

Sampling for the annual WSR Arctic grayling population estimate was conducted from April 29 through May 10, 2024. Fyke nets were deployed in Fish Creek and the RO Channel to capture fish as they migrated into the developed wetlands for spawning. The spring 2023 population estimate of 4,767 fish ≥200 mm (95% CI 4,404–5,129 fish) was a slight increase from the 2022 estimate of 4,594 fish, both above the post-mining population goal of 800–1,600 fish ≥200 mm. Similarly, one fyke net was deployed in Pond AB from May 3 through May 10. The spring 2023 Pond AB population estimate for Arctic grayling ≥200 mm was 1,243 fish (95% CI 866–1,620 fish), a substantial increase compared to the 2022 Pond AB population estimate of 241 fish (95% CI 60–422 fish). During the spring of 2023 and 2024, a total of 417 Arctic grayling ≥200 mm were captured and tagged in Pond AB, indicating the population is larger than previously estimated. Additionally, in 2024, eight juvenile Arctic graylings were captured, suggesting successful spawning within Pond AB may have occurred.

Element Concentrations in Juvenile Arctic Grayling

In August 1993, baseline element data were collected from 24 juvenile Arctic grayling captured in Last Chance Creek Ponds prior to the construction of the Fort Knox mine. During the 2024 spring sampling, eight juvenile Arctic grayling were captured and retained from the Fish Creek wetlands

for element analysis. These fish were analyzed for aluminum, arsenic, cadmium, lead, mercury, and selenium. Results showed that all mean element concentrations in the whole-body samples of Arctic grayling from 2024 were lower compared to those from 1993. However, selenium data from 1993 were not available for comparison.

Burbot

The annual burbot population assessment in the WSR and Pond AB was performed from September 24 to October 2, 2024. The fall 2023 WSR population estimate for burbot ≥400 mm was 598 fish (95% CI 55–1,141 fish); the large variance is attributed to only three fish tagged in 2023 being recaptured in 2024. The 2023 Pond AB population estimate for burbot ≥300 mm is 22 fish (95% CI 8–35 fish). It is likely that the burbots captured in 2024 belong to the same isolated population residing in Pond AB in 2022 and 2023. Pond AB burbot were excluded from the WSR burbot population estimate and a separate population estimate will be performed until fish movement between the two water bodies is observed.

Stilling Basin

Fish sampling in the Fort Knox Stilling Basin was conducted from July 31 through August 2, 2024. Population estimates of the Arctic grayling residing in the Stilling Basin were last performed in 2007–2009 and ranged between 815 to 1,159 fish (Ott and Morris 2010). During the 2019 sampling, 71 Arctic grayling were captured and tagged during nine hours of angling effort; however, a population estimate could not be generated without a recapture event in 2020 (Bear and Ott 2020). In 2024, six hours of angling yielded only one captured Arctic grayling, with another hooked but not landed. This reduced capture rate suggests that the current population of adult Arctic grayling may be lower than in 2007–2009 or 2019. Additionally, approximately 20 juvenile Arctic grayling were observed swimming in the shallow edges of the Stilling Basin.

Larval *Diplostomulum* of the Eye and *Myxobolus sp.*

During July 2024 Stilling Basin sampling, 22 burbot were captured, 15 of which displayed a milky appearance in one or both eyes. In the September 2024 WSR sampling, 99 burbot were captured, with 35 exhibiting the same eye condition. Six burbot were sent to the ADF&G Fish Pathology Laboratory for diagnostic testing. Lab report results (No. 2025-0016), received on February 18, 2025, confirmed the presence of larval Diplostomulum of the eye, commonly known as eye fluke, in all six samples. An incidental finding during the fish pathology lab work was an infection by an

unidentified *Myxobolus sp.* within the capillaries of the gills. Seventy-five percent of the burbot samples submitted tested positive for the infection.

Structure of Report

This report is presented in several sections as follows:

1) Introduction;
2) Water quality;
3) Arctic grayling population assessment;
4) Juvenile Arctic grayling whole body element concentrations;
5) Burbot population assessment;
6) Stilling Basin sampling;
7) Summary discussion;
8) A chronology of events from 2011 to 2024; and
9) Appendices.

Introduction

Fairbanks Gold Mining Incorporated (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located approximately 26 road miles (42 km) northeast of Fairbanks, Alaska, in the headwaters of the Fish Creek drainage, which flows into the Little Chena River. Development associated with the mine includes an open–pit mine, mill, tailings storage facility (TSF), two heap leach facilities, and a Water Supply Reservoir (WSR), collectively covering approximately 8,711 acres (Figure 1). Construction of the WSR dam and spillway was completed in July 1996, with the first gold pour occurring in November 1996. Ore extraction at the Gil Mine, located about 8 miles east of Fort Knox, commenced in 2021. To support ore transportation from the Gil Mine to the Fort Knox mill, significant improvements were made to the Gil Haul Road and causeway between 2021 and 2024 (Figure 2). Ore hauling from the Gil Mine was temporarily halted in the fall of 2024.

Prior to the construction of Fort Knox, extensive placer mining operations had altered the upper Fish Creek valley. FGMI rehabilitation of the previously disturbed habitat has been simultaneous with its mining activities, and natural revegetation continues to progress. Baseline fish research was initiated prior to construction of the Fort Knox mine and its associated facilities. Since 1992, ADF&G has conducted annual fish monitoring and population assessments at the Fort Knox mine. Fish Creek water quality sampling commenced in 1997, followed by winter water quality monitoring of the WSR in 1998, and Reverse Osmosis (RO) discharge channel measurements in 2019. Wetlands construction between the tailings dam and WSR began in 1998 and a channel connecting the wetlands along the south side of the valley was built in 1999. Repair work on dikes separating Ponds D and E and a fish passage channel improving their connection to the WSR was completed in summer 2002. Buell and Moody (2005) provided recommendations for additional work to enhance fish and wildlife habitat between the tailings dam and the WSR.

In 1992, Arctic grayling (*Thymallus arcticus)* populations were assessed to estimate the number of fish available to colonize the WSR (Weber Scannell and Ott 1993). Arctic grayling were distributed throughout the Fish Creek drainage but were largely confined to habitats in flooded mine cuts and settling ponds in Last Chance Creek. Resident Arctic grayling exhibited stunted growth, with fish >220 mm being scarce. Baseline sampling in 1994 and 1995 recorded an average size of spawners of 185 mm (Weber Scannell and Ott 1994). Following completion of the

freshwater dam in 1996, filling the WSR inundated the inlets and outlets of former mine cuts, expanding the available aquatic habitat. From 1996 through 1998 very few Arctic grayling fry were observed or captured in the WSR or last Chance Creek (Ott and Morris 2000). In spring 1999, FGMI constructed a channel connecting the Fish Creek developed wetland complex with the WSR. Since its construction, Arctic grayling have successfully spawned in the wetlands complex, with the average size of spawners increasing to 280 mm.

In 2019, fish habitat in the wetlands complex expanded when RO water discharged from Outfall 002 was routed through Pond AB and into the dry channel north of Centerline Road (Figure 3). The substantial increase in water flooded numerous low-lying areas, creating small ponds and adding 7.9 acres of new wetlands habitat during the establishment of the RO Channel. As RO water flows from Outfall 002 through Pond AB, its relatively warm temperature (~6°C) cools before merging with Fish Creek and entering the WSR. In 2023, a reduction in RO water discharge rate resulted in lower water levels within the RO channel wetlands complex. Although the area remains flooded, its fish-bearing capacity has decreased compared to years with higher discharge levels (Appendix 8).

Currently, the WSR supports viable, self-sustaining populations of both Arctic grayling and burbot (*Lota lota)*. Arctic grayling spawning predominantly occurs in the wetland complex between the WSR and the tailings dam and overwinter in the WSR. Burbot spawning, documented by radio telemetry, likely occurs in Solo Bay where Solo Creek water mixes into the WSR (Ott et al. 2013). Burbot use of the Fish Creek wetlands has been observed during the spring Arctic grayling fyke netting when they are incidentally captured. Both Arctic grayling and burbot recruit into the Stilling Basin over the WSR spillway (Bear and Burrows 2019).

This report summarizes the fish and water quality data collected during 2024 and discusses these findings in relation to previous research. A chronology of events from 2011 to 2024, with emphasis on biological factors, is presented in Appendix 1.

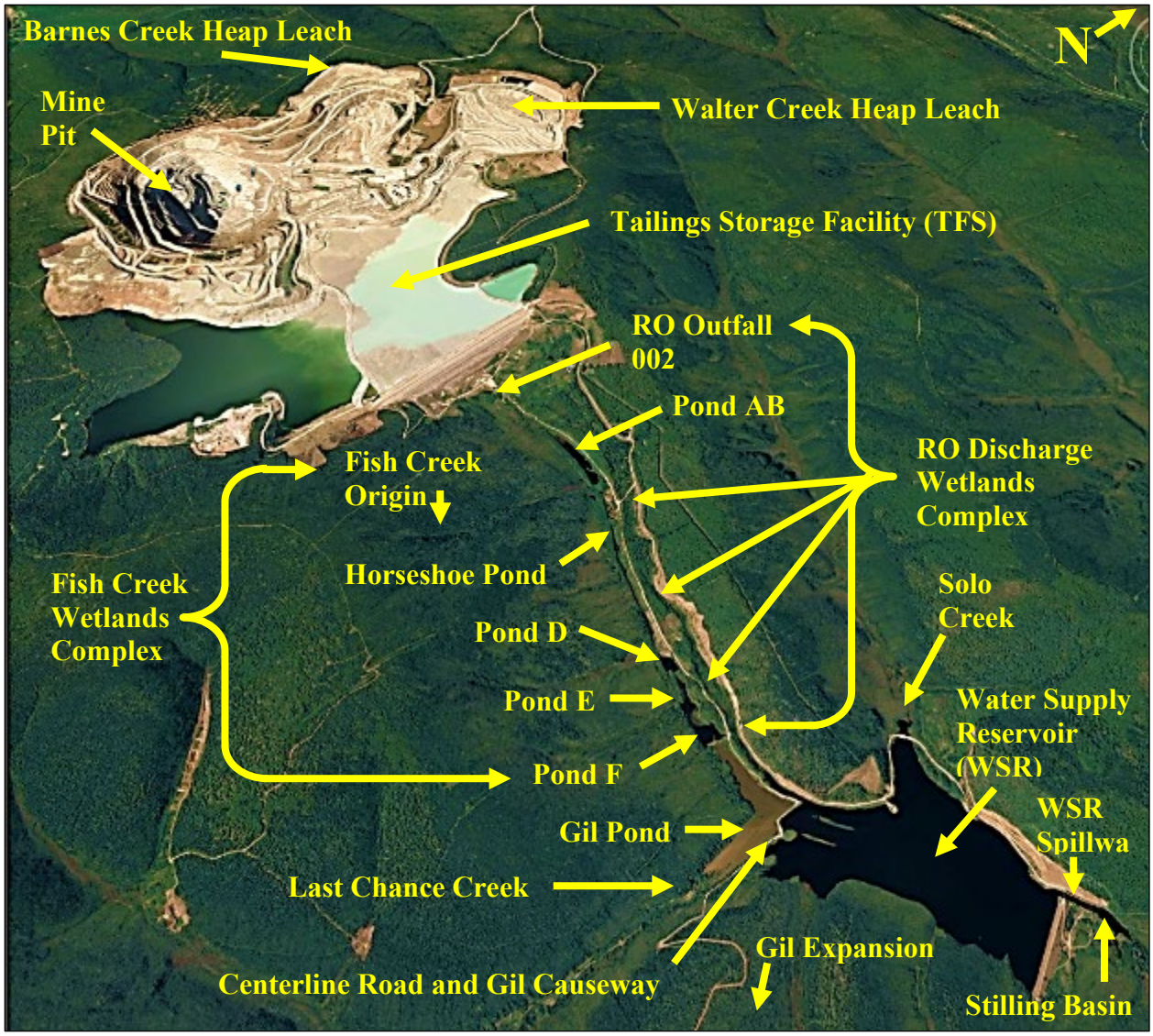

Figure 1. Fort Knox gold mine and associated facilities.

Figure 2. Gil Causeway, May 2020 (left) and May 2022 (right).

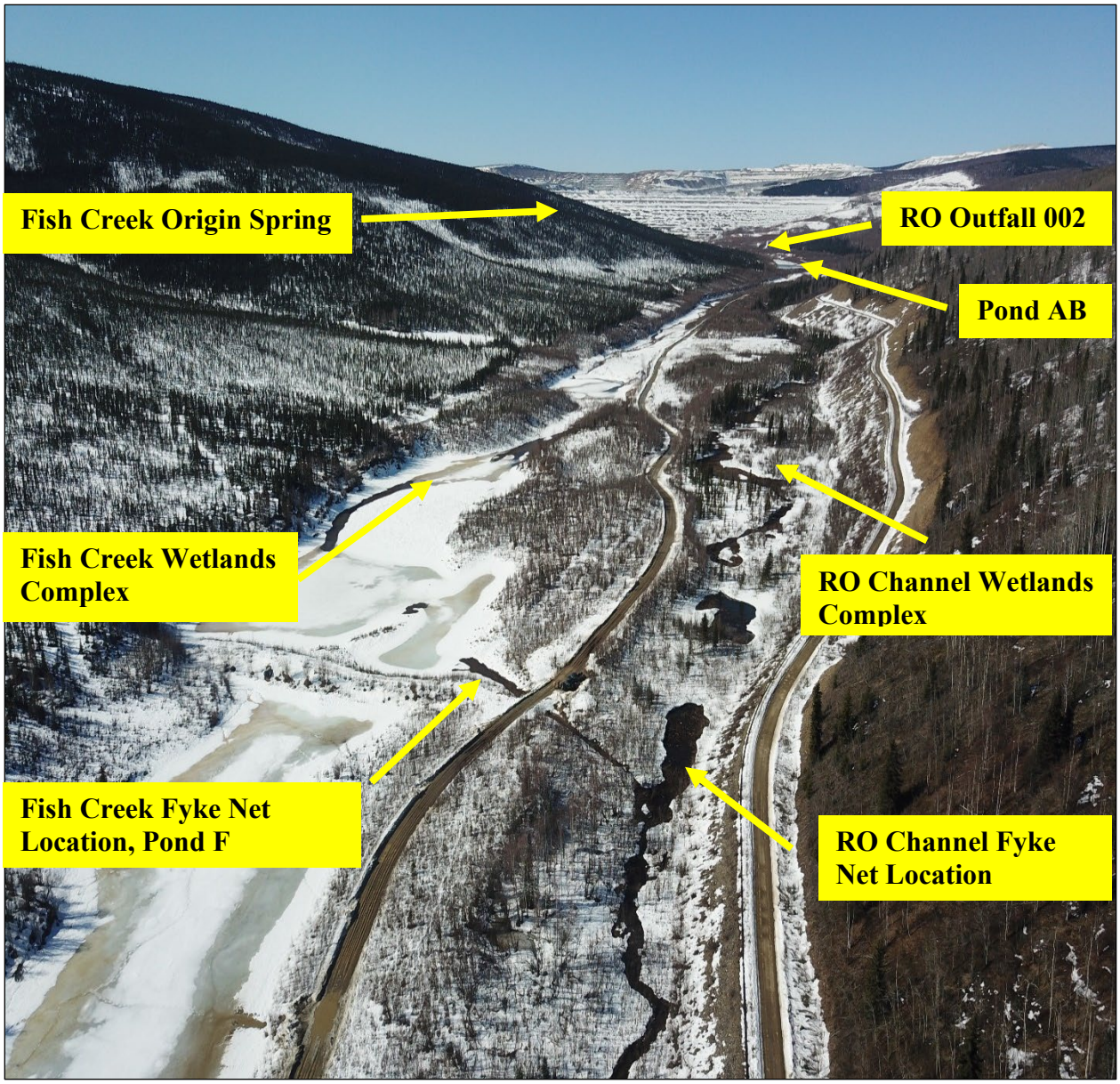

Figure 3. Fish Creek wetlands (left) and RO Channel wetlands (right), divided by Centerline Road. Photo from 2022 during high RO discharge rate years.

Water Quality

The Water Supply Reservoir (WSR) was constructed to be the primary water supply for mining activities and mill operations at Fort Knox. When full, it contains about 3,363 acre-feet (1.1 billion gallons) of water. Since 1998, water levels have remained mostly constant, except during winter in certain years when large volumes were drawn for mining processes (Appendix 7). Beginning in 2015, operational water demands have been satisfied from mine pit and tailings impoundment

dewatering wells, and no water has been utilized from the WSR. In 2021, the supply pipeline connecting the WSR to the Tailings Storage Facility (TSF) was permanently disconnected.

In spring 2015, FGMI initiated the discharge of non-contact water from dewatering wells around the open pit, combined with mine operations water treated through Reverse Osmosis (RO), into the RO Channel wetlands complex from Outfall 001. This discharge was authorized under the Alaska Department of Environmental Conservation (ADEC) Alaska Pollution Discharge Elimination System (APDES) permit number AK0053643. On January 15, 2019, FGMI brought two additional RO facilities (RO2 and RO3) online and began discharging from Outfall 002 (Figure 4). Discharge from Outfall 001 was rerouted into Outfall 002 and consequently, discharge from Outfall 001 ceased. Water discharge through the RO systems generally increased from 2015–2020 but declined in 2021–2024 as TSF water balance requirements were met. During 2024, 1,623 acre-feet of RO water were discharged into the RO Channel wetlands, a decline from the 2020 peak of 9,663 acre-feet (Figure 4 and Appendix 8).

Since 1998, annual monitoring of WSR water quality has been conducted during late winter or early spring. This ongoing effort aims to evaluate conditions that may impact aquatic life within the wetlands complex and to document changes over time.

Figure 4. Outfall 002, RO water discharge of up to 3,000 gpm during 2019–2021 (2020 left) and reduced to 400 gpm during 2022–2024 (2024 right) into the RO Channel wetlands.

Methods

Since 1998, six sites within the WSR have been sampled annually. Beginning in 2018, two additional sites in Fish Creek and the RO Channel were included to evaluate the effects of RO water discharged into the wetlands complex (Figure 5). In 2024, water quality sampling was conducted on April 9 while the WSR was ice-covered.

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.

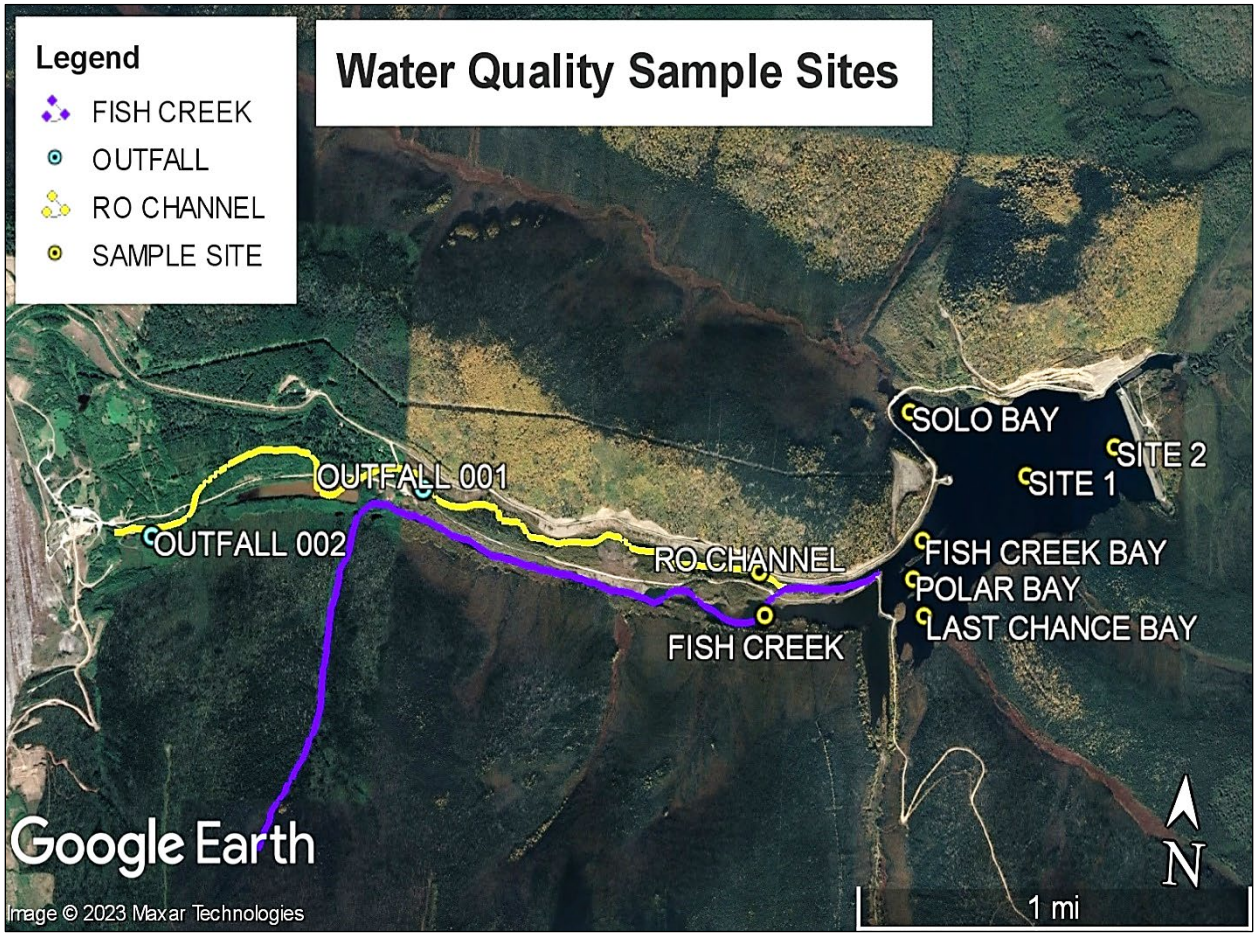

Figure 5. Fort Knox water quality sample sites, April 9, 2024.

Results and Discussion

In 2024, ice thickness in the WSR was consistent with past years, measuring slightly less than one meter across all six sampling locations (Figure 5). Beneath the 0.6 m snow cover, 15 cm of slushy overflow was observed at most sites. This overflow water may have affected water quality readings at the one-meter depth sample from mixing while drilling the test hole but did not impact measurements from the remainder of the water column.

WSR water temperatures recorded in 2024 ranged from 0.2° C to 3.5° C (Figure 6). The minimum temperature of 0.2° C was recorded in Site 1, just below the ice surface. The maximum temperature of 3.5° C was recorded at Site 2 at 17 m depth, just above the reservoir bottom. Temperature at all six sample sites increased with water depth. For historical comparison, the Site 2 dataset, the deepest section of the reservoir, is considered indicative of overall WSR water conditions. The 2024 Site 2 water column average temperature was similar to past years with 2023 being the warmest recorded since 1997 (Figure 7).

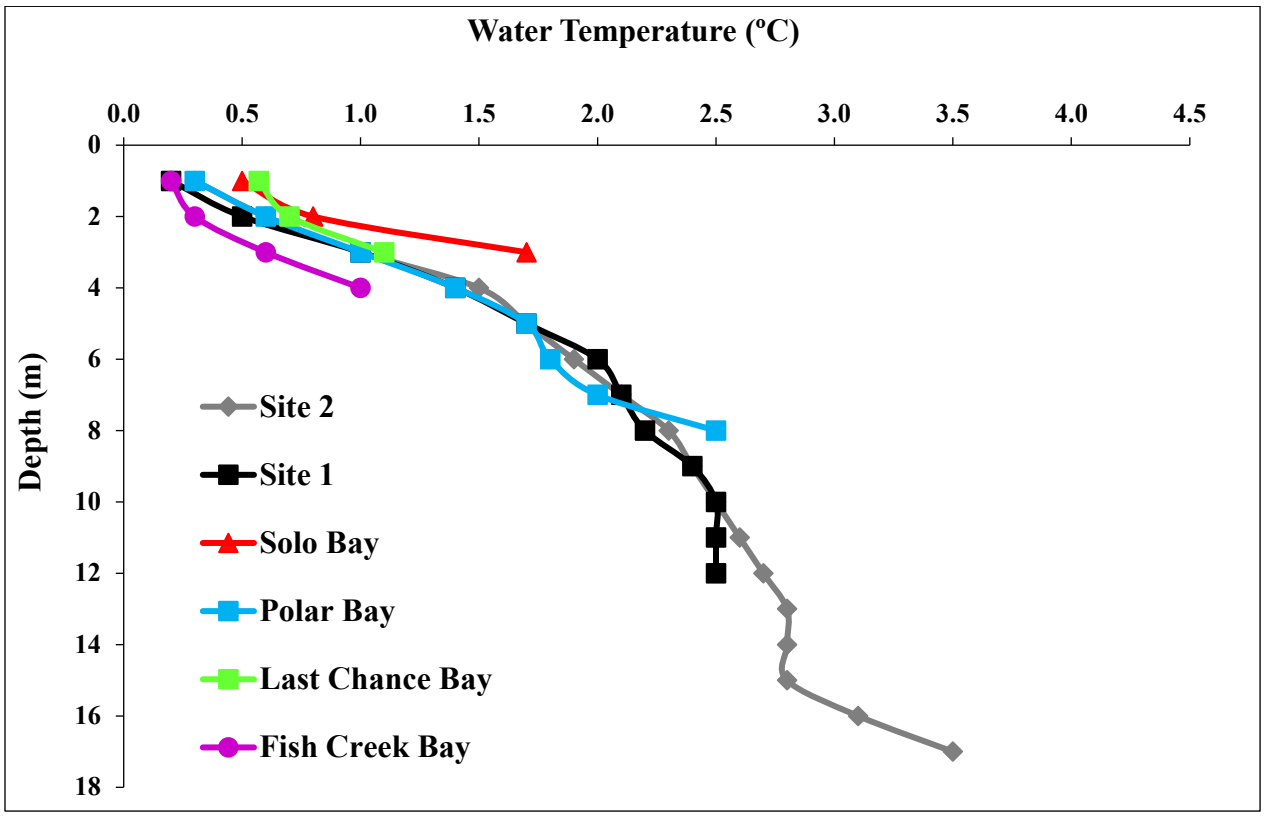

Figure 6. Fort Knox WSR water temperature vertical profiles, April 9, 2024.

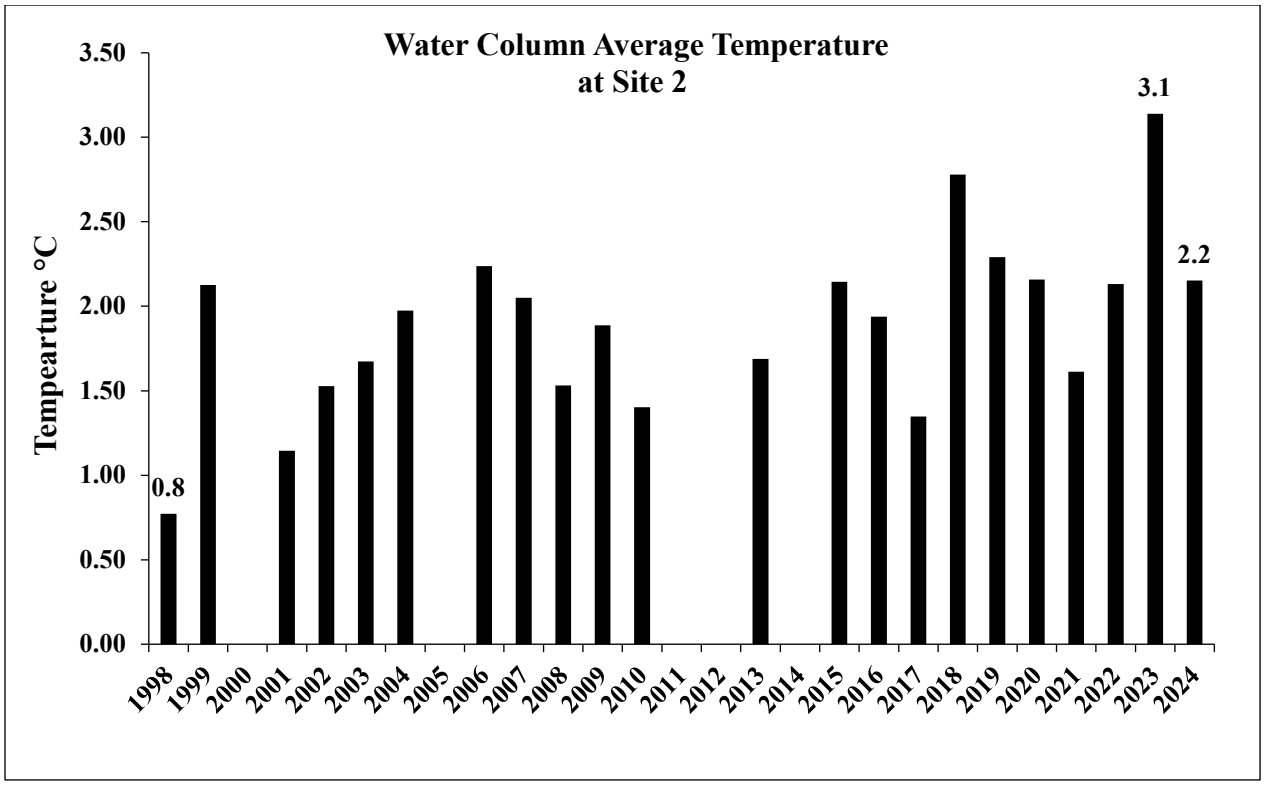

Figure 7. Site 2 annual water column average temperature, 1998–2024.

Dissolved oxygen (DO) is essential for the survival of fish, aquatic invertebrates, and aquatic plants. WSR water becomes hypoxic when DO levels drop below 2 mg/L, and anoxic as DO approaches 0 mg/L below 10 m depth. In 2024, Fish Creek Bay recorded the highest DO point concentration at 12.00 mg/L, followed by Polar Bay at 11.20 mg/L (Figure 8). Fish Creek Bay had the highest water column average DO concentration (9.53 mg/L) for the ninth consecutive year, followed by Solo Bay at 7.97 mg/L. These maximums are higher than years prior to 2015 and are likely a result of RO water discharge that began in March 2015.

In 2024 the water column average DO (mg/L) at Site 2 was above the pre-RO average, but below the post-RO average (Figure 9). This is likely a result of the reduced RO water discharge rate entering the WSR during the winter of 2023/2024. Across all WSR sampling sites, DO concentrations were notably high within the upper 8 m of the water column, but declined sharply to near 0 mg/L below this depth (Figure 8).

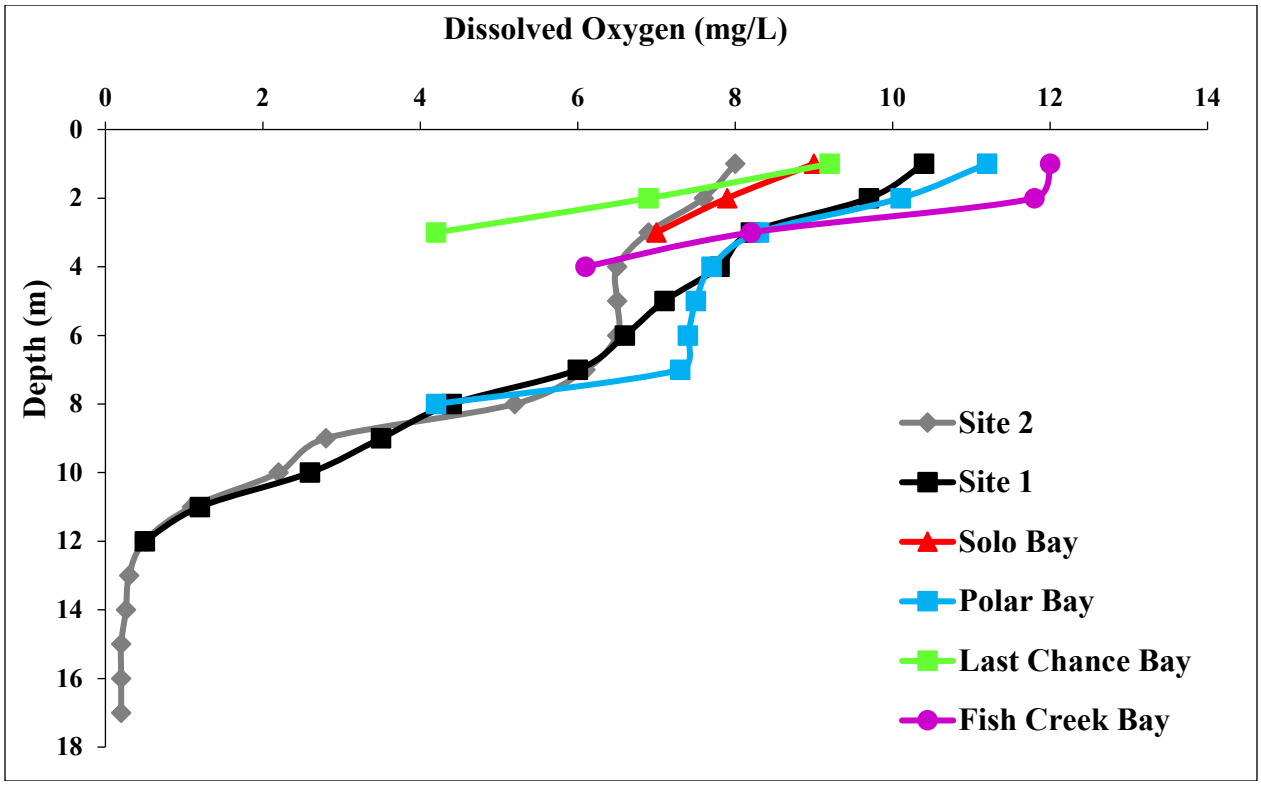

Figure 8. Fort Knox WSR dissolved oxygen (mg/L) vertical profiles, April 9, 2024.

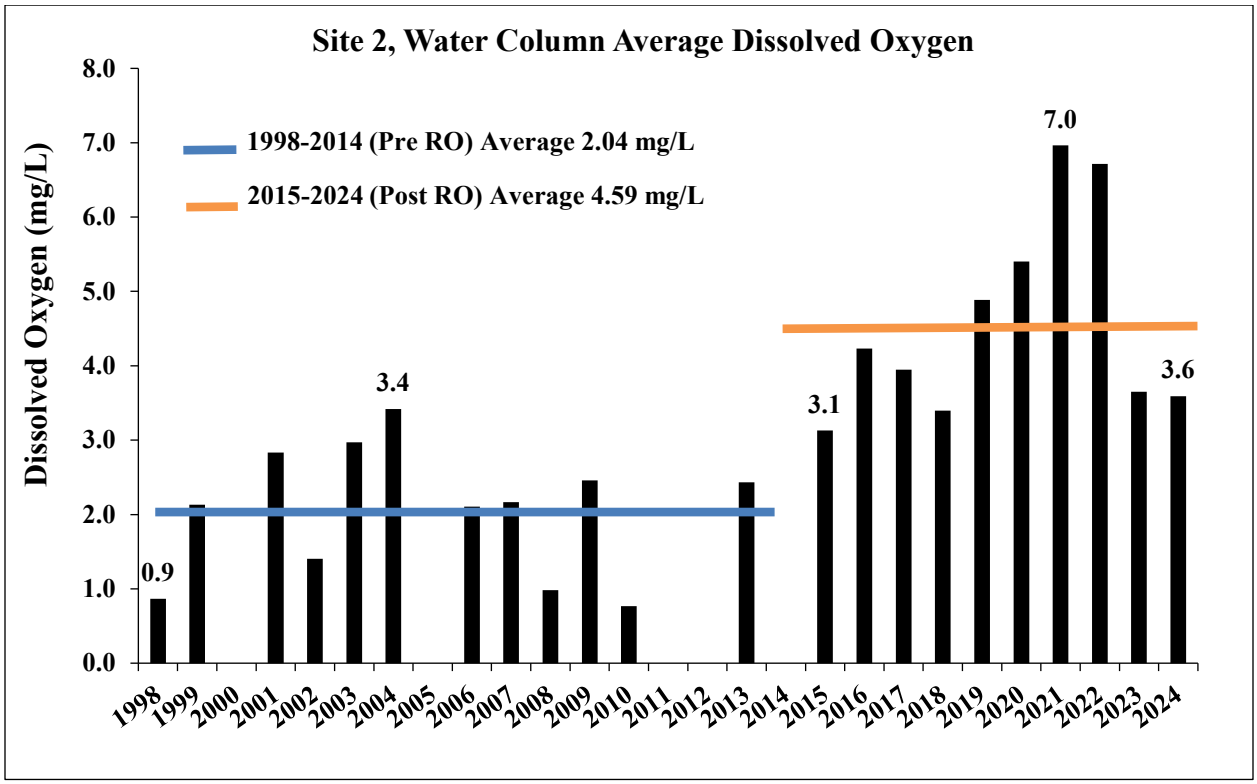

Figure 9. Site 2 water column average dissolved oxygen (mg/L), 1998–2024.

In 2024, temperature specific DO percent saturation (%) values were stratified between the surface and bottom (Figure 10). DO (%) showed the same stratification at 8 m as DO (mg/L). This is compared to 2022 where the larger input of RO water mixed with the WSR reducing stratification of oxygen (Figure 11). The 2024 water profile resembles typical lake oxygen distributions without significant freshwater input during winter months (Palshin 2021).

With reduced RO water discharge entering the WSR from Outfall 002 during the winter of 2022/2023 and 2023/2024, DO levels were lower at all sites compared to 2022. Notably, in 2022, the Last Chance Bay site showed lower DO levels and deviated from the other five sites, likely due to less influence from RO water (Figure 11). However, in 2024, its DO profile aligned more closely with the rest of the WSR sites (Figures 10).

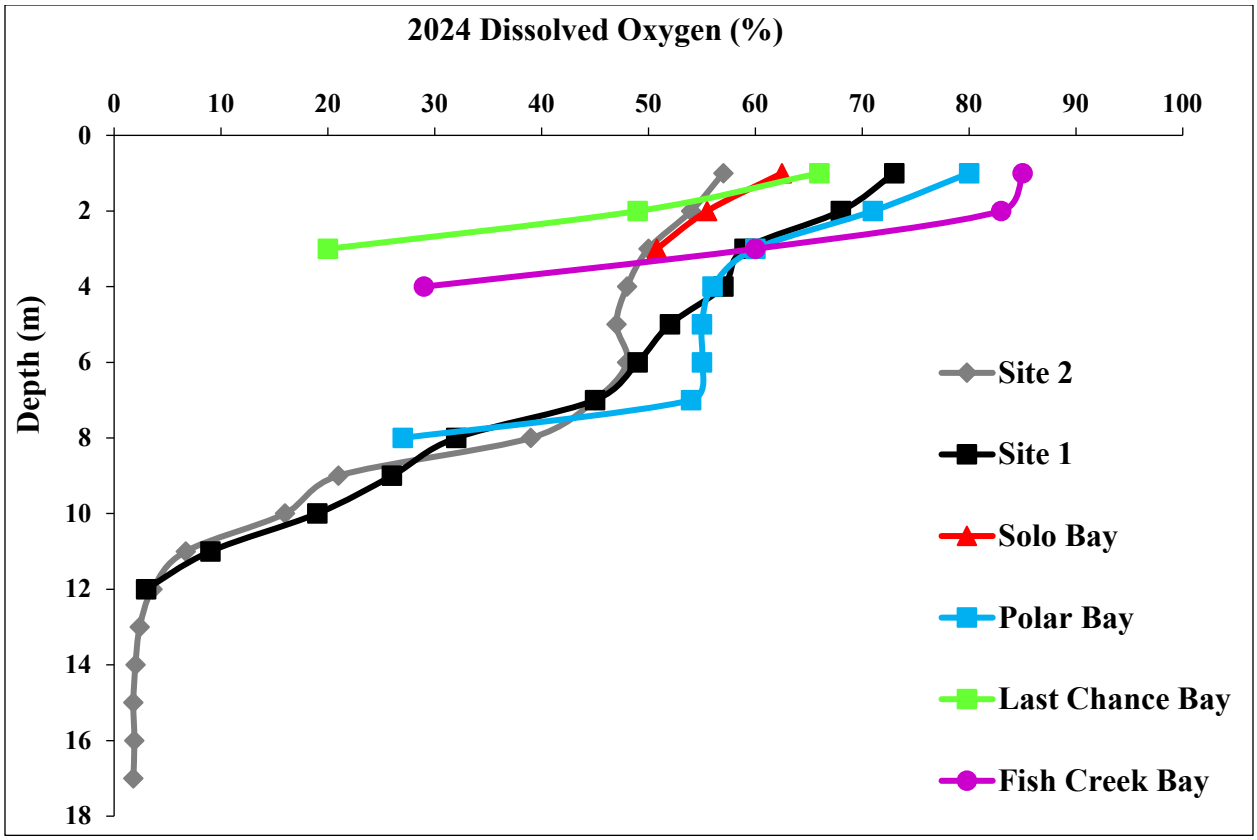

Figure 10. Fort Knox WSR dissolved oxygen (% saturation) vertical profiles, April 9, 2024.

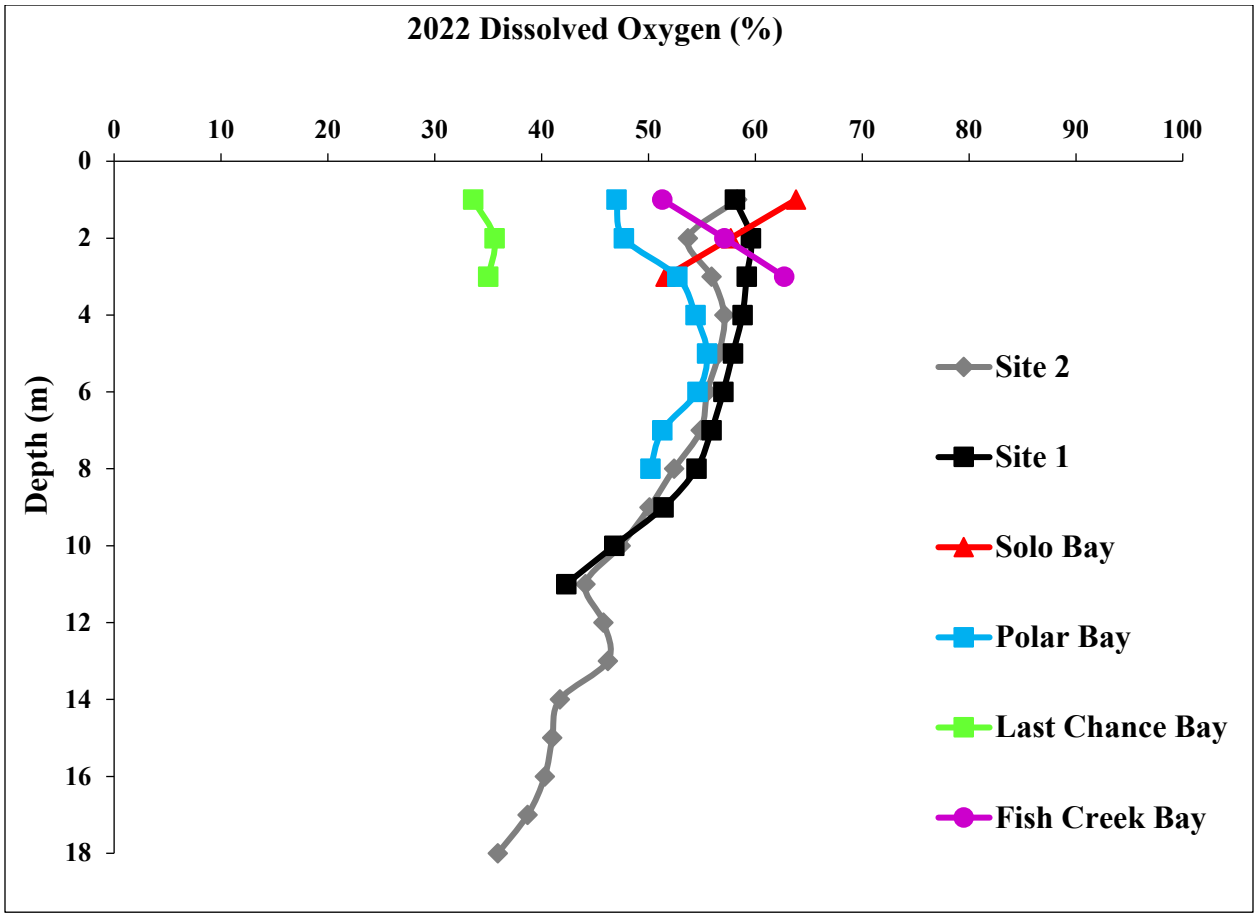

Figure 11. Fort Knox WSR dissolved oxygen (% saturation) vertical profiles, April 14, 2022.

The pH of water significantly influences aquatic plants and invertebrates, with potential impacts on fish reproduction, recruitment, growth rates, and overall health. In 2024, the WSR pH values were relatively consistent across all sites but at a lower range compared to previous years. Values ranged from 6.2 at Solo and Last Chance Bay to 6.7 at Fish Creek and Polar Bay (Figure 12). Most WSR pH measurements in 2024 complied with the ADEC standard for aquatic life (6.5 to 8.5); however, the measurements at Solo and Last Chance Bay were slightly below this threshold (Figure 12).

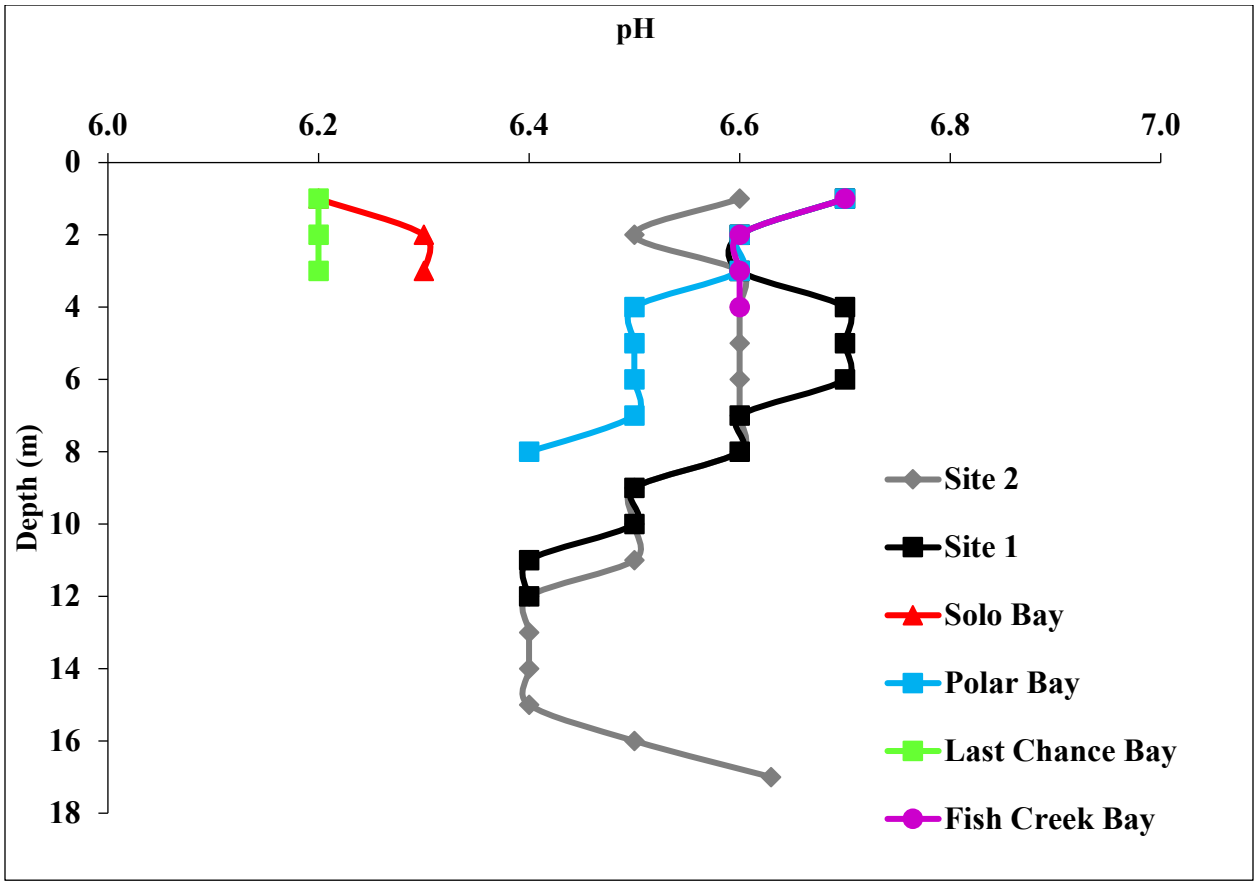

Figure 12. Fort Knox WSR pH vertical profiles, April 9, 2024.

Specific conductance measures how effectively water conducts electrical currents and increases with higher concentrations and mobility of charged ions. It can serve as an indicator of water quality. In 2024, specific conductance values were consistent across all six sites (Figure 13) and generally increased with depth, as minerals sink from the surface and accumulate near the bottom. The 2024 WSR conductance values ranged from 91.1 to 277.2 µS/cm, with and average of 135 µS/cm for all six sites combined. This is lower compared to 2021 and 2022, where average readings across the water column were around 400 µS/cm and 300 µS/cm, respectively. At Site 2, the water column's average specific conductance in 2024 was 159.8 µS/cm, compared to the 2022 average of 427.2 µS/cm and the 2023 average of 255.7 µS/cm (Figure 14). Higher conductance values indicate greater concentrations of dissolved solids, including chloride, nitrate, phosphate, sodium, magnesium, calcium, and iron.

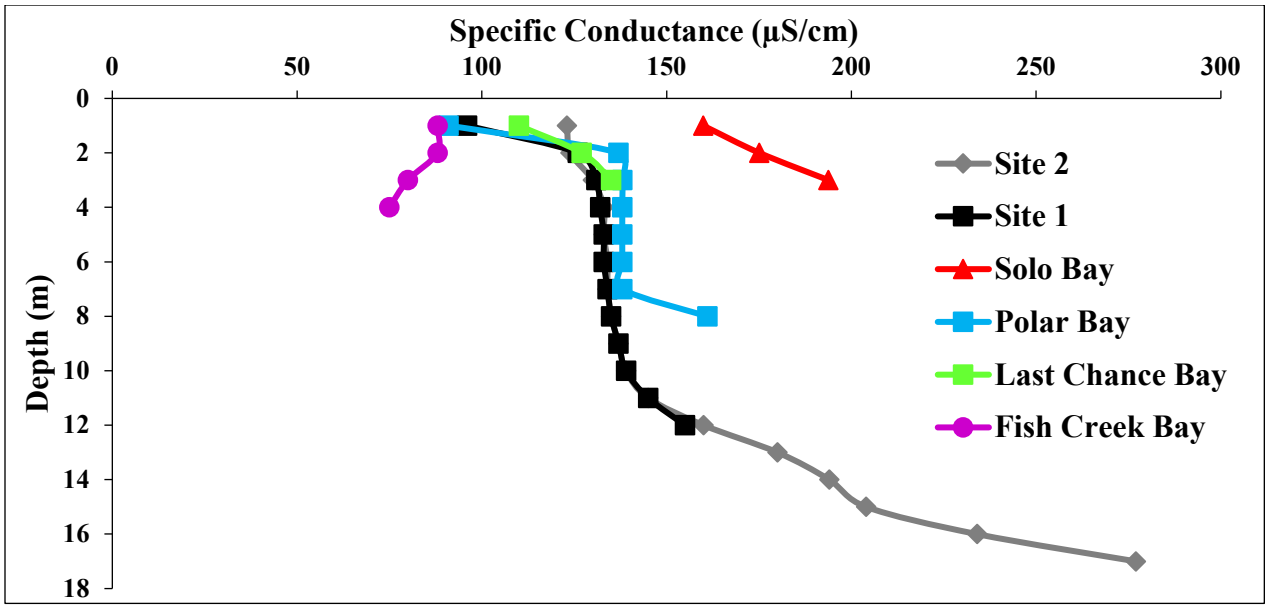

Figure 13. Fort Knox WSR specific conductivity (µS/cm) vertical profiles, April 9, 2024.

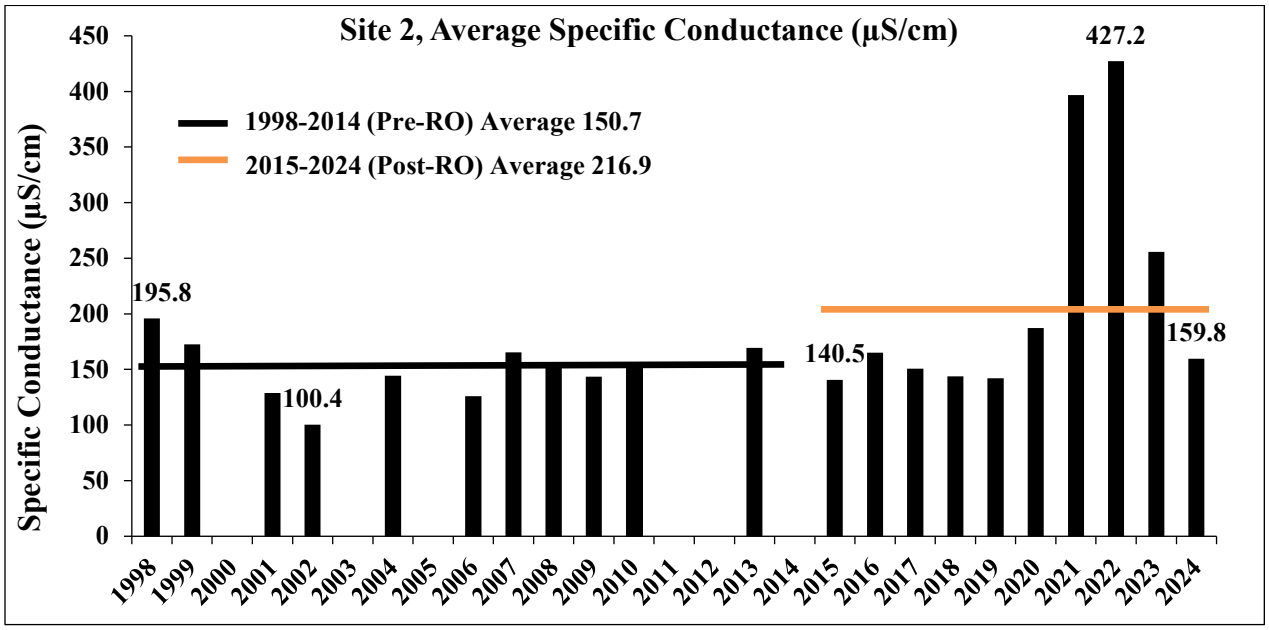

Figure 14. Site 2 specific conductance, pre-RO (1998–2014) and post-RO (2015–2024) averages.

Oxidation-reduction potential (ORP) indicates the capacity of a lake or river system to break down waste products, such as contaminants or decaying biological material. Higher ORP levels signify sufficient oxygen availability for bacteria to effectively decompose these materials. In 2024, ORP values were consistent across sample sites, ranging from 177 to 323 mV (Figure 15). At Site 2, ORP decreased below 12 meters, reflecting low or absent dissolved oxygen, which limits decomposition processes. The 2024 total WSR average across all six sites was 298 mV and slightly lower than the 2023 average of 337 mV.

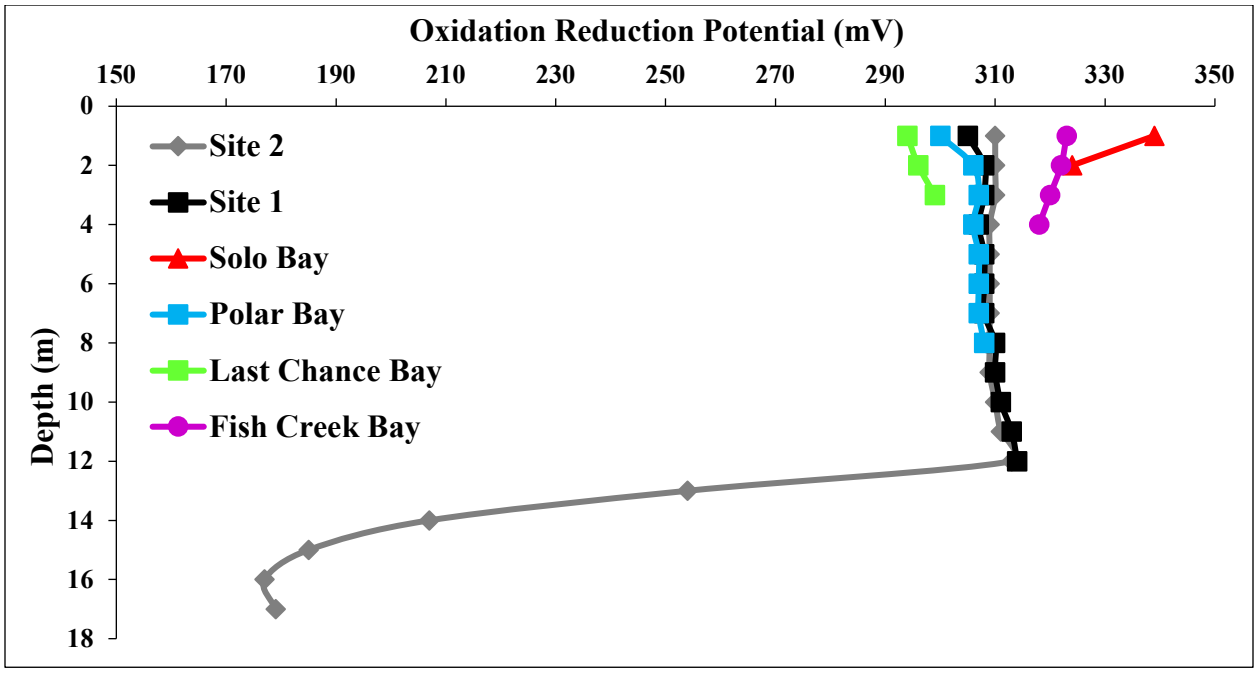

Figure 15. Fort Knox WSR oxidation reduction potential (mV) vertical profiles, April 9, 2024.

From 2019 to 2024 water quality data were collected from Fish Creek at Pond F and the RO Channel downstream of Outfall 002 (Figure 5). On April 9, 2024, the recorded water temperature was 1.6°C at the Pond AB outlet and 0.36°C in Fish Creek at the Pond F outlet (Figure 16).

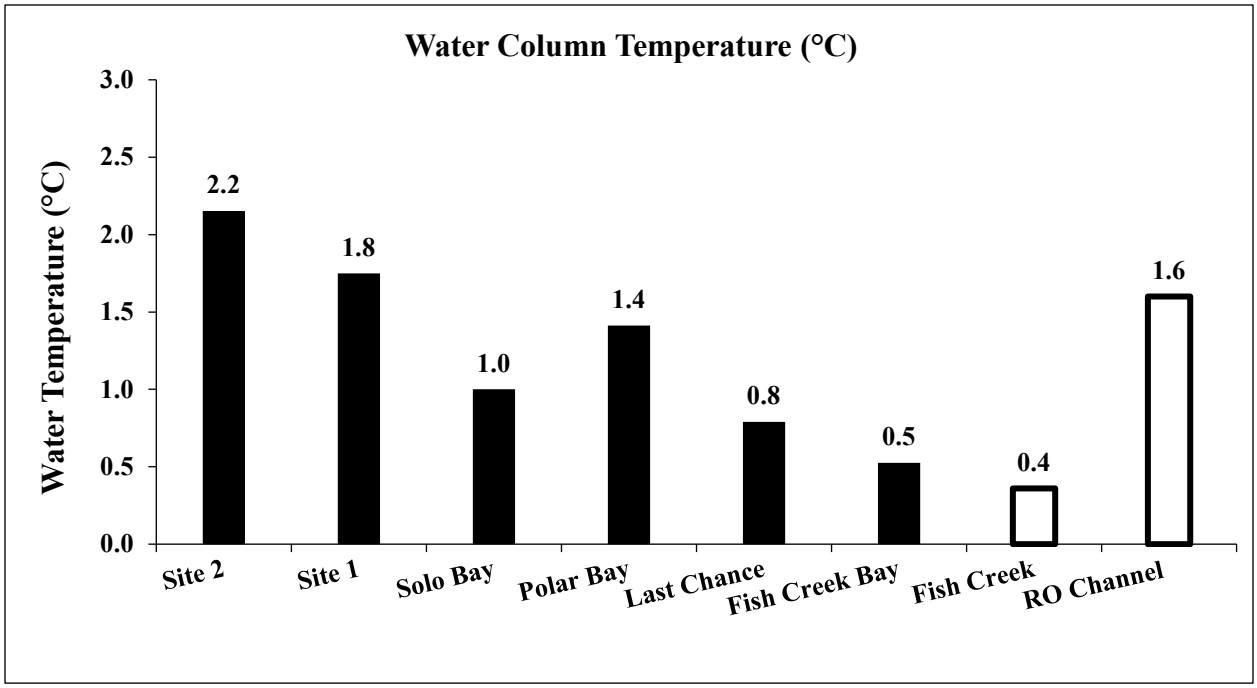

Figure 16. Water temperatures April 9, 2024. Filled bars are the average for the water column, unfilled bars are single point temperatures at 1 m depth.

The DO levels in Fish Creek and the RO Channel were higher compared to the six WSR sample sites (Figure 17). Typically, the majority of the RO water discharge flows through Pond AB into the RO Channel located on the north side of Centerline Road. On April 9, 2024, all RO water discharge was directed through Pond AB's natural outlet into Fish Creek by a blocked culvert. This RO water, combined with natural hydraulic agitation during downstream movement and the exposure to air, contributed to the elevated DO concentrations observed in Fish Creek at Pond F.

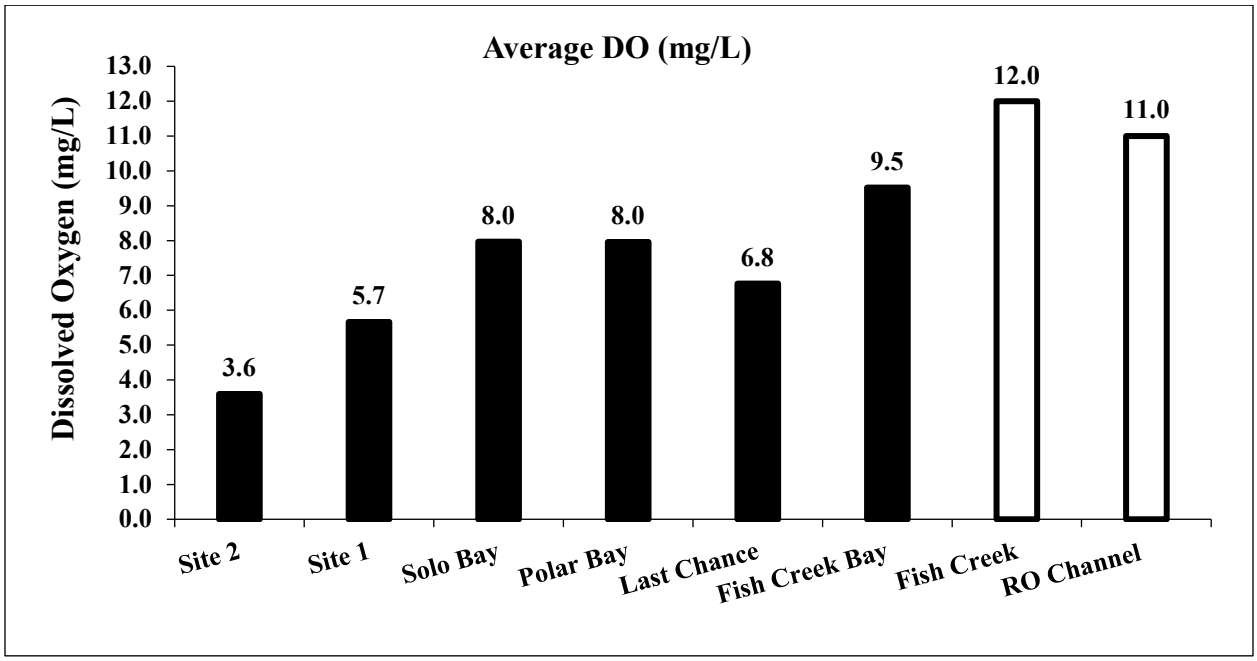

Figure 17. Dissolved oxygen (mg/L), April 9, 2024. Filled bars are the average for the water column, unfilled bars are point temperatures at 1 m depth.

Reverse osmosis (RO) water generally exhibits very low conductivity. The RO water discharged from Outfall 002 is mixed with non-contact groundwater from de-watering wells, which introduces minerals and increases specific conductance before entering the Fish Creek drainage. In 2024, the RO Channel specific conductance was recorded at 40.4 µS/cm downstream of Outfall 002 at Pond AB—the lowest value among all sites and consistent with 2023 measurements (Figure 18). In contrast, specific conductance during the 2021 and 2022 (high discharge years) was significantly higher, at 455 µS/cm and 494 µS/cm, respectively, more than double the levels observed in 2019–2020 and 2023–2024 lower discharge years (Figure 19).

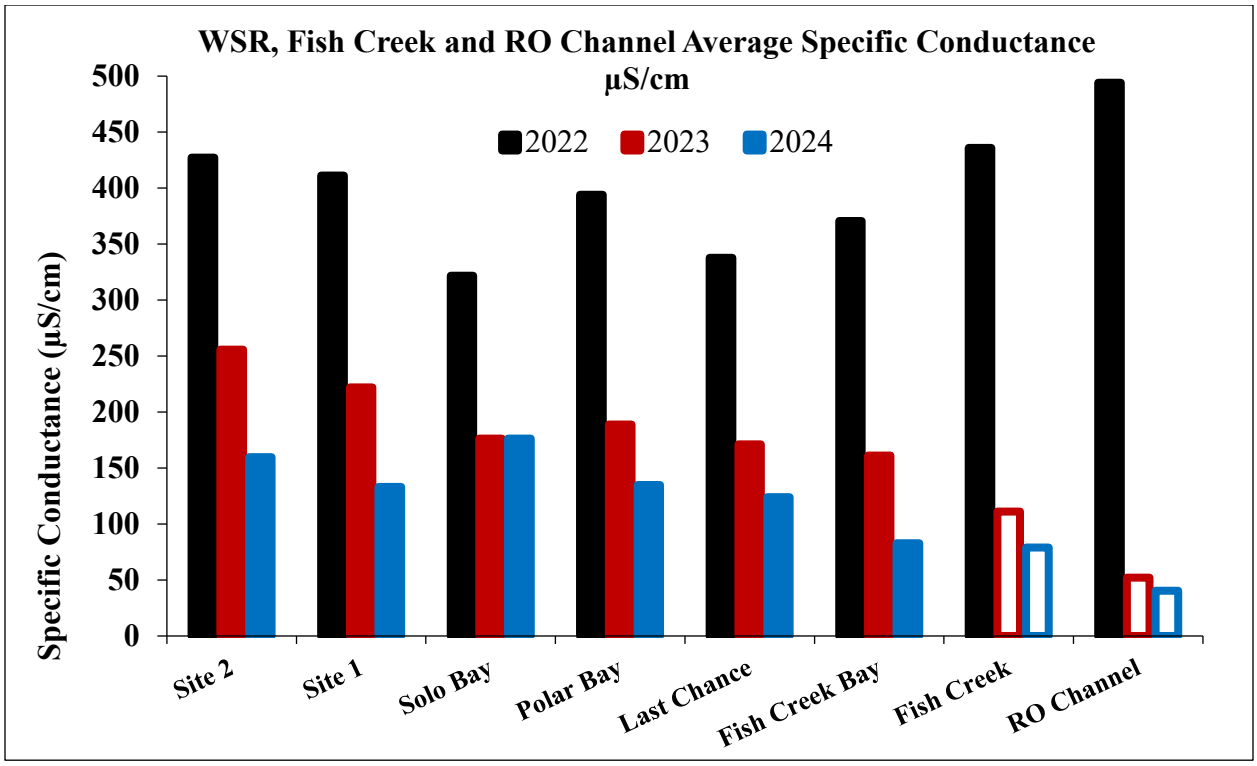

Figure 18. Specific conductance (µS/cm), April 9, 2024. Filled bars are the average for the water column, unfilled bars are point temperatures at 1 m depth.

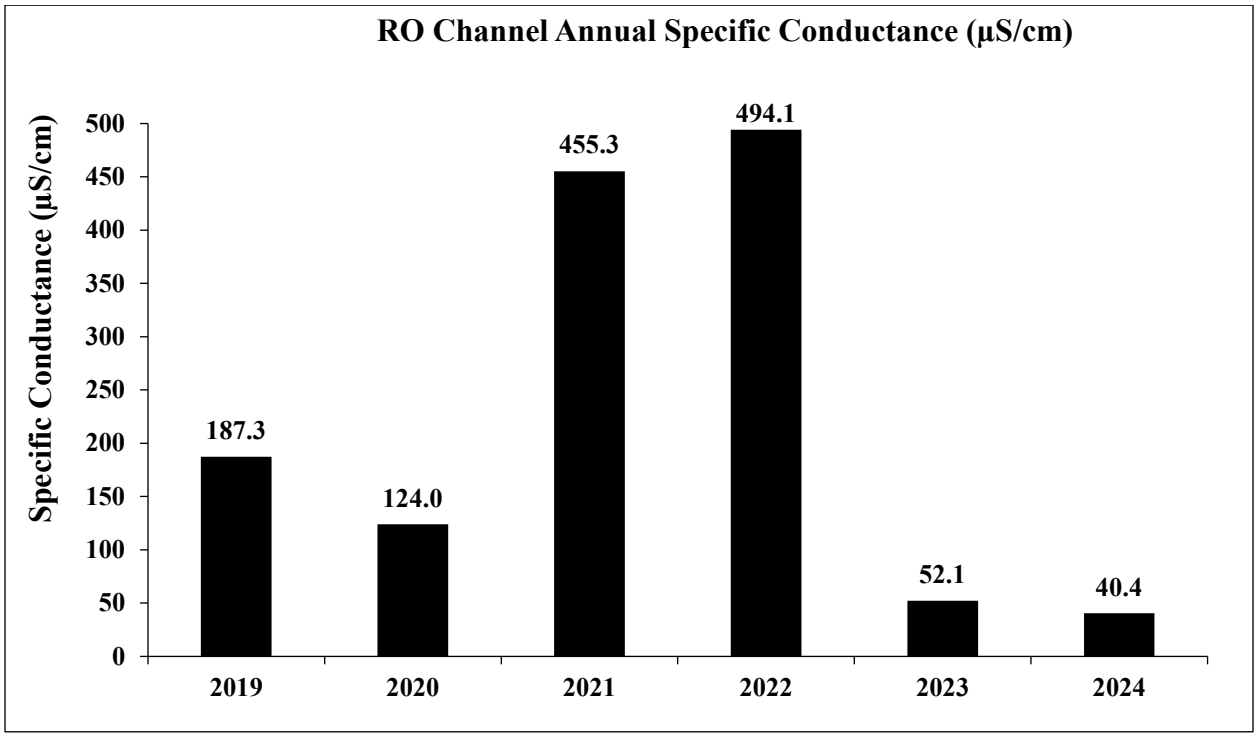

Figure 19. RO Channel specific conductance (µS/cm) downstream of Outfall 002, 2019–2024.

Arctic Grayling

Arctic grayling have successfully spawned in the wetland complex every year since 1999 (Figure 20). However, in some years substantial aufeis and resultant cold-water temperatures in the wetland complex, and formation of beaver dams limit the availability of spawning habitat. In recent years, Fish Creek 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.

Methods

The 2024 Arctic grayling sampling methods included fyke nets, angling, and visual observations. One fyke net was set in Fish Creek at the Pond F outlet and one in the RO Channel on April 29 (Figure 21). The RO Channel had low water compared to previous years. The blocked Pond AB culverts had been cleared restoring water flow to the RO Channel but the reduced discharge rate of approximately 400 gpm during winter 2023/2024 limits the size. A third fyke net was set in Pond AB on May 3 after the preferred area was clear of ice (Figure 21). Fyke nets were checked daily until they were removed on May 10.

Fyke nets in Fish Creek and the RO Channel were used to capture Arctic grayling moving from the Water Supply Reservoir (WSR) into the wetlands complex for spawning (Figure 22). Additionally, the RO Channel net was used to assess Arctic grayling use of the wetland habitats created by the RO discharge waters. The Pond AB fyke was used to determine if fish were continuing to reside in the uppermost waterbody in the wetlands complex that was first documented in the 2022 spring Arctic grayling sampling (Bear and Ott 2023).

Water temperatures were recorded during the duration of the Arctic grayling spawning timing for an annual comparison. Hobo brand temperature loggers were deployed on April 25 in the RO Channel near the Pond AB outlet culverts and in Fish Creek near Pond F. Temperature readings were measured hourly to capture the peak daily high temperatures during the 2024 spring sampling. The temperature loggers were removed on May 10.

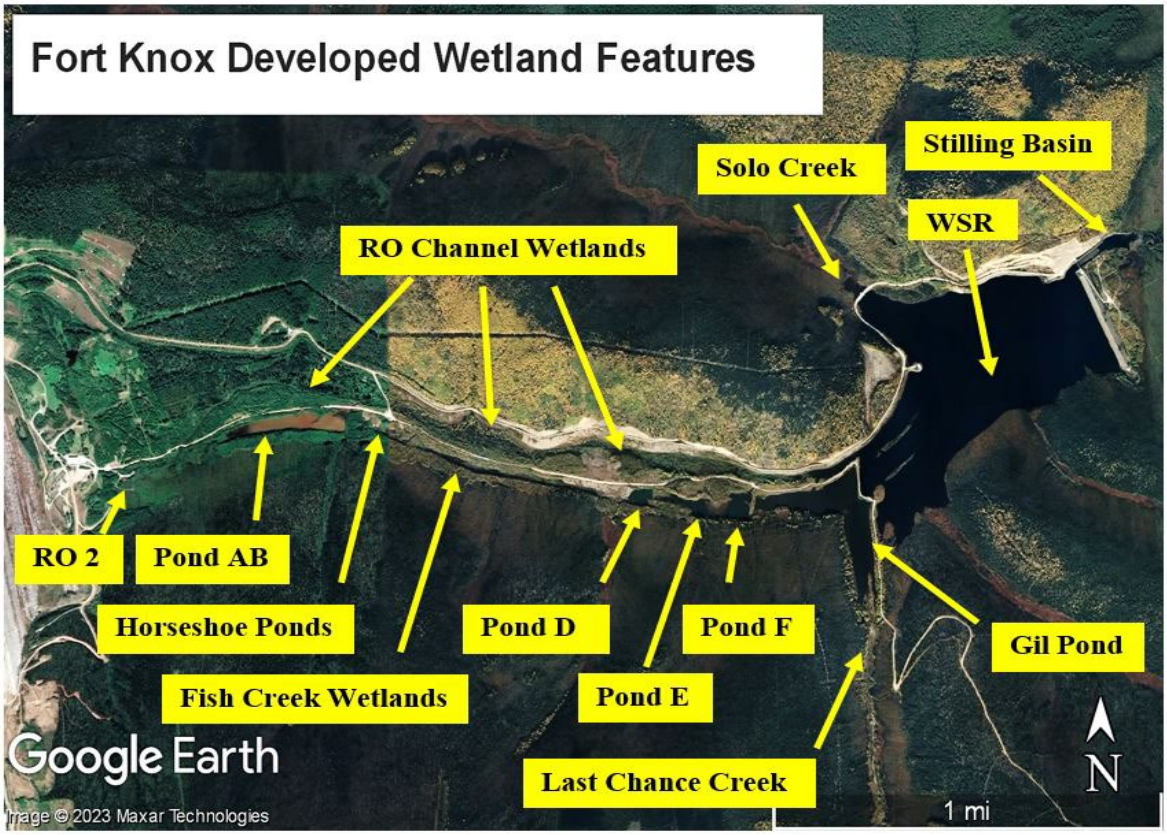

Figure 20. Fish Creek and RO Channel wetlands features.

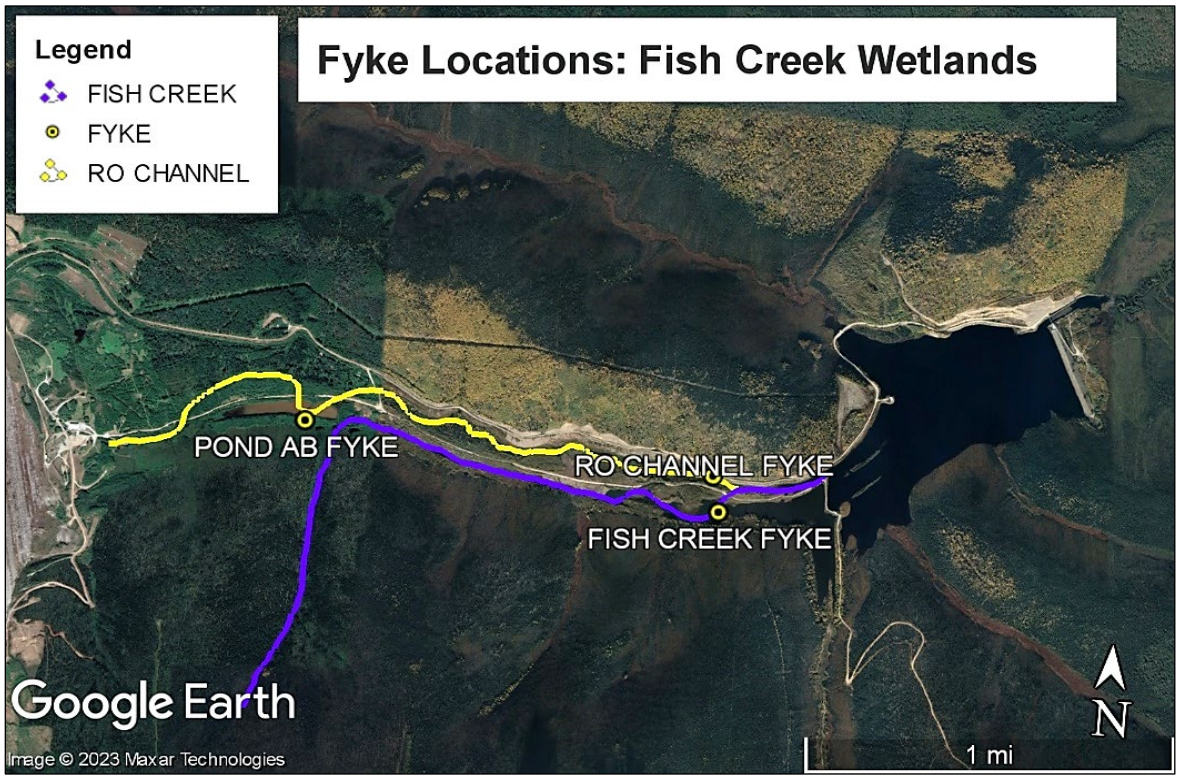

Figure 21. Fish Creek wetland fyke locations, 2024.

Figure 22. Fyke net locations: RO Channel (left), Fish Creek Pond F (middle), and Pond AB (right), 2024.

Arctic grayling were measured to fork length (FL, nearest mm), inspected for tags and spawning condition, then released. Untagged Arctic grayling ≥200 mm and burbot ≥300 mm were tagged with a numbered Floy® T-bar internal anchor tag.

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

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

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

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

The 95% CI for the population estimate was calculated as:

$$95\%\ \text{CI} = N_c \pm (1.960)\sqrt{\widehat{\text{var}}(\widehat{N}_c)}$$

Whole body element analysis of juvenile Arctic grayling for aluminum, arsenic, cadmium, lead, mercury and selenium was conducted on fish collected from the Fish Creek wetlands complex downstream of Fort Knox mine. The objective was to evaluate differences in concentrations when compared to baseline element data collected in 1993 before the Fort Knox mine was in operation. Arctic grayling between 150–200 mm FL were collected during summer 1993 (Appendix 9) and 2024 (Appendix 10). Selecting fish from this length range ensures that most fish are age-2 or age-3. Fish were handled with nitrile gloves and each fish was placed in an individual plastic bag

labeled with date, location, species, and an identification number. Bags were transported to Fairbanks in an insulated cooler then immediately froze in a low temperature freezer at the ADF&G laboratory. Frozen fish were shipped via overnight air to a private analytical laboratory. Whole body fish are freeze-dried, digested, and analyzed for select metals using U.S. Environmental Protection Agency standard methods. The analytical laboratory provides quality assurance information for each analyte, including matrix spikes, standard reference materials, laboratory calibrations curves and internal quality control are included in the laboratory results. All element analysis results are for whole body fish in mg/kg dry weight.

Results and Discussion

Fish Creek

The 2024 Fish Creek daily peak water temperature at the Pond F outlet was similar to previous years after the discharged RO water was restored to the RO Channel on April 29 by unblocking the Pond AB outlet culverts (Figure 23). The RO Channel water temperature remained warmer than Fish Creek after the blocked Pond AB culverts were cleared on April 29 (Figure 24). Discharged RO water dilutes the influx of cold spring melt water keeping the RO Channel and Pond AB warmer than Fish Creek.

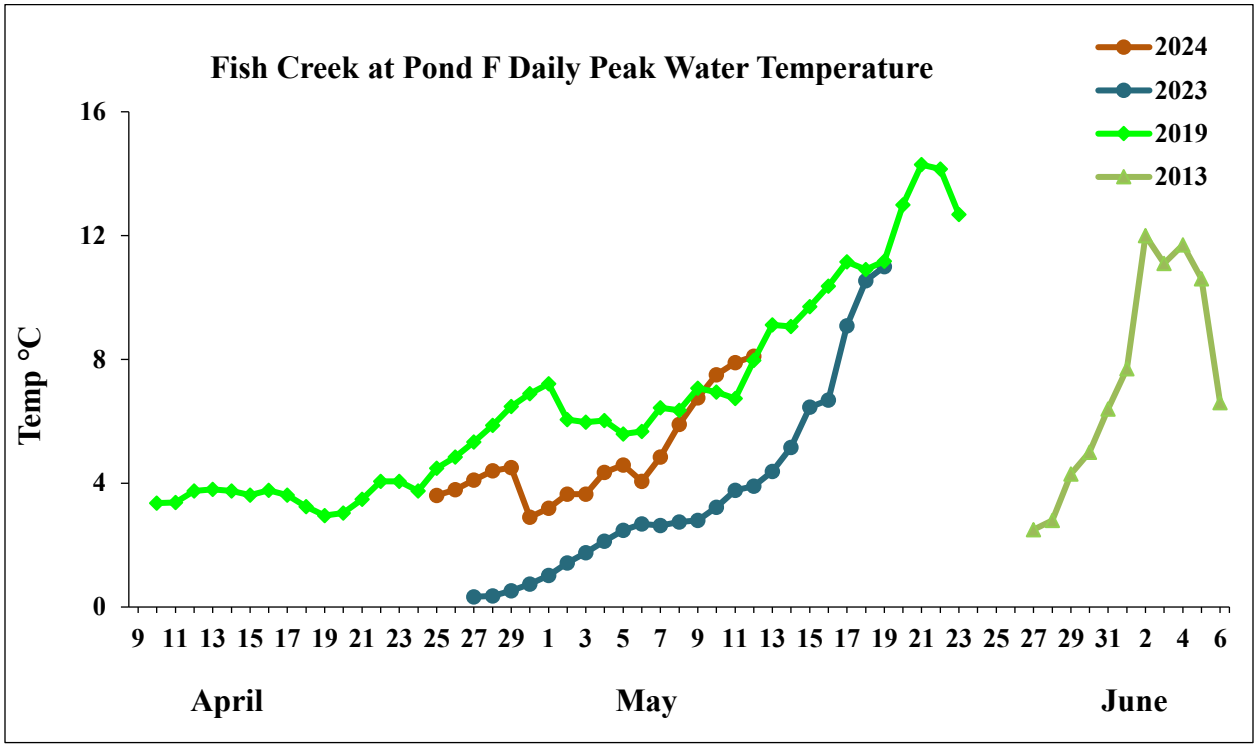

Figure 23. Fish Creek at Pond F daily water temperature maximums; select years for reference.

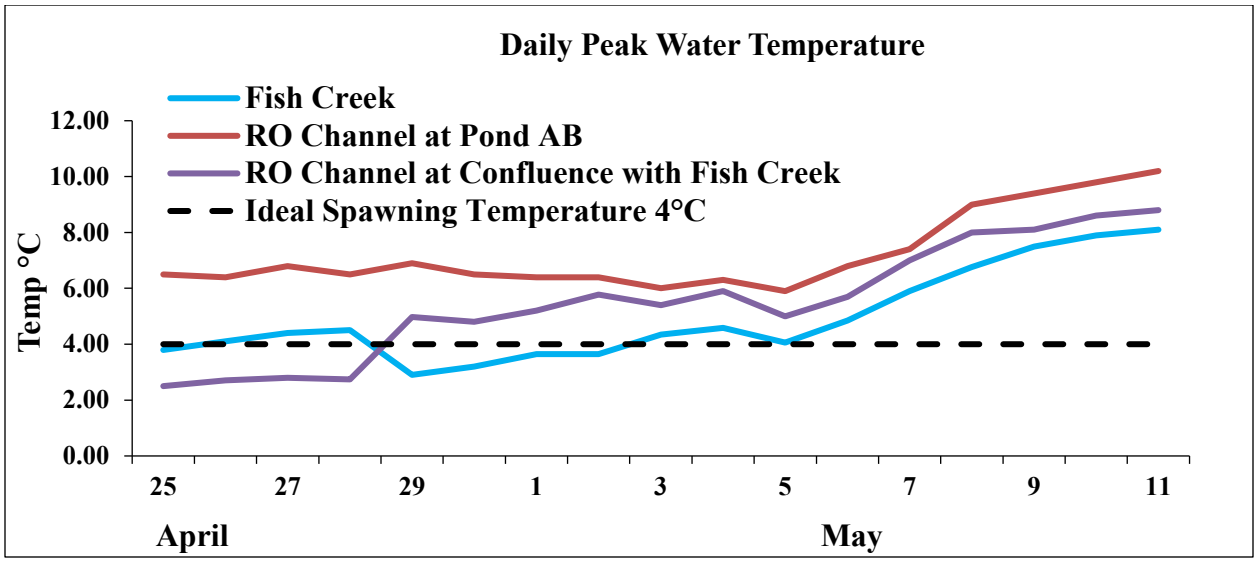

Figure 24. Fish Creek at Pond F, RO Channel at Pond AB and RO Channel near confluence with Fish Creek daily peak water temperatures, 2024.

From April 29 to May 10, all fish caught in fyke nets were handled with the majority being Arctic grayling. The Arctic grayling catch per unit of effort (CPUE) in Fish Creek varied during the first few days of sampling and peaked at 9.6 fish/hour on May 9. The RO Channel CPUE reached a high of 2.1 fish/hour on May 10 one day after Fish Creek's peak CPUE (Figure 25). With the lower RO water discharge rate of 400 gpm during spring 2024 the RO Channel water levels were lower than in previous years. The lower water levels resulted in fewer Arctic grayling moving into the RO Channel and a lower CPUE compared to previous years.

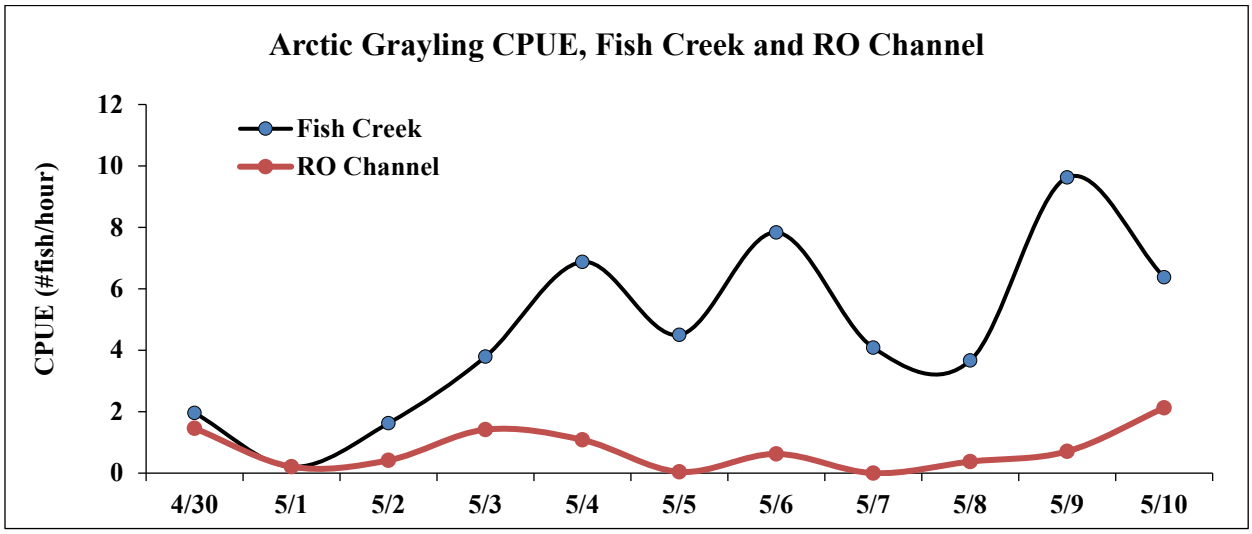

Figure 25. Catch per unit of effort (CPUE) in #fish/hour) at the Pond F and the RO Channel fyke nets in the wetlands complex, 2024.

Female Arctic grayling were categorized as not ripe, ripe, or spent, based on their spawning condition (Figure 26). On the first day of capture, April 30, 91% of the female Arctic grayling were categorized as not ripe and 9% were classified as ripe. By May 9, the number of ripe females increased to 96% and the number of not ripe females decreased to 3%. No fish were classified as spent during the first nine days and only 1% of females were spent on May 9, likely because Fish Creek water temperatures had remained relatively low and near 4°C for most of the sampling period (Figure 24).

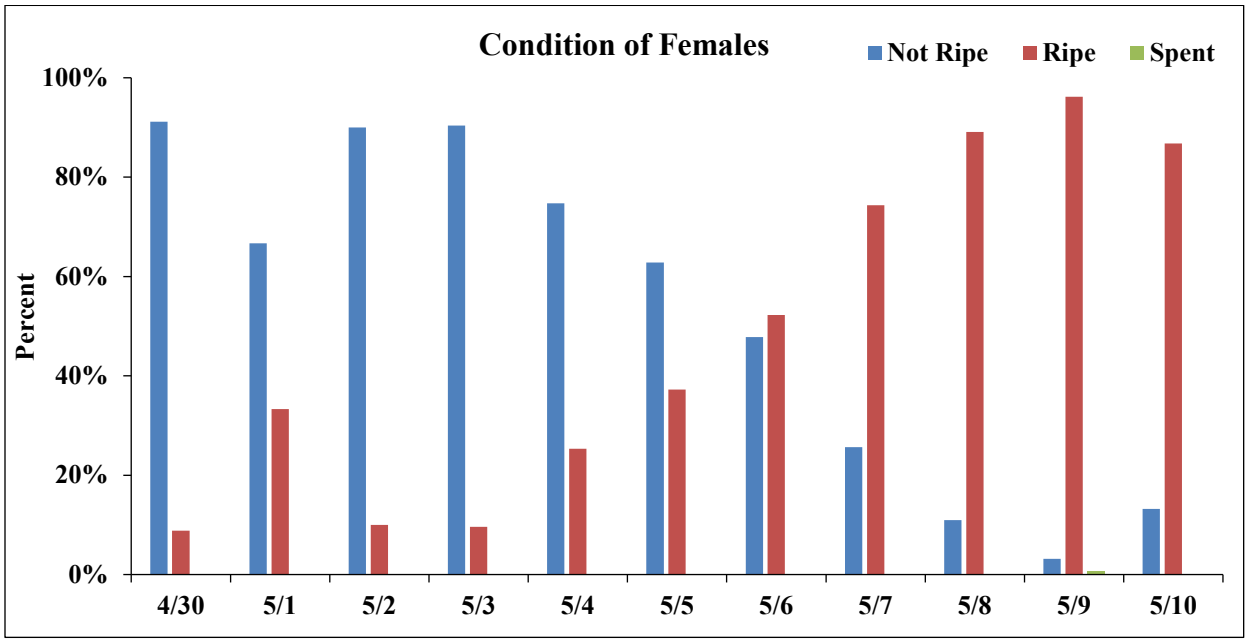

Figure 26. Spawning condition of Arctic grayling females categorized as: not ripe, ripe, or spent, 2024.

Recruitment is defined as those fish ≥200 mm captured in spring 2024 that would have been too small (<200 mm) to mark in 2023. These age-2 and age-3 Arctic grayling are generally between 200 and 240 mm long during spring sampling timing. Recruitment is variable among the sampling years but follows a peak and decline trend. The highest recorded recruitment of 406 fish was in 2017 then declined from 2018 to 2020. Recruitment peaked again in 2022 with 370 fish and began to decline in 2023 and 2024 (Figure 27). Substantial recruitment (≥300 fish) was observed in the spring of 2004, 2010, 2014, 2017 and 2022. In 2024, the recruitment was 119 Arctic grayling between 200 to 240 mm long.

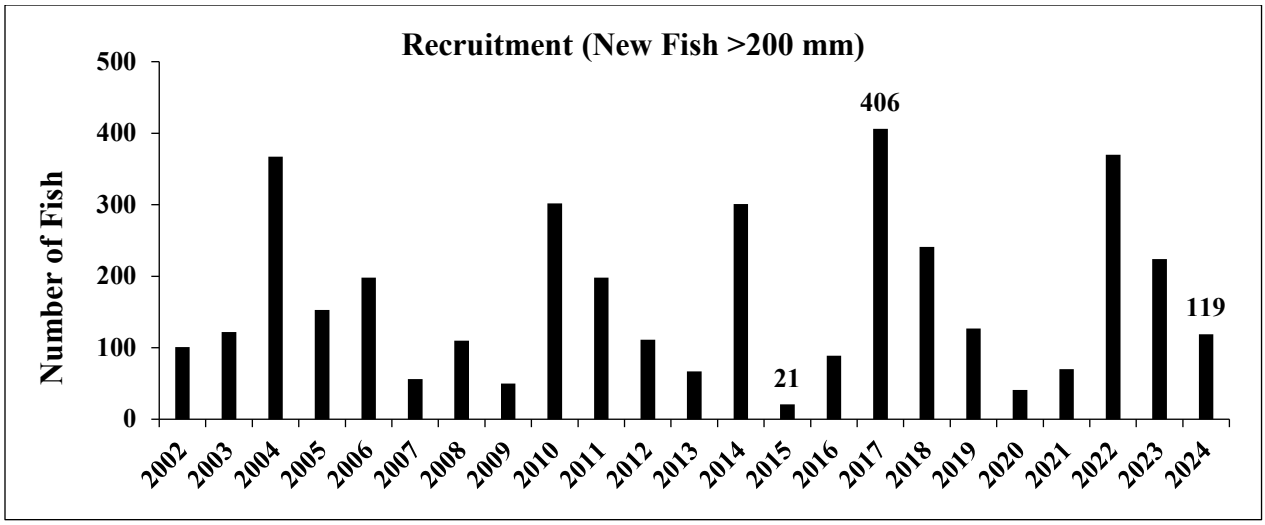

Figure 27. Number of new Arctic graying recruitment captured (fish 200-240 mm).

The 2023 population abundance estimate of Arctic grayling in the WSR was calculated using spring 2023 as the mark event and spring 2024 as the recapture event. During the spring of 2024 1,295 Arctic grayling ≥240 mm were captured, of those 351 were recaptures from the spring 2023 tagging event. The 2024 capture number does not include 119 fish that were ≤240 mm as they were likely too small to tag in 2023.

The spring 2023 population abundance estimate for Arctic grayling ≥200 mm was 4,767 (95% CI 4,404–5,129 fish) (Figure 28). The population was declining from 2017–2021 but increased in 2022–2023 and remains above the post mining goal of 800–1,600 fish ≥200 mm.

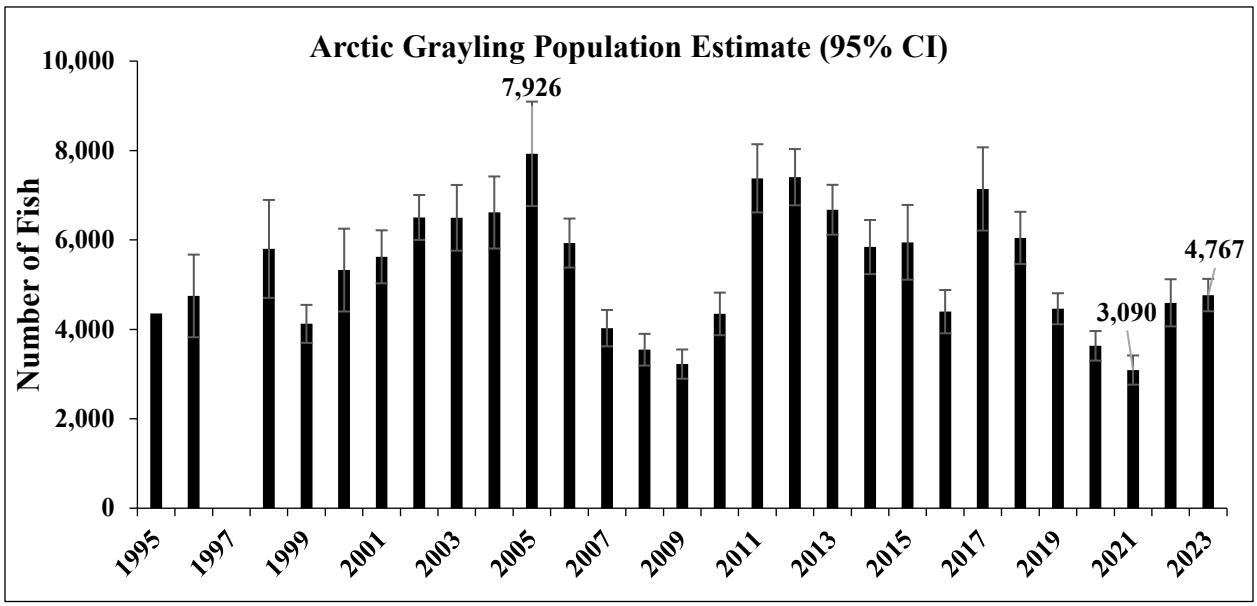

Figure 28. WSR and Fish Creek wetlands annual estimates of the Arctic grayling population with 95% CI, 1995–2023.

Annual average growth of Arctic grayling in each size class has increased since the construction of the WSR in 1994. Average growth prior to the development of the WSR ranged from 3–17 mm per year (Figure 29). In 2024, the average growth rate for fish 200–209 mm at the time of marking was 43 mm (n = 4). For fish 250–259 mm at time of marking, the average growth was 23 mm (n = 76).

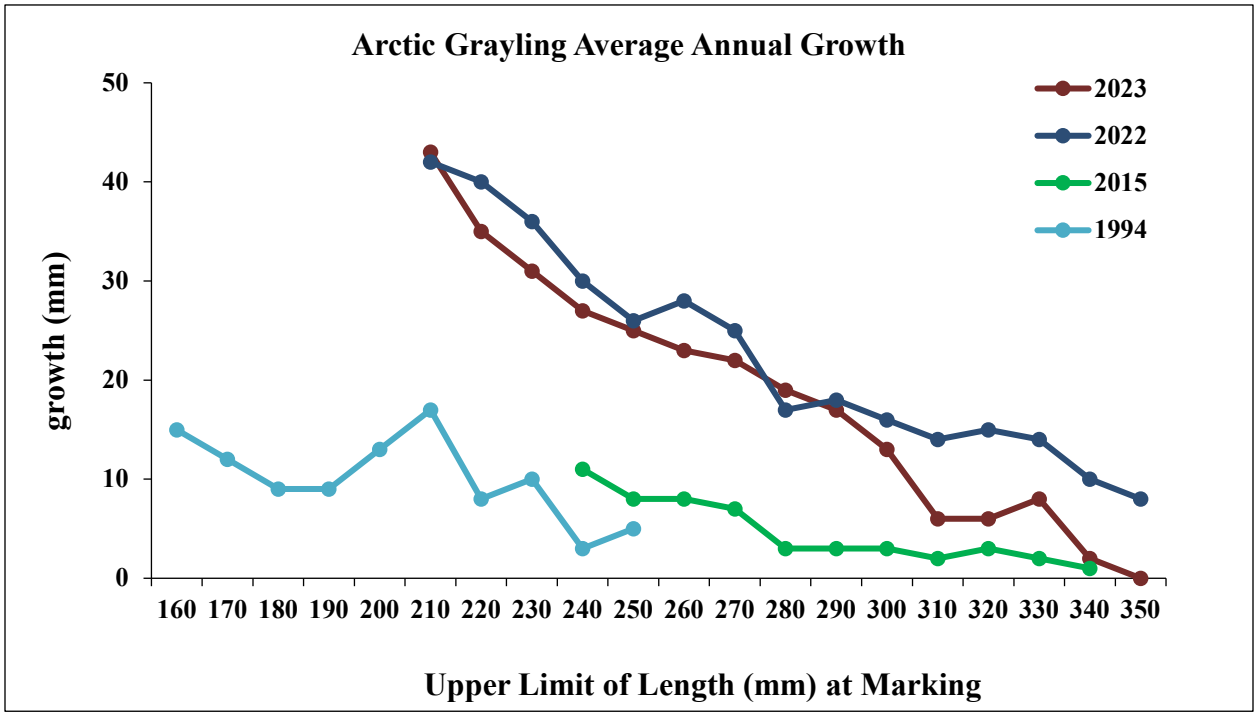

Figure 29. Average annual growth of Arctic grayling by size group in the WSR in selected years including baseline (before WSR) in 1994.

The 2023 length frequency distribution of Arctic grayling caught in Fish Creek and the RO Channel is presented in Figure 30. Data from 1995, before construction of the WSR, are included for comparison. The 1995 data set reflects the stunted condition of the population when growth was limited by available habitat and food sources at that time. The current population has very few large Arctic grayling ≥300 mm, or juveniles ≤110 mm. Most of the current population is between 260 and 300 mm (Figure 30).

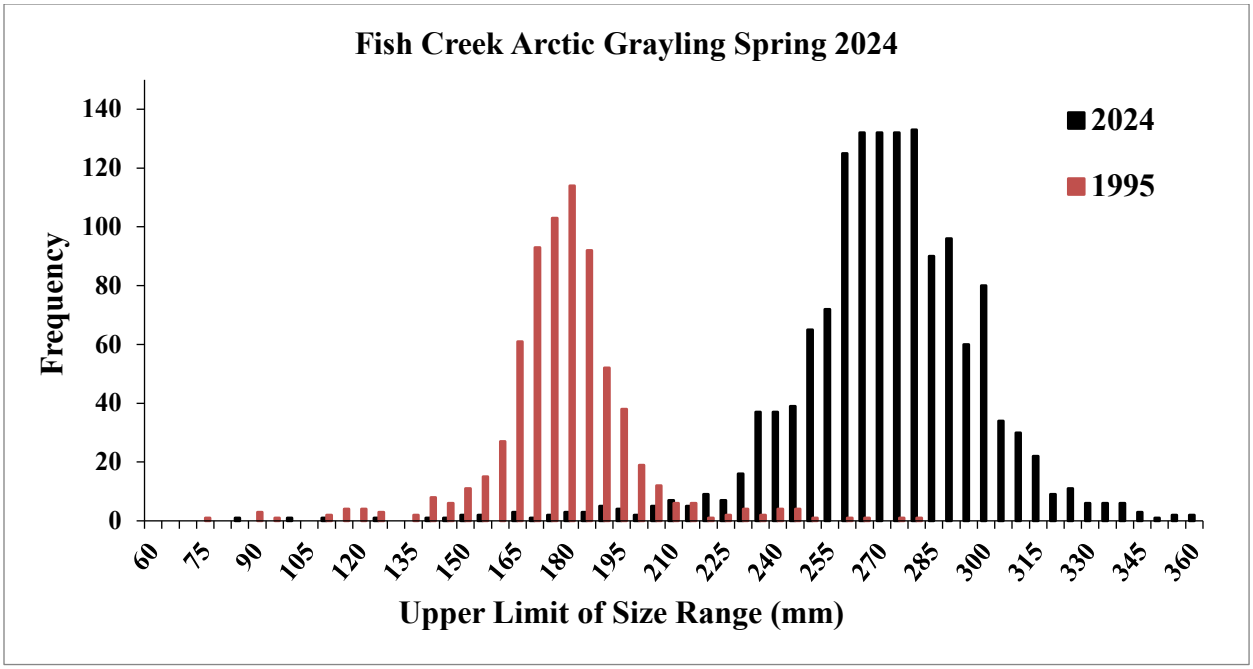

Figure 30. Length frequency distribution of Arctic grayling captured in spring 1995 and 2024.

Pond AB

Pond AB is the uppermost waterbody in the wetlands system located immediately downstream of the tailings dam. It is downstream of Outfall 002 in the RO Channel (Figure 20). One fyke net was placed in Pond AB from May 3 to May 10 and captured 234 Arctic grayling, 224 of which were taggable (≥200 mm). Captured fish ranged from 85 to 299 mm with an average size of 261 mm (Figure 31). Twenty-eight Arctic grayling were recaptured from the 2023 sampling event, all of which had been tagged in Pond AB. Two additional Arctic grayling recaptures had been tagged during the 2022 Pond AB spring sampling. One additional recapture (tag #12273) had been tagged in the lower RO Channel fyke net during spring 2022. This recaptured fish is the second documentation of a tagged Arctic grayling movement from the lower wetlands into Pond AB. However, the population appears to remain mostly isolated from the WSR and Fish Creek wetlands population.

Arctic grayling were able to access Pond AB after RO water discharge from Outfall 002 began in 2019, but access was immediately limited by an increase in beaver activity in the RO Channel. Some fish can possibly move upstream and downstream through the RO Channel during high water events, but passage is substantially restricted by the numerous beaver dams and vertical obstructions.

Arctic grayling residing in Pond AB appear to be the same cohort of fish that have grown larger since 2022. This can be seen in the increase of average length from 173 mm in 2022 to 237 mm in 2023 (Figure 31). The average length increased again to 261 mm in 2024 with very few larger or smaller fish captured. Eight juvenile Arctic grayling were captured in 2024 under 120 mm. These age-1 or age-2 fish may represent successful spawning in Pond AB during the past two years. Continued sampling of Pond AB will determine if the population remains isolated and if successful spawning occurs.

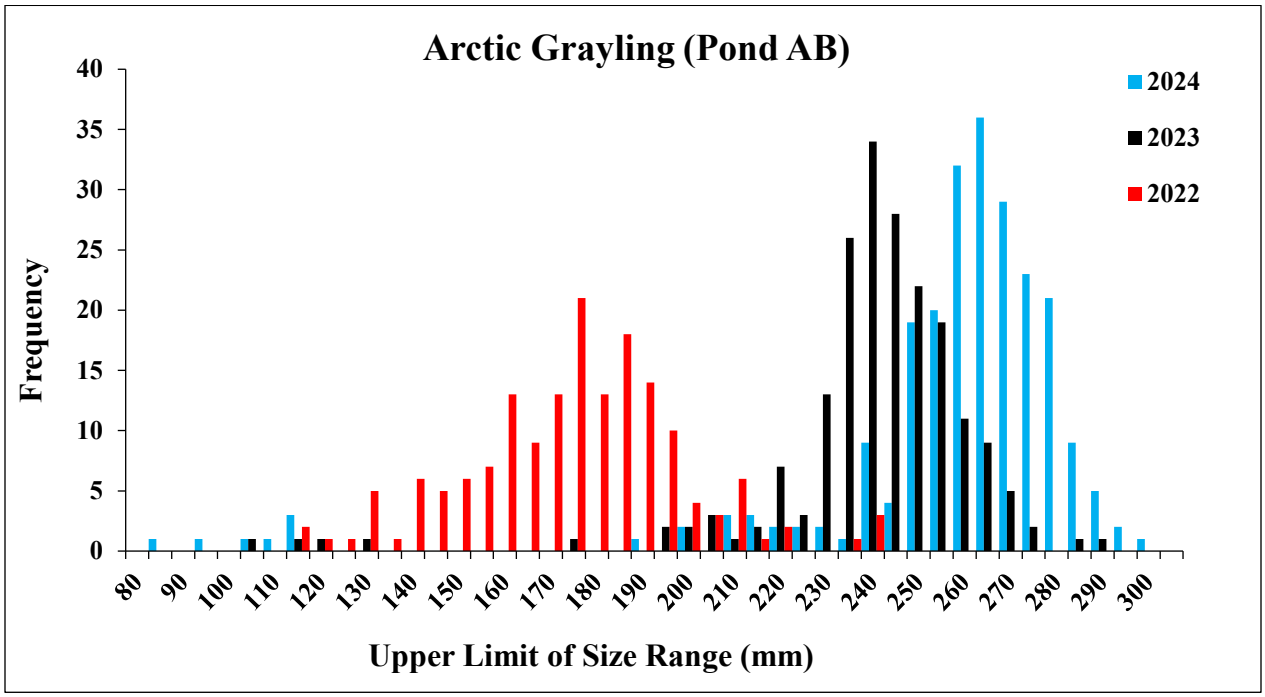

Figure 31. Pond AB Arctic grayling length frequency, 2022–2024.

The 2023 population estimate of Arctic grayling in Pond AB was calculated using spring 2023 as the mark event and spring 2024 as the recapture event. During spring 2024, 185 Arctic grayling ≥240 mm were captured, of those 28 were recaptures from the spring 2023 Pond AB tagging event.

The spring 2023 Pond AB population estimate for Arctic grayling ≥200 mm was 1,243 fish (95% CI 866–1,620 fish) (Figure 32). This is substantially higher than the 2022 population estimate of 241 fish (95% CI 60–422 fish). During spring 2023 and 2024 a total of 417 Arctic grayling ≥200 mm were captured and uniquely tagged.

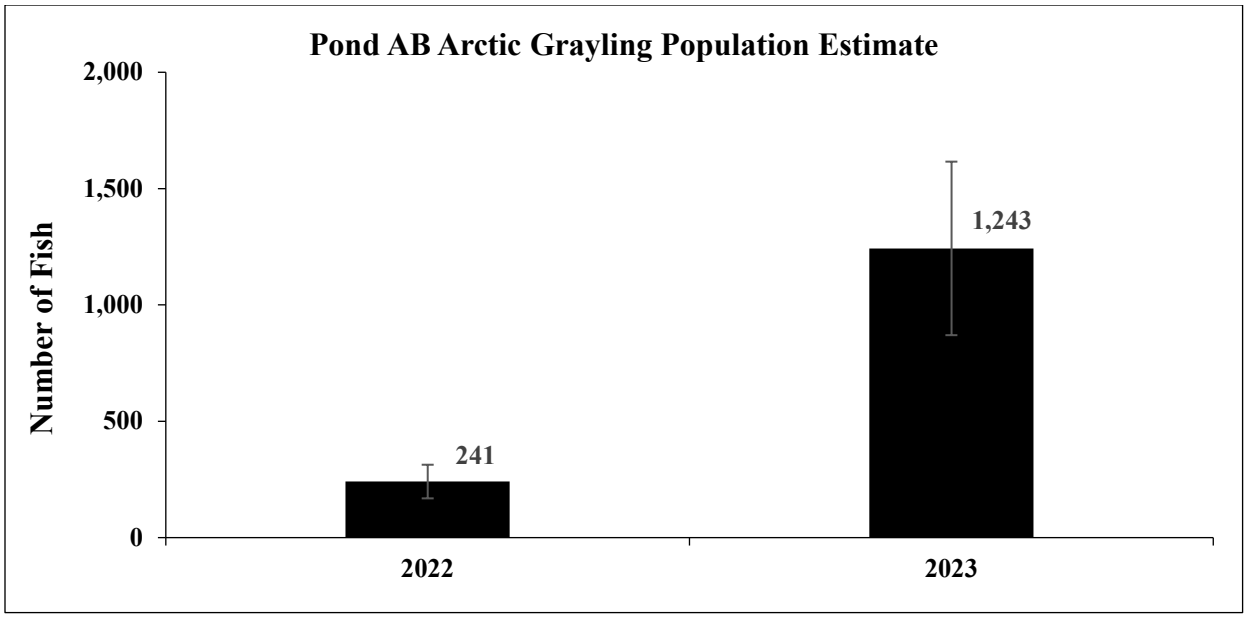

Figure 32. Pond AB annual estimates of the Arctic grayling population with 95% CI, 2022–2023.

Element Concentrations in Juvenile Arctic Grayling

In 2024, juvenile Arctic grayling were sampled to analyze whole body concentrations of selected elements for comparison to pre-mining levels. Baseline element data were collected in 1993 through 1995 before construction of the Fort Knox mine. Juvenile Arctic grayling were selected for long-term monitoring as a population was already established in the Fish Creek drainage prior to the mine construction. The WSR spillway into the lower Fish creek drainage prohibits upstream/return movement of fish into the WSR (report cover photo and Figure 20). Arctic grayling captured in Fish Creek upstream of the WSR spillway have spent the entirety of their life cycle in the Fort Knox wetlands complex. These Arctic grayling serve as an indicator of the changing conditions in the wetlands complex over time.

In 1993, baseline element data were collected from 24 juvenile Arctic grayling captured in Last Chance Creek ponds. These fish were the most likely to inhabit the WSR once its construction was completed in 1996. The mean length of these fish was 167.2 mm FL $\pm$7.9 mm (Appendix 9). In 2024, eight juvenile Arctic grayling were captured in the Fish Creek wetlands during the spring sampling for comparison (Appendix 10). The mean length of these fish was 169.8 mm FL ±9.1 mm. These fish were analyzed for aluminum, arsenic, cadmium, lead, and mercury; which were all comparable to 1993 baseline samples; and additionally, selenium in 2024. Results are reported as whole-body concentrations in mg/kg dry weight.

In 2024, the mean aluminum concentration in Fish Creek juvenile Arctic grayling was 20.43 mg/kg; this is lower than the mean aluminum concentration observed in the 1993 samples of 43.21 mg/kg (Figure 33). Aluminum's low solubility at neutral pH minimizes its toxicity to fish, which occurs primarily in extreme conditions of acidic (pH <6) or alkaline (pH >8) waters. The gill is the target organ for waterborne aluminum toxicity, with accumulation in internal organs being extremely slow. Symptoms of the toxic mechanism include inability of gills to process oxygen, impairment of aerobic swimming performance, and reduced growth and reproductive success. Dietary toxicity is negligible and bioaccumulation via the food chain does not occur (Wilson 2011). None of the captured or observed Arctic grayling during the 2024 Fish Creek sampling events displayed these symptoms.

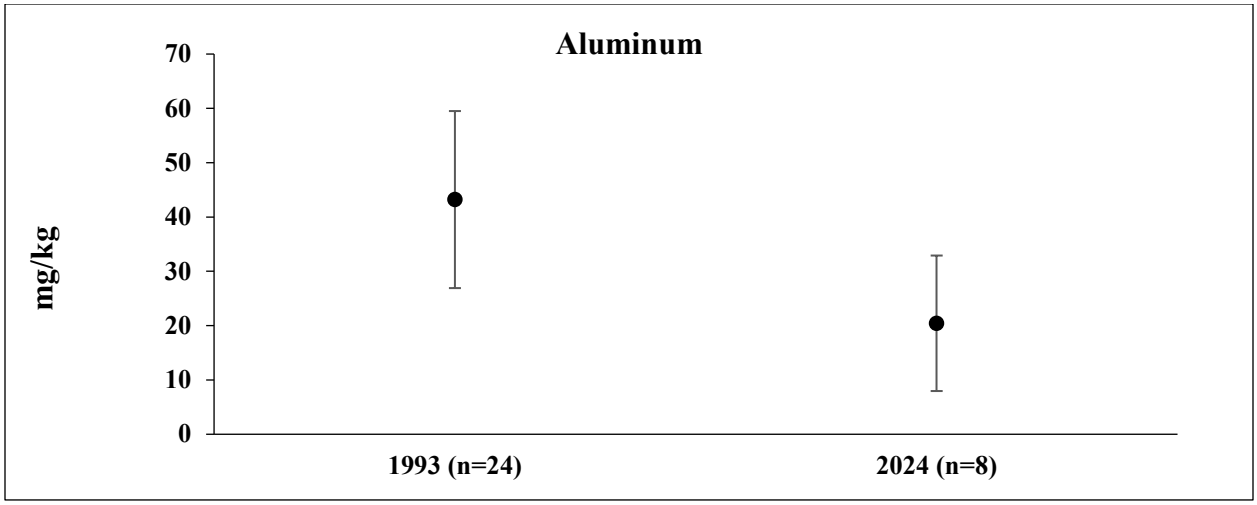

Figure 33. Mean aluminum concentrations (±1 SD) in juvenile Arctic grayling from Last Chance Creek ponds and Fish Creek wetlands (whole body dry weight).

In 2024, the mean arsenic concentration in juvenile Arctic grayling from Fish Creek was 0.27 mg/kg. The highest arsenic concentration observed in the 2024 samples was 0.38 mg/kg. In 1993, arsenic concentrations were below the detection limit of 1 mg/kg dry weight in all 24 juvenile Arctic grayling from Last Chance Creek ponds (Figure 34). The method detection limit for arsenic in 2024 (converted to dry weight) ranged from 0.10 mg/kg to 0.17 mg/kg. The inhabitants of aquatic environments, such as fish, are unable to escape the negative impacts of arsenic and the amount found in various fish organs is used as an indicator for ecosystem metal contamination. Arsenic has a multidimensional impact on fish as they bioaccumulate in various tissues and can harm respiratory, digestive, reproductive, and neurological systems (Malik 2023).

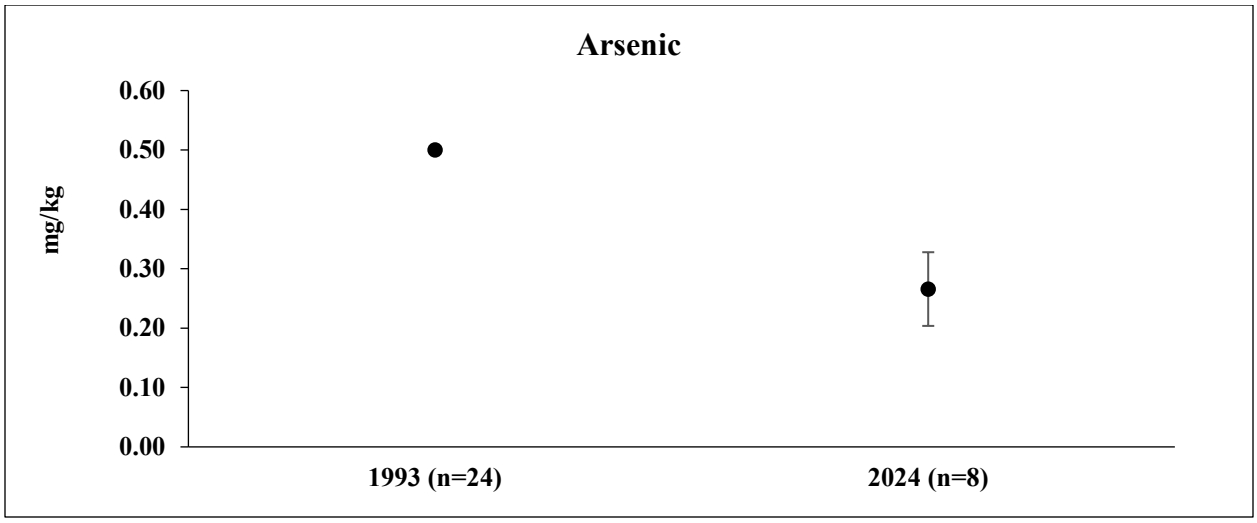

Figure 34. Mean arsenic concentrations (±1 SD) in juvenile Arctic grayling from Last Chance Creek ponds and Fish Creek wetlands (whole body dry weight).

In 2024, the mean cadmium concentration in juvenile Arctic grayling from Fish Creek was 0.04 mg/kg. The highest cadmium concentration observed during 2024 sampling was 0.06 mg/kg. In 1993, the mean cadmium concentration was 0.08 mg/kg, and the highest was 0.15 mg/kg. The 1993 mean concentration of 0.08 mg/kg is twice as high as the 2024 mean concentration of 0.04 mg/kg (Figure 35). Since 2004, juvenile Arctic grayling from Bons Pond, a freshwater reservoir at the Red Dog Mine in Northwest Alaska, have been sampled 14 times for whole-body element concentrations. The mean cadmium concentration has ranged from 0.09 mg/kg in 2017 to 0.27 mg/kg in 2014 (Clawson 2024). In comparison, cadmium concentrations in Arctic grayling from Fish Creek on the Fort Knox Mine are generally lower than observed in fish from Bons Pond.

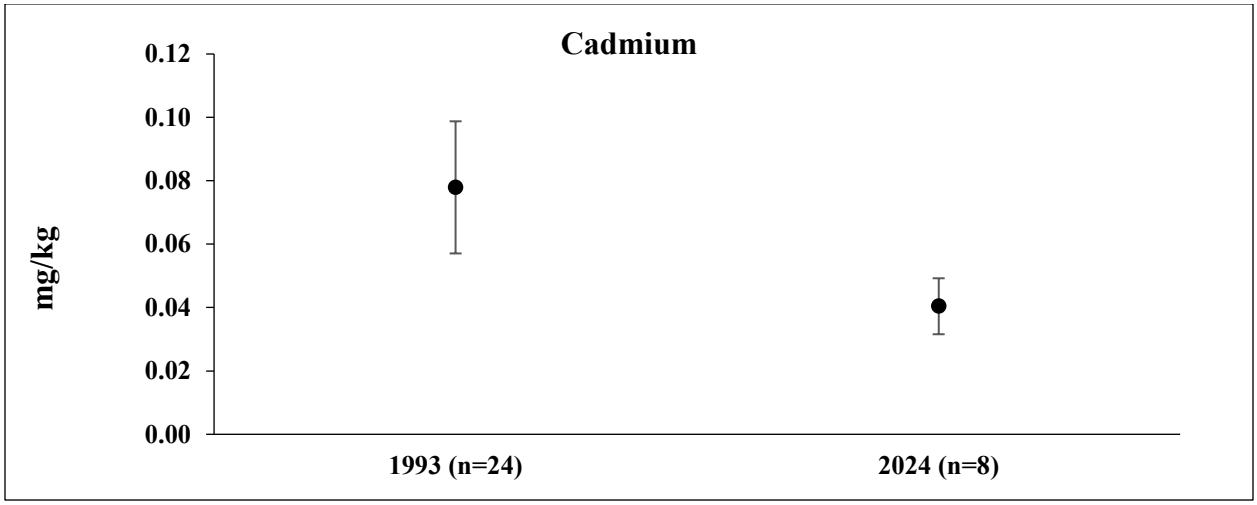

Figure 35. Mean cadmium concentrations (±1 SD) in juvenile Arctic grayling from Last Chance Creek ponds and Fish Creek wetlands (whole body dry weight).

In 2024, the mean lead concentration in juvenile Arctic grayling from Fish Creek was 0.08 mg/kg. The highest lead concentration observed during 2024 sampling was 0.12 mg/kg. In 1993, the mean lead concentration was 0.10 mg/kg and the highest was 0.47 mg/kg. The 1993 mean concentration of 0.10 mg/kg exceeded than 2024 mean concentration of 0.08 mg/kg (Figure 36). Mean concentrations of lead in juvenile Arctic grayling from Bons Pond at Red Dog Mine have ranged from 0.29 mg/kg in 2017 to 1.29 mg/kg in 2024 (Clawson 2024). Comparatively, lead concentrations in Arctic grayling from the Fort Knox Mine are consistently lower than those observed in Arctic grayling from Bons Pond.

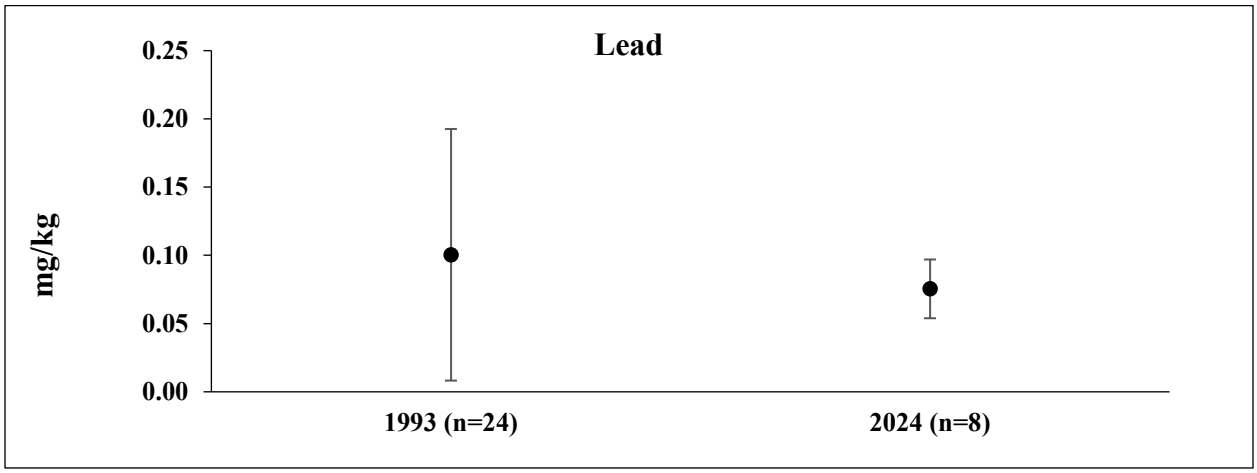

Figure 36. Mean lead concentrations (±1 SD) in juvenile Arctic grayling from Last Chance Creek ponds and Fish Creek wetlands (whole body dry weight).

In 2024, the mean mercury concentration in juvenile Arctic grayling from Fish Creek was 0.19 mg/kg. The highest mercury concentration observed during 2024 sampling was 0.29 mg/kg. In 1993, the mean mercury concentration was 0.21 mg/kg and the highest concentration was 0.29 mg/kg. The 1993 mean concentration of 0.21 mg/kg is slightly higher than 2024 mean concentration of 0.19 mg/kg, but most values overlap (Figure 37). Mean mercury concentrations in juvenile Arctic grayling from Bons Pond at Red Dog Mine have ranged from 0.02 mg/kg in 2004 and 2014 to 0.06 mg/kg in 2018 and 2019 (Clawson 2024). Unlike other tested elements, mercury concentrations are higher in Arctic grayling from Fort Knox. Mercury exposure in fish can induce a variety of adverse effects with some species being more susceptible than others. Mercury-induced toxicological pathology in fish is influenced by species age, environmental conditions such as water temperature, exposure duration and concentration levels. Toxic mercury accumulation, which can result in fish mortality, primarily depends on exposure time and concentration combinations (Morcillo 2017).

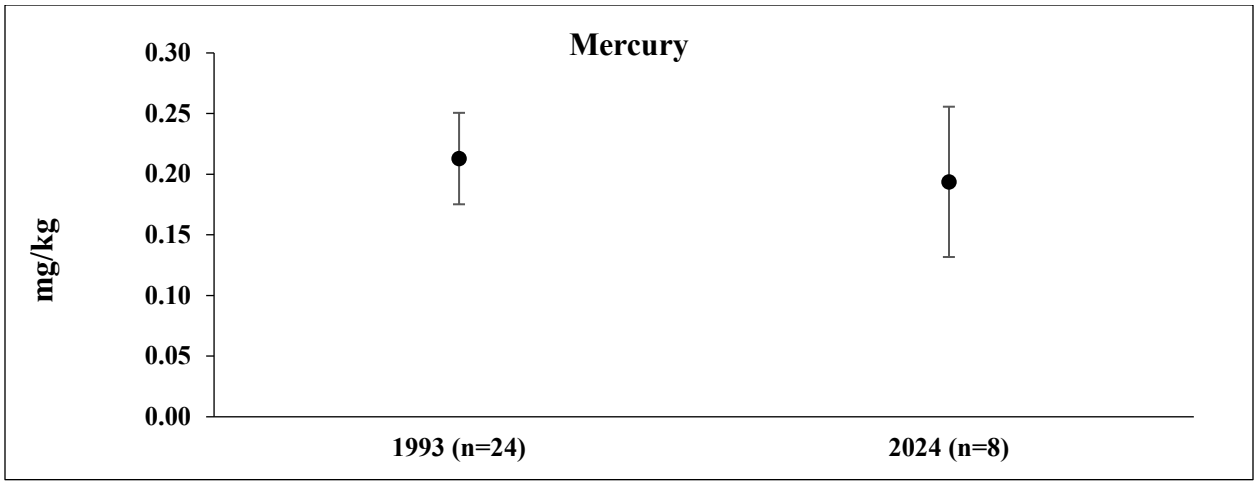

Figure 37. Mean mercury concentrations (±1 SD) in juvenile Arctic grayling from Last Chance Creek ponds and Fish Creek wetlands (whole body dry weight).

In 2024, the mean selenium concentration in Fish Creek juvenile Arctic grayling was 2.45 mg/kg with a maximum concentration of 3.29 mg/kg dry weight (Appendix 10). Selenium concentrations were not included in the 1993 baseline data collection. Preventing a direct comparison. For a reference, the Fish Creek Arctic grayling concentrations are lower than the United States Environmental Protection Agency (EPA) toxicity threshold of 8.5 mg/kg dry weight (EPA 2016). Selenium concentrations in juvenile Arctic grayling from Fish Creek on Fort Knox Mine are substantially lower than those from Bons Pond on Red Dog Mine. Mean selenium concentrations in juvenile Arctic grayling from Bons Pond have ranged from a low of 9.3 mg/kg dry weight in 2019 to a high of 16.68 mg/kg dry weight in 2024 (Clawson 2024).

Current Issues

Beaver dams throughout the Fish Creek wetlands complex, including the Pond D and F outlets, were rebuilt during summer and fall of 2023. ADF&G staff removed the Pond D beaver dam on April 24, 2024, to allow fish access into Pond D and further up Fish Creek during the spring spawning migration (Figure 38). Access further up the Fish Creek wetlands is limited by a 3-m high beaver dam in the channel connecting Pond D and the Horseshoe Ponds (Figure 20). No Arctic grayling were observed upstream of this dam during the two weeks of sampling in spring 2024. Arctic grayling appear to have adequate areas to spawn and rear when the lower Fish Creek, specifically the Pond D outlet dam, are consistently removed.

Figure 38. Beaver dam removed by ADF&G from Pond D outlet, April 2024

On April 24, 2024, the RO Channel was mostly dry with very little spring melt water or discharged RO water flowing through the channel. There was no aufeis throughout the valley floor as there was during spring 2023. The Pond AB outlet culverts had been blocked by beavers during the fall of 2023 (Figure 39) and discharged RO water was flowing out the Pond AB natural outlet into Fish Creek (Figure 40). ADF&G staff cleared the Pond AB culverts returning water flow into the RO Channel on April 24 before the spring spawning timing (Figure 39). In the RO Channel between Pond AB and the WSR a series of six or more small beaver dams create ponds and were partial obstructions to fish passage. These dams likely prevent most fish from moving from the WSR into Pond AB.

Figure 39. Pond AB culverts were blocked during fall of 2023 and cleared by ADF&G staff in April 2024, returning water flow to the RO Channel.

Figure 40. RO water exiting Pond AB and into Fish Creek, bypassing the blocked outlet culverts, April 2024.

Burbot

Methods

The annual burbot population assessment in the Fort Knox WSR was performed from September 24 to October 2, 2024. This sampling is performed in the fall when water temperatures are lower so handling is less stressful for captured fish. Twenty-four hoop traps were set in the WSR and six in Gil Pond (Figure 41). The Gil Pond is connected to the WSR with a fish passage culvert (FH15-III-0219-A3) allowing movement between the two waterbodies. Hoop traps were set at depths ranging 1.5–4.5 meters. Deep water areas were avoided to prevent burbot mortality from low dissolved oxygen levels. Hoop traps were baited with cut herring and checked every two to three days. From September 30 to October 2 two hoop traps were set in Pond AB to determine if burbot were continuing to inhabit the uppermost water body in the Fish Creek wetlands complex as first documented in 2022 (Bear 2022). The WSR was ice free for the duration of our trapping efforts and water temperatures ranged between 7.2° C on September 26 to 6.1° C on October 2.

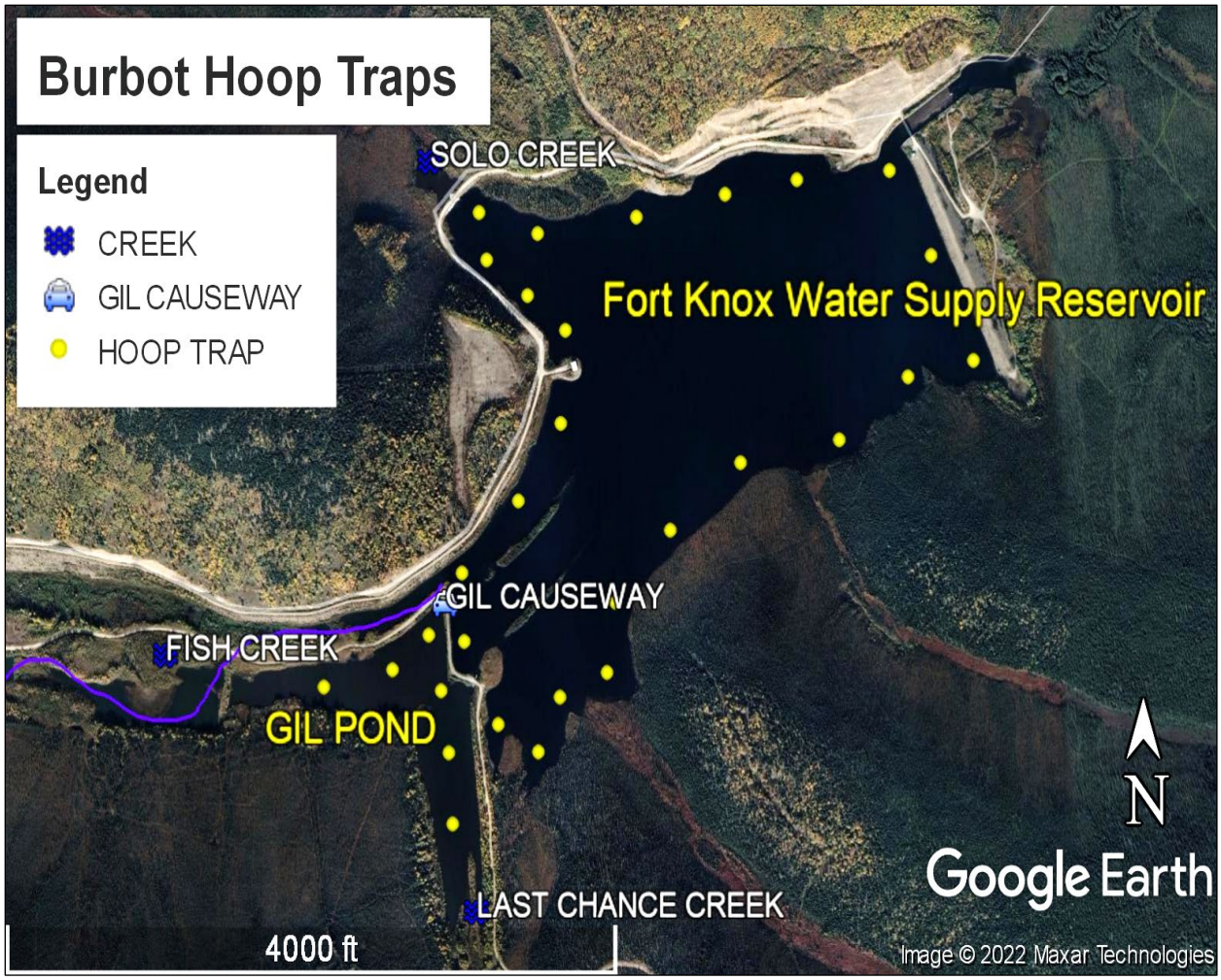

Figure 41. Burbot hoop trap locations in the WSR and Gil Pond.

Burbot were measured to total length (TL) nearest mm, inspected for tags, then released. Untagged burbot ≥300 mm were marked with a numbered Floy® T-bar internal anchor tag. Abundance of burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982), see Arctic grayling methods section of this report for formulas.

Results and Discussion

Water Supply Reservoir

Burbot residing in the WSR and Fish Creek wetlands were incidentally captured during the 2024 spring Arctic grayling fyke netting event. During the 2024 spring WSR sampling event, 17 burbot were captured with 7 of these ≥300 mm. Unlike past spring sampling events, burbot were not tagged with Floy tags but instead were counted, measured, and released. Burbot tagged during the

spring event are not part of the annual WSR burbot population estimate as only burbot tagged and recaptured during the fall sampling events are used in the calculations. No tagged burbot from past years sampling events were captured during spring 2024 sampling. No burbot were captured in the Pond AB fyke net from May 3–10, 2024.

The 2023 WSR burbot population estimate used 2023 fall hoop trapping as the mark event, and 2024 fall hoop trapping as the recapture event. During September 2023, 107 burbot were captured, 80 were ≥300 mm and tagged, of these 57 were ≥400 mm. In the 2024 capture event, 99 burbot were captured, 55 were ≥300 mm and tagged, of these 30 were ≥400 mm, with 3 fish recaptured from the 2023-mark event. In both years, fish from Gil Pond were included in the population estimate as it is connected to the WSR by fish passage culverts.

A post-mining population goal was not established for the burbot within the WSR, however a small population of fish larger than 400 mm has remained present. The fall 2023 WSR population estimate for burbot ≥400 mm was 598 fish (95% CI 55–1,141 fish) (Figure 42). Because only 3 fish from the 2023 sampling were recaptured in 2024, a large variance was calculated during the statistical analysis. The point estimate of 598 fish is well above any past years' population estimate, which have ranged from a low of 80 fish in 2013 to a high of 402 fish in 2018 (Figure 42). Given the large confidence interval, it is likely that the population size is like past years' estimates.

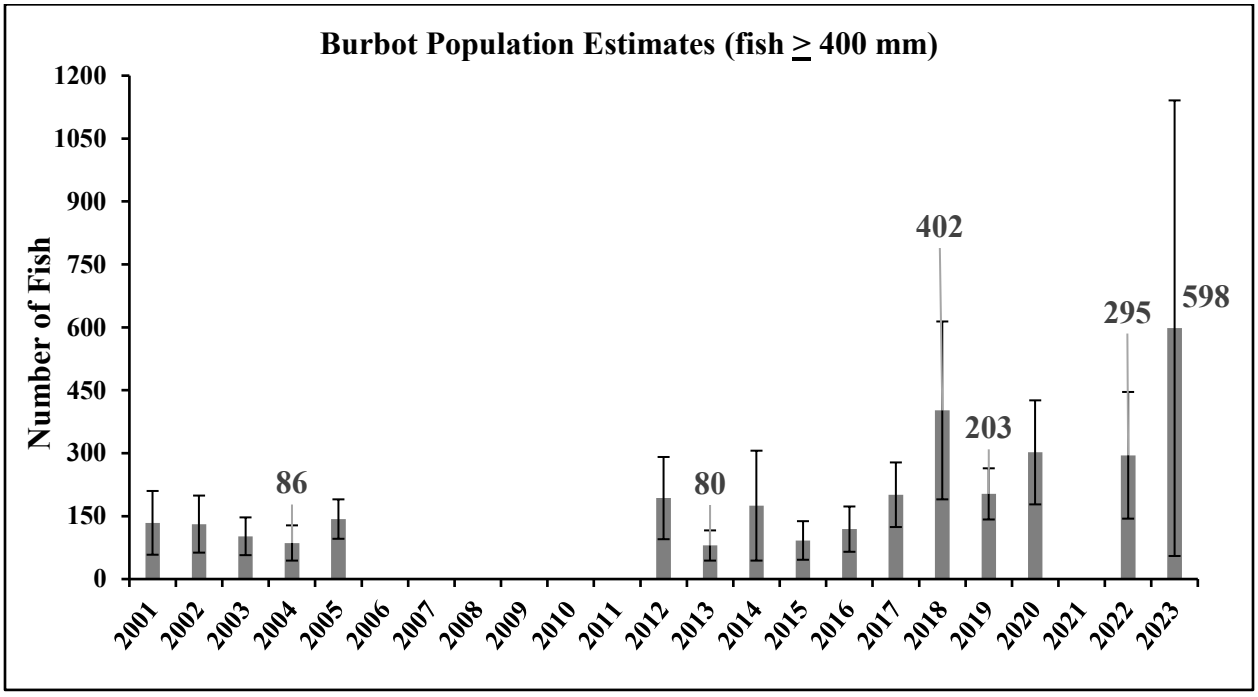

Figure 42. WSR Annual estimates of the Burbot populations ≥400 mm with 95% CI, 2001-2023.

CPUE of all burbot captured in 2024 was 0.4 fish per day per trap (Figure 43). This is the same as the 2023 CPUE, and less than half of the 2018 CPUE (1.1 fish per day per trap). The 2024 CPUE is the third lowest since sampling began in 1996. The CPUE of burbot ≥400 mm decreased from 0.2 fish per day per trap in 2023 to 0.1 in 2024 as fewer large fish were captured in 2024 (Figure 43 and 44).

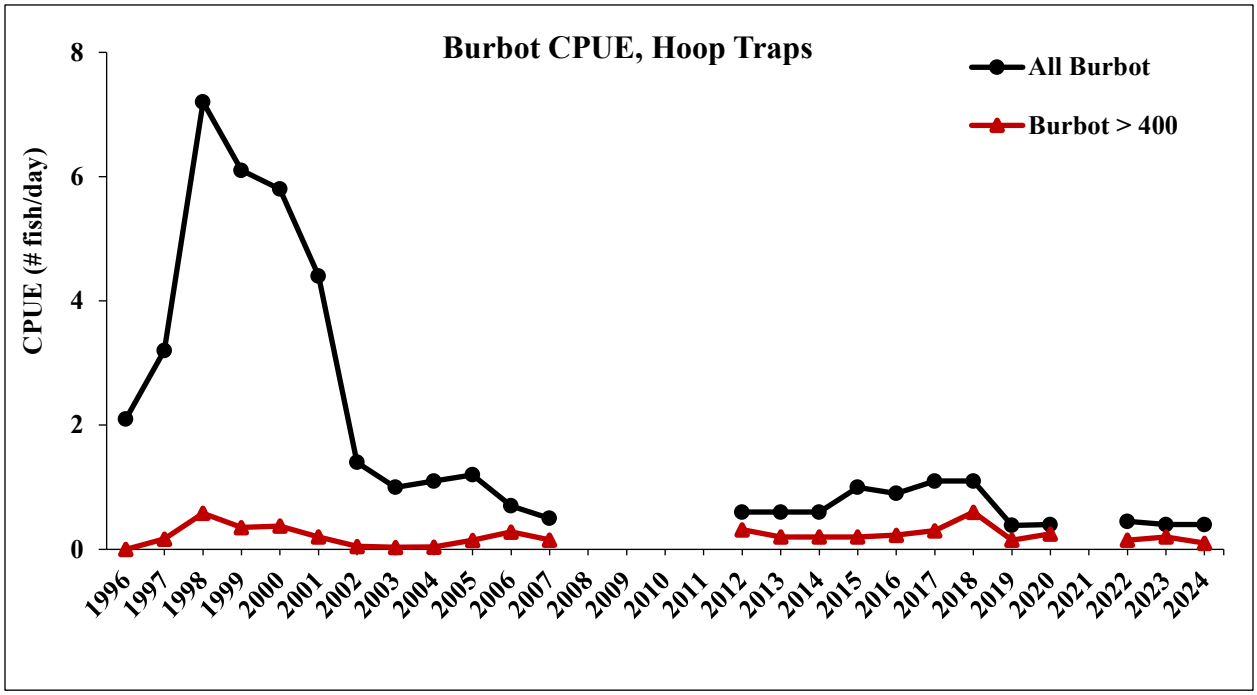

Figure 43. CPUE for burbot in the Fort Knox WSR.

In 2024, burbot lengths ranged 58–705 mm with 32 juvenile burbot <200 mm and 1 burbot >600 mm. In 2023, only 13 juvenile burbot <200 mm were captured, but 18 burbot >600 mm were captured. The 2024 length distribution is shifted lower without as many large burbot captured compared to the 2023 distribution (Figure 44). Large burbot captures may have declined as older burbot naturally die out, decreasing cannibalism within the population and allowing for an increase in survival for the juvenile burbot.

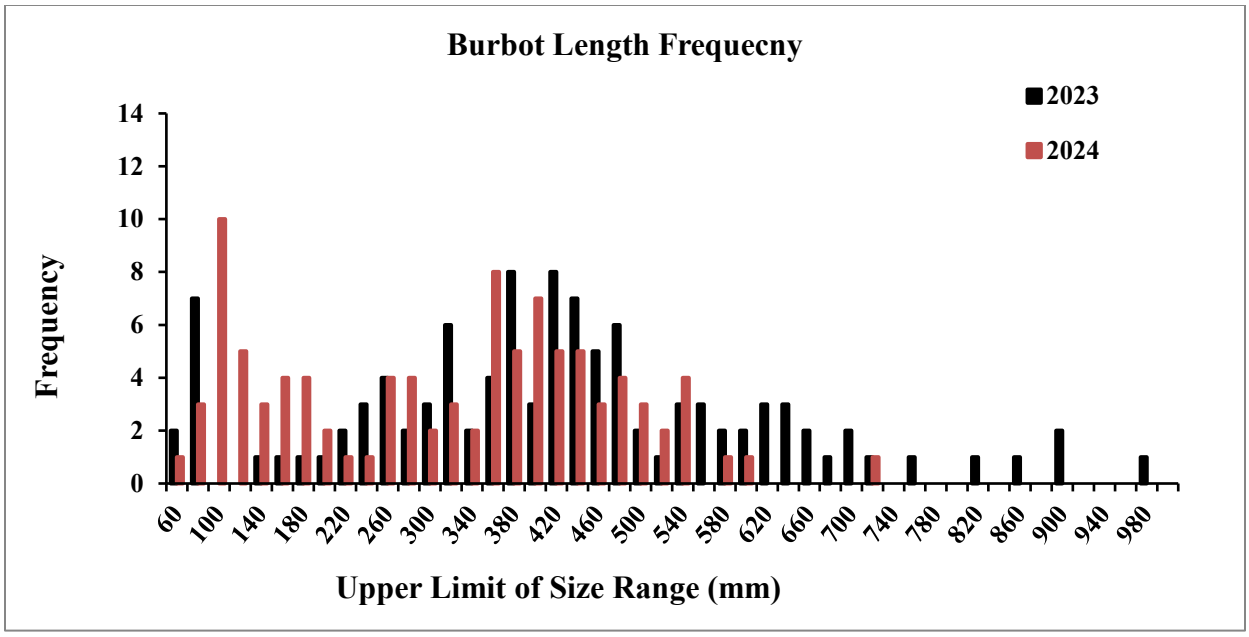

Figure 44. Length-frequency distribution of burbot captured in the WSR, 2023 and 2024.

Annual burbot growth in the WSR has ranged from 24 mm in 2013 to 70 mm in 2016. The 2023 annual growth rate is 34 mm and the average annual growth rate since 2000 was 45 mm (Figure 45).

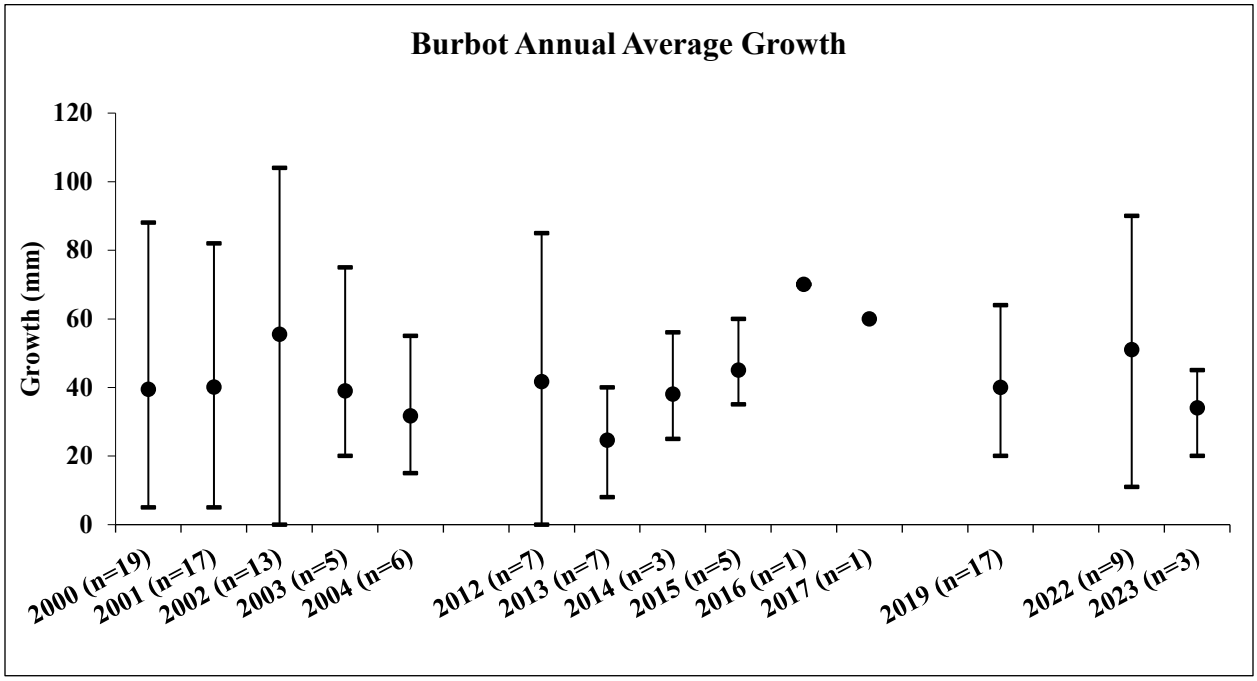

Figure 45. Average annual burbot growth rate in the WSR 2000–2023. Note number of recaptured fish per year is indicated in parentheses.

Pond AB

Burbot were first documented in Pond AB during 2022 when seven fish were captured during the fall sampling. During the 2023 sampling event, 25 burbot were captured in the Pond AB hoop traps. In 2024 three burbot were captured but sampling time and effort decreased from 2023. Burbot lengths in 2024 ranged from 295 to 355 mm with an average of 306 mm. One of the three burbot captured in 2024 was tagged in Pond AB during the 2023 sampling and is the first documented recapture in Pond AB. It is likely that the fish captured in 2024 were part of the same isolated population of burbot that were residing in Pond AB in 2022 and 2023. The 2023 Pond AB population estimate for burbot ≥300 mm is 22 fish (95% CI 8–35 fish). The RO Channel connecting Pond AB to the WSR has numerous beaver dams that may prevent fish passage at typical water levels as no burbot tagged in the WSR have been recaptured in Pond AB. The Pond AB burbot were not included in the WSR burbot population estimate and a separate population estimate will be performed until consistent fish movement between the two water bodies is observed.

Current Issues

Larval *Diplostomulum* of the Eye

During September 2024 WSR burbot sampling, 99 burbot were captured, and 35 had a milky appearance to one or both pupils (Figure 46). Typically, burbot pupils are black, surrounded by yellow or golden colored irises (Figure 47). Some affected burbot also exhibited bulging or protruding eyes beyond what is typical for the species appearance. In previous WSR and Fish Creek wetlands sampling events, one or two burbot with similar eye conditions have been observed, but not in a large percentage of the population. Milky eyes had previously been attributed to physical trauma to the fish's head or to naturally occurring eye cataracts that develop in aging fish, and no special diagnostic testing was performed.

During July 2024 Stilling Basin fieldwork, 15 of the 22 burbot captured showed the same eye condition. Five whole-body burbot samples were collected and sent to the ADF&G Fish Pathology Laboratories operated by the Division of Commercial Fish in Anchorage (Bear 2024). One additional burbot were collected in September during the WSR sampling and were submitted for diagnostic testing. Results from these burbot samples were received on February 18, 2025, and are contained in their lab report No. 2025-0016 (Ferguson 2025). Each fish sample submitted

contained larval *Diplostomulum* of the eye (eye fluke). Each fish had between 5 to 25 flukes occupying various regions of the eye resulting in partial or complete blindness.

Figure 46. Burbot captured in WSR with milky pupils, October 2024.

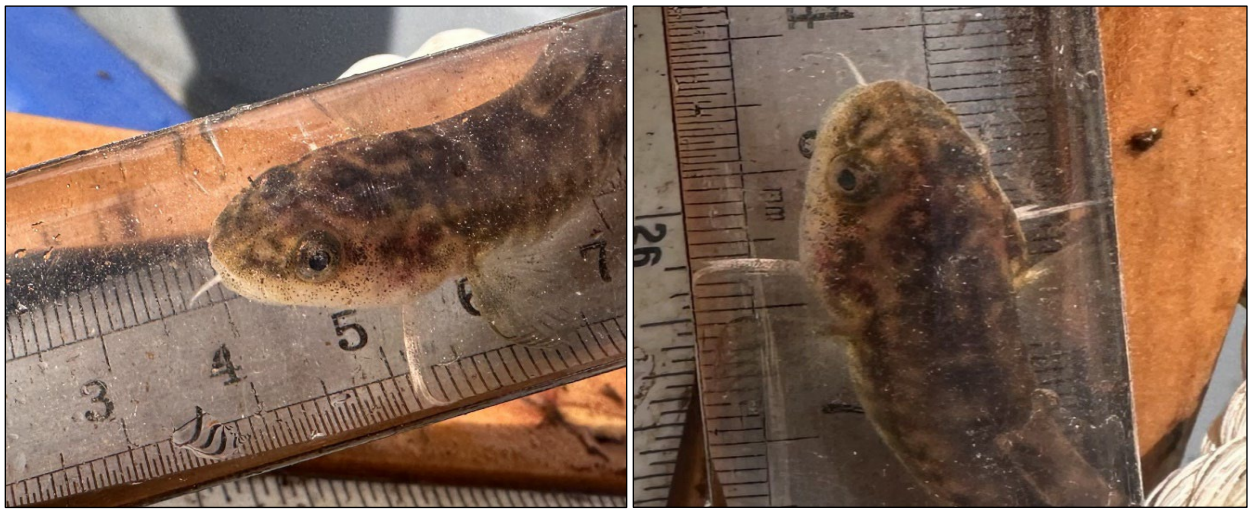

Figure 47. Burbot captured in WSR with normal pupils, September 2023.

In the *Diseases of Wild and Cultured Fishes in Alaska Field Guide,* published by the ADF&G Pathology Laboratory, identifies larval *Diplostomulum* of the eye, commonly known as eye fluke, as a digenean larval trematodes of the genus *Diplostomulum.* This parasite infects the eyes of many freshwater fish species found in Alaska. A common trematode found in the lens is *D. spathaceum* while others are found in the vitreous chamber (pupil) of the eye. The parasite can remain in the eye for extended periods of time, often resulting in cataracts and blindness in the host fish (Meyers et al. 2019).

The life cycle begins when fish become parasitized through the water from infected snails. Free-swimming invasive cercariae from the snail penetrates the fish's skin and migrates to the eye, where the larvae mature. The host fish is then consumed by a piscivorous bird (e.g., seagull) where the larval fluke matures into an adult while in the bird's intestinal tract. The adult fluke produces eggs, which are expelled into the water through bird feces. Eggs mature into miracidium that infest snails in the water. The cycle is complete when the snails release free swimming cercaria into the water and parasitize fish again (Meyers et al. 2019).

Glaucous-winged Gull, Glaucous Gull and the Herring Gulls (seagulls) are common in interior Alaska. During the summer of 2024, up to twelve seagulls were observed nesting on the rock faces near the WSR spillway and Stilling Basin (Bear 2024). These birds are potential hosts for various parasites, bacteria, viruses, and fungi that can infect resident fish populations.

Unidentified *Myxobolus sp*. Infection in Burbot Gills

During the fish pathology lab work (No. 25-0016), an incidental finding revealed an infection by an unidentified *Myxobolus sp.* within the capillaries of the gills. Seventy-five percent of the burbot samples submitted tested positive for the infection. This family of parasites also exhibits a complex lifecycle. Myxospores are released from deceased fish, ingested by an invertebrate (commonly oligochaete worms), where they undergoe sexual reproduction. These invertebrates then release infectious spores (actinospores) into the aquatic environment that penetrate and re-infect fish. Member of the *Myxobolus* family are typically host-specific at the family level and display a high degree of tissue tropism (Ferguson 2008).

Currently there are only two validly recognized *Myxobolus* species that infect the gills of burbot: *Myxobolus lotae* from the Kola Peninsula of Russia, and *Myxobolus warniakensis* from Northeast Poland (Muzzall *et al* 2011). The unidentified *Myxobolus* sp. in these burbot from Alaska exhibit significantly smaller pseudocysts (50-200% smaller) and smaller myxospores compared to both previously described species (Ferguson 2025). Therefore, the *Myxobolus* sp. in these burbot samples from Alaska is most likely a novel species. Continued research is essential to validate the preliminary finding of the Alaska isolate.

Stilling Basin

Methods

Fish sampling was conducted in the Fort Knox Stilling Basin from July 31 to August 2, 2024. Sample methods included hoop traps, minnow traps, and rod and reel angling for Arctic grayling. On July 31, five hoop traps baited with cut herring were deployed near the middle of the Stilling Basin. Additionally, ten minnow traps, baited with cured salmon eggs, were placed along the shoreline in shallow water (Figure 48). All traps were checked daily and fished for 48 hours before removal. Captured burbot were measured, tagged if ≥300 mm, then subsequently released. Angling for Arctic grayling is typically best near the spillway's low water channel that brings insects and cool water from the WSR into the Stilling Basin. Six hours of angling using both fly rods and spinning gear was performed. On August 1, two Fort Knox Environmental Department summer interns assisted with the grayling angling efforts.

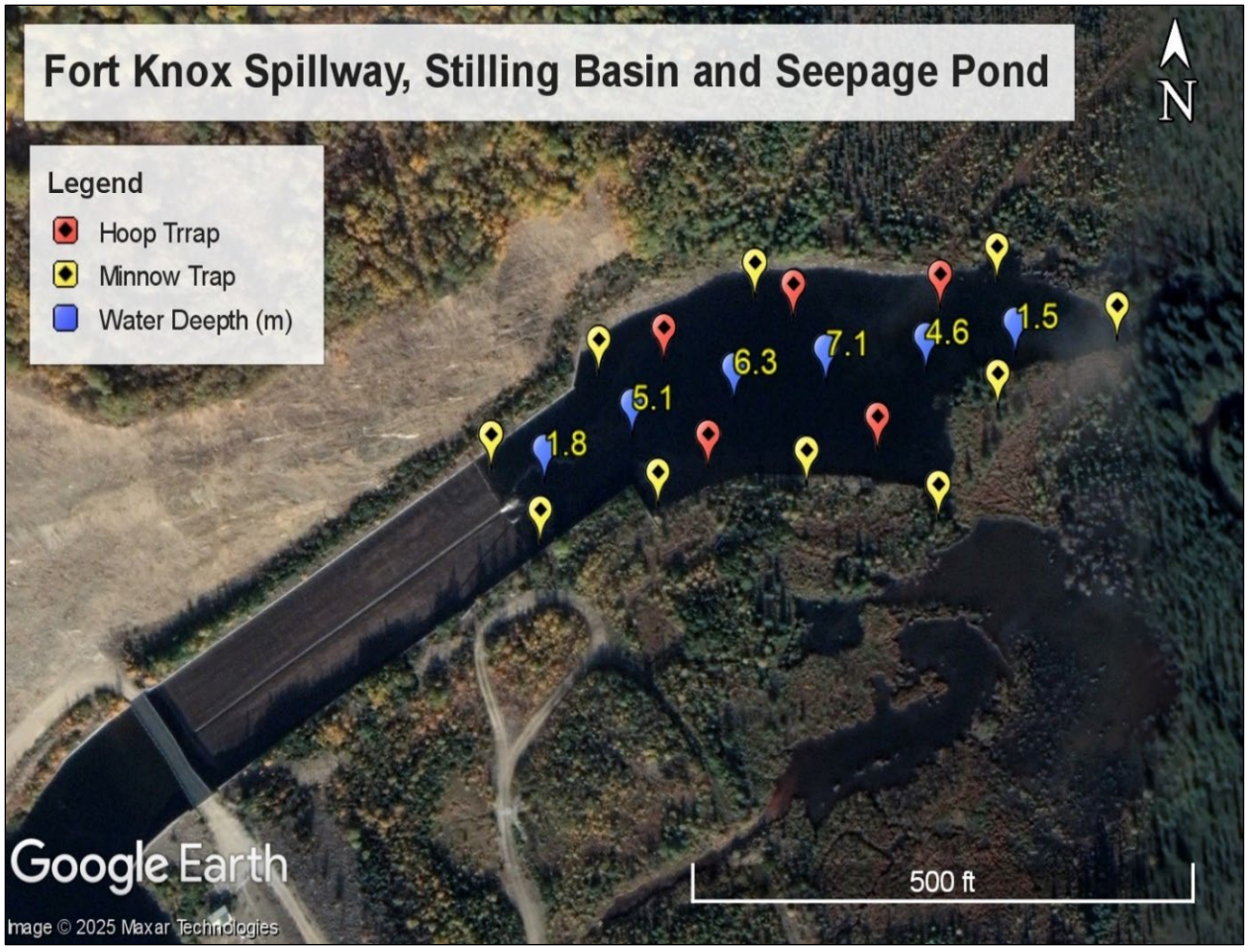

Figure 48. Stilling Basin Pond sample locations and bathymetry (depth in meters).

Results and Discussion

Population estimates of the Arctic grayling residing in the Stilling Basin were last performed in 2007–2009 and ranged between 815 to 1,159 fish (Ott and Morris 2010). During the 2019 Stilling Basin sampling, 71 Arctic grayling were captured and tagged during nine hours of angling effort, however a population estimate was not generated without a recapture event (Bear and Ott 2020). During 2024 sampling, six hours of angling effort yielded one Arctic grayling, with a second one hooked but not successfully landed. Based on the reduced capture rates, the current population of adult Arctic grayling is likely lower than 2007–2009 and 2019. Approximately 20 juvenile Arctic grayling were observed swimming in the shallow water around the basin's edge.

Arctic grayling recruit into the Stilling Basin over the WSR spillway. Arctic grayling tagged during spring sampling in the WSR and Fish Creek wetlands have been recaptured in the Stilling Basin during past sampling events (Bear and Ott 2020). Fish movement upriver from Fish Creek into the Stilling Basin is unlikely as the outlet typically has a large beaver dam creating a vertical obstruction. Multiple beaver dams also exist further downriver in Fish Creek drainage limiting fish movement. Arctic grayling residing in the Stilling Basin may be able to exit and move downstream in Fish Creek but are unlikely to return.

In August and September of 2022, the WSR spillway relief valve was opened, lowering the WSR water level approximately one meter for maintenance and inspections (Bear and Ott 2023). The resulting high-water event in the Stilling Basin may have caused resident Arctic grayling to exit and move downstream in Fish Creek. The current beaver dam at the outlet is less impassable compared to past years, Arctic grayling could be steadily exiting the Stilling Basin in search of cooler water or food downstream.

In 2024, eight burbot were caught in the hoop traps, with lengths ranging from 90 to 373 mm. Three burbot were ≥300 mm and tagged with a unique numbered Floy tag near the dorsal fin. Fourteen burbot were caught in ten minnow traps with lengths ranging from 45 to 150 mm. One 70 mm slimy sculpin was also captured. Minnow traps exclude large burbot from entering and typically capture more juvenile fish from the population.

The burbot catch rates are similar to the 2019 Stilling Basin sampling but larger burbot were captured during that event. In 2019, eight burbot ranging from 320 to 615 mm were captured and tagged during 22 hours of fishing effort. Two of these were recaptured burbot that had been tagged

in the WSR in October 2016, the first documented burbot to recruit from over the WSR spillway (Bear 2020). During the 2024 sampling no tagged burbot were recaptured from the 2019 Stilling Basin sampling or past WSR tagging events.

Current Issues

Out of the 22 burbot captured during the 2024 Stilling Basin sampling, 15 exhibited a milky appearance in one or both of their eye pupils. The ADF&G fish pathology lab report (No. 25-0016) confirmed the presence of larval *Diplostomulum* of the eye and *Myxobolus sp* in the gills. These infections are consistent with the eye fluke and gill identified in the burbot samples submitted during fall 2024 WSR sampling.

Conclusion

The WSR and developed wetlands remain vital components to the fish bearing capacity of the Fish Creek drainage. These water bodies provide overwintering, spawning and rearing habitats for both Arctic grayling and burbot. The Alaska Department of Fish and Game encourages Fairbanks Gold Mining Incorporated to continue supporting Fish Creek rehabilitation projects designed to improve the wetland ecosystem and enhance resident fish populations. Additionally, ADF&G endorses FGMI's active management of beaver populations within the developed wetlands, a necessary component to ensure Arctic grayling have access to spawning areas within the drainage.

To address emerging challenges collaboratively with FGMI, the ADF&G intends to continue performing the annual biomonitoring efforts focused on documenting water quality, aquatic habitat conditions, and fish health. By continuing this annual work, we may identify emerging issues, monitor their development, and ensure the long-term well-being of the aquatic habitat and fish populations.

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Appendix 1. A Summary of Mine Development with Emphasis on Biological Factors, 2011–2024[1]

2011

- February 9, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. ADF&G 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 May 9–24. ADF&G 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.

[1] The chronology for the years 1992–2010 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).

- September 28, ADF&G met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

2012

- ADF&G 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.
- ADF&G 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.
- 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, ADF&G 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.
- The 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.
- ADF&G 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 ADF&G began sampling, but by May 27 water had begun to flow out of the WSR and over the spillway.
- June 25, ADF&G 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, ADF&G 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, ADF&G 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).
- 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, ADF&G 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, ADF&G collected water quality data in the WSR which was ice covered, high DO concentrations were found in Fish Creek Bay.
- April 17, ADF&G 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, ADF&G field inspected the culvert replacement in Solo Creek and concluded that it had been installed in accordance with the Fish Habitat Permit.
- Spring 2015, ADF&G 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$200 mm) for spring 2014 was 5,841 – a slight reduction from the 2011 and 2012 estimates.
- The estimated population of large burbot ($\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, ADF&G 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, ADF&G 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.

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, ADF&G 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, ADF&G 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, ADF&G 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, ADF&G 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.
- 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 (≥200 mm) 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 the RO Channel.
- 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.
- 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 the RO Channel diverting the 3000 gpm of RO water from Outfall 002 into Fish Creek instead of the RO Channel.
- 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. The RO Channel site had higher water temperature (6.0°C) compared to WSR sites.
- April 12 to May 03, ADF&G 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 (95% CI 5,461–6,629 fish).
- June 15, FGMI received a Fish Habitat Permit to lower Centerline Road culvert to improve flow of RO water from Pond AB into the RO Channel.
- June 25–27, ADF&G captured 71 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 27–29, WSR water level lowered 1.70 vertical feet for required spillway structural inspection. Water discharged through Stilling Basin into lower Fish Creek.
- September 25–October 9, ADF&G 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 190–613 fish).

2020

- Fort Knox continued discharge of RO water into the RO Channel wetlands. Outfall 001 not operated in 2020. Outfall 002 discharged 9,663 acre-feet of RO water.
- The majority of discharged RO water confined to the RO Channel 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.
- April 10, water temperature in the RO Channel was 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 the RO Channel 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 (95% CI 4,114–4,808 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 (95% CI 142–264 fish).
- October 2020, Fort Knox began hauling ore to Barns Creek Heap Leach (BCHL) and began leaching processes.
- On 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 the RO channel wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 8,752 acre-feet of RO water.
- The majority of discharged RO water confined to the RO Channel 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 the RO Channel.
- On April 15, water quality data were collected at six sites in the WSR and two sites in the developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was higher than all previous year's data.
- On April 15, water temperature in the RO Channel was 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 the RO Channel to capture Arctic grayling and burbot moving into developed wetlands.
- Our estimated population of Arctic grayling (≥200 mm) for Spring of 2020 was 3,632 fish (95% CI 3,301–3,963 fish).
- From April 30 to May 12, 48 burbot were captured in the Fish Creek and the RO Channel fyke nets. Six of these were ≥300 mm and tagged with a unique numbered Floy tag. 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 Jun 9 and WSR water levels returned to normal.
- July–September, Gil Haul Road improvements cross Fish Creek and Gil Causeway. Three 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.

2022

- Fort Knox continued discharge of RO water from outfall 002 into the RO Channel wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 4,682 acre-feet of RO water.

- April 5, 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 14, ADF&G Habitat Section deployed HOBO temperature loggers into upper Fish Creek and the RO Channel.
- The WSR outlet spillway had substantial aufeis built up during the 2021/2022 winter, similar to what was observed in April 2020 and 2021.
- April 14, water quality data were collected at six sites in the WSR and two sites in the developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was the second highest year recorded at 6.71 mg/L.
- April 14, water temperature in the RO Channel was 2.69°C from warm RO discharge water compared to 0.84°C in Fish Creek from natural spring thawing.
- April 21, Fort Knox environmental staff submitted a wildlife mortality report for three dead Arctic grayling recovered from Pond AB. As part of their investigation and response efforts, Fort Knox stopped processing and discharging water from all three RO facilities until water test results were analyzed.
- April 22, ADF&G and FGMI staff performed wetlands survey to document any issues that may be affecting habitats. Arctic grayling were observed swimming in Fish Creek and no additional fish moralities were found.
- April 22, Heavy snowfall during winter 2021/2022 resulted in runoff entering Fish Creek creating turbidity, Fort Knox staff worked on stormwater diversion improvements during summer 2022.
- From May 2 to May 17 ADF&G spring sampling with two fyke nets placed in Fish Creek and the RO Channel to capture Arctic grayling and burbot moving into developed wetlands.
- From May 9 to 17 a fyke net was placed in Pond AB, the uppermost waterbody in the Fish Creek wetlands, and captured 165 Arctic grayling with an average size of 173 mm. These are the first documented grayling in Pond AB.
- Our estimated population of Arctic grayling (≥200 mm) for spring of 2021 was 3,090 fish (95% CI 2,763–3,417 fish).
- From May 2 to May 17, 35 burbot were captured in the Fish Creek and the RO Channel fyke nets. Five of these were ≥300 mm and tagged with a unique numbered Floy tag. One burbot was captured that had been previously tagged during past year's wetlands or WSR burbot sampling.
- August 22, Fort Knox initiated a WSR water drawdown to extend a culvert under FH permit FH15-III-0219-A2. The relief valve was closed on August 24 and WSR water levels returned to normal by September 16.
- August 26, Slippery Creek and Fish Creek near the Gil Project mine pits were sampled for fish presence. Forty-one Arctic grayling and 39 slimy sculpin were captured.

- September 6, during the Fort Knox WSR water drawdown two upland areas along the WSR were excavated and shallow water aquatic habitat was created within the WSR.
- Gil Causeway and Haul Road improvements and widening continue throughout the year including using excavated gravel from the WSR as road fill and berm stabilization.
- September 6–16, ADF&G staff sampled burbot in the WSR with hoop traps. The 2020 WSR burbot population is 302 fish (95% CI 171–432 fish).
- September 14–16, hoop traps were set in Pond AB and seven burbot were captured between 170 mm to 301 mm. These are the first burbot documented in Pond AB.
- October, 2022–April 2023, winter discharge rate of RO water was reduced to 1600 gpm and maintained during the winter.

2023

- Fort Knox continued discharge of RO water from outfall 002 into the RO Channel wetlands. Outfall 001 not operated in 2021. Outfall 002 discharged 1,260 acre-feet of RO water.
- April 14, water quality data were collected at six sites in the WSR and two sites in the developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was lower than recorded in 2021/2022 from the reduced RO discharge winter 2022/2023.
- April 14, the water temperature in the RO Channel near Pond AB was 1.66°C from warm RO discharge water compared to 0.01°C in Fish Creek near Pond F from natural spring thawing.
- The WSR outlet spillway had substantial aufeis built up during the 2022/2023 winter, similar to what was observed in April 2022.
- April 27, ADF&G Habitat deployed two hobo temperature loggers into Fish Creek at Pond F and the lower RO Channel near its confluence with Fish Creek.
- April 27, the lower RO Channel had aufeis filling the valley with water flowing over the glaciated ice. The water temperate near its confluence with Fish Creek was -0.08°C compared to 2.69°C in 2022. The reduced RO discharge rate allowed water to cool and freeze in the RO Channel. In years with high RO Water discharge a thawed channel and flowing water was present.
- From May 8 to 19 ADF&G sampled with a fyke net placed in Fish Creek and from May 15 to 19 a fyke net in the RO Channel (after it thawed) to capture Arctic grayling and burbot moving into developed wetlands.
- The 2022 WSR and Fish Creek wetlands population estimate of Arctic grayling (≥200 mm) was 4,594 fish (95% CI 4,066–5,121 fish).
- From May 8 to 19 a fyke net was placed in Pond AB, the uppermost waterbody in the Fish Creek wetlands. It captured 201 Arctic grayling with an average size of 237 mm.
- The 2022 Pond AB population estimate of Arctic grayling (≥200 mm) was 241 fish (95% CI 60–422 fish). This is the first population estimate generated for the potentially isolated Pond

AB fish. However, one tagged Arctic grayling from the WSR was captured in Pond AB, the first documented to move through the RO channel.

- September 11–20, ADF&G staff sampled burbot in the WSR with hoop traps. The 2022 WSR population estimate for burbot ≥400 mm is 295 fish (95% CI 144–447 fish).
- September 11–20, hoop traps were set in Pond AB and 25 burbot were captured between 280 mm to 355 mm with an average of 306 mm. A population estimate could not be generated with sufficient recaptures from the 2022 sampling event.
- October 1, 2023–April 30, 2024, winter discharge rate of RO water was reduced and maintained during the winter.

2024

- Fort Knox continued discharge of RO water from outfall 002 into the RO Channel Wetlands. Outfall 001 has not operated since 2021. Outfall 002 discharged 1,623 acre-feet of RO water.
- April 9, water quality data were collected at six sites in the WSR and two sites in the developed wetlands. Average dissolved oxygen at Site 2 (middle of the WSR) was slightly lower than recorded in 2022/2023 and significantly lower than peak RO discharge during 2020/2021.
- April 9, the WSR outlet spillway did not have aufeis built up during the 2023 / 2024 winter like past high RO discharge years (2019 – 2022).
- April 24, the RO Channel was mostly dry with very little spring melt water or discharged RO water flowing through the channel. The Pond AB outlet culverts had been blocked by beavers during winter 2023/2024 diverting discharged RO water into Fish Creek.
- April 24, the water temperature in Pond AB was 6.5°C from discharged RO water and cooled to 3.6°C at the Pond F outlet after flowing down Fish Creek.
- April 24, ADF&G Habitat deployed two hobo temperature loggers into Fish Creek at Pond F and the RO Channel downstream of the Pond AB culverts.
- April 29, ADF&G staff cleared the blocked Pond AB culvert returning discharged RO water to the RO Channel.
- April 29, ADF&G staff cleared the blocked Pond D outlet allowing Arctic grayling access further up Fish Creek wetlands increasing available spawning area.
- April 29–May 10, ADF&G sampling with fyke nets placed in Fish Creek and the RO Channel to capture Arctic grayling moving into the developed wetlands for spawning.
- The 2023 WSR and Fish Creek wetlands population estimate of Arctic grayling (≥200 mm) was 4,767 fish (95% CI 4,404–5,129 fish).
- May 3 to 10 a fyke net was placed in Pond AB, the uppermost waterbody in the Fish Creek wetlands. It captured 234 Arctic grayling with an average size of 261 mm.
- The 2023 Pond AB population estimate of Arctic grayling (≥200 mm) was 1243 fish (95% CI 866–1620 fish). Recaptured grayling tag #12273 was the second documented fish to move

from the lower RO channel into Pond AB but the population is still considered separate until significant movement is documented.

- Eight Arctic grayling whole body samples were sent to ACT Laboratories for element analysis comparison to pre-mining baseline data. All 2024 mean element concentrations lower than the 1994 baseline samples mean.
- July 31–August 2, ADF&G sampling conducted in the Stilling Basin. 1 Arctic Grayling captured, and the population may be lower than past years based on reduced ability to capture fish (n=71 in 2019). Eight burbot were captured with hoop traps, and 14 juvenile burbot with minnow traps. One slimy sculpin was also captured.
- 22 total burbot were captured in the stilling basin with 15 having milky appearances to one or both eyes. The ADF&G Fish Pathology Laboratory confirmed the presence of Larval *Diplostomulum* of the eye (Eye Fluke) and an unidentified *Myxobolus sp.* within the capillaries of the gills. Lab report No. 2025-0016.
- September 24–October 2, ADF&G staff sampled burbot in the WSR with hoop traps. The 2023 WSR population estimate for burbot ≥400 mm is 598 fish (95% CI 55–1,141 fish) but has a wide confidence interval from a low number of recaptured burbot (n=3).
- Ninety-nine total burbot were captured during the September 2024 WSR sampling. Thirty-five of the captured burbot had a milky appearance to one or both of their eye pupils. The ADF&G Fish Pathology Laboratory confirmed Larval *Diplostomulum* of the eye (Eye Fluke) and an unidentified *Myxobolus sp.* within the capillaries of the gills. Lab report No. 2025-0016.
- September 30–October 2, 2 hoop traps were set in Pond AB. Three burbot were captured between 295 mm to 355 mm. One burbot was recaptured from the 2023 sampling event.
- The 2023 Pond AB population estimate for burbot ≥300 mm is 22 fish (95% CI 8–35 fish).
- December 15, FGMI Wildlife Mortality Report: moose struck and killed on Fort Knox Gold Mine access road. State Troopers, ADF&G and ADEC notified.

Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 9, 2024.

Site Number (Name)	Depth (m)	Temperature (°C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	ORP (mV)
1 (Middle WSR)	1	0.2	73.0	10.4	96.0	6.7	305
	2	0.5	68.0	9.7	126.0	6.6	308
	3	1.0	59.0	8.2	131.0	6.6	308
	4	1.4	57.0	7.8	132.0	6.7	307
	5	1.7	52.0	7.1	133.0	6.7	308
	6	2.0	49.0	6.6	133.0	6.7	308
	7	2.1	45.0	6.0	134.0	6.6	308
	8	2.2	32.0	4.4	135.0	6.6	310
	9	2.4	26.0	3.5	137.0	6.5	310
	10	2.5	19.0	2.6	139.0	6.5	311
	11	2.5	9.0	1.2	145.0	6.4	313
	12	2.5	3.0	0.5	155.0	6.4	314
2 (WSR Near Dam)	1	0.3	57.0	8.0	123.0	6.6	310
	2	0.6	54.0	7.6	124.0	6.5	310
	3	1.0	50.0	6.9	130.0	6.6	310
	4	1.5	48.0	6.5	133.0	6.6	309
	5	1.7	47.0	6.5	133.0	6.6	309
	6	1.9	48.0	6.5	134.0	6.6	309
	7	2.1	45.0	6.1	134.0	6.6	309
	8	2.3	39.0	5.2	135.0	6.6	309
	9	2.4	21.0	2.8	137.0	6.5	309
	10	2.5	16.0	2.2	139.0	6.5	310
	11	2.6	6.7	1.1	145.0	6.5	311
	12	2.7	3.6	0.5	160.0	6.4	313
	13	2.8	2.4	0.3	180.0	6.4	254
	14	2.8	2.0	0.3	194.0	6.4	207
	15	2.8	1.8	0.2	204.0	6.4	185
	16	3.1	1.9	0.2	234.0	6.5	177
	17	3.5	1.8	0.2	277.0	6.6	179
3 (Solo Bay)	1	0.10	48.0	6.80	135.0	6.5	339
	2	0.50	48.0	6.70	137.0	6.4	324
7 (Last Chance Bay)	1	0.57	66.0	9.20	110.0	6.2	294
	2	0.70	49.0	6.90	127.0	6.2	296
	3	1.10	20.0	4.20	135.0	6.2	299

11 (Polar Bay)	1	0.30	80.0	11.20	91.0	6.7	300
	2	0.60	71.0	10.10	137.0	6.6	306
	3	1.00	60.0	8.30	138.0	6.6	307
	4	1.40	56.0	7.70	138.0	6.5	306
	5	1.70	55.0	7.50	138.0	6.5	307
	6	1.80	55.0	7.40	138.0	6.5	307
	7	2.00	54.0	7.30	138.0	6.5	307
	8	2.50	27.0	4.20	161.0	6.4	308
12 (Fish Creek Bay)	1	0.20	85.0	12.00	88.0	6.7	323
	2	0.30	83.0	11.80	88.0	6.6	322
	3	0.60	60.0	8.20	80.0	6.6	320
	4	1.00	29.0	6.10	75.0	6.6	318

Appendix 3. Population estimates of Arctic Grayling >200 mm in the Fort Knox Water Supply Reservoir (WSR), 1995–2023.

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]	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
2021		3,090	2,763–3,417
2022		4,594	4,066–5,121
2023		4,767	4,404–5,129

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

[2]In 1995, ADF&G 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]From 1998 through 2023 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, 2023–2024.

Upper Limit of Size (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Sample Size
210	43	55	33	4
220	35	53	21	4
230	31	63	15	9
240	27	48	15	24
250	25	48	5	39
260	23	40	7	76
270	22	40	1	58
280	19	36	0	50
290	17	43	4	36
300	13	34	0	29
310	6	16	0	9
320	6	14	0	6
330	8	12	5	5
340	2	2	1	2
350	0	0	0	0

Appendix 5. Population Estimate of Burbot (≥400 mm) in the Fort Knox Water Supply Reservoir (WSR), 2001–2023.

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	302	171–432
2021	No Population Estimates Performed	
2022	295	144–447
2023	598	55–1,141

Appendix 6. Population estimates of Arctic Grayling >200 mm in the Fort Knox Pond AB, 2022–2023.

Year		Population Estimate	95% Confidence Interval
2022		241	60–422
2023		1,243	866–1,620

Appendix 7. Winter (October 1 to April 30) water use from the WSR, 1997–2015.

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
No water was withdrawn from the WSR after 2014/15				

Appendix 8. Total RO water discharge from Outfall 001 and 002 into RO Channel Wetlands Complex, 2015–2024.

Year	Acre-Feet of RO Water[1]
2015	163
2016	461
2017	618
2018	806
2019	6,681
2020	9,663
2021	8,752
2022	4,682
2023	1,260
2024	1,623

[1]RO Water Discharged from Outfall 001 (2015–2018) and Outfall 002 (2019–2024).

Appendix 9. Fish Creek Juvenile Arctic grayling whole body element concentrations in dry weight, 1993.

Shaded cells indicate value was at or below method detection limit (MDL), so detection limit for that sample is reported. Detection limits for identified elements were based on % solids which varied for each fish.

Sample Number	Date collected	Length (mm)	Weight (g)	Al mg/kg	As mg/kg	Cd mg/kg	Pb mg/kg	Hg mg/kg	% Solids
080193FCRAGJ01	8/1/1993	175	53.4	47.5	<1	0.09	0.15	0.15	24.6
080193FCRAGJ02	8/1/1993	172	50.2	10.8	<1	0.07	0.04	0.24	25.8
080193FCRAGJ03	8/1/1993	171	48.0	73.3	<1	0.08	0.09	0.21	25.0
080193FCRAGJ04	8/1/1993	155	36.0	18.8	<1	0.06	0.09	0.19	23.8
080193FCRAGJ05	8/1/1993	168	46.3	15.0	<1	0.07	0.07	0.25	25.7
080193FCRAGJ06	8/1/1993	158	39.0	11.4	<1	0.07	0.05	0.23	24.3
080193FCRAGJ07	8/1/1993	168	43.8	8.6	<1	0.07	0.03	0.23	24.0
080193FCRAGJ08	8/1/1993	170	50.5	127.0	<1	0.09	0.12	0.19	25.0
080193FCRAGJ09	8/1/1993	171	54.8	168.0	<1	0.09	0.22	0.19	26.8
080193FCRAGJ10	8/1/1993	171	49.6	67.3	<1	0.09	0.08	0.21	25.2
080193FCRAGJ11	8/1/1993	165	45.0	15.2	<1	0.08	0.17	0.19	23.9
080193FCRAGJ12	8/1/1993	156	38.8	18.2	<1	0.06	0.04	0.2	25.0

080193FCRAGJ13	8/1/1993	169	42.8	20.7	<1	0.08	0.05	0.23	23.1
080193FCRAGJ14	8/1/1993	175	54.8	28.6	<1	0.07	0.07	0.29	25.2
080193FCRAGJ15	8/1/1993	176	53.4	14.7	<1	0.09	0.07	0.27	22.9
080193FCRAGJ16	8/1/1993	152	34.0	38.0	<1	0.15	0.06	0.18	23.4
080193FCRAGJ17	8/1/1993	155	37.9	56.6	<1	0.06	0.12	0.19	23.0
080193FCRAGJ18	8/1/1993	179	55.0	51.6	<1	0.09	0.07	0.21	24.0
080193FCRAGJ19	8/1/1993	164	40.6	17.4	<1	0.10	0.47	0.23	23.2
080193FCRAGJ20	8/1/1993	172	52.0	157.0	<1	0.06	0.15	0.13	24.1
080193FCRAGJ21	8/1/1993	158	38.8	20.2	<1	0.08	0.05	0.2	23.3
080193FCRAGJ22	8/1/1993	174	47.0	38.1	<1	0.06	0.07	0.19	22.3
080193FCRAGJ23	8/1/1993	178	55.0	2.2	<1	0.04	0.04	0.23	22.5
080193FCRAGJ24	8/1/1993	162	43.8	10.8	<1	0.07	0.04	0.28	24.9
Mean		167.3	46.3	43.2	<1	0.1	0.1	0.2	24.2
Standard Deviation		7.99	6.69	46.10	0.00	0.02	0.09	0.04	1.14

Appendix 10. Fish Creek Juvenile Arctic grayling whole body element concentrations in dry weight, 2024.

Shaded cells indicate value was at or below method detection limit (MDL), detection limit for that sample is reported. Detection limits for identified elements were based on % solids which varied for each fish.

Sample Number	Date collected	Length (mm)	Weight (g)	Al mg/kg	As mg/kg	Cd mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	% Solids
050524WSRAGJ01	5/5/2024	178	57.2	107.3	0.38	0.05	0.12	0.16	2.24	25.9
050524WSRAGJ02	5/5/2024	180	59.5	9.1	0.30	0.06	0.05	0.11	3.29	27.1
050524WSRAGJ03	5/5/2024	179	54.0	8.8	0.28	0.04	0.08	0.24	3.24	25.3
050524WSRAGJ07	5/5/2024	162	38.2	13.7	0.22	0.04	0.08	0.29	1.74	23.6
050524WSRAGJ08	5/5/2024	168	40.4	9.9	0.27	0.04	0.08	0.16	2.55	21.1
050524WSRAGJ09	5/5/2024	172	50.9	7.9	0.28	0.03	0.06	0.15	3.06	22.0
050524WSRAGJ10	5/5/2024	155	34.4	3.8	0.20	0.04	0.08	0.26	1.94	21.7
050524WSRAGJ11	5/5/2024	164	39.0	2.9	0.19	0.03	0.06	0.19	1.58	24.0
Mean		169.75	46.70	20.43	0.27	0.04	0.08	0.19	2.45	23.84
Standard Deviation		9.08	9.77	35.28	0.06	0.01	0.02	0.06	0.69	2.16