3473.01/WP2119

Fish Entrainment

REPORT

Prepared for:

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1.0 Introduction

With the cancellation of the proposed Kemano Completion Project (KCP) by the Province of British Columbia in 1995, Alcan and the province reached an agreement in 1997 to establish the Nechako Environmental Enhancement Fund (NEEF). A management committee was set up to decide how this fund should be administered and in 2001 a decision was made that the best use of the funds would be for the construction of a cold water release facility (CWRF) at Kenney Dam (Figure 1). Currently water is released from the Nechako Reservoir at the Skins Lake Spillway, some 87 km west of Kenney Dam.

The proposed CWRF would be constructed with multiple objectives in mind, including the continued conservation of salmon species that use the Nechako River (as required under the 1987 Settlement Agreement) and release of water during the summer months to manage the river water temperatures and flows. In the context of the operation of a CWRF at Kenney Dam, questions have been raised about the potential risk of entrainment of resident species within the reservoir and associated mortalities and population effects.

The Nechako Watershed Council (NWC) was formed in 1998 to provide a forum for the diverse interests in the Nechako Watershed and the communities that depend on the watershed. The intent was to work cooperatively in addressing long-standing water management and related issues. In 2002, NWC and provincial government representatives released a work plan that would lead to the construction of the CWRF at Kenney Dam. The plan, prepared by NWC, outlined the activities and costs of further studies required prior to construction of the CWRF (NWC, 2002). The plan duration is 11-years and includes a logical sequence of studies and investigations leading to the construction of the CWRF. The proposed work activities for year 2 of the plan are part of a Pre-Engineering and Environmental Review component that include the following activities:

- Activity No.1. Fish Entrainment Studies at Kenney Dam
- Activity No.2. Establishment of Release Water Temperature Criteria
- Activity No.3. Examination of Total Gas Pressure Effects on Fish

As part of Activity No.1, Triton Environmental Consultants Ltd. (Triton) has undertaken the following tasks:

1. Identification of species that currently reside in Knewstubb Arm, as well as their relative abundance, size, weight, age and temporal distribution;
2. Identification of the risks to reservoir populations due to entrainment at the proposed facility; and,

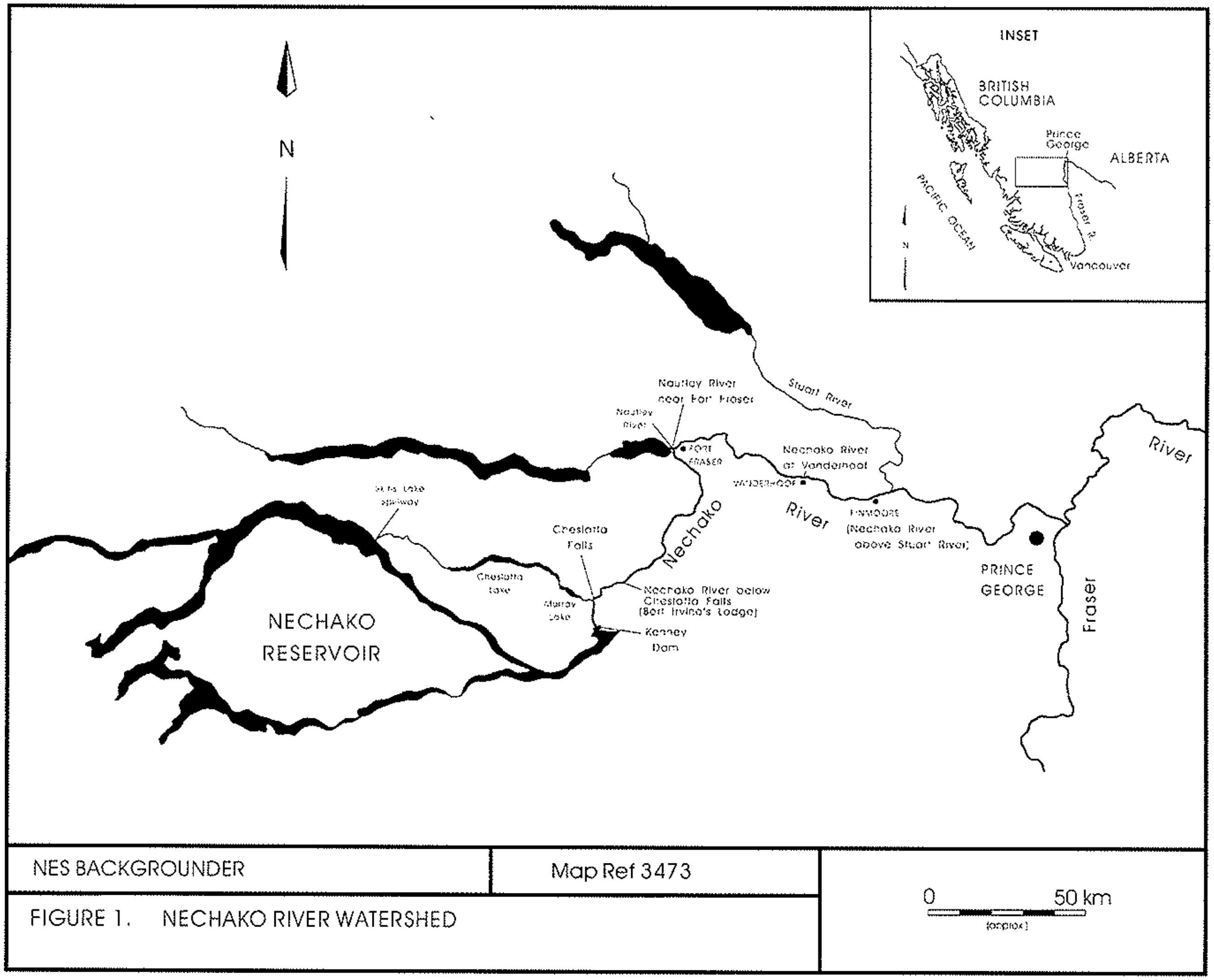
3. Identification of agency concerns about such impacts on reservoir populations in order to determine what additional information they may require to make a determination of impact.

In completing this work, the following specific tasks have been undertaken:

- Completed a literature review on fish entrainment at hydraulic facilities;
- Reviewed federal and provincial guidelines and publications related to fish entrainment;
- Queried federal/provincial fisheries databases (FISS, Fish Wizard);
- Reviewed past projects in the area to confirm fish species presence;
- Reviewed agency concerns for similar projects in the province of B.C.;
- Sampled fish across 4 seasons using gill nets (sinking and floating), minnow traps, prawn traps, set lines, a floating lake trap, angling and a creel census out of Nechako Lodge; and,
- Met with a representative from the Ministry of Water, Land and Air Protection to discuss potential entrainment issues.

The objective of this report is to present, for each task, the findings of the work done to date.

Figure 1. Nechako River Watershed



2.0 Background

The feasibility of constructing and operating a CWRF at Kenney Dam has been investigated at various times since 1950 and most recently during the studies for the now cancelled KCP. These studies followed the signing of an agreement, the 1987 Settlement Agreement (Anonymous, 1987), settling a legal dispute between Alcan, the provincial government and the federal government. The intent of the Agreement was to ensure conservation of Nechako River chinook salmon (*Onchorhynchus tshawytscha*) and protect migrating sockeye salmon (*O. nerka*) that use the Nechako River as a corridor to tributary rivers, while allowing further hydroelectric development on the Nechako River.

The 1987 Settlement Agreement indicated that, should Alcan wish to complete and operate the proposed expanded hydroelectric project it first had to design and construct a multilevel water release facility at Kenney Dam. The purpose of the facility was to:

- Release cooler, hypolimnetic water from the Nechako Reservoir during the summer months; and;
- Release water to achieve fish protection year round.

Between 1988 and early 1991 the KCP Design Team completed studies to establish a design concept for this facility that would meet the fish protection criteria. The KCP Design Team issued its report in March 1991, including a summary of the design concepts and criteria for the Kenney Dam Release Facility (Triton and Klohn Leonoff, 1991).

The design of the water release facility was formally approved on March 25, 1993 (KDRF, 1993). However, the Kemano Completion Project was cancelled in 1995 by the provincial government and the proposed structure was not constructed.

In 2000, the Nechako Environmental Enhancement Fund (NEEF) Management Committee resurrected the CWRF idea and after 2 years of public consultation and review, directed that the fund be used to construct a CWRF at the Kenney Dam. In this context most of the design criteria referred to above would need to be revisited as design capacities of many of the components would have changed since the cancellation of the KCP. As part of the various investigations needed to establish the feasibility of the CWRF, the NEEF Management Committee commissioned several studies (Triton, 2001a and b) that examined the amount of CWRF water needed to meet downstream water temperature control requirements at varying water release temperatures. The studies found that the minimum volume of water released from a CWRF to meet river temperature requirements occurred at the lowest release water temperature. If the CWRF were operated at lower temperatures, water that is currently being used for cooling the river at higher release temperatures could then be used for other water use purposes.

2.1 Proposed facility

The NEEF Management Committee initially considered seven configurations for a CWRF at Kenney Dam. A preferred configuration was subsequently selected (Klohn Crippen, 2001). Conceptual layout, hydraulic capacities, construction planning and cost estimate are available in the 2001 Klohn Crippen report prepared for the NEEF Management Committee: Water Release Facility at Kenney Dam, Updated Conceptual Layout and Cost Estimate.

In summary, the main components of the preferred CWRF include:

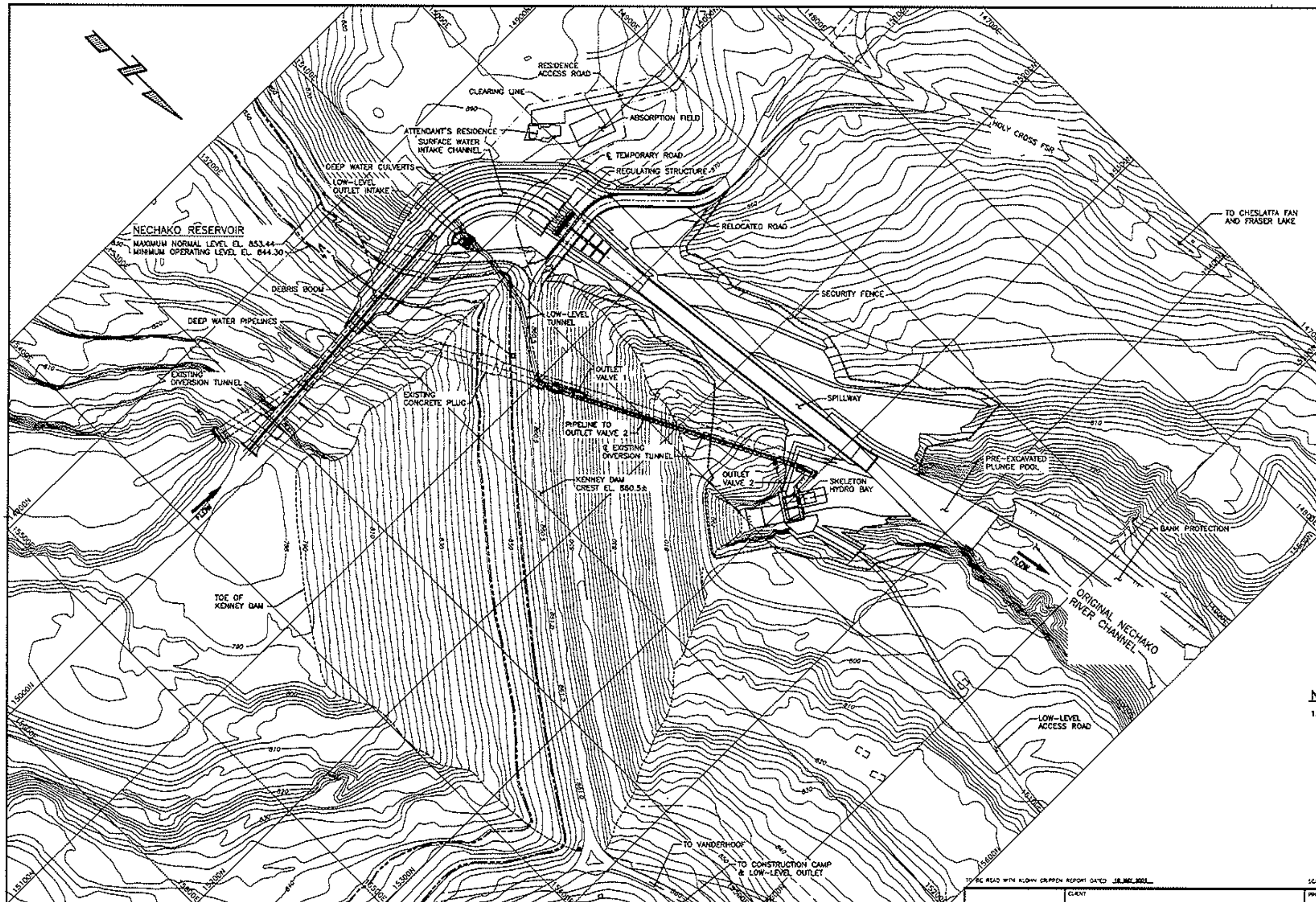
- A surface-water intake channel;
- Deep-water intakes and pipelines;
- A high-level outlet regulating structure, capable of releasing water from the reservoir surface or from deep water sources, either individually or simultaneously;
- A surface spillway equipped with a flip bucket energy dissipater;
- A low-level outlet structure capable of releasing water from the reservoir surface or from deep water sources, either individually or simultaneously; and
- The low level outlet equipped with one or more hollow-cone valves for energy dissipation and dissolved gas control.

These facilities are shown in Figure 2[1].

Work conducted by the Nechako Watershed Council (4thought Solutions, 2005 (in prep)) has resulted in the definition of a range of potential flow releases from the structure. These range from monthly average flows as low as 25 m^3/s in the fall and winter to peak flows of 100 m^3/s to 150 m^3/s in May and June. As well, cooling flows would be released in July and August at a controlled water temperature possibly as low as 10°C. Model studies (Triton 2001) have shown that these releases would likely be between 40 m^3/s and 170 m^3/s with cooling release most frequently in the lower end of this range (the requirement for a 170 m^3/s cold water release has a frequency of less than one in 200 years on average (Triton, 1991)). Therefore, under normal operations, the facility would generally be operated using the low level outlet (which currently has a design capacity of 60 m^3/s (Klohn Crippen, 2001) from late August until early to mid- May. The main gates and spillway would be used in Late May and June until the releases drop below the low-level outlet capacity in early July. The spillway could be used during July and August if downstream water temperature control required releases that exceed the low-level outlet capacity.

[1] Reproduced from Klohn Crippen, 2001

In the event that reservoir management required release of water in excess of that needed for downstream fish protection and other uses (the annual water allocation and the 'freed-up" flows), releases of up to 450 m^3/s could be made through the main gates and spillway (the estimated once in 200 years event (Klohn Crippen, 2001). These releases would typically occur during May, June, July and August, but experience has shown that fall rain event could also require excess water releases in September and October.



NOTES:

1. TOPOGRAPHY BASED ON McELHANNEY GEOSURVEYS LTD. TOPOGRAPHIC PLAN DATED SEPTEMBER 1988 AND ON McELHANNEY ENGINEERING SERVICES LTD. SOUNDINGS PLAN DATED OCTOBER 1988.

SCALE 0 — 100m

TO BE READ WITH KLOHN CRIPPEN REPORT DATED 18 MAY 2001

CLIENT: NECHAKO ENVIRONMENTAL ENHANCEMENT FUND

KLOHN CRIPPEN

PROJECT: WATER RELEASE FACILITY AT KENNEY DAM

TITLE: CONCEPTUAL LAYOUT
CASE E
PLAN

PROJECT No. PP1229 03

FIG. No. FIGURE 1

2.2 *Fish entrainment*

Entrainment occurs when fish and other living organisms are passed through the intake structure and discharged back out into the environment (Savitz *et al.*, 1998). Entrained organisms may experience pressure changes, mechanical injury and changes in the dissolved gas content of water (Gray *et al.*, 1986), which do not always result in mortality, but do represent a loss from the reservoir population. The entrainment of fish by water intake structures cannot only negatively impact individual fish but may also affect fish populations in waters adjacent to such structures.

The proposed CWRF has the potential to entrain fish, fish eggs, larvae, juveniles and adults, and other living organisms through both the surface and deep-water intakes. Fish entrained through the deep-water intake would experience a lethal change in water pressure as they are drawn from depth and released at the surface, but also would likey be mechanically damaged as they passed through the hollow-cone valve/s proposed for energy dissipation and dissolved gas control. Fish entrained through the surface spillway would have a greater chance of survival but could still be injured as they are passed around the facility.

Entrainment mortalities are of concern to facility operators because they contravene Section 32 of the Fisheries Act, which states "No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this Act" (Government of Canada, 1991). Methods to prevent entrainment including visual and acoustic deterrents or the screening of intake structures incur significant financial and maintenance commitments, and few large facilities have implemented this option.

2.3 *Issues related to construction of the CWRF*

Agency policies (*e.g.* Ministry of Water, Land and Air Protection (MWLAP) and FOC) regarding fish impacts at hydro facilities have generally focused on new projects involving significant changes in flow and harmful alteration, disruption or destruction of fish habitat, as well as barriers to anadromous fish migration. In the context of a CWRF at Kenney Dam, these concerns do not apply. Kenney Dam has been in place since 1952 without any fish passage or water release facilities and prior to dam construction, the Nechako Canyon was a barrier to salmon migration (Department of Fisheries and the Environment, 1979). There are, however some issues regarding fish impacts that must be considered and addressed with the agencies prior to the construction of the CWRF, including:

- Currently the net flow in Knewstubb Arm is east towards Knewstubb Lake. Construction of the CWRF would result in a reversal of this flow north toward the dam and into the Nechako Canyon. This reversal could result in a change in transport of plankton and invertebrates toward the dam, potentially bringing fish closer to the facility and resulting in incidental entrainment and mortality of resident species; and,

- Concern has also been expressed that the operation of the CWRF could alter the thermocline in Knewstubb Arm (D. Cadden, pers. comm.). Changes in the thermocline could lead to a redistribution of fish in Knewstubb Arm, which may increase their risk of entrainment through the facility.

The level of concern the Agencies have with regards to fish entrainment through water release facilities has been documented in recent development applications including the Forest Kerr Hydro Project (2003), Brilliant Dam Expansion Project (2001) and Waneta Generation Station Upgrade (1991). During the Forest Kerr application process, DFO indicated that entrainment mitigation measures such as screening and visual or acoustic deterrents are generally cost prohibitive and provide limited effectiveness for reducing or avoiding entrainment mortalities (EAO, 2001; DFO, 2002). .While agency concerns have focused on new facilities, the Brilliant Dam and Waneta Upgrade projects dealt with the expansion and/or alteration of existing facilities. For each of these projects, the proponent was responsible for estimating the magnitude of fish entrainment through the new facilities and evaluating the impact on the affected fish populations..

A number of studies have been conducted to estimate fish entrainment and subsequent population effects at hydroelectric facilities (Jensen *et al.*, 1982; Rago, 1984; Gray *et al.*, 1986; Jensen, 1990). These studies provide some guidance as to the degree of entrainment mortality at other facilities. However, as there has not been flow past Kenney Dam since its construction in 1952, there is little or no information available to use in estimating the effect of entrainment on resident fish stocks in the reservoir, even though it is suspected that entrainment has been occurring at the Skins Lake Spillway since it started operating in 1956. Given the available data on fish populations in the reservoir, it is our judgment that the effect has been small.

Contact with B.C. Hydro Personnel (K. Conlin, pers. comm.) indicate that Fisheries and Oceans Canada are concerned with entrainment issues at B.C. Hydro facilities. However, the concerns are being prioritized in situations where there are upstream or downstream migrations of resident or anadromous species or where entrainment may endanger a "population of fish". However, the Fisheries Act and the Policy for the management of Fish Habitat require FOC to focus on the loss of "fish" from the "fishery" and thus theoretically the loss of a single fish remains a concern. Policy changes within FOC will be required for this issue to be resolved. Other groups such as the Canadian Electrical Association are actively pursuing the consistent application of the policy with FOC across Canada, including issues such as this one; it is expected that the required policy changes will take a significant period of time.

3.0 Existing information

3.1 Fish species

A list of species found in the Nechako Reservoir and surrounding tributaries was compiled from federal/provincial Fisheries Information Summary System (FISS) records to assess the potential impacts of entrainment on reservoir populations. Additional references were consulted where fish presence was not documented in FISS or where records were sparse. Thirteen species of fish have been recorded in the Nechako Reservoir Watershed in FISS, and records of three additional species not recorded in FISS also occur in various other reports reviewed as part of the project. Table 1 summarizes existing information about these species; bolded common names indicate species caught during the current study.

Table 1. Existing fish species information for the Nechako Reservoir

Common Name	Scientific Name	Source	Comments
Burbot	*Lota lota*	FISS	Throughout Reservoir. Also known from several tributary lakes.
Dolly Varden	*Salvelinus malma*	FISS; SKR, 2004	FISS record of DV in Tahtsa Lake pre-dates reservoir construction (1951). SKR captured DV in headwaters of Andrews Creek.
Kokanee	*Oncorhynchus nerka*	FISS	Throughout Reservoir. Spawns in large tributaries or along lakeshores.
Lake Chub	*Couesius plumbeus*	FISS; SKR 2004; Hatfield, 1997 and 1998a	FISS records from Tahtsa Reach and Eutsuk system. SKR records from tributaries to Tahtsa Reach, Hatfield records from Tahtsa Reach and Ootsa Lake tributaries.
Lake Trout	*Salvelinus namaycush*	FISS	Natalkuz Lake. FISS record pre-dates reservoir construction (1951). No further records of lake trout were found.
Largescale Sucker	*Catostomus macrocheilus*	FISS	Throughout Reservoir and in many tributary systems
Longnose Dace	*Rhinichthys cataractae*	FISS; Hatfield, 1997	Andrews Creek; Parrott Creek (tributaries to Ootsa Lake).
Longnose Sucker	*Catostomus catostomus*	FISS	Throughout Reservoir and in many tributary systems
Mountain Whitefish	*Prosopium williamsoni*	FISS	Throughout Reservoir. Also in some larger tributaries.
Northern Pikeminnow	*Ptychocheilus oregonensis*	FISS	Throughout Reservoir. Most common species encountered during current study.

Table 1 (con't)

Common Name	Scientific Name	Source	Comments
Peamouth Chub	*Mylocheilus caurinus*	FISS	Yellow Moose Lake, Hoult Lake, and Emmett Lake (form part of Lower Nechako Reservoir Watershed)
Prickly Sculpin	*Cottus asper*	FISS	Throughout Reservoir
Rainbow Trout	*Oncorhynchus mykiss*	FISS	Throughout Reservoir.
Redside Shiner	*Richardsonius balteatus*	Saimoto and Tamblyn, 1995; Hatfield, 1998b	Saimoto and Tamblyn captured shiners in tributary lakes to Whitesail Reach. Hatfield captured them in tributaries to Rhine Creek (a Tahtsa Reach tributary).
Slimy Sculpin	*Cottus cognatus*	Envirocon, 1989b; Hallam, Knight & Piesold, 1994.	Envirocon captured slimy sculpins in Tahtsa Narrows; Hallam, Knight & Piesold captured thm an inlet stream to Tahtsa Reach.
White Sucker	*Catostomus commersoni*	DeGisi and Schell, 1997	Needle Lake and Andrews Creek (tributaries to Ootsa Lake).

Bold indicates species captured during entrainment study.
Additional references included only where fish presence was not documented in FISS or records are sparse.

Some of the species recorded in FISS have not been noted in the reservoir itself (e.g. peamouth chub, longnose dace, redside shiner, white sucker), but may be present based on their presence in tributary systems. A single record of Dolly Varden exists in the FISS database for the Upper Nechako Reservoir (Tahtsa Lake), however this record is from 1951, prior to the construction of the Kenney Dam (FISS, 2004). SKR Consultants Ltd. captured Dolly Varden in the headwaters of a tributary stream (Andrews Creek) to Ootsa Lake, but suggested that this population may have recently emigrated from a neighboring watershed (SKR, 2004). A single record of lake trout exists in the FISS database (Natalkuz Lake), but this record also pre-dates the reservoir (FISS, 2004).

3.2 Life histories

Life history information was reviewed for the 16 species identified above, taking into consideration characteristics that may relate to entrainment potential. Table 2 presents a summary of this review (from Scott & Crossman, 1973).

Table 2. Life history overview

Species	Life history stages				
	Spawning	**Eggs**	**Larvae**	**Fry**	**Adult**
Burbot	January to March in 1 – 4 ft of water over sand/gravel bottom or 5-10 ft gravel shoals	Eggs semi-pelagic	Larvae pelagic, distributed high in water column	Frequently found along rocky shores; sometimes in weedy areas of tributary streams	Prefer cool water; restricted to hypolimnion in summer, but may move to nearshore areas to feed at night; spawn in shallower waters
Dolly Varden	September to early November in rivers with medium to large gravel bottoms	Laid in gravel stream bed	Remain in gravel for 2 - 3 weeks	Remain in streams for 3 - 4 years	Cold lakes and in the sea
Kokanee	September to October; Larger tributaries with gravel substrate or gravel beds along lakeshore	Laid in gravel nest	Remain in substrate for 2-3 months	Immediately move downstream to lake	Extensive daily vertical and onshore-offshore movements; reside in upper to mid layers in summer and move into deeper water with increasing temperatures and in winter
Lake chub	May to June in tributary streams with gravelly substrate	No nest prepared			Prefer shallow quiet waters, but may move deeper in summer
Lake trout	Usually in October over a large boulder or rubble bottom in inland lakes at depths of <40 ft	Demersal	Remain near hatching grounds	Seek deeper water	Tend to inhabit deep water, but can be found at various depths; remain in hypolimnion in summer
Largescale sucker	Sandy tributary streams or sandy/gravelly shoals of lakes	Adhesive and stick to substrate	Pelagic and distributed throughout water column	Move into benthic habitats at 16 - 18 mm	Usually inhabit shallower areas of lakes, but have been caught to 25 m
Longnose dace	May to July in stream riffles with gravelly bottom	Adhesive and stick to substrate	Pelagic	Pelagic	Bottom dwelling; inhabit quiet waters near shore
Longnose sucker	April to May in streams or shallow areas of lakes; current from 30 to 45 cm/s and bottom gravel	Adhesive and demersal; adhere to gravel and substrate	Remain in gravel	Move downstream to lake	Inhabit benthic environments

Table 2 (con't)

Species	Life history stages				
	Spawning	**Eggs**	**Larvae**	**Fry**	**Adult**
Mountain whitefish	Late fall or early winter; usually in streams over gravel substrate, possibly on gravelly shoals of lakes	Stick to bottom substrate; no nest is prepared		Remain in shallows and move offshore when 30 - 40 mm	Usually found in littoral habitats, rarely deeper than 20 m; benthic feeders; frequent the upper 4.6 - 6.1 m of water column
Northern pikeminnow	Late May to July in gravelly shallows on lake shores or a short distance up tributary streams	Adhesive and demersal; settle into the gravel		Feed in shallower areas near shore	Move into deeper offshore habitats, but are still found feeding in shallow areas; mostly piscivorous
Peamouth chub	In lake shallows and slow-moving rivers over gravel-rubble substrate	Adhesive and stick to substrate		School in weedy shallows of lakes	Move further offshore
Prickly sculpin	Under large rocks in streams with boulder, cobble or flat rock bottom	Adhere to ceiling of spawning chamber		Form pelagic schools for approximately 1 month before moving to the bottom	Rarely found far from shore
Rainbow trout	Mid-April to June in clean tributary streams with fine gravel substrate	Fall into spaces in gravel substrate then covered by female	Remain in gravel for 15 days	May move down into the reservoir almost immediately, but may spend up to 3 years in the stream before moving downstream; usually reside in littoral areas	Can be found in all areas, but prefer temperatures under 21°C (preferred temperature is 13°C)
Redside shiner	In lakes or streams in shallow riffles or shoals	Adhesive and stick to substrate or aquatic vegetation	Drift with the current and depend on the yolk sac for 15 days	Stay near the surface and lakeshore in areas with lots of vegetation	Usually occur in schools and rarely venture far from shore
Slimy sculpin	In spring under a rock or ledge	Adhesive; deposited on the ceiling of the nest		Deeper waters of lakes; cooler, rocky or gravelly streams	Deeper waters of lakes, may move into lake shallows at night
White sucker	Early May to early June in gravelly streams or lake margins	Scattered and adhere to gravel or drift downstream and adhere to substrate in quiet areas	Remain in gravel for 1 - 2 weeks	Migrate to lake; feed near the surface	Shallow, benthic feeders; usually inhabit warm shallow lakes or bays and tributaries of large lakes

4.0 Methodology

4.1 Access

The Knewstubb Arm of the Nechako Reservoir was accessed via the Kenney Dam Road, extending south from the town of Vanderhoof (100 km west of Prince George). The dam is located approximately at the 85 km mark on the Kenny Dam Road. A 16' aluminum river boat was used to conduct the work on the reservoir, and was launched from one of three locations: the Nechako Lodge, the Knewstubb Lake Recreational Site, or an access road immediately to the west of the dam (Figure 3).

For the February sampling event snowmobiles were used to conduct the work. A 6" diameter ice auger was used to drill through the 30 – 40 cm deep ice to deploy various sampling gear. A triangle of three holes cleaned out with a metal pry bar was required to set gear such as minnow traps through the ice (Photo 1).

4.2 Fish Sampling

Fish sampling in the Knewstubb Arm of the Nechako Reservoir was conducted in November 2003 and February, May, August and September 2004 and was focused along the face of the Kenney Dam and in adjacent bays (Figure 3). Fish sampling in other areas of the Knewstubb Arm was conducted opportunistically in conjunction with stream surveys (see Section 4.3) and littoral habitat mapping (see Section 4.4).

Gear used to sample for fish included prawn traps, minnow traps, angling, gill nets, set lines and a lake trap. The use of beach seines was considered, but use of the technique was not feasible due to the abundant wood within the reservoir. Lengths were taken from captured fish (total or fork length, depending on the species), with weights taken only from a sub-sample of representative individuals. Destructive sampling (*e.g.* the collection of otoliths) was not completed, however several scale samples were taken from representative kokanee, rainbow trout and mountain whitefish. Photographs of the fish species encountered were also taken (*e.g.* Photos 2 to 4). The selected gear was consistent with Resources Inventory Standards Committee (RISC) standards (*e.g.* multi-panel gill net), and the level of effort significantly exceeded standards for lake inventory (*e.g* Province of British Columbia 2001).

4.2.1 Prawn traps

Prawn traps were set at 10 to 16 locations throughout Knewstubb Arm on 4 out of 5 sampling events (ice in February prevented the use of prawn traps) (Figure 3). Traps were baited with fresh beef liver and set overnight at depths of 1.5 to 38 m.

4.2.2 Minnow traps

Minnow traps were set at 12 to 20 locations throughout Knewstubb Arm on all 5 sampling events (Figure 3). Traps were baited with dry or moist cat food and set overnight at depths of 0.5 to 8 m.

4.2.3 Angling

Angling was opportunistically used to sample for larger fish. Angling was conducted on three separate occasions (total 160 minutes) in November and on one occasion (total of 90 minutes) in August. Angling was conducted using various spoons and jigs at a depth of 20 m or greater, using the boat to slowly troll. Shoreline habitats could not be effectively angled due to the abundant wood that snagged lines.

Angling effort was minimal as the technique targets larger fish that are likely less susceptible to entrainment as they are better swimmers than smaller fish (Jones, Kiceniuk and Bamford, 1980). Additionally, the technique is time consuming (low catch efficiency in a large reservoir) and the presence of fish species targeted by the angling (adult rainbow trout) within Knewstubb Arm was confirmed by the operator of Nechako Lodge.

4.2.4 Lake trap

One lake trap was set in Knewstubb Arm on 4 out of 5 sampling events (ice in February prevented use of the lake trap) (Figure 3). The trap consisted of a floating fine-mesh (approximately 1 cm) panel with a 3 m draft and a length of 30 m, which was set perpendicular to shore. A second panel consisting of a live box and 15 m wings was attached to the deep end of the first panel, forming a "T" (Photo 5). Fish moving along the reservoir margins would be stopped by the first panel (perpendicular to shore) and would have to either turn around or work there way along the net. At the far end of the net fish were funneled into the live box by the wings extending from either side. As the trap was not destructive to captured fish, it was set on the first day of each sampling event, and retrieved on the last day (two days later).

4.2.5 Set lines

Set lines were used at 3 to 8 locations during the first 3 sampling events (Figure 3). An array of 3 to 5 hooks was attached to a central weighted line by 1 m lengths of monofilament fishing line. The first hook in the array was attached so as to sit on the bottom of the reservoir, with subsequent hooks elevated slightly off the bottom. Hooks were baited with fresh beef liver and set at depths from 3 to 57 m. Lines were left overnight for around 18 to 24 hours. Set lines were not used on the final two events (August and September) as the technique had not captured any fish to date, and the gear typically snagged on the woody bottom of the reservoir and was often irretrievable.

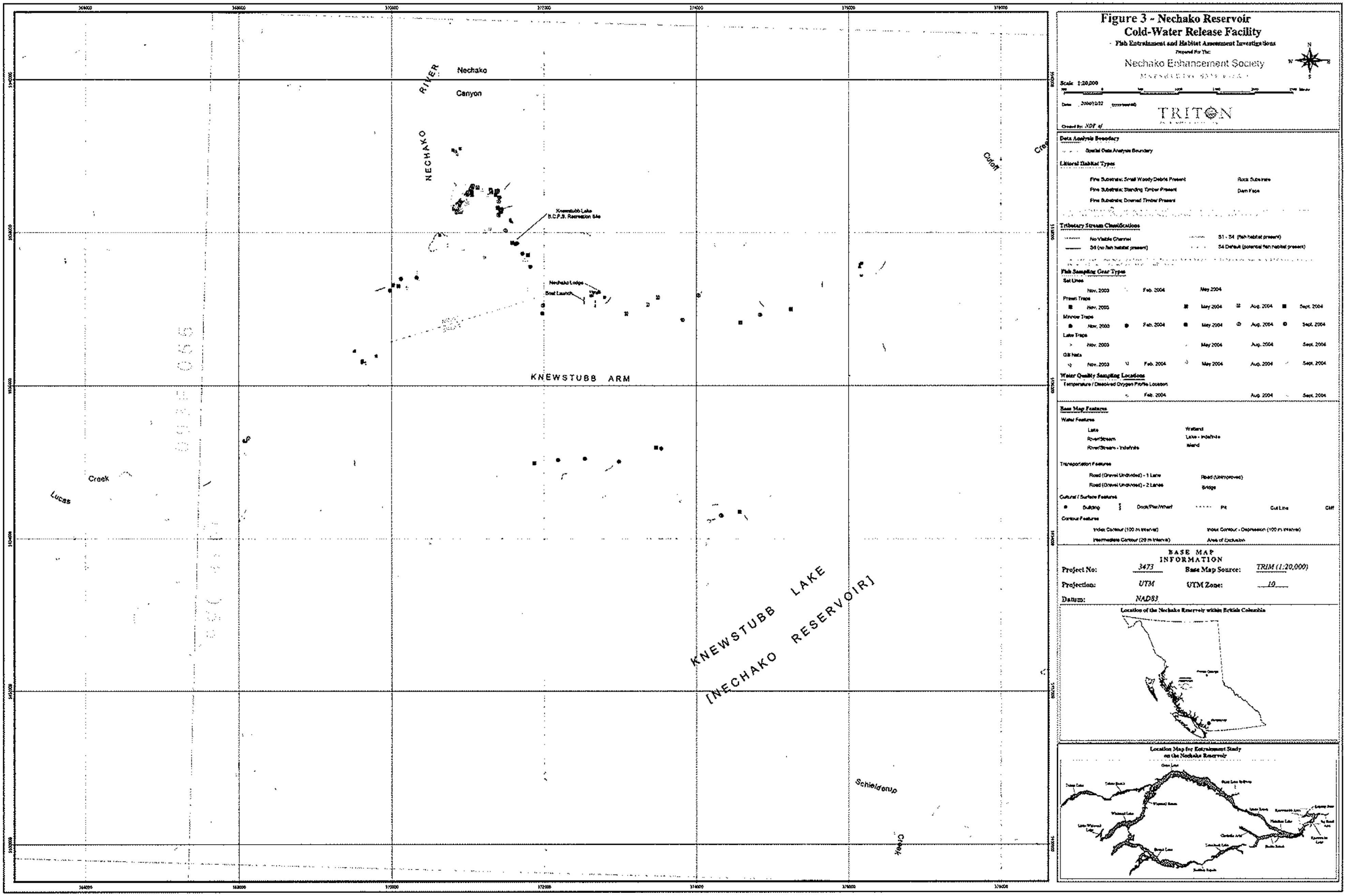


Figure 3 - Nechako Reservoir
Cold-Water Release Facility
- Fish Entrainment and Habitat Assessment Investigations
Nechako Enhancement Society
Scale 1:20,000
TRITON
Data Analysis Boundary
Littoral Habitat Types
Tributary Stream Classifications
Fish Sampling Gear Types
Water Quality Sampling Locations
Base Map Features
BASE MAP INFORMATION
Project No: 3473
Base Map Source: TRIM (1:20,000)
Projection: UTM
UTM Zone: 10
Datum: NAD83
Location of the Nechako Reservoir within British Columbia
Location Map for Entrainment Study on the Nechako Reservoir
Nechako
Canyon
RIVER
NECHAKO
Knewstubb Lake B.C.F.S. Recreation Site
Nechako Lodge
Boat Launch
KNEWSTUBB ARM
KNEWSTUBB LAKE
[NECHAKO RESERVOIR]
Cutoff
Lucas
Creek
Schieldenup
Creek

4.2.6 Gill nets

Gill nets were set in Knewstubb Arm near the dam face on all 5 of the sampling events (Figure 3). Multi-panel floating gill nets (6 panels: 25 mm, 76 mm, 51 mm, 89 mm, 38 mm, and 64 mm mesh size) with a total length of approximately 100 m and a draft of 3 m were used. Nets were typically set perpendicular to the face of Kenny Dam.

Exceptions to the previously stated methodology included the use of a sinking net (similar panel specifications to the floating nets) in August, which was deployed to the west of the dam face. Sinking nets were typically not used due to the abundant submerged wood. Additionally, a vertical set was required to deploy a gill net in February. An opening was made in the ice with an ice auger, and a weighted end of the gill net was dropped through the hole. The top end of the net was spread out by lacing it to a wooden pole which was also pushed vertically through the hole and allowed to float up against the underside of the ice, keeping the vertical net somewhat spread out.

4.3 Stream and spawner surveys

Mapped drainages (based on the 1:20,000 TRIM map base) flowing into the Knewstubb Arm were surveyed to assess their potential to support spawning populations of fish (*e.g.* kokanee). Streams large enough to support such populations could result in seasonal movements of fish species into specific areas of Knewstubb Arm for staging purposes. Similarly, the confluences of such streams with the reservoir may be seasonally abundant with outmigrating fry.

Mapped stream confluences with the reservoir were accessed by boat. Where present, channel widths were measured and the stream classified as having the potential to be fish-bearing or non-fish bearing. Photographs were taken at each site to support the classification (*e.g.* Photo 6).

4.3.1 Lucas Creek

Lucas Creek (Figure 3) is a known fish-bearing stream (FISS, 2004). As such, spawner surveys were scheduled in November to target mountain whitefish, May to target rainbow trout, and September to target kokanee (Photo 7). Spawner surveys were ground based, and completed by two biologists wearing polarized glasses. Riffle and glide sections were surveyed walking abreast, with each observer responsible for the centreline to their margin of the creek. Pools were first observed from the banks. If no fish could be seen from the banks, one observer would wade through the pool in a downstream direction with the other stationed at the tail-out of the pool looking for scattering fish. Sections of the creek with appropriate spawning gravels were also carefully examined for redds or signs of fresh digging. Shorelines and debris jams were examined for fish carcasses.

4.4 *Habitat mapping*

Littoral habitat mapping was completed to identify any unique habitats that may attract higher densities of fish, or attract fish on a seasonal basis (*e.g.* shoal spawning kokanee). The littoral habitats of Knewstubb Arm were coarsely mapped and classified as one of five habitat types (Table 3). Littoral habitats were observed using an Aqua-Vu Z series underwater camera, periodically deployed to a depth below the drawdown effect of the reservoir. The camera could not be continuously towed behind the boat due to the abundant standing wood. Representative frames were captured by connecting the Aqua-Vu camera to a Sony DCR-TRV330 Handycam. Examples of each habitat type are shown in Photos 8 to 12.

Table 3. Habitat types used to describe the littoral habitat of Knewstubb Arm.

Type	Description
1	Fine substrates, with small diameter wood present.
2	Fine substrates, with larger diameter standing wood present.
3	Fine substrates, with larger diameter downed wood present.
4	Rock substrates. Minimal or no wood present.
5	Kenney Dam. Large diameter rock and occasional wood present.

4.5 *Temperature and dissolved oxygen profiles*

Temperature and dissolved oxygen (DO) profiles were measured using a YSI 85D DO, Conductivity, Salinity, Temperature meter to a depth of 30 m (maximum length of probe cable) during the February, August and September sampling events. Profiles were measured at 2 locations within the bay in front of Kenney Dam (Figure 3).

4.6 *Creel Census*

Creel census forms (Appendix 1) were left at the Nechako Lodge for distribution, and posted at the Knewstubb Lake Recreation Site (Photo 13). The lodge owner (Elisabeth Doerig) handed out forms to numerous fishers over a one-year period, however only one form was returned, which contained data from outside of the study area (Ootsa Lake). Elisabeth indicated that most of the sport fisherman travel beyond the arm to fish due to the abundant snags and wood in Knewstubb Arm. Elisabeth did indicate that her sons fish Knewstubb Arm when they are short on time, and have captured adult rainbow trout and kokanee.

4.7 *Risk Assessment*

As noted above, entrainment of fish has been observed at various hydroelectric and reservoir release facilities. This entrainment can be caused by a sudden change in release rate when fish are in the vicinity of the gates (creating a velocity field that the fish cannot swim against) or if they swim after food items and inadvertently enter a velocity field that they can't swim against. In this report a qualitative examination of the risk of entrainment is made based on two factors:

- The likelihood that individual fish of a size that cannot resist entrainment will be found in the vicinity of the facility; and,
- The consequence of some fish being entrained – would the entrained fish be lost (i.e. would they be killed) and would their removal from the population of fish in the reservoir have a detrimental effect on the overall population.

5.0 Results

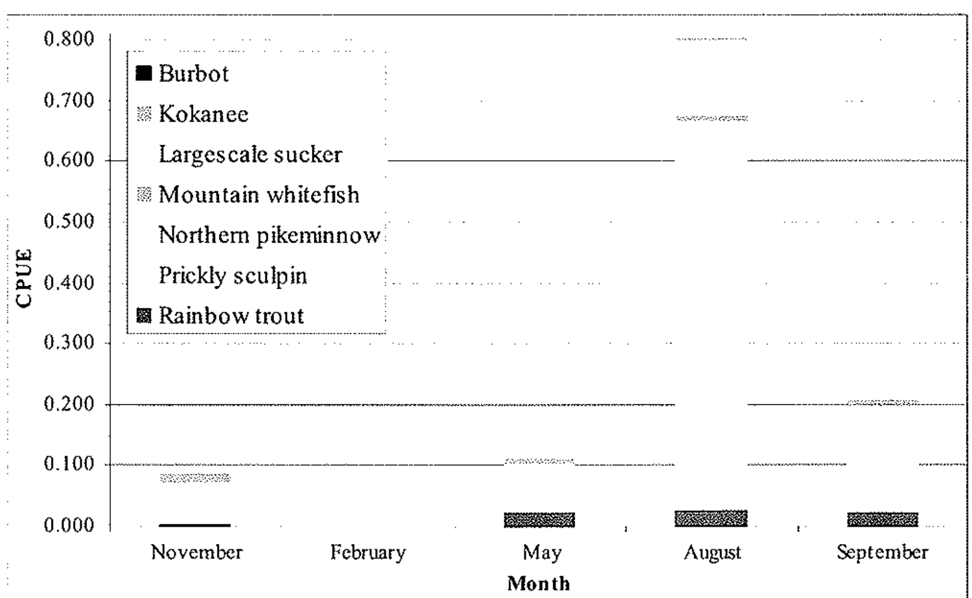
5.1 Fish sampling

A total of 677 fish belonging to 7 species were caught during the 5 sampling events with sampling gear being deployed for a total of 3003.59 hours. Catch numbers for each sampling event were standardized by dividing the total catch by the effort (total number of hours sampling gear was deployed on each event), which gave the Catch Per Unit Effort (CPUE). CPUE values for each species by season are provided in Table 4 and Figure 4.

Table 4. Catch per unit effort (CPUE) by season and species

	November	February	May	August	September
Burbot	0.000	0.000	0.000	0.002	0.000
Kokanee	0.012	0.000	0.005	0.002	0.002
Largescale sucker	0.000	0.000	0.033	0.123	0.000
Mountain whitefish	0.002	0.000	0.000	0.009	0.002
Northern pikeminnow	0.063	0.000	0.045	0.626	0.170
Prickly sculpin	0.002	0.000	0.002	0.013	0.006
Rainbow trout	0.006	0.000	0.026	0.029	0.025
Total CPUE	0.086	0.000	0.110	0.804	0.205

Figure 4. Catch per unit effort (CPUE) by season and species



5.1.1 Size and age classes

Fish lengths were between 100 and 300 mm for 82% of fish caught (Figure 5). Most species also individually fell within this range with the exception of largescale suckers (88% ranged from 200 to >300 mm) and prickly sculpin (all from <50 to 100 mm).

Weights were taken for 12% of the catch. Weights were positively correlated with length for kokanee, mountain whitefish and rainbow trout, however measurements for largescale suckers and northern pikeminnows were more variable (Figure 6).

During the August and September sampling events scales were collected from 22 fish representative of the kokanee, mountain whitefish and rainbow trout catches. Most of these fish were age 4+ and 5+ (Figure 7). There did not appear to be any seasonal correlations with size or age classes.

Figure 5. Length distribution by species

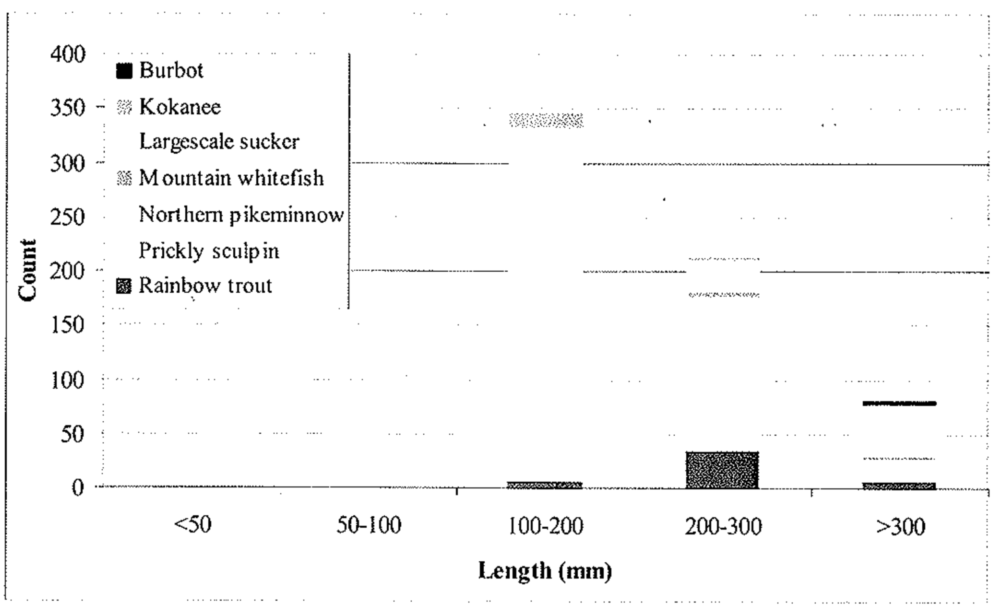


Figure 6. Fish lengths and weights by species

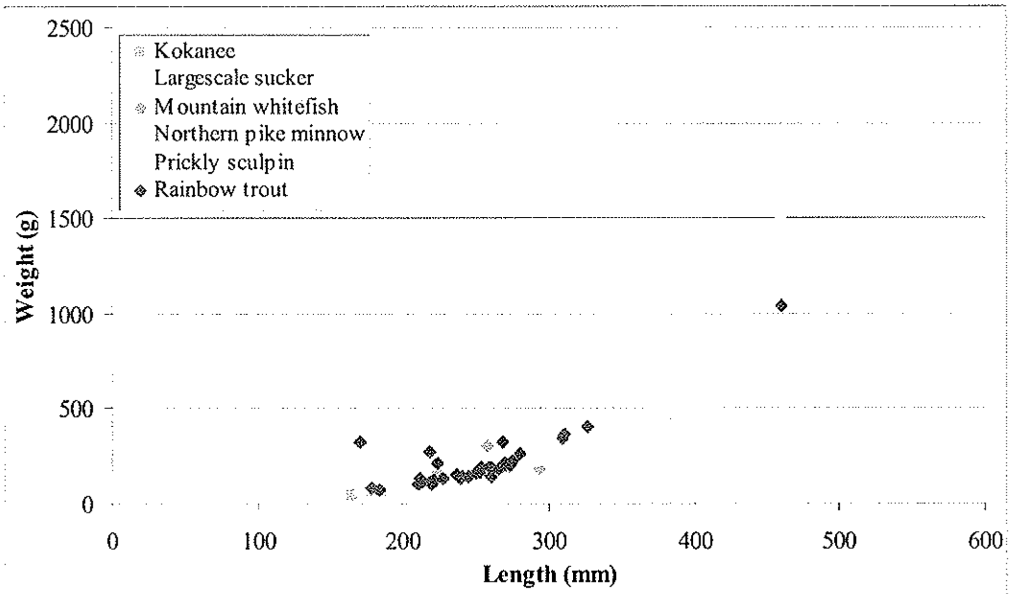
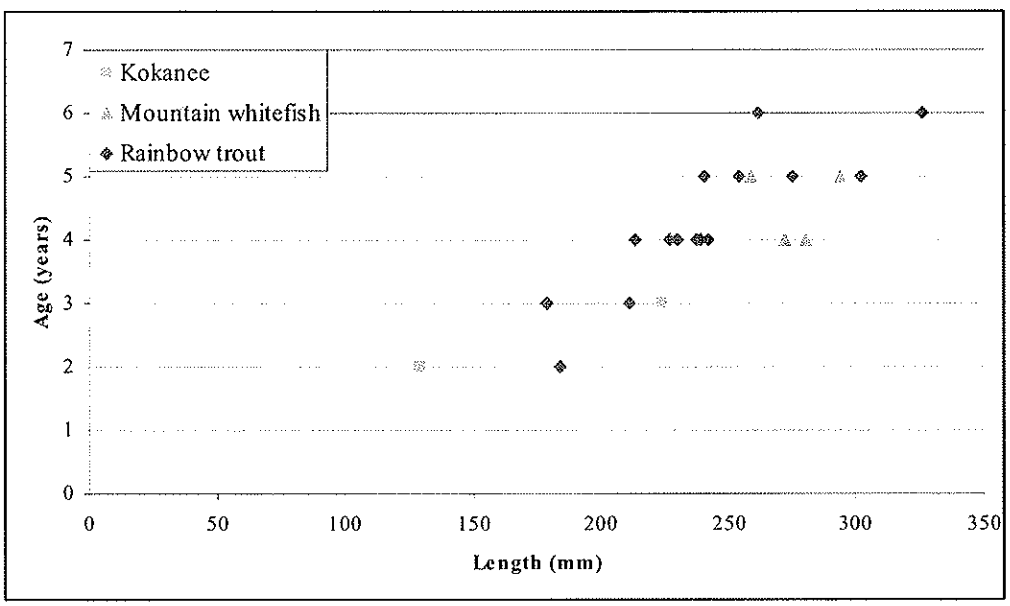


Figure 7. Age distribution from scale samples by species and length



5.1.2 Seasonal distribution

The highest CPUE occurred in August, followed by September, May and November. No fish were caught in February despite 583.09 hours of sampling effort. 65% of the total catch occurred in August, 16% in September, 10% in November and 9% in May.

Northern pikeminnow was the most abundant fish caught across all sampling events, accounting for 75% of the total catch. Of the northern pikeminnows caught, 68% were caught in August and 57% were caught using gill nets.

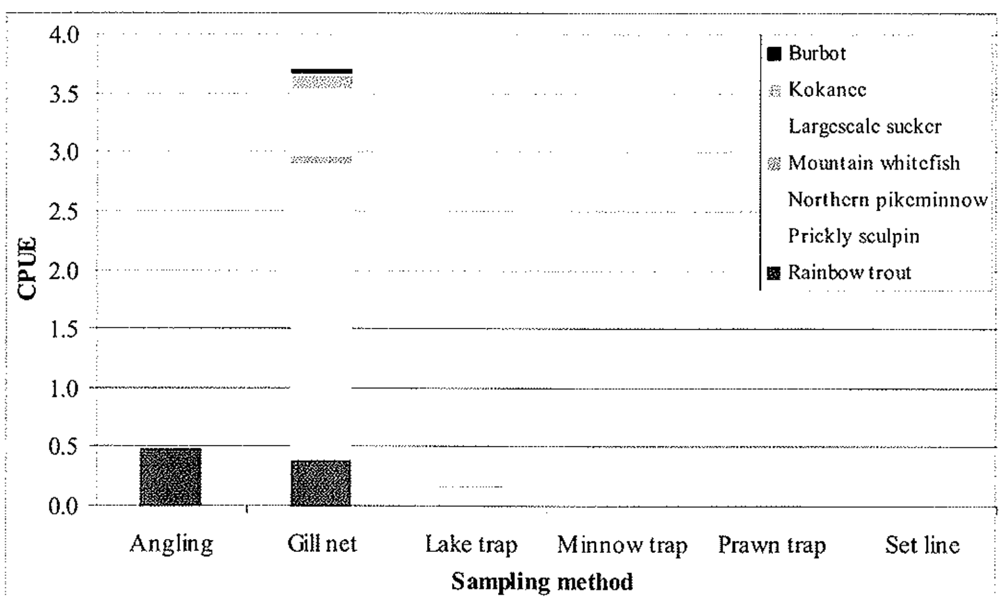
Largescale sucker was the next most abundant catch (13% of total), but was caught only during the May and August sampling events. Gill nets caught 78% of the catch for this species.

Rainbow trout accounted for 7% of the total catch, and was evenly distributed across sampling events in May, August and September, with a lower number caught in November. 94% of the rainbow trout were caught using gill nets, however this was the only species caught while angling.

Kokanee was the next most abundant catch (2%) with numbers evenly distributed in May, August and September and a slightly higher catch in November. 100% of the kokanee were caught using gill nets.

Prickly sculpin also comprised 2% of the total catch, which were all caught using minnow traps during the November, May, August and September sampling events. Mountain whitefish accounted for 1% and were caught in November, August and September, mostly using gill nets. Only one burbot was caught across all sampling events and it was caught in a gill net in August. Figure 8 shows the fish species caught using different types of sampling gear.

Figure 8. Catch per unit effort (CPUE) by sampling gear and species caught



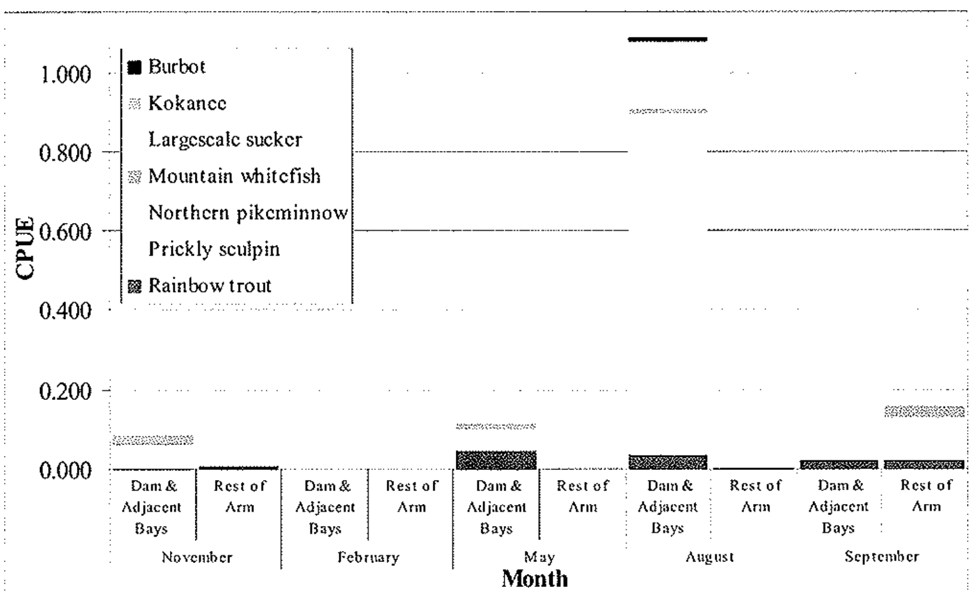
5.1.3 Spatial distribution

Sampling data was broken down into 2 areas within Knewstubb Arm: 1. Kenney Dam and adjacent bays; and 2. the rest of Knewstubb Arm (Figure 3). As sampling effort was concentrated in the former area, CPUE was used to standardize the data for comparison. Table 5 and Figure 9 provide a spatial breakdown of species caught within the reservoir.

Table 5. CPUE by location and species in each season

Month	**November**		**February**		**May**		**August**		**September**	
Location	Dam & Adjacent Bays	Rest of Arm	Dam & Adjacent Bays	Rest of Arm	Dam & Adjacent Bays	Rest of Arm	Dam & Adjacent Bays	Rest of Arm	Dam & Adjacent Bays	Rest of Arm
Species										
Burbot	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Kokanee	0.014	0.000	0.000	0.000	0.009	0.000	0.003	0.000	0.002	0.000
Largescale sucker	0.000	0.000	0.000	0.000	0.003	0.072	0.169	0.000	0.000	0.000
Mountain whitefish	0.003	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.026
Northern pikeminnow	0.056	0.108	0.000	0.000	0.047	0.044	0.843	0.043	0.179	0.103
Prickly sculpin	0.003	0.000	0.000	0.000	0.003	0.000	0.018	0.000	0.006	0.000
Rainbow trout	0.006	0.009	0.000	0.000	0.047	0.000	0.038	0.007	0.026	0.026

Figure 9. CPUE by location and species in each season



Overall, CPUE was slightly higher in the dam and adjacent bays (0.33) compared to the rest of Knewstubb Arm (0.10). However, CPUE was similar at both locations in all months except August, where large gill net catches (370 fish, mainly northern pikeminnow) near the dam face contributed to a high CPUE value for that area.

5.2 Stream and spawner surveys

During May, August and September 19 drainages to Knewstubb Arm (not including Lucas Creek) were surveyed. Although 4 of these drainages were found to have the potential to provide fish habitat, no fish were observed at the time of the survey. None of four potentially fish-bearing streams were of a size to support spawning populations of kokanee, and likely would only provide limited rearing and spawning habitat for rainbow trout.

During the November 2003 and September 2004 spawner surveys on Lucas Creek, no fish, carcasses or redds were observed. During the May 2004 survey rainbow trout were observed in spawning colours and exhibiting courtship behaviour.

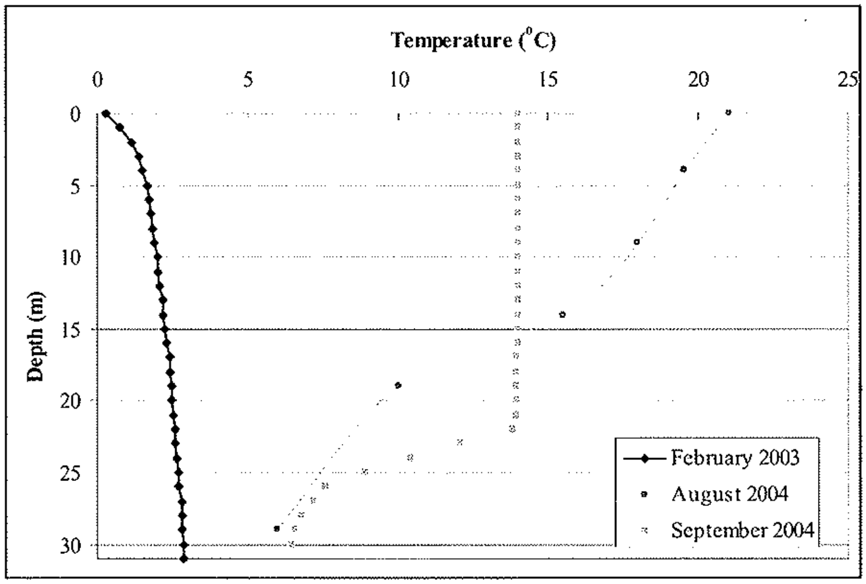
5.3 Habitat mapping

The majority of littoral habitats within Knewstubb Arm were classified as fine substrate with standing timber present. Approximately 500 m of rock substrate exists at the dam face and the remainder of littoral habitats consist of fine substrate with downed timber or small woody debris. Photos 1 to 5 provide examples of habitats observed.

5.4 Temperature and dissolved oxygen (DO) profiles

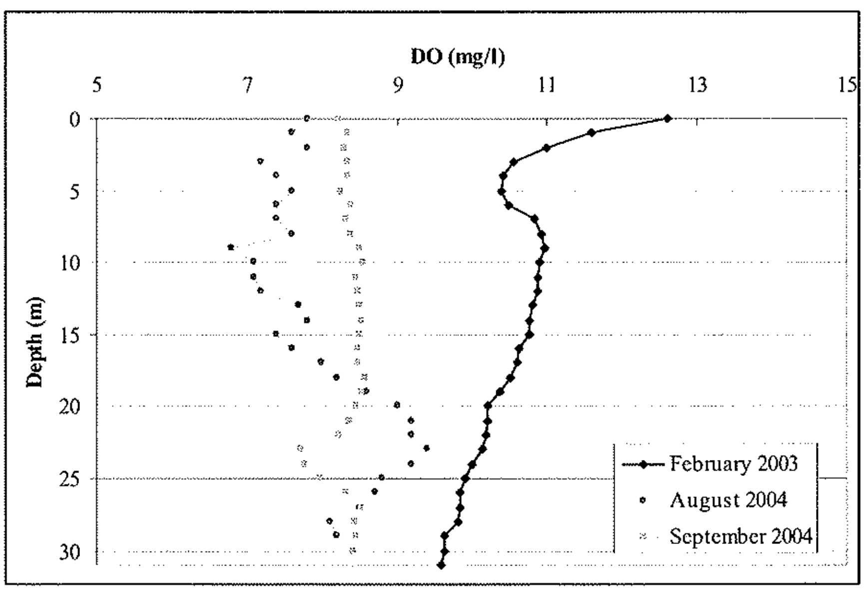
Water temperatures were fairly uniform in February indicating mixing of layers, and temperatures increased slightly with depth. The August temperatures were quite high at the surface, reflective of the weather conditions and showed a thermocline between 15 and 20 m with a drop of around 6°C. The surface temperature in September was 6°C cooler than in August, and the thermocline was around 7 m deeper. The water was well mixed in September to a depth of 22 m. These results are similar to those recorded during a monitoring program in 1991 (Perrin, 1996). Temperature profiles are shown in Figure 10.

Figure 10. Knewstubb Arm temperature profile



DO levels were higher in February, likely due to lower water temperatures, and decreased slightly with depth corresponding to a slight increase in temperature. DO levels were similar in August and September, with a slight increase below 15 m in August corresponding to decreased temperatures. DO results were also similar to those reported in 1991 (Perrin, 1996). DO profiles are shown in Figure 11.

Figure 11. Knewstubb Arm dissolved oxygen profile



6.0 Discussion

6.1 Species of importance

Burbot, kokanee, mountain whitefish and rainbow trout have been identified in previous studies as being important for recreational fishing in the Nechako Reservoir (Envirocon, 1989a). Detailed life histories for these species are provided below, considering characteristics that may increase entrainment vulnerability.

6.1.1 Burbot

Burbot are the only species present in the Nechako Reservoir that spawn in winter. Scott and Crossman (1973) report that most spawning takes place from January to March, usually in somewhat shallow waters, over sand or gravel shoals, although there is some evidence of deep water spawning. Most spawning activity occurs in lakes, but rivers and large creeks may also be used. Burbot do not build nests and the eggs are semi-pelagic. Eggs hatch at after approximately 30 days, depending on water temperature, showing up between February and June. Newly emerged larvae are pelagic, but usually remain high in the water column since burbot larvae prefer cool water (around 12°C, Harzevili *et al.*, 2004). Fry form schools in the in the nearshore littoral areas until reaching approximately 30 mm, when they become solitary and move to deeper waters.

Adult burbot prefer cooler water and are usually restricted to the hypolimnion in the summer, although they may move into near shore habitats at night to feed (Scott and Crossman, 1973). The optimum reported temperature for this species is 15.6° - 18.3°C, and the upper limit for the species is 23.3°C (Scott and Crossman, 1973). Burbot have been captured as deep as 200+ metres in the Great Lakes.

Burbot are voracious feeders. Young burbot feed on insect larvae and small invertebrates, while burbot over 500 mm feed almost exclusively on fish.

6.1.2 Kokanee

Kokanee are an important sport fish resource in British Columbia, accounting for 7% of the freshwater sport fish catch in the province in 2000 (Jack, Levy and Williams, 2003), and one of two key target species for recreational fishing in the Nechako Reservoir (the other being rainbow trout). Kokanee can be well adapted to life in fluctuating reservoirs, as they inhabit the pelagic environment, feed on zooplankton and often spawn in tributary streams (Maiolie and Elam, 1996). Due to their pelagic nature, however, reservoir stocks of kokanee can become severely depleted by entrainment downstream (Stober, Tyler and Petrosky, 1983).

Kokanee in the Nechako Reservoir generally spawn in late September and early October, in larger tributaries with gravel substrate. Kokanee also spawn on gravel shoals and areas of upwelling groundwater in lakes, but no such areas have been identified in the vicinity of Kenney Dam, and lake spawning has not been documented in the Nechako Reservoir.

Kokanee generally reach sexual maturity at age 3-5, and only spawn once before dying (*i.e.* a semelparous life history). Eggs hatch in December to January, but the fry may not emerge until March to May (Scott and Crossman 1978). Fry immediately move downstream to the lake (Reservoir) and are probably present in the river from early April to late June (Irvine, 1978).

Kokanee inhabit all depths during the spring and fall, but usually reside in the upper-middle layers of open lake during summer months. They move into deeper water with increasing temperatures in the summer and in the winter (Scott and Crossman 1978). In the Dworshak Reservoir in Idaho, Maiolie and Elam (1996) noted that during the day kokanee were tightly schooled showing 2 distinct patterns – during July to October, they were located in the top 25m of water, and in November to April they were split into 2 groups – one shallow above 40 m and one deeper below 45 m. Scott and Crossman also note that kokanee have extensive daily vertical movements likely associated with temperature and food.

In the Dworshak Reservoir, dive surveys indicated that during winter kokanee of all age classes were found in the lower reservoir near the dam, whereas in summer age-1 and age-2 kokanee were spread throughout the reservoir and were found in late summer in high densities at the upper end of the reservoir where there were spawning streams (Maiolie and Elam 1998). It was also noted that fry distribution was different from other age groups – in summer as fry moved out of tributary streams they were documented in the upper reaches of the reservoir; by October they had dispersed throughout the reservoir and in winter they were concentrated at the dam face (Maiolie and Elam, 1996 & 1998).

The upper lethal temperature for kokanee was noted to be 24.4°C, and preferred temperatures are between 12-14°C.

6.1.3 Mountain whitefish

Mountain whitefish spawn in late fall in the shallows of streams (12 cm to 1220 cm) over gravel or gravel/rubble substrate. No nest is prepared for their eggs, which fall to the bottom and between holes in the substrate (Scott and Crossman, 1978). It is unknown if spawning occurs over gravel shoals in lakes, although this seems likely. Eggs hatch in the spring, and newly hatched fry remain in shallow water along shorelines or stream edges for a few weeks, then move offshore once they reach 30-40 mm. As adults, they tend to stay near littoral habitats and are rarely found at depths greater than 20 m. They feed primarily on benthic organisms and tend to frequent the upper 4.6-6.1 m of the water column.

6.1.4 Rainbow trout

Rainbow trout accounted for 53% of the freshwater sport fish catch in British Columbia in 2000 (Jack, Levy and Williams, 2003), and are one of two key target species for recreational fishing in the Nechako Reservoir (the other being kokanee). They are present throughout the Reservoir and inhabit most accessible tributary lakes and streams.

Life history patterns of rainbow trout are extremely variable across their range, but they generally spawn in the spring from April to June in clean tributary streams with fine gravel substrate. Eggs hatch in 4-7 weeks, but fry do not emerge until about 15 days after hatching. Fry may move down into the reservoir almost immediately, or may spend up to 3 years in the stream before moving downstream. Young rainbow trout can inhabit all areas of the lake, but usually reside in littoral areas. Irvine (1978) found that fry preferred shallow regions and were rarely encountered in areas with heavy current, but were abundant in similar, but calmer areas. No rainbow trout fry were encountered during the present study, which could indicate populations in Knewstubb Arm rear in the spawning streams.

Lake-resident rainbow trout prefer moderately deep to deep cool lakes with adequate shallows and vegetation for good food production. Adults can be found in all areas of the lake, but prefer water temperatures under 21°C (preferred temperature is 13°C). The upper lethal temperature is 24°C.

Rainbow trout were identified by the agencies as a species of concern with respect to loss through entrainment for the Waneta Upgrade Project in southeast B.C. (EAO, 1998).

6.2 Entrainment risks

Previous studies of entrainment risks and mortalities have mainly focused on anadromous species (which are not present within the Nechako Reservoir), not resident fish populations. This is because juveniles of anadromous species require a downstream migration path to the ocean in order to complete their life cycle, which requires passing through or around any anthropogenic structures along the way. Species exhibiting migratory behaviour are therefore more likely to become entrained compared to species that can fulfill their life history requirements within a lacustrine or reservoir setting (Pizzimenti, Meldrim and Malone, 1991).

However, entrainment also poses risks to resident populations and cannot only affect individuals, but the population as a whole. Cada (1991) indicated that information about the fish community can assist in determining entrainment risks. Table 6 highlights characteristics of the four species of concern that may increase their risk of entrainment based on proposed operating times of the surface and deep water intakes at the CWRF. Note that the most abundant fish found in this study, northern pike minnow, is not included in the table as it is not normally included in the "fishery" in the Nechako Reservoir.

Table 6. Potential entrainment risks to species of concern

Species of concern	Life stage	Characteristics	Surface water intake		Deep water intake
			Low level intake (Operating early July to early May)	*High level intake and spillway (Operating early May to early July)*	
Burbot	Eggs/larvae	• Generally spawn in deep areas in winter • Eggs and larvae are pelagic and larvae usually remain high in the water column	Low risk – generally spawn in deep areas away from outlet	Low risk - spawn in winter when high level intake is not operational	Low risk – generally spawn in deep areas away from outlet
	Juveniles	• Generally found in nearshore habitats	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during survey and unlikely to be found at this depth
	Adults	• Move into nearshore habitats to feed at night • Prefer cooler water and usually inhabit hypolimnion in summer	Moderate risk – captured during survey and may be found at this level during winter months	Low risk - unlikely to be found high in the water column during summer operating period	Moderate risk – captured during survey and known to inhabit deeper waters
Kokanee	Eggs/larvae	• Known to spawn in tributary streams to reservoir	N/A	N/A	N/A
	Juveniles	• Known to concentrate at the dam face in Dworshak Reservoir	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during survey and unlikely to be found at this depth
	Adults	• Known to concentrate at the dam face in Dworshak Reservoir • Pelagic with extensive daily vertical movements likely associated with temperature and food • Usually reside in upper to middle layers of lake • Adults may inhabit all depths and may derive a significant portion of its food from bottom (benthic) organisms	Moderate risk - species observed within the vicinity of the dam	Low risk – usually inhabits deeper waters during summer	Moderate risk – captured during survey and known to inhabit deeper waters

Table 6 (con't)

Species of concern	Life stage	Characteristics	Surface water intake		Deep water intake
			Low level intake (Operating early July to early May)	*High level intake and spillway (Operating early May to early July)*	
Mountain whitefish	Eggs/larvae	• Spawn in tributary streams	N/A	N/A	N/A
	Juveniles	• Tend to remain in littoral habitats	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during survey and unlikely to be found at this depth
	Adults	• Tend to remain in littoral habitats • Rarely found deeper than 20 m	Moderate risk - species observed within the vicinity of the dam	Moderate risk - species observed within the vicinity of the dam	Low risk - unlikely to be found at this depth
Rainbow trout	Eggs/larvae	• Spawns in tributary streams	N/A	N/A	N/A
	Juveniles	• May inhabit littoral areas, but are generally not found in areas with high current	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during seasonal surveys of Knewstubb Arm	Low risk - none captured during survey and unlikely to be found at this depth
	Adults	• Inhabit all areas of the lake Prefer cooler water (13°C), therefore adults may inhabit deeper waters in summer	Moderate risk - species observed within the vicinity of the dam	Moderate risk – usually inhabits deeper waters during summer	Moderate risk – captured during survey and known to inhabit deeper waters

All of the species of concern have been known to spawn on gravel shoals of lakes. Gravel substrates in the vicinity of Kenney Dam appear to be limited to the drawdown zone of the reservoir. Successful spawning in the drawdown zone would be difficult as eggs deposited by fall spawners (*e.g.* kokanee) would be exposed as reservoir levels drop over the winter. Suitable habitat for spring spawners (*e.g.* rainbow trout) would be limited as the reservoir would typically be at the lowest elevation in spring and rainbow are known to spawn in tributary streams. At such time, any narrow strip of appropriate substrate could be exposed to the wave action of the reservoir. Regardless, gravel in the drawdown zone of the reservoir is not unique to the Knewstubb Arm, so it is unlikely that there are seasonal spawning migrations of fish to the area to spawn in the drawdown zone. At a preliminary level this idea is supported by data collected as part of this study, which, although was not exhaustive, did not identify large schools of newly emergent fish, or large schools of spawning fish.

Floating eggs and weakly swimming early larvae are the stages of resident fish species most susceptible to entrainment, however few studies have quantified this risk (Cada, 1991). Due to the difficulty in quantifying the risk to these life stages, annual entrainment estimates usually do not take them into account. Of the species of concern, only burbot have pelagic eggs and larvae, which presents potential for entrainment. However, as they spawn in winter in deep water, the pelagic larvae stage may occur when there is still ice on Knewstubb Arm (to mid-April), in which case the deep water intake would not be operating. Also, any loss of eggs and larvae from the reservoir could provide recruitment of burbot to the downstream fishery, as studies have shown low mortality rates for entrained eggs and larvae under a variety of severe pressure conditions (Cada, 1991).

It has been suggested that the probability of a resident fish becoming entrained is inversely proportional to both their age (size) and their distance from the project (Pizzimenti, Meldrim and Malone, 1991). In a number of studies at other hydropower projects fish smaller than 100 mm made up a majority of estimated annual entrainment (CH2M Hill, 2003). As large fish are stronger swimmers, they are not as susceptible to entrainment velocities as smaller individuals of the same species (Jones, Kiceniuk and Bamford, 1980).

During the current study, no fish smaller than 100 mm of a species of concern were collected. A study in 1979 at Kenney Dam found rainbow trout juveniles ranging from 120 to 170 mm in summer, and only greater than 170 mm in fall (Envirocon, 1989). No kokanee juveniles less than 100 mm were found at Kenney Dam and only one mountain whitefish less than 100 mm was found in the 1979 study (Envirocon, 1989). Current and historical findings indicate a low occurrence of juveniles in the area surrounding the proposed CWRF, which suggests they may have a lower risk of becoming entrained through either intake structure. The current and historical studies are particularly relevant for the surface intake as the gear was typically deployed to sample at shallow and intermediate depths (*e.g.* less than 20 m). The occurrence of juveniles in the vicinity of the deep water intake is less supported by the data, as efficient sampling at such depths is difficult. However, life history information for juveniles of target species supports a low abundance of juveniles at depth (*e.g.* Ford *et. al* 1999) due to their general preference for littoral or epilimnion habitats.

A better understanding of changed flow and temperature conditions in Knewstubb Arm as a result of the operation of the CWRF will provide additional insight into the entrainment risks to species in the vicinity of Kenney Dam. As all of the species of concern feed on larvae or invertebrates at some point in their life cycle, a change in the direction of the drift of these organisms towards the dam may initiate changes in the spatial distribution of fish within Knewstubb Arm, consequently changing their risk of entrainment. Reservoir modeling done in connection with the Kemano Completion Project indicates that there will be a reversal of the direction of the flow through Knewstubb Arm (Triton, 1991). However, with the changes in planned releases resulting from the cancellation of KCP and the ongoing work of the Nechako Watershed Council (see Section 2.1), the results of the work done for KCP can only be used as an indication of the magnitude of the changes in both velocity and the development and eventual drawdown of the thermocline in Knewstubb Arm as a result of the facility operation. Generally the operation of the release facility would be expected to attract kokanee to the vicinity of the dam as direction of the drift of their food would be expected to change from away from to towards the dam. As kokanee are typically a food source for rainbow trout, they would also be expected to congregate near the dam. There is some evidence for this at Skins Lake where observations of both species in the plunge pool below the spillway are indicative of the fish likely being entrained through the facility. However, we can only speculate on the timing or method of entrainment (does it happen during periods of relatively rapid flow change or because fish pursue food too close to the gate?). Nevertheless, these species are the most likely to be entrained.

If they are entrained into the low level outlet conduit and the design includes a hollow cone valve, then near total mortality would be expected because of the instantaneous pressure change as they pass the valve (likely causing their swim bladders to explode or by impingement on the hood downstream of the valve outlet). As this outlet would likely be used annually between early July and early May (10 months of the year) the risk of loss of any entrained fish is significant. In the eventuality that a power generation facility were included in the facility (on the low level outlet) any mortality of entrained fish would likely drop to 10% to 15% as fish can pass through Francis turbines (the likely turbine to be used in a facility with the head characteristics at Kenney Dam) with much lower chances of suffering physical damage.

If the high level outlet were in operation (based on current information this would likely occur in May and June annually and possibly in July or August if downstream cooling requirements exceed the 60 m^3/s capacity of the low level outlet (which would be infrequent)), some fish would likely be entrained but would pass down the spillway into the Nechako Canyon. The head drop through the gates at the head of the spillway would be less (10 to 15 metres rather than 90 metres on the hollow cone valve), so extensive damage to swim bladders would not be likely. Some abrasion (scale loss) would be likely as fish pass down the spillway but overall mortality would likely be less than for passage through the power plant.

Finally, burbot is currently the only species of concern that is likely to be found at the depth of the deep water intake, however changes in the thermocline may lead to changes in the vertical distribution of burbot and other fish species in the water column, which could increase or decrease their risk of entrainment.

In summary, fish likely to be entrained through the facility would be rainbow trout or kokanee, but entrainment rates would not likely be greater than those currently experienced at the Skins Lake Spillway. The consequences of entrainment would vary with the time of year and ultimate facility design with a concept including a power plant generally resulting in lower mortality. As well, as the entrainment rates would not likely be greater than those currently experienced at Skins Lake, the risk to the population of fish in the reservoir is not likely to increase.

6.3 Possible effects on downstream populations

Species of fish captured in the Knewstubb Arm during the entrainment study (see Table 4) are all present in the Nechako River downstream of the Kenny Dam.[2] Additionally, all species potentially present in the reservoir (see Table 1) have been documented in the Nechako River or its tributaries. The introduction of new species through entrainment from the reservoir into the Nechako River should therefore not be an issue in itself. However, a change to the community composition in downstream habitats resulting from the entrainment of fish will have to be considered.

The most noticeable differences in community structure between the reservoir and the upper Nechako River is the increased species diversity within the river, and the lower proportion of the total community comprised by northern pikeminnow (NFCP, 2004).

[2] Note that kokanee and sockeye salmon are both the same species (*O. nerka*) with different life histories.

7.0 Conclusions

The sampling data collected as part of the entrainment study and previous sampling efforts in the vicinity of the Kenny Dam provide an initial baseline of fish community structure within Knewstubb Arm. The data collected for the current study outlines the relative abundance of fish species that currently utilize the reservoir in the vicinity of Kenney Dam, their size and corresponding risk of entrainment.

The classification of habitats within Knewstubb Arm indicates that the littoral zone of the majority of the Arm is similar and comprised of fine substrates with abundant standing and downed wood. The large diameter rock substrate of the dam face is unique within Knewstubb Arm, however during this study the dam face and adjacent bays did not indicate the presence of significantly different numbers or species of fish than the rest of Knewstubb Arm. Lucas Creek is the only stream within the arm that has the potential to support a significant population of spawning fish. Lucas Creek is distant from the intake of the proposed release facility (Figure 3) and there is no direct link to indicate that fry (a life stage susceptible to entrainment) outmigrating from Lucas Creek would be susceptible to entrainment, as would be the case if a tributary confluence were in the immediate vicinity of the intake structure. Data collected as part of the study, although not exhaustive, supports this assumption, as schools of newly emergent fry were not captured or observed within Knewstubb Arm.

Previous studies conducted for the KCP indicate that changes in the flow and thermocline of Knewstubb Arm will occur with the operation of the CWRF. Flow modeling based on final intake designs and velocities in conjunction with known burst speeds of individual fish species would provide a basis for determining potential entrainment zones in the immediate vicinity of the intake facility. Using this information entrainment risks to reservoir species could be further quantified and used to estimate entrainment numbers for individual species. However, it is concluded that the species most likely to be entrained are kokanee salmon and rainbow trout. Further, based on the qualitative risk assessment, an incremental increase in the risk of entrainment is not likely and the risk to the fish populations in the reservoir is very low.

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PHOTO APPENDIX


Photo 1. Drilling through the ice in February to deploy sampling gear

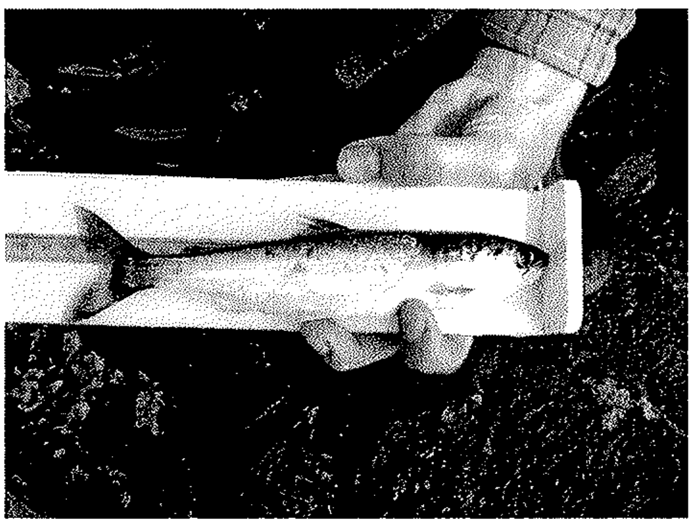


Photo 2. Kokanee captured in the gill net during May sampling event

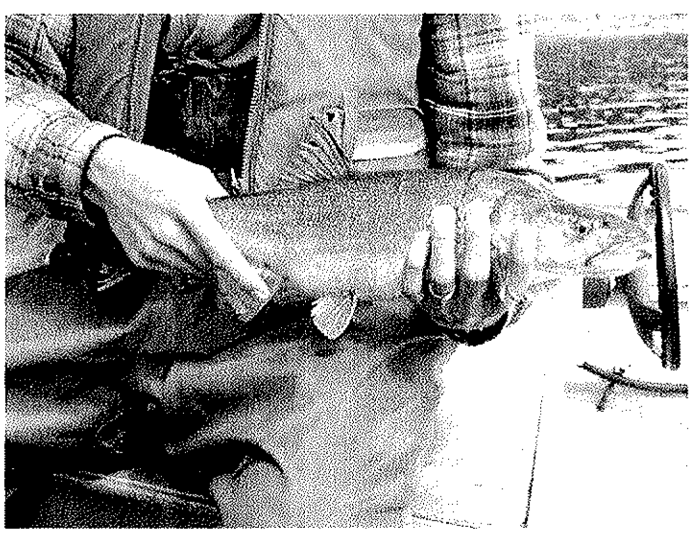


Photo 3. Northern pikeminnow captured in the gill net during May sampling event

Photo 4. Rainbow trout captured in the gill net during September sampling event

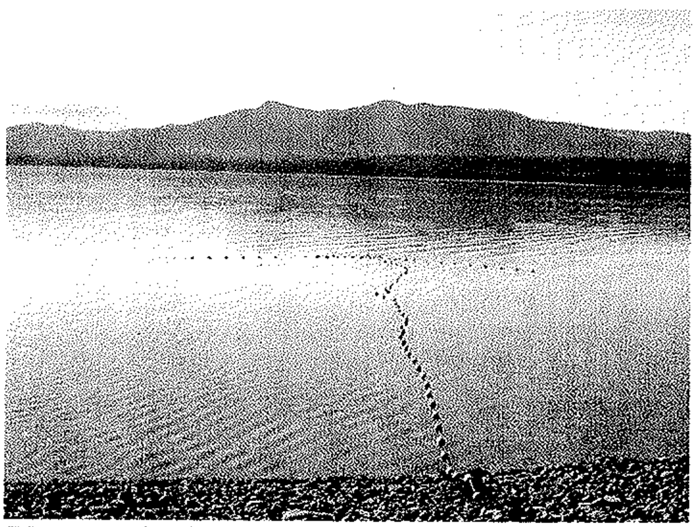


Photo 5. Floating lake trap during May sampling event

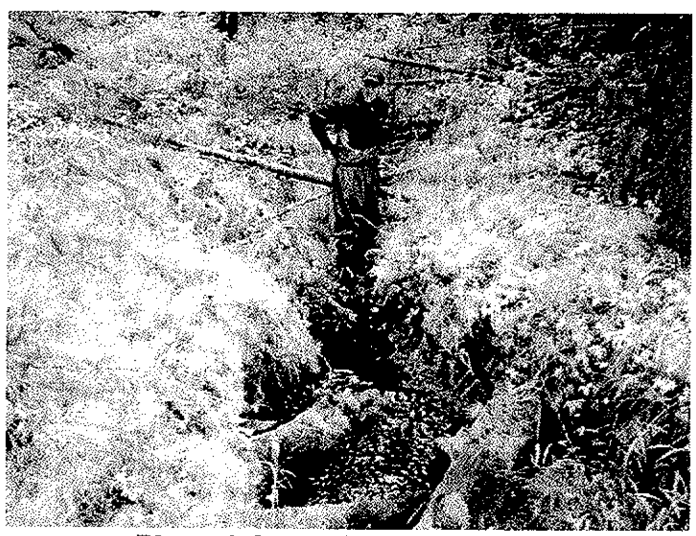


Photo 6. September stream survey

Photo 7. Lucas Creek September spawner survey

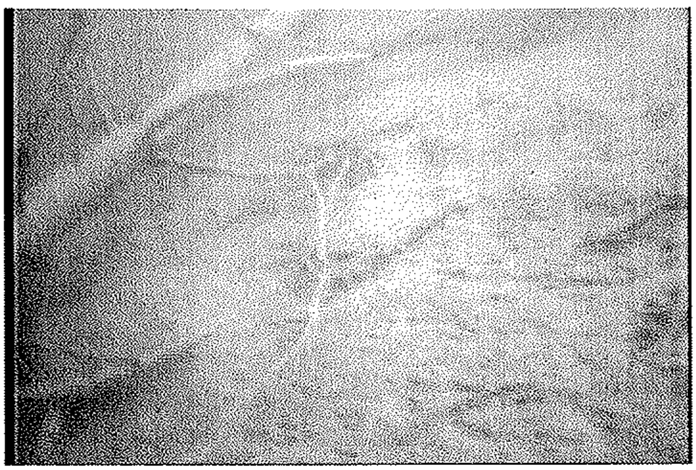


Photo 8. Type 1 littoral habitat, described by fine substrates, with small diameter wood present.

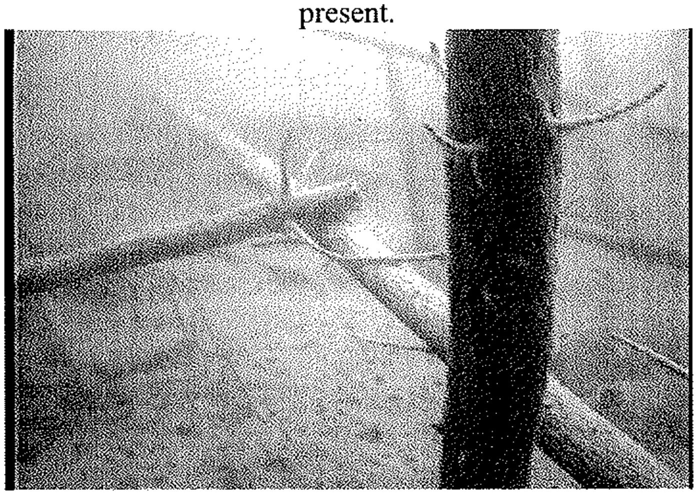


Photo 9. Type 2 littoral habitat, described by fine substrates, with larger diameter standing wood present.

Photo 10. Type 3 littoral habitat, described by fine substrates, with larger diameter downed wood present.

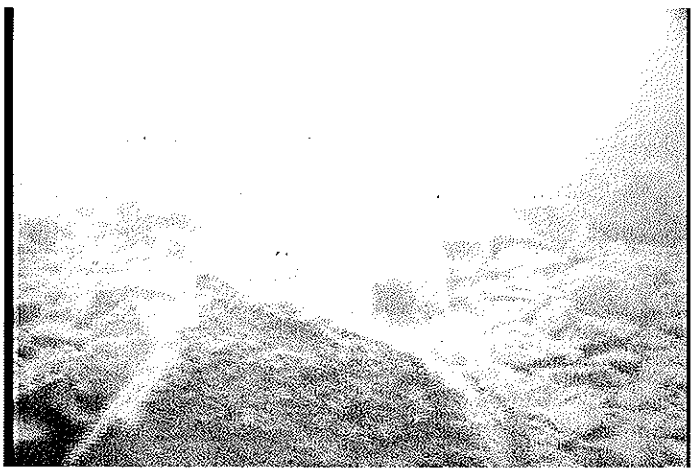


Photo 11. Type 4 littoral habitat, described by rock substrates. Minimal or no wood present.

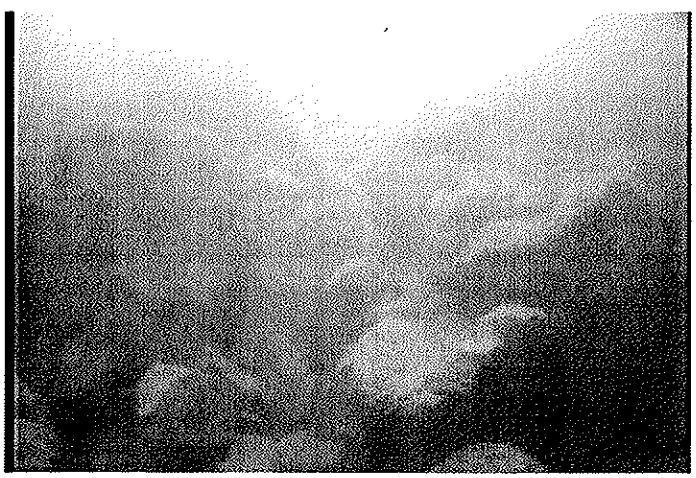


Photo 12. Type 5 littoral habitat - Kenney Dam. Large diameter rock and occasional wood present.

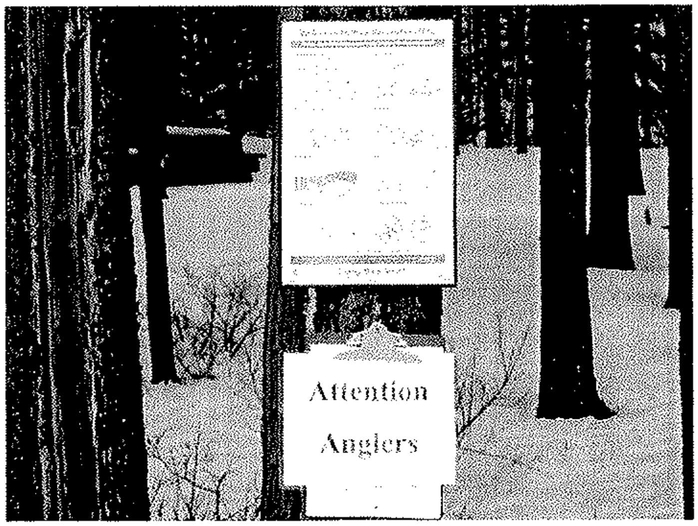


Photo 13. Creel census forms posted at the Knewstubb Lake Recreation Site

APPENDIX 1

CREEL CENSUS FORM

Knewstubb Arm Creel Census Form

This creel census is being conducted in order to identify fish species that reside in the **Knewstubb Arm** of the Nechako Reservoir, as well as their relative abundance, size, weight and temporal distribution. Data will be used to outline the potential risks to reservoir populations of entrainment or impingement from the proposed Cold Water Release Facility on the Kenny Dam.

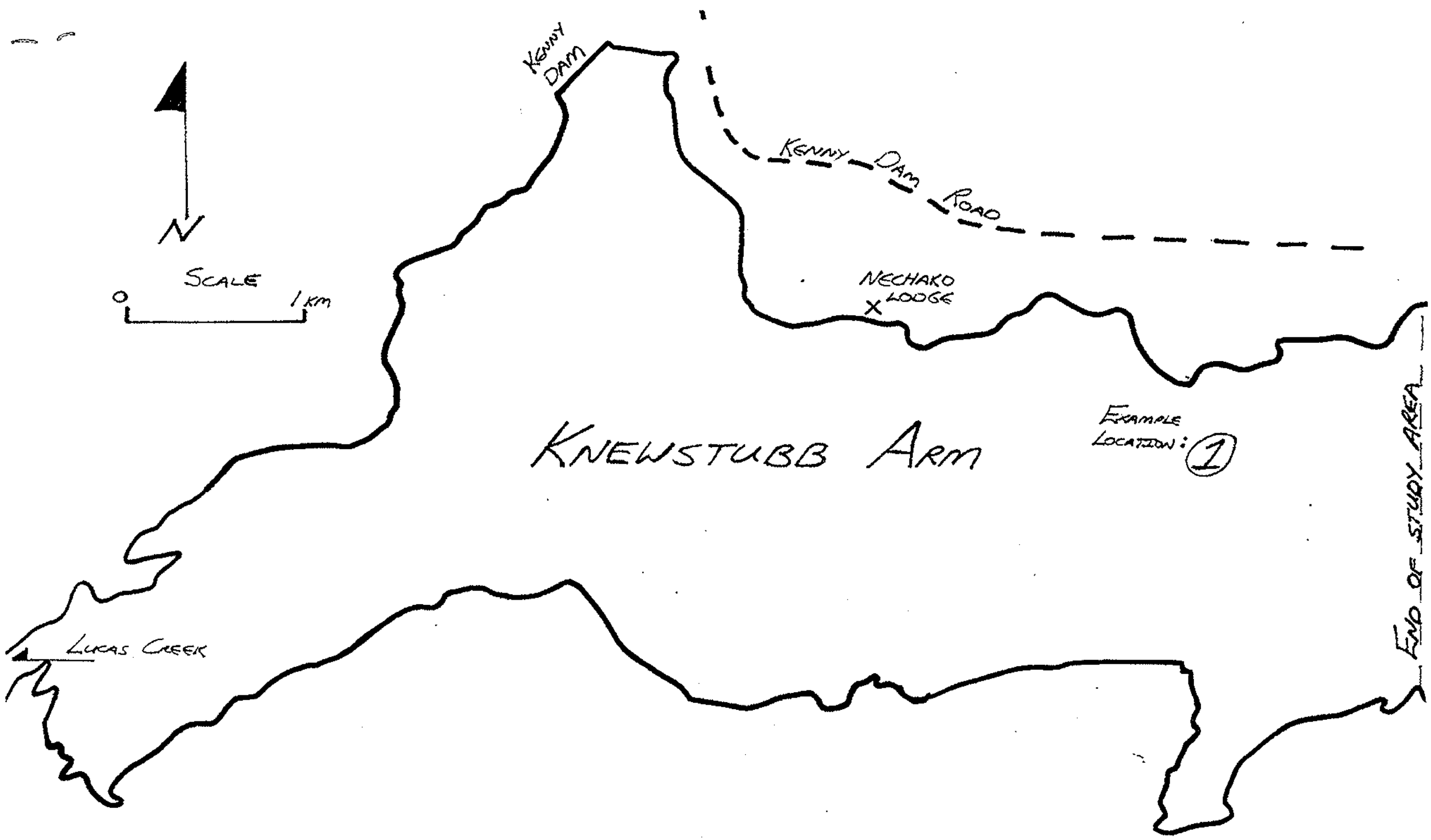
Date: ________________ Number of anglers in party: __________

Start time: ________________ End time: ________________

Fish Species	**Length (mm or inches)**	**Weight (lb or kg)**	**Sex (M/F)**	**Angling Method (Fly, spin cast …)**	**Approximate Depth Captured**	**Approximate Location Captured**
Rainbow trout	386 mm	1 kg	F	Spin cast	20 m (bottom)	1 (indicate on map on back)
						2
						3
						4
						5
						6
						7
						8
						9
						10
						11
						12
						13
						14
						15
						16
						17

In order to be entered into a draw for a $50 gift certificate to Northern Trout Fitters, please mail completed forms to:

NES – Year 2 Technical Studies
Triton Environmental Consultants Ltd.
201 – 1157 5th Avenue
Prince George, BC
V2L 3L1



Please indicate on map where individual fish were captured. Use numbers from table on other side of form ("Approximate Location Captured").