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Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2003

by Alvin G. Ott
and William A. Morris

Constructed Arctic Grayling Spawning Channel
Photograph by Al Ott 2000

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Acknowledgements

We thank Fairbanks Gold Mining Inc. (John Wild, Clyde Gillespie) for their continued support of our study to evaluate the fisheries resources in the water supply reservoir and developed wetlands. We also thank Fairbanks Gold Mining Inc. for their commitment to conduct concurrent rehabilitation in the wetlands downstream of the tailing dam and in Last Chance Creek. We thank Alaska Department of Natural Resources employees Nancy Ihlenfeldt, Jack Winters, and Alan Townsend, who assisted with fieldwork. Jack Winters and Clyde Gillespie provided constructive review of our report.

Executive Summary

Water Quality

- dissolved oxygen concentrations continue to be low in the water supply reservoir (WSR) – page 11
- dissolved oxygen concentrations decrease with depth in both summer and winter – page 11
- pH has shown a general decreasing trend since 1999 – page 14
- conductivity was highest in spring 1999 and very similar for the years 2000 through 2003 – page 14

Arctic Grayling

- Arctic grayling successfully spawned in the wetland complex in spring 2003 – pages 20 and 22
- Arctic grayling spawning in the wetland complex peaked on May 18, 19, and 20 when water temperatures peaked at 6.73, 7.04, and 6.57°C – pages 19 and 20
- the estimated population in spring 2002 was 6,503; slight increases have occurred each year since 1999 – page 23
- outmigration of fish in spring 2003 appeared to be less than in spring 2001 and 2002 – pages 16 and 17

Burbot

- successful spawning of burbot in the WSR continues based on catches of small juvenile fish in hoop traps and fyke-nets – pages 28 and 29
- the estimated population for burbot >200 mm in summer 2003 was 1,103, a substantial decrease from summer 2002 – pages 27 and 34
- the estimated population for burbot >400 mm in summers 2001, 2002, and 2003 was 134, 131, and 102 – page 28
- annual growth rates continue to be higher for the larger burbot (>400 mm) – pages 28 and 37

Introduction

Fairbanks Gold Mining Inc. (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located in the headwaters of the Fish Creek drainage about 25 km northeast of Fairbanks (Figure 1). The project includes an open-pit mine, mill, tailing impoundment, water supply reservoir (WSR), and related facilities.

During construction of the WSR dam, we monitored activities (e.g., stream diversions, erosion control, culvert placement) in the field and summarized the various aspects of dam construction (Ott and Weber Scannell 1996, Ott and Townsend 1997). Construction of the WSR dam and spillway was complete by July 1996.

Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of many disturbed habitats has been rapid. Wetland development began in summer 1998. A channel connecting wetlands to the WSR was constructed in May 1999. Civil work to stabilize Last Chance Creek and minimize aufeis was done in fall 2001. Repair work on the dike separating Ponds D and E was completed in summer 2002.

Fish research began in 1992 and focused on streams in and downstream of the project area (Weber Scannell and Ott 1993). In 1993, sampling to assess if a population of fish was available to colonize the WSR continued, and we started to collect fish data in abandoned settling ponds and mine cuts that would be flooded by the WSR (Weber Scannell and Ott 1994). Stream reaches above and below the proposed impoundment were sampled (Ott et al. 1995).

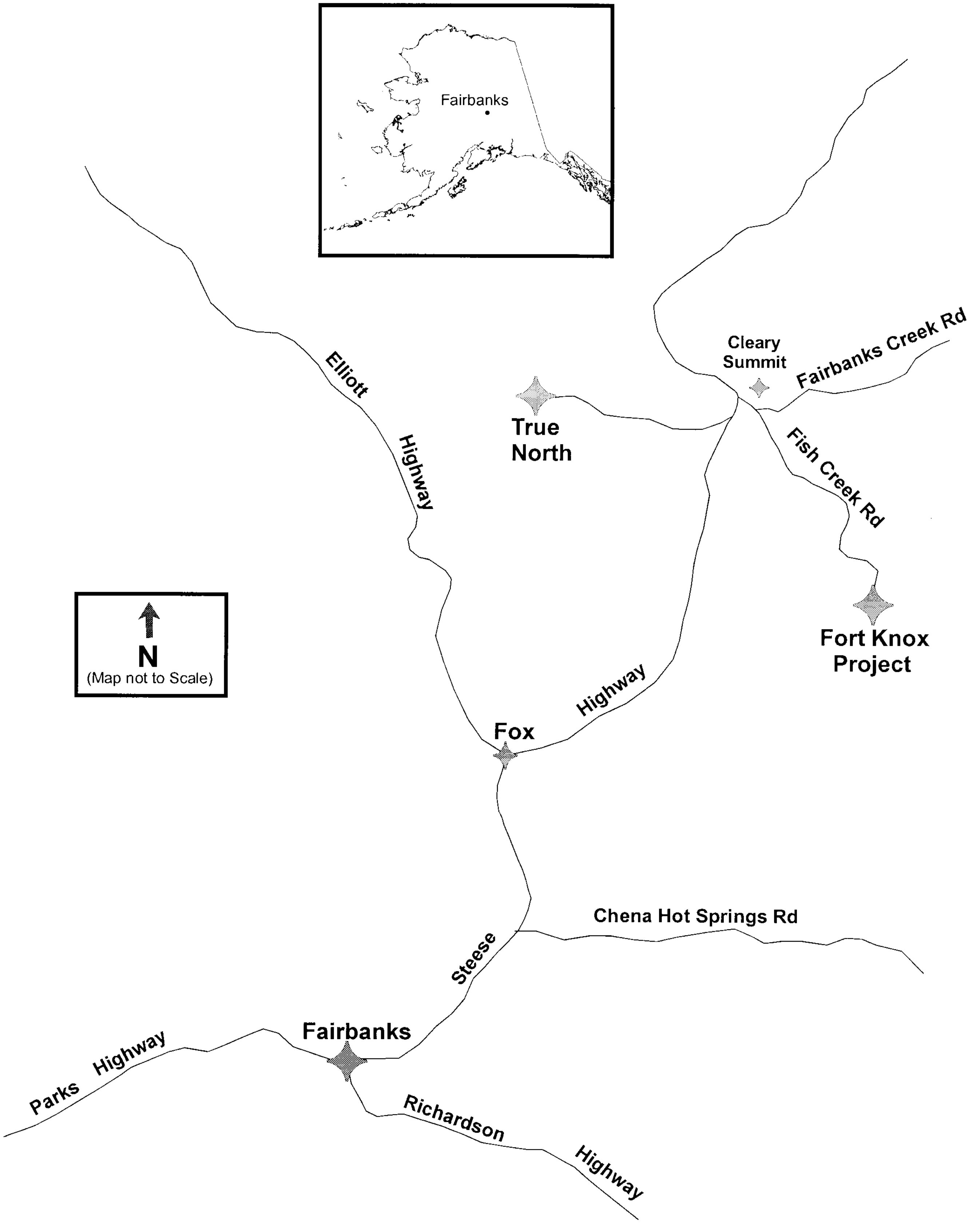


Figure 1. Fort Knox project location.

Stream sampling continued in 1995 and we estimated the Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to colonize the WSR. In 1995 the Arctic grayling population in Fish Creek, upstream of the proposed location of the WSR dam, was estimated at 1,700 fish <150 mm, and 4,350 fish >200 mm. The number of burbot, between 150 and 331 mm, in the upper Fish Creek drainage was estimated at 876 fish.

From 1996 to present, we have monitored the Arctic grayling and burbot populations in the WSR including estimates of their populations (Ott and Weber Scannell 1996, Ott and Townsend 1997, Ott and Weber Scannell 1998, Ott and Morris 1999, Ott and Morris 2000, Ott and Morris 2001, Ott and Morris 2002a, Ott and Morris 2002b). Water quality monitoring in the WSR began in 1997 and continues annually. Fisheries work was expanded to cover the wetlands in spring 1999 and in spring 2001 we began to capture fish in the stilling basin below the WSR spillway. Our report summarizes fish and water quality data collected during 2003 and discusses these findings in relation to previous work.

Methods

Sampling Sites

Multiple fyke-net sampling sites have been used (Figures 2 and 3) to target Arctic grayling. Changes in fyke-net locations have been due to finding the most effective catch sites and to major water surface elevation changes which can occur during spring when the WSR refills. Sites were added in the constructed wetlands after Channel #5 was constructed in spring 1999. In spring 2003, fyke-nets were fished at five stations (#6, #11, #16, #18, and #19). The general area for each fyke-net was fixed in spring 2003 as the sites were not affected by the water surface elevation in the WSR. In spring and fall 2003, hoop traps targeting burbot were fished throughout the WSR, both east and west of the Gil Extension road crossing.

Water Quality

Temperature (°C), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance (u S/cm), and depth (m) were measured with a Hydrolab® Minisonde® water quality multiprobe connected to a Surveyor® 4 digital display unit. The meter was calibrated to suggested specifications prior to use in the field. The DO oxygen concentration was calibrated using the open-air method. Conductivity and pH were calibrated with standard solutions. Water quality measurements were made at the surface, at 1 m depth intervals, and at the bottom.

Fish

Field sampling methods and gear included visual observations, fyke-nets, seines, and hoop traps (Figure 4). Prior to setting burbot hoop traps, DO oxygen profiles were run at the five water quality sites to ensure adequate DO concentrations were present. When DO concentrations are low (e.g., < 3 mg/L at depth), hoop traps are placed in shallow areas to avoid the low DO deep water areas. Burbot and Arctic grayling >200 mm captured during May and June were measured and marked with a numbered Floy® internal anchor tag. During the burbot recapture event in late fall, fish were measured and marked fish recorded, but new tags were not placed on unmarked fish.

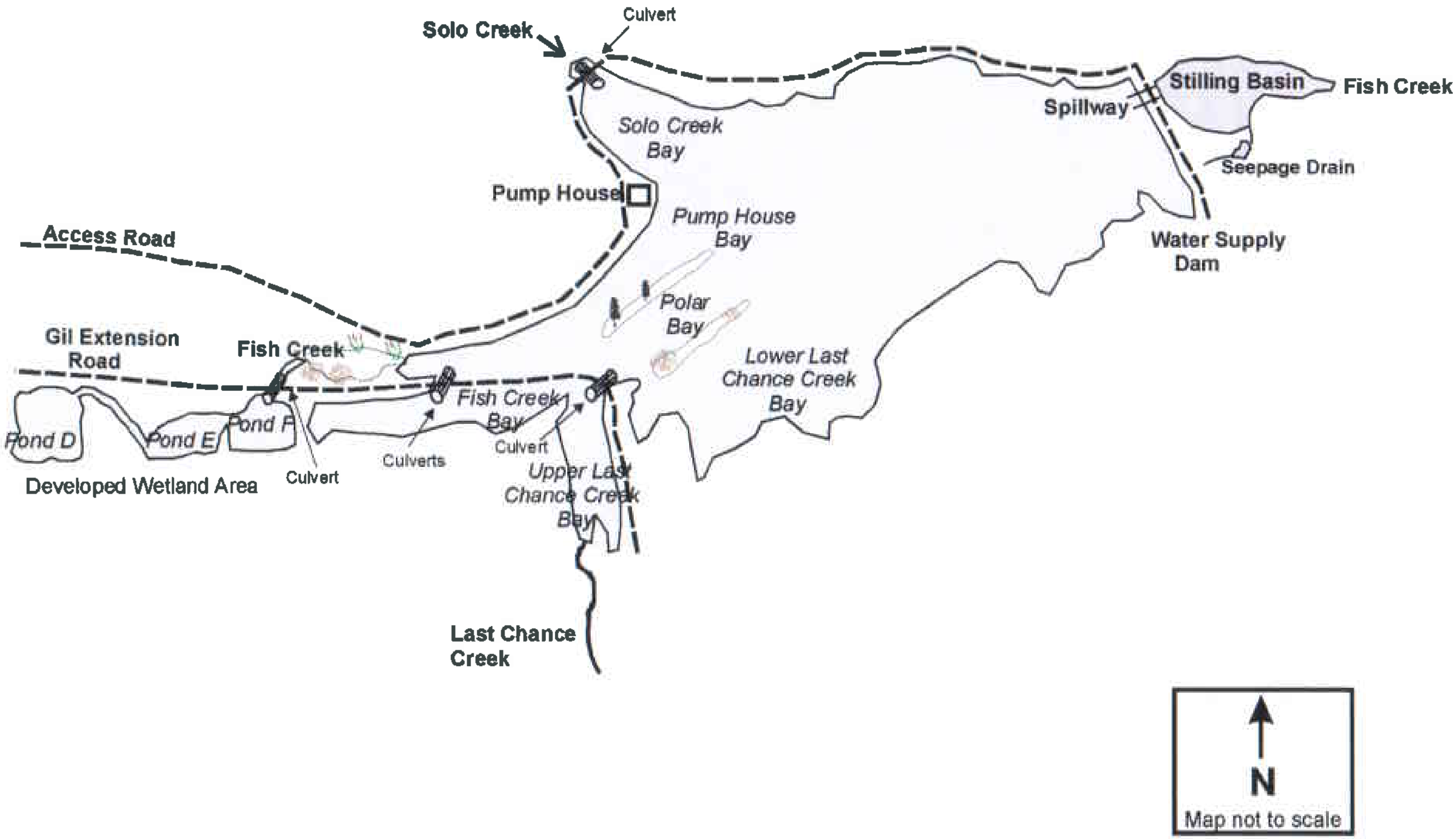


Figure 2. Sample areas in the Fort Knox WSR, stilling basin, and developed wetlands.

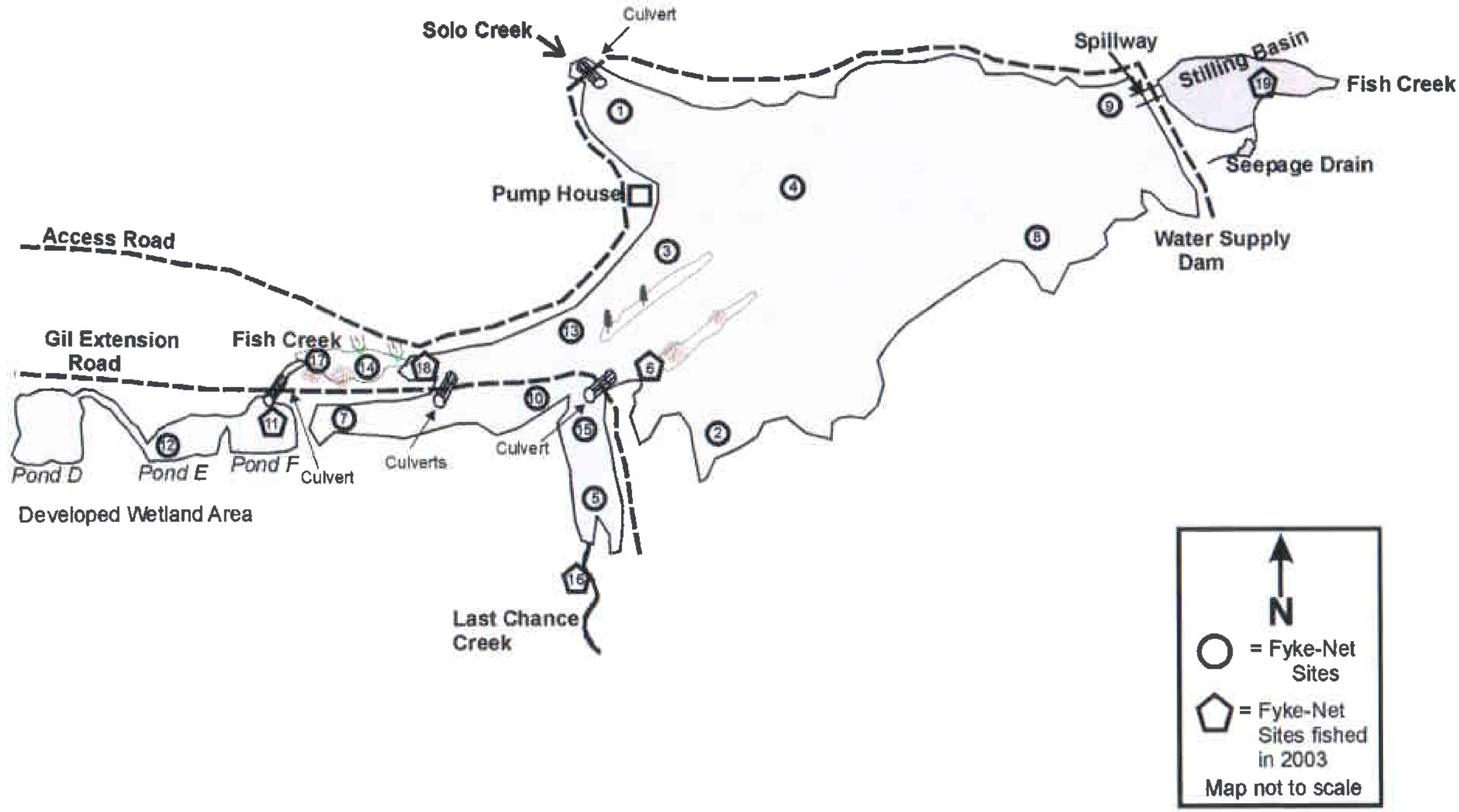


Figure 3. Fyke-net sample sites in the Fort Knox WSR, stilling basin, and developed wetlands (1996-2003).

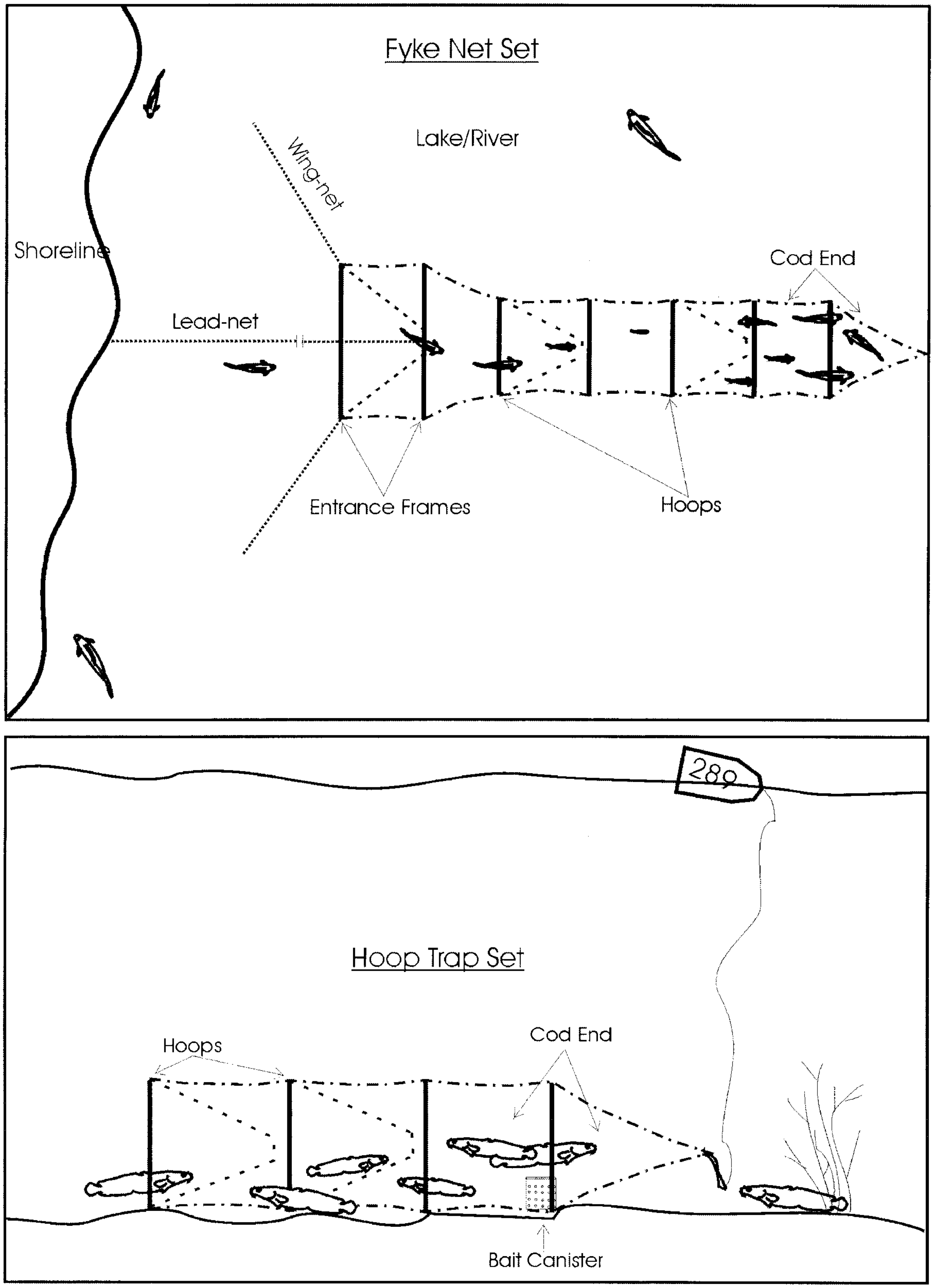


Figure 4. Diagram of fyke-net and hoop trap sets.

Three sizes of fyke-nets were used. Entrance frames were either 0.9 m^2 or 1.2m^2 or 0.69 m by 0.99 m (mini-fyke). The larger fyke-nets were 3.7 m long, had five hoops, a 1.8 m cod end, and two 0.9 m by 7.6 m wing nets attached to the entrance frame. The mini-fyke nets were 3.7 m long, had four hoops, a 1.8 m cod end, and two 0.91 m by 4.6 m wing nets. All netting was 10 mm square mesh. Center leads varied from 7.6 m to 30.4 m and were deployed to the maximum extent possible without submerging the top of the entrance frame. Nets were set with the center lead either perpendicular to or at an angle to the shore. Generally, fyke-nets were checked every 24 hours.

Hoop traps baited with whitefish were used to capture burbot. Traps generally were fished 24 hrs and were rebaited if reset. Hoop traps were 1.6 m long with four hoops 54 cm in diameter. Netting was 8.5 mm bar mesh. All traps were kept stretched and open with spreader bars. Each trap had two throats and a cod end that was tied shut.

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

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

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

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

95% CI for the population estimate was calculated as

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

Results and Discussion

Water Supply Reservoir, Water Quality

Five water quality sites were established and sampled in the WSR beginning in fall 1997 (Figure 5). Two new sites were added in fall 2002 -- both located upstream of the Gil Causeway crossing. Data collected at Site #1 are presented in Appendix 1.

Ponding of water in the WSR began in November 1995. Water levels varied greatly in 1996 and 1997, due to water use and winter seepage below the dam that exceeded freshwater input. The WSR reached the projected maximum surface elevation of 1,021 feet on September 29, 1998 following a period of appreciable rainfall. The WSR contains 3,363 acre-feet (1.096 billion gallons) of water.

Water levels during summers 1999 and 2000 were fairly constant and flow through the low-flow channel in the spillway was present. In winter 2000/2001, about 1,464 acre-feet (477 million gallons) of water was pumped from the WSR to the tailing impoundment and water did not flow over the spillway until mid-summer 2001 (Table 1). Water use during winters 2001/2002 and 2002/2003 was minimal. During 2002/2003, water flowed through the spillway all winter except for about two weeks.

Table 1. Winter water use from the WSR, 1997 through 2003.

Year	Acre-Feet of Water Removed
1997/1998	660
1998/1999	605
1999/2000	577
2000/2001	1,464
2001/2002	320
2002/2003	337

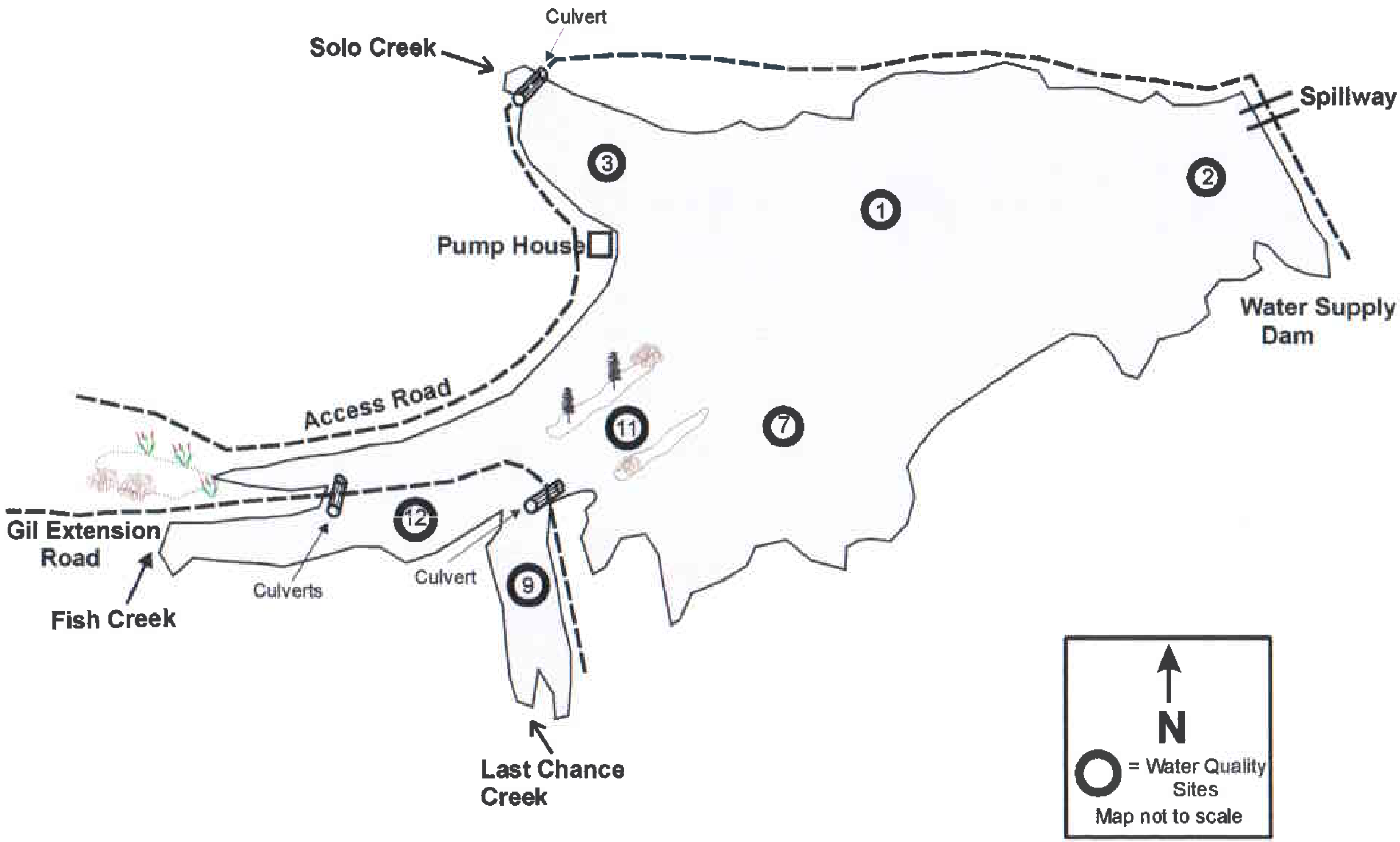


Figure 5. Water quality sample sites in the Fort Knox WSR.

Seepage flow below the WSR dam is monitored frequently. Seepage flow has remained fairly constant for the last four years (Table 2).

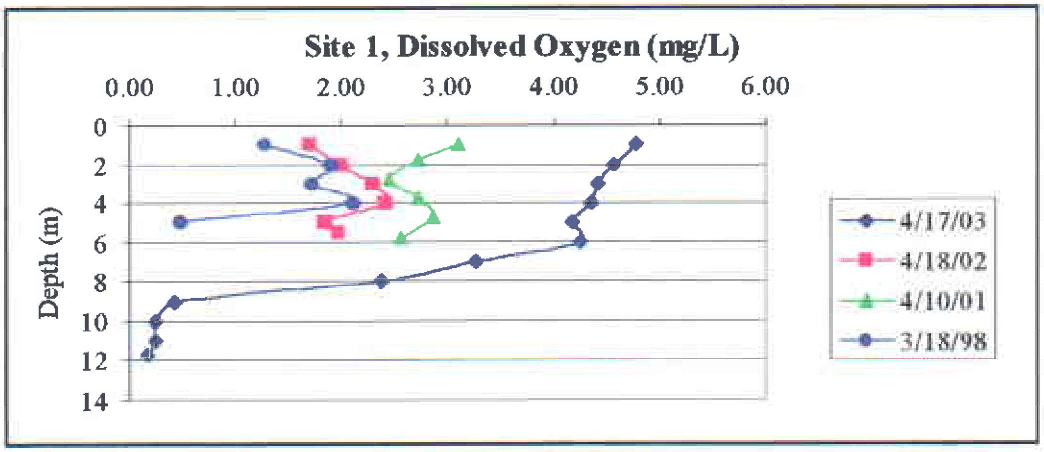
Table 2. Seepage flow rates below the WSR dam.

Year	Rate of Flow (cfs)	Geometric Mean (cfs)
1999	1.16 to 1.82	1.47
2000	1.03 to 1.86	1.38
2001	1.03 to 1.78	1.31
2002	1.13 to 1.78	1.41
2003	1.13 to 1.78	1.36

Water quality information was collected in the WSR in April (late winter) and in late May (immediately after the WSR was ice-free) in 2003. Comparisons among sample years were made using Site #1 that is located in about the middle of the WSR. Site #1 is affected by freshwater input from both Last Chance and Solo creeks.

In late winter at Site #1 in 2003, dissolved oxygen decreased with depth (Figure 6). The highest DO concentrations were seen in late winter 2003, with the lowest in late winter 1998. Increased DO concentrations at certain depths as seen in 1998, 2001, and 2002 probably are due to freshwater input from Last Chance and Solo creeks.

In early spring at Site #1 in 2003, DO concentrations decreased with depth and were the lowest observed since 1999 (Figure 7). The highest DO concentrations were seen in spring 1999. Decreased DO concentrations with depth have been seen each spring since 1999, except for spring 2002. On May 28, 2002, both DO concentration and temperature profiles by depth were similar, indicating that water was completely mixed when samples were taken.



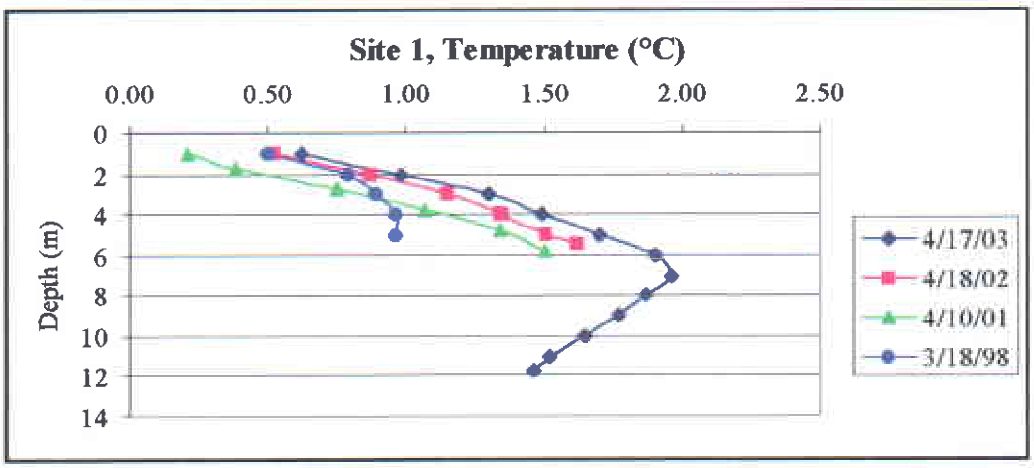
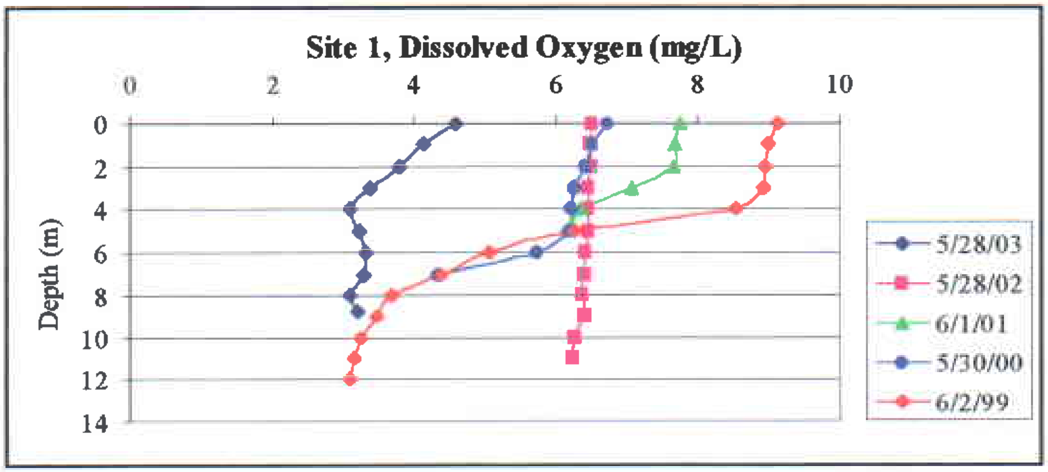


Figure 6. Dissolved oxygen concentration and temperature at Site #1 (middle of WSR) by depth in late winter 1998, 2001, 2002, and 2003.



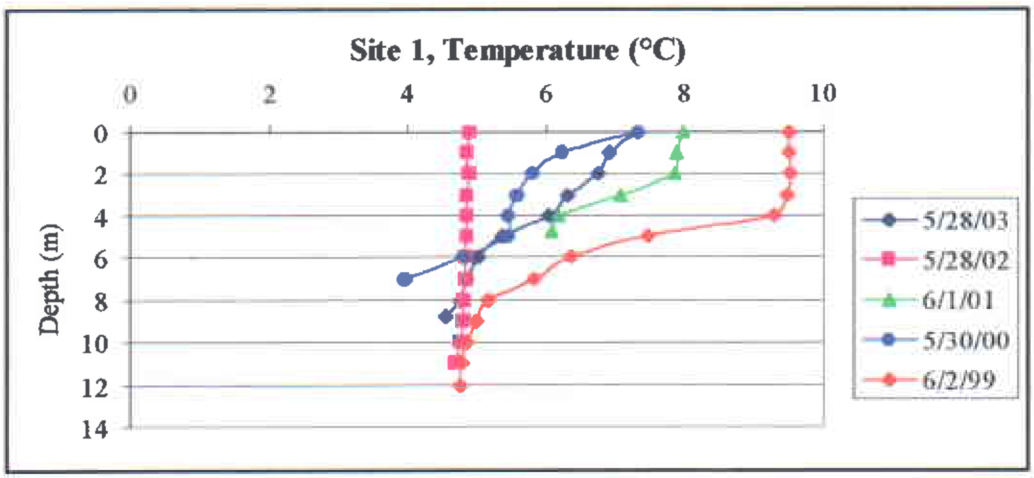


Figure 7. Dissolved oxygen concentration and temperature at Site #1 (middle of WSR) by depth in early spring 1999 through 2003.

Conductivity and pH measurements at Site #1 during early spring were compared among sample years. The general trend from 1999 to 2003 has been for a decrease in pH, except for a slight increase in spring 2001 (Figure 8).

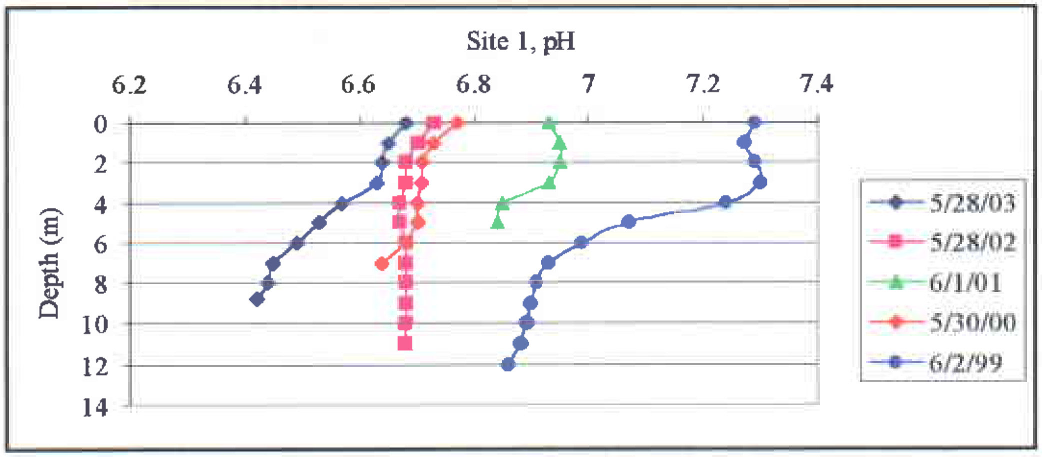


Figure 8. The pH in the WSR at Site #1 in early spring 1999 through 2003.

Conductivity was highest in spring 1999 and very similar for the years from 2000 through 2003, although there was a slight increase in 2001 (Figure 9). Again, there was more freshwater input in spring 2001 that would have mixed with the WSR waters due to the drawdown (i.e., water use) in winter 2000/2001.

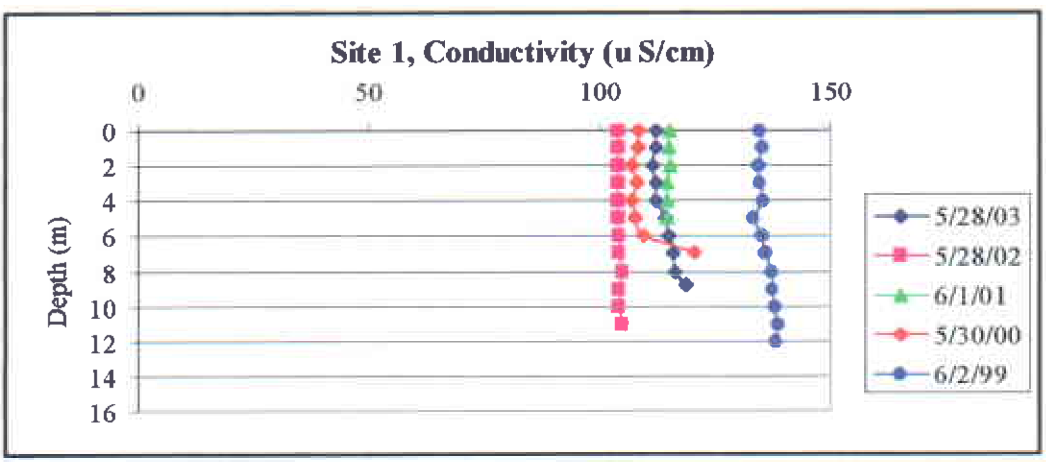


Figure 9. Conductivity in the WSR at Site #1 in early spring 1999 through 2003.

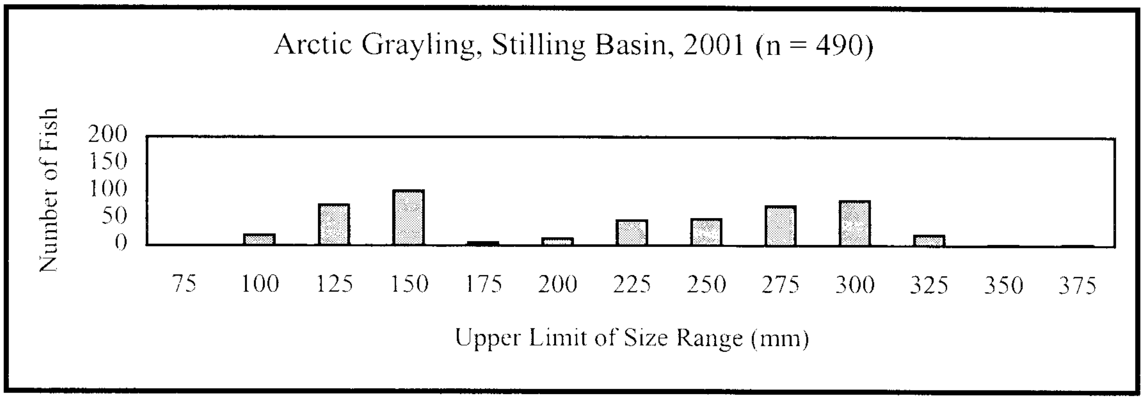
The trend in pH and conductivity appear to be related to the volume of freshwater input in the spring relative to the quantity of water used from the WSR the previous winter. In spring 1999 both pH and conductivity were higher and, as stated earlier, the WSR did not reach full capacity until fall 1998. The WSR stratifies quickly following breakup, thus minimizing potential mixing of surface water input with waters in the WSR. The slight increase in both pH and conductivity in spring 2001 probably was the result of freshwater input that had to mix with water in the WSR because of the substantial water use during winter 2000/2001. We plan to continue the water-quality sampling program, but will expand sampling to include surface water input that we believe have a higher pH and conductivity.

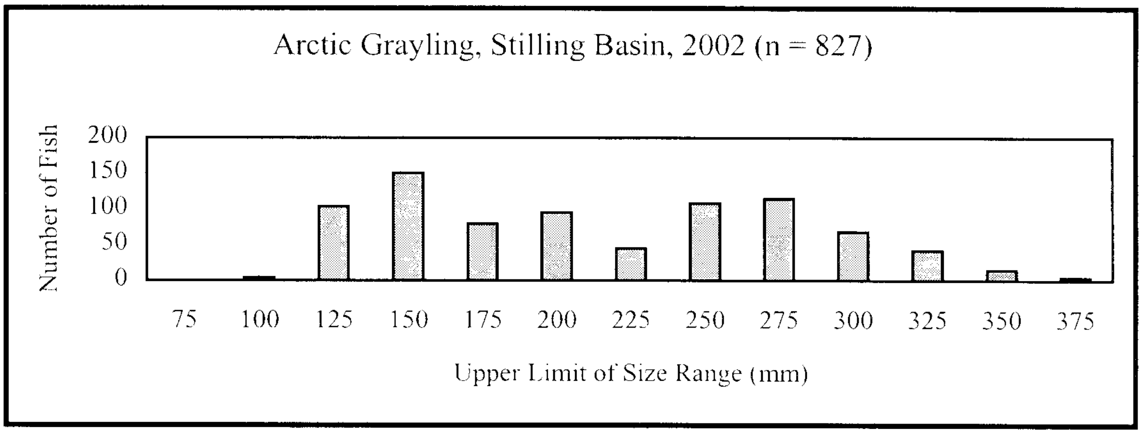
Stilling Basin, Arctic Grayling and Burbot

The stilling basin, located immediately downstream of the WSR spillway, is fed by groundwater, seepage flow, and by surface flow from the WSR (Figure 3). In spring 2003, we sampled the stilling basin with one fyke-net for an eight-day period. The sample event was designed to gather information relative to the number of fish in the stilling basin and the number of fish leaving the WSR. Sample effort in 2001 and 2002 was much greater than in 2003 so comparisons among years is limited.

We caught 213 Arctic grayling in the stilling basin in spring 2003. In 2002, all fish under 200 mm were marked with an adipose clip. In 2003, we caught nine Arctic grayling with this mark. We also caught nine fish with Floy-tags® that were marked in the WSR; three of those fish were tagged in spring 2003. The number of Arctic grayling and recaptured fish in spring 2003 indicate that outmigration was less in 2003 than in 2002. Length-frequency distribution for Arctic grayling caught in 2001, 2002, and 2003 are shown in Figure 10.

We caught 10 burbot in the stilling basin in 2003. None of the burbot were marked. In three years of sampling in the stilling basin, we have not caught a burbot that was marked in the WSR. Our sample effort in future years will be set up to reflect the same sample time and effort as in 2003.





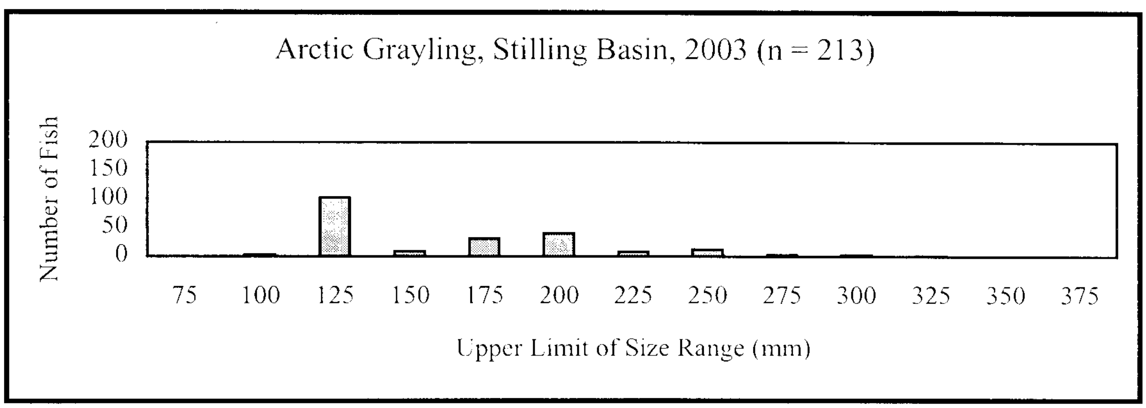


Figure 10. Length frequency distribution of Arctic grayling captured in the stilling basin below the WSR in spring 2001, 2002, and 2003.

Water Supply Reservoir, Last Chance Creek, and Developed Wetlands, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. Fish were most concentrated in Lower and Upper Last Chance Creek ponds and overwintered in these flooded placer mine cuts. The Arctic grayling in these ponds were characterized as stunted: fish larger than 220 mm long were rare; annual growth rate was 9 mm; and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning primarily occurred in outlets and inlets between Polar Ponds #1 and #2. Adult Arctic grayling also used Last Chance Creek for spawning, but based on visual observations success was never high. All of these ponds have been flooded by the WSR and are now referred to as Upper Last Chance and Polar bays (Figure 2).

Flooding of the Fish Creek valley by the WSR inundated Polar Ponds #1 and #2, thus eliminating the Arctic grayling spawning habitat associated with the pond complex. After flooding of the WSR, catches of age-0 Arctic grayling from 1996 through 1999 were very low.

Ponds C, D, E, and F were interconnected, fed by surface flow during some breakups, but only by ground water during the remainder of the ice-free season. Flow through the pond complex is relatively stable, and not influenced by normal rainfall events. These conditions (i.e., stable flow, warm water, stream and wetland habitats) are ideal for Arctic grayling spawning and survival and growth of age-0 fish. Water flow out of the pond complex entered the WSR via a perched culvert that did not provide for the upstream passage of fish. It should be noted that the perched culvert was installed in 1995 in accordance with an approved plan and a Fish Habitat Permit. Fish passage was not provided to allow potential use of the wetland as a passive treatment facility for total dissolved solids at mine closure.

The near absence of age-0 Arctic grayling from spring 1996 through 1998 led to the decision to construct a channel from Pond F to the WSR. In spring 1999, FGMI constructed the outlet channel (Channel #5, Figure 2). Immediately upon completion of construction, Arctic grayling entered the channel and associated wetland complex to spawn. From spring 1999 through 2001, Arctic grayling spawned successfully in

Channel #5, in the pond complexes, and in interconnecting channels. In 2002, spawning was limited to Channel #5 and Ponds E and F due to extensive aufeis (about 4 m thick) upstream in Ponds C and D that kept water temperatures in these reaches cold (< 4.0°C). Arctic grayling successfully spawned throughout the wetland complex in spring 2003 with most of the spawning occurring in the Channel #5 and in the channel connecting Ponds D and E.

Arctic Grayling Spawning (Timing – Temperature)

In spring 2003, we fished fyke-nets in the developed wetlands, the WSR, and Last Chance Creek from May 5 to May 23 to mark new fish with numbered Floy-tags®, to recapture marked fish, and to gather information on the relationship between water temperature and Arctic grayling spawning. Continuous temperature data recorders were set in known spawning areas in the Pond F outlet channel, the channel connecting D and E Ponds, the upper portion of Channel C (inlet to Pond D), and in Last Chance Creek. Arctic grayling were first captured in Pond F on May 6. Large numbers of spawning fish were seen in the Pond F outlet channel on May 18, 19, and 20 when water temperatures peaked at 6.73, 7.04, and 6.57°C (Figure 11 and Table 3). The number of adult female Arctic grayling handled in the wetland complex in spring 2003 during spawning was 872.

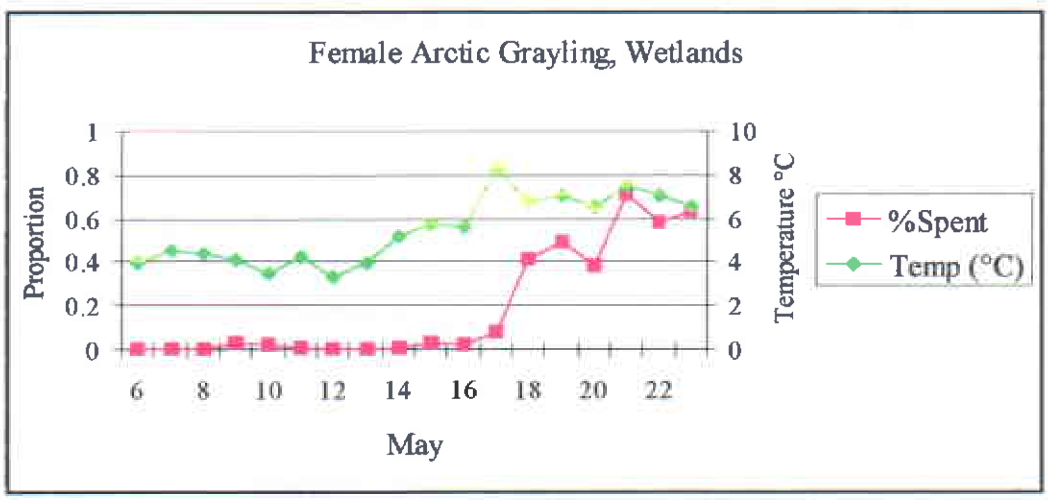


Figure 11. Peak daily water temperature in Pond F outlet channel and % of females captured judged to be spent.

Table 3. Chronology of Arctic grayling spawning in the Fort Knox developed wetlands in spring 2003.

Date	Description of Field Work, Fish Catches, and Spawning Activity
May 1, 2003	Stowaway temperature probes placed in Pond F outlet and channel between Ponds C and D
May 5, 2003	Fyke-net set in Pond F outlet
May 6, 2003	Second fyke-net set in wetland complex outlet in Water Supply Reservoir, Arctic grayling adults captured in Pond F outlet fyke-net
May 7, 2003	Arctic grayling adults captured in both fyke-nets
May 15, 2003	Active spawning observed in Pond F outlet and in the channel between Ponds D and E, first spent females caught
May 18, 2003	Large number of spawners in Pond F outlet channel, active spawning observed in Pond D outlet
May 19, 2003	Large number of spawners in Pond F outlet channel, active spawning observed in Pond D outlet
May 20, 2003	Still large numbers of spawners in Pond F outlet channel
May 21, 2003	Very little spawning activity in wetland complex
May 22, 2003	Very little spawning activity in wetland complex
May 23, 2003	Very little spawning activity in wetland complex

Visual observations of Arctic grayling to assess spawning were made in Last Chance Creek, in the channel connecting Ponds D and E, and in Channel C. A fyke-net was fished in Last Chance Creek from May 10 to 23, 2003. The Last Chance net was set later due to instream ice and aufeis. Adult Arctic grayling were captured, but catches were low. We caught only 38 females during the sample period. By comparison, in the wetland complex we handled 872 female Arctic grayling.

Spawning activity was not observed in Last Chance Creek. As in 2002, adult fish left Last Chance Creek without spawning. Some spawning was seen in Channel C and moderate numbers (10 to 20) of spawners were present in the channel between Ponds D and E. Water temperatures in Last Chance Creek were cold throughout the spring 2003 sample event due to massive aufeis in reaches of the stream upstream of the fyke-net. Peak water temperatures in Last Chance Creek, Pond F outlet, the channel between Ponds D and E, and in Channel C are shown in Figure 12. The majority of the fish spawned in the Pond F outlet channel where water temperatures warmed the quickest.

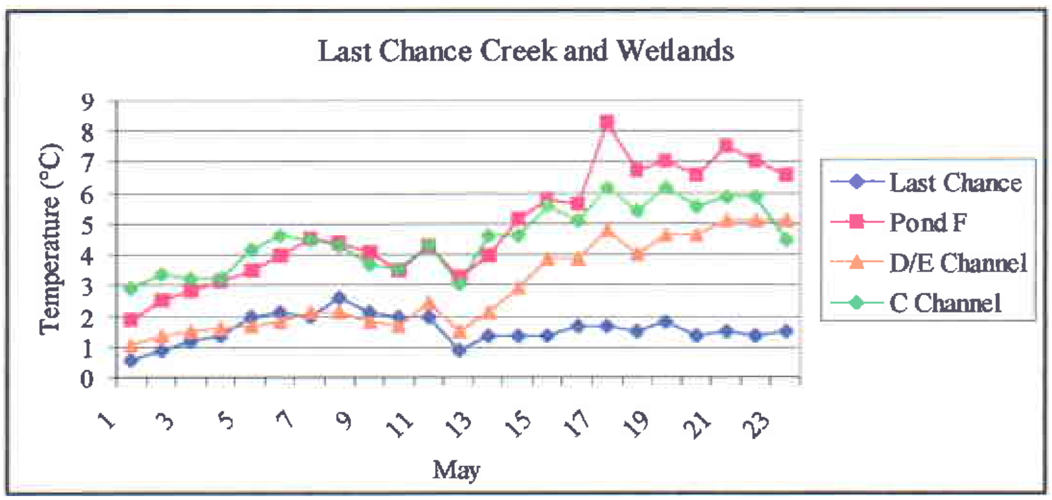


Figure 12. Peak water temperatures in spring 2003 in Last Chance Creek, Pond F outlet, the channel between Ponds D and E, and in C channel.

Peak spawning by Arctic grayling in the wetland complex occurred from May 30 to June 2 in 2002 (Ott and Morris 2002b) and from May 18 to 20 in 2003. In 2003 it was apparent, based on catches after May 20, that small numbers of new ripe females continued to enter the system. Thus, spawning by Arctic grayling continued well into June 2003.

Visual surveys for age-0 Arctic grayling were made in late June 2003 in Last Chance Creek and in the developed wetlands. No age-0 fish were seen in Last Chance Creek. Large numbers of age-0 fish were present in the developed wetlands, particularly in Ponds E and F and in Pond F outlet. Age-0 Arctic grayling also were observed feeding on the surface in Solo Bay. Length of Arctic grayling age-0 fish in summer 1999, 2002, and 2003 are presented in Table 4. The average size of age-0 fish in early September 1999 and 2002 was similar. The highly variable sizes of age-0 fish in 2002 and 2003 reflect an extended time frame for spawning and the variety of rearing habitats (shallow ponds and streams in wetland complex) available.

Table 4. Age-0 Arctic grayling caught in the wetland complex in summer 1999, 2002, and 2003.

Date	Number of Fish	Average Length (mm)	Range (mm)	Standard Deviation
9/1/99	21	91	76-97	5.4
7/19/02	41	44	32-57	4.8
8/22/02	113	84	66-102	7.2
9/3/02	145	88	60-114	9.5
6/25/03	20	28	21-46	7.3
7/28/03	50	59	33-75	8.4
8/9/03	65	72	58-113	11.1

Arctic Grayling (Mark/Recapture, Population Estimate, and Growth)

We estimated the abundance of Arctic grayling in the WSR using spring 2002 as the mark event (n_1 = 1252) and spring 2003 as the recapture event. In spring 2003, we caught 1,904 Arctic grayling > 220 mm (n_2 = 1904), with 366 recaptures (m_2 = 366). Our spring 2002 estimated Arctic grayling population in the WSR for fish > 200 mm was 6,503 (95% CI 6,001 to 7,005) (Figure 13, Appendix 2).

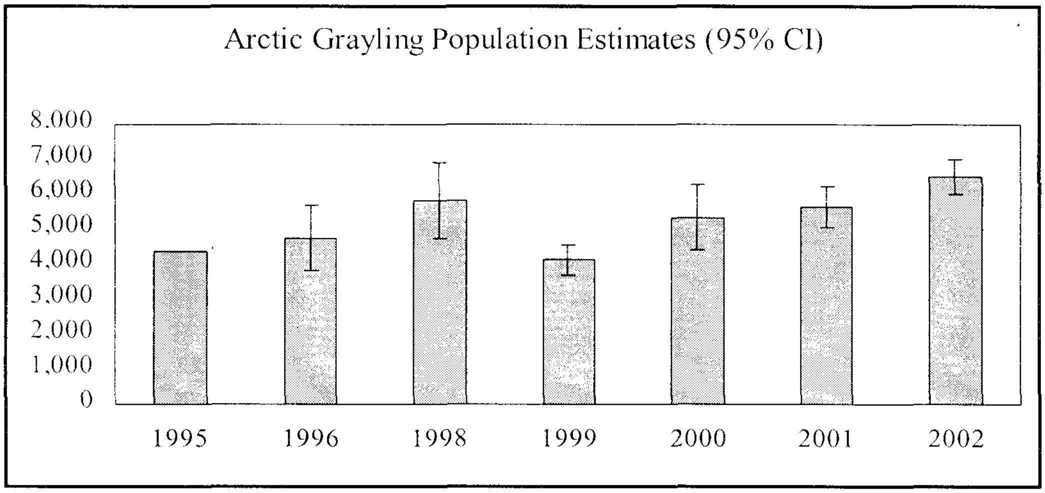
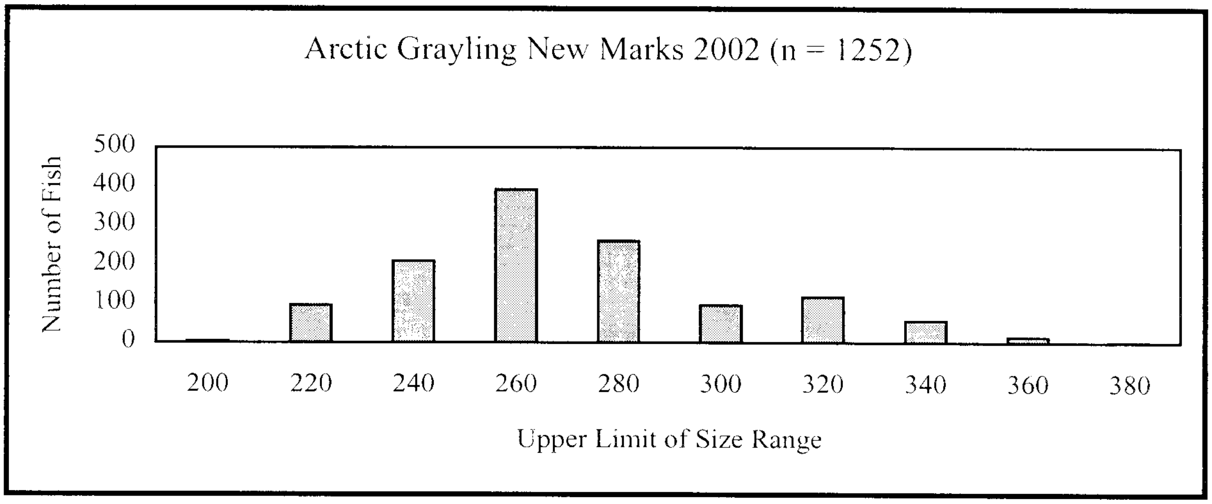


Figure 13. Estimates of the Arctic grayling population in the WSR at the Fort Knox Mine (1995-2002).

For our 2002 estimated Arctic grayling population we did not include fish that had been marked prior to 2002. Tag loss has shown a trend towards larger fish losing tags at a differentially higher rate than smaller fish (Ott and Morris 2002b). Therefore, our spring 2002 mark event of 1,252 fish includes only fish tagged in 2002.

We compared the length frequency distributions for fish marked in 2002 with those recaptured in 2003 to eliminate those fish handled in 2003 that would have been too small (<200 mm) to mark in 2002. Our comparison of the length frequency diagrams indicated that fish < 220 mm in spring 2003 should not be included in the population estimate (i.e., they would have been too small in 2002 to have been marked (Figure 14).



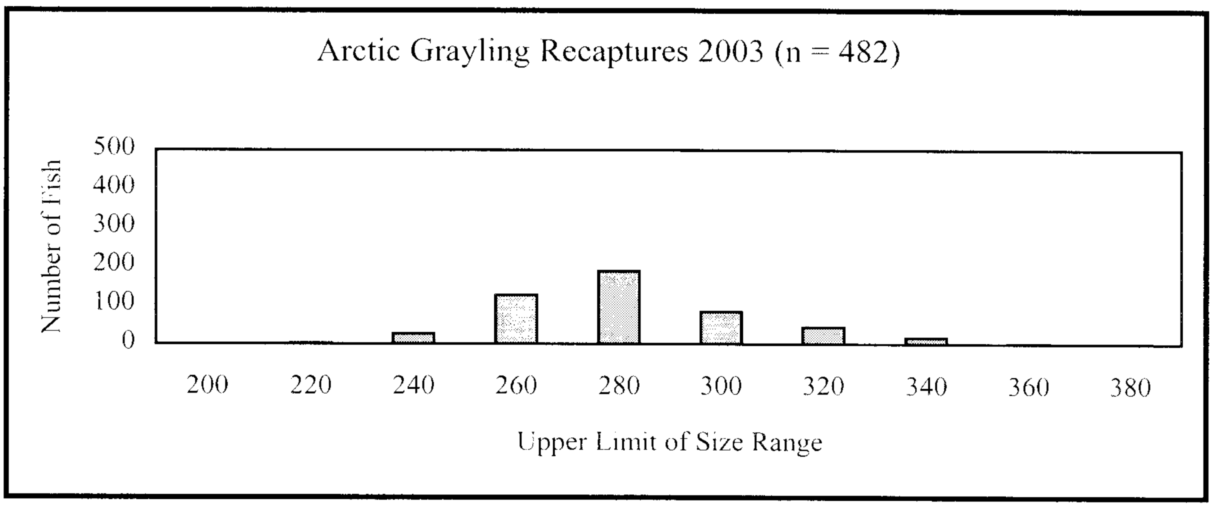


Figure 14. Length frequency distribution of Arctic grayling tagged in spring 2002 and recaptured in spring 2003 in Last Chance Creek, the WSR, and the developed wetlands.

In spring 2002 and 2003 we had a sufficient number of recaptures to show growth rates by size. Average growth of Arctic grayling prior to construction of the WSR was 9 mm per year. Once the WSR was flooded, annual growth rates from 1996 through 1998 were 41, 38, and 39 mm (Ott and Morris 2002a). Annual growth rates from spring 2002 to spring 2003 for Arctic grayling < 210 mm when tagged averaged 34 mm (Figure 15). Generally, growth rates appear to have slightly decreased in 2002/2003 compared with 2001/2002 for the various size ranges (Figure 15).

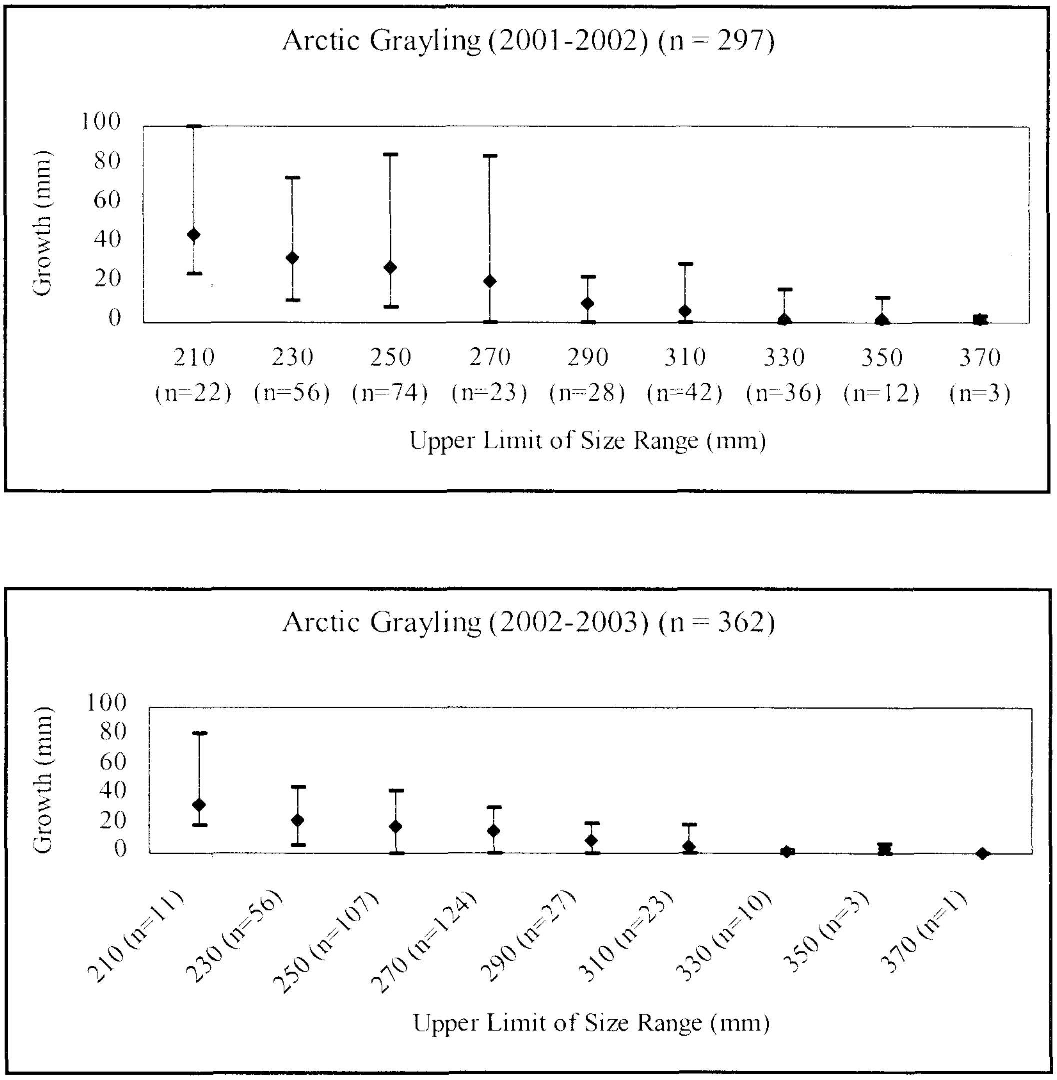
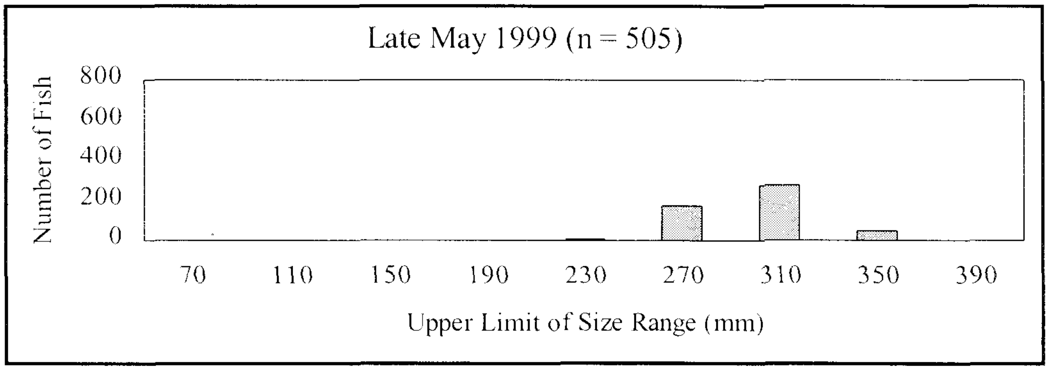


Figure 15. Maximum, minimum, and average growth for Arctic grayling > 200 mm long for 2001/2002 and 2002/2003.

Length frequency distributions for Arctic grayling collected in spring 1995 and 1996 and in spring 1998 through 2002 were presented by Ott and Morris (2002b). Through 1999, little or no recruitment of small fish was seen, but after construction of the channel connecting Pond F with the WSR, substantial numbers of smaller Arctic grayling have been caught. Length frequency distributions for 1999 and 2003 are presented in Figure 16 to show the large recruitment that has occurred in the WSR Arctic grayling population.



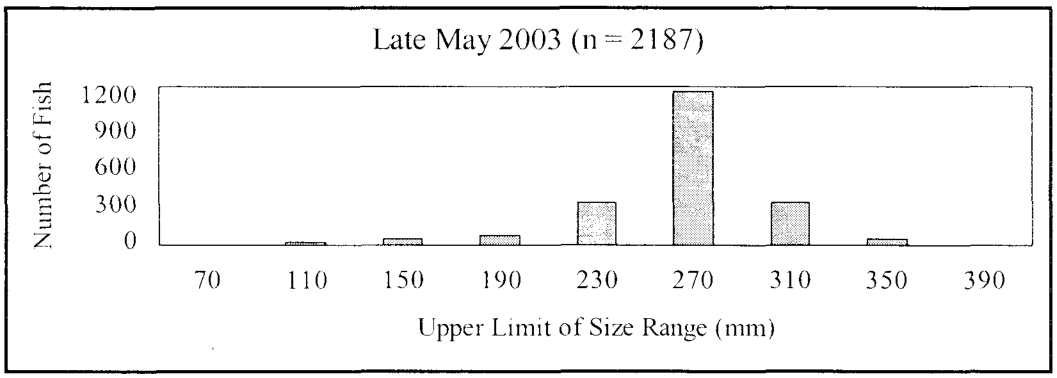


Figure 16. Length frequency distribution of Arctic grayling in the WSR and wetland complex in spring 1999 and 2003. Note the different y-axis scales.

Water Supply Reservoir, Burbot

Burbot were found in Lower Last Chance Creek Pond and in Polar Ponds #1 and #2 prior to construction of the WSR dam (Ott and Weber Scannell 1996). In May 1995, we conducted a mark/recapture effort and estimated the abundance of burbot (150 to 331 mm) to be 825 fish (Ott and Weber Scannell 1996). The WSR began to pond water in November 1995, flooding the ponds and creek containing burbot.

Estimates of the burbot population in the WSR were made during the ice-free season following construction of the WSR (Figure 17 and Appendix 3). The estimated population of burbot > 200 mm long peaked in 1999 and has decreased substantially the last two years. These data continue to indicate that fish lost in the population are smaller (i.e., < 400 mm), and as noted during field sampling, those burbot between 275 and 375 mm have consistently been in poor condition. However, small burbot appear to be in better condition in 2003 than in prior years. The estimated number of large burbot (>400 mm) was 134 in 2001, 131 in 2002, and 102 in 2003. The burbot population for fish >400 mm appears to be relatively stable.

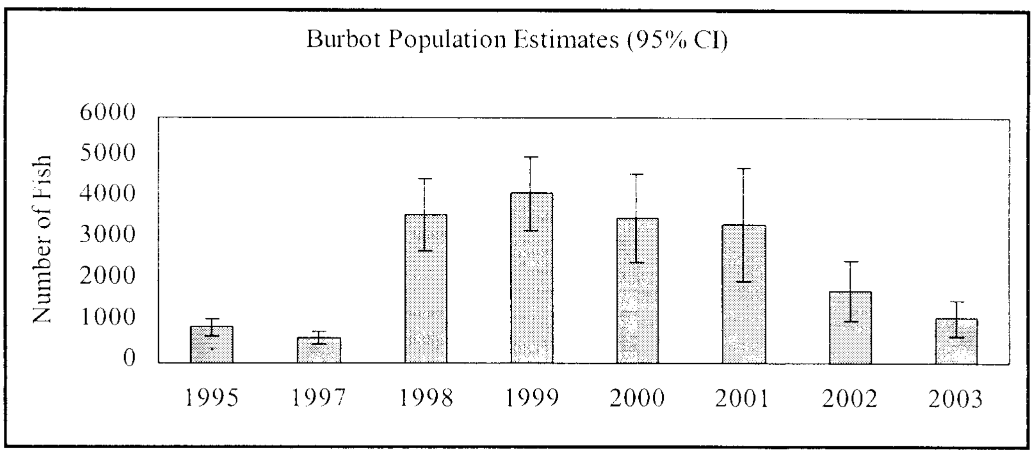


Figure 17. Estimates of the burbot population in the WSR at the Fort Knox Mine (1995 to 2003).

Catches of burbot in the stilling basin below the WSR dam indicate that very few burbot are outmigrating from the WSR. Catch per unit of effort for hoop traps fished in the WSR has been calculated annually since 1996 (Appendix 4). Catch rates from 1998 through 2001 were similar, but there was a sharp decrease in spring 2002 and again in spring 2003. The decreased catch rate supports the declining trend observed in the population estimates for burbot >200 mm.

Annual growth of burbot was tracked from 1998 through 2003. Average growth by size is presented in Appendix 5. Annual growth of burbot between spring 2002 and spring 2003 for fish >450 mm ranged from 41 to 104 mm while growth for fish <450 mm ranged from 0 to 40 mm.

Length-frequency distributions for burbot captured from May 1995 to June 2002 were presented by Ott and Morris (2002). Length frequency for spring 2001, 2002, and 2003 is shown in Figure 18. Catches have declined each year since 2001 and numbers of fish in the 225 to 375 mm group have decreased substantially. Recruitment of new fish to the population continues and appears to be increasing.

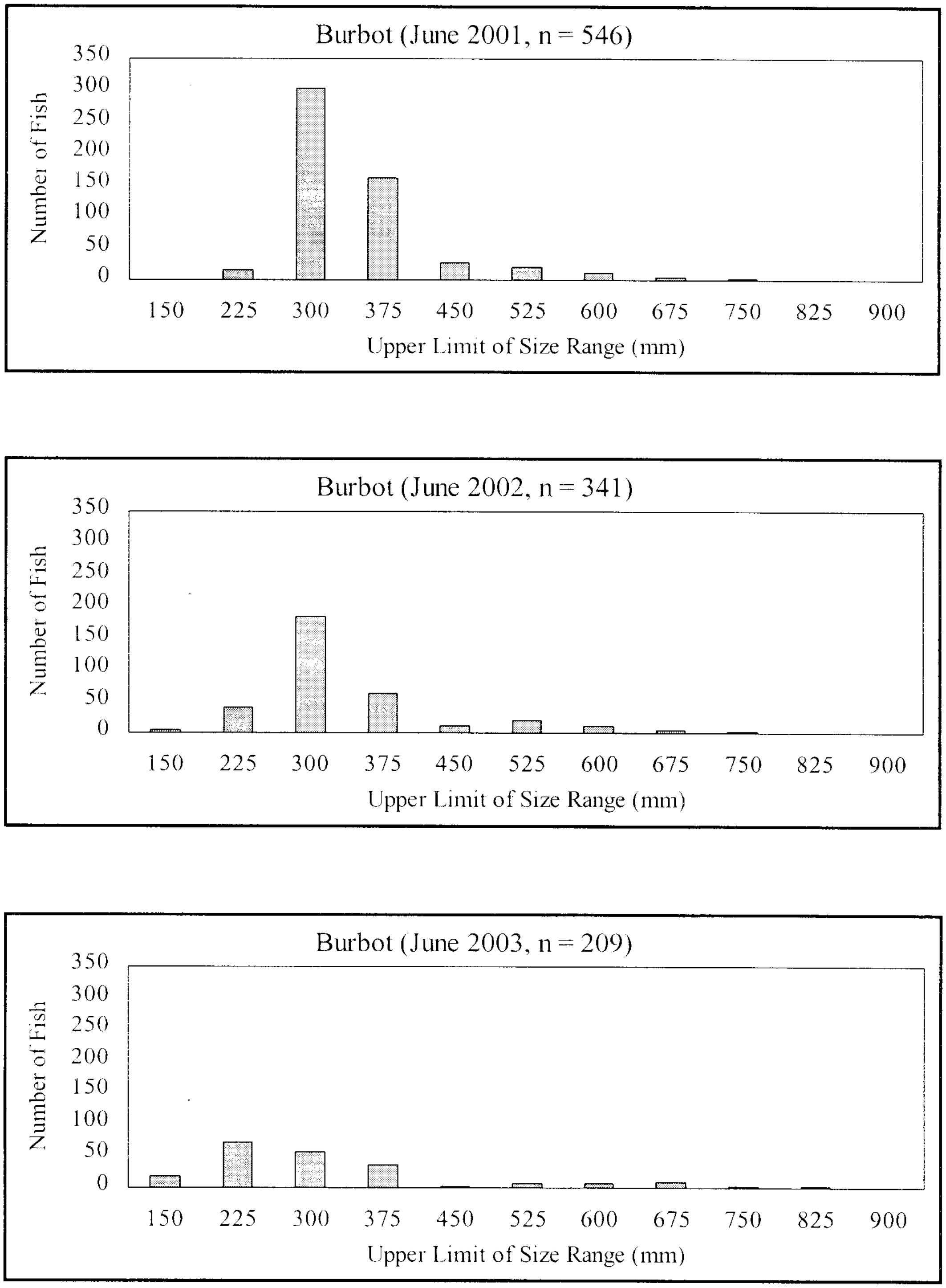


Figure 18. Length-frequency distribution of burbot caught in the WSR, 2001 to 2003.

Conclusion

We predicted prior to construction of the WSR dam that opportunities existed to enhance fish resources, specifically the Arctic grayling population, in upper Fish Creek. Our goal was to reach a density of 10 to 20 Arctic grayling >200 mm per hectare of surface area (i.e., 800 to 1,600 fish >200 mm) ten years after construction of the WSR dam. Concurrent reclamation began in 1996 and has continued annually. The most significant civil work conducted, from a biological viewpoint, was excavation of a channel in spring 1999 to connect the developed wetland with the WSR. Arctic grayling spawning success in this channel and the associated wetlands (Ponds D, E, and F) has been high every year since 1999.

Progress to Date

Monitoring of fishery resources and water quality has continued in the WSR and developed wetlands for the following reasons: (a) to gather data to evaluate predictions that a viable Arctic grayling population could be developed; (b) to provide data on successes and failures of restoration activities that could be applied to future projects; (c) to fill the department's commitment to monitor the project and provide data for the environmental audits required by the State's mill site lease; (d) to provide biological information needed for management decisions when the area is converted to public recreation and use at the end of mining operations; and (e) to gather information on the fish and wildlife use of the developed wetlands to be used to assess mitigation under the U.S. Army Corps of Engineer's permit for the project.

A viable Arctic grayling population has been established in the WSR. Our goal of having 800 to 1,600 Arctic grayling >200 mm in the WSR was exceeded in 1998. The estimated population in the WSR in spring 2002 was 6,503 fish. Furthermore, we have documented the outmigration of Arctic grayling through the low flow channel in the WSR spillway. These fish have the potential to enter the Chena River fishery.

We did not make any predictions on what might happen with the burbot population. The burbot population grew rapidly following the ponding of water behind the WSR dam, reaching a high of 4,136 in 1999. Since 1999, the burbot population has decreased substantially to an estimated 1,103 in summer 2003. However, there are a small number of large burbot (i.e., >400 mm) and their numbers have stayed relatively stable in 2001 and 2002, with a slight decrease in 2003.

Water quality data collected have shown that the flooding of ice-rich permafrost materials in the valley has created a condition in which dissolved oxygen concentrations are depressed with depth in both winter and summer. Essential to overwintering survival of fish is the freshwater input to the WSR, primarily from Solo Creek.

Wildlife use of the WSR and developed wetlands generally has increased since construction and with concurrent reclamation. A summary of the wildlife species and uses in the area was provided by Ott and Morris (2002b). Increased waterfowl and shorebird use has been seen in both the open water areas and in the wetlands. Birds of prey, primarily bald eagle (*Haliaeetus leucocephalus*), use has increased possibly due to the presence of large concentrations spawning Arctic grayling available in early spring during nesting. Horned grebes (*Podiceps auritus*) and Pacific loons (*Gavia pacifica*) are frequently observed in the WSR. Mink (*Mustela vison*) and river otters (*Lutra canadensis*) use both the WSR and the stilling basin below the dam.

Future Plans

The department will continue to work cooperatively with FGMI to gather data on the fish resources and water quality to provide a basis for management decisions at mine closure and to identify further options for enhancing aquatic habitats. One potential option is the construction of a second wetland complex located along the north side of the valley between the tailing dam and the WSR. The wetland complex would be fed by water from the tailing impoundment at mine closure. Finally, compilation of long-term data on the WSR and developed wetlands will aid both industry and government agencies in better decision making in the future.

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Appendix 1. Water Quality (Site #1), WSR

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
1	5/28/03	0	7.33	39.6	4.59	112.0	6.68
		1	6.91	35.2	4.12	112.3	6.65
		2	6.75	32.3	3.80	111.4	6.64
		3	6.30	28.4	3.38	112.2	6.63
		4	6.03	25.8	3.10	112.2	6.57
		5	5.36	29.5	3.23	114.1	6.53
		6	5.01	25.7	3.32	115.1	6.49
		7	4.85	26.7	3.30	115.9	6.45
		8	4.76	25.1	3.10	116.4	6.44
		8.75	4.55	26.3	3.20	118.6	6.42
1	4/17/03	1	0.62	34.9	4.78	N/T	6.75
		2	0.98	33.8	4.57	N/T	6.74
		3	1.30	32.9	4.41	N/T	6.73
		4	1.49	32.5	4.35	N/T	6.72
		5	1.70	32.1	4.17	N/T	6.72
		6	1.90	32.2	4.24	N/T	6.73
		7	1.96	24.9	3.27	N/T	6.69
		8	1.87	18.1	2.38	N/T	6.63
		9	1.77	3.2	0.43	N/T	6.49
		10	1.65	1.8	0.24	N/T	6.56
		11	1.52	1.8	0.24	N/T	6.54
		11.7	1.46	1.1	0.16	N/T	6.26
1	9/30/02	0	6.90	72.8	8.52	100.3	6.87
		1	6.90	72.4	8.48	100.1	6.84
		2	6.89	72.1	8.45	100.5	6.83
		3	6.83	70.9	8.32	100.2	6.82
		4	6.84	70.1	8.23	100.4	6.81
		5	6.74	67.4	7.93	100.3	6.78
		6	6.65	64.1	7.55	101.0	6.75
		7	6.46	56.5	6.69	102.3	6.67
		8	6.14	40.1	4.80	101.3	6.58
		9	5.67	52.0	6.28	98.6	6.58
		9.5 (bottom)	5.21	67.5	8.24	95.6	6.68

Appendix 1, water quality continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
1	5/28/02	0	4.89	54.0	6.51	103.8	6.73
		1	4.85	53.6	6.48	103.8	6.70
		2	4.87	53.5	6.48	103.8	6.68
		3	4.86	53.3	6.46	103.9	6.68
		4	4.85	53.4	6.46	103.7	6.67
		5	4.84	53.3	6.46	103.7	6.67
		6	4.82	52.8	6.41	104.1	6.68
		7	4.83	52.6	6.38	104.0	6.68
		8	4.80	52.5	6.36	104.7	6.68
		9	4.80	52.4	6.38	104.3	6.68
		10	4.76	51.5	6.26	104.3	6.68
		11 (bottom)	4.69	51.5	6.24	105.0	6.68
1	4/18/02	1	0.52	11.9	1.69	146.0	6.77
		2	0.87	14.4	1.98	145.2	6.67
		3	1.15	16.8	2.28	144.6	6.67
		4	1.34	17.7	2.41	144.2	6.65
		5	1.51	13.5	1.83	146.5	6.64
		5.5 (bottom)	1.62	14.8	1.97	146.5	6.63
1	10/1/01	0	7.23	65.8	7.61	121.1	7.28
		1	7.20	64.4	7.44	121.5	7.28
		2	7.19	64.2	7.41	121.1	7.29
		3	7.18	64.1	7.40	121.7	7.28
		4	7.17	63.8	7.36	121.1	7.28
		5	7.16	63.1	7.31	121.4	7.27
		6	7.15	62.8	7.26	121.1	7.27
		7	7.14	62.4	7.22	121.7	7.27
		8	7.00	59.0	6.83	123.1	7.26
		9	6.46	18.0	2.11	115.1	7.00
		10 (bottom)	6.22	18.1	2.14	116.5	7.02
1	6/1/01	0	7.96	67.9	7.74	114.9	6.93
		1	7.88	67.1	7.67	115.0	6.95
		2	7.86	67.0	7.65	115.2	6.95
		3	7.06	60.7	7.06	114.7	6.93
		4	6.16	53.0	6.35	114.6	6.85
		4.75 (bottom)	6.08	51.6	6.21	114.6	6.84

Appendix 1, water quality continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
1	4/10/01	1	0.21	22.1	3.10	130.1	6.64
		1.75	0.38	19.3	2.72	131.4	6.62
		2.75	0.75	17.7	2.45	131.2	6.61
		3.75	1.07	19.9	2.72	129.8	6.61
		4.75	1.34	21.0	2.85	128.8	6.61
		5.75 (bottom)	1.50	18.8	2.56	131.1	6.59
1	8/29/00	0	11.17	79.2	8.46	108.8	7.11
		1	10.50	77.6	8.44	108.8	7.13
		2	10.29	77.1	8.42	108.8	7.13
		3	9.92	72.6	8.01	108.8	7.09
		4	8.85	54.1	6.14	106.8	6.90
		5	8.19	41.2	4.72	106.3	6.77
		6	6.98	41.7	4.93	97.7	6.66
		7	6.05	18.6	2.24	109.6	6.50
		8	5.53	5.3	0.65	136.8	6.39
		9	5.23	3.4	0.45	140.0	6.45
		10 (bottom)	5.04	2.6	0.33	142.5	6.47
1	6/23/00	0	18.23	95.2	8.81	103.8	7.56
		1	17.35	93.0	8.75	102.6	7.57
		2	12.95	52.6	5.50	105.1	6.91
1	6/23/00	3	7.67	24.9	2.92	108.8	6.69
		4	5.71	17.4	2.15	114.0	6.57
		5	5.08	13.9	1.76	117.2	6.54
		6	4.60	9.9	1.25	119.4	6.52
		7	4.39	8.4	1.08	121.9	6.51
		8	4.30	6.5	0.83	122.5	6.50
		9 (bottom)	4.10	2.6	0.34	125.9	6.49
1	5/30/00	0	7.31	56.3	6.72	108.4	6.77
		1	6.24	53.1	6.51	108.2	6.73
		2	5.79	51.9	6.40	106.8	6.71
		3	5.56	50.3	6.25	107.9	6.71
		4	5.45	49.9	6.21	107.1	6.70
		5	5.42	49.6	6.18	107.5	6.70
		6	4.81	45.1	5.73	109.3	6.68
		7 (bottom)	3.95	33.3	4.33	120.5	6.64

Appendix 1, water quality continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
1	6/2/99	0	9.49	82.9	9.13	134.7	7.29
		1	9.50	81.4	8.99	134.9	7.27
		2	9.52	81.1	8.95	134.5	7.29
		3	9.48	80.7	8.92	134.7	7.30
		4	9.29	77.1	8.54	135.5	7.24
		5	7.47	54.5	6.26	133.4	7.07
		6	6.36	42.3	5.05	134.9	6.99
		7	5.81	36.3	4.39	135.6	6.93
		8	5.14	29.8	3.67	137.3	6.91
		9	4.98	28.2	3.48	137.5	6.90
		10	4.86	26.5	3.24	137.8	6.89
		11	4.79	25.5	3.16	138.4	6.88
		12 (bottom)	4.75	24.9	3.09	138.3	6.86
1	10/1/98	surface	6.27	62.7	7.49	145.1	7.60
		1	6.24	62.6	7.49	145.0	7.57
		2	6.21	62.4	7.47	144.6	7.58
		3	6.20	62.3	7.45	144.5	7.58
		4	6.14	62.9	7.54	144.8	7.60
		5	6.03	64.1	7.70	144.8	7.62
		6	5.87	64.3	7.75	144.3	7.61
		7	5.84	64.3	7.74	144.4	7.61
		8 (bottom)	5.82	64.5	7.79	144.0	7.59
1	7/28/98	surface	17.33	84.2	7.85	161.9	7.56
		1	16.83	81.2	7.67	162.0	7.54
		2	16.66	80.5	7.65	162.2	7.55
		3	14.30	45.7	4.55	157.5	7.08
		4	11.78	25.7	2.72	141.4	6.84
		5	9.93	50.7	5.51	118.6	6.97
		6 (bottom)	9.25	33.3	3.71	127.6	6.90

Appendix 1, water quality concluded.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
1	7/28/98	surface	17.21	83.6	7.84	159.6	7.64
		1	17.14	82.9	7.80	159.8	7.63
		2	16.81	82.3	7.78	160.3	7.63
		3	14.49	46.9	4.64	157.6	7.13
		4	7.92	27.1	3.51	165.0	6.87
		5	6.68	64.7	7.63	115.2	7.03
		6	3.48	9.6	1.14	170.0	6.75
		7 (bottom)	5.23	1.0	0.12	173.0	6.81
1	3/18/98	1	0.50	N/T	1.27	176.0	6.96
		2	0.79	N/T	1.89	178.0	6.89
		3	0.89	N/T	1.71	179.0	6.87
		4	0.96	N/T	2.10	182.0	6.84
		5 (bottom)	0.96	N/T	0.47	186.0	6.75

N/T = Not Tested

Appendix 2. Arctic Grayling Population Estimates in the WSR

Estimates of the Arctic grayling population in the WSR and developed wetlands at the Fort Knox Mine (1995 to 2002). We used fyke-nets for the capture and recapture events, except where noted.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	4,358	
1996[2]	150	4,748	3,824-5,672
1996[3]	150	3,475	2,552-4,398
1998[4]	200	5,800	4,705-6,895
1999[4]	200	4,123	3,698-4,548
2000[4]	200	5,326	4,400-6,253
2001[4]	200	5,623	5,030-6,217
2002[4]	200	6,503	6,001-7,005

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

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

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

[4]The 1998 through 2002 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

Appendix 3. Burbot Population Estimates in the WSR

Estimates of the burbot population in the WSR and developed wetlands at the Fort Knox Mine (1995 to 2003). We used hoop traps for the capture and recapture events, except where noted.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	876	666-1,087
1997[2]	250	622	462-782
1998[2]	300	703	499-907
1998[3]	200	3,609	2,731-4,485
1999[3]	200	4,136	3,215-5,057
2000[3]	200	3,536	2,444-4,629
2001[4]	200	3,391	2,017-4,764
2001	400	134	58-210
2002[4]	200	1,763	1,045-2,480
2002	400	131	62-199
2003[4]	200	1,103	671-1,535
2003	400	102	57-147

[1]We used fyke-nets in the Polar Pond complex to make the 1995 population estimate.
[2]The 1997 and 1998 estimates were made with a capture and recapture event in May of the same year.
[3]The 1998, 1999, and 2000 population estimates were made using a mark event in spring with the recapture event occurring one year later in the spring.
[4]The 2001, 2002, and 2003 population estimates were made with capture and recapture events in the same year.

Appendix 4. Burbot Catches in the WSR

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
5/22/96	small hoop	11	36	3.3
5/22/96	large hoop	4	6	1.5
5/23/96	small hoop	11	19	1.7
5/23/96	large hoop	4	2	0.5
5/20/97	small hoop	11	58	5.3
5/20/97	large hoop	13	24	1.8
5/21/97	small hoop	11	61	5.5
5/21/97	large hoop	17	56	3.3
5/28/97	small hoop	11	45	4.1
5/28/97	large hoop	19	42	2.2
5/29/97	small hoop	11	32	2.9
5/29/97	large hoop	20	39	2.0
5/20/98	small hoop	7	87	12.4
5/21/98	small hoop	9	61	6.8
5/21/98	large hoop	3	20	6.7
5/22/98	small hoop	9	57	6.3
5/27/98	small hoop	9	61	6.8
5/28/98	small hoop	9	67	7.4
5/29/98	small hoop	9	44	4.9
6/3/99	small hoop	17	135	7.9
6/4/99	small hoop	17	124	7.3
6/5/99	small hoop	17	136	8.0
6/7/99	small hoop	17	142	4.2
6/8/99	small hoop	17	89	5.2
5/30/01	small hoop	24	191	7.9
5/31/01	small hoop	24	105	4.4
6/1/01	small hoop	24	122	5.1

Appendix 4. Burbot (concluded).

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
6/6/01	small hoop	30	209	7.0
6/7/01	small hoop	30	76	2.5
6/27/01	small hoop	30	98	3.3
6/28/01	small hoop	30	140	4.7
6/3/02	small hoop	30	58	1.0
6/5/02	small hoop	30	58	1.0
6/6/02	small hoop	30	41	1.4
6/8/02	small hoop	30	118	2.0
6/10/02	small hoop	30	120	2.0
10/3/02	small hoop	30	69	1.2
5/29/03	small hoop	30	62	2.1
5/30/03	small hoop	30	34	1.1
6/2/03	small hoop	30	75	0.8

CPUE = catch per unit of effort (24 hours)

Appendix 5. Annual growth of burbot (2002 to 2003).

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)	Growth (mm)
27267	Gray	230	6/10/02	Upper WSR	5/8/03	WSR	240	10
27170	Gray	270	6/8/02	Upper WSR	5/29/03	WSR	280	10
27157	Gray	300	6/8/02	Upper WSR	5/29/03	Upper WSR	308	8
27048	Gray	315	6/3/02	WSR	5/29/03	WSR	355	40
27121	Gray	315	6/6/02	WSR	6/2/03	WSR	330	15
13814	Green	382	6/6/02	WSR	5/30/03	WSR	405	23
27085	Gray	405	6/6/02	WSR	5/29/03	WSR	405	0
27124	Gray	455	6/6/02	WSR	5/29/03	WSR	500	45
9151	Gray	460	6/3/02	Pond E	5/28/03	WSR	505	45
27001	Gray	460	6/3/02	WSR	5/29/03	WSR	520	60
6611	OR	460	6/10/02	Polar 2	6/2/03	WSR	540	80
31397	BL	510	6/5/02	WSR	6/2/03	WSR	570	60
13909	Green	525	6/5/02	WSR	5/29/03	WSR	580	55
27024	Gray	546	6/3/02	WSR	5/28/03	WSR	605	59
5651	Yellow	546	6/3/02	WSR	5/29/03	WSR	650	104
31362	BL	559	6/3/02	WSR	5/29/03	WSR	600	41
13938	Green	559	6/3/02	WSR	5/28/03	WSR	600	41
31963	BL	584	6/3/02	WSR	5/30/03	WSR	650	66
32908	BL	610	6/3/02	WSR	5/30/03	WSR	675	65