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Arctic Grayling and Burbot Studies in the Fort Knox Water Supply Reservoir and Developed Wetlands, 2001

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

Photo by Alvin Ott, Suturing a Radiotagged Burbot

ARCTIC GRAYLING AND BURBOT STUDIES IN THE FORT KNOX WATER SUPPLY RESERVOIR AND DEVELOPED WETLANDS (2001)

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Acknowledgments

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Executive Summary

This report summarizes data collected on water quality, zooplankton, burbot (*Lota lota*) and Arctic grayling (*Thymallus arcticus*) in the Fort Knox water supply reservoir (WSR) and developed wetlands. Water quality data have been collected since 1997. Zooplankton sampling began in 2000. Annual fish studies began in 1992.

Water in the WSR continues to show depressed oxygen concentrations with depth; however, the magnitude of the decrease was less in 2001 than in previous years. Decreased dissolved oxygen concentrations likely are related to a high chemical and/or biological oxygen demand from large quantities of flooded organic and inorganic materials and terrestrial vegetation. Smaller decreases in dissolved oxygen concentrations with depth in 2001 may have been the result of removal of large quantities of the most oxygen-depleted water from the bottom of the WSR to the tailing impoundment in late winter 2001.

Zooplankton tows were made in the WSR in April 2001, prior to breakup. Zooplankton densities in April 2001 were similar to August 2000; however, communities in April were dominated by copepods, whereas August communities were dominated by daphnids.

Substantial increases due to recruitment were first seen in the burbot population in the WSR in 1998. Since 1998, numbers have remained fairly constant with the population dominated by burbot from 275 to 325 mm long in 2001. Small burbot caught in summer 2001 indicated successful spawning is still occurring. Three large burbot were radiotagged in fall 2001 to better assess movement, determine wintering areas, and to possibly identify spawning habitats.

Prior to flooding of the WSR, Arctic grayling in ponds within the general area were stunted; fish larger than 220 mm long were rare, annual growth was 9 mm, and age at maturity was low. However, the estimated number of Arctic grayling was relatively large at 4,358 fish. Monitoring of Arctic grayling was conducted annually but in the first three years following flooding of the WSR in 1996, little or no recruitment was seen. Access to

spawning and rearing habitat for Arctic grayling was increased in spring 1999 and successful spawning was documented the next three years. Substantial increases in the number of Arctic grayling were documented in spring 2000 with a population estimate of fish > 200 mm at 5,326 (95% CI 4,400 to 6,253).

We predicted, prior to construction of the WSR dam, that opportunities existed to enhance the fish resources in the Fish Creek valley. During construction of the WSR dam, Fairbanks Gold Mining Inc. worked with the ADF&G to optimize habitat diversity within the area to be flooded. Work began in 1996 to construct wetlands in the area between the WSR and the tailing impoundment. Construction of Channel #5, connecting the wetlands with the WSR, provided spawning and rearing habitat for Arctic grayling in spring 1999. Evidence of substantial recruitment of age-1 Arctic grayling, likely in response to the increase in spawning habitat available during 1999, was seen in spring 2000. Work to improve habitat diversity and productivity is an ongoing process in cooperation with FGMI, state, and federal agencies. Rehabilitation of lower Last Chance Creek was completed in late fall 2001 with the goal of achieving more channel stability during breakup and thus increasing Arctic grayling spawning success in that stream. We also are discussing the opportunity of creating a second series of wetlands along the north side of the valley that would be fed by water from the tailing impoundment at site closure. We believe this project would further increase overall habitat diversity for both fish and wildlife resources in the valley.

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. In 2001, FGMI developed the True North Mine located west of Pedro Dome. Trucking of ore from the True North Mine to the Fort Knox Mine for processing began in late April 2001.

During construction of the WSR, we monitored activities 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 disturbed habitats has been rapid. Development of wetlands between the tailing dam and head of the WSR began in summer 1998 with additional civil work, seeding, and willow sprigging occurring in summers 1999, 2000, and 2001. Rehabilitation in the lower 2 km of lower Last Chance Creek was completed in early winter 2001 to improve fish passage and minimize flow variability during spring.

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

Stream sampling continued in 1995 and we estimated the size of the Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to colonize the WSR (Ott and Weber Scannell 1996). The Arctic grayling population in Fish Creek, upstream of the WSR dam in 1995 was estimated at 1,700 individuals <150 mm, and 4,350 individuals ≥ 150 mm. The number of burbot, between 150 and 331 mm, in the upper Fish Creek drainage was estimated at 876 fish.

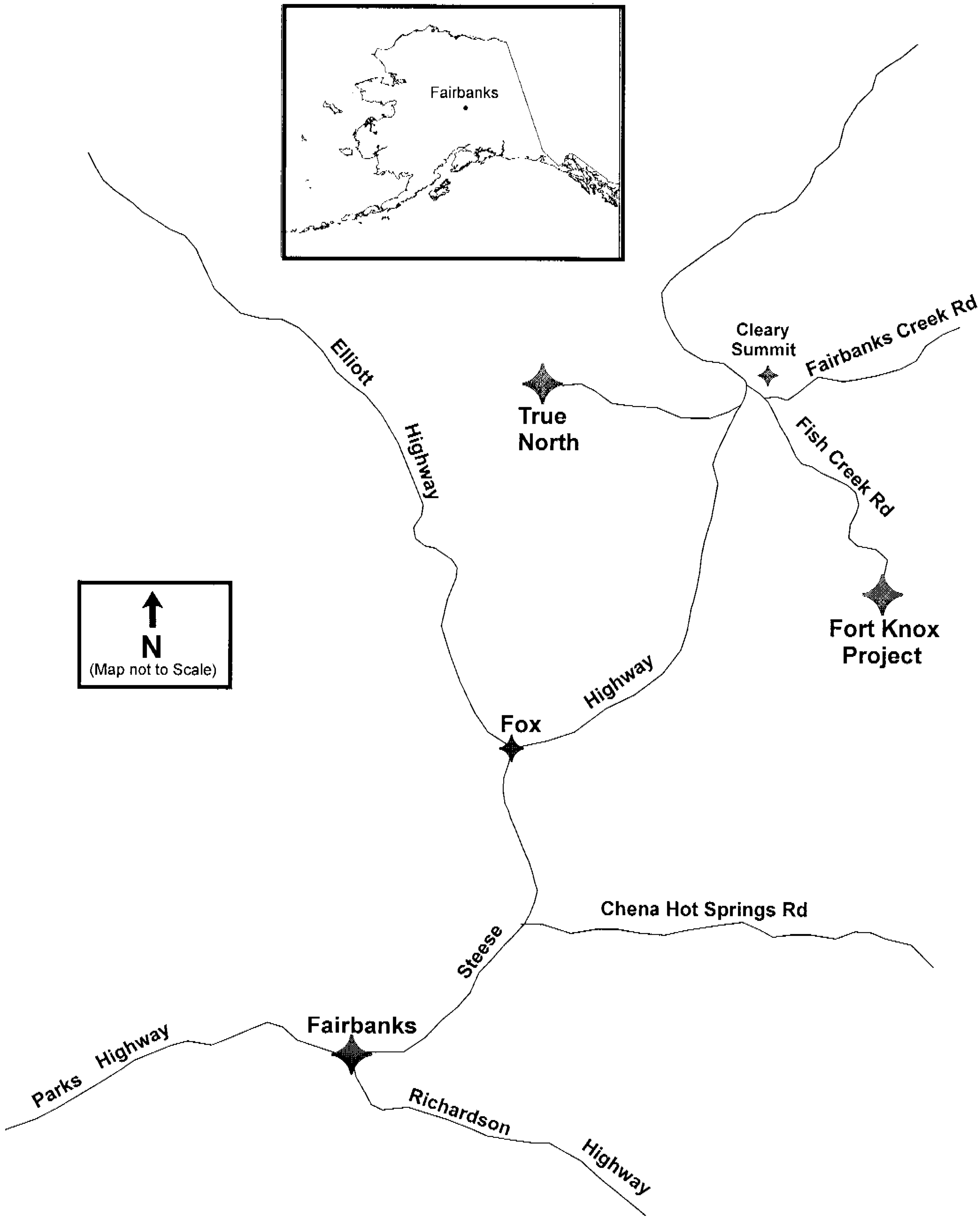


Figure 1. Fort Knox project location.

From 1996 to present, we have monitored Arctic grayling and burbot use of the WSR, gathering information on growth, production of age-0 fish, and catch per unit of effort (CPUE) (Ott and Weber Scannell 1996, Ott and Townsend 1997, Ott and Weber Scannell 1998, Ott and Morris 1999, Ott and Morris 2000, and Ott and Morris 2001). Water quality monitoring in the WSR was started in September 1997 and fisheries work was expanded to include the constructed wetlands in spring 1999. Zooplankton and phytoplankton sampling was first done in summer 2000. This report summarizes fish and water quality data collected during 2001 and discusses these findings in relation to previous work.

Methods

Sampling Sites

Water quality sampling began in fall 1997 in the WSR and in summer 1999 in the developed wetlands. Multiple fyke-net sampling sites have been used (Figures 2 and 3). Changes in fyke-net locations have been due mainly to finding the most effective catch sites and to major water surface elevation changes. Sites were added in the constructed wetlands after Channel #5 was built. In spring 2001, we fished fyke-nets at three stations (#12, #14, and #15) in the WSR and at two stations in the stilling basin below the WSR spillway. The general area for each fyke-net site is fixed but exact location varies with water level. In spring 2001, hoop traps were fished throughout the WSR both east and west of the Gil Extension road crossing.

Water Quality

Temperature (°C), dissolved oxygen concentration (mg/L), dissolved oxygen 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 water quality display unit. The meter was calibrated to suggested specifications prior to use in the field. The dissolved 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. In the developed wetlands, measurements were made near the shoreline at a depth of about 0.5 m.

Zooplankton

Zooplankton samples were collected using a 130 mm diameter Wisconsin Plankton Net and Bucket during April when the WSR was still ice-covered. A single vertical tow through the top 5 m of the water column was made at three sites where water depths were adequate. At other sites, vertical tow distances were 3 or 4 m. The 5 m tow

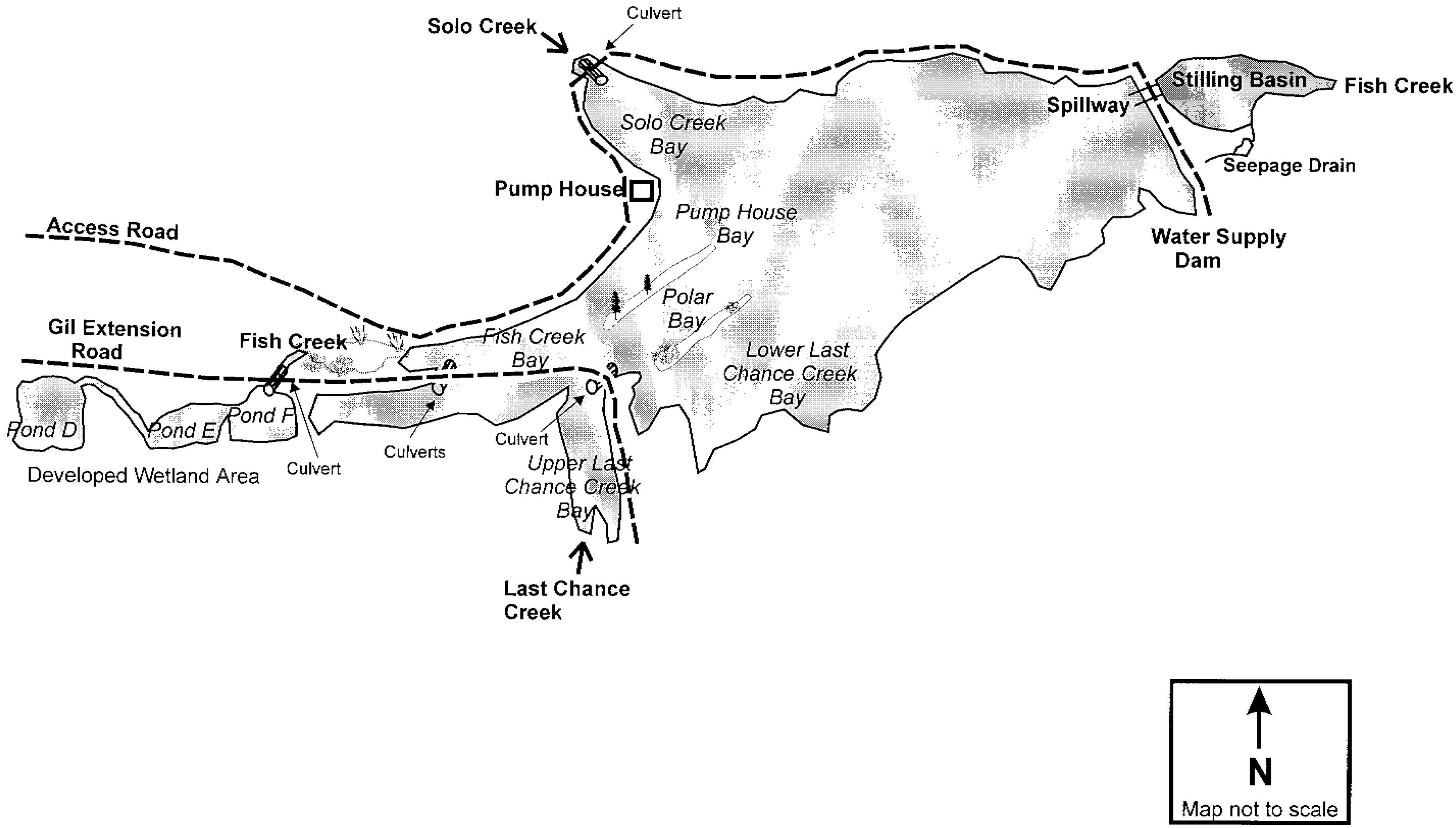


Figure 2. Sample areas in the Fort Knox water supply reservoir, stilling basin, and developed wetlands.

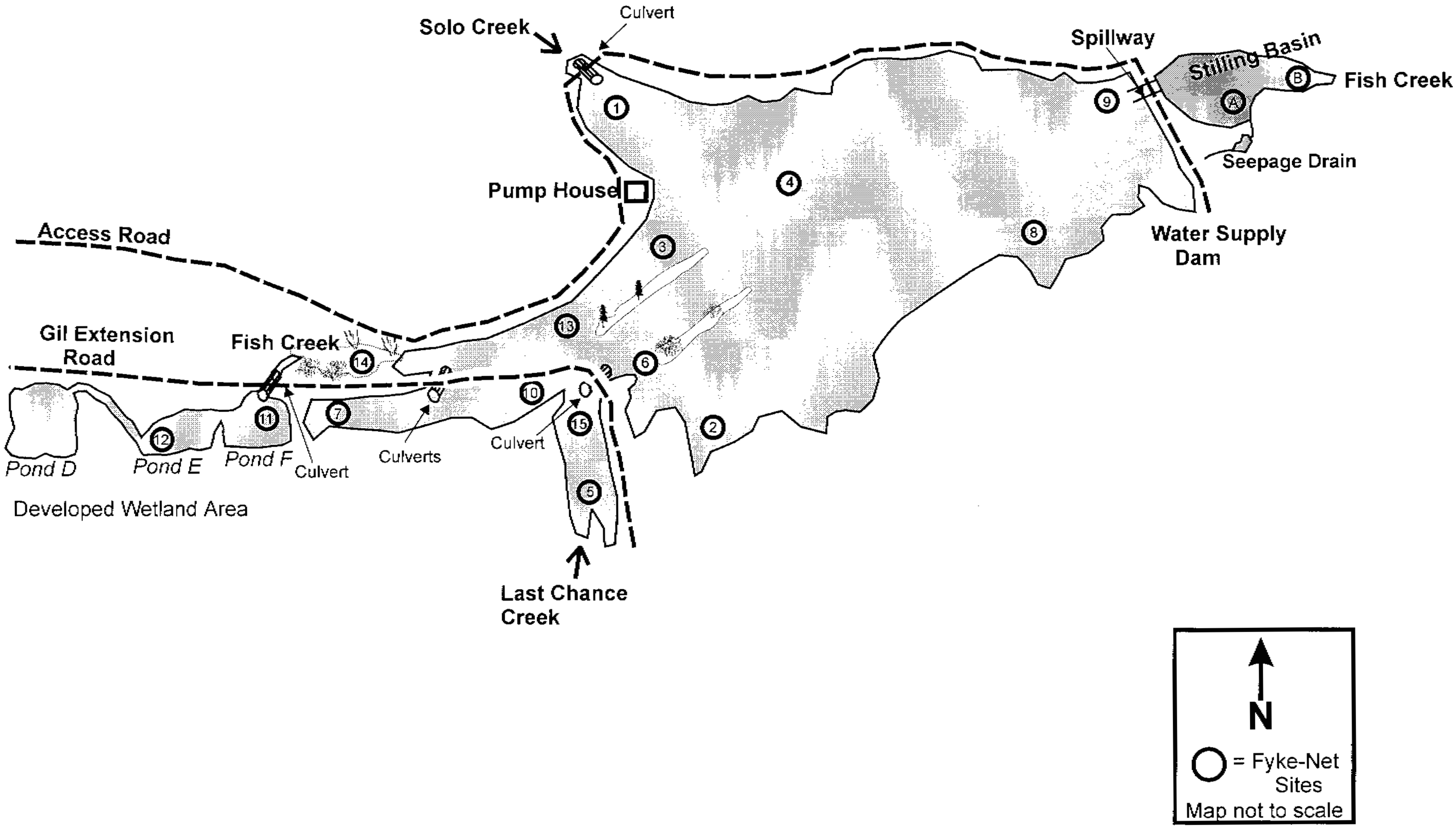


Figure 3. Fyke-net sample sites in the Fort Knox water supply reservoir, stilling basin, and developed wetlands (1996-2001).

sampled 63.3 l of water. The vertical plankton net was lowered to depth, slowly pulled to the surface, and zooplankton were removed by opening the clamp on the outlet hose. Zooplankton were washed into plastic containers, labeled, and preserved in 70% ethyl alcohol.

Fish

Field sampling methods and gear included visual observations, fyke-nets, and hoop traps (Figure 4). Burbot and Arctic grayling captured during May and June were measured and marked with a numbered Floy® internal anchor tag. One burbot, recaptured in 2001, which had been marked and injected with oxytetracycline in 1995, was retained for age validation studies.

Three sizes of fyke-nets were used. Entrance frames were either 0.9 m^2 or 1.2 m^2 or 0.69 m by 0.99 m (mini-fyke). The large 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. Unbaited fyke-nets were fished 24 hrs and either reset or removed.

We used hoop traps baited with whitefish and salmon roe to capture burbot. Traps generally 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.

LOTEK Enigineering, Inc. MBFT-6 VHF radio-transmitters (60 mm X 10 mm diameter, 10 g with a 430 mm antenna) were surgically implanted in three large burbot on October 3, 2001. Fish were captured in baited hoop traps; several fish over 500 mm were held in

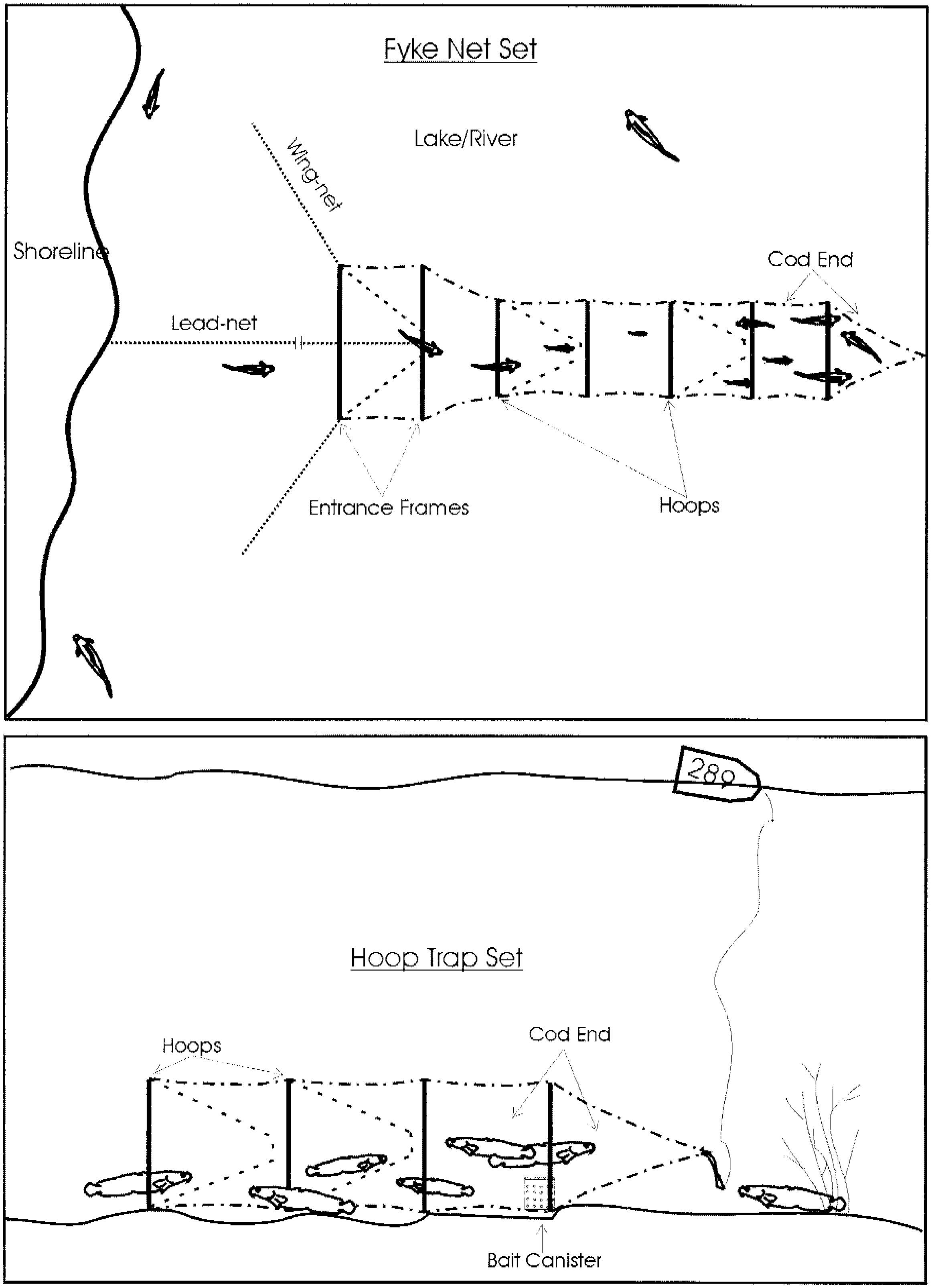


Figure 4. Diagram of Fyke-net and hoop trap sets.

a large tub and transported to the boat launch area of the reservoir for transmitter implantation. The three largest burbot were selected to receive transmitters.

Each burbot was anesthetized in a tub containing water and approximately 20-ppm clove oil extract. Once anesthetized, fish were placed ventral side up in a wetted surgical trough lined with moist foam. A 15 to 25 mm-ventral incision was made through the body wall and into the peritoneal cavity. Incision placement was slightly offset from the midline of the ventral surface and 4 to 5 cm cranial to the vent. A transmitter, sterilized for 24 hours in a dilute chlorhexidine gluconate solution, was rinsed with sterile saline solution and placed into the peritoneal cavity with the antenna end facing caudally. A needle guide was then inserted into the incision and carefully moved to the body wall at the caudal end of the peritoneal cavity, just caudal and adjacent to the vent. A 14 gauge Abbocath ® catheter was then inserted into the musculature of the fish, caudal to the peritoneal cavity and pushed towards the cavity until contact with the needle guide was achieved. The catheter was then fed through the incision using the needle guide. The antenna was fed through the catheter and the catheter was removed. This antenna routing technique ensures minimal trauma to the fish and allows the tail musculature and skeletal structure to anchor the transmitter in place. The location of the pelvic girdle in burbot is too far cranial to allow use of the structure for anchoring the transmitter.

Incision closure was achieved with three to four ethilon 3-0 sutures. Vetbond ™ surgical glue was then applied to the exterior of the incision. Throughout the procedure, each fish was monitored for state of anesthesia; freshwater was applied to the gills of fish while fully anesthetized. As fish began to show signs of the anesthetic wearing off, additional 20-ppm clove oil extract solution was applied to the gills. Upon completion of surgery fish were placed in a large freshwater bath with battery powered aerators. Once recovered, swimming upright and attempting to swim down in the tub, fish were released back into the reservoir.

Radio-tracking of the tagged burbot was conducted using a LOTEK Engineering, Inc. SRX-400 Telemetry Receiver connected to a LOTEK H-antenna. Radio-tracking usually began at the highest, road accessible, vantage point over the reservoir. Once the general location of each fish was determined, we moved to areas closer to each fish for final location determination.

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)

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

95% CI for the population estimate was calculated as

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

Results and Discussion

Water Supply Reservoir, Water Quality

Five water quality sample sites were established and sampled in the WSR beginning in fall 1997 (Figure 5). Data collected at these five sites during all sample events are presented in Appendix 1.

Ponding of water behind the WSR dam began in November 1995. Water levels varied widely in 1996 and 1997, due to water use and winter seepage below the dam that exceeded freshwater input. The WSR reached the projected maximum water level of 1,021 feet on September 29, 1998 following summer rainfall. Water levels during summers 1999 and 2000 were fairly constant and flow through the low-flow channel in the spillway was present. Between February and June 2001, 1,464 acre-feet of water were pumped from the WSR to the tailing impoundment and by break-up, water levels in the WSR had dropped about 2 m. The WSR contains 3,363 acre-feet of water when water begins to flow through the low flow channel in the spillway.

By mid-summer 2001, the WSR had filled and water flowed through the low flow channel in the spillway until late November 2001. Seepage flow below the dam remained fairly constant during 1999 at a rate of 1.16 to 1.82 cfs (geometric mean 1.47 cfs); in 2000 at a rate of 1.03 to 1.86 cfs (geometric mean 1.38 cfs); and in 2001 at a rate of 1.03 to 1.78 cfs (geometric mean 1.31 cfs).

In April 2001, the five water quality stations were sampled. At Stations 1 and 2, located in the middle of the WSR, dissolved oxygen concentrations did not decrease with depth, and ranged from 2.45 to 3.10 mg/L (Site 1) and from 2.47 to 3.15 mg/L (Site 2). Dissolved oxygen concentrations decreased with depth in Lower Last Chance Bay with the highest measurement being 0.75 mg/L just below the ice. At Station 11 (Polar Bay), dissolved oxygen concentrations were higher in the middle of the water column (2.75 to 4.75 m), and ranged from 3.21 to 3.65 mg/L. The highest dissolved oxygen

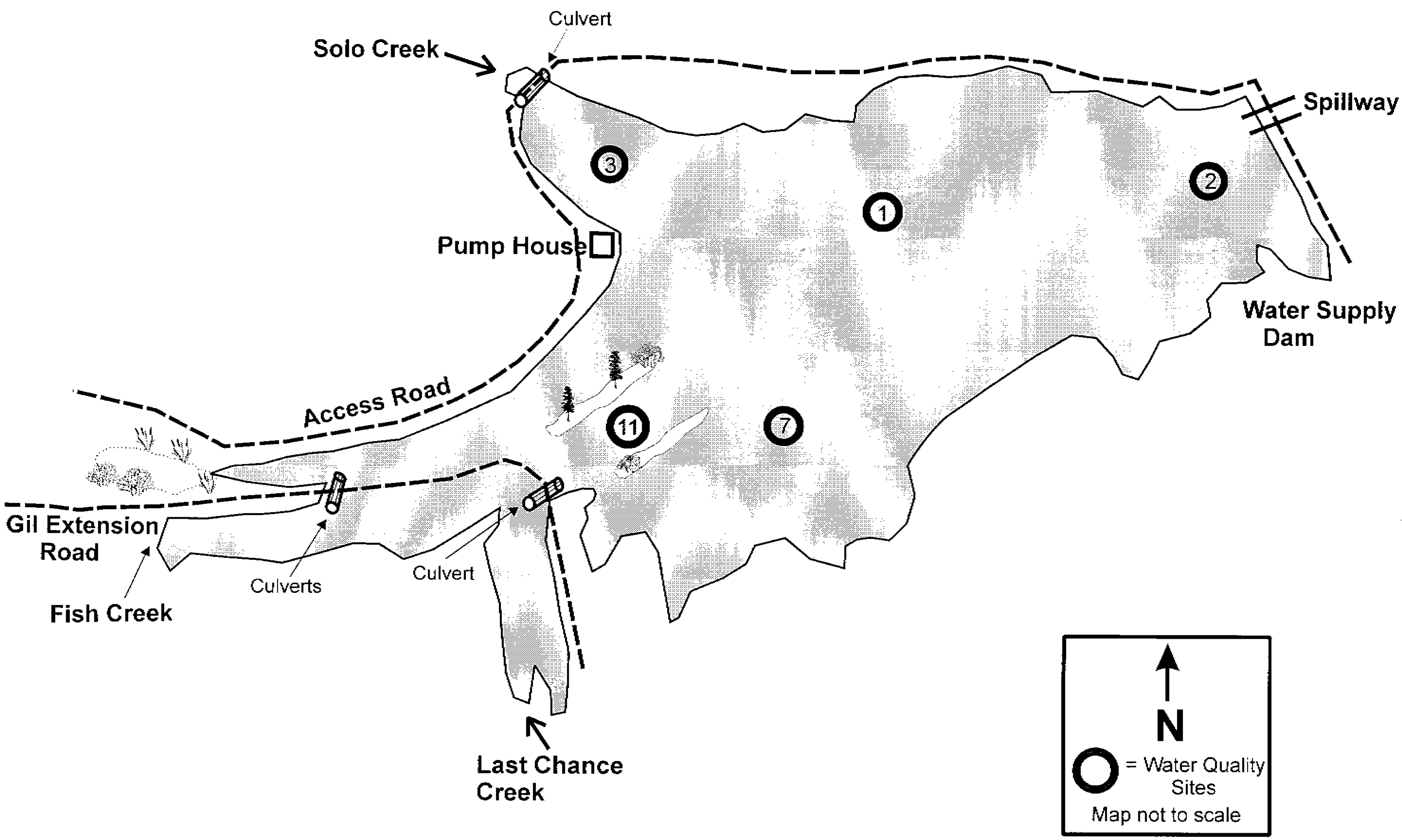


Figure 5. Water quality sample sites in the Fort Knox water supply reservoir.

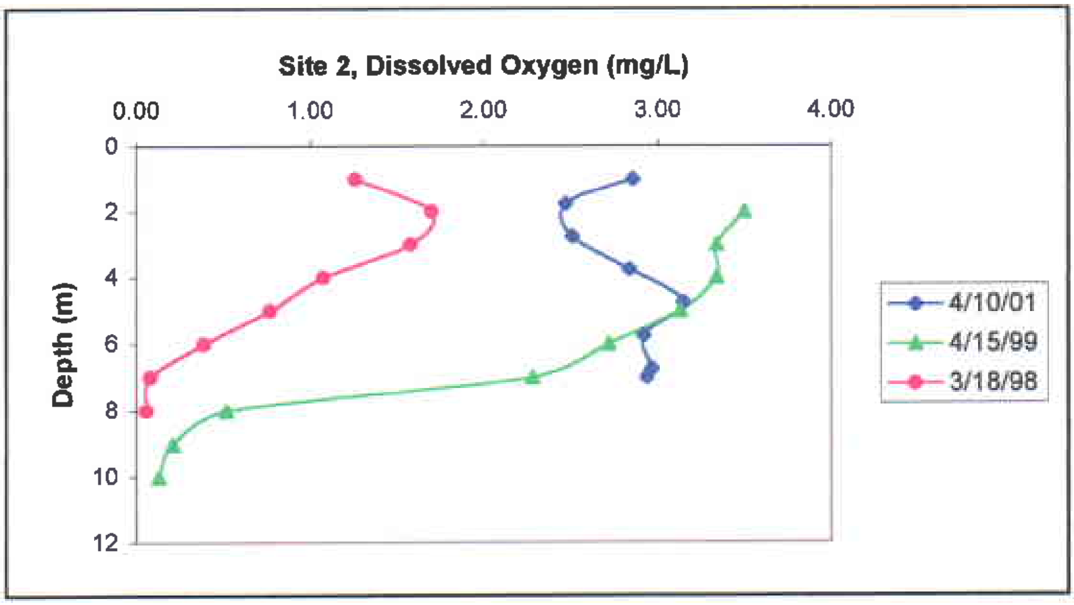
concentrations just below the ice occurred in Solo Bay (7.28 and 8.38 mg/L). Generally, the concentrations of dissolved oxygen were higher than those measured in previous years and decreased concentrations with depth were not as prevalent. The higher dissolved oxygen concentrations were found in areas of the WSR influenced by freshwater input from Solo and Last Chance creeks. Winter discharge from the developed wetlands is minimal – most of the water flowing out of Pond F turns into a large aufeis field near its confluence with the WSR.

In early June (just after the ice had cleared) and in early October (prior to freeze-up) 2001, we again sampled the five water quality stations. In June, dissolved oxygen decreased slightly with depth at the five sites. In October dissolved oxygen also decreased with depth but at Sites #1 and #2, located in the middle of the WSR, we saw fairly substantial decreases (Appendix 1). The WSR in late 2001 was full and anticipated water use for the remainder of the winter is about 32 acre-feet per month until summer 2002.

We compared dissolved oxygen concentrations in late winter 1998, 1999, and 2001 at Station 2 (Figure 6). Dissolved oxygen concentrations were much higher in 2001 than in 1998 and did not decrease with depth as dramatically as in either 1998 or 1999.

Dissolved oxygen concentrations in early spring, immediately after the ice melted, also were compared at Station 2. Dissolved oxygen concentrations were highest in 1999 and lowest in 2000 (Figure 7). Decreased dissolved oxygen concentrations with depth were not as large in 2001 as in the two previous years.

Water is withdrawn from the bottom of the WSR and dissolved oxygen concentrations have, in the past, been lowest near and at the bottom, particularly during late winter. Water removed from the WSR in late winter 2001 probably was low in dissolved oxygen. Removal of the low dissolved oxygen waters may explain why concentrations did not decrease substantially with depth in April 2001.



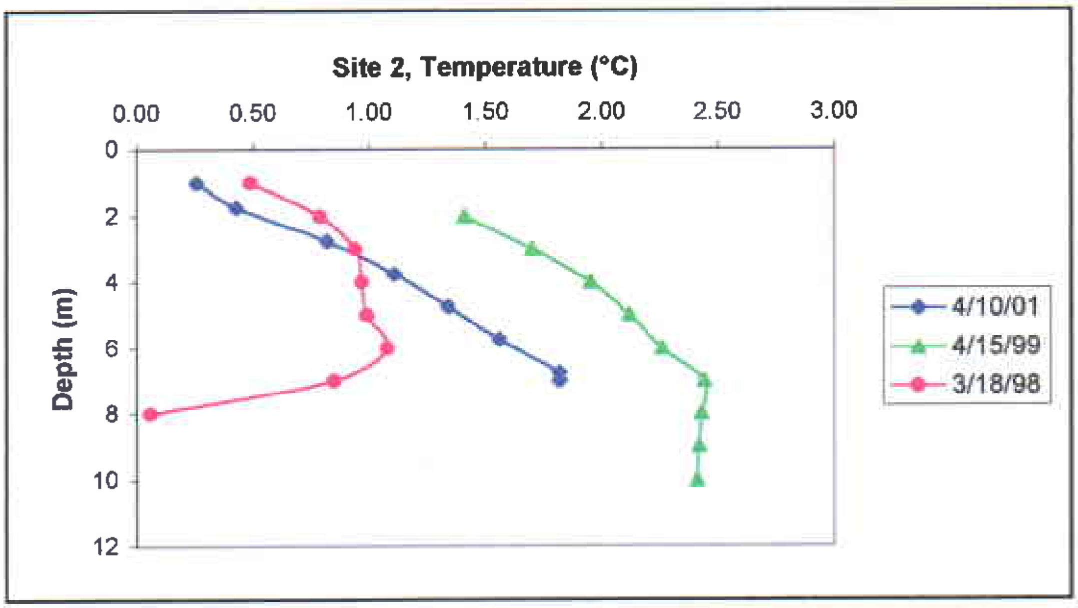
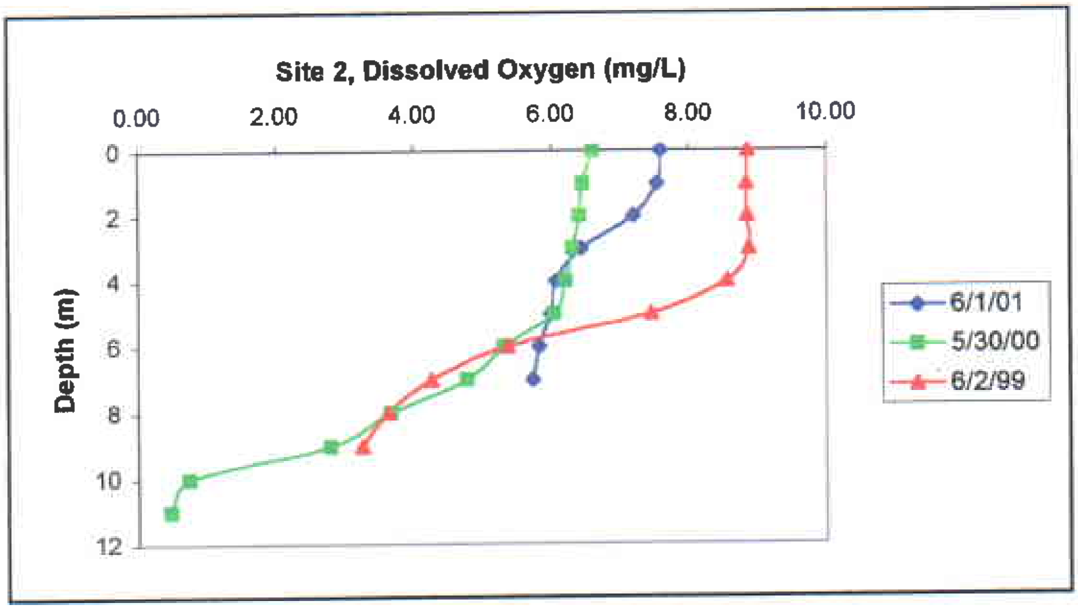


Figure 6. Dissolved oxygen concentration and temperature at Site #2 (Spillway) by depth in the water supply reservoir in late winter 1998, 1999, and 2001.



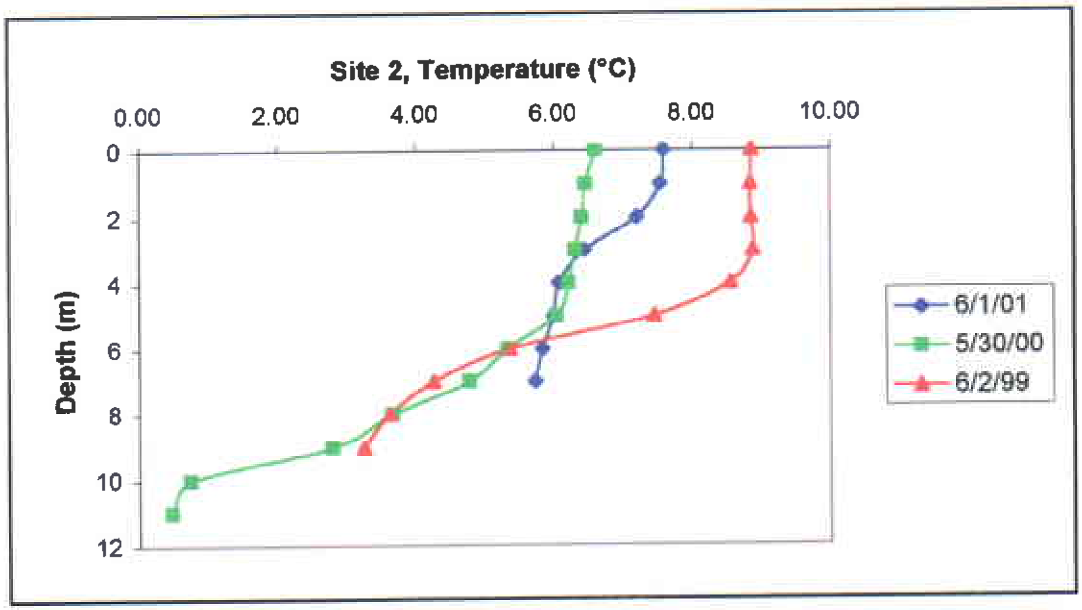


Figure 7. Dissolved oxygen concentration and temperature at Site #2 (Spillway) by depth in the water supply reservoir in early spring 1999, 2000, and 2001.

Water Supply Reservoir, Zooplankton

On April 10 and 13, 2001, we collected zooplankton samples at the five water quality stations. The WSR was completely ice covered, but water was present under the snow cover and some overflow was present along the edges. Zooplankton sample results are summarized in Table 1.

Table 1. Fort Knox zooplankton sample results (April 10 and 13, 2001).

Sample Site	Sample Depth (m)	Number of Copepoda Cyclopoida	Number of Copepoda Calanoida	Number of Branchiopoda Daphnidae	Estimated number per liter
#3 Solo Bay	3	268	2	8	7
#3 Solo Bay	4	973	14	0	19
#2 Main Reservoir	5	1230	60	32	20
#1 Main Reservoir	5	728	31	28	12
#11 Polar Bay	5	340	43	184	9
#7 Last Chance Bay	4	52	2	3	1

Zooplankton densities in April 2001 were similar to August 2000 densities; however, communities in April were dominated by copepods, whereas August communities were dominated by daphnids. In April 2001, zooplankton numbers were lowest in Last Chance Bay where dissolved oxygen concentrations were less than 1 mg/L at all depths.

The fact that the numbers of daphnids were relatively high during August 2000 but not in April 2001 may be explained by water quality conditions that act to limit daphnid hatching. Low dissolved oxygen concentrations and low water temperatures can inhibit the overwintering eggs of Daphnidae from hatching until conditions become more favorable. Copepods, on the other hand, do well at low oxygen concentrations and in habitat conditions that generally are stressful to daphnids (Thorp and Covich 1991).

Stilling Basin, Arctic Grayling and Burbot

The stilling basin, located immediately below the WSR spillway, is fed by groundwater and seepage flow from the WSR dam and by water from the WSR when flows pass over the spillway (Figure 3). In spring 2001, water was not flowing over the spillway. Sampling with fyke-nets began on May 2, 2001 when the stilling basin was ice-free, but while the WSR was still 100% ice covered.

We set a fyke-net on May 2 (Station A) in the stilling basin near the point where the flow from the seepage channel enters. The net was set at that location because we hypothesized that adult Arctic grayling would select the stream and riffle zones below a beaver dam complex for spawning. A second fyke-net (Net B) was set on May 9, blocking the outlet of the stilling basin to Fish Creek. The second net was placed at the outlet because actively spawning Arctic grayling were observed in the outlet area (i.e., shallow run at the head of a riffle). Arctic grayling adults trying to enter the seepage channel were never observed; this may have been related to the fact that water in the channel remained cooler than in the stilling basin.

We caught 130 adult females, 99 adult males and 212 juvenile fish <200 mm in the stilling basin. About 63% of adult male fish caught on May 3 (water temperature of 5.4°C) were ripe. The proportion of ripe males varied during sampling, but generally over 70% were ripe. Some individually marked males judged to be spent were later recaptured and determined to be ripe. Although catches were low the last four days of sampling (May 18 to 21), 67 to 100 percent of the males were still ripe.

The first ripe female was captured on May 4, but few ripe females were seen until May 9, 10, and 11 (water temperatures of 5.0 to 7.0°C at the outlet). About 10% of the females handled were ripe from May 9 to 11. The first spent female was caught on May 10. From May 11 to 12 water temperatures at the outlet were cooler (5.0 to 5.2°C). Water temperatures rose on May 13 to 10.2°C, then decreased the next five days (7.1 to 7.8°C). On May 14, 50% of the captured females were spent and by May 17, 75% of the females had completed spawning. The proportion of spent females gradually increased, reaching over 80% by May 20 (Figure 8). Active spawning was observed in Fish Creek immediately below the stilling basin, but most spawning activity was seen in the outlet area of the stilling basin. Water temperature increases in the stilling basin occurred more rapidly than in the seepage collection system due to a larger surface area in the stilling basin affected by solar input.

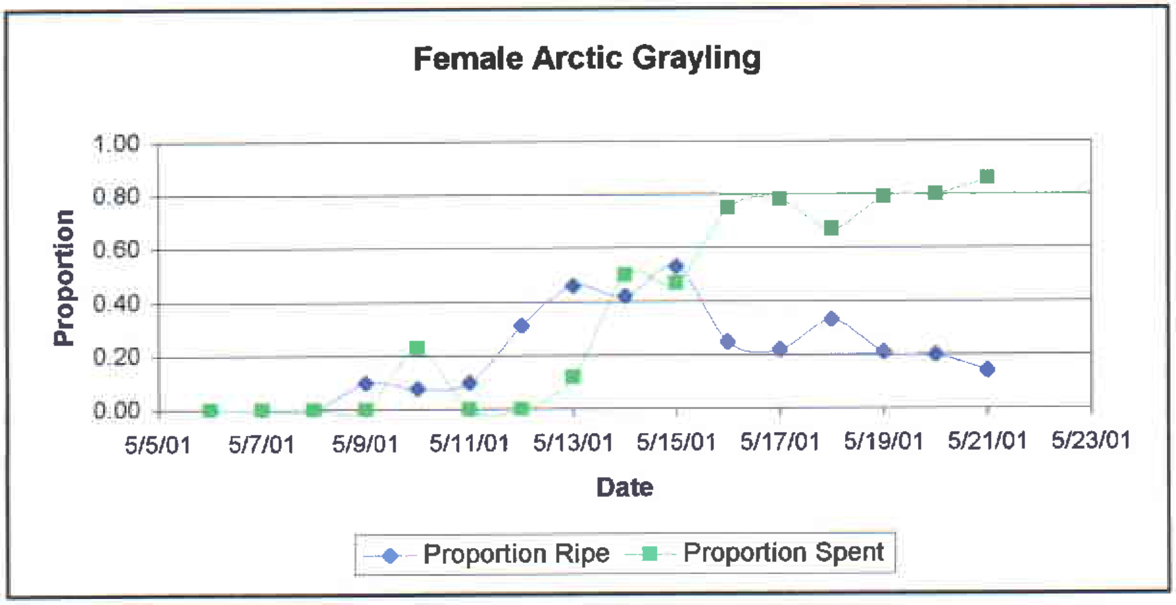


Figure 8. The proportion of ripe and spent female Arctic grayling in the stilling basin in May 2001.

Our spring 2001 work in the stilling basin was the first time that we have sampled this area. We captured Arctic grayling in the stilling basin that had been captured and tagged in the WSR in 1996, 1998, 1999, and 2000. The total number of Arctic grayling > 200 mm captured in the stilling basin was 229, of which 26 had previously been caught and marked in the WSR. Only a couple of burbot were caught in the stilling basin and none of these fish were marked. The Arctic grayling leaving the WSR and entering Fish Creek may eventually show up in the Chena River fishery.

Water Supply Reservoir and Developed Wetlands, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR dam. Fish were most concentrated in Lower and Upper Last Chance Creek ponds. The Arctic grayling within the population appeared stunted; fish larger than 220 mm long were rare, annual growth was 9 mm, and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning occurred primarily in the outlet and inlets between Polar Ponds #1 and #2 – these ponds now referred to as Polar Bay in the WSR (Figure 2).

We continued to sample Arctic grayling in the WSR during the ice-free season following construction of the WSR dam (Table 2). Flooding of the Fish Creek valley by the

Table 2. Estimates of the Arctic grayling population in the water supply reservoir at the Fort Knox Mine (1995 to 2000). Capture and recapture events were done using fyke-nets, except where noted.

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

[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]Gear type for the population estimate was a boat-mounted electroshocker.

WSR dam, inundated Polar Ponds #1 and #2 along with the spawning habitat. Nonetheless, the number of Arctic grayling increased to an estimated 5,800 fish >200 mm long in 1998; however, catches of small Arctic grayling were very low from 1996 through 1999. In early spring 1999, FGMI constructed an outlet channel (Channel #5) that connected several flooded ponds in the developed wetlands area with the WSR. Arctic grayling successfully spawned in Channel #5, in the pond complexes, and in interconnecting channels in 1999, 2000, and 2001, with substantial numbers of age-0 fish observed throughout the wetland complex each year. We estimated the abundance of the Arctic grayling population in the WSR using spring 2000 as the mark event (n_1 = 598) and spring 2001 as the recapture event. In spring 2001, we caught 835 Arctic grayling > 240 mm (n_2 = 835), with 93 recaptures (m_2 = 93). Comparison of 2000 and 2001 length frequency diagrams indicated that many fish captured and tagged in 2001 would have been too small to enter our estimable population in 2000 (i.e., they would have been under 200 mm long in 2000). Therefore, in computing the 2000 estimate, only fish larger than 240 mm in 2001 were used in estimating the Arctic grayling population over 200 mm long in 2000. Our spring 2000 estimated Arctic grayling population size for fish >200 mm was 5,326 (95% CI 4,400 to 6,253). In comparison, our spring 1998 and 1999 estimated population sizes of Arctic grayling were 5,800 (95% CI 4,705 to 6,895) and 4,123 (95% CI 3,698 to 4,548).

In spring 2001 we handled 1,237 fish that were previously marked or were > 200 mm and tagged. Of these 1, 237 fish, 402 of were < 240 mm. The apparent increase in numbers of Arctic grayling > 200 mm is due to recruitment of new fish. Furthermore, we captured large numbers of Arctic grayling less than 200 mm and observed these smaller fish in almost every portion of the constructed wetlands and WSR. We believe that the increases in Arctic grayling numbers in the WSR are the direct result of rehabilitation work to develop wetlands along the south side of the Fish Creek valley and the construction of Channel #5 that connected these wetlands with the WSR.

As part of our sample event to mark and recapture Arctic grayling in spring 2001, we operated additional fyke-net sites to gather information to investigate the relationship between spawning by Arctic grayling and water temperatures. Fyke-nets were fished in the outlet channel below Pond F and in the inlet to Pond E to capture and determine spawning condition of Arctic grayling. A fyke-net was set in a small pond thawed by surface flows in the wetland complex downstream of the outlet channel from Pond F on May 17. Because of ice cover, the second net placed in the inlet to Pond E, was not set until May 20. The WSR was still 90% ice covered.

Fyke-nets in the wetland complex were fished until June 7. Nets were checked daily and fish were marked, assessed for spawning condition (not ripe, ripe, partially spent, and spent) and the information recorded. Continuous temperature data recorders were set at each net to record temperature each half hour. We caught 248 adult females and 339 adult males in the wetland complex. On May 18 (Pond F outlet water temperature of 2.8°C), 28 of the 29 males handled were ripe and one of 22 females was ripe. The proportion of ripe males remained at 89% or higher until May 30, when the percent ripe and number caught per day decreased dramatically. By May 25, the majority of females were ripe and some were spent (Pond F outlet water temperature of 6.5°C) (Figure 9). From May 27 until June 1, water temperatures in the Pond F outlet channel warmed (8.2 to 11.4°C), catch per day of females decreased, and 70% of the females were judged to be spent on May 31. Numbers of Arctic grayling females and males captured in the first part of June in the two fyke-nets remained low. Both nets effectively blocked movement either upstream or downstream, thus it appears that spent fish were milling and/or feeding in the wetland complex.

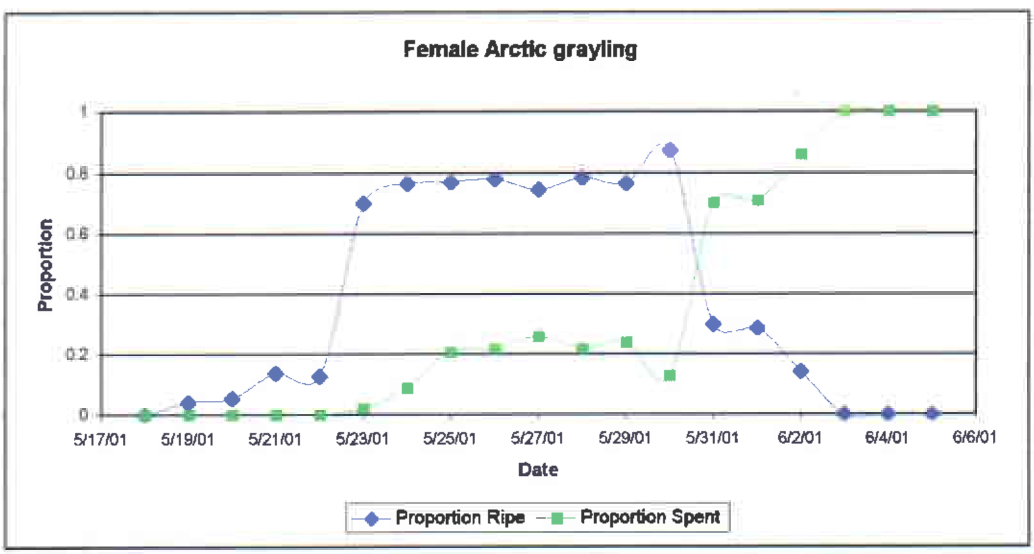


Figure 9. The proportion of ripe and spent female Arctic grayling in the wetland complex May/June 2001.

We did not install a continuous temperature recorder in Upper Last Chance Bay, but we did fish a fyke-net in that area to capture additional Arctic grayling for the mark/recapture estimate. Actively spawning Arctic grayling were observed in a pool/riffle combination located upstream of the 10-foot diameter culvert in the Gil Extension Causeway across the WSR. The pool/riffle combinations were created by lower water surface elevations in the WSR. Water from Upper Last Chance Bay flowed across a gravel riffle, into a small pool, and then through a second riffle before entering a pool that extended through the entire length of the culvert. The number of fish observed in these reaches and water temperatures were recorded (Table 3).

Table 3. Water temperatures in flowing water connecting Upper Last Chance Bay with the water supply reservoir and observations on Arctic grayling spawning activity.

Date	Time	Temperature (°C)	Observations
May 20	1300	3.5°C	no fish observed
May 23	1620	5.0°C	spawning with males defending territories
May 25	1300	6.0°C	active spawning
May 26	1500	5.0°C	video of fish spawning taken many fish spawning (about 30)
May 27	1500	4.3°C	no fish activity observed
May 28	1330	6.2°C	a couple of fish spawning
May 28	1530	6.3°C	about 10 fish actively spawning
May 29	1500	6.5°C	about 12 fish actively spawning
May 30	1340	7.8°C	about 6 fish actively spawning
May 31	1200	8.8°C	lots of activity (about 12 fish), fish spawning
June 1	1215	9.3°C	lots of activity (about 12 fish), fish spawning
June 3	1245	9.6°C	no fish seen
June 4	1220	12.2°C	no fish seen

In spring 2001, we marked 1,079 Arctic grayling captured in the outlet of Pond F, the inlet of Pond E, and in Upper Last Chance Creek Bay. A summary of marks put out each year and the number of recaptures each spring is presented in Table 4.

Table 4. Number of Arctic grayling marked by year and the number of recaptures seen during the May/June sample event (1998 through 2001). The total number of Arctic grayling handled in May 1998, May 1999, May 2000, and May/June 2001 >200 mm was 1,140, 1,275, 1,261, and 1,237, respectively.

Year (Tag Color)	Number of Fish Tagged	Number of Recaptures May 1998	Number of Recaptures May 1999	Number of Recaptures May 2000	Number of Recaptures May 2001
93 (yellow)	413	4	4	2	1
94 (white)	798	5	8	4	1
95 (orange)	1315	39	36	24	14
96 (blue)	591	124	102	107	48
98 (orange)	181		34	22	6
99 (yellow)	497			140	40
00 (green)	300				48
01 (gray and orange)	1,079				

Length frequency distribution for Arctic grayling collected during spring in 1995, 1996, 1998, 1999, 2000, and 2001 is presented in Figure 10. From 1995 to 1999, Arctic grayling recruitment was not documented – fish were growing larger in the WSR. Channel #5 connecting the wetlands to the water supply reservoir was built in spring 1999 and in spring 2000 and 2001, substantial numbers of smaller fish were caught, indicating successful spawning and recruitment from fish using the wetlands complex.

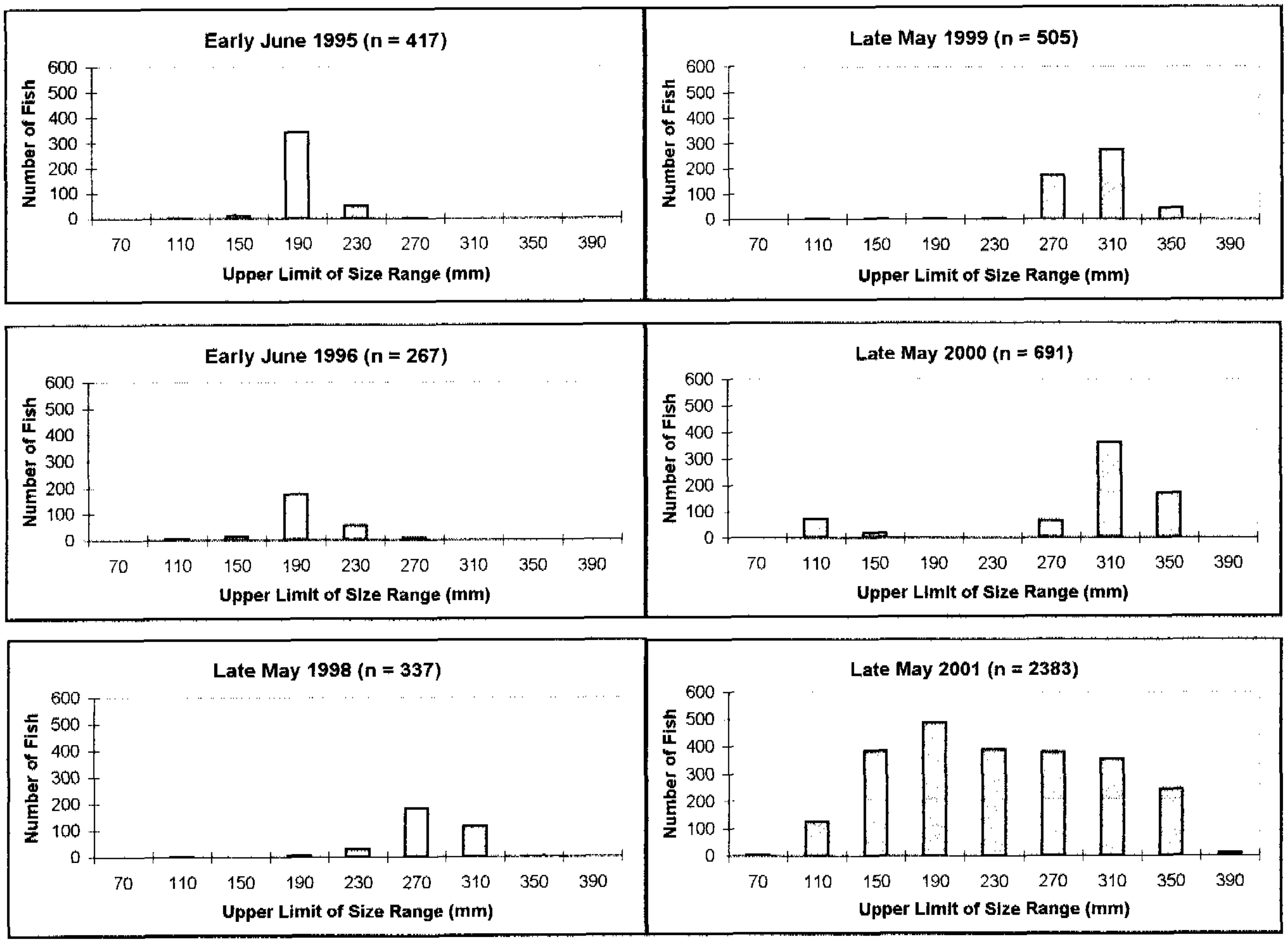


Figure 10. Length-frequency distribution of Arctic grayling in the water supply reservoir and wetland complex (1995 through 2001).

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 abundance of burbot (150 to 331 mm) to be 825 fish (Ott and Weber Scannell 1996). Flooding of the WSR began in November 1995, and the Last Chance Creek and Polar Ponds were inundated, isolating burbot upstream of the WSR dam.

Estimates of the burbot population in the WSR were made during the ice-free season following construction of the WSR dam (Table 5). Burbot population estimates in the WSR for 1997 and 1998 were 622 and 703 fish. The 1997 and 1998 estimates were for burbot ≥250 and ≥300 mm. Recaptures of small marked fish (<300 mm) were too low in 1997 and 1998 to make population estimates, but with a higher number of recaptures we were able to use spring 1999 as the recapture event to estimate the spring 1998 burbot population for fish >200 mm at 3,609 (Table 5).

Table 5. Estimates of the burbot population in the water supply reservoir at the Fort Knox Mine (1995 to 2001).

Year	Minimum Size of Burbot in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995	150	876	666-1087
1997	250	622	462-782
1998	300	703	499-907
1998	200	3,609	2,731-4,485
1999	200	4,136	3,215-5,057
2000	200	3,536	2,444-4,629
2001	200	3,391	2,017-4,764

We estimated the burbot population in the WSR using spring 2000 as the mark event (n_1 = 341) and spring 2001 as the recapture event. In spring 2001 (June 6 and 7), we caught 330 (n_2) burbot with 31 recaptures (m_2). Our spring 2000 estimate of abundance of burbot >200 mm was 3,536. In spring 2001, we also conducted a second sampling event in the WSR (June 27 and 28) to estimate the spring 2001 burbot population. The number of marked fish was 303 (n_1) and we handled 211 (n_2) during the recapture event with 18 (m_2) recaptures. The spring 2001 estimated burbot population for fish >200 mm was 3,391 (95% CI 2,017-4,764) (Table 5).

We marked 439 burbot in spring 2001 with individually numbered gray Floy® internal anchor tags. CPUE for hoop traps fished has been calculated since 1996 (Table 6). Catch rates have been similar the last four years. Calculated length frequency distributions for burbot captured from May 1995 to May 2001 are shown in Figure 11. The population is dominated by burbot from 275 to 325 mm long.

The trend for increasing burbot numbers, specifically those from 275 to 325 mm long in the WSR, began in 1998 and reflects recruitment to the population following construction of the WSR dam. Furthermore, based on the presence of fish <250 mm in the spring 2001 sample, new fish are continuing to enter the population.

Annual growth of tagged burbot was tracked from 1998 through 2001. Average growth is shown in Table 7 and represents the annual growth of individually marked fish recaptured one year after the fish was marked. Annual growth continues to be higher for the small burbot (<275 mm) and large burbot (>400 mm). The higher annual growth for the large burbot has been seen for the last four years. The growth rate for intermediate sized burbot remains low. We believe the slow growth is related to the fact that these fish are switching from a diet of primarily insects to fish.

Table 6. Burbot catches in the water supply reservoir (1996 to 2001) using hoop traps.

Sample Date	Gear Type	Number of Traps	Catch (Total)	Mean CPUE[1] (BB/trap/day)
May 22, 96	small hoop	11	36	3.3
May 22, 96	large hoop	4	6	1.5
May 23, 96	small hoop	11	19	1.7
May 23, 96	large hoop	4	2	0.5
May 20, 97	small hoop	11	58	5.3
May 20, 97	large hoop	13	24	1.8
May 21, 97	small hoop	11	61	5.5
May 21, 97	large hoop	17	56	3.3
May 28, 97	small hoop	11	45	4.1
May 28, 97	large hoop	19	42	2.2
May 29, 97	small hoop	11	32	2.9
May 29, 97	large hoop	20	39	2.0
May 20, 98	small hoop	7	87	12.4
May 21, 98	small hoop	9	61	6.8
May 21, 98	large hoop	3	20	6.7
May 22, 98	small hoop	9	57	6.3
May 27, 98	small hoop	9	61	6.8
May 28, 98	small hoop	9	67	7.4
May 29, 98	small hoop	9	44	4.9
June 3, 99	small hoop	17	135	7.9
June 4, 99	small hoop	17	124	7.3
June 5, 99	small hoop	17	136	8.0
June 7, 99	small hoop	17	142	4.2
June 8, 99	small hoop	17	89	5.2
May 30, 00	small hoop	24	191	7.9
May 31, 00	small hoop	24	105	4.4
June 1, 00	small hoop	24	122	5.1
June 6, 01	small hoop	30	209	7.0
June 7, 01	small hoop	30	76	2.5
June 27, 01	small hoop	30	98	3.3
June 28, 01	small hoop	30	140	4.7

[1]CPUE = catch per unit of effort

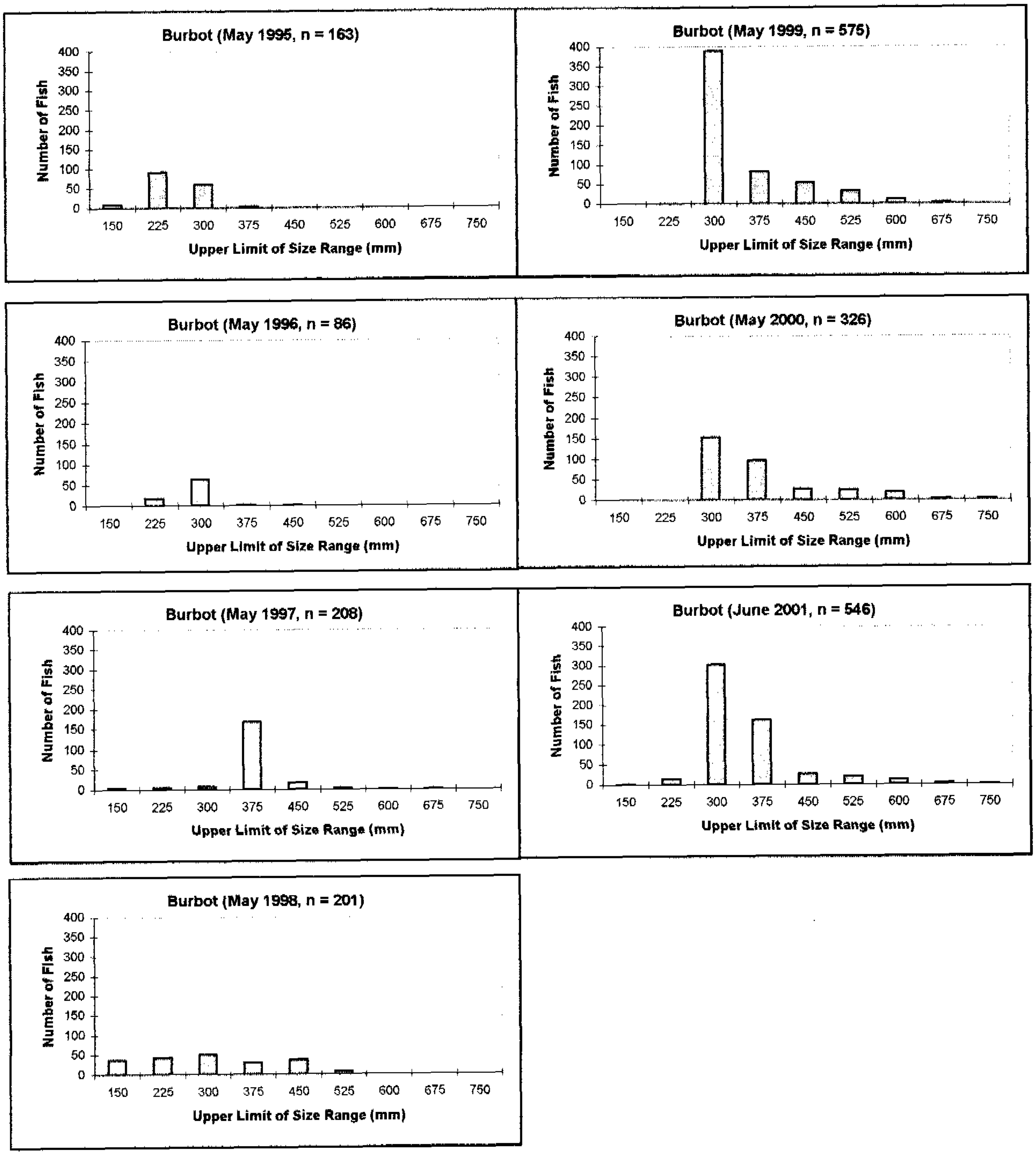


Figure 11. Length-frequency distribution of burbot caught in the water supply reservoir, 1995 to 2001.

Table 7. Growth of burbot tagged in May 1998, June 1999, and June 2000 and recaptured in June of 1999, 2000, and 2001 using hoop traps.

Length at Tagging (mm)	Sample Size	Average Growth (mm)	Standard Deviation
225-249	3	33	7.8
250-274	6	16	15.3
275-299	22	8	5.4
300-324	12	13	8.6
325-349	5	8	1.5
350-374	7	15	10.6
375-399	14	9	8.9
400-424	10	23	14.4
425-449	10	31	18.9
450-474	12	30	20.3
475-499	7	38	12.8
500-524	8	35	17.5
525-549	7	48	22.0
550-574	6	30	17.2
575-599	3	32	15.9
600-624	1	80	

To better understand movement of burbot in the WSR, including selection of overwintering areas and possible spawning sites, we radiotagged three burbot on October 3, 2001. Burbot were caught using small hoop traps fished along the north side of the WSR near Solo Creek Bay. Three of the largest fish were selected and radiotags were surgically implanted. One of the burbot was a female (780 mm) – two could not be sexed (710 and 715 mm).

All three radiotagged-burbot were relocated on October 22 and November 29, 2001. In late October all three fish had returned to the general area of initial capture and in late November, the three fish were dispersed. Burbot #1 was in the main part of the WSR and the other two were near Polar Bay. Burbot #1 and #2 were found in the same general areas they were found in during late November and December, but in late January these two fish had moved into Solo Bay. The fact that both Burbot #1 and #2 are in the same location now may indicate a pre-spawning aggregation in Solo Bay. We will continue to periodically relocate these fish to assess movement, to locate wintering areas and, potentially, to locate spawning areas.

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Appendix 1 - Water Quality: Water Supply Reservoir

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	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
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

Appendix 1 (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	6/23/00	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
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

Appendix 1 (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	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
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 1 (continued).

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
2	10/1/01	0	7.33	65.6	7.55	120.9	7.25
		1	7.30	65.7	7.55	120.3	7.25
		2	7.28	65.7	7.56	121.3	7.25
		3	7.28	65.7	7.57	120.6	7.25
		4	7.27	65.7	7.57	121.0	7.25
		5	7.26	65.7	7.57	120.8	7.25
		6	7.25	65.5	7.55	120.9	7.25
		7	7.20	65.2	7.52	121.2	7.26
		8	6.76	27.3	3.20	117.1	7.04
		9	6.55	6.4	0.74	115.0	6.98
		10	6.33	4.7	0.55	118.9	7.00
		11	6.16	6.1	0.72	116.6	7.00
		12 (bottom)	6.07	7.1	0.84	116.8	7.01
2	6/1/01	0	7.86	66.6	7.59	114.9	7.05
		1	7.76	65.9	7.55	114.7	7.10
		2	7.22	62.3	7.20	114.4	7.07
		3	6.31	54.2	6.44	114.9	7.00
		4	6.06	50.7	6.07	114.3	6.94
		5	5.94	50.0	5.99	114.6	6.93
		6	5.84	48.6	5.83	114.3	6.91
		7 (bottom)	5.68	47.7	5.73	114.3	6.88
2	4/10/01	1	0.26	20.2	2.86	130.9	6.69
		1.75	0.43	17.5	2.47	131.2	6.62
		2.75	0.82	18.1	2.51	129.7	6.62
		3.75	1.11	20.6	2.84	127.9	6.61
		4.75	1.34	23.1	3.15	127.5	6.61
		5.75	1.56	21.4	2.92	127.9	6.63
		6.75	1.82	21.9	2.97	127.4	6.62
		7 (bottom)	1.82	21.8	2.94	127.4	6.60
2	8/29/00	0	11.22	80.7	8.63	107.5	7.24
		1	10.72	79.2	8.55	107.7	7.19
		2	10.59	78.8	8.54	108.1	7.18
		3	9.70	68.5	7.58	107.9	7.07
		4	8.89	54.0	6.13	106.8	6.87
		5	8.56	44.3	5.04	106.7	6.78
		6	7.15	29.9	3.54	102.9	6.64
		7	6.04	11.5	1.42	114.2	6.50
		8	5.86	4.7	0.57	126.2	6.40

Appendix 1 (continued).

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
2	8/29/00	9	5.38	3.5	0.42	138.2	6.34
		10	5.17	2.7	0.34	139.9	6.37
		11	4.90	2.4	0.29	142.2	6.41
		12	4.84	2.5	0.31	142.7	6.42
		13 (bottom)	4.81	2.3	0.29	143.2	6.44
2	6/23/00	0	18.76	95.5	8.75	103.1	7.57
		1	18.43	93.3	8.61	103.0	7.61
		2	14.73	72.2	7.21	103.7	7.15
		3	8.20	23.7	2.75	108.0	6.65
		4	6.37	22.7	2.75	108.9	6.62
		5	5.69	16.7	2.07	112.1	6.58
		6	4.89	14.0	1.76	115.8	6.55
		7	4.61	10.3	1.31	119.2	6.52
		8	4.26	9.5	1.21	121.8	6.50
		9	4.07	7.4	0.96	123.9	6.51
		10	3.89	4.6	0.59	128.4	6.50
		11	3.57	2.3	0.30	134.2	6.46
		11.5 (bottom)	3.41	2.0	0.26	139.8	6.43
2	5/30/00	0	7.14	55.3	6.61	109.3	6.73
		1	6.57	53.2	6.46	108.0	6.72
		2	6.07	52.2	6.41	106.9	6.71
		3	5.65	51.0	6.31	105.7	6.71
		4	5.59	50.0	6.21	105.5	6.70
		5	5.47	48.5	6.04	106.5	6.69
		6	4.30	41.5	5.32	109.1	6.66
		7	3.89	36.8	4.78	114.7	6.64
		8	3.48	28.0	3.67	126.0	6.61
		9	3.26	21.9	2.80	133.0	6.59
		10	2.51	5.5	0.74	164.6	6.52
		11 (bottom)	2.29	3.4	0.47	179.7	6.50
2	6/2/99	0	9.74	81.0	8.86	134.2	7.47
		1	9.72	80.5	8.84	134.4	7.44
		2	9.70	80.6	8.85	134.9	7.44
		3	9.66	80.9	8.88	134.8	7.43
		4	9.66	77.9	8.56	135.1	7.40
		5	9.31	67.7	7.45	133.9	7.16
		6	7.26	46.0	5.36	133.7	7.04
		7	6.13	36.0	4.26	135.0	6.97

Appendix 1 (continued).

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
2	6/2/99	8	5.50	29.9	3.62	136.0	6.90
		9	5.11	26.5	3.25	137.1	6.84
		9.5 (bottom)	4.98	25.4	3.14	137.6	6.81
2	4/15/99	2	1.41	25.4	3.50	161.4	6.13
		3	1.70	24.5	3.34	160.8	6.30
		4	1.95	24.7	3.34	159.8	6.22
		5	2.12	23.3	3.13	159.8	6.23
		6	2.26	20.3	2.72	160.1	6.19
		7	2.44	17.1	2.28	160.8	6.16
		8	2.43	3.9	0.52	166.1	6.16
		9	2.42	1.7	0.21	180.6	6.17
		10	2.41	1.0	0.13	244.9	6.24
2	10/1/98	surface	6.35	60.6	7.21	144.3	7.62
		1	6.25	60.1	7.18	144.8	7.58
		2	6.24	59.7	7.11	144.3	7.57
		3	6.22	59.0	7.06	144.5	7.56
		4	6.22	58.4	6.99	144.7	7.56
		5	6.20	58.0	6.94	144.4	7.56
		6	6.20	58.0	6.95	144.4	7.57
		7	6.18	58.0	6.97	144.4	7.56
		8	6.12	59.0	7.08	144.6	7.58
		9 (bottom)	6.13	58.7	7.00	144.7	7.60
2	7/28/98	surface	17.52	87.1	8.11	161.6	7.41
		1	17.25	85.1	7.98	162.1	7.44
		2	16.86	83.3	7.92	161.2	7.46
		3	14.17	48.0	4.80	156.9	6.98
		4	11.63	28.7	3.04	142.3	6.78
		5	10.31	22.8	2.46	138.4	6.70
		6	8.26	7.3	0.82	155.2	6.65
		7	7.62	4.4	0.52	159.8	6.64
		8 (bottom)	6.78	3.7	0.44	169.1	6.63
2	3/18/98	1	0.49	N/T	1.26	176.0	7.01
		2	0.79	N/T	1.70	175.0	6.93
		3	0.94	N/T	1.58	176.0	6.85
		4	0.97	N/T	1.08	178.0	6.81
		5	0.99	N/T	0.77	182.0	6.77
		6	1.08	N/T	0.39	184.0	6.75

Appendix 1 (continued).

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
2	3/18/98	7	0.85	N/T	0.08	214.0	6.60
		7.8 (bottom)	0.06	N/T	0.06	281.0	6.53
2	9/25/97	surface	9.34	N/T	6.10	143.0	7.23
		1	9.23	N/T	5.76	145.0	7.10
		3	9.18	N/T	5.67	147.0	7.05
		5	9.01	N/T	4.58	147.0	6.95
		7.5 (bottom)	8.49	N/T	2.65	145.0	6.92

Appendix 1 (continued).

Site 3 is located in Solo Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
3	10/1/01	0	7.24	65.1	7.51	121.6	7.28
		1	7.23	64.5	7.43	121.5	7.28
		2	7.21	64.2	7.40	121.2	7.28
		3	7.16	63.5	7.33	121.5	7.28
		4	7.09	63.0	7.29	121.2	7.29
		5 (bottom)	6.82	63.0	7.35	121.4	7.29
3	6/1/01	0	9.03	72.4	8.04	115.8	6.87
		1	8.86	71.7	8.00	115.3	6.94
		2	8.83	71.4	7.98	115.3	6.97
		3	8.66	70.2	7.86	115.4	6.97
		3.5 (bottom)	8.21	65.6	7.41	115.0	6.96
3	4/13/01	1	0.03	59.8	8.38	149.7	6.79
		1.75	0.27	43.1	6.05	145.5	6.71
		2.75	0.61	25.8	3.57	139.8	6.69
3	4/13/01	1	0.04	51.7	7.28	147.7	6.69
		1.75	0.34	32.7	4.57	140.9	6.65
		2.75	0.66	19.0	2.62	135.6	6.62
		3.75	0.90	11.6	1.60	136.3	6.57
		4.75	1.09	3.9	0.53	137.0	6.53
		5.5 (bottom)	1.20	3.0	0.41	137.3	6.52
3	8/29/00	0	11.02	78.1	8.37	108.9	7.13
		1	10.23	76.2	8.34	108.5	7.11
		2	10.00	74.2	8.15	108.4	7.09
		3	9.96	73.8	8.12	108.5	7.08
		4	9.74	70.2	7.75	108.8	7.02
		5	7.55	43.6	5.09	100.3	6.80
		6	5.56	69.1	8.46	82.1	6.76
		7	5.54	14.1	1.71	112.0	6.46
		8	5.34	4.2	0.51	132.3	6.40
		9 (bottom)	5.22	3.0	0.37	138.0	6.45
3	6/23/00	0	18.34	93.8	8.67	103.6	7.48
		1	16.30	88.7	8.56	103.0	7.43
		2	10.25	33.1	3.69	107.0	6.68
		3	6.92	20.8	2.48	112.1	6.60
		4	5.80	14.1	1.74	113.4	6.55
		5	5.18	12.1	1.52	115.2	6.51

Appendix 1 (continued).

Site 3 is located in Solo Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
3	6/23/00	5.75 (bottom)	4.79	7.6	0.98	118.1	6.50
3	5/30/00	0	5.80	49.0	6.06	108.8	6.70
		1	5.82	48.0	5.95	108.9	6.69
		2	5.80	47.9	5.91	108.9	6.69
		3	4.72	43.0	5.50	110.9	6.67
		3.5 (bottom)	4.56	40.6	5.19	112.3	6.66
3	6/2/99	0	9.67	88.4	9.67	135.1	7.32
		1	9.60	84.4	9.29	134.8	7.32
		2	9.21	77.9	8.66	134.8	7.27
		3	7.71	57.4	6.50	134.5	7.10
		4	6.93	48.1	5.59	132.5	7.02
		5	5.61	64.3	7.83	115.0	7.11
		6	5.02	69.2	8.55	110.5	7.14
		7 (bottom)	4.92	70.7	8.75	110.5	7.11
3	10/1/98	surface	6.11	71.2	8.53	144.2	7.30
		1	6.05	70.5	8.44	144.2	7.32
		2	5.98	69.4	8.36	144.2	7.34
		3	5.88	69.2	8.35	144.2	7.36
		4 (bottom)	4.93	69.5	8.59	139.4	7.36
3	7/28/98	surface	17.24	86.9	8.15	161.3	7.57
		1	16.71	80.0	7.58	161.8	7.52
		2	16.33	66.9	6.38	161.2	7.33
		3 (bottom)	14.62	58.4	5.75	150.6	7.19
3	3/18/98	1	0.47	N/T	0.31	176.0	6.93
		1.5 (bottom)					
3	9/25/97	surface	9.36	N/T	5.90	156.0	7.94
		1	9.25	N/T	5.62	156.0	7.68
		3	9.10	N/T	5.42	155.0	7.38
		4.5 (bottom)	8.96	N/T	4.30	155.0	7.13

Appendix 1 (continued).

	Site 7 is located in Lower Last Chance Bay						
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
7	10/1/01	0	6.98	65.1	7.57	121.8	7.28
		1	6.91	64.0	7.43	122.2	7.29
		2	6.85	63.7	7.41	121.8	7.29
		3	6.61	64.4	7.54	122.2	7.31
		4	6.51	61.6	7.23	122.5	7.28
		5 (bottom)	6.34	56.3	6.63	122.8	7.24
7	6/1/01	0	9.41	69.2	7.61	115.9	6.92
		1	9.12	68.6	7.61	115.7	6.92
		2	8.97	68.4	7.61	115.6	6.90
		3	8.73	67.1	7.51	115.8	6.91
		4 (bottom)	6.27	45.0	5.35	115.8	6.82
7	4/13/01	1	0.09	5.3	0.75	143.1	6.53
		1.75	0.29	3.7	0.54	143.6	6.52
		2.75	0.51	3.0	0.41	142.9	6.52
		3.75	0.62	2.7	0.37	154.5	6.50
		4.75 (bottom)	0.55	2.3	0.32	275.9	6.42
7	8/29/00	0	10.54	75.7	8.22	108.3	7.06
		1	10.11	72.5	7.95	108.9	7.04
		2	9.94	71.5	7.84	108.4	7.02
		3	9.71	68.3	7.60	108.8	7.00
		4	9.30	67.1	7.50	105.9	6.95
		5 (bottom)	8.38	68.5	7.81	103.0	6.93
7	6/23/00	0	18.23	90.7	8.40	103.9	7.40
		1	16.22	82.5	7.92	103.4	7.23
		2	12.30	47.3	4.98	105.4	6.79
		3	8.07	16.9	1.96	111.1	6.64
		4	6.00	6.7	0.82	116.0	6.51
		5	5.36	4.2	0.52	119.0	6.46
7	5/30/00	0	6.80	52.3	6.30	110.7	6.75
		1	6.39	49.4	5.99	110.5	6.72
		2	4.93	41.1	5.19	110.7	6.70
		3	4.19	35.1	4.54	116.8	6.64
		4	4.10	33.4	4.31	117.5	6.63
		5 (bottom)	3.99	29.6	3.84	119.0	6.61

Appendix 1 (continued).

	Site 7 is located in Lower Last Chance Bay						
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
7	6/2/99	0	8.84	72.0	8.06	133.5	7.21
		1	8.82	70.3	7.90	133.8	7.20
		2	8.65	68.2	7.67	133.6	7.21
		3	6.21	42.5	5.09	134.9	7.01
		4	6.17	38.8	4.64	135.0	7.01
		4.5 (bottom)	6.16	37.1	4.45	134.9	7.00
7	10/1/98	surface	5.63	67.6	8.22	143.6	7.59
		1	5.52	68.0	8.29	143.9	7.57
		2	5.37	68.4	8.36	143.4	7.58
		3	5.00	68.9	8.51	143.4	7.59
		4	4.92	69.0	8.53	143.0	7.59
		5 (bottom)	4.97	66.6	8.21	143.2	7.56
7	7/28/98	surface	17.22	82.5	7.71	160.5	7.59
		1	16.82	79.7	7.54	161.2	7.57
		2	13.82	58.9	6.70	155.5	7.31
		3 (bottom)	13.22	43.1	4.40	146.3	7.20
7	9/25/97	surface	9.22	N/T	6.34	141.0	7.01
		1	8.97	N/T	5.77	141.0	7.01
		3	8.86	N/T	4.90	142.0	6.94
		4	8.90	N/T	4.76	141.0	6.92
		4.5 (bottom)					

Appendix 1 (continued).

Site 11 is located in Polar Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
11	10/1/01	0	7.12	63.9	7.40	122.5	7.27
		1	7.10	63.1	7.30	122.3	7.27
		2	7.08	63.1	7.30	122.0	7.28
		3	7.07	62.8	7.27	122.0	7.28
		4	7.06	62.9	7.28	122.4	7.29
		5	7.06	63.0	7.29	122.3	7.29
		6	7.00	62.8	7.29	125.5	7.28
		7	6.87	62.6	7.28	127.2	7.28
		8(bottom)	6.30	66.2	7.81	128.7	7.32
11	6/1/01	0	9.36	71.6	7.91	116.2	6.94
		1	9.22	70.7	7.80	115.7	6.91
		2	9.10	70.0	7.76	115.9	6.95
		3	9.10	69.6	7.72	115.8	6.95
		4	8.95	68.8	7.65	115.9	6.96
		5	6.55	56.2	6.64	116.0	6.91
		6.5 (bottom)	6.07	51.3	6.12	118.0	6.84
11	4/13/01	1	0.22	14.7	2.05	139.0	6.53
		1.75	0.21	19.2	2.71	151.5	6.54
		2.75	0.34	26.2	3.65	161.4	6.59
		3.75	0.67	23.2	3.21	154.2	6.56
		4.75	0.77	23.7	3.27	166.2	6.58
		5.75	2.10	9.6	1.29	165.9	6.50
		6.75	2.61	3.1	0.42	260.0	6.32
		7.25 (bottom)	2.47	2.4	0.32	355.1	6.30
11	8/29/00	0	10.80	75.1	8.15	108.4	7.09
		1	10.07	74.8	8.22	108.2	7.09
		2	9.84	70.9	7.84	108.2	7.07
		3	9.64	68.5	7.59	108.5	7.00
		4	9.50	76.0	8.47	105.7	7.01
		5	9.03	74.2	8.34	104.5	7.00
		6	7.15	14.9	1.75	112.2	6.68
		7	6.37	4.4	0.53	121.1	6.45
		8 (bottom)	5.87	2.6	0.32	139.8	6.45
11	6/23/00	0	18.15	93.8	8.71	103.7	7.53
		1	15.99	86.0	8.35	103.3	7.42
		2	13.45	57.6	5.88	105.3	6.95
		3	7.29	23.0	2.73	110.5	6.63

Appendix 1 (concluded).

Site 11 is located in Polar Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
11	6/23/00	4	6.07	16.6	2.02	113.6	6.56
		5	5.39	11.8	1.48	118.0	6.52
		6	4.94	9.0	1.14	120.6	6.49
		7	4.73	6.5	0.82	123.0	6.48
		8	4.62	4.7	0.60	125.0	6.48
		8.5 (bottom)	4.52	3.6	0.45	126.7	6.43
11	5/30/00	0	6.21	51.0	6.25	109.7	6.78
		1	5.64	47.4	5.88	110.3	6.69
		2	4.80	42.7	5.40	111.9	6.70
		3	4.43	38.6	4.94	114.9	6.66
		4	4.25	37.2	4.77	116.3	6.64
		5	3.95	33.9	4.40	117.8	6.64
		6	3.81	31.6	4.10	121.5	6.63
		7	3.88	31.5	4.09	124.4	6.60
		8 (bottom)	3.30	7.4	1.05	231.6	6.35
11	6/2/99	0	8.37	66.7	7.60	134.0	7.15
		1	8.00	61.3	7.01	133.7	7.12
		2	7.44	54.7	6.34	133.9	7.13
		3	6.52	44.2	5.26	134.0	7.06
		4	6.17	40.1	4.80	135.1	7.03
		5	5.86	36.4	4.42	135.9	7.01
		6	6.58	44.5	5.26	135.1	7.03
		7 (bottom)	7.38	53.8	6.44	134.0	7.09
11	10/1/98	surface	5.80	71.9	8.69	144.1	7.57
		1	5.78	72.0	8.70	144.1	7.57
		2	5.75	72.1	8.73	143.9	7.58
		3	5.59	72.3	8.78	144.0	7.59
		4	5.57	72.5	8.82	143.3	7.60
		5	5.53	72.4	8.81	143.8	7.59
		6	5.51	72.3	8.81	143.3	7.59
		7 (bottom)	5.51	72.6	8.84	143.5	7.57
11	7/28/98	surface	17.07	82.4	7.75	160.6	7.60
		1	16.82	79.0	7.47	161.0	7.57
		2	16.15	60.8	5.84	160.0	7.23
		3	14.57	38.1	3.72	155.8	7.00
		4	12.31	15.5	1.66	152.8	6.84
		5	10.53	7.1	0.78	166.7	6.80
		5.5 (bottom)	9.78	5.0	0.56	175.8	6.83