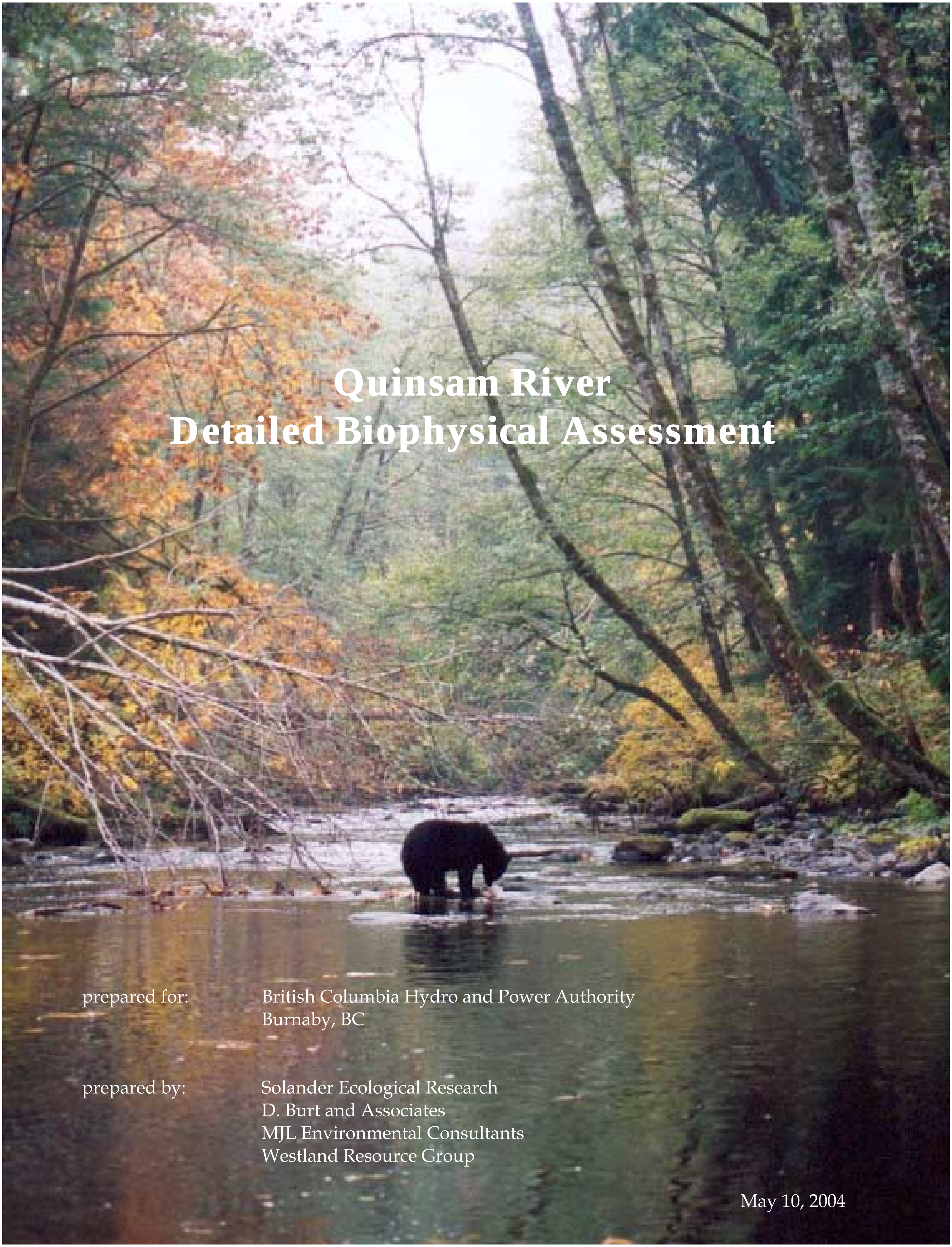

Quinsam River
Detailed Biophysical Assessment

prepared for: British Columbia Hydro and Power Authority
Burnaby, BC

prepared by: Solander Ecological Research
D. Burt and Associates
MJL Environmental Consultants
Westland Resource Group

May 10, 2004

cover: Black bear feeding on salmon carcasses, Quinsam River, October 1999.
(photo: Todd Hatfield)

SUMMARY

The Quinsam River is a major tributary of the Campbell River, with productive anadromous and resident fish stocks. Biophysical data have been collected throughout the Quinsam watershed sporadically and for a variety of purposes. Participants in the Campbell River Water Use Plan agreed that a detailed and up to date biophysical study of the Quinsam watershed would aid development of the WUP. BC Hydro therefore commissioned an assessment of the Quinsam River and Quinsam Lakes. There were four main study objectives:

1. Identify and quantify fish habitat for the Quinsam River mainstem,
2. Identify and quantify fish habitat for different flow scenarios with respect to different salmonid species and life stages, which will provide incremental fish benefits and provide recommendations for seasonal operations,
3. Identify and quantify the fish use and assemblage in the Quinsam River, and
4. Identify and quantify operational impacts to Wokas and Upper Quinsam Lakes and to assess the fish and fish habitat values in Upper, Lower and Middle Quinsam Lakes.

Field work was carried out in fall 1999 and winter 2000, with tasks divided into the following components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.

This report is structured as a series of stand-alone sections with a common general introduction that briefly reviews the general ecologic and hydrologic setting of the Quinsam watershed. Data summaries and photographs are presented separately in a Technical Addendum. The report contains no explicit recommendations for changes to BC Hydro operations in the Quinsam watershed, because these decisions will be made by the Consultative Committee for the Campbell River WUP.

Component 1

The original objectives of Component 1 were to identify and quantify fish habitat in the Quinsam River mainstem between Wokas Lake Dam and the Campbell River confluence. These objectives were to be met by assessing reach designations, developing a linear habitat map of the river, conducting habitat assessments of representative sites for each reach, and identifying transect locations for Component 2.

A total of 30 site cards were completed for the Quinsam River mainstem, and approximately 20 km of the river was surveyed, or about 45% of the total mainstem exclusive of lakes.

Water samples confirm that the Quinsam River mainstem is oligotrophic and typical of most streams on the east coast of Vancouver Island. All data collected here are consistent with earlier observations for the Quinsam River, and are well within the Water Quality Criteria set by MWLAP.

Data collected on Site Cards provide a representative sample of 30 locations throughout the watershed, and are summarized in the report. These samples are not random in their distribution, describing instead conditions around the flow transects selected for Component 2. The transect locations were selected based on a combination of accessibility and habitat criteria. The large number of surveyed locations throughout the watershed nevertheless ensured that the Site Cards represent a broad array of habitat types and locations in the Quinsam mainstem.

The linear habitat data provide a more detailed assessment of channel conditions than those data collected for the Site Cards. The dominant mesohabitat type varied among the reaches surveyed. Dominant mesohabitat types were rapid, riffle, or run. The ratios among different mesohabitats and the degree of dominance also varied among the reaches surveyed. For example, almost ¾ of reach 5 was riffle at the observed flow, whereas riffles made up closer to ¼ of the length for most other reaches. In general, pools were relatively rare in all surveyed sections of the watershed.

The suitability ratings assigned in the field imply that spawning habitat is relatively rare and patchy throughout the surveyed sections of the Quinsam River. In contrast, both fry and juvenile habitat are relatively abundant. Since this study was completed at only a single flow it is difficult to extrapolate from these results to higher flows.

Component 2

The principal objective of Component 2 was to "identify and quantify fish habitat for different flow scenarios with respect to different salmonid species and life stages, which will provide incremental fish benefits and provide recommendations for seasonal operations."

The field program established 57 transects on the Quinsam River between Wokas Dam and the mouth. Transect data were collected at three different flows, roughly 20%, 40% and 80% MAD. Analysis shows a trend of decreasing fry habitat in relation to flow for both the anadromous and resident sections of the Quinsam River. In contrast, parr rearing habitat increases over low flows, but is relatively insensitive to flow over moderate to high flows. This indicates a trade-off between fry and juvenile life stages in both the resident and anadromous sections of the river. The trade-off is steeper over lower flows than over moderate to high flows. There were no apparent trade-offs between the anadromous and resident sections of the river.

There is a general trend in the Quinsam River mainstem of increasing spawning habitat with additional flow, at least over the three flows assessed for this study. This pattern is most apparent for chinook. Coho and steelhead spawning PUWs also increase with flow, although there is a tendency toward a plateau at flows in excess of 50% mad. The relationship of pink salmon spawning habitat vs. flow stands in contrast, in that there is a fairly well-defined maximum PUW at approximately 16% - 40% mad. There is thus an apparent trade-off between pink salmon and the three other salmonid species for the spawning life stage. However, this trade-off does not appear to be profound in that the loss of spawning habitat for pink salmon is relatively small over the range of flows from 20% to 80% mad. In comparison the gain in chinook spawning habitat over this range is approximately 300%.

To allow a direct comparison of Quinsam observations with regional data and other flow standards, the results were compared to three other reference points:

1. MWLAP Region 1 fish-flow guidelines,
2. meta-analysis of PHABSIM data, and
3. Tennant's Method.

Limitations of this study component are discussed.

Component 3

The objective of Component 3 was to identify and quantify fish use and assemblage in the Quinsam River mainstem between Wokas Lake Dam and the Campbell River confluence. This objective was to be met by selecting sample sites, electrofishing these sites, and estimating standing stocks for all salmonids and potential smolt yields for coho and steelhead. The fish population survey was conducted from September 26 to October 15, 1999. A total of 13 sites were sampled.

Electrofishing sites were not selected at random—they were intentionally selected using subjective criteria intended to delineate habitats with high fish use. The site selection procedures used here are consistent with Provincial electroshocking assessment protocols.

Electrofishing assessments conducted for this study confirmed the presence of rearing salmon and trout over the full length of the Quinsam River below Wokas Dam. Coho were observed over the full length of the river; steelhead extended throughout the anadromous reaches; and cutthroat were observed only in the upper watershed. Other fish species were distributed sporadically and were relatively less abundant. Species captured in anadromous reaches included steelhead, coho, chinook, threespine stickleback, lamprey and coastrange sculpin; in resident reaches (i.e., upstream of the anadromous barrier) cutthroat, coho, rainbow and coastrange sculpin were captured. The presence of coho within resident reaches is assumed to be due to the Quinsam Hatchery outplanting program.

Coho and steelhead/rainbow were the most numerous species captured in this study. This finding is not surprising since preferred habitats of coho and steelhead were targeted for assessment, and there is an ongoing program of outplanting hatchery-produced fry of these species. Data from this study component were compared to reference points created using three data sources:

1. raw data used for Ptolemy's 1993 habitat capacity model,
2. regional data compiled by Paul Higgins (BC Hydro), and
3. Bradford et al.'s (1997) data on coho smolt production in regional streams.

Component 4

The original objective of the Lakes Assessment was to identify and quantify operational impacts to Wokas and Upper Quinsam Lakes and to assess the fish and fish habitat values in Upper, Middle and Lower Quinsam Lakes. Due to budget limitations, BC Hydro decided to focus the investigation on Upper Quinsam and Wokas Lakes. Field work was carried out in fall 1999 and spring 2000.

Available data indicate that Wokas Reservoir fluctuates from 360.90 to 364.91 m, a range of approximately 4 m. This range is substantially greater than that occurring on natural lakes in the region. It should be noted however, that the operational range of the reservoir is usually on the order of 2 m—an additional 2 m drawdown occurred in 1999 to accommodate specific fish concerns in Miller Creek. This circumstance is not expected to be repeated.

Of the 14 tributaries assessed only five had year-round rearing capability, as determined by sampling in October 1999. Hawkins Creek appears to have the highest fish production capability based on flow regimes, channel stability and quality of fish habitat present. Access problems for fish, caused by accumulations of gravel, existed at all the fish-bearing streams. The lowest reach of each of these streams are aggraded, apparently as a result of logging and mining activity in the watershed. Aggradation is also an issue at several of the smaller tributaries, which may affect seasonal use of these streams.

Accumulation of gravel at the mouth of several of the tributaries has formed a gravel fan that de-waters during low summer flows. The dewatered gravel fan increases in area as reservoir levels decline, resulting in an upstream and downstream obstruction to fish passage when stream flows and/or reservoir levels are insufficient to cover the gravel bar.

The tributary confluence fans are used by spawning salmonids. There is spawning within the drawdown zone of the reservoir, but spawning also occurs upstream of the high water elevation. Redds within the drawdown zone are susceptible to inundation if reservoir elevation increases. In general, one would expect reservoir levels to be declining over the spring incubation period, but the available data indicate that elevations may sometimes increase over this period.

Production capability of the study lakes was based on the yearling capacity model developed by Facchin (1983), which was later modified for coastal lakes. As expected, theoretical production capability was determined primarily by lake size, with the greatest capability being assigned to Upper Quinsam Lake. The same model was used to predict the effect of reservoir drawdown on fish production in Upper Quinsam and Wokas Lakes. The calculations suggest that the maximum effect would be a 10% to 12% loss in fish production due to the effects of reduced lake size and shoal area.

There was a common issue observed at the inlet and outlet of Middle and Lower Quinsam Lake, in relation to BC Hydro operations. Although no de-watered redds were observed, there was a general concern that if the stream flows were reduced during the remainder of the incubation period (June), then the redds will begin to de-water. Such dewatering would result in lower spawning and incubation success of salmonids.

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GENERAL INTRODUCTION

A Water Use Plan (WUP) is presently being developed for the Campbell River generating system on Vancouver Island, with an expected completion date of 2002. Water Use Planning is a joint initiative of BC Hydro, the public, First Nations, and various governments and agencies, that will redefine BC Hydro's water rights (i.e., renegotiate water licences) taking into account current social and economic values (Province of British Columbia 1998). A WUP for the Campbell River system is deemed necessary because water rights were negotiated several decades ago and legislation and public values have changed considerably since then, particularly in regard to environmental issues (Campbell River Hydro/Fisheries Advisory Committee 1997). The WUP will provide a single management strategy for all affected watersheds.

The Campbell River generating system has been a source of hydroelectric power since 1947. It presently meets about 12% of peak load on Vancouver Island (Campbell River Hydro/Fisheries Advisory Committee 1997). BC Hydro's Campbell River generating system is a complex array of three impoundments and four diversions. The lowest elevation facility is John Hart Dam and Generating Station. This facility was built in 1947 and impounds John Hart Reservoir. The next facility upstream is the Ladore Dam and Generating Station, which was completed in 1957 and impounds Lower Campbell Reservoir. This impoundment receives water released from Upper Campbell Reservoir and from diversions on the Quinsam and Salmon Rivers. The highest elevation facility in the system is Strathcona Dam and Generating Station, which was completed in 1958, and impounds Upper Campbell Reservoir and Buttle Lake. This impoundment receives water diverted from the Heber River and Crest Creek, via the Elk River. The Strathcona development has a substantial storage capacity, whereas the lower reservoirs do not (Burt and Burns 1995).

Purpose of this study

The Quinsam River is a major tributary of the Campbell River (Figure 1), and has productive anadromous and resident fish stocks. Biophysical data have been collected throughout the Quinsam watershed sporadically and for a variety of purposes. Burt (2000) compiled and reviewed the available data and literature and identified the following key data gaps:

1. a comprehensive assessment of fisheries habitat in the Quinsam River mainstem downstream of the diversion,
2. a comprehensive assessment of fisheries habitat and operational impacts of Upper, Middle, and Lower Quinsam Lakes,
3. a comprehensive assessment of flow versus habitat relationships in the mainstem Quinsam River, and
4. fish species composition and habitat use in the Quinsam River mainstem.

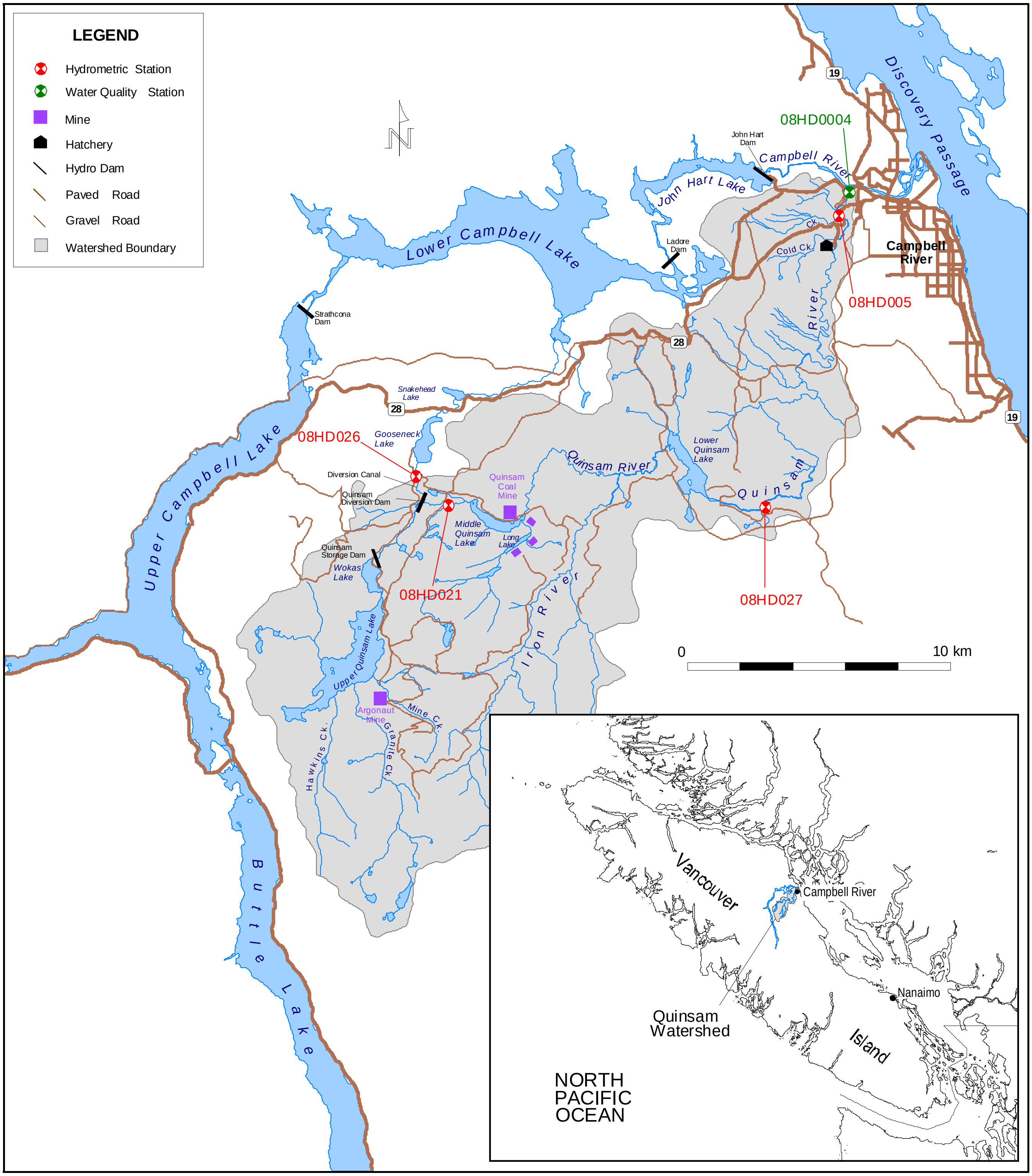


Figure 1. Map of the Quinsam River Watershed showing Water Survey Canada hydrometric stations. Inset shows the location of the watershed on Vancouver Island. (from Burt 2003)

Participants in the Campbell River WUP agreed that a detailed and up to date biophysical study of the Quinsam watershed would aid development of the Water Use Plan. BC Hydro therefore commissioned an assessment of the Quinsam River and Quinsam Lakes. There were four main study objectives (BC Hydro 1999):

1. identify and quantify fish habitat for the Quinsam River mainstem,
2. identify and quantify fish habitat for different flow scenarios with respect to different salmonid species and life stages, which will provide incremental fish benefits and provide recommendations for seasonal operations,
3. identify and quantify the fish use and assemblage in the Quinsam River, and
4. identify and quantify operational impacts to Wokas and Upper Quinsam Lakes and to assess the fish and fish habitat values in Upper, Lower and Middle Quinsam Lakes.

The tasks for the assessment were divided into the following components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.
Component 5. Report preparation and summary.

Field work for components 1 to 4 was carried out in fall 1999 and winter 2000. Westland Resource Group conducted the linear habitat mapping. D. Burt and Associates conducted components 2 and 3. MJL Environmental Consultants completed the lakes assessment. Solander Ecological Research was responsible for compiling results into a final report, and received extensive input from the other contractors.

This report is structured as a series of stand-alone sections with a common general introduction that briefly reviews the general ecologic and hydrologic setting of the Quinsam watershed. Data summaries and photographs are presented separately in a Technical Addendum. The Campbell River WUP will treat all affected watersheds under one management program, and in some cases trade-offs may be made among watersheds. These decisions will be made by the Consultative Committee for the Campbell River WUP. The report therefore contains no explicit recommendations for changes to BC Hydro operations in the Quinsam watershed.

Ecological Setting

The Quinsam River is located on the eastern side of Vancouver Island near the town of Campbell River. The watershed is within the Eastern Vancouver Island Ecoregion, and straddles two Ecosections, the Leeward Island Mountains, and the Nanaimo Lowlands (Campbell et al. 1990). The Leeward Island Mountains Ecosection is a mountainous area from the crest of the Vancouver Island Ranges to the Nanaimo Lowlands. The Nanaimo Lowland Ecosection is a coastal plain situated on the south-eastern margin of Vancouver Island.

The climate of coastal British Columbia is determined largely by frontal systems that sweep in from the Pacific Ocean (Campbell et al. 1990). In winter, low pressures systems bring frequent moist, mild air onto the coast. In summer, high pressure systems develop over the North Pacific Ocean, and the frequency of frontal systems is greatly reduced. The high elevation mountains of the Vancouver Island Ranges produce an effective rain-shadow for the eastern portion of Vancouver Island. As a result, the Leeward Island Mountains Ecosection receives substantially less precipitation than the Windward Island Mountains Ecosection. In general, skies are clearer on the leeward side and drier conditions prevail; temperatures in both ecosections are moderated by the ocean.

Vegetation in the Quinsam Watershed is dominated by the Western Hemlock Zone (western hemlock and western redcedar predominate, with red alder dominating disturbed sites). The Coastal Douglas-fir Zone (Douglas-fir predominates; grand fir, western redcedar, bigleaf maple, and western flowering dogwood may also occur) is found along the Nanaimo Lowlands. The Mountain Hemlock Zone (mountain hemlock, amabilis fir, and sometimes yellow-cedar are typical of lower-elevation forests of this type) and the Alpine Tundra Zone (most vegetation is made up of low-growing, evergreen dwarf shrubs) occur at higher elevations of the Vancouver Island Range.

Fish species in the Quinsam River include chinook, coho, sockeye, pink, and chum salmon, cutthroat, and rainbow trout, Dolly Varden char, lamprey, sculpins, and sticklebacks. Cutthroat, rainbow, sockeye, and Dolly Varden are present in both resident and anadromous life history forms. A brief description of each species' life history is presented in Burt (2003). Life history timing of fish species in the Quinsam is presented in Appendix A.

The distribution of resident stocks varies by species, but as a group they are distributed throughout the watershed, in lakes, tributaries, and the mainstem (Figure 2). The distribution of anadromous stocks also varies by species and is influenced by natural cascades and falls. An impassable barrier approximately 1 km downstream of Middle Quinsam Lake represents the present limit of spawning and rearing of anadromous species. Burt (2003) provides a detailed account of species distributions throughout the watershed.

In addition to water diversion for power production, resource use in the Quinsam River watershed includes logging, mining, gravel extraction, agriculture, and urban development. Most of the watershed is second growth forest, a result of previous logging and fires. Quinsam Coal Limited has been mining coal in open pit and underground mines near Middle Quinsam Lake since 1987 (Burt 2003). Iron ore mines, now defunct, were active near Upper Quinsam Lake beginning in the 1950s (Burt 2003). Agriculture and urban development are located only in the lower elevation areas of the watershed (Burt 2003).

Water quality in the Quinsam River and Quinsam Lakes is typical of eastern Vancouver Island: clear, oligotrophic, and generally alkaline. Specific concerns about water quality have been raised in regard to forest fertilization, Quinsam Hatchery effluent, and especially the Quinsam Coal mine (Burt 2003). Concern regarding potential acid drainage from the coal mine has triggered extensive monitoring of water quality.

Monitoring of receiving waters has detected trends of increasing concentrations of calcium, hardness, conductivity, magnesium, sodium, sulphate, and strontium. Although few of the values exceeded guideline concentrations, the increase in sulphate is of notable concern because freshwater biota are highly sensitive to changes in pH. Increased sulphate concentrations have been detected as far downstream as the mouth of the river. For further review of water quality data from the Quinsam system please see Burt (2003) and reports referenced therein.

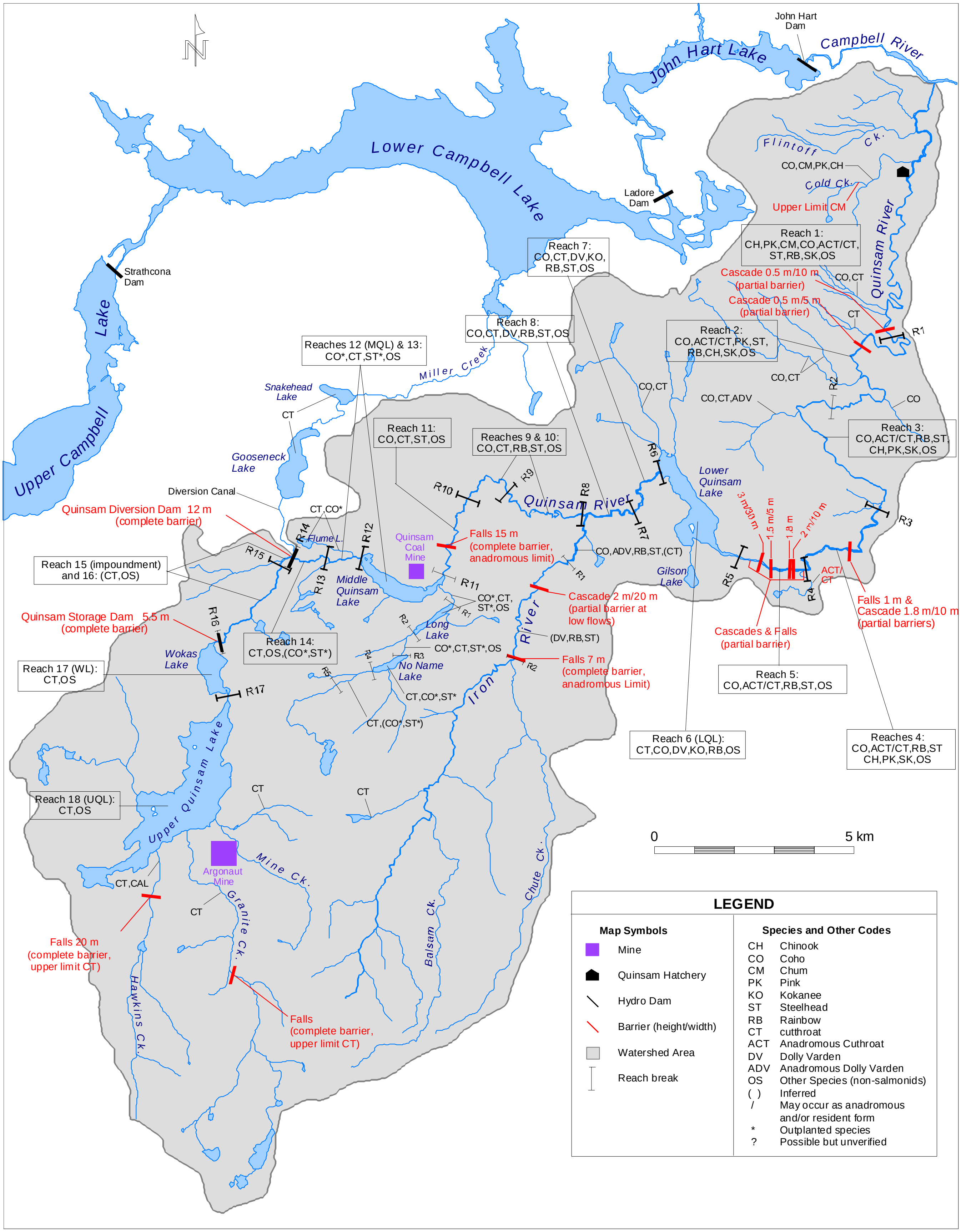


Figure 2. Map of fish distribution in the Quinsam River watershed. (from Burt 2003).

Hydrologic Setting

The Quinsam River (Figure 1) is the only major tributary of the lower Campbell River, entering about 3.4 km upstream of the Campbell River estuary. The mainstem of the Quinsam is approximately 45 km in length (excluding lakes), and the watershed is 283 km^2 (Burt 2003). There are numerous lakes in the watershed, the largest of which are: Lower Quinsam Lake (1.5 km^2), Middle Quinsam Lake (0.8 km^2), Upper Quinsam Lake (5.0 km^2), and Wokas Lake (0.6 km^2). Smaller lakes include, Gilson, No Name, Long, and Flume Lakes.

Inflows to the Quinsam River are primarily in the form of rainfall, although some winter precipitation falls as snow, particularly at higher elevations. Patterns of inflow to Wokas Reservoir (as modeled by Knight Piesold Consultants for BC Hydro) indicate considerable variability in magnitude and timing (Figure 3). Substantial storm-related inflows can occur at almost any time of the year, although the general trend is for greatest inflows during fall and winter, and minimal inflows during summer months (Figure 3).

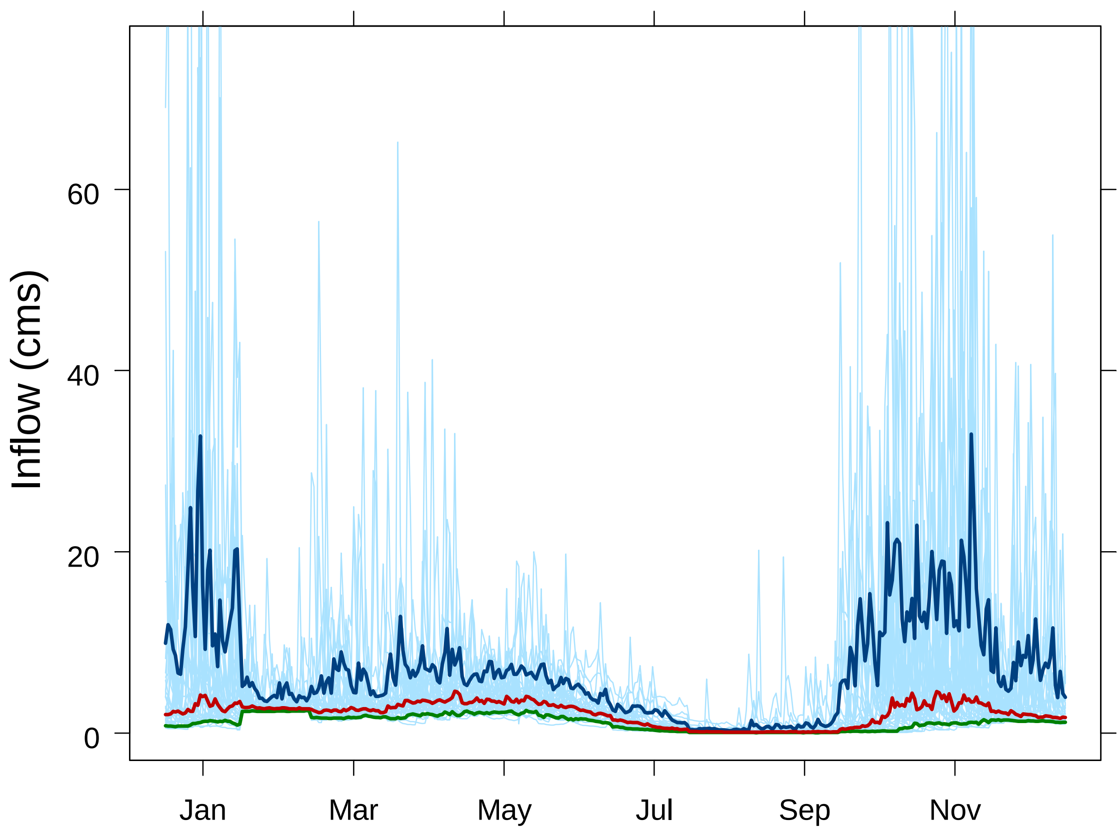


Figure 3. Estimated inflows to Wokas Reservoir, 1961-2000. Blue line is 90th percentile, red line is median, and green line is 10th percentile.

Water Survey of Canada has four active streamflow gauges in the watershed (Figure 1; Table 1), but only one of these has a record over the period that BC Hydro has been diverting water.

Although diversions have not been continuously recorded, for the Campbell River WUP BC Hydro constructed a time series of estimated diversions for the period 1957 to 1999, which can be appended to ongoing empirical diversion measurements to make a complete diversion record. The BC Hydro constructed time series is based on empirical measurements and hydrologic modeling. The estimates allow "naturalizing" of downstream gauge data by adding diversion estimates to empirical data. However, it should be stressed that this will not provide accurate predictions of daily flows due to modeling error, the attenuating effect of distance, and the additional attenuating effect of lakes in the system. Nevertheless, these "naturalized" flows should be reasonable for calculating annual and monthly statistics, and for determining general trends in streamflow. Streamflow data are summarized in Table 1, and presented in a series of graphs (Figure 4 to Figure 8). In addition to flow gauges, there is a continuous reservoir elevation gauge at Wokas Reservoir that has operated since 1998.

Table 1. Water Survey of Canada active gauges in the Quinsam watershed.

Name	Station ID	years of record	Observed MAD	Naturalized MAD [2]
Quinsam River at the confluence with Campbell River	08HD005	1956 to present	8.64	10.49
Quinsam River at "Argonaut Bridge" below Quinsam diversion	08HD021	1993 to present	1.83	3.08
Quinsam River diversion	BC Hydro modeled data	1957 to 2001	1.82 [1]	na
Quinsam River below Lower Quinsam Lake	08HD027	1997 to present	7.14	8.39

[1] BC Hydro has constructed a time series of estimated diversions for the period 1957 to 1999, based on empirical measurements and hydrologic modeling.
[2] Naturalized MAD is estimated by adding mean daily flows from synthesized diversion record to mean daily gauged streamflows.

The Quinsam diversion facilities came into service in 1957. The facilities consist of a storage dam at the outlet of Wokas Reservoir and a diversion dam approximately 1 km downstream. At the Quinsam Diversion Dam water is diverted along a 1.7 km long canal that flows into Gooseneck Lake. Gooseneck Lake drains into Snakehead Lake, which in turn drains via Miller Creek into Lower Campbell Reservoir (BC Hydro 1998). The diversion works have a maximum capacity of 8.5 cms, and divert, on average, flow of 2.83 cms (BC Hydro 1998). Active water licences restrict water storage and diversion with the following conditions (Burt 2003):

Quinsam River Storage Dam

- maximum storage of 12.3 million m^3 per annum (10,000 acre-feet) in Wokas/Upper Quinsam Lakes.

- minimum storage of 0.6 m above the 361.65 m elevation in Wokas/Upper Quinsam Lakes. This lowermost 0.6 m (2 ft) of drawdown is reserved for augmenting low flows for fisheries purposes.
- (This translates into an operational range of 362.26 m to 364.54 m [V. Plesa, BC Hydro, personal communication with M.J. Lough.])

Quinsam River Diversion Dam

1. maximum allowable diversion of 148 million m^3 per annum (120,000 acre-feet).
2. minimum flow of 0.28 cms (10 cfs) for the Quinsam River immediately upstream of Middle Quinsam Lake year round (for fisheries purposes).
3. 1.70 cms (60 cfs) to be maintained immediately below Lower Quinsam Lake from February 1 – May 31, and from September 1 – November 15 (for adult salmonid migrations).

Burt (2003) discusses in detail the effects of the Wokas Storage Dam and the Quinsam Diversion on the hydrology of the Quinsam River system, and summarizes the effects as:

1. A reduction in annual total discharge due to diversion (MAD reduced by ~50% at Argonaut Bridge, ~20% at Lower Quinsam Lake outlet, ~17% at the mouth).
2. An alteration of seasonal flow patterns due to both diversion and storage facilities (generally a reduction in mean monthly flows from November to June; sometimes flow augmentation by releases at Wokas Dam in order to meet the minimum flow requirements of the water licence).
3. Unnatural changes in flow (ramping) when Wokas Dam and Quinsam Diversion facilities are opened or closed (ramping is generally performed over a 4 hour period; effects are most pronounced in reaches between Wokas Dam and Upper Quinsam Lake).
4. Increased fluctuation in water levels of Wokas and Upper Quinsam Lakes due to storage and drawdown at Wokas Dam.

Some of these effects are clearly evident in Figure 4 to Figure 8 and Table 1.

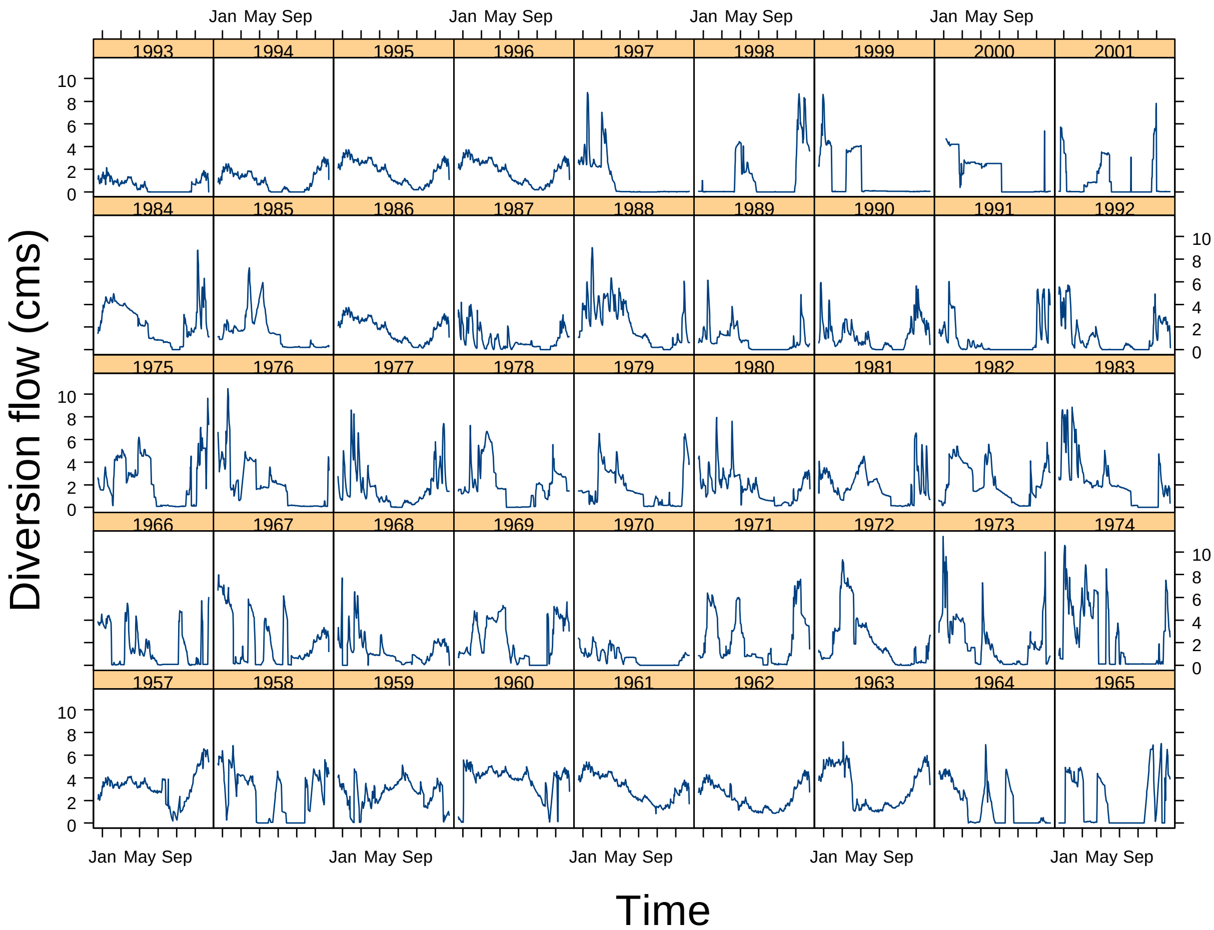


Figure 4. Quinsam diversion history, 1957-2001 (data from BC Hydro).

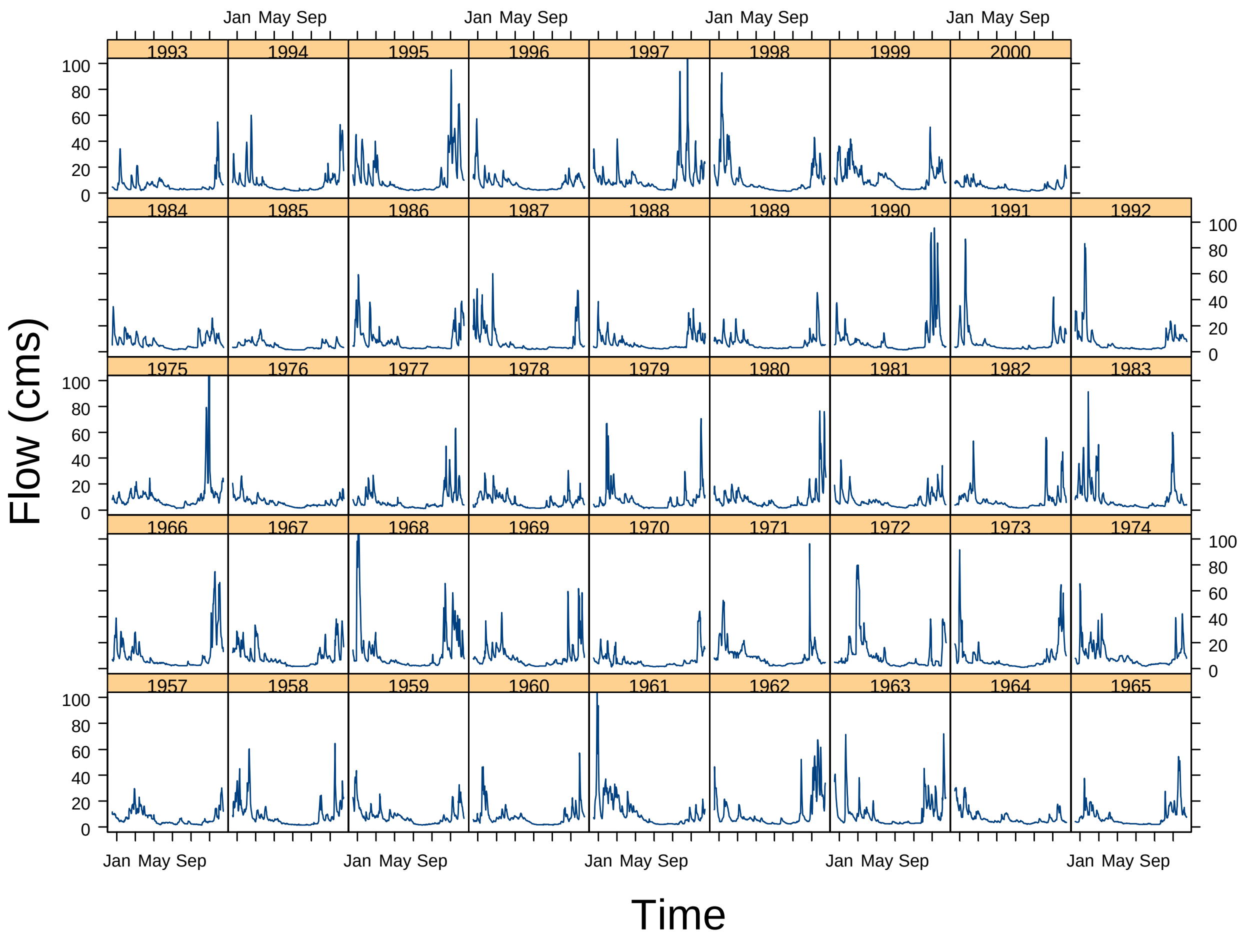


Figure 5. Quinsam River gauged flows near the confluence with Campbell River, 1957-2000 (WSC 08HD005).

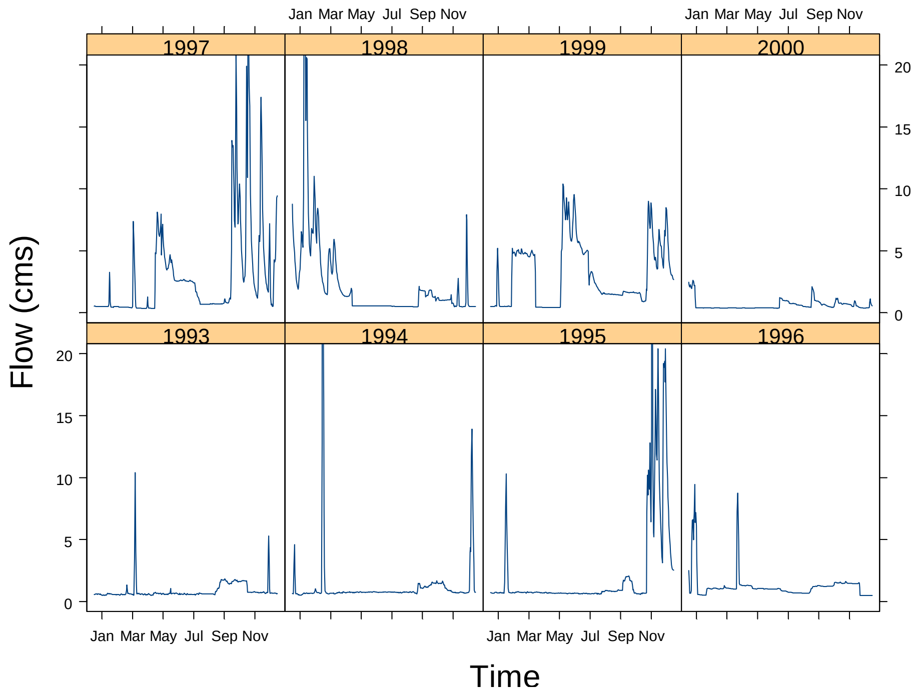


Figure 6. Quinsam River gauged flows at “Argonaut Bridge” below Quinsam diversion, 1993-2000 (WSC 08HD021).

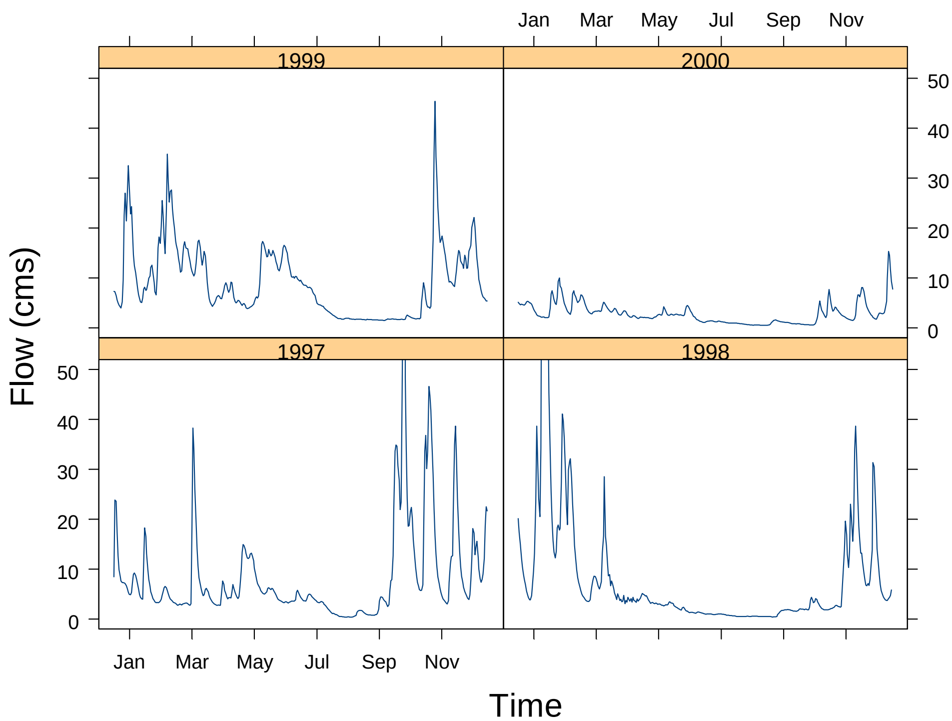


Figure 7. Quinsam River gauged flows below Lower Quinsam Lake, 1997-2000 (WSC 08HD027).

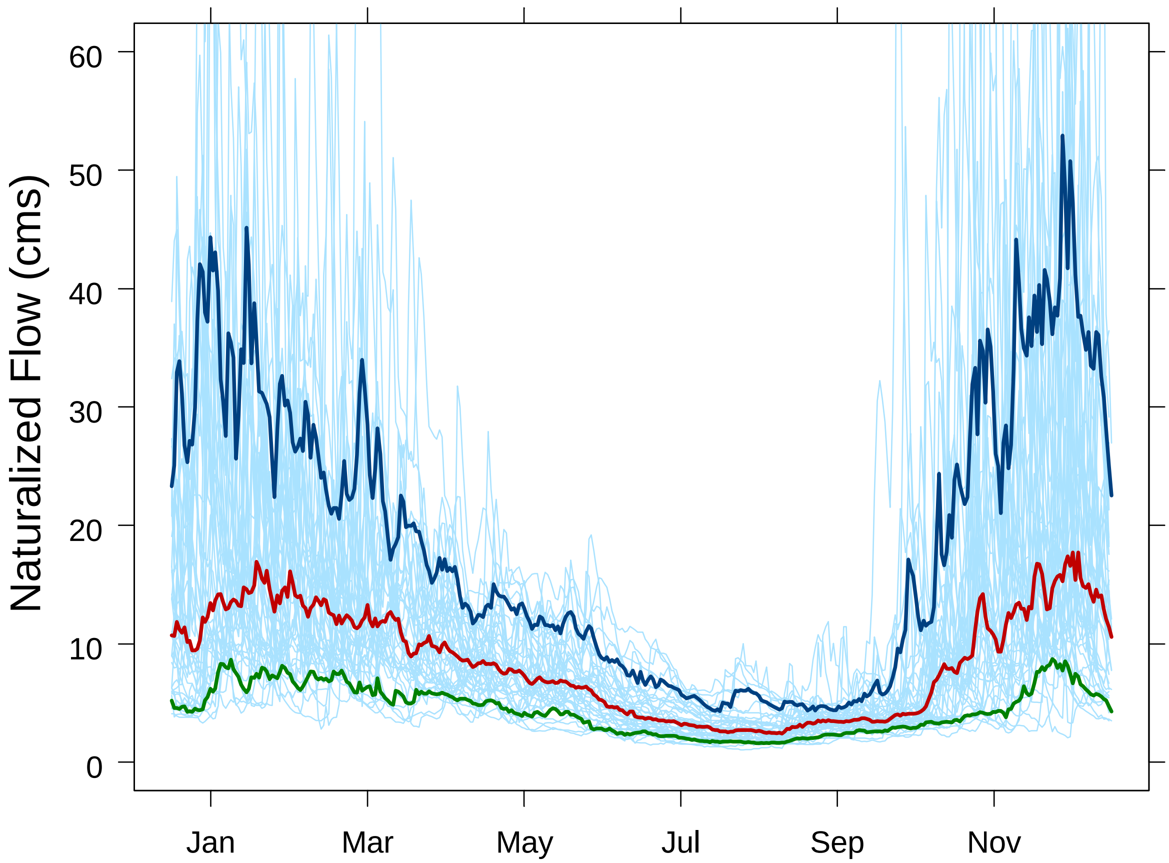


Figure 8. “Naturalized” flows in Quinsam River near the confluence with Campbell River, 1957-2000. Data were “naturalized” by combining gauged flows with BC Hydro diversion record (some of which is synthesized). Blue line is 90th percentile, red line is median, and green line is 10th percentile.

COMPONENT 1. HABITAT MAPPING OF QUINSAM RIVER

Introduction

As part of the Campbell River Water Use Plan, BC Hydro commissioned a detailed biophysical assessment of the Quinsam River mainstem and its major lakes. The main tasks for the assessment were divided into five components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.
Component 5. Report preparation and summary.

This section of the report presents findings from Component 1, the linear habitat mapping and assessment. Field work was conducted in fall 1999 (primarily October) by Westland Resource Group. The section was written by Solander Ecological Research, with input from Chris Parks of Westland.

A brief review of the natural resources of the Quinsam watershed is presented in the General Introduction to this report. A more extensive review is presented in Burt (2003).

Methods

The original objectives of Component 1 were to identify and quantify fish habitat in the Quinsam River mainstem between Wokas Lake Dam and the Campbell River confluence. These objectives were to be met by assessing reach designations, developing a linear habitat map of the river, conducting habitat assessments of representative sites for each reach, and identifying transect locations for Component 2.

Personnel from Westland and D. Burt and Associates discussed the reach breaks designated in Burt (2000), and assessed them to be appropriate for the purposes of this study. These same personnel also discussed how best to identify transect locations for Component 2. It was agreed that efficiency was greatest if D. Burt and Associates selected transect locations while conducting their work, rather than waiting for completion of the habitat map. Responsibility for this task was therefore transferred to Component 2.

Locations for habitat survey data collection are indicated in Figure 9.

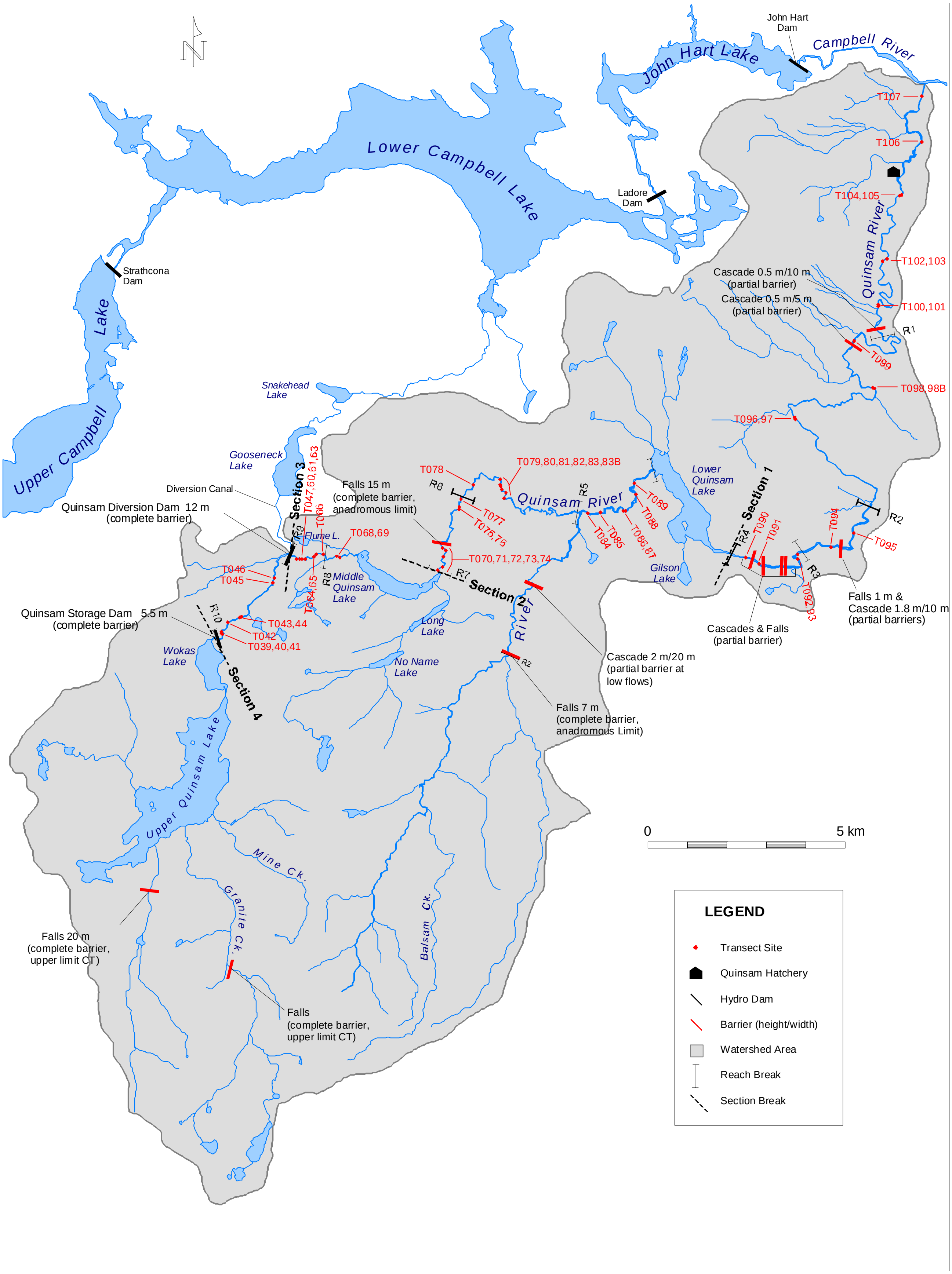


Figure 9. Map of Quinsam River watershed indicating locations of survey data collection.

Water Samples

On October 17, 1999 water samples were collected from five locations:

1. below Wokas Dam in the bedrock canyon,
2. at the "Argonaut Bridge" near WSC hydrometric station 08HD021,
3. below Lower Quinsam Lake at WSC hydrometric station 08HD027,
4. the Quinsam River 100 m upstream of the Iron River, and
5. the Iron River 100 m upstream of the Quinsam River.

Samples were shipped via courier to Cantest Ltd. in Burnaby for analysis of pH, conductivity (µS/cm), total alkalinity $CaCO_3$ (mg/L), nitrate N (mg/L), and soluble reactive phosphorous (mg/L). Laboratory analyses of water samples were performed using procedures based on those described in Province of British Columbia British Columbia (1994) and American Public Health Association (1989, 1995). One sample bottle for site Quinsam 1 broke in transit, so the site was re-sampled on November 2, 1999.

Additional pH and conductivity measurements were taken in the field using portable meters, as part of data collection for completion of RIC site cards.

Alkalinity data were used to predict maximum salmonid densities ($g \cdot 100\ m^{-2}$) using equations in Ptolemy (1993).

Site Cards

A total of 30 site cards were completed for the Quinsam River mainstem. Locations for these assessments coincided with transect locations assigned during Component 2 (Figure 9). Where transects were close together, only a single site card was completed. Measurements were taken according to methods in Resources Inventory Committee (1999). Photographs were taken of representative habitats.

Linear Habitat Map

Data for the linear habitat map were collected using a laser rangefinder, electronic compass and level, and a portable microcomputer, which were mounted as a unit on a monopod. Targets for the rangefinder consisted of small patch of reflective tape attached to extensible survey rods. All survey equipment and software were supplied by BC Hydro.

To work efficiently a mapping field crew required a minimum of three persons; the Quinsam surveying was performed with three to four persons. Methods of data collection are similar to those described by Parasiewicz (2001). The data collection sequence began by two crew members, one on each river bank, finding the transition between one mesohabitat section and another (e.g., the transition between a riffle and a run). Each crew member placed the base of a surveying rod at the stream edge. A third crew member then positioned himself in the centre of the river with the rangefinder-compass-computer unit, with the base of the monopod on the streambed. The rangefinder was used to measure the distance to each survey rod, which was entered into the computer along with extension height of the survey rod. (To obtain a clear view for the rangefinder, the survey rods were extended to varying heights depending on visibility through vegetation.) Crew members working on the streambanks then moved downstream to the transition edge of the same mesohabitat section, and the rangefinder was used to measure distance to these points. A single mesohabitat section thus had four measurements associated with it, which delimited the section into a trapezoid. Also entered into the microcomputer were subjective assessments of mean water depth, dominant substrate, and habitat suitability for salmonid fry, juveniles, and spawning. This marked the end of the measurement for one mesohabitat section.

At this point the crew members on the streambanks remained where they were, while the person with rangefinder unit moved downstream to the middle of the next habitat section. The rangefinder operator then shot upstream to each survey rod. The survey rods were then moved downstream to the transition with the next habitat section. In this way the rangefinder operator and survey rods were "leapfrogged" downstream through each mesohabitat section. For mesohabitat sections that were exceptionally long, or extended around bends in the river (where the rangefinder could not "see"), it was necessary to leap-frog within a habitat section. Where mesohabitat sections were very short and the rangefinder had a clear view, it was not necessary to leapfrog through each section—the rangefinder operator could remain in position while the surveyors with rods moved through successive sections.

The original intent of Component 1 was to map the entire mainstem of the Quinsam, from Wokas Lake dam through to the confluence with the Campbell River. However, once work began, it became evident that this goal was unreasonable given the limitations imposed by both the mapping equipment and the river channel. Surveying proceeded at a rate of about 750 to 1200 m per day once the crew was familiar with the equipment. The distance covered was considerably less under difficult circumstances (e.g., poor access, complex stream channel morphology, dense riparian vegetation, etc.). After discussions with BC Hydro, the survey team therefore decided to map in their entirety reaches 10, 9, and 4, then to sub sample the remaining reaches focusing on areas around the flow transects. In total, approximately 20 km of the river was surveyed, or about 45% of the total mainstem exclusive of lakes. Table 2 outlines the sampling effort for each reach and transect.

Survey data were analysed by Alf Leake, BC Hydro, to create habitat summaries for surveyed areas.

Table 2. Summary of Quinsam River reaches and transects surveyed and mapped for Component 1.

Reach	Transects Mapped	Transects Not Mapped	Comments
10	39, 40, 41, 42, 43, 44, 45, 46		Fully mapped
9	47, 60, 61, 63, 64, 65, 66		Fully mapped
8	67, 68, 69		Channel not mapped in detail from below T66 to 100 m above T68. Elevations only.
7	70, 71, 72, 73, 74, 75, 76, 77	78	Failure of impulse unit during helicopter access time for T78
6	79, 80, 81, 82, 83, 83b		Fully mapped
5	84, 85, 86, 87, 88	89	surveyed 100m u/s of T84 to 100 m d/s of T85; surveyed 100m u/s of T86 to 100 m d/s of T87; surveyed 70m u/s and d/s of T88
4	90, 91, 92, 93, 94		Began mapping at the outlet of Lower Quinsam Lake
3	95		surveyed 100m u/s and d/s of transect
2	96, 97, "coho 1a", "coho 1b"	98	surveyed 100m u/s of T96 to 100 m d/s of T97; surveyed 100m u/s of coho 1a to 100 m d/s of coho 1b; high flow, unstable substrate, and kettles prevented safe mapping of
1	100, 101, 102,103,104,105, "Quinsam Campsite #2"	"Argonaut 1"	surveyed 100m u/s of T100 to 100 m d/s of T101; surveyed 100m u/s of T102 to 100 m d/s of T103; high flows prevented safe mapping of Argonaut 1

Results

Data were collected for this study component prior to the onset of fall rainstorms (Figure 10), with the exception of data for Reaches 1 and 3, which were sampled shortly after fall rains began.

Water Samples

Water samples were collected prior to the onset of fall rainstorms (Figure 10; Table 3), with the exception of the SRP and Nitrate resample at the site below Wokas Dam. This resample was taken after several days of heavy rain, which may affect the test value when compared to the other samples. Flows immediately below the Wokas Dam and the Quinsam Diversion Dam can be erratic due to operation of the dams (Figure 10), and as such are not indicative of a natural summer base flow condition. The effect of operations is attenuated with distance downstream (Figure 10; see also Figures in General Introduction), where flows at the time of sampling were close to the annual minimum.

Water chemistry data are presented in Table 4 and can be compared to historic values observed for the Quinsam River (Table 5). Data collected for this study are within the range of previous observations, although the samples taken from the Iron River indicate a somewhat higher conductivity and alkalinity than samples from the Quinsam mainstem.

Predictions of maximum salmonid biomass based on Ptolemy's (1993) equations indicate a range of about 157 to 172 g $\cdot$ 100 m^{-2} for the Quinsam mainstem (Table 6). Suitable habitats in the Iron River, with its slightly higher alkalinity, are predicted to have higher productivity and salmonid biomass than equivalent habitats in the Quinsam River.

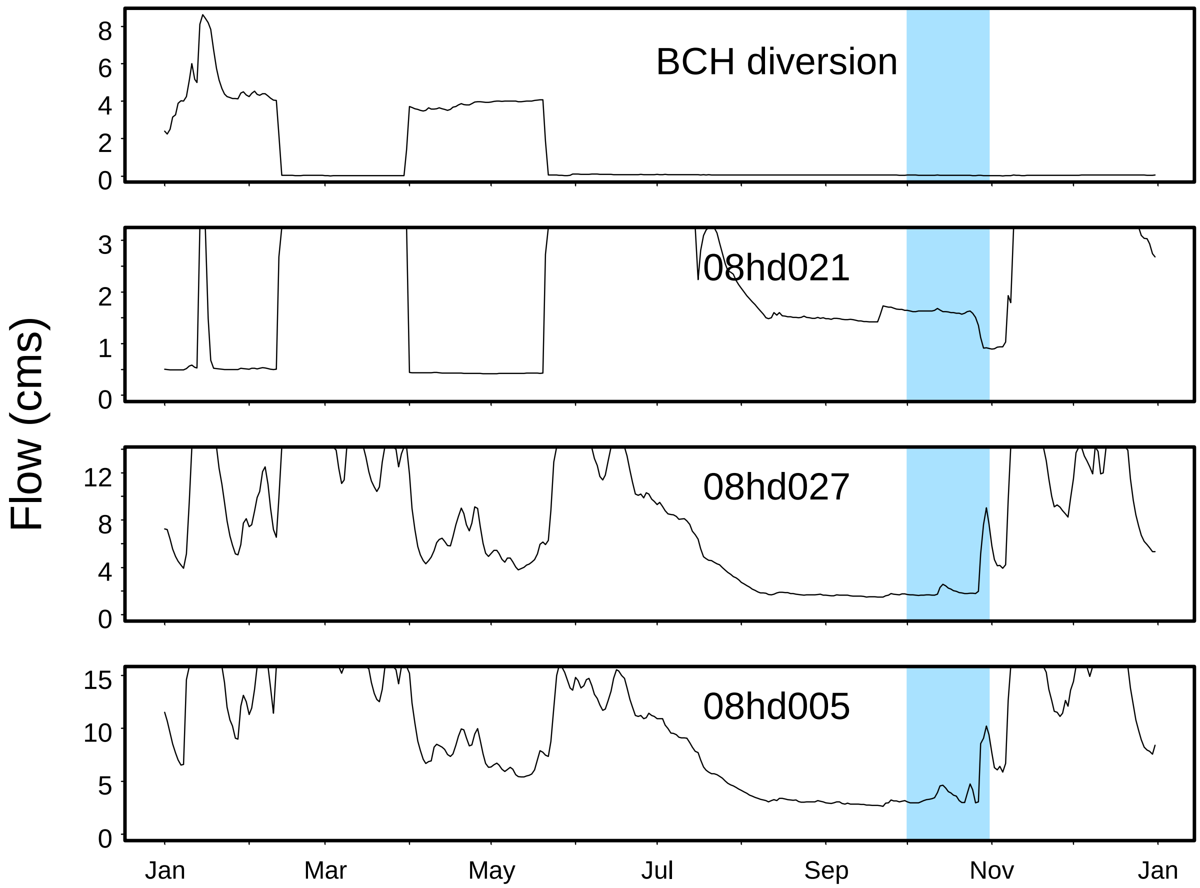


Figure 10. Quinsam River diversions and streamflows in 1999. The blue areas denote the month of October, the period during which field work was conducted for this study component. (Note: flow scale differs among the four graphs.)

Table 3. Gauged flows at time of nutrient sampling in Quinsam River.

Station	Minimum flow in 1999 (m^3 s^{-1})	Flow on Oct 17 1999 (m^3 s^{-1})
08hd005 (confluence with Campbell River)	2.63	2.75
08hd021 (Argonaut Bridge)	0.42	1.42
08hd027 (below Lower Quinsam Lake)	1.48	1.53

Table 4. Results of water chemistry analyses from five locations in the Quinsam watershed.

	Quinsam River 1 (d/s Wokas dam)	Quinsam River 2 (Argonaut Bridge)	Quinsam River 3 (WSC stn 08HD027)	Quinsam River 4 (100m u/s of Iron R)	Iron River 1 (100m u/s of Quinsam R)	Detection Limit
Date	17-Oct-99	17-Oct-99	17-Oct-99	17-Oct-99	17-Oct-99	
pH	7.2	7.25	7.31	7.46	7.33	
Conductivity (uS/cm)	70	35	36	51	70	1
Total Alkalinity CaCO3 (mg/L)	21.7	20	18.8	22.5	31.3	0.5
Nitrate N (mg/L)	0.045 *	< 0.005	0.006	0.005	0.081	0.005
Soluble Reactive Phosphorous (mg/L)	0.001 *	< 0.001	0.005	0.005	< 0.001	0.001

* note: original sample bottle broke in transit. These data are from a second sample taken Nov 2, 1999

Table 5. Historic water quality data for the Quinsam River (taken from Burt 2003).

Parameter	Minimum	Maximum	Median
pH	7.1	8.3	7.6
Alkalinity	12.0	54.3	29.0
Nitrate / Nitrite – N	0.002	0.961	0.140
Total Phosphorus	0.002	0.64	0.02

Table 6. Predictions of maximum salmonid density at five locations in the Quinsam watershed, based on alkalinity measurements during fall 1999. Calculations utilized equations from Ptolemy (1993).

Site	Alkalinity (mg/L)	Maximum Biomass (g/100 m^2)
Quinsam River 1 (d/s Wokas dam)	21.7	169.10
Quinsam River 2 (Argonaut Bridge)	20	162.34
Quinsam River 3 (WSC stn 08HD027)	18.8	157.39
Quinsam River 4 (100m u/s of Iron R)	22.5	172.19
Iron River 1 (100m u/s of Quinsam R)	31.3	203.09

Site Cards

A summary of site card data is presented in Table 9. Complete site cards are included in the Technical Addendum for this report.

Linear Habitat Map

The intent of this part of Component 1 was to map the entire mainstem of the Quinsam River at a single flow. However, due to logistical constraints it was possible to map only approximately 20 km of the river (Table 2, Table 7). Furthermore, difficulties extracting summary data from the database meant that a habitat map could not be produced. Survey data were therefore reviewed by hand and a summary was tabulated (Table 8).

Table 7. Habitats surveyed during habitat mapping.

Reach	Length of Habitat Surveyed (m)	Area of Habitat Surveyed (m^2)
1	1,296.8	25,902.7
2	1,915.2	36,490.6
3	776.4	7,212.0
4	4,381.8	109,332.3
5	4,037.8	81,953.2
6	1,044.9	10,648.1
7	1,261.5	22,904.5
8	521.0	5,063.6
9	1,385.9	12,998.1
10	3,607.1	43,686.4
total	**20,228.5**	**356,191.5**

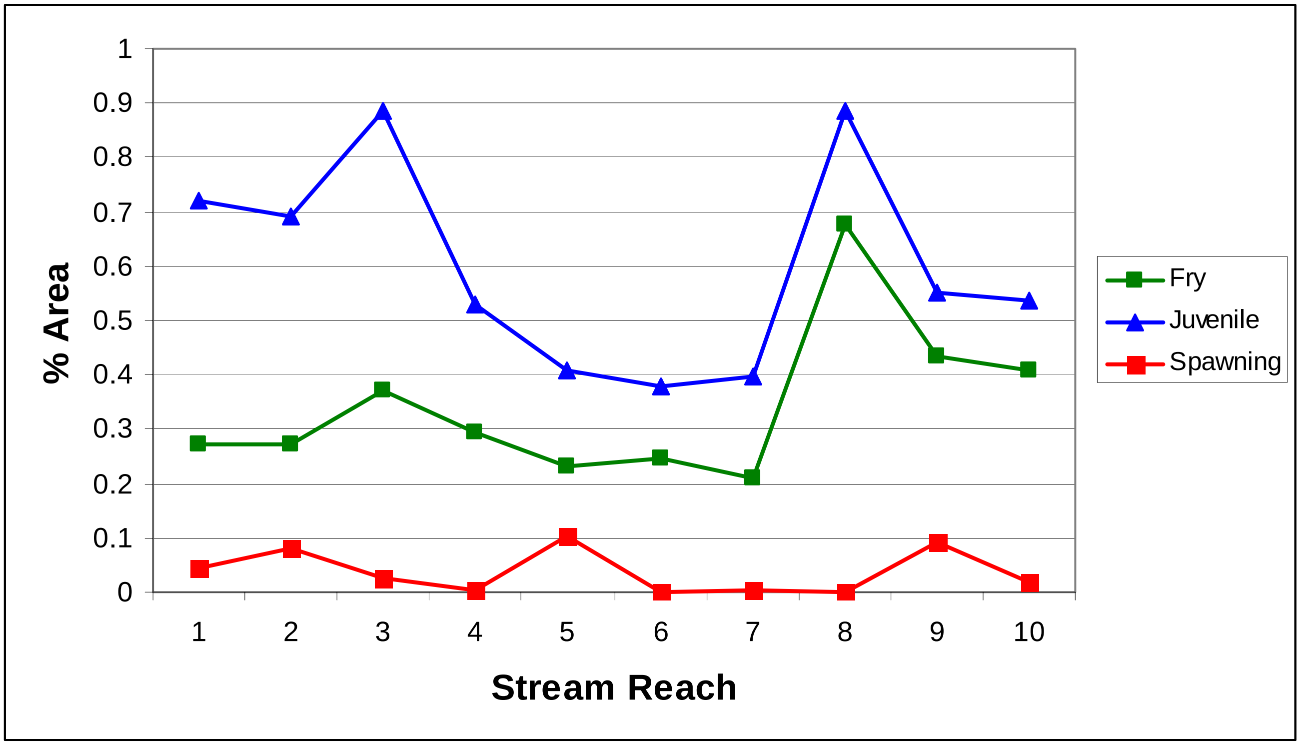


Figure 11. Mean suitability among reaches as observed by field crews during habitat mapping of the Quinsam River. Mean suitability was calculated for each mesohabitat unit, and a weighted mean calculated based on observed abundance of each habitat type in a reach. See Table 8 for data.

Table 8. Summary of habitats surveyed during habitat mapping. Suitabilities were assessed visually in the field and refer to salmonids as a group.

Reach	Habitat Type	Habitat Length (m)	%	Habitat Area (m^2)	%	Mean Suitability Rating (% useable) Fry	Juvenile	Spawning
1	backwater	-	0%	-	0%	0%	0%	0%
1	cascade	-	0%	-	0%	0%	0%	0%
1	pool	36.8	3%	695.1	3%	20%	100%	0%
1	rapid	174.5	13%	3,417.2	13%	20%	50%	5%
1	riffle	372.1	29%	7,377.4	28%	27%	70%	0%
1	run	713.4	55%	14,412.9	56%	29%	77%	7%
	subtotal	**1,296.8**	**100%**	**25,902.7**	**100%**			
2	backwater	-	0%	-	0%	0%	0%	0%
2	cascade	-	0%	-	0%	0%	0%	0%
2	pool	185.6	10%	3,640.4	10%	22%	100%	5%
2	rapid	192.6	10%	3,278.7	9%	23%	53%	0%
2	riffle	1,095.1	57%	22,246.4	61%	29%	61%	11%
2	run	441.9	23%	7,325.1	20%	26%	86%	6%
	subtotal	**1,915.2**	**100%**	**36,490.6**	**100%**			
3	backwater	-	0%	-	0%	0%	0%	0%
3	cascade	-	0%	-	0%	0%	0%	0%
3	pool	132.0	17%	1,619.5	22%	22%	96%	2%
3	rapid	-	0%	-	0%	0%	0%	0%
3	riffle	27.4	4%	454.2	6%	60%	30%	0%
3	run	617.0	79%	5,138.2	71%	40%	91%	3%
	subtotal	**776.4**	**100%**	**7,212.0**	**100%**			
4	backwater	-	0%	-	0%	0%	0%	0%
4	cascade	725.4	17%	28,015.5	26%	10%	17%	0%
4	pool	444.6	10%	11,918.6	11%	31%	91%	0%
4	rapid	273.5	6%	5,037.7	5%	13%	31%	0%
4	riffle	1,204.0	27%	27,852.2	25%	32%	46%	0%
4	run	1,734.3	40%	36,508.3	33%	44%	76%	2%
	subtotal	**4,381.8**	**100%**	**109,332.3**	**100%**			
5	backwater	-	0%	-	0%	0%	0%	0%
5	cascade	-	0%	-	0%	0%	0%	0%
5	pool	105.3	3%	1,402.3	2%	30%	100%	15%
5	rapid	-	0%	-	0%	0%	0%	0%
5	riffle	2,938.1	73%	64,238.4	78%	18%	32%	6%
5	run	994.4	25%	16,312.5	20%	43%	71%	27%
	subtotal	**4,037.8**	**100%**	**81,953.2**	**100%**			
6	backwater	-	0%	-	0%	0%	0%	0%
6	cascade	-	0%	-	0%	0%	0%	0%
6	pool	-	0%	-	0%	0%	0%	0%
6	rapid	577.3	55%	5,205.0	49%	23%	21%	0%
6	riffle	239.7	23%	3,085.3	29%	28%	40%	0%
6	run	227.9	22%	2,357.8	22%	23%	71%	0%
	subtotal	**1,044.9**	**100%**	**10,648.1**	**100%**			
7	backwater	-	0%	-	0%	0%	0%	0%
7	cascade	255.0	20%	7,231.0	32%	7%	10%	0%
7	pool	43.8	3%	1,001.7	4%	35%	85%	0%
7	rapid	237.0	19%	3,290.8	14%	28%	48%	2%
7	riffle	452.5	36%	7,976.0	35%	26%	39%	0%
7	run	273.2	22%	3,405.0	15%	27%	84%	1%
	subtotal	**1,261.5**	**100%**	**22,904.5**	**100%**			
8	backwater	-	0%	-	0%	0%	0%	0%
8	cascade	-	0%	-	0%	0%	0%	0%
8	pool	75.6	15%	785.5	16%	55%	100%	0%
8	rapid	-	0%	-	0%	0%	0%	0%
8	riffle	-	0%	-	0%	0%	0%	0%
8	run	445.4	85%	4,278.1	84%	70%	87%	0%
	subtotal	**521.0**	**100%**	**5,063.6**	**100%**			
9	backwater	-	0%	-	0%	0%	0%	0%
9	cascade	1.9	0%	13.6	0%	0%	0%	0%
9	pool	194.1	14%	1,937.5	15%	60%	83%	11%
9	rapid	138.8	10%	1,238.0	10%	20%	20%	3%
9	riffle	468.1	34%	4,543.2	35%	30%	31%	9%
9	run	583.0	42%	5,265.8	41%	54%	75%	10%
	subtotal	**1,385.9**	**100%**	**12,998.1**	**100%**			
10	backwater	29.9	1%	223.7	1%	80%	50%	0%
10	cascade	169.0	5%	1,558.3	4%	10%	14%	0%
10	pool	222.5	6%	2,426.3	6%	46%	88%	3%
10	rapid	952.8	26%	10,779.0	25%	22%	40%	2%
10	riffle	969.5	27%	12,648.4	29%	47%	46%	4%
10	run	1,263.4	35%	16,050.8	37%	50%	68%	1%
	subtotal	**3,607.1**	**100%**	**43,686.4**	**100%**			

Table 9. Summary of data collected on site cards at 30 locations in the Quinsam River watershed.

Site	Date	Mean Channel Width (m)	Mean Wetted Width (m)	Gradient (%)	Dominant	Subdominant	D95 (cm)	D (cm)	Stream morph	Stream pattern	LWD abundance	LWD distribution	Riparian Vegetation type	stage
Camp 2	28/Oct/99	27.1	21.8	2	cobble	gravel	40	7	riffle-run	straight	few	even	mixed	mature forest
coho 1a	26/Oct/99	18.2	16.5	1	gravel	cobble	15	8	riffle-run	sinuous	few	even	shrubs	shrubs
T039	24/Oct/99	14.2	10.6	2	cobble	boulder	70	8	riffle-pool	sinuous	few	even	deciduous / mixed	pole sapling / young forest
T041	24/Oct/99	16.8	13.8	1.5	cobble	boulder	75		riffle-pool	sinuous	few	clumped	mixed	pole sapling / young forest
T042	24/Oct/99	12.4	10.5	2.5	bedrock	boulder	100	40	riffle-pool	straight	none		mixed	mature forest / young forest
T043/044	24/Oct/99	14.0	12.8	2	cobble	boulder	40	12	riffle-pool	straight	few	clumped	mixed	young forest
T046	24/Oct/99	13.7	10.6	1.8	cobble	boulder	50	35	riffle-run	straight	abundant	clumped	deciduous	pole sapling
T047	13/Oct/99	14.2	10.6	2	cobble	boulder	30	5	riffle-pool	straight	few	clumped	mixed	young forest
T049	23/Oct/99	14.8	10.6	1.3	bedrock	cobble	70	35	riffle-pool	straight	few	clumped	deciduous	young forest
T060	13/Oct/99	13.8	10.1	2	cobble	gravel	20	3	riffle-pool	sinuous	few	clumped	mixed	young forest
T061	13/Oct/99	9.4	7.7	2.5	cobble	boulder	30		riffle-pool	sinuous	few	clumped	mixed	young forest
T063	13/Oct/99	13.1	12.1	2	cobble	gravel	20	5	riffle-pool	sinuous	few	even	mixed	young forest
T064	13/Oct/99	11.7	10.0	2	cobble	boulder	40	5	riffle-pool	sinuous	few	even	mixed	young forest
T066	14/Oct/99	12.4	10.4	2	cobble	boulder	40	5	riffle-pool	sinuous	abundant	clumped	deciduous	young forest
T070	21/Oct/99	13.6	11.5		boulder	cobble	100	40	riffle-pool	sinuous	few	even	mixed	pole sapling
T071	21/Oct/99	15.3	14.3		boulder	cobble	80	30	riffle-pool	sinuous	abundant	clumped	mixed	pole sapling
T072	21/Oct/99	14.1	12.4		bedrock	boulder	100	30	riffle-pool	sinuous	few	even	mixed	young forest
T073/074	22/Oct/99	25.0	23.3	3	boulder	cobble	80	30	riffle-pool	sinuous	few	even	mixed	young forest
T075/076	23/Oct/99	17.9	12.2	2.5	cobble	boulder	60	20	riffle-pool	sinuous	few	clumped	mixed	young forest
T077	24/Oct/99	14.3	7.5	3	cobble	bedrock	70	20	riffle-pool	sinuous	abundant	clumped	mixed	mature forest / young forest
T078	30/Oct/99	16.5	9.3	1	cobble	gravel	20	5	riffle-pool	irregular	abundant	even	deciduous / mixed	young forest
T079-085b	30/Oct/99	16.2	10.9	1.5	gravel	fines	10	5	riffle-pool	irregular	abundant	even	deciduous / mixed	mature forest / pole sapling
T084/085	25/Oct/99	23.2	16.5	1.5	cobble	gravel	20	5	riffle-pool	sinuous	abundant	even	mixed	young forest
T086/087	25/Oct/99	23.3	15.3	1	cobble	gravel	10	4	riffle-pool	sinuous	abundant	even	deciduous / mixed	mature forest / young forest
T096/097	18/Oct/99	20.0	18.4	0.5	gravel	fines	7	7	run-pool	straight	abundant	even	deciduous	pole sapling
T100/101	26/Oct/99	24.4	21.6	2	boulder	cobble	100	10	riffle-pool	sinuous	abundant	even	mixed	mature forest / young forest
T1000	14/Oct/99	13.5	11.0	1	gravel	cobble	30	8	riffle-run	sinuous	abundant	even	shrubs	shrubs
T1001	15/Oct/99	25.6	24.9	1	boulder	cobble	60	20	run-pool	straight	none		mixed	mature forest
T102	25/Oct/99	25.2	23.1	3	cobble	boulder	55	15	riffle-pool	sinuous	abundant	even	mixed	mature forest
T104	27/Oct/99	22.0	20.3	1.5	cobble	boulder	60	10	riffle-pool	sinuous	few	even	deciduous	mature forest

Discussion

Water Samples

The water samples analyzed for this study confirm that the Quinsam River mainstem is oligotrophic and typical of most streams on the east coast of Vancouver Island. All data collected here are consistent with earlier observations for the Quinsam River (see data and discussion in Burt 2003). The observed values are well within the Water Quality Criteria set by MWLAP (Resources Inventory Committee 1998).

The alkalinity measures taken here can be used as inputs to Ptolemy's (1993) equations for predicting maximum salmonid density (Table 6). Predictions for the Quinsam mainstem range from about 157 to 172 g $\cdot$ 100 m^{-2}. Predictions are slightly higher for the Iron River, with its higher alkalinity. The biomass predictions are discussed in greater detail in report section for Component 3, the stock assessment.

Site Cards

Data collected on Site Cards provide a representative sample of 30 locations throughout the watershed. These samples are not random in their distribution, describing instead conditions around the flow transects selected for Component 2. The transect locations were selected based on a combination of accessibility and habitat criteria. The large number of surveyed locations throughout the watershed nevertheless ensured that the Site Cards represent a broad array of habitat types and locations in the Quinsam mainstem.

Linear Habitat Map

The linear habitat data provide a more detailed assessment of channel conditions than those data collected for the Site Cards. Less than 800 m of reaches 3 and 8 were sampled, which limits the utility of data for those stream sections. However, all other reaches were sampled more intensively and it seems reasonable to assume that the data represent general conditions throughout those reaches, at least at the observed, relatively low flow.

The dominant mesohabitat type varied among the reaches surveyed. Dominant mesohabitat types were rapid, riffle, or run. The ratios among different mesohabitats and the degree of dominance also varied among the reaches surveyed. For example, almost ¾ of reach 5 was riffle at the observed flow, whereas riffles made up closer to ¼ of the length for most other reaches. In general, pools were relatively rare in all surveyed sections of the watershed.

The suitability ratings assigned in the field imply that spawning habitat is relatively rare and patchy throughout the surveyed sections of the Quinsam River. In contrast, both fry and juvenile habitat are relatively abundant. Since this study was completed at only a single flow it is difficult to extrapolate from these results to higher flows.

It is difficult to draw conclusions from these data or to provide detailed recommendations with respect to water management and BC Hydro operations. Since the data were collected at only one flow we should not assume that ratios among habitat types remain constant at all flows. For example, other studies have found that mesohabitat abundance is affected by changes to flow because habitat boundaries and habitat types shift with changes in flow; at low flows a particular site may be a pool, while at higher flows it may be a riffle (Herger et al. 1996; Hilderbrand et al. 1999; Parasiewicz 2001). On the other hand, the relatively high proportion of riffle habitats throughout the watershed implies that the availability of suitable habitat for fish and other aquatic organisms may be sensitive to fluctuations in water stage. Unfortunately, until a study such as this is repeated at other flows we will not know the functional relationship between flow and mesohabitat availability. It would be useful to compare the results of such a study with the results of the flow transect analysis completed for Component 2.

COMPONENT 2. FLOW TRANSECTS FOR QUINSAM RIVER

Introduction

As part of the Campbell River Water Use Plan, BC Hydro commissioned a detailed biophysical assessment of the Quinsam River mainstem and its major lakes. The main tasks for the assessment were divided into five components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.
Component 5. Report preparation and summary.

This section of the report presents findings from Component 2, transect development and fisheries flow assessment for the Quinsam River. Field work was conducted from September 1999 through September 2000 by D. Burt and Associates (DBA). The report was written by Solander Ecological Research, with considerable input from D. Burt and Associates. DBA also conducted much of the analysis.

A brief review of the natural resources of the Quinsam watershed is presented in the General Introduction to this report. A more extensive review is presented in Burt (2003).

Methods

The principal objective of Component 2 was to "identify and quantify fish habitat for different flow scenarios with respect to different salmonid species and life stages, which will provide incremental fish benefits and provide recommendations for seasonal operations." This objective was to be met by a series of steps as outlined in the Terms of Reference for this project (BC Hydro 1999). Briefly, these steps were to:

1. establish transect locations on the Quinsam River mainstem,
2. collect flow and habitat data at three target flows, and
3. analyse and summarise results using methods described in Burt and Burns (1995).

Data

Transects and target flows.— The field program established 57 transects on the Quinsam River between Wokas Dam and the mouth (Figure 12). One additional transect was placed on the Iron River for the purposes of calculating discharge downstream of the Iron River confluence. The initial study design called for the collection of transect data at three different flows, roughly 15%, 30%, and 80–100% of natural MAD. Actual target flows were closer to 20%, 40% and 80% MAD due to difficulties in precise prediction of flows. Data were collected for 56 transects at high flow (one site was deemed too dangerous), at all 57 transects for the medium flow, and at

46 transects for the low flow. Funding constraints restricted the number of sites that could be assessed at low flow.

Transect sites were selected using subjective criteria based on access, available habitat types and operator experience. Access was a significant logistic constraint and had a large influence on the number of sites that could be measured per day. Many areas of the river were not easily accessible by road. Within the constraints of access, the field crew attempted to distribute transects evenly throughout the watershed, in all reaches, and to adhere to the TOR with respect number of transects placed in each reach. The TOR also directed the types of habitat to be targeted within each portion of the river. Placement of transects within habitat types was based on operator experience and an understanding of the study requirements as described in the TOR.

There were insufficient transects to group and analyze data by reach, so the river was divided into four "sections" (Table 10; see also Figure 12). In some cases sections were combined for analysis to improve sample size for calculations.

Table 10. For the purposed of analysing Quinsam River transect data the river was divided into four sections (see also Figure 12).

Section	Description	Number of Transects
1	Mouth to bottom of Lower Quinsam Lake	19
2	Top of Lower Quinsam Lake to Middle Quinsam Lake	21
3	Top of Middle Quinsam Lake to the diversion dam	8
4	Top of the diversion head pond to Wokas Dam	8

The basic procedure for data collection in the field involved,

1. installation of transect pins and survey benchmarks at each transect site,
2. measurement of depth and velocity data across the transects,
3. collection of bank profile and water surface elevation data using survey techniques, and
4. collection of general site data.

Water depth and velocity, water surface elevations, and streambank profiles were collected at each of the three flows; general habitat data (see below) were collected only on the first visit to each transect. Field activities were conducted on the following dates:

- 27-29 September 1999
- 5-6, 12-22, 27 October 1999
- 4-8, 10-13, 17, 20-21, 24, 27 January 2000
- 10, 14-15 March 2000
- 2-3 September 2000.

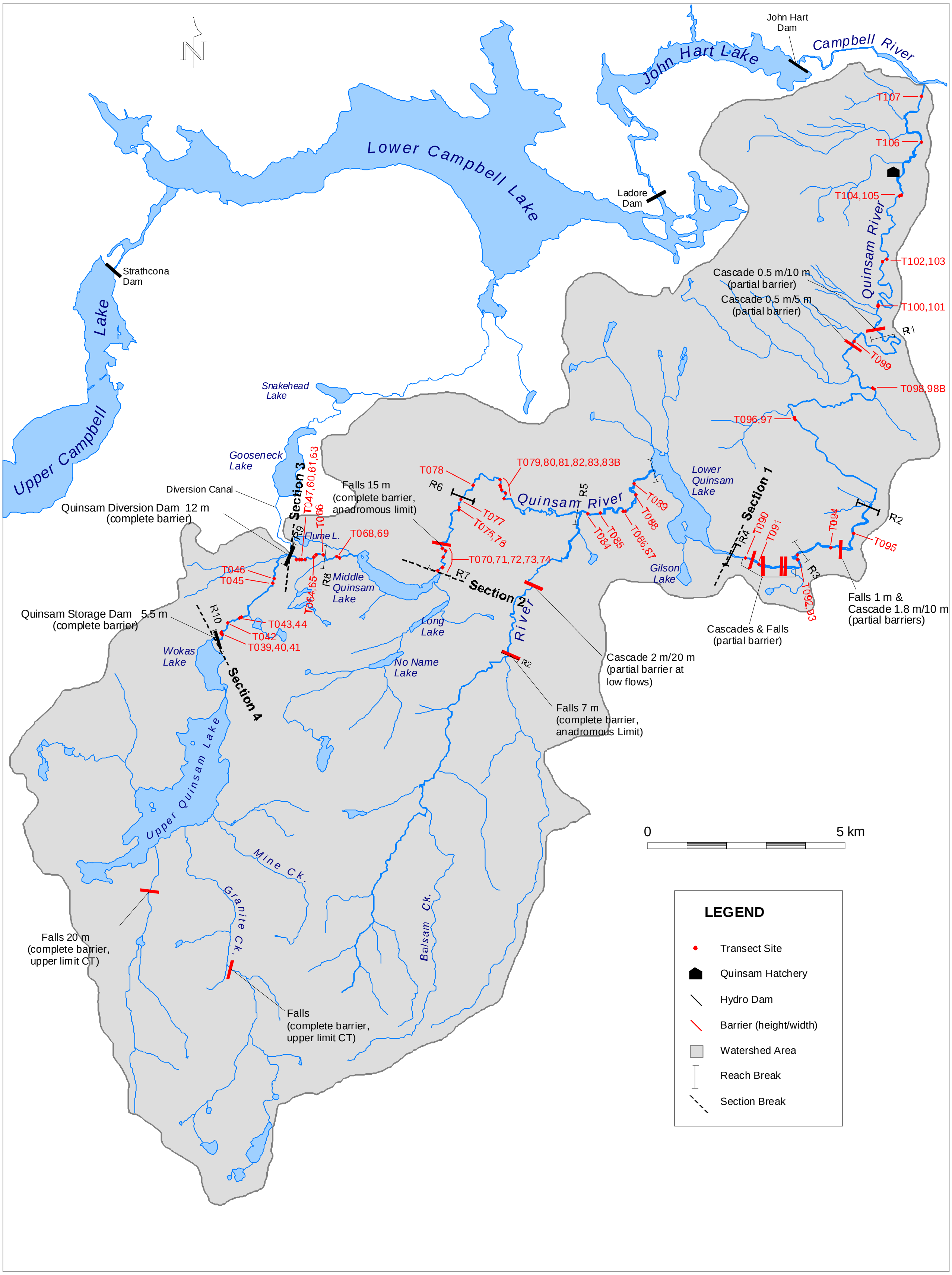


Figure 12. Map of the Quinsam River Watershed showing locations of transect sites measured during 1999 and 2000.

Crew.— Field work was conducted by DBA, using Dave Burt, Kent Handy, and Tom Van Enter as crew members. Data summaries and initial analyses were conducted by Dave Burt.

Transect Markers.— Transects were positioned to capture representative habitat within the selected habitat unit. The transect positions were delineated by installing head stakes on either side of the river, perpendicular to the flow. In addition, a permanent benchmark hub was installed offset to the transect line. Transect head stakes consisted of either 8 inch galvanized spikes driven into the base of trees, or 60 cm lengths of rebar driven into the ground. All transect benchmarks were positioned with rebar. Transect sites were flagged with tape and identified using a unique-numbered hub tag tacked to a tree. Brush around the head stakes and benchmark were cleared to facilitate surveying.

General Data.— General data recorded for each transect location included date, crew, UTM coordinates (from GPS), location reference (e.g., distance from a bridge or road), habitat type (pool, run, riffle, cascade, or falls) at the transect, habitat type upstream and downstream of the transect, D90, Dmax, and roughness height. In addition, a photo was taken capturing the view looking upstream at each site for each flow.

Detailed Data.— Measuring depth and velocity involved extending a tape measure between transect head stakes, with the 0 point anchored to the left stake (facing downstream). Data were collected at points along the tape by wading. Parameters recorded at each position (vertical) along the transect included tape distance, water depth, water velocity, and substrate (dominant and subdominant categories). Verticals were spaced at intervals equal to roughly 1/20th the wetted width, however, the spacing was sometimes decreased to capture local transitions in depth or velocity. Depth and velocity were measured using a Swoffer model 2100 flow meter mounted on a 1.5 m top-setting rod. Velocity readings were taken at 20% and 80% of the depth from the surface when depths were > 1 m, and at 60% when < 1 m. Dominant and subdominant substrates were classified according to the modified Wentworth scale (Anonymous 1995).

At each transect a builders level and rod were used to survey the following features:

- elevation of the transect head stakes,
- water surface elevations at each cross-section (left and right river's edge),
- water surface elevations 25 m upstream of transects (left and right side at the river's edge), and
- profile of each bank, from water's edge to the high water mark (this task continued the instream profile along the transect lines).

All survey data were referenced to each transect's benchmark. Benchmark elevations were arbitrarily set at 100 m since geodetic elevations of benchmarks were not available.

Analysis

Selecting transects for analysis.— Transects were classified in terms of their appropriateness for spawning, steelhead parr rearing, and insect production. The classification process was subjective, but was aided by the use of site photos, substrate data (size categories, D90, and roughness), and habitat type (pool, glide, or riffle). The analysis was run on the subset of transects deemed appropriate for spawning, steelhead and rainbow rearing, and insect production.

Calculations for spawning and rearing.— Analysis of transect data requires coupling observed depth and velocity in each transect cell to habitat suitability index (HSI) values, or "curves." HSI curves describe depth and velocity preferences for a given species and life stage. Specific HSI curves were approved for use in WUP studies for spawning (chinook, coho, steelhead and pink) and rearing (chinook fry, coho fry, steelhead/rainbow fry and parr, and cutthroat fry and parr). The WUP HSI curves used in this analysis were dated February 2000.

The analysis involved a series of calculations:

1. calculating the width of each transect cell,
2. multiplying each cell's observed depth and velocity by the corresponding HSI values,
3. weighting each cell's width by multiplying it by the output of step 2,
4. calculating weighted usable width (WUW) for each transect as the sum of the weighted cell widths, and
5. calculating percent usable width (PUW) for each transect by dividing the WUW by the observed wetted width.

These calculations were repeated for each species and life stage for which there was an HSI curve, for all transects, at each of the three flows (i.e., 10 curves × 57 transects × 3 flows). Mean WUW and PUW per species and age group were calculated for each river section, along with 95% confidence limits. Data compilation and calculation was completed using relational database software (Paradox) and associated script files. Algorithms for the script files were based on formulae in the Excel spreadsheet designed by Ptolemy et al. (1993).

Results of the transect analyses were referenced to discharge using the nearest Water Survey Canada (WSC) gauging station (see General Introduction for the location of gauging stations) where appropriate. Flows were pro-rated using watershed area for two groups of transects, which were found to have a poor fit between the metered flows and gauged flows. Flows at all other transects were assumed to be equal to WSC gauged flows and were not corrected for potential differences in inflows. The gauging station used to reference a given transect was based subjectively on proximity to the station and the apparent extent of tributary inflow as determined from TRIM maps. When it was unclear which gauging station to use, metered transect discharge was compared with gauging station discharge to decide which station was most appropriate. This process resulted in the referencing of sites as shown in Table 11. All references to natural MAD utilize data from Burt (1999).

Table 11. Scheme used to reference transect sites to Water Survey Canada gauging stations.

Reach	Transects	Natural MAD ($m^3 s^{-1}$)	Reference
1	T106 & T107	10.41	08HD005
1 & 2	T099 -T105		08HD005 minus Cold Creek and Hatchery inputs (0.85 cms) [a]
2 – 5	T084 - T098B	8.39	08HD027
5 – 7	T070 - T083B	4.78	Calculated using metered flows from transects in this section, divided by prorated MAD based on watershed area just above the Iron River [b]
6 – 9	T047 - T069	3.085	08HD021
10	T039 - T046	3.085	08HD021 + 08HD026

[a] The hatchery draws from a groundwater source at the head of Cold Creek and outflows augment the Quinsam beyond what would normally occur. During low summer flows this can effectively double Quinsam flows. The groundwater is also "spilled" into Cold Creek in late summer to maintain a minimum flow there. The combined outflow is about 0.85 $m^3 s^{-1}$.
[b] Based on metered flows at transects, neither HD027 or HD027 appeared to represent this area well, thus transect data were used to estimate flows for this region.

Maxima functions were fit to each set of habitat vs. flow data. These functions use the form:

$$y = aQ^c e^{bQ^d}$$

where,

y = amount of habitat,
Q = amount of flow,
a = parameter influencing the height of the maxima function,
b = parameter influencing the slope of the ascending and descending limbs of the function,
c = parameter for the lag response of habitat to flow (e.g., whether the curve rises immediately from the origin),
d = parameter influencing the magnitude of the post-peak habitat response to flow (e.g., whether the descending limb of the curve asymptotes at 0 or a higher value).

Curves were fitted to the data by minimizing the sum of squared differences between observed PUW and modeled PUW. The minimum sum of squares was obtained by optimizing for the four parameters (a, b, c and d), using the Microsoft Excel Solver application.

Calculations for insect production.— The analysis of transect data for the purpose of examining insect production habitat was considerably simpler than that for salmonid rearing and spawning. Rather than utilizing HSI curves, the analysis simply calculated wetted width over the three flows for the subset of appropriate transects. This analysis was completed separately for river sections 1 and 2, and for sections 3 and 4 combined. An analysis of covariance was conducted on arcsine-square root transformed data to assess for differences among sections in the relationship between % wetted width and % mad.

Additional Reference Points.— To allow a direct comparison of Quinsam observations with regional data and other flow standards, reference points were created using three sources:

1. MWLAP Region 1 fish-flow guidelines (Ptolemy personal communication),
2. meta-analysis of PHABSIM data (Hatfield and Bruce 2000), and
3. Tennant's Method (Tennant 1976).

Results

Conditions during the study period.— Streamflows in the Quinsam River during the period of study are plotted in Figure 13. Streamflows are affected by BC Hydro diversions below Wokas Reservoir and the effects are apparent throughout the watershed, though more so in the upper watershed than at lower elevation. The effect of regulation is particularly apparent immediately below the point of diversion, as can be seen in the pattern at WSC gauge 08hd021. However, when diversions are high the effect can be seen readily at lower sites also, as shown during May 1999. In general, the effect of diversion is attenuated with distance downstream from the diversion, by natural inflows and by the dampening effect of Middle and Lower Quinsam Lakes. A good example of this attenuation can be seen in September 2000 where a sharp peak at 08hd021 is considerably flatter at 08hd027 and 08hd005.

Transect data collection targeted "low," "medium," and "high" flows. Flows in September and October 1999 were considered "medium" flows, early January 2000 flows were considered "high," and "low" flows were sampled opportunistically at other times depending on where the transects were in the watershed.

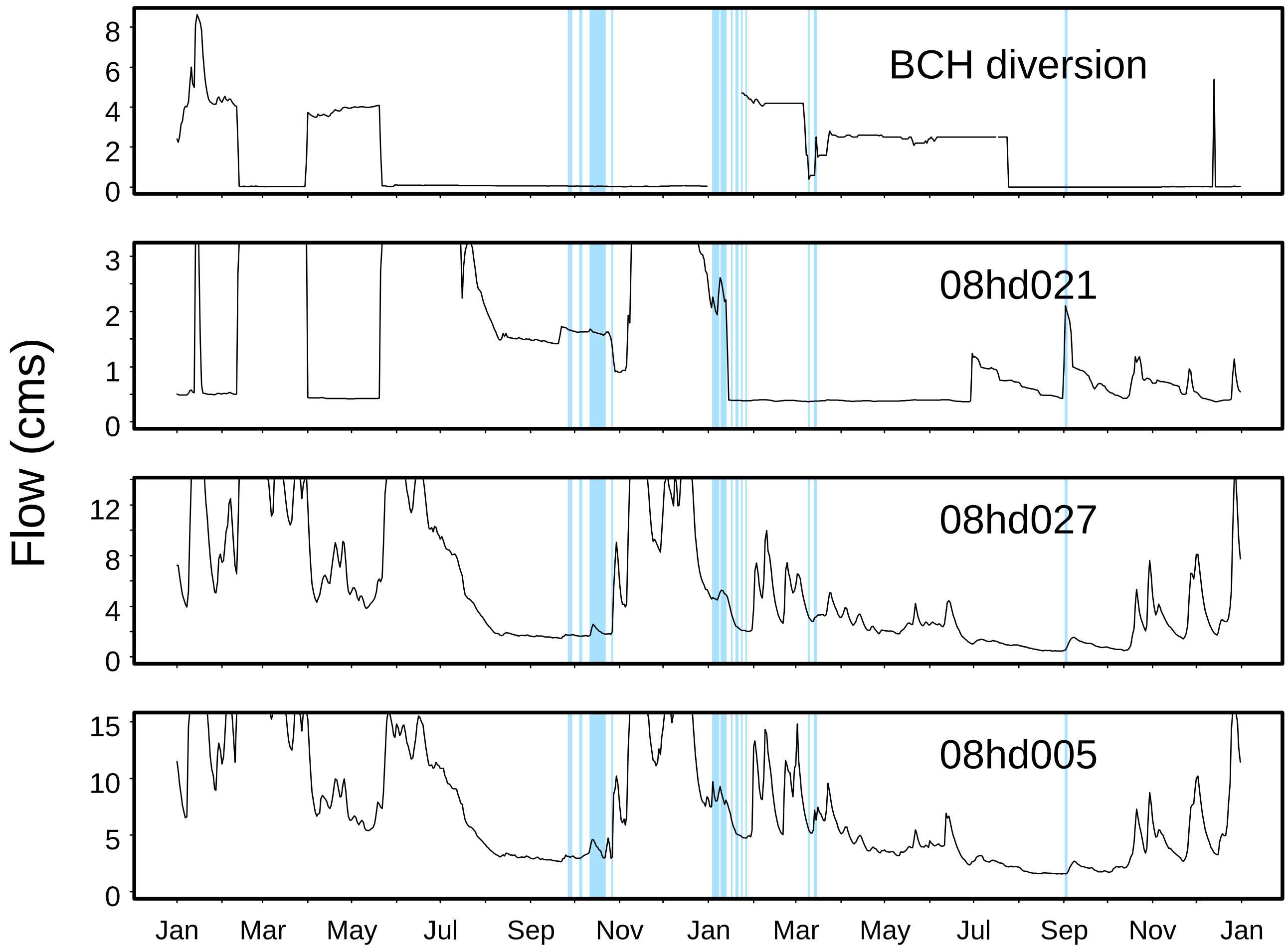


Figure 13. Quinsam River flows in 1999 and 2000. The blue areas denote periods during which field work was conducted for this study component. (Note: flow scale differs among the four graphs.)

Habitat characteristics at transects.— Transect sites were selected to represent a variety of habitat types over the length of the Quinsam River (Table 12). In keeping with the TOR, habitats were surveyed in roughly the proportion with which they occur in section 4 of the river, whereas riffle habitats were emphasized in all other sections.

Table 12. Summary of habitat characteristics of transects, and their appropriateness for examining the three main issues of spawning, rearing, and invertebrate production.

Site	Section	Reach	Hab. Type	D90	Dmax	Roughness	Spawning	Rearing	Insect Prod.	Comments
T107	1	QR01	Rf	60	80	20	●	●	●	Spawning gravel present but rather large
T106	1	QR01	Rn	130	300	40		●		No spawning gravel
T105	1	QR01	Rf	50	70	40	●	●	●	Spawning gravel in pockets only
T104	1	QR01	Rn	60	70	40	●	●		Spawning gravel in pockets only
T103	1	QR01	Rf	60	110	65		●	●	No spawning gravel
T102	1	QR01	Rn	80	180	55	●	●	●	Spawning gravel in pockets only
T101	1	QR01	Rn	70	100	50				Low gradient run
T100	1	QR01	Rf	60	100	50		●	●	No spawning gravel
T099	1	QR02	Rf	100	180	80		●	●	No spawning gravel
T098B	1	QR02	Rf	4	25	1	●			Small gravel riffle
T098	1	QR02	Rn	28	120	50				Despite D90, dominant substrates are gravels & fines
T097	1	QR02	Rn	7	20	1				Dominant substrates are gravels and fines
T096	1	QR02	Rf	5	7	1	●			Low gradient riffle; abundant spawning gravel
T095	1	QR03	Rf	70	100	50		●	●	No spawning gravel
T094	1	QR03	G	25	40	18	●			Top of low gradient riffle; abundant spawning gravel
T093	1	QR04	Rf	90	170	80		●	●	Boulder riffle
T092	1	QR04	Rf	80	110	45	●	●	●	Spawning gravel in pockets only
T091	1	QR04	Rf	80	130	50		●	●	No spawning gravel
T090	1	QR04	G	80	110	50				No spawning gravel, low gradient (slough-like)
T089	2	QR05	Rf	27	42	11	●		●	Low gradient riffle; abundant spawning gravel
T088	2	QR05	Rn	25	33	7				
T087	2	QR05	P	60	90	20				
T086	2	QR05	Rf	30	50	15	●		●	Low gradient riffle; abundant spawning gravel
T085	2	QR05	Rf	35	40	10	●		●	Low gradient riffle; abundant spawning gravel
T084	2	QR05	G	25	30	5	●			Abundant gravel but questionable use; good Q site
T083B	2	QR06	G	4	6	1				Low gradient run
T083	2	QR06	G	10	11	2	●			Possible spawning use; abundant gravel
T082	2	QR06	G	8	10	3				Low gradient run
T081	2	QR06	P	5	8	3				
T080	2	QR06	Rn	12	17	5				
T079	2	QR06	Rf	11	12	4	●			Low gradient riffle; abundant spawning gravel
T078	2	QR06	Rn	20	30	10				
T077	2	QR07	Rf	80	150	20		●	●	
T076	2	QR07	Rn	50	70	40	●	●		Spawning gravel in pockets only
T075	2	QR07	Rf	130	170	50		●	●	
T074	2	QR07	Rn					●		
T073	2	QR07	P	50	100	30				
T072	2	QR07	Rf			15		●		Bedrock shelf
T071	2	QR07	Rn	60	110	30		●	●	No spawning gravel
T070	2	QR07	Rn	80	120	30		●		
T069	3	QR08	G	12	15	10	●			Possible TR spawning use
T068	3	QR08	P	18	25	14				
T067	3	QR08	Rn	2	3	0.1				
T066	3	QR09	Rn	30	50	20				
T065	3	QR09	Rf	40	55	15	●	●	●	Possible TR spawning use
T064	3	QR09	P	40	70	26				
T063	3	QR09	Rn	50	60	20	●	●	●	Possible TR spawning use
T061	3	QR09	Rf	45	60	23	●	●	●	Possible TR spawning use
T060	3	QR09	P	30	55	25				
T047	3	QR09	Rf	40	100	25	●	●	●	Pockets with TR spawning potential
T046	4	QR10	Rf	65	100	45	●	●	●	Pockets with TR spawning potential
T045	4	QR10	Rn	50	130	90		●		
T044	4	QR10	Rf	40	80	40		●	●	
T043	4	QR10	Rn	40	55	35	●			Pockets with TR spawning potential
T042	4	QR10	Rf	45	75	57		●	●	No spawning gravel
T041	4	QR10	P	60	100	55				
T040	4	QR10	Rn	50	35	45				
T039	4	QR10	Rf	40	90	29	●	●	●	Pockets with TR spawning potential

Rearing.— The analysis of flows with respect to fry and juvenile rearing was conducted on the subset of transects deemed appropriate for examination of steelhead rearing (Table 12). The analysis was done separately for fry and parr life stages of steelhead and rainbow. This species has both an anadromous (steelhead) and resident (rainbow) form. For the purposes of our analyses the HSI curves are assumed to be identical for steelhead and rainbow at early life stages. The analysis was completed separately for sections 1 and 2 (for steelhead), and for sections 3 and 4 (for rainbow).

A summary of the number of transects used in the analysis is shown in Table 13, and a summary of the analysis of rearing habitat vs. flow is presented in Figure 14. Results from fitting maxima functions to these data are summarized in Table 17. A traditional dome-shaped curve was observed for steelhead parr only. Both curves for fry are decreasing over the observed flows, and the curve for rainbow parr is increasing over the observed flows. A linear ascending limb was added to these curves by simply connecting to the origin, however, the real shape of the function over these flows is unknown.

Maximum PUW was calculated based on the fitted maxima functions, and the linear extrapolation to the origin. The function for rainbow parr indicated no single flow over the range of observed flows at which spawning habitat is maximized. In this case an arbitrary value of 80% mad was used, since this value is close to the maximum flow at which field observations were made. Table 15 indicates the maximum PUW, the flow at which maximum PUW is observed, and a range of flows over which PUW is within 95% of the maximum PUW. A value of 95% was chosen arbitrarily to define values "close to" the maximum PUW.

Table 13. Sample sizes for transect sites selected for rearing analysis.

Species	Section	Reach	Flow	N
Steelhead	1 + 2	1 to 7	L	16
			M	19
			H	18
Rainbow	3 + 4	9, 10	L	9
			M	9
			H	9

Figure 14. Summary graphs of available rearing habitat versus flow for steelhead and rainbow in the appropriate reaches of the Quinsam River. Maxima functions have been fit to each data set (see text).

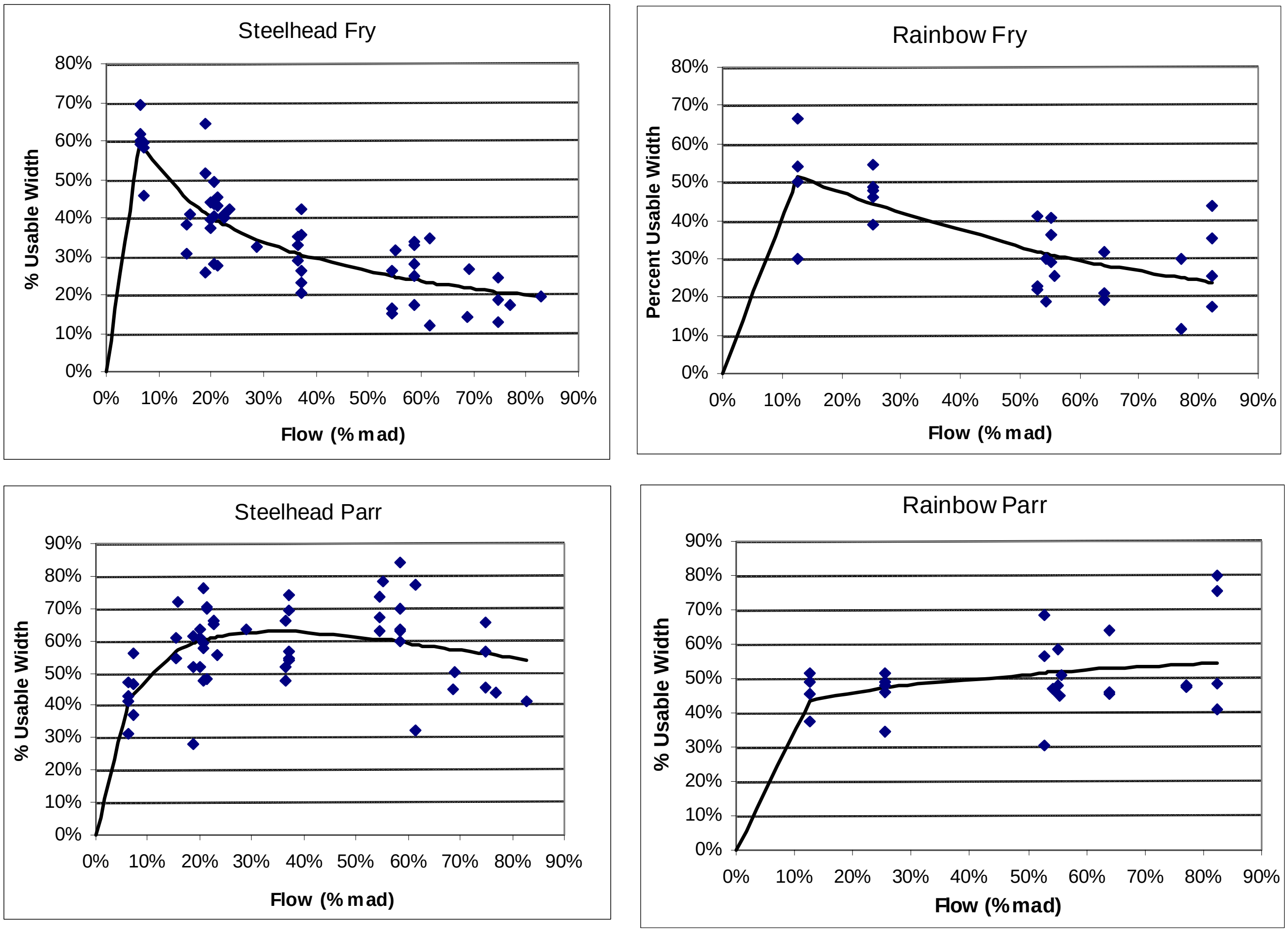


Table 14. Parameter values for maxima functions fitted to rearing habitat vs. flow data.

Parameter	ST fry	ST parr	RB fry	RB parr
a	100.036	100.045	100.037	100.047
b	-6.369	-5.296	-6.204	-5.190
c	0.385	1.162	0.844	0.120
d	0.164	0.303	0.273	0.000
SSQ	0.309	0.623	0.240	0.284
R^2	0.741	0.459	0.598	0.497

Table 15. Summary of usable widths for transects selected for rearing analysis in anadromous reaches (steelhead, sections 1 and 2), and resident reaches (rainbow, sections 3 and 4).

	ST fry	ST parr	RB fry	RB parr
Max PUW	54.0%	62.8%	52.5%	54.3%
Q @ Max PUW (% mad)	9.0%	34.3%	10.0%	80.0%
Range (% mad)	8.55% - 10.53%	19.71% - 58.04%	9.8% - 15.5%	52.3% - na

Spawning.— The analysis of flows with respect to spawning life stages was conducted on the subset of transects deemed appropriate for examination of spawning (Table 12). The analysis was done separately for four salmonid species: chinook, pink, coho, and steelhead. Since these species are anadromous and naturally restricted to sections 1 and 2, the analysis was completed for these river sections only. A summary of the number of transects used in the spawning analysis is shown in Table 16, and a summary of the spawning habitat vs. flow relations is presented in Figure 15. Results from fitting maxima functions to the observed spawning habitat vs. flow is presented in Table 17. Chinook, coho, and steelhead spawning habitat availability increases continuously over the range of flows examined. The fitted maxima function indicates that pink salmon spawning habitat is maximized at 25.6% mad.

Although a single maximum value can be calculated from a dome-shaped function, there is in fact a range of flows that can provide close to the maximum habitat (PUW). Table 18 indicates the maximum PUW, the flow at which maximum PUW is observed, and a range of flows over which PUW is within 95% of the maximum PUW. A value of 95% was chosen arbitrarily to define values "close to" the maximum PUW. Maximum PUW was calculated based on the fitted maxima functions. Where the functions indicated no single flow at which spawning habitat is maximized, an arbitrary value of 80% mad was used, since this value is close to the maximum flow at which field observations were made.

Table 16. Sample sizes for transect sites selected for spawning analysis (anadromous reaches only).

Species	Section	Reach	Flow	N
Chinook	1	1 to 4	L	6
			M	8
			H	7
Pink	1	1, 2	L	5
			M	6
			H	5
Coho	1, 2	1 to 7	L	8
			M	13
			H	12
Steelhead	1	1 to 7	L	8
			M	13
			H	12

Figure 15. Summary graphs of available spawning habitat versus flow for chinook, pink, coho and steelhead in the appropriate reaches of the anadromous sections of the Quinsam River. Maxima functions have been fit to each data set (see text). Locations above the Iron River confluence are indicated in red.

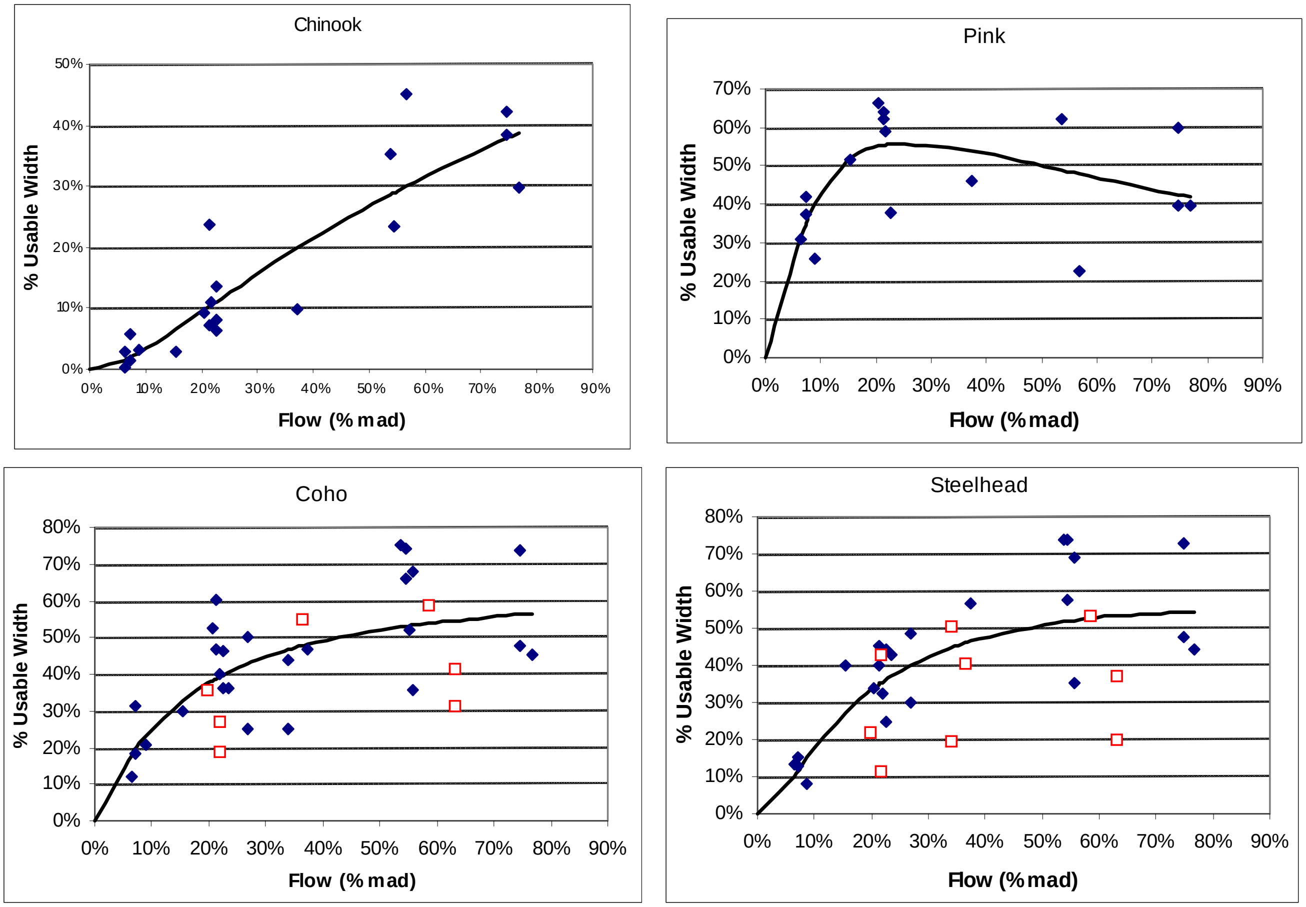


Table 17. Parameter values for maxima functions fitted to spawning habitat vs. flow data.

Parameter	Chinook	Pink	Coho	Steelhead
a	100.026	100.019	100.027	100.026
b	-5.357	-5.625	-5.148	-5.217
c	-0.593	-2.045	-0.941	-1.446
d	-0.243	-0.256	-0.200	-0.268
SSQ	0.078	0.203	0.535	0.597
R^2	0.823	0.603	0.518	0.541

Table 18. Maximum percent usable width (PUW) and the corresponding flows, as determined by fitted maxima functions. Where the functions indicated no single flow at which spawning habitat is maximized, an arbitrary value of 80% mad was used, since this value is close to the maximum flow at which field observations were made. Also indicated is the range of flows over which PUW is within 5% of the maximum PUW. (Note: where functions are continuously increasing there is no upper flow value.)

	Chinook	Pink	Coho	Steelhead
Max PUW	40.0%	55.8%	56.7%	54.3%
Q @ Max PUW (% mad)	80.0%	25.6%	80.0%	80.0%
Range (% mad)	75.1% - na	16.5% - 40%	59.3% - na	53.5% - na

Invertebrate production.— The analysis of flows with respect to invertebrate production habitat was conducted on the subset of transects deemed appropriate for examination of this topic (Table 12). The analysis was completed separately for sections 1 and 2 (anadromous reaches), and for sections 3 and 4 (resident reaches).

A summary of the number of transects used in the analysis is shown in Table 19. The relationship of wetted widths vs. flow in each river section is shown in Figure 16. In both the anadromous and resident sections of the river there is a tendency for insect rearing habitat to increase over the flows examined, although this tendency is fairly weak at the higher flows. Equations describing these relationships are summarized in Table 20. The shape of the relationships appear to be fairly consistent among the different river sections (Figure 16), however, analysis of covariance on arcsine-square root transformed data indicated a significant difference ($p < 0.001$) among sections in slope and intercept of the three relationships of % wetted width vs. % mad.

Table 19. Sample sizes for transect sites selected for invertebrate analysis.

Section	Reach	Flow	N
1	1 to 4	L	7
		M	10
		H	9
2	5, 7	L	3
		M	6
		H	6
3	9	L	4
		M	4
		H	4
4	10	L	4
		M	4
		H	4

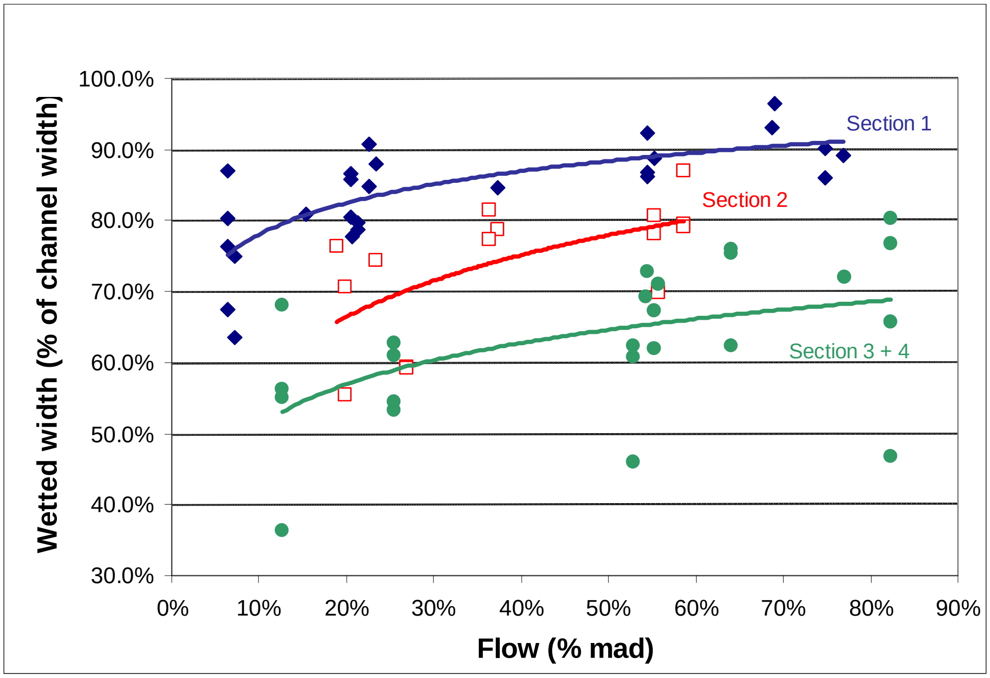


Figure 16. Summary of wetted widths at transects deemed appropriate for insect rearing.

Table 20. Equations describing relationships between wetted width (% channel width) as a function of flow (% mad) at transects throughout the Quinsam River mainstem. The relationships are used as a proxy to describe the available habitat for invertebrates in relation to flow.

Section	Equation	R^2
1	y = 0.929 + 0.064 Ln(x)	0.556
2	y = 0.867 + 0.126 Ln(x)	0.364
3 + 4	y = 0.705 + 0.084 Ln(x)	0.264

Additional Reference Points.— Reference points based on existing guidelines were calculated for the Quinsam River for rearing and spawning salmonids. The reference points for rearing are presented in Table 21 and those for spawning are presented in Table 22. The inclusion of these reference points is not meant as an endorsement; their inclusion merely facilitates comparison of the Quinsam River IFN study results to standards or guidelines that some readers may be familiar with.

Table 21. Multiple reference points (flow in $m^3 s^{-1}$) for rearing salmonids in four portions of the Quinsam River.

Reach	Transects	Natural MAD ($m^3 s^{-1}$)	ST/RB parr rearing Quinsam River (this study)	Region 1 guideline for ST parr rearing (20% mad)	Meta-analysis (ST parr)	Meta-analysis (salmonid parr)	Tennant's "Good" Summer Flow (40% mad)	Tennant's "Good" Winter Flow (20% mad)
1	T106 & T107	10.41	3.57	2.08	4.73	3.34	4.16	2.08
2 – 5	T084 - T098B	8.39	2.88	1.68	4.19	2.89	3.36	1.68
5 – 7	T070 - T083B	4.78	1.64	0.96	3.05	1.99	1.91	0.96
6 – 10	T047 - T069	3.085	2.47	0.62	2.39	1.49	1.23	0.62

Table 22. Multiple reference points (flow in $m^3 s^{-1}$) for spawning salmonids in four portions of the Quinsam River.

Reach	Transects	Natural MAD ($m^3 s^{-1}$)	ST parr rearing Quinsam River (this study)	Region 1 guideline for ST spawning (50 to 100% mad)	Meta-analysis (ST spawning)	Meta-analysis (salmonid spawning)	Tennant's "Good" Summer Flow (40% mad)	Tennant's "Good" Winter Flow (20% mad)
1	T106 & T107	10.41	8.33	5.21 - 10.41	6.83	5.74	4.16	2.08
2 – 5	T084 - T098B	8.39	6.71	4.2 - 8.39	5.93	4.98	3.36	1.68
5 – 7	T070 - T083B	4.78	3.82	2.39 - 4.78	4.12	3.45	1.91	0.96
6 – 10	T047 - T069	3.085	2.47	1.54 - 3.09	3.10	2.60	1.23	0.62

Discussion

There is a trend of decreasing fry habitat in relation to flow for both the anadromous and resident sections of the Quinsam River (Figure 14). In contrast, parr rearing habitat increases over low flows, but is relatively insensitive to flow over moderate to high flows. This indicates a trade-off between fry and juvenile life stages in both the resident and anadromous sections of the river. The trade-off is steeper over lower flows than over moderate to high flows. The trade-off may be of direct concern to resource managers since both life stages are present and active in the river at the same time. There were no apparent trade-offs between the anadromous and resident sections of the river. For example, steelhead/rainbow are present in all river sections, and the pattern of habitat availability versus flow was similar in each section.

There is a general trend in the Quinsam River mainstem of increasing spawning habitat with additional flow (Figure 15), at least over the three flows assessed for this study. This pattern is most apparent for chinook. Coho and steelhead spawning PUWs also increase with flow, although there is a tendency toward a plateau at flows in excess of 50% mad. The relationship of pink salmon spawning habitat vs. flow stands in contrast, in that there is a fairly well-defined maximum PUW at approximately 16% - 40% mad. There is thus an apparent trade-off between pink salmon and the three other salmonid species for the spawning life stage. However, this trade-off does not appear to be profound in that the loss of spawning habitat for pink salmon is relatively small over the range of flows from 20% to 80% mad. In comparison the gain in chinook spawning habitat over this range is approximately 300%.

Trade-offs may be of direct concern to resource managers since several species may be present and actively spawning in the river at the same time. To address this trade-off it is likely necessary for managers to make explicit priorities in terms of which species to favour.

The maxima functions fitted to the habitat-flow data indicate maximum PUWs that are consistent with several other instream flow guidelines (Table 21, Table 22). The rearing values obtained in this study are fairly consistent with those obtained from Hatfield and Bruce's (2000) meta-analysis and with Tennant's (1976) general guideline for "good" flows. However the values obtained in this study are somewhat higher than the 20% mad guideline used by WLAP Region 1 biologists. It should be noted though that the PUW value observed at 20% mad is still fairly high relative to the maximum PUW observed here.

There is a somewhat greater consistency between the habitat-flow relations observed here and the reference points for spawning habitat. Both the Region 1 guideline and the meta-analysis values do a reasonable job of predicting maximum PUW. The Tennant Method performs quite poorly, especially since the key spawning times are within the winter flow prescription time window.

The results of this study can help set priorities for resource management in the Quinsam River. Yet, it is also important to understand the limitations of this work. For example, this study concentrates on a subset of species from a much larger ecological community. There are 16 species or life history forms listed for the Quinsam (Burt 2003) and the analysis presented here for a mere five of them may not extrapolate easily. Caution is therefore advised in developing flow prescriptions based on this subset of species.

Another issue that stands out with respect to flow on the Quinsam is that of passage. The Quinsam has numerous bedrock cascades that act as flow-dependent barriers to several migrating species; passage is considered by several agency personnel as a significant constraint to natural recruitment in the river. This study does not address the issue of passage. To assess the effects of flow on fish migrations a detailed survey of the cascades would be necessary, probably coupled with behavioural observations of migrating fish. Indeed, this has been recommended as part of the Campbell River WUP monitoring program.

A final concern is a more general one. Although a study such as this requires enormous effort to complete it nevertheless provides only a limited picture of the ecological complexity of the Quinsam River. Much has been written about the dangers of developing flow prescriptions from instream flow studies that concentrate solely on hydraulically-defined habitat for a small set of species (e.g., Instream Flow Council 2002). Considerable uncertainty remains about how flow may alter complex ecological relationships such as inter- and intraspecific competition, predation, and geomorphic concerns (e.g., Castleberry et al. 1996). Flow has been coined a "master variable" (Poff et al. 1997) that influences many physical and biological processes. Therefore, considerably more information than that presented here should be considered in a final flow recommendation.

This study was commissioned as part of the data collection and analysis phase during development of a Water Use Plan for BC Hydro's Campbell River system. The WUP decision-making approach integrates information from all watersheds in the system and may make trade-offs among different resources depending on the values of stakeholders represented in the process. For this reason this report explicitly makes no recommendations regarding BC Hydro operations in the Quinsam watershed. Although this report was not formally written up prior to finalizing the WUP, information from the study was made available to the WUP Fisheries Technical Committee and was thus considered during the decision-making process.

COMPONENT 3. STOCK ASSESSMENT OF QUINSAM RIVER

Introduction

As part of the Campbell River Water Use Plan, BC Hydro commissioned a detailed biophysical assessment of the Quinsam River mainstem and its major lakes. The main tasks for the assessment were divided into five components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.
Component 5. Report preparation and summary.

This section of the report presents findings from Component 3, fish stock assessment of the Quinsam River. Field work was conducted in fall 1999 by D. Burt and Associates (DBA). The report was written by Solander Ecological Research, with input from D. Burt and Associates.

A brief review of the natural resources of the Quinsam watershed is presented in the General Introduction to this report. A more extensive review is presented in Burt (2003).

Methods

The objective of Component 3 was to identify and quantify fish use and assemblage in the Quinsam River mainstem between Wokas Lake Dam and the Campbell River confluence. This objective was to be met by selecting sample sites, electrofishing these sites, and estimating standing stocks for all salmonids and potential smolt yields for coho and steelhead.

Data

The fish population survey on the Quinsam River was conducted from September 26 to October 1, 1999 (road access sites) with the final sites completed on October 15, 1999 (helicopter access sites). A total of 13 sites were sampled for this study— nine sites in anadromous reaches (including one on the Iron River), and four in resident reaches. Sample locations are shown in Figure 17.

Locations of the DBA sampling sites were selected to complement ten additional sites assessed by the Vancouver Island Steelhead Recovery Program (VISRP) during August 1999. Although completed for other purposes the VISRP electroshocking data were made available for use in this study. The VISRP sites were selected to target steelhead fry and thus were characterized by shallow water depths, low velocities, and substrates ranging from large gravels to boulders. To compliment these, a portion of DBA sites were selected using similar criteria, while others were selected to target coho fry (pool habitats with some form of cover nearby).

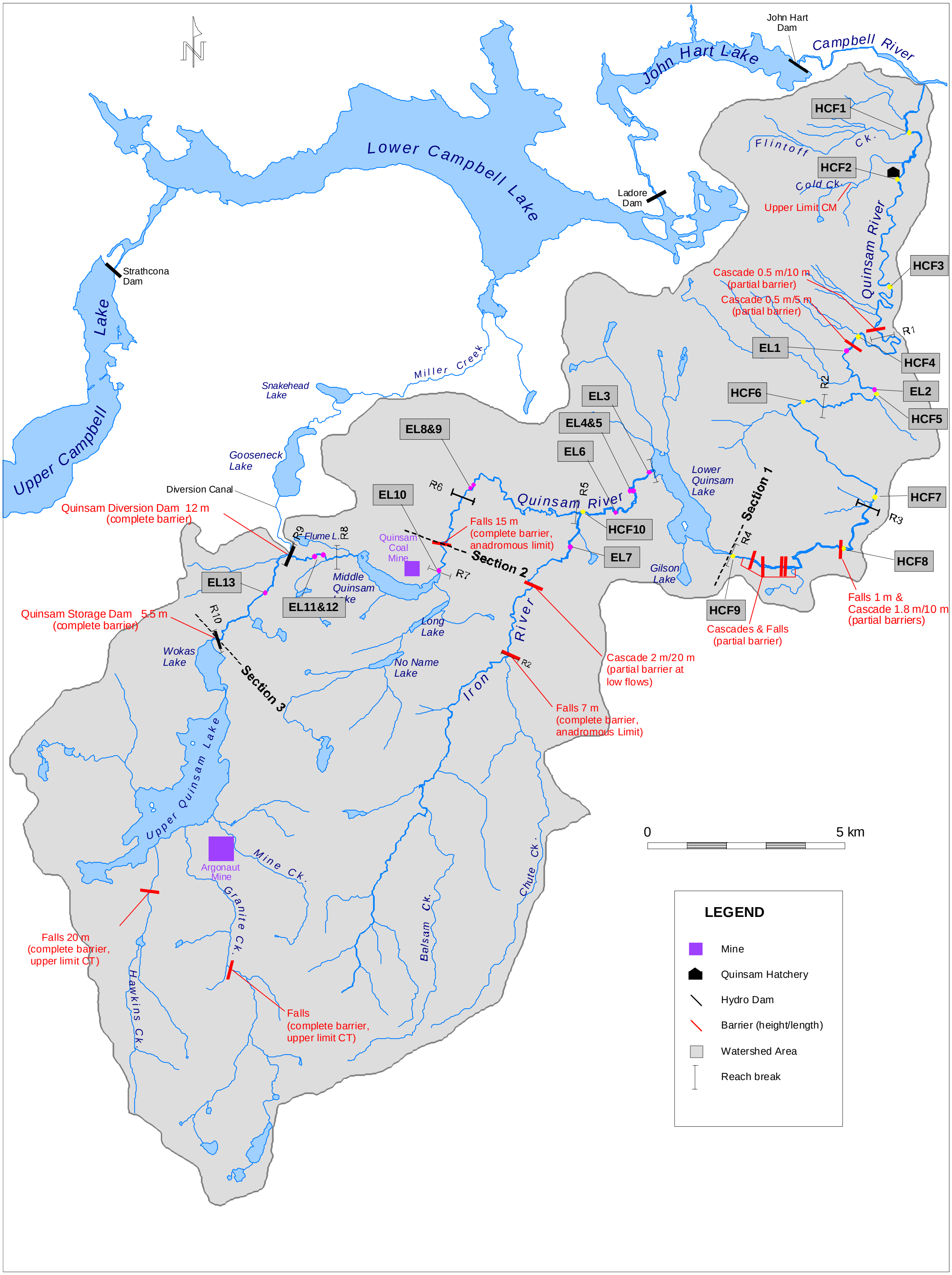


Figure 17. Map of the Quinsam watershed showing locations of electrofishing sites.

Activities undertaken at each site included fish sampling by electrofisher, collection of depth and velocity data along a transect within the site, and collection of site biophysical characteristics. The following describes the methods used to collect each of these data sets.

Fish population sampling was conducted with a backpack electrofisher using two-catch removal sampling (i.e., two separate catches for each site). Statistical aspects of the removal method are described in Seber and Le Cren (1967), and sampling protocols in De Leeuw (1981). The procedure involved enclosing a stream section with stop nets, using rocks to mould the lead line to the stream bottom, and aluminium poles to hold the float line above water. The nets used were 8.5 mm nylon hexagonal mesh, 1 m in height, and 10 and 20 m in length. Enclosures ranged in size from 30 to 85 m^2 (mean = 66 m^2). The Quinsam River was sufficiently wide and fast at the sample sites that spanning nets across the full stream width was not possible. Therefore, nets were arranged to enclose longitudinal sections adjacent to one bank.

Electrofishing was performed by a three-person crew using a Smith-Root model 12A backpack electrofisher and dip nets. For each catch, three or more passes were made within the netted enclosure (e.g., up, down, up). This high level of effort generally resulted in removal of most fish within the enclosure such that the enclosed population was equal to the sum of catch 1 and catch 2, or only slightly greater. The time between catches was determined by the time required to sample the first catch, which in most cases was about ½ hours.

After each catch, fish were identified and measured (fork length to nearest mm). Weights were measured for a subsample of the captured fish (nearest 0.1 g, OHAUS portable electronic balance, model C-505). In general, these subsamples included at lease one measurement for each mm size interval of captured fish. Alka-Seltzer tablets (CO_2) were used as an anaesthetic. Scales were taken from a small subsample of captured trout and mounted on slides on site for age determination in the laboratory. Scale samples focussed on fish with lengths in the overlapping portions of the length-frequency distribution. The above procedures are described in greater detail in Anonymous (1995, Chapter 8).

After completion of the fish sampling, a transect was run across the enclosure at a representative hydraulic location using a 30 m tape. Depth, velocity, and substrate data were recorded at 20–50 cm intervals along the transect. Depths were measured using a 1.5 m top-setting rod. Velocities were taken at 40% of depth (from the bottom) using a Swoffer flow meter mounted to the top-setting rod. Substrate material was categorized into dominant and subdominant types based on the modified Wentworth Scale (Anonymous 1995).

General habitat information was collected at each fish population site following the methods outlined in Anonymous (1995). Table 23 summarises habitat data collected at fish population sites and associated collection methods.

Table 23. Habitat data collected at fish population sites and the methods used.

Parameter	Units	Measured (M) or Estimated (E)	Method
Coordinates	UTM	M	Trimble Scoutmaster GPS
Habitat Type	—	—	Pool, glide, riffle or cascade
Mainstem or Sidechannel	—	—	Channel type designation
Field Gradient	%	M	Suunto clinometer
Sample Width	m	M	Tape measure (mean width of site)
Mean Depth	m	M	Top-setting rod
Maximum Depth	m	M	Top-setting rod
Mean Velocity	m/s	M	Velocity meter
Maximum Velocity	m/s	M	Velocity meter
Turbidity	–	E	Designated as clear, glacial, tannic, etc.
Temperature	ºC	M	Hand held thermometer
Time	—	—	Time temperature taken
Conductivity	µs	M	Horiba Twin Conductivity B-173 Compact Meter
Cover	%	E	Overstream & instream vegetation, cutbank, large woody debris, and boulder
Substrate Size Distribution	%	E	Fines, small and large gravel, cobble, boulder, and bedrock
Substrate Compaction	—	E	Identified as low, medium, or high
Sand in Substrate	—	E	Identified as low, medium, or high
Substrate D90	cm	M	Tape measure
Substrate Dmax	cm	M	Tape measure
Photos	—	—	Roll#, photo#, orientation, description

Analysis

Analyzing the fish population data involved

1. calculating amount of usable habitat (m^2) for steelhead/rainbow and coho fry within netted enclosures,
2. calculating fish densities (fish/100 m^2) by species and age group within the enclosures and adjusting densities based on usable habitat, and
3. comparing fish densities with theoretical maximum densities using Provincial models (Ptolemy 1993).

Calculation of Usable Habitat.— Calculation of usable habitat within electrofishing enclosures involved the pairing of depth and velocity data from the site transects with habitat suitability index (HSI) values for the species and age groups captured at each site. The HSI curves used for juvenile steelhead, rainbow and coho were those developed for Water Use Plans (WUP; dated February 2001; note: the HSI data for juvenile steelhead and rainbow are the same). The curves used for cutthroat trout were MWLAP curves (dated 1994). Currently, no B.C. curves are available for Dolly Varden (which were captured at the Iron River site).

The rationale for this approach is that within any given fish sample site there is spatial variation in hydraulic suitability for fish. For example, a portion of the site may be unsuitable for rearing due to insufficient or excessive depths and/or velocities. The portion of the site that has suitable depths/velocities is referred to as "usable habitat." Usable habitat within the electrofishing enclosures was quantified by:

1. determining the proportion of the sample site width that was usable (percent usable width or PUW) for each species and age group, and
2. multiplying PUW values by the total area of the site to obtain weighted usable area (WUA).

WUA was calculated for age 0+ (i.e., fry) and 1+ (i.e., parr) of steelhead, rainbow and cutthroat trout, and age 0+ coho salmon.

PUW was calculated by coupling depth and velocity measurements from each position along a given transect (a "cell") with an associated HSI weighting factor for each species/age group (Milhouse et al. 1984). The calculation can be expressed as follows:

$$C_i = f(D)_i \times f(V)_i$$

where

C_i = the composite weighting factor for a given species and age in cell i
$f(D)_i$ = the suitability weighting factor for depth in cell i
$f(V)_i$ = the suitability weighting factor for velocity in cell i.

The composite weighting factors (C_i) were used to weight each transect cell (i.e., $C_i \times W_i$, where W_i = width of cell i). The sum of all cell weighted widths (C_iW_i) provided weighted usable width for each transect by species. These calculations were facilitated through a database program developed by J. Lettic (Digital Information Services, Nanoose Bay, B.C.), using algorithms from a spreadsheet by MWLAP (Ptolemy et al. 1993). PUW for each transect was obtained by dividing WUW by the transect width. WUA was then calculated by multiplying PUW by the total area of the site enclosure.

Calculation of Fish Density.— Calculation of fish density at a given electrofishing site first involved estimating total fish population (by species and age group) within the enclosure. This was then divided by the area of the enclosure to determine observed density, or by WUA of the enclosure to determine WUA-adjusted density. In this study densities are expressed as the number fish per unit area (FPU) where a unit area equals 100 m^2. Observed densities are thus expressed as FPU, and WUA-adjusted densities as AFPU, which are calculated as follows.

Estimates of fish populations ($\tilde{n}$) within netted enclosures, and associated probability of capture values ($\tilde{p}$), were calculated using formulae from Seber and Le Cren (1967). There are two formulae for calculating $\tilde{n}$, the choice of which depends on whether $\tilde{p}$ is less than or greater than 0.5. Thus, it is important to determine $\tilde{p}$ prior to calculation of $\tilde{n}$. The formulae are as follows:

$$\tilde{p} = \frac{(C_1 - C_2)}{C_1}$$

$$\tilde{n} = \frac{C_1^2}{(C_1 - C_2)}, \text{ for } \tilde{p} > 0.5$$

$$\tilde{n} = \frac{(C_1 + C_2)}{\tilde{p}_{est}}, \text{ for } \tilde{p} \leq 0.5.$$

where

$\tilde{p}$ = *probability of a fish being caught*
$\tilde{n}$ = *population of fish within the enclosure*
$\tilde{p}_{est}$ = *estimate of the proportion of fish captured in C_1 and C_2 combined*
C_1 = *number of individuals in the first capture*
C_2 = *number of individuals in the second capture.*

Fish densities were calculated by dividing $\tilde{n}$ by the total area of the enclosure to achieve observed density, or by WUA within the enclosure to achieve the WUA-adjusted density. Equations for these calculations area as follows:

$$FPU = \frac{\tilde{n}}{TA} x 100$$

$$AFPU = \frac{\tilde{n}}{WUA} x 100$$

where

FPU = fish per unit area (fish per 100 m^2),
$\tilde{n}$ = estimate of population within the enclosure,
TA = total area of the electrofishing enclosure,
WUA = weighted usable area within the electrofishing enclosure.

Calculation of Theoretical Maximum Density.— Maximum potential density is an estimate of the maximum capacity of aquatic habitat at a given location to support juvenile salmonids. In British Columbia, two models have been developed by the Province to estimate maximum potential density in fluvial habitats (Ptolemy 1993). These models require inputs of mean fish size (weight in grams) and alkalinity (mg/L) of the stream during critical period stream flow (CPSF; the period of lowest flow during the growing season). There is one model for juvenile trout (steelhead/rainbow and cutthroat), char and chinook, and a separate model for coho. The models are based on data from 240 different streams or reaches in British Columbia. The formulae are as follows:

$$FPU_{ALK} = \sqrt{ALK} \times 36.3 \div size_g$$ (for trout, char, and chinook), and

$$FPU_{ALK} = 100 \times (ALK)^{0.4} \div size_g$$ (for coho).

where

FPU_{ALK} = fish per unit area (unit area is 100 m^2),
ALK = total alkalinity at summer low flow (mg/L),
$SIZE_g$ = mean wet weight (g) per size class (age group).

A useful feature of the models is that prior to factoring in fish size, one has an estimate of maximum potential biomass. Maximum biomass is positively correlated to stream alkalinity (a measure of a stream's biological productivity). Fish size does not affect maximum biomass, but rather dictates the number of fish that can be present (i.e., a single biomass may be represented by many small fish, a few large fish, or a combination of size classes). An alkalinity value of 27.3 mg/L was used in all calculations. This value was supplied to DBA by Ron Ptolemy during a previous study, and is the same value used by VISRP.

Additional Reference Points.— To allow a direct comparison with regional electrofishing data, reference points were created using three data sources:

1. raw data used for Ptolemy's 1993 habitat capacity model,
2. regional data compiled by Paul Higgins (BC Hydro), and
3. Bradford et al.'s (1997) data on coho smolt production in regional streams.

Higgins' database includes observations for the "Coast Mountains and Island" physiographic region — BC observations are from Ptolemy (1993) and US data are from Platts and McHenry (1988). Bradford et al.'s (1997) data come from observations in 86 streams throughout Alaska, British Columbia, Washington, Oregon and California.

Probability distribution functions (pdf) and cumulative distribution functions (cdf) were created using each data source. The pdfs indicate probabilities associated with different electrofishing catch rates and the cdfs indicate quantiles associated with the catch rates. Together these plots provide a reference point for the Quinsam observations by allowing a direct comparison to regional data.

Results

Electrofishing sites on the Quinsam River were distributed over the entire length of the river, from just below Wokas Reservoir to immediately upstream of the river's confluence with the Campbell River. DBA conducted sampling at 13 sites primarily in mid and upper reaches; VISRP conducted sampling at an additional 10 sites, in lower reaches only. The distribution of these sampling sites is indicated on Figure 17. Physical characteristics of the sampling sites and the fish species captured at each site are summarized in Table 24.

Electrofishing was conducted for this study in August – October 1999. During this time streamflows were at their lowest for the year and were relatively stable (Figure 18). Hydraulic conditions would therefore have been consistent over several weeks and fish would likely have had sufficient time to distribute themselves among preferred habitats. Since the survey periods coincided with the active rearing period for salmonids it is expected that fish would have been at their most "catchable." Water temperature and clarity were conducive to successful electrofishing.

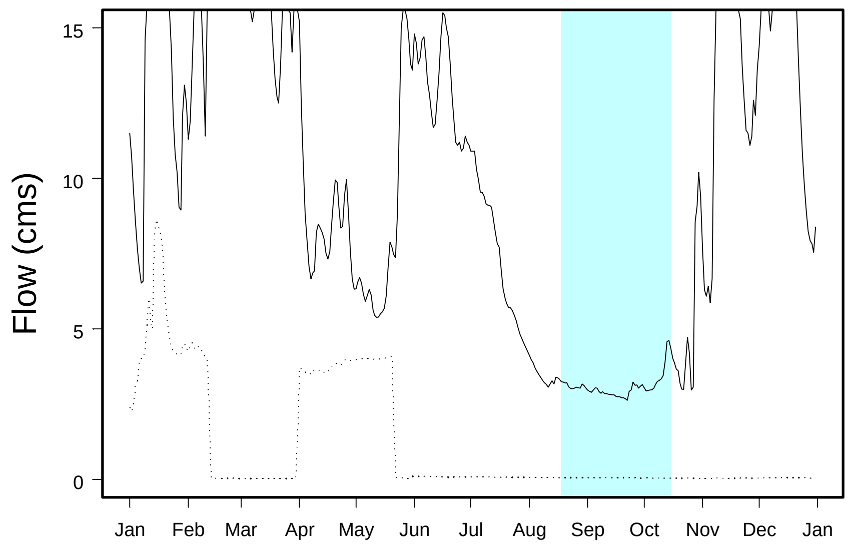


Figure 18. Streamflows in 1999 in the Quinsam River. Electrofishing was conducted for this study in August – October 1999, as indicated by the shaded blue area. The solid line indicates gauged streamflows in the Quinsam River at its confluence with the Campbell River (WSC 08hd005); the dotted line indicates diversions from the Quinsam River by BC Hydro (BC Hydro data).

During field work attempts were made to distinguish among fish of wild and hatchery origin. Hatchery fish were identified in field notes when encountered. A portion of outplanted coho are marked with fin clips, and all outplanted steelhead are fin clipped. No marked steelhead were encountered during the study. All coho above the anadromous barrier are from hatchery outplants. Marked coho were encountered at sites EL3, EL5, EL6, and EL8 (i.e., Section 2). Not all hatchery coho are marked, however, the larger size of hatchery coho helps to identify these fish. Based on fry lengths, it is possible that all coho at EL3, EL5, EL6, and EL8 were of hatchery origin. Coho are usually planted in September while steelhead are planted in October (Burt 2003), after many of the sites were sampled for this study. DBA sampled before the ST were outplanted.

Coho were observed over the full length of the river; steelhead extended throughout the anadromous reaches; and cutthroat were observed only in the upper watershed. Other fish species were distributed sporadically. The presence of rearing coho above the anadromous barrier at reach 7 is due to outplanting of coho fry by DFO; distribution below the barrier is due to downstream dispersal of outplanted fry as well as natural recruitment.

A total of 188 salmonids were caught by the DBA sampling program. This catch complements that of the VISRP, which caught 430 fish. A summary of length, weight and condition is presented in Table 25 for both the DBA and VISRP catches, and length-frequency relationships for the DBA catch are plotted for coho, steelhead, and cutthroat (Figure 19, Figure 20, Figure 21). DBA estimated that all but three of the fish caught were young-of-year, and all but 10 of the fish captured by VISRP were young-of-year. DBA also noted that observed fish condition in the Quinsam was consistent with observations from elsewhere in British Columbia.

Physical characteristics of the sampling sites and the fish species captured at each site are summarized in Table 24. The habitat types surveyed cannot be easily characterized (e.g., by mesohabitat type) because the overall habitat unit may not correspond to the habitat type that is actually sampled. For example, a mesohabitat unit may be a pool or riffle but the portion of habitat sampled (microhabitat) could be a glide. This is one of the reasons behind calculating an "adjusted" density score based on the availability of suitable habitat.

Physical characteristics varied among electroshocking sites (Table 24), and thus the suitability for rearing salmonids also varied. For example, species- and life stage-specific suitability (PUW) within the enclosures varied from 18% to 99% (Table 26). On average, habitats with greater suitability would be expected to have a greater biomass or density of fish than those with low suitability. To correct for this variance and allow a more meaningful comparison among sites an adjusted density and biomass were calculated for each site (Table 26).

There was considerable variation among sites in biomass and density of fish captured (Table 26). For comparison the sites were grouped into three sections as follows: section 1 = reaches below Lower Quinsam Lake; section 2 = reaches between Lower Quinsam Lake and the anadromous barrier; section 3 = reaches above the anadromous barrier. When grouped in this way there was a decreasing gradient in mean adjusted total salmonid biomass from section 1 to section 3 (i.e., the lowest reaches had the greatest biomass). When the density data were broken down by species a similar gradient was observed for coho fry, and for steelhead fry in sections 1 and 2 (Figure 22, Figure 23; note that steelhead are restricted to sections 1 and 2).

WUA-adjusted biomass at each site is compared to Provincial reference points for habitat capacity (Ptolemy 1993) in Figure 24 and Figure 25. Results indicate that at most sites biomass for coho and steelhead fry are below the theoretical capacity determined by this model, however, a few sites exceed the capacity estimates. These same results are broken down by age class and plotted as an Allen Plot in Figure 26, which indicates that most sites are below the Provincial target capacity.

Table 24. Summary of electrofishing sites. (HCF# are sites used by VISRP, EL# are sites assessed by DBA).

Site	Date	Reach	UTM Easting	UTM Northing	Habitat Type	Water Clarity	Water Temp. (°C)	Mean Depth (m)	Mean Velocity (m/s)	Substrate (%) Fi	SG	LG	Co	Bo	Br	D90 (cm)	Cover Types	Species Captured
Anadromous Reaches																		
HCF01	18/08/1999	1	335,439	5,544,089	riffle	clear	15.0	0.30	0.21	10	10	20	30	30	0	60	BO	ST, CO, CH
HCF02	18/08/1999	1	334,993	5,543,012	riffle	clear	20.0	0.30	0.19	5	5	20	40	30	0	80	BO	ST, CO
HCF03	17/08/1999	1	334,699	5,540,173	riffle	clear	19.0	0.18	0.39	5	10	40	40	5	0	25	BO/LWD/CB	ST, CO
HCF04	20/08/1999	1	333,847	5,538,996	riffle	clear	19.0	0.25	0.17	5	5	20	35	35	0	65	BO/OV/CB	ST, CO
EL01	01/10/1999	2	333,480	5,538,525	pool	clear	12.0	0.55	0.02	0	0	0	0	5	95	30	CB/BO	CO, SB
EL02	01/10/1999	2	334,218	5,537,608	glide	clear	12.0	0.35	0.30	5	5	50	30	10	0	25	OV/IV/BO	ST, CO, SB, L
HCF05	20/08/1999	2	334,242	5,537,543	glide	clear	19.0	0.40	0.20	10	5	45	35	5	0	25	IV/BO/CB/OV/LWD	ST, CO
HCF06	19/08/1999	3	332,258	5,537,303	glide	clear	20.0	0.25	0.02	50	25	25	0	0	0	8	OV/CB/LWD	ST, CO
HCF07	19/08/1999	3	334,130	5,534,854	riffle	clear	20.0	0.15	0.13	2.5	10	45	40	2.5	0	15	LWD/IV/OV/BO	ST, CO
HCF08	17/08/1999	4	333,180	5,533,610	riffle	clear	17.0	0.18	0.14	2	3	15	40	15	25	30	OV/BO	ST, CO
HCF09	19/08/1999	4	330,445	5,533,500	riffle	clear	21.0	0.35	0.18	2.5	2.5	5	35	55	0	60	BO/OV	ST, CO
EL03	30/09/1999	5	328,371	5,535,603	glide	clear	13.5	0.35	0.16	10	20	40	30	0	0	10	OV/LWD	CO, CT, SB, CC
EL04	26/09/1999	5	328,025	5,535,120	glide	clear	14.0	0.12	0.19	5	15	45	35	0	0	15	BO	CC
EL05	26/09/1999	5	328,001	5,535,120	small sidech.	clear	14.0	0.14	0.05	60	30	10	0	0	0	3	OV/LWD/CB	ST, CO, CC
EL06	30/09/1999	5	327,463	5,534,665	edge of pool	clear	13.0	0.19	0.21	75	15	10	0	0	0	2	CB/OV/LWD	ST, CO, SB
HCF10	19/08/1999	5	326,652	5,534,742	riffle	clear	18.0	0.20	0.30	0	10	25	60	5	0	50	BO	ST
EL07	15/10/1999	Iron R.	326,303	5,533,903	glide on edge of riffle	clear	6.0	0.18	0.13	0	10	60	20	10	0	40	BO/CB/LWD	ST, DV, CC
EL08	15/10/1999	6	323,890	5,535,540	backchannel	clear	11.0	0.14	0.00	90	10	0	0	0	0	1	IV	CO, CT
EL09	15/10/1999	6	323,870	5,535,515	glide on edge of pool	clear	12.0	0.20	0.02	0	15	70	15	0	0	30	OV	ST, CT, CO, SB
Resident Reaches																		
EL10	27/09/1999	7	322,921	5,533,327	run	clear	16.0	0.29	0.25	15	10	30	35	10	0	70	OV/BO/LWD	CT, CO, CC
EL11	27/09/1999	9	319,920	5,533,855	edge of riffle	clear	15.0	0.17	0.33	10	5	25	55	5	0	30	BO/OV	CT, CC
EL12	28/09/1999	9	319,780	5,533,813	glide on edge of riffle	clear	15.0	0.25	0.07	0	10	40	50	0	0	20	OV/BO/LWD	CT, CO, CC
EL13	28/09/1999	10	318,375	5,532,870	glide on edge of riffle	clear	15.0	0.33	0.10	5	40	25	10	20	0	50	BO/OV	RB, CC

Notes:
Species abbreviations: ST = steelhead, CO = coho, DV = Dolly Varden, CT = cutthroat, RB = rainbow, SB = stickleback (general), CC = sculpins (general), L = Lamprey
Substrate Abbreviations: Fi = fines, SG = small gravel, LG = large gravel, Co = cobble, Bo = boulder, BR = bedrock
Cover abbreviations: BO = boulder, LWD = large woody debris, OV = overstream vegetation, IV = instream vegetation, CB = cutbank
Coho captured in resident reaches are from DFO fry outplants.

Additional reference points are provided by quantile plots of Provincial data (Figure 27) and BC and US regional data (Figure 28). The plots indicate that mean rearing fish biomass in section 1 of the Quinsam River is in the second quartile of streams in the province and region, whereas section 2 and 3 are in the lowest quartile. Ptolemy (1993) has shown that alkalinity is a good predictor of biological productivity of BC streams. A quantile plot of BC stream alkalinity data (Figure 29) indicates that the Quinsam River is in the second quartile of streams in the region in terms of alkalinity concentration.

Table 25. Summary of length, weight, and condition factor (K) of salmonid fry (age 0+) captured at the 13 Quinsam River electrofishing sites during September and October 1999, and the 10 VISRP sites assessed during August 1999 (mean length and weight only).

		n	Length (mm)			Weight (g)		K
Stream	Species		Mean	Min	Max	Mean	SD	
Anadromous Reaches:								
Quinsam R.	Steelhead	26	67	52	86	3.4	1.3	1.09
	Coho	81	67	43	87	3.6	1.6	1.15
	Cutthroat	6	70	58	83	3.3	1.4	0.91
Iron R.	Steelhead	24	52	38	72	1.7	0.9	1.08
	Dolly Varden	2	66	64	68	2.7	0.7	0.93
MELP Sites	Steelhead	135	–	–	–	2.0	–	–
	Coho	285	–	–	–	2.5	–	–
Resident Reaches:								
Quinsam R.	Rainbow	4	69	61	80	3.7	1.6	1.06
	Coho (colon.)	8	79	67	88	5.4	1.5	1.09
	Cutthroat	34	59	47	78	2.2	0.9	0.96

Notes:

1. Only 3 age 1+ fish were captured in DBA samples (1 steelhead, 1 Dolly Varden, and 1 coho)
2. Condition factor (K) = Weight/Length^3 x 10000 (Fulton's condition factor)
3. Smaller size of fish from MELP sites was due to earlier sampling time.

Table 26. Summary of catch data, suitability, and population and biomass estimates for all electrofishing sites assessed in 1999 by DBA and VISRP.

Stream	Reach	Site	Date	Area (m^2)	Spp.	Age	C1	C2	N	Mean Lgth (mm)	Mean Wt (g)	Capture Prob.	Pop Est	PUW (%)	BPU (g/100 m^2)	ABPU (g/100 m^2)	FPU (#/100 m^2)	AFPU (#/100 m^2)
Anadromous Reaches Below Lower Quinsam Lake																		
Quinsam R.	1	HCF01	18-Aug-1999	122.3	CO	0	48	12	60	64	3.3	75.0%	64.0	39%	175	448	52.3	134
		HCF01		122.3	ST	0	16	7	23	64	3.3	56.3%	28.4	55%	77	140	23.3	42
		HCF01		122.3	CH	0	1	0	1	73	4.8	100.0%	1.0	35%	4	11	0.8	2
Quinsam R.	1	HCF02	18-Aug-1999	102.7	CO	0	12	6	18	64	3.4	50.0%	24.0	51%	79	155	23.4	46
		HCF02		102.7	ST	0	17	3	20	58	2.1	82.4%	20.6	78%	42	54	20.1	26
Quinsam R.	1	HCF03	17-Aug-1999	83.3	CO	0	9	1	10	51	1.5	88.9%	10.1	27%	19	69	12.2	45
		HCF03		83.3	ST	0	10	1	11	52	1.7	90.0%	11.1	46%	23	49	13.3	29
		HCF03		83.3	ST	1	1	0	1	119	16.5	100.0%	1.0	58%	20	34	1.2	2
Quinsam R.	1	HCF04	20-Aug-1999	90.3	CO	0	32	2	34	60	2.7	93.8%	34.1	67%	101	151	37.8	56
		HCF04		90.3	ST	0	1	0	1	67	3.1	100.0%	1.0	81%	3	4	1.1	1
		HCF04		90.3	ST	1	1	0	1	126	22.4	100.0%	1.0	51%	25	49	1.1	2
Quinsam R.	2	EL01	1-Oct-1999	68.7	CO	0	18	0	18	59	2.8	100.0%	18.0	99%	73.4	74.0	26.2	26.4
Quinsam R.		EL02	1-Oct-1999	76.3	CO	0	21	8	29	61	2.8	61.9%	33.9	55%	124.5	228.4	44.5	81.6
	2	EL02		76.3	ST	0	5	0	5	65	3.2	100.0%	5.0	49%	21.0	43.0	6.6	13.4
		EL02		76.3	ST	1	1	0	1	125	19.3	100.0%	1.0	69%	25.3	36.5	1.3	1.9
Quinsam R.	2	HCF05	20-Aug-1999	57.0	CO	0	46	19	65	55	2.1	58.7%	78.4	60%	286	477	137.5	229
		HCF05		57.0	ST	0	6	2	8	54	1.9	66.7%	9.0	27%	30	109	15.8	58
Quinsam R.	3	HCF06	19-Aug-1999	73.5	CO	0	33	12	45	56	2.0	63.6%	51.9	77%	138	180	70.6	92
		HCF06		73.5	ST	0	2	1	3	44	0.9	50.0%	4.0	52%	5	9	5.4	10
Quinsam R.	3	HCF07	19-Aug-1999	90.4	CO	0	18	1	19	51	1.6	94.4%	19.1	46%	33	71	21.1	46
		HCF07		90.4	ST	0	14	2	16	53	1.7	85.7%	16.3	71%	31	44	18.1	25
Quinsam R.	4	HCF08	17-Aug-1999	81.6	CO	0	16	0	16	59	2.4	100.0%	16.0	59%	47	80	19.6	33
		HCF08		81.6	ST	0	8	0	8	60	2.5	100.0%	8.0	71%	24	34	9.8	14
		HCF08		81.6	ST	1	4	0	4	124	18.2	100.0%	4.0	26%	89	343	4.9	19
Quinsam R.	4	HCF09	19-Aug-1999	71.6	CO	0	18	0	18	55	2.2	100.0%	18.0	63%	56	88	25.1	40
		HCF09		71.6	ST	0	14	2	16	59	2.7	85.7%	16.3	80%	61	76	22.8	29
		HCF09		71.6	ST	1	3	0	3	138	29.6	100.0%	3.0	53%	124	234	4.2	8
Anadromous Reaches Between Lower Quinsam Lake and the 15 m Falls																		
Quinsam R.	5	EL03	Sept.30,1999	82.8	CO	0	5	0	5	83	6.5	100.0%	5.0	76%	39.3	51.6	6.0	7.9
		EL03		82.8	ST	0	0	0	0		3.4		0.0	35%	0.0	0.0	0.0	0.0
		EL03		82.8	CT	0	0	1	1	71	3.4	0.0%	1.1	65%	4.6	7.1	1.3	2.1
Quinsam R.	5	EL04	Sept.26, 1999	85.3	CO	0	0	0	0		3.6		0.0	46%	0.0	0.0	0.0	0.0
		EL04		85.3	ST	0	0	0	0		3.4		0.0	63%	0.0	0.0	0.0	0.0
Quinsam R.	5	EL05	Sept.26, 1999	41.3	CO	0	11	5	16	79	5.1	54.5%	20.2	66%	249.0	377.9	48.8	74.1
		EL05		41.3	ST	0	11	3	14	67	3.4	72.7%	15.1	45%	124.5	278.6	36.6	81.9
Quinsam R.	5	EL06	Sept.30,1999	61.0	CO	0	2	1	3	80	5.4	50.0%	4.0	56%	35.4	62.8	6.6	11.6
		EL06		61.0	CO	1	1	0	1	97	8.9	100.0%	1.0	56%	14.6	25.9	1.6	2.9
		EL06		61.0	ST	0	2	0	2	71	4.0	100.0%	2.0	19%	13.1	70.5	3.3	17.6
		EL06		61.0	CT	0	0	0	0		3.3		0.0	78%	0.0	0.0	0.0	0.0
Quinsam R.	5	HCF10	Aug. 19, 1999	70.2	ST	0	21	8	29	42	0.9	61.9%	33.9	73%	43.0	58.9	48.3	66.2
Iron River		EL07	Oct.15,1999	85.1	ST	0	22	2	24	52	1.7	90.9%	24.2	71%	48.3	68.2	28.4	40.1
		EL07		85.1	DV	0	2	0	2	66	2.7	100.0%	2.0	#N/A	#N/A	#N/A	2.4	#N/A
		EL07		85.1	DV	1	1	0	1	113	16.3	100.0%	1.0	#N/A	#N/A	#N/A	1.2	#N/A
Quinsam R.	6	EL08	Oct.15,1999	29.8	CO	0	7	0	7	69	3.2	100.0%	7.0	69%	75.2	109.4	23.5	34.2
		EL08		29.8	ST	0	0	0	0		3.4		0.0	18%	0.0	0.0	0.0	0.0
		EL08		29.8	CT	0	2	0	2	81	4.9	100.0%	2.0	99%	32.9	33.1	6.7	6.8
Quinsam R.	6	EL09	Oct.15,1999	70.4	CO	0	3	0	3	62	2.9	100.0%	3.0	81%	12.4	15.3	4.3	5.3
		EL09		70.4	ST	0	4	1	5	65	3.3	75.0%	5.3	45%	25.0	55.2	7.6	16.7
		EL09		70.4	CT	0	2	1	3	62	2.2	50.0%	4.0	99%	12.5	12.6	5.7	5.7
Resident Reaches																		
Quinsam R.	7	EL10	Sept.27,1999	51.3	CT	0	14	0	14	62	2.5	100.0%	14.0	53%	68.6	129.7	27.3	51.6
	7	EL10		51.3	CO	0	1	1	2	84	6.8	90.0%	2.2	51%	29.5	58.1	4.3	8.5
Quinsam R.	9	EL11	Sept.27,1999	58.5	CT	0	14	0	14	55	1.6	100.0%	14.0	47%	39.0	83.3	23.9	51.1
		EL11		58.5	CO	0	0	0	0		3.6		0.0	26%	0.0	0.0	0.0	0.0
Quinsam R.	9	EL12	Sept.28,1999	69.4	CT	0	6	0	6	63	2.5	100.0%	6.0	87%	21.8	24.9	8.6	9.9
		EL12		69.4	CO	0	5	1	6	78	5.0	80.0%	6.3	83%	44.9	54.1	9.0	10.9
Quinsam R.	10	EL13	Sept.28,1999	81.0	RB	0	4	0	4	69	3.7	100.0%	4.0	35%	18.3	52.4	4.9	14.1

Notes:

1. Where capture probability was < 50%, the population estimate was based on (C1+C2)/0.9, where 0.9 is the estimated capture efficiency for both catches combined.
2. Adjusted densities were based on WUP 2001 HSI curves. For the MELP data (HCF01 to HCF10), the orginal data was reanalised using the new curves.
3. Biomass was calculated as mean weight × no. of fish.

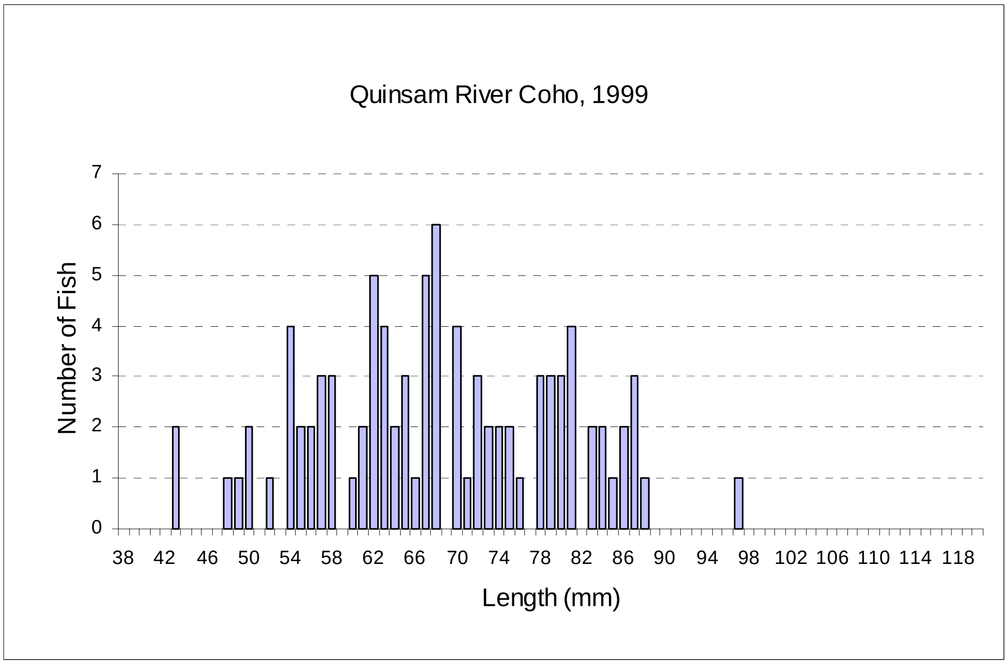


Figure 19. Length frequency distribution of coho captured by this study in September - October 1999 (13 electrofishing sites).

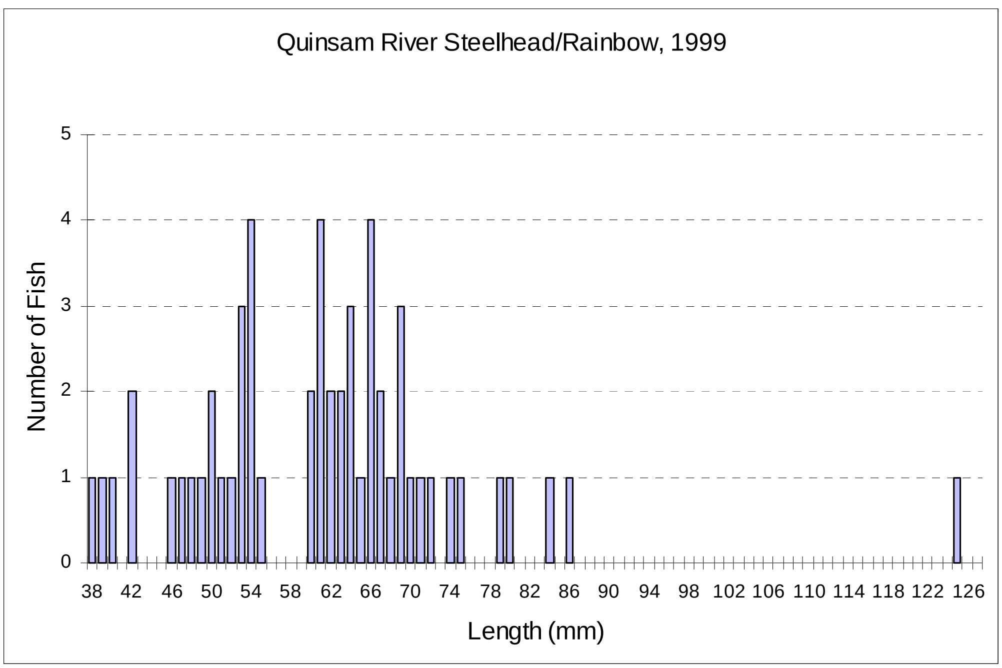


Figure 20. Length frequency distribution of steelhead and rainbow captured by this study in September - October 1999 (13 electrofishing sites).

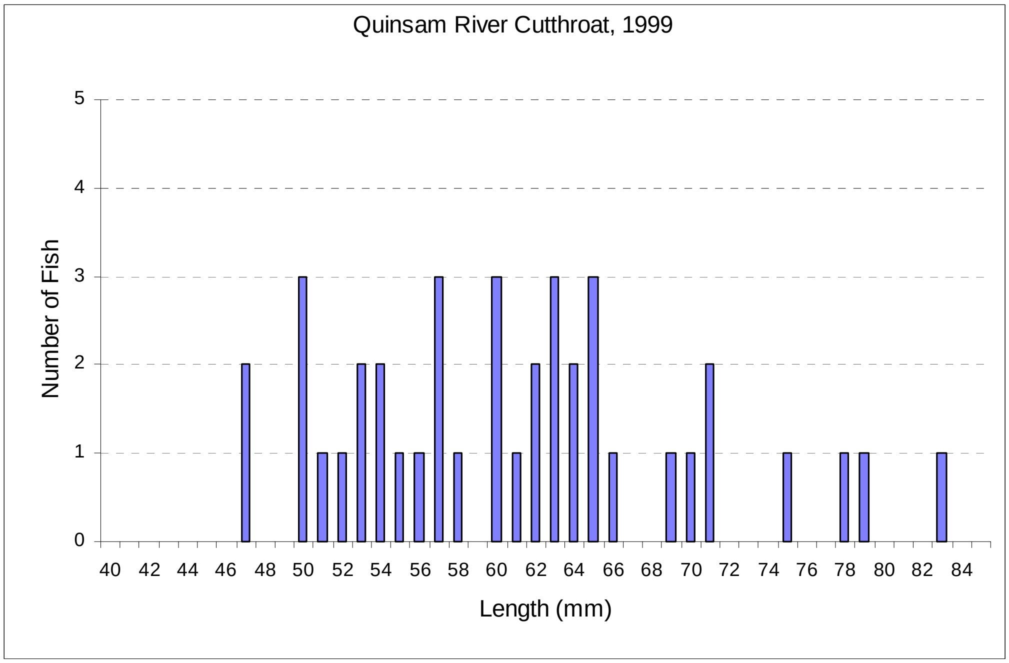


Figure 21. Length frequency distribution of cutthroat captured by this study in September - October 1999 (13 electrofishing sites).

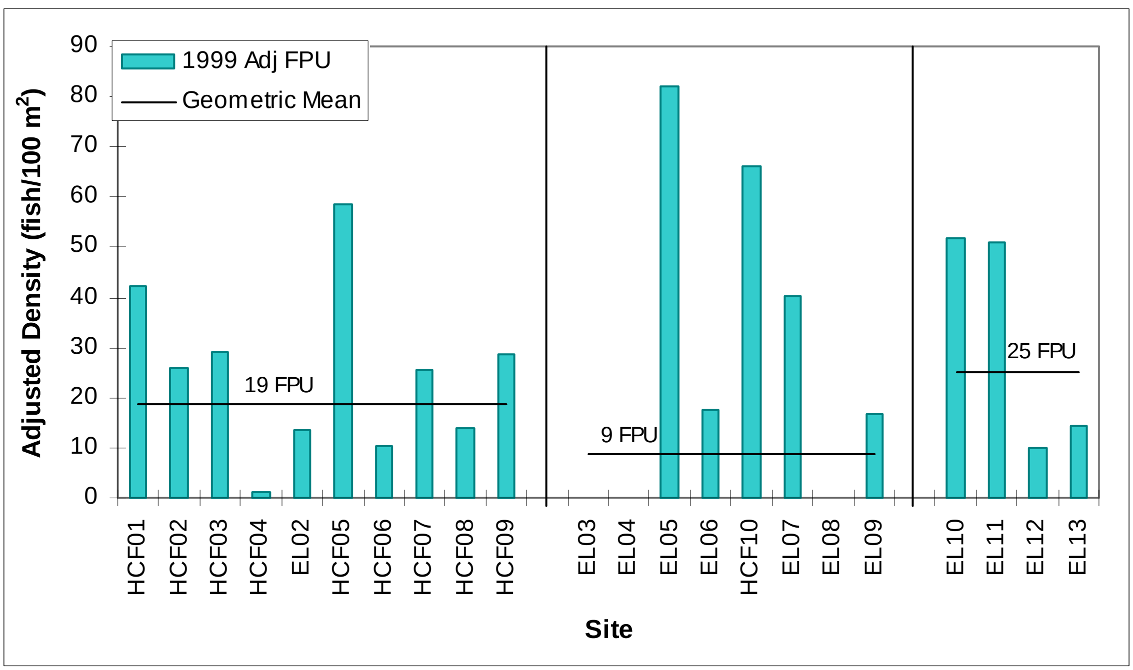


Figure 22. Adjusted density of steelhead fry (rainbow and cutthroat fry combined for resident reaches) from 1999 electrofishing sites on the Quinsam River. The solid horizontal lines show the geometric means for each region.

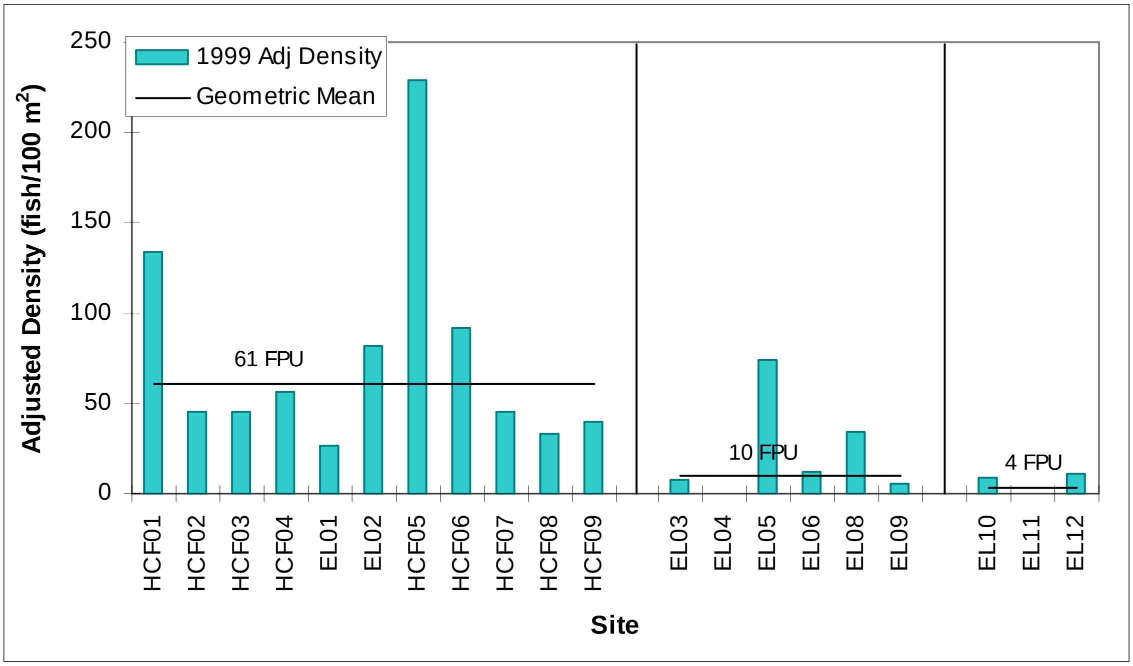


Figure 23. Adjusted density of coho fry from 1999 electrofishing sites on the Quinsam River. The solid line shows the geometric mean for each region. Coho captured in the resident region were from hatchery outplants. In addition, some coho captured in the middle region appear to have been of hatchery origin (fin clips).

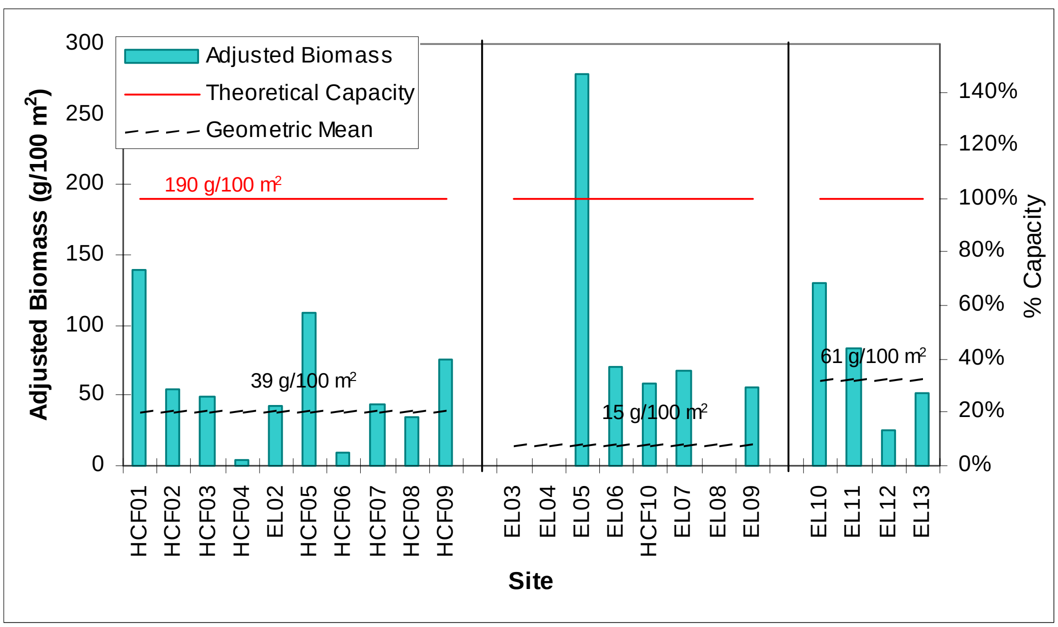


Figure 24. Adjusted biomass of steelhead fry from 1999 electrofishing sites expressed in g · 100 m^{-2} (primary y-axis) and as a percentage of the theoretical capacity biomass (secondary y-axis). For the resident region, biomass equals rainbow and cutthroat fry combined. The dashed line show the geometric mean biomass, while the solid lines show the theoretical maximum biomass (190 g · 100 m^{-2}) based on the alkalinity model (Ptolemy 1993).

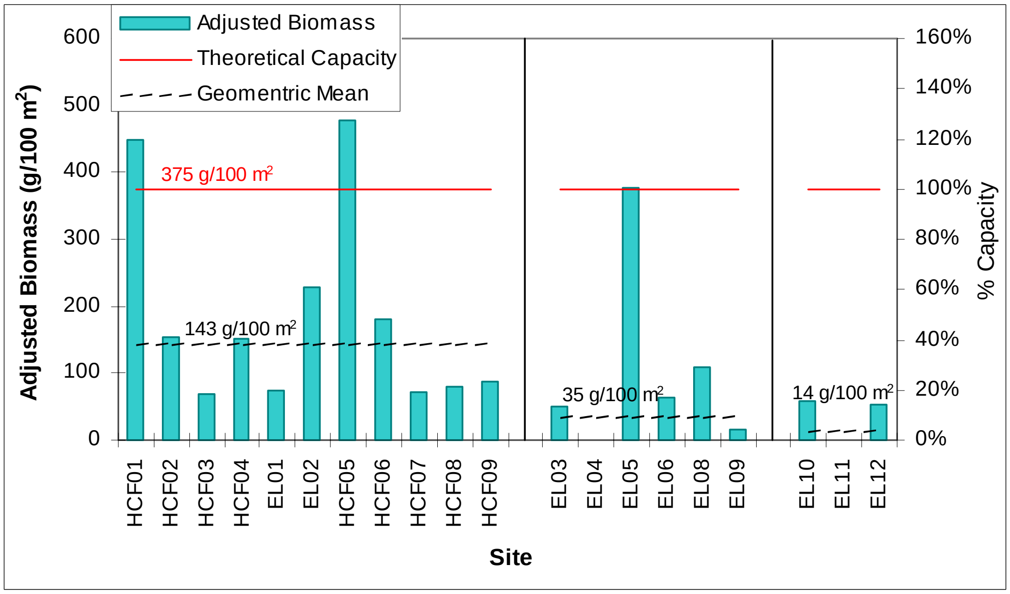


Figure 25. Adjusted biomass of coho fry from 1999 electrofishing sites expressed in g · 100 m^{-2} (primary y-axis) and as a percentage of the theoretical capacity biomass (secondary y-axis). Coho captured in the resident region are from hatchery outplants. The dashed lines show the geometric mean biomass, while the solid lines show the theoretical maximum biomass (190 g · 100 m^{-2}) based on the alkalinity model (Ptolemy 1993).

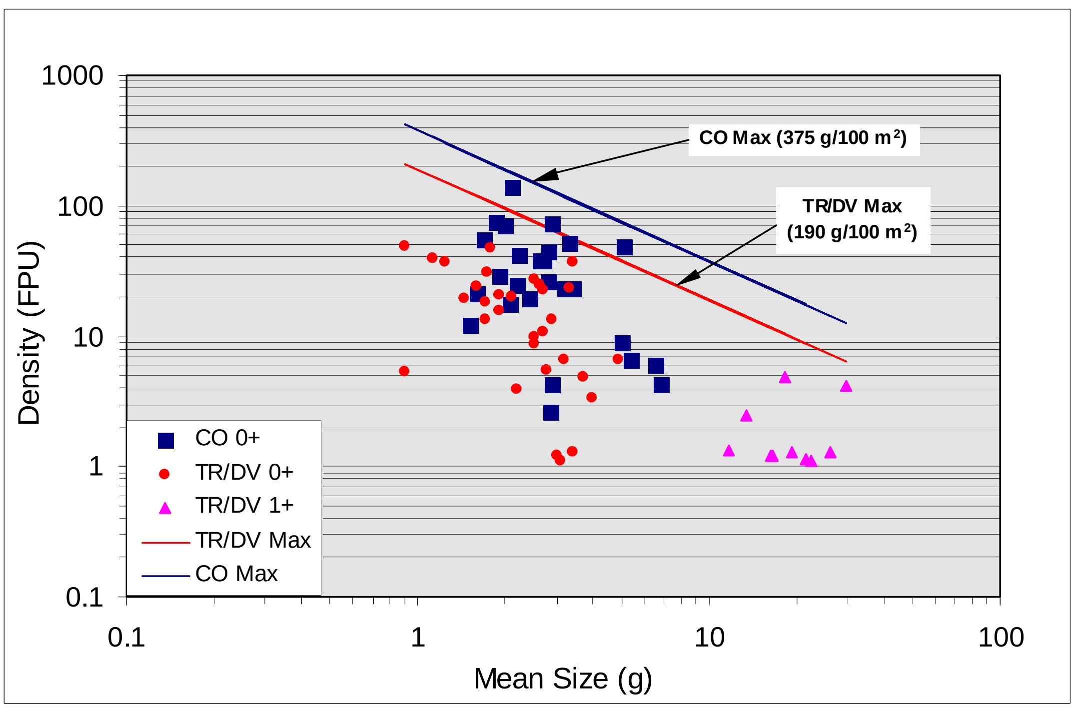


Figure 26. Scatterplot of observed fish densities against mean weight. Data are from the 13 electrofishing sites assessed in this study (September - October 1999) and the 10 sites assessed by VISRP (August 1999 and July - August 2000). Maximum biomass lines are based on the alkalinity models (Ptolemy 1993) and equate to 190 g · 100 m^{-2} for trout and Dolly Varden, and 375 g · 100 m^{-2} for coho.

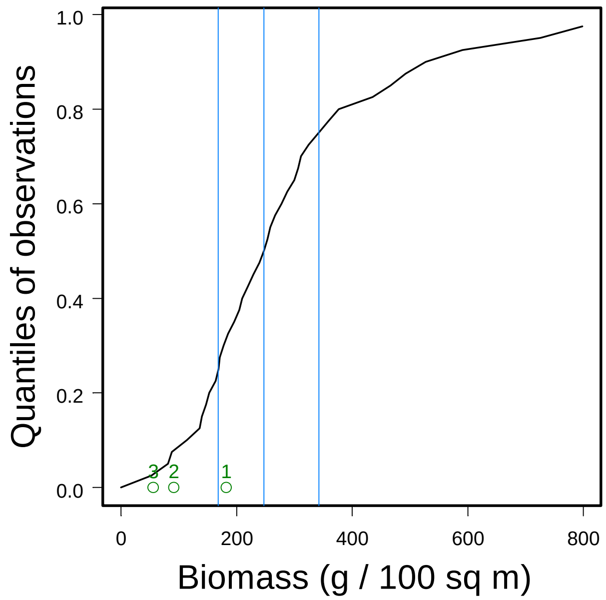


Figure 27. Quantile plot of Provincial electrofishing data, with quartiles (< 168; 168 – 247; 247 – 342; > 342) indicated by vertical blue lines. Mean fish biomass for Quinsam River sections 1 to 3, based on data collected for this study, are indicated in green.

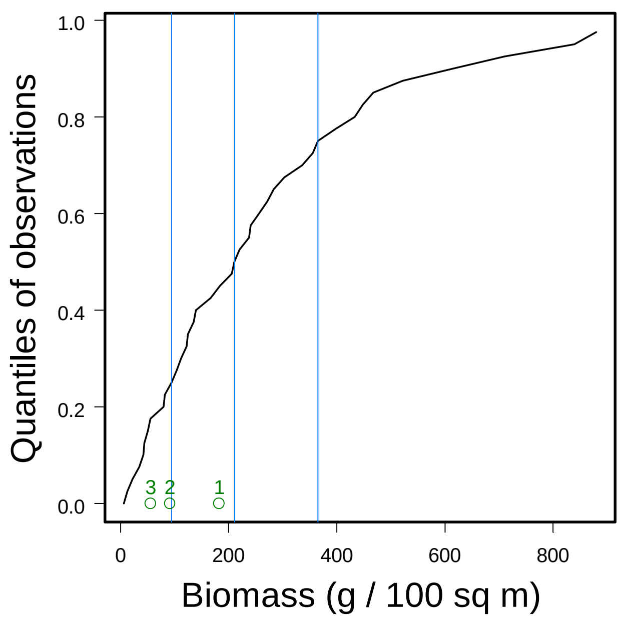


Figure 28. Quantile plot of regional electrofishing data (Coast Mountains and Island region of BC and US; data obtained from P. Higgins, BC Hydro), with quartiles (< 94.3; 94.3 – 211; 211 – 365; > 365) indicated by vertical blue lines. Mean fish biomass for Quinsam River sections 1 to 3, based on data collected for this study, are indicated in green.

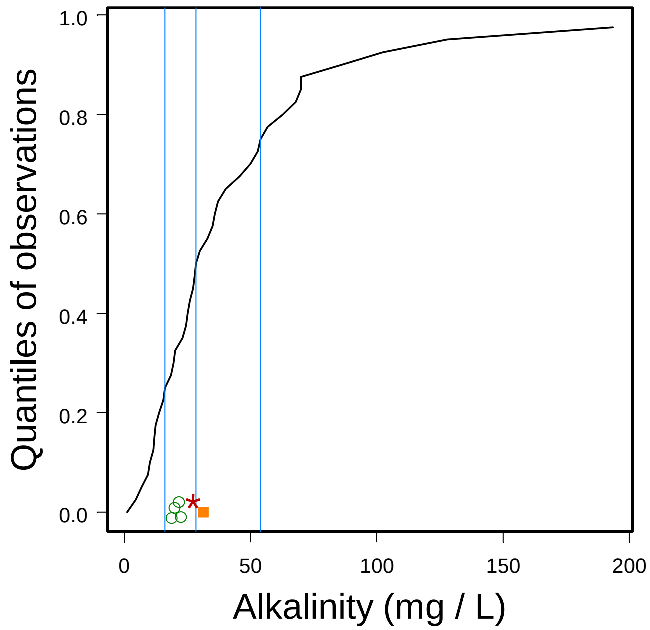


Figure 29. Quantile plot of Provincial alkalinity data, with quartiles (< 16.1; 16.1 – 28.5; 28.5 – 54; > 54) indicated by vertical blue lines. Alkalinity is a good predictor of biological productivity of BC streams (Ptolemy 1993). Water samples from this study and others (green circles = Quinsam River and orange square = Iron River see Component 1; red star = Provincial data) indicate that the Quinsam River is in the second quartile of streams in the province in terms of alkalinity level during low flow conditions.

Discussion

The objective of Component 3 was to identify and quantify fish use and assemblage in the Quinsam River mainstem between Wokas Lake Dam and the Campbell River confluence. Considerable information on the Quinsam watershed was already availably from previous environmental studies (summarized in Burt 2003). A decision was therefore made to address the objective by undertaking detailed electrofishing assessments at multiple locations throughout the mainstem, rather than attempting an overview survey of the river and its tributaries. This approach was approved by BC Hydro.

Habitat types and electrofishing sites.— The Quinsam River has a wide variety of aquatic habitat types, from steep bedrock-controlled canyon-like sections in the upper watershed to low-gradient alluvial sections in the lower watershed. In between, there are numerous other habitat types including lakes, marshes, bedrock cascades, riffles, glides and pools. Habitat types and their relative abundance and distribution are discussed in more detail in Component 1 and in Burt (2003).

Electrofishing sites were not selected at random—they were intentionally selected using subjective criteria intended to delineate habitats with high fish use (note the generally high PUW values in Table 26)—and this has implications for the interpretation of data from this study. The site selection procedures used by DBA and VISRP are consistent with Provincial electroshocking assessment protocols, but because different species and life stages were targeted at different sites interpretation of the results should proceed cautiously. For example, the sites selected by VISRP were targeted at steelhead, whereas DBA targeted different species at different sites. Since steelhead biomass is generally considerably lower than coho biomass the targeting of steelhead habitat by VISRP may downward bias total biomass estimates in the river, especially in section 1.

To some extent biases in site selection are offset by adjusting biomass estimates based on hydraulic suitability of a site (see Table 26). However, since fish select sites based on factors other than just hydraulic suitability this adjustment is likely imperfect. Similarly, since HSI curves have not been developed for all species (particularly non-salmonids) correction for site selection bias is not possible for some species. Sites were selected also for electrofisher sampling efficiency, which biases catches to those species and life stages that inhabit relatively shallow accessible portions of a river. Lack of parr-aged fish (1+ age group and older) observed in this study is in part due to sample sites being located in shallow habitats.

Fish assemblage.— Based on existing data (see Burt 2003) we know that the Quinsam River system supports several salmonid and non-salmonid fish species, and some species are present in both anadromous and resident forms. Anadromous salmonids include all five species of salmon (chinook, coho, pink, chum, and sockeye salmon) and two trout species (steelhead and cutthroat). Resident salmonids include rainbow and cutthroat trout, kokanee, and Dolly Varden char. Non-salmonids include coastrange sculpins, threespine sticklebacks, and lamprey.

Electrofishing assessments conducted for this study confirmed the presence of rearing salmon and trout over the full length of the Quinsam River below Wokas Dam. Coho were observed over the full length of the river; steelhead extended throughout the anadromous reaches; and cutthroat were observed only in the upper watershed. Other fish species were distributed sporadically and were relatively less abundant (Table 24). Species captured in anadromous reaches included steelhead, coho, chinook, threespine stickleback, lamprey and coastrange sculpin; in resident reaches (i.e., upstream of the anadromous barrier) cutthroat, coho, rainbow and coastrange sculpin were captured. The presence of coho within resident reaches is assumed to be due to the Quinsam Hatchery outplanting program.

Stock status.— Coho and steelhead/rainbow were the most numerous species captured in this study. This finding is not surprising since preferred habitats of coho and steelhead were targeted for assessment, and there is an ongoing program of outplanting hatchery-produced fry of these species. Alternatively, this finding may be an artefact of the sampling regime. For example, more cutthroat trout may have been found if small tributaries in the watershed were sampled; the presence of Dolly Varden primarily in the Iron River may be due to their preference for colder systems; and most chinook have migrated to sea by about mid June.

Statements regarding the status of Quinsam River fish stocks depend in part on the reference points used. Good measures of habitat capacity are elusive: in a general sense the number of fish produced by a stream depends on the availability of physical habitat for rearing fish (e.g., Bradford 1999; Bradford et al. 1997), but it is also influenced by a number of other factors, such as flow regime, nutrient concentrations, temperature, light availability, invertebrate production, and species interactions. The main factors limiting fish production may therefore be different among streams, and even within a stream may vary in time and space.

Ptolemy (1993) developed a habitat capacity model for BC based on alkalinity (a proxy for overall nutrient content of a stream) and electrofishing data from the Provincial database. There is one model for coho and a separate model for trout and char species as a group. Biomass predictions from these models are substantially greater than the direct estimates of biomass obtained from this study's electrofishing assessments, indicating that the Quinsam River salmonid populations are below (at some sites well below) carrying capacity. The alkalinity models suggest that habitat with appropriate depth and velocity criteria should be able to support biomass of 190 g · 100 m^{-2} for trout and char, and 375 g · 100 m^{-2} for coho. Observed (unadjusted) densities in 1999 (DBA and VISRP sites) tended to be well below these levels (Figure 26), particularly at sites in sections 2 and 3. The model does not, of course, indicate the reason for habitat being below capacity. It simply suggests that either the river is underseeded, conditions lead to uncharacteristically high mortality, or a combination of the two.

Examination of the available data and comparisons to other reference points indicate that this view may be somewhat incautious. One indication comes from the hatchery outplanting program, which has been releasing coho and steelhead smolts in the upper watershed in an attempt to increase utilization of the stream for rearing. The program has been in place since 1978 and survival rates have been monitored through the enumeration of emigrating smolts at the hatchery counting fence. Data from the monitoring program indicate that survival is dependent on the number of fish released (Figure 30). This density-dependent response is not likely to occur if the habitat is grossly underseeded. The fact that the pattern is observed separately in two different species adds weight to this inference. The hatchery release program could be used to elaborate the form of the response curve by adding observations beyond the present extremes of the relationship (i.e., by releasing very few fry in some years and considerably more fry in other years).

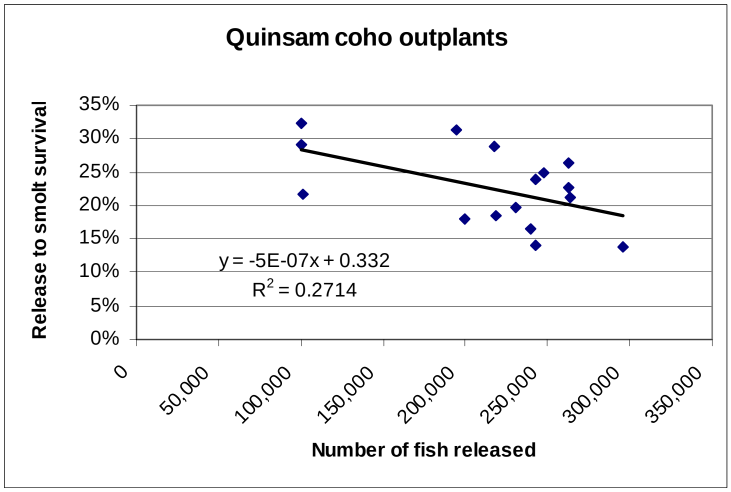
Other data also indicate that the Quinsam River may be producing fish at a rate that is reasonable for a stream of its general characteristics. Alkalinity is a good predictor of biological productivity of BC streams (Ptolemy 1993) and the Quinsam River is in the second quartile of streams in the province in terms of alkalinity level (Figure 29). Biomass data from this study were compared to Provincial and regional data (Figure 27 and Figure 28); the lower reaches of the Quinsam (i.e., section 1) was found to be in the second quartile of streams. However, sections 2 and 3, which are higher in the watershed have notably lower standing stock biomass than that observed in section 1.

A comparison was also made between observed coho standing stock biomass in the Quinsam and the coho smolt abundance data published by Bradford et al. (1997). They found (like other authors, e.g., Marshall and Brittain [1990]) that coho smolt output is strongly correlated to stream length. Based on the regression equation in Bradford et al. (1997) the Quinsam River, with a total stream length of 59.15 km (Burt 2003; this figure includes lakes), is predicted to produce, on average, about 52,000 coho smolts annually. Data from the counting fence operated by Quinsam Hatchery shows that mean coho smolt abundance from naturally spawning coho is 60,260 (min = 27,304; max = 156,116) plus an additional 45,614 (min = 21,932; max = 69,410) smolts from the outplanting program. The counting fence data thus indicate that the Quinsam River is producing slightly more wild coho on average, and considerably more coho smolts in total than would be predicted from Bradford et al.'s (1997) regional data. On a per km basis, the Quinsam River wild coho smolt output is equivalent to the 45th percentile in Bradford et al.'s (1997) database; output is equivalent to the 64th percentile when mean output of wild and outplanted fish are taken together.

This study found that Quinsam River standing stock fish biomass followed a gradient from the upper to lower watershed (Figure 24 and Figure 25), with considerably greater biomass occurring in the lowest section of the river. Electrofishing sites were intentionally selected using subjective criteria intended to delineate habitats with high fish use; electrofishing sites had high PUW values, even in sections 2 and 3 (Table 26). Thus, the gradient cannot be explained based simply on availability of suitable habitat — "good" habitat in the upper Quinsam had considerably fewer fish than hydraulically similar habitat in the lower Quinsam. Additionally, this pattern occurred despite the ongoing outplanting of hatchery fish.

Productivity gradients within streams and lake chains are common (Vannote et al. 1980; Newbold et al. 1981; Ward and Stanford 1983; Kling et al. 2000), so perhaps it is not surprising that this pattern was also observed on the Quinsam River. The mechanisms involved in creating this gradient were not addressed directly by this study, but may involve natural biotic and abiotic factors (e.g., spawning escapements or nutrient concentrations) or anthropogenic effects such as BC Hydro diversions of water. Determining the relative importance of different factors would require considerably greater study than a single assessment such as the one conducted in this study.

This study was commissioned as part of the data collection and analysis phase during development of a Water Use Plan for BC Hydro's Campbell River system. The WUP decision-making approach integrates information from all watersheds in the system and may make trade-offs among different resources depending on the values of stakeholders represented in the process. For this reason this report explicitly makes no recommendations regarding BC Hydro operations in the Quinsam watershed. Although this report was not formally written up prior to finalizing the WUP, information from the study was made available to the WUP Fisheries Technical Committee and was thus considered during the decision-making process.



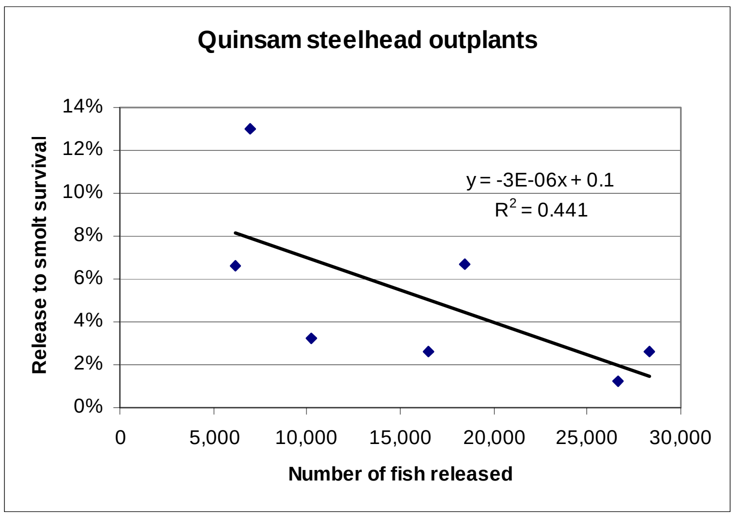


Figure 30. Quinsam Hatchery outplanting data show that survival of coho and steelhead smolts is density-dependent, indicating that the habitat is likely not grossly underseeded. (Note: the trendlines are indicated for description only and should not be used as predictive equations.)

COMPONENT 4. LAKES ASSESSMENT

Introduction

As part of the Campbell River Water Use Plan, BC Hydro commissioned a detailed biophysical assessment of the Quinsam River mainstem and its major lakes. The main tasks for the assessment were divided into five components:

Component 1. Linear habitat mapping and fish habitat assessments.
Component 2. Transect development and fisheries flow assessment.
Component 3. Standing stock assessment.
Component 4. Lakes assessment.
Component 5. Report preparation and summary.

This section of the report presents findings from Component 4, the Lakes Assessment. Field work was carried out in fall 1999 and spring 2000 by MJL Environmental Consultants. The report was written jointly by Solander Ecological Research and MJL Environmental Consultants, based on calculations and assessments predominantly by MJL.

The original objective of the Lakes Assessment was to identify and quantify operational impacts to Wokas and Upper Quinsam Lakes and to assess the fish and fish habitat values in Upper, Middle and Lower Quinsam Lakes[1] (BC Hydro 1999). Due to budget limitations, BC Hydro decided to focus the investigation on Upper Quinsam and Wokas Lakes. This decision seemed reasonable given that:

1. more information was already available for Lower and Middle Quinsam Lakes than for Upper Quinsam and Wokas Lakes, due to numerous environmental studies associated with the Quinsam Coal development.
2. BC Hydro operations potentially have a greater effect on Upper Quinsam and Wokas Lakes than Middle or Lower Quinsam Lakes, due to impacts associated with water storage and reservoir drawdown, and
3. no reconnaissance inventory information of fisheries values was available for the inlet streams to Upper Quinsam and Wokas Lakes that were potentially impacted by BCH operations.

A brief review of the natural resources of the Quinsam watershed is presented in the General Introduction to this report. A more extensive review is presented in Burt (2000).

Methods

The Lakes Assessment included field and office review of Wokas Lake, and Upper, Middle, and Lower Quinsam Lakes. Fieldwork was conducted in the fall of 1999 and spring of 2000. The

[1] Although the gazetted name for the lowest elevation of the three Quinsam lakes is "Quinsam Lake," we refer to it in this report by its common alias "Lower Quinsam Lake" to ensure a distinction among the three lakes.

location of the study lakes within the Quinsam watershed is shown in Figure 1 in the General Introduction.

The objectives of the Lakes Assessment were:

1. to upgrade the level of fisheries information at Upper Quinsam and Wokas Lakes and their tributaries,
2. to identify and quantify operational impacts to Wokas and Upper Quinsam Lakes, and
3. to assess Upper, Middle, and Lower Quinsam Lakes for operational issues which may affect fish or fish habitat.

To address these objectives, the following investigations were conducted:

1. a review of historic operations data,
2. a reconnaissance inventory of tributaries to Upper Quinsam and Wokas Lakes,
3. bathymetric profiles of selected sites in Upper Quinsam and Wokas Lakes,
4. calculations of theoretical production capability of Lower, Middle and Upper Quinsam Lakes, and
5. assessment of drawdown-related effects and access for fish near stream mouths in Lower Quinsam, Middle Quinsam, Upper Quinsam and Wokas Lakes.

Historic Operations

A review of historic operations data was not part of the original terms of reference, but a brief treatment is useful here as it sets the context for evaluation of water management in the watershed. We therefore reviewed available reservoir elevation data, and historic diversion flows.

Reservoir elevation data are collected at a staff gauge near the outlet of Wokas Lake. Historic elevation data date back only to early 1998. The available data were plotted as a time series to indicate the range of reservoir elevations and the temporal patterns of elevation changes.

Diversion flows have been directly measured only since 1997, by a DCP installed in the diversion canal. Recently, BC Hydro has modeled Quinsam diversions to produce an estimated historic diversion record. The standard caveats apply to synthesized data, but the data nevertheless provide an excellent indication of the temporal patterns of diversion.

In the context of the Lakes Assessment the historic diversion record is relevant predominantly to understand how water management affects residence time in Middle and Lower Quinsam Lake. Daily diversion volumes were therefore plotted as a proportion of lake volume.

Upper Quinsam and Wokas Lake Tributaries

The terms of reference limited the scope of this work to an abbreviated reconnaissance inventory of the tributary streams to Upper Quinsam and Wokas Lakes. Habitat surveys and fish sampling were conducted on the lowest reach of the 14 inlet streams indicated on 1:20,000

TRIM maps. The initial inventory took place during October 1999, when tributary streams were at the low flow stage of late summer.

Sampling was conducted according to RIC standards (British Columbia Ministry of Fisheries 1998). Field data were recorded on RIC Site Cards and Fish Summary Forms. The sites were photographed using a Yashica Microtec 35mm camera and the images were stored in digital format.

Stream channel measurements were taken using a stadia (survey) rod, 50 m tape, meter stick, and hip chain. Stream gradients were measured using an Abney level or a clinometer.

A 2-person field crew used electrofishing and visual observations to collect fish information. Electrofishing was conducted using a Smith-Root Model 12B-backpack electrofisher; stop nets were not used. Captured fish were anaesthetized in a bucket with Alka-Seltzer, measured for fork-length, then released at the capture site.

Bathymetric Profiles at Upper Quinsam and Wokas Lakes

Existing bathymetric data for Upper Quinsam and Wokas Lakes were of low resolution. Additional sounding data were collected to augment the existing data, with particular attention paid to shallow shoal and nearshore areas of the lakes. Data were collected in October 1999, when the water levels of Upper Quinsam and Wokas Lakes were near the midpoint of their drawdown range. Both transects and spot sounding were used to collect bathymetric data. The intent was to use these data to better assess effects of reservoir drawdown.

MJL was directed to focus data collection efforts within the operational range of Wokas and Upper Quinsam Reservoirs (362.26 m to 364.54 m). It should be noted however, that water levels may exceed this range depending on inflows, evaporation, and subsurface drainage (see Figure 31). Field observations of water level marks on the dam indicate normal high water of 365.15 m, which was used as the upper limit for the study.

Sounding Transects.**—**Transects were selected at areas where detailed information was required, such as shoals, bays, or stream mouths. A 2-person crew used a 4 m boat equipped with a Lowrance X-16 recording depth sounder at a boat speed of 1 m/s to record sounding plots along each transect. A GPS with a differential beacon receiver (DGPS) was used to record the Universal Transverse Mercator (UTM) coordinates of the start and finish locations of each transect. These endpoints were later plotted on a digital map using Arcview mapping software. As an additional reference, transect endpoint locations were identified on 1:10,000 scale air photos, using a laser range finder to determine the distance from the high water mark to the sounding location.

Spot Sounding.**—**Spot soundings were used to locate the 362.3 m GSC elevation at points along the shoreline, at embayments, and shoals. The 362.3 m contour was used to approximate the shoreline at the low point of the drawdown zone.

A 2-person crew used a 4 m boat equipped with a stadia rod and a laser range finder to collect the data. The boat was held on station directly over the 362.3 m elevation while a DGPS was used to establish the position. At sites with poor DGPS reception locations were recorded on a 1:10,000 scale air photo by using the laser range finder to measure the distance from the high water mark to the sounding location. Positions were later plotted on a digital map using Arcview mapping software.

Production Capability of Lakes

Several models are available for calculating the theoretical production capability of lakes. The morphoedaphic model (Ryder et al. 1974) and the yearling capacity model (Facchin 1983) are frequently used in British Columbia. The morphoedaphic model has been found to work poorly for reservoirs, especially those with high flush rates (Ryder et al. 1974), so it was not used here. In contrast, the yearling capacity (YCAP) model is applicable because it considers the shoal areas, which can be very productive (Johnston et al. 1991). Upper Quinsam Lake has considerable shoal areas that are affected by operational drawdown.

Originally devised as a stocking tool for lakes in southern interior BC, the YCAP model has been modified for oligotrophic coastal lakes. The coastal YCAP and corresponding production capability is expressed as follows (Peter Law, personal communication):

$$YCAP = TDS\ (((2.47 \times \text{shoal area}) + (0.247 \times \text{surface area})) \times 0.5)$$

$$PROD = YCAP \times \text{survival} \times \text{growth}$$

where,

YCAP is the yearling capacity (number of fish),
TDS = total dissolved solids (mg L^{-1})
PROD = annual production (kg yr^{-1})
shoal area = shoal area of the lake (ha)
surface area = surface area of the lake (ha)
survival = survival to age 2 (assumed here to be 40%)
growth = growth increment (assumed here to be 0.34 kg)

The theoretical production capability of Lower, Middle, and Upper Quinsam and Wokas Lakes was calculated using these formulae.

Physical features of the study lakes were derived from historical data, and are summarized in Table 29.

The effect of reservoir drawdown on fish production of Upper Quinsam and Wokas Lakes was assessed by comparing YCAP calculations at full pool elevation (365.1 m) and drawdown elevation (362.3 m). Bathymetric data collected in 1999 was combined with historic bathymetric data to estimate the surface area of Upper Quinsam and Wokas Lakes at full pool and minimum reservoir elevation.

Obstructions and Effects of Drawdown at Stream Mouths

Tributary stream confluences were examined for indications that fish habitat was affected by changing reservoir levels. Investigations focussed on two main concerns:

1. Potential access problems at stream mouths that could prevent spawning fish from entering the stream, or juveniles from leaving the stream during low summer flows, and
2. The effects of drawdown at the mouth of each stream, and whether these areas are utilized as spawning habitat by the cutthroat trout population in the lakes.

Examinations occurred primarily at tributaries of Upper Quinsam and Wokas Lakes (see methods in section "Upper Quinsam and Wokas Lake Tributaries"). The tributaries were first examined during the low flow period in September and October 1999, and then re-visited during March and April 2000 so that access issues and spawning locations could be assessed during the spring spawning period of cutthroat and rainbow trout. The lower reach of each stream was visually inspected for signs of de-watering and access obstructions. The drawdown zone at the mouth of each tributary was also inspected for spawning activity or indications of recent spawning, such as redds. Locations were recorded and the elevations were surveyed using a stadia rod and a Pentax AL-6 Autolevel.

Limited investigations were also conducted at tributaries of Middle and Lower Quinsam Lake. Examination of these tributaries occurred only in April 2000, and consisted of a brief overview assessment of the stream mouths—they were not sampled for fish and were not assessed according to RIC standards. Eight tributaries of Lower Quinsam Lake were assessed, and nine tributaries of Middle Quinsam Lake were assessed. The confluence area of these tributaries was assessed for quality of fish habitat and potential effects of BC Hydro operations on fish or fish habitat. The assessment was based only on a visual assessment.

Results

Historic Operations

Historic reservoir elevation data are plotted in Figure 31. Elevation data date back only to early 1998, so it is not possible to assess whether the period on record differs substantially from other periods. Minimum reservoir elevation over the period is 360.90 m, and maximum elevation is 364.91 m.

Historic daily diversion flows (based on the BC Hydro modeled data) are plotted in Figure 32 and Figure 33 as a proportion of lake volume for Middle and Lower Quinsam Lakes. These plots indicate how lake retention time is affected by the diversion of Quinsam River flows.

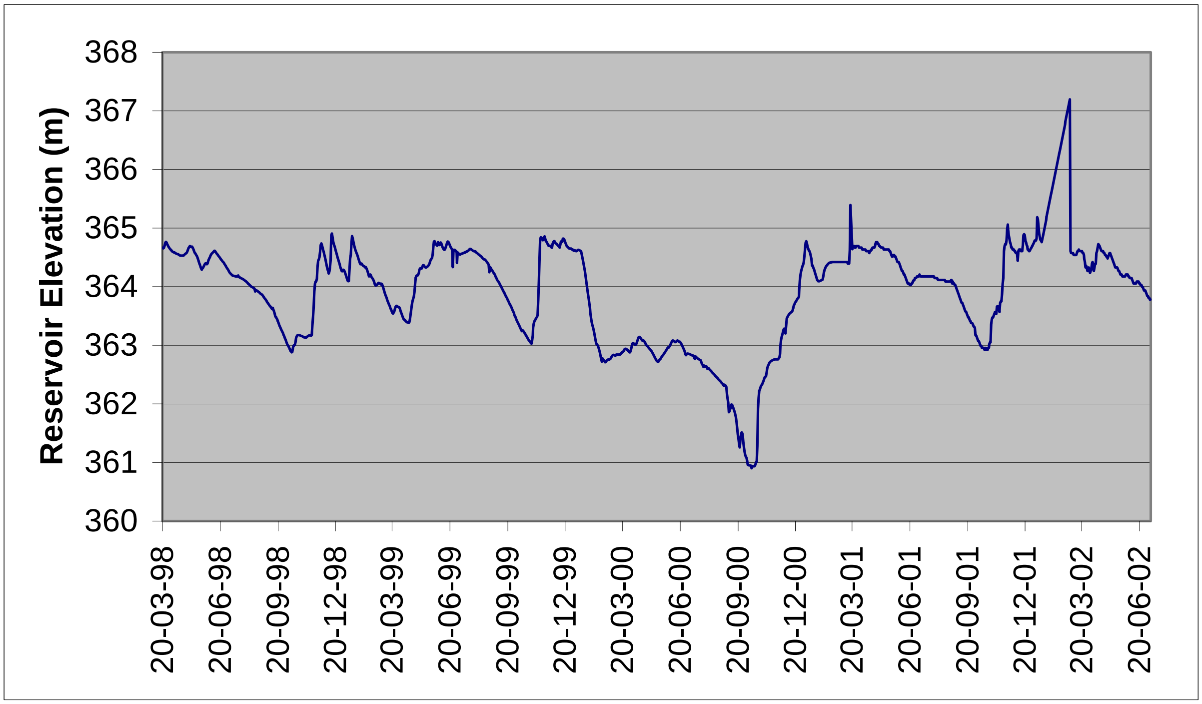


Figure 31. Historic reservoir elevations for Wokas Reservoir, 1998 – 2002 (data from BC Hydro). The relatively deep drawdown during fall of 2000 was accomplished with the use of large pumps, and was done to accommodate fish in Miller Creek. Note: the data used to create this plot were not QA'ed, and it appears that the elevations recorded in March 2002 are in error.

Upper Quinsam and Wokas Lake Tributaries

Locations of the 14 tributaries assessed in the field are shown in Figure 34. Most of the tributaries do not have an assigned Watershed Code, so they are referred to here by site number as indicated on Figure 34. A summary of habitat measures is presented in Table 27, and a summary of fish sampling results is presented in Table 28. Only five of the 14 tributaries were fish bearing at the time of the survey. Individual Site Cards and Fish Forms are presented in the Technical Addendum.

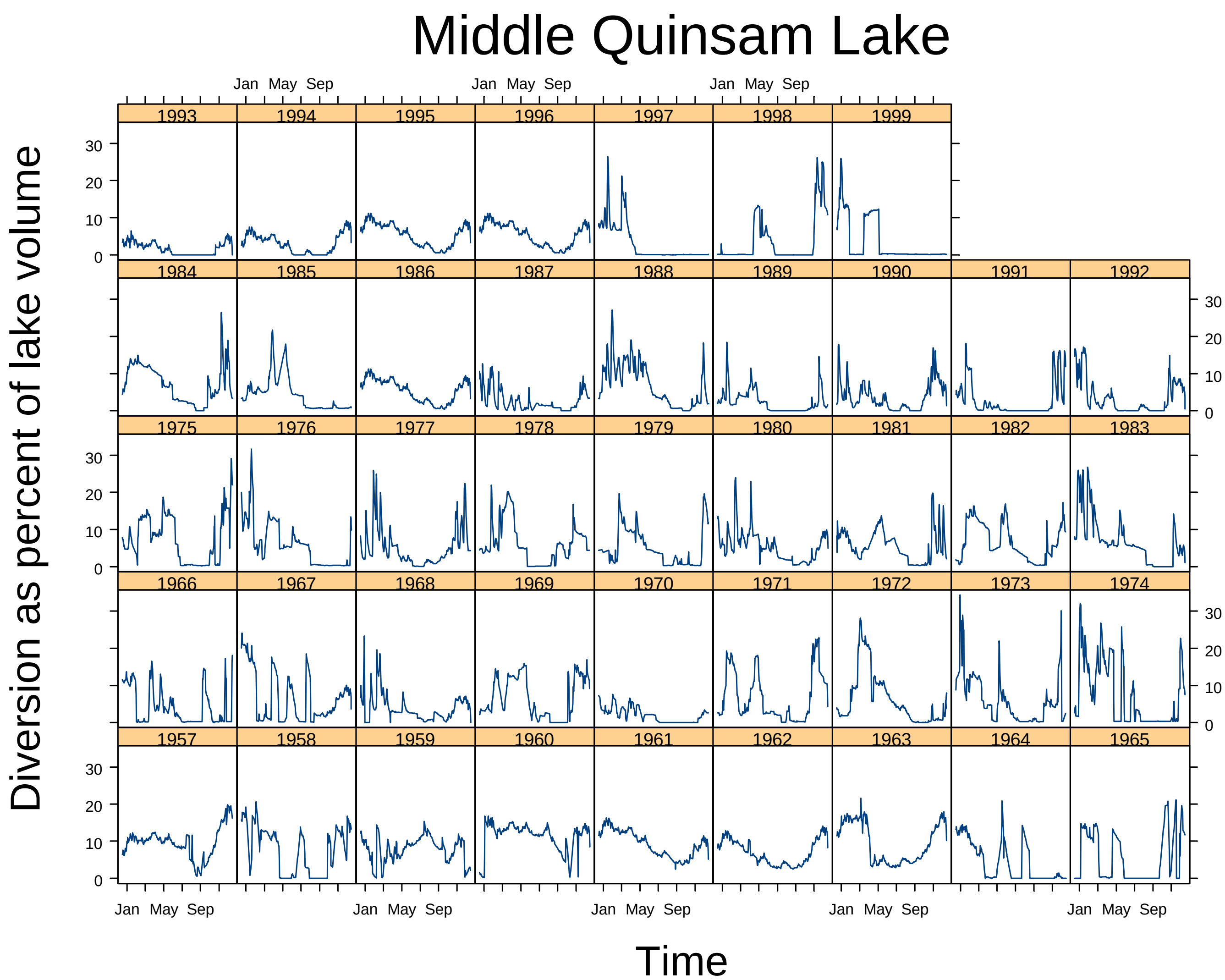


Figure 32. Historic inflow from the Quinsam River diverted from Middle Quinsam Lake. Historical inflow factors in constraints such as minimum flow orders, which have changed over time. Inflow is presented as daily inflow as a proportion of lake volume; 100% represents replacement of the entire lake volume within a 1-day period. Note that data indicate diversion *from* the system. Data are from BC Hydro and represent an amalgam of measured and synthesized values using standard hydrologic techniques.

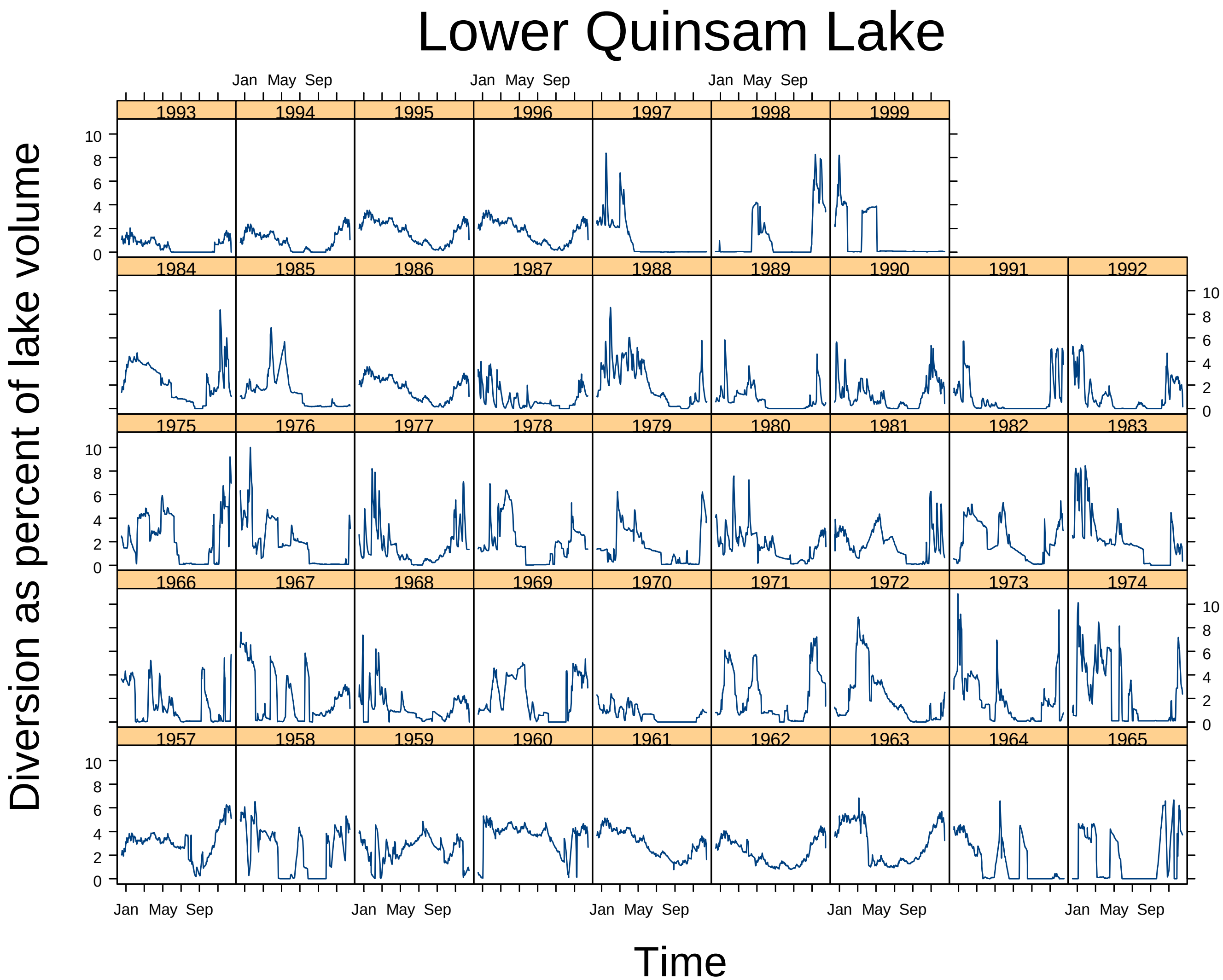


Figure 33. Historic inflow from the Quinsam River diverted from Lower Quinsam Lake. Historical inflow factors in constraints such as minimum flow orders, which have changed over time. Inflow is presented as daily inflow as a proportion of lake volume; 100% represents replacement of the entire lake volume within a 1-day period. Note that data indicate diversion *from* the system. Data are from BC Hydro and represent an amalgam of measured and synthesized values using standard hydrologic techniques.

Table 27. Summary of habitat surveys conducted on streams tributary to Upper Quinsam and Wokas Lakes, October 5 - 9, 1999.

Stream Name	Site	Average Channel Width (m)	Average Gradient (%)	Fish Species Present	Comments
unnamed	1	1.6	1.3	--	Dry. Good rearing habitat, but intermittent flows
Mine Creek	2	4.1	1.5	CCT, CC	Severely aggraded
unnamed	3	2.9	1.0	--	Dry.
Sihun Creek	4	31.5	3.0	CCT, CAS, CAL, CC	Good potential fish habitat, but de-watered when sampled
Hawkins Creek	5	6.3	4.8	CCT, CAS, CC	Premium fish habitat. Gravel fan at mouth de-waters
unnamed	6	1.5	13.0	--	Dry when sampled
unnamed	7	1.9	15.0	--	Dry with some pools. Lack of fish suggests intermittent most of summer.
unnamed	8	1.8	16.5	--	Limited fish values. Channel appears aggraded.
unnamed	9	2.4	9.0	CCT	Nice looking fish habitat but not accessible from lake at low flows
Quinsam River	10	4.6	7.0	--	Heavily aggraded, all of R1 is dry. Moderate fish values if flowing.
unnamed	11	1.7	28.0	--	Dry. Fair fish values at lower end.
unnamed	12	11.2	2.3	CCT	Aggraded channel, signs of volatile flows
unnamed	13	2.5	24.0	--	Dry. Steep, flashy, limited fish values
unnamed	14	2.4	5.0	--	Intermittent, but possible fish use during higher spring and summer flows

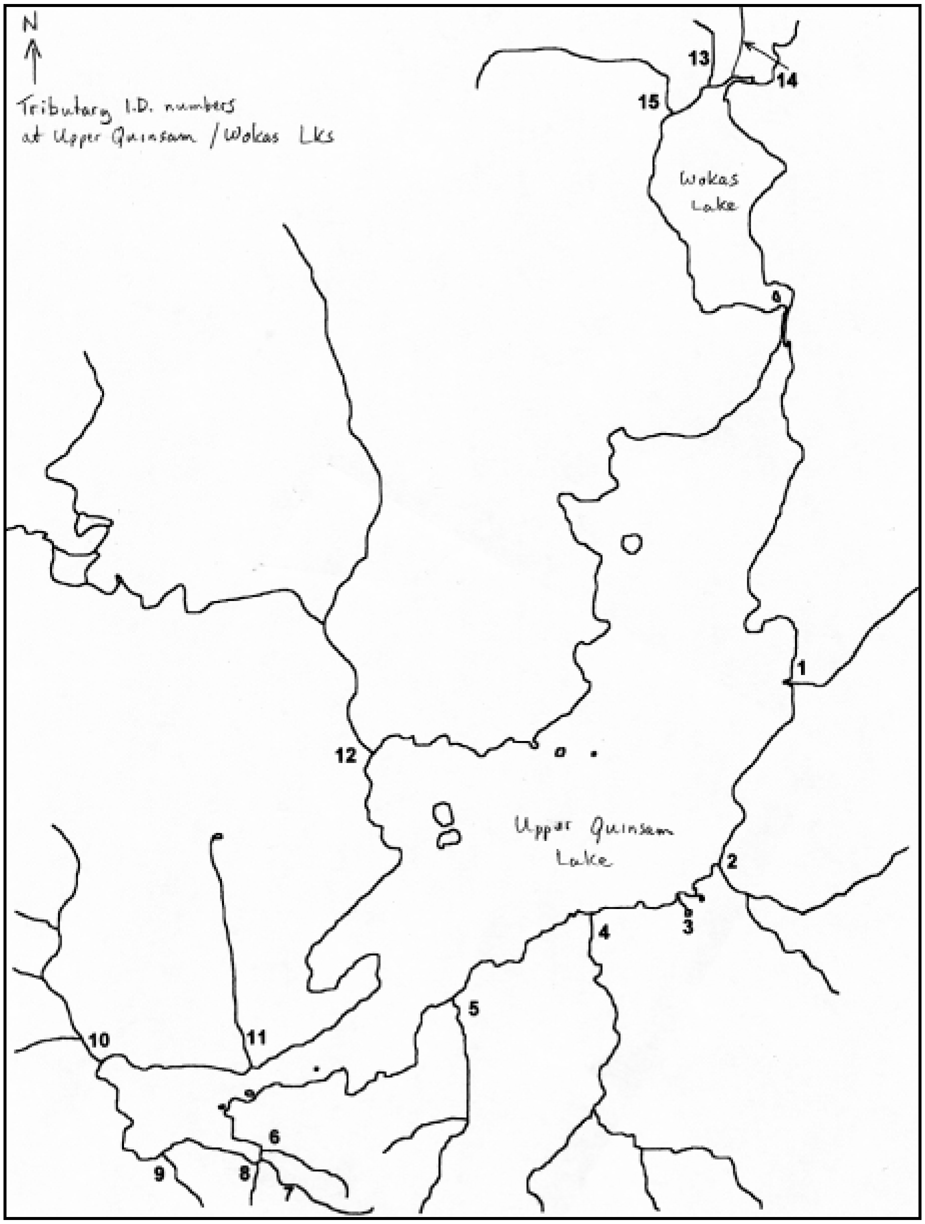


Figure 34. Map of Upper Quinsam Lake showing the locations of tributaries assessed during this study. Tributary ID codes (1 – 14) are used since Watershed Codes are not available for all tributaries.

Table 28. Fish summary from samples collected at inlet streams of Upper Quinsam and Wokas Lakes, October 5 - 9, 1999.

Site	Length of tributary sampled (m)	Species [2]	Fish Caught	Length Range (mm)	Weight Range (g)
1	No sampling [1]	--	--		
2	114	CCT	9	32 - 79	0.2 - 4.1
		CC[3]	6	29 - 60	0.2 - 2.2
3	No sampling [1]	--	--		
4	200	CCT	31	36 - 268	0.4 - 11.6 [4]
		CAS	6	64 - 84	2.6 - 7.2
		CAL	3	68 - 81	2.9 - 5.3
		CC[3]	8	43 - 53	0.7 - 1.3
5	100	CCT	12	33 - 74	0.4 - 4.3
		CAS	9	67 - 118	2.3 - 20.8 [5]
		CC[3]	7	43 - 75	0.7 - 3.1 [6]
6	20	--	0		
7	50	--	0		
8	No sampling [1]	--	--		
9	100	CCT	4	73 - 133	4.2 - 22.9
10	150	--	0		
11	No sampling [1]	--	--		
12	200	CCT	1	64	2.9
13	No sampling [1]	--	--		
14	No sampling [1]	--	--		

1 Stream was dry at time of survey and was not sampled for fish
2 CCT: coastal cutthroat trout, CAS: prickly sculpin, CAL: coastrange sculpin, CC: sculpin (*spp*)
3 Too small to identify to species in the field
4 Weights from a sub-sample of 29 juvenile CCT
5 Weights from a sub-sample of 7 CAS
6 Weights from a sub-sample of 4 CC

Bathymetric Profiles at Upper Quinsam and Wokas Lakes

The bathymetric map based on historic data is available through "FishWizard" on the BC Fisheries web site (http://www.bcfisheries.gov.bc.ca/fishinfobc.html), and is included in the Technical Addendum to this report. The shoreline perimeter of Upper Quinsam and Wokas Lake at maximum and minimum water elevation is shown in Figure 35.

Production Capability of Lakes

YCAP values are based on physical features of a lake. Physical data for the study lakes are summarized in Table 29. Production capability estimates indicate that Upper Quinsam Lake is theoretically capable of the highest production of the study lakes, mostly due to its larger size.

Table 29. Characteristics of the study lakes and their theoretical fish production capability as estimated using the YCAP model.

Lake	Area (ha)	Mean Depth (m)	TDS (mg/l)	Shoal Area (ha)	Production Capability (kg/yr) [1]	Production Capability (fish) [2]
(Lower) Quinsam	117	8	50	71	720	2118
Middle Quinsam	71	4	46	56	495	1455
Upper Quinsam	504	13	30	153	1025	3015
Wokas	61	14	30	22	142	417

Upper Quinsam and Wokas Lakes have large shoal areas that contribute to productivity of the lakes. Comparison of productivity at maximum and minimum reservoir elevations indicates that the production of Upper Quinsam Lake at low pool is 22% less than it is at full pool, and Wokas Lake at low pool is 20% less than at full pool (Table 30). Depth soundings indicated steep slopes along the edge of the shoal areas, which remain deep even as the lake levels drop. As a result, new littoral areas are not recruited at the same rate that shoal area is de-watered as the reservoir is drawn down.

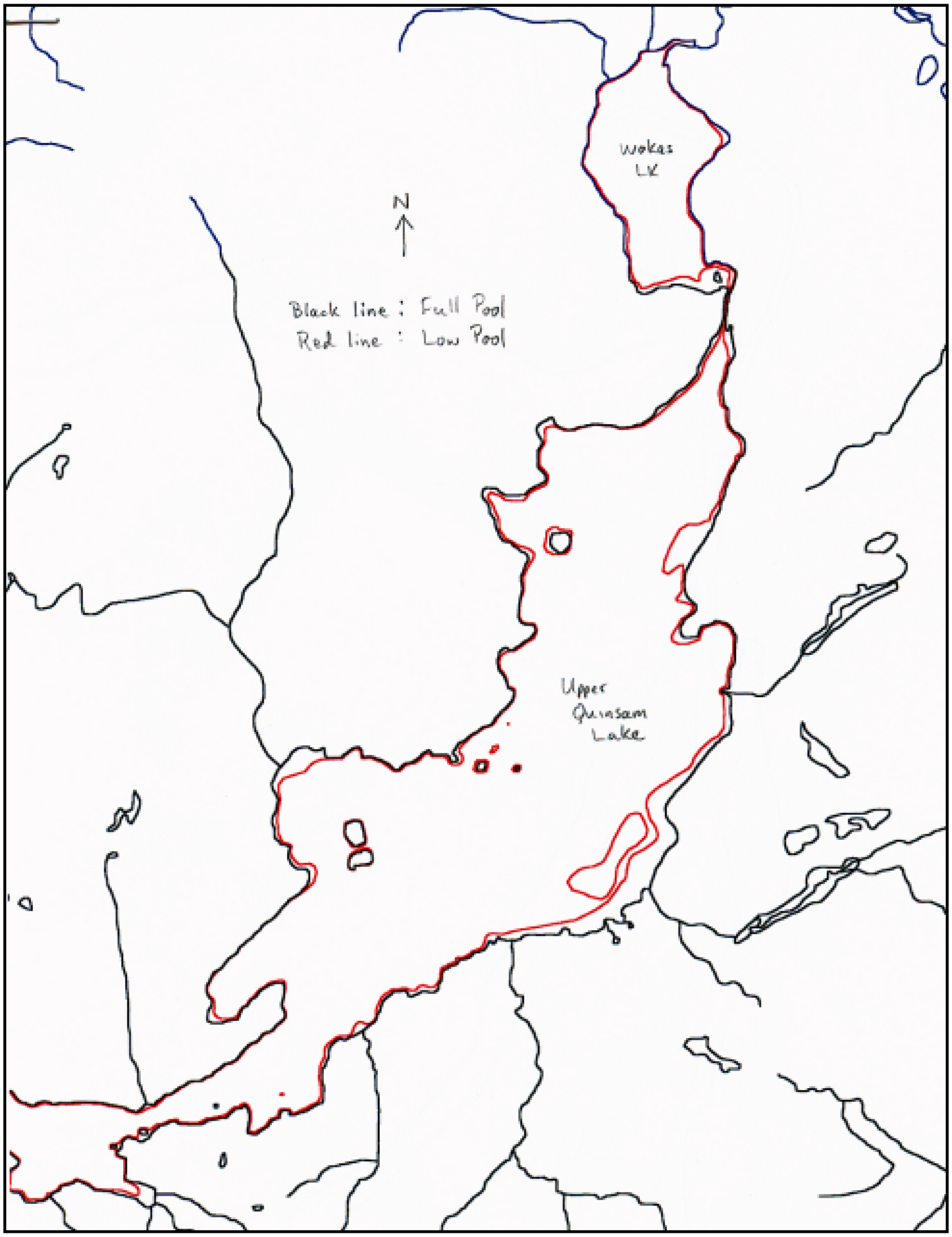


Figure 35. Map of Upper Quinsam and Wokas Lake showing the outline at maximum water elevation (black) and minimum elevation (red).

Table 30. Comparison of theoretical production capability of Upper Quinsam and Wokas Lakes when at full pool or low pool.

Lake	Area (ha)	Mean Depth (m)	TDS (mg/l)	Shoal area (ha)	Theoretical Production Capability (fish) [2]
Upper Quinsam --Full Pool	504	13	30	153	3,015
Upper Quinsam -- Low Pool	454	13 [1]	30	113	2,348
Wokas -- Full Pool	61	14	30	22	417
Wokas -- Low Pool	55	14 [1]	30	17	334

[1] Mean depth not available for these lakes at low pool. Substituted full pool values.

[2] Assumes 40% survival from yearling to Age 2 and an average fish weight of 0.34 kg.

Obstructions and Effects of Drawdown at Stream Mouths

Upper Quinsam and Wokas Lakes.—Fish passage in the main tributaries to the reservoir was found to be restricted during late-summer flows. The lower sections of Hawkins, Sihun, Mine, Tributary 12, and Upper Quinsam Creeks were de-watered, precluding fish passage into or out of these streams. These conditions appeared to be mostly due to severe stream channel aggradation. The lack of access appeared to be independent of reservoir levels since the lower reach of the stream was often dry. Additional obstructions were found at some of the smaller streams (Table 31).

Table 31. Summary of obstructions to fish passage in tributaries of Upper Quinsam and Wokas Lakes, October 5-9, 1999.

Site	Reach	Type	Height (m)	Description
2	1	De-watered channel	n/a	Seasonal obstruction; extends throughout Reach 1
4	1	De-watered channel	n/a	Seasonal obstruction extends upstream from lake for 400 m
5	1	De-watered channel	n/a	Seasonal obstruction at the gravel fan at mouth of stream
9	1	De-watered channel	n/a	Seasonal obstruction extends upstream from lake for 50 m
		Falls	10	Barrier to upstream migration located 140 from lake
10	2 [1]	De-watered channel	n/a	Seasonal obstruction; extends from lake u/s ~ 400m
12	1	De-watered channel	n/a	Seasonal obstruction; extends throughout Reach 1

[1] Site 10/Reach 2 is the second reach of the Quinsam River above Upper Quinsam L.

Fish passage was not found to be restricted when the tributaries were re-visited in the spawning period during the following spring. Although reservoir elevation was relatively low, access to the main spawning streams was now possible due to higher discharge in the streams.

An estimated total of 166 cutthroat trout redds were observed on tributary fans (130 redds on Hawkins Creek, and 36 redds on Sihun Creek). Evidence of these redds was observed in the fall, although the redds were from 1999 spring spawning. The redds were on gravel fans within the drawdown zone at the mouth of some streams, and were most numerous on Hawkins and Sihun Creeks (Figure 36).

Stream channels on the gravel fans are unconfined and apparently change course from year to year. As a result, the location and elevation of redds also change over time.

Figure 36. Cutthroat trout redds from spring spawning at the mouth of Hawkins Creek, as viewed in October 2000. (photo: MJL)

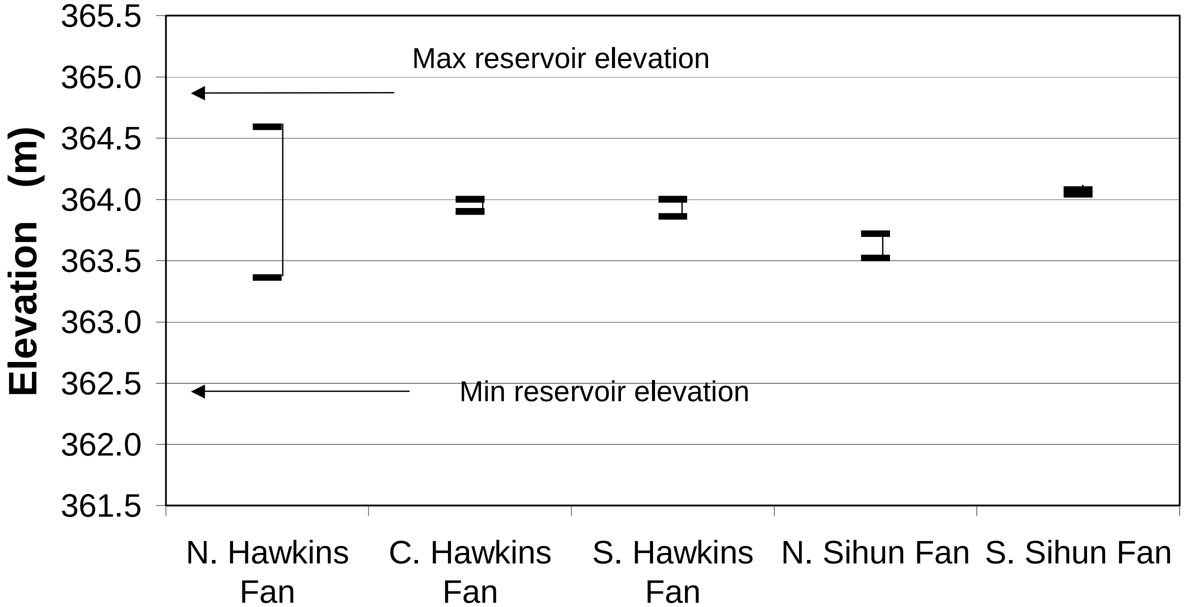


Figure 37. Elevation limits of cutthroat trout redds at the north (N), central (C), and south (S) forks of stream mouths on gravel fans in the drawdown zone of Upper Quinsam Lake, 1999.

Middle Quinsam Lake.—The normal range of water level fluctuation was estimated to be approximately 0.75 - 1.0 m. At the time of this survey (April 12, 2000), the lake was 0.73 m below the normal high water level. The staff gauge on the bridge at the lake outlet was at 0.45 m. The Quinsam River discharge (at the Argonaut gauge) was 0.4 cms during our survey.

The lower portion of eight tributary streams was examined as well as the lake outlet area (Figure 38). Summaries of field notes are presented in the Technical Addendum for this report.

Potential operational issues appear to occur only for the inlet and outlet streams to Middle Quinsam Lake. A summary of observations at each these sites is presented below.

Inlet

The area between transect T-069 (see map of transect locations in Component 2) and Middle Quinsam Lake was examined, and found to contain premium trout spawning and rearing habitat. 168 live trout redds were observed in this section (Figure 39), which appeared to be from cutthroat trout spawners. Redds were in water depths of 5 cm to 50 cm, although most were in 10 to 20 cm of water.

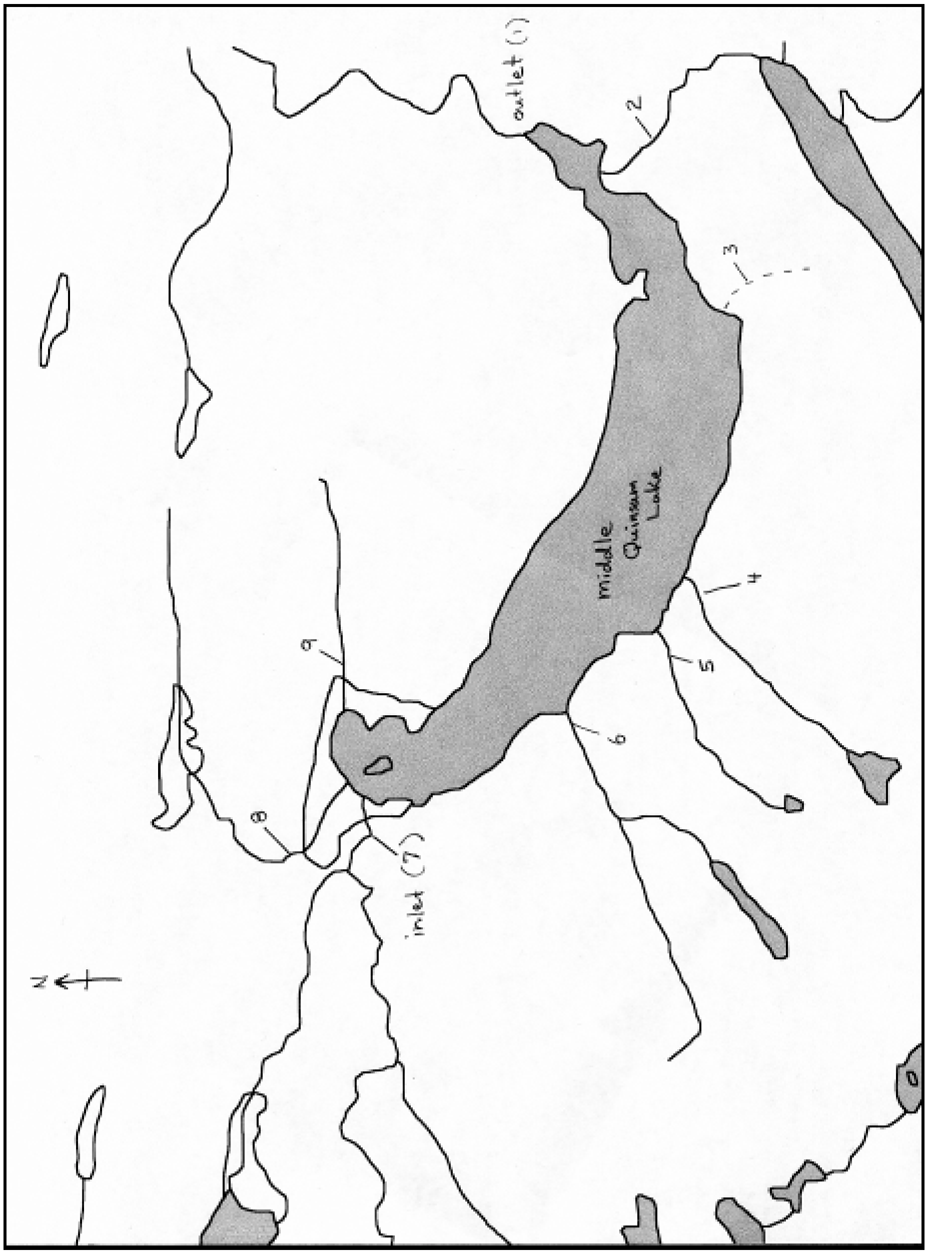


Figure 38. Map of Middle Quinsam Lake showing the locations of tributaries assessed during this study. Tributary ID codes (1 – 9) are used since Watershed Codes are not available for all tributaries.

Operational issues at this location centre around flow management, with greatest effect coming from flow decreases. Flow reductions during the trout spawning and incubation window (late January to June) may de-watered redds. Flow increases at any time during this same period would be unlikely to cause any detrimental effects such as bedload movement or scour because historical high flows have probably already scoured the susceptible areas.

Figure 39. Twenty trout redds were observed in this run in Tributary 7 (Quinsam River), just upstream of Middle Quinsam Lake, April 12, 2000. (photo: MJL)

Outlet

The area directly beneath and upstream of the bridge is functioning trout spawning habitat (Figure 40). We counted 18 live redds in the approximately 16 m^2 of functional spawning habitat. The size of the redds and substrate suggested that the spawners were relatively large fish, perhaps cutthroat trout. The 18 redds were in water that ranged from 8 cm to 50 cm. The shallow redds were very close to de-watering at these flows.

Operational issues at this location centre around flow management. If flows, and hence water levels are reduced at any time during the period from late January to June, any redds excavated in the shallows during previous high water levels may become de-watered.

Figure 40. Trout spawning area at outlet of Middle Quinsam Lake on April 12, 2000. (photo: MJL)

Lower Quinsam Lake.—The normal range of water level fluctuation was estimated to be approximately 0.45 m, a range that is similar to many of the non-regulated lakes in the Campbell River watershed (Rutherford and Lough 1999). At the time of survey, the lake was 0.35 m below the normal high water level, and the Quinsam River discharge (at the Argonaut gauge) was 0.4 cms.

The location of all streams examined is indicated on Figure 41. Summaries of field notes are presented in the Technical Addendum for this report.

Operational issues appeared to be a possibility only for the inlet stream to Lower Quinsam Lake. A summary of observations at this site is presented below.

Inlet

The inlet area has premium trout spawning and rearing habitat in the lower 100 m. Three trout redds were observed at a water depth of 0.6 m in the first gravel patch upstream of the confluence of Quinsam Lake. The premium habitat continued upstream as far as we could see.

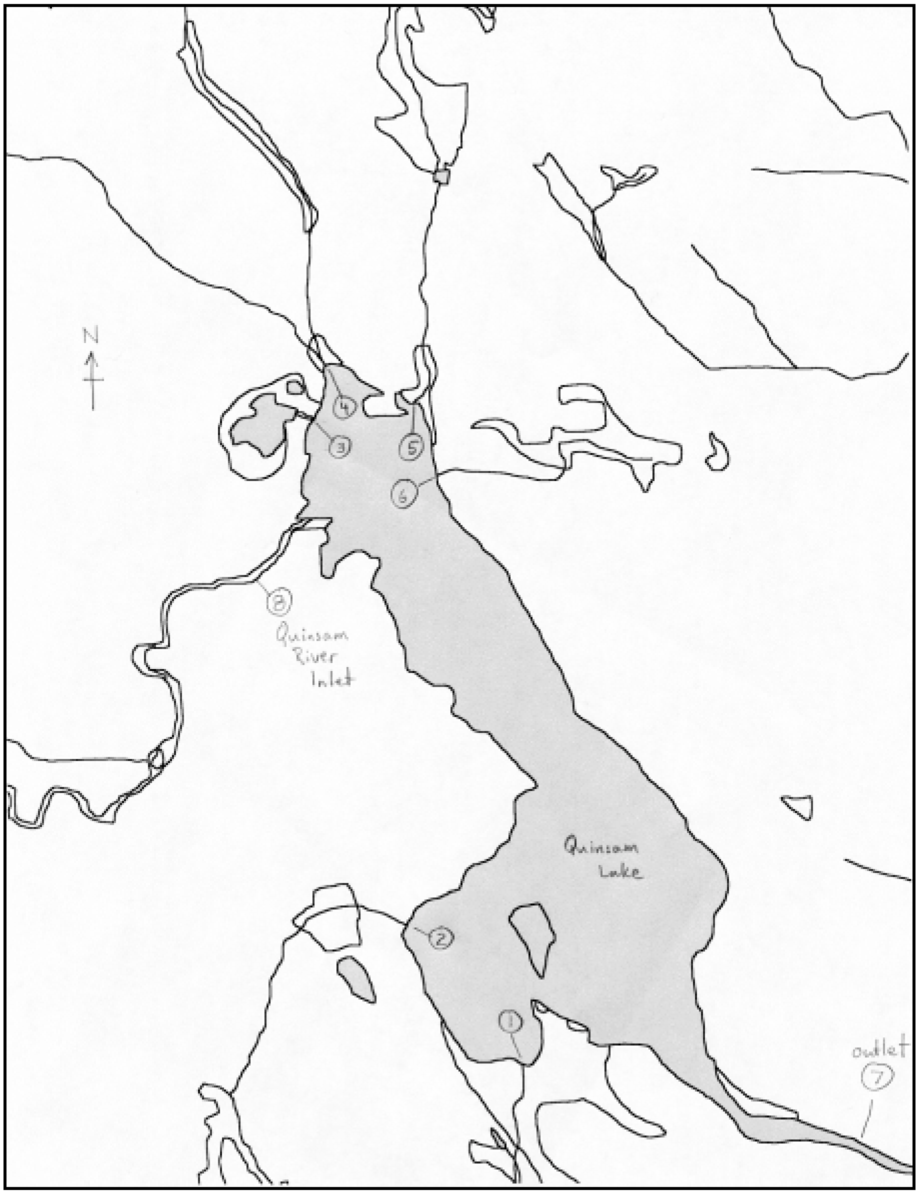


Figure 41. Map of Lower Quinsam Lake showing the locations of tributaries assessed during this study. Tributary ID codes (1 – 8) are used since Watershed Codes are not available for all tributaries.

The gravel fan at the mouth of the stream was partially de-watered when we viewed it at these water levels (Figure 42), although much of the fan was still submerged to a maximum depth of 0.7 m.

Potential operational issues at this site are similar to those of the stream spawning sites upstream of Middle Quinsam Lake: if flows are reduced during the trout spawning and incubation period (late January to June) there is potential for de-watering of redds. The effect depends on the distribution of spawning activity and subsequent flows in the river.

Figure 42. Looking upstream at the Quinsam River inlet as it enters Quinsam Lake. Part of the gravel fan at the mouth de-waters at low flows and therefore may be affected by BC Hydro operations. (photo: MJL)

Discussion

Historic Operations

The limited data available indicate that Wokas Reservoir fluctuates from 360.90 to 364.91 m, a range of approximately 4 m. This range is substantially greater than that occurring on natural lakes in the region (Rutherford and Lough 1999). It should be noted however, that the operational range of the reservoir is usually on the order of 2 m—an additional 2 m drawdown occurred in 1999 to accommodate specific fish concerns in Miller Creek. This circumstance is not expected to be repeated.

The water licence for Wokas and Upper Quinsam Lakes limits storage to 10,000 acre feet per year (~12.3×10^6 m^3 per year) and dictates that some of the storage is to be reserved for providing flows for fisheries purposes (Burt 2000). A storage volume of 10,000 acre feet is capable of providing 1 cms for about 142 days. However, due to unpredictable inflows this volume of water is not necessarily available at any one time. Additionally, much of the available water is diverted to Lower Campbell Reservoir for power generation. The proportion of stored water used to augment downstream flows for fish is not known.

The reconstructed diversion record for the Quinsam system provides an insight to how water is managed in the system and how patterns of diversion have changed through time. In general, diversion flows are highly variable with the exception of repeated low diversion volumes during the summer.

A diversion can influence a lake by affecting the amount of water flowing through it – the lake's residence time. Since the point of diversion is below Wokas Lake, diversions influence residence time primarily on Middle and Lower Quinsam Lake by diverting water out of the system. These lakes therefore have longer residence times than they would under natural conditions. The effect on residence time is greatest for Middle Quinsam Lake (Figure 32) since it is approximately one third the volume of Lower Quinsam Lake.

The biological effect of changes in residence time were not assessed as part of this study and there are no empirical data available for these lakes that would allow a proper analysis. Therefore any statements regarding this issue must be regarded as speculative. However, the discussion can be guided by general results from the literature.

Lake productivity is in part a balance between competing effects of inflow. Productivity depends on inflow of nutrients from external sources, because there is a net export of nutrients from the water column to profundal sediments. Nutrients must be replenished with inflow if lake productivity is to be maintained (Wetzel 2001). A competing effect is one of flushing and dilution: large volume inflows have the capacity to flush nutrients (and organisms) from a system (Welch 1981; Cooke et al. 1986; see also chemostat results in Hatfield 2001) and thereby disrupt lacustrine production. Therefore, for lake productivity to be maintained, inflows must be with a certain volume range. To determine this range for our study lakes would require considerably more data than that collected for this study, or would require modeling beyond the scope of this study.

Upper Quinsam and Wokas Lake Tributaries

Of the 14 tributaries assessed only five had year-round rearing capability, as determined by sampling in October 1999. Hawkins Creek appears to have the highest fish production capability based on flow regimes, channel stability and quality of fish habitat present. Access problems, caused by accumulations of gravel, existed at all the fish-bearing streams. The lowest reach of each of these streams are aggraded, apparently as a result of logging and mining activity in the watershed. Aggradation is also an issue at several of the smaller tributaries, which may affect seasonal use of these streams by fish.

Accumulation of gravel at the mouth of several of the tributaries has formed a gravel fan that de-waters during low summer flows. The dewatered gravel fan increases in area as reservoir levels decline, resulting in an upstream and downstream obstruction to fish passage when stream flows and/or reservoir levels are insufficient to cover the gravel bar.

The tributary confluence fans are used by spawning salmonids. There is spawning within the drawdown zone of the reservoir, but spawning also occurs upstream of the high water elevation. Redds within the drawdown zone are susceptible to inundation if reservoir elevation increases. In general, one would expect reservoir levels to be declining over the spring incubation period, but the available data indicate that elevations may sometimes increase over this period (Figure 31).

Bathymetric Profiles at Upper Quinsam and Wokas Lakes

The bathymetry data collected for this study augmented existing bathymetric data. New data indicated that the substantial shoal areas in Upper Quinsam and Wokas Lakes are surrounded by relatively steep-sided shoreline. These data are useful for examining the effects of reservoir drawdown because they allow a more accurate assessment of the lake area vs. shoal area relationship.

Production Capability of Quinsam Lakes

Production capability of the study lakes was based on the yearling capacity model developed by Facchin (1983), later modified for coastal lakes. As expected, theoretical production capability was determined primarily by lake size, with the greatest capability being assigned to Upper Quinsam Lake. The same model was used to predict the effect of reservoir drawdown on fish production in Upper Quinsam and Wokas Lakes. The calculations suggest that the maximum effect would be a 10% to 12% loss in fish production due to the effects of reduced lake size and shoal area. This would occur if the reservoir levels were maintained at low pool during the growth period in the summer and fall months, in comparison to a stable reservoir at maximum elevation. Operational data indicate that reservoir levels tend to be lowest during the period of greatest fish growth (Figure 31).

There is considerable uncertainty in the values produced by these calculations, and care must be taken to consider the low resolution of these methods. For example, the confidence intervals of theoretical capability estimates may span a 5-fold range (Johnston et al. 1991). Predicting abundance or production based on simple habitat values is fraught with difficulty because individuals and populations are affected by many factors. This project did not consider other potential influences on fish production, such as littoral zone productivity, species interactions within the aquatic foodweb, riparian interactions, land use, harvest, stocking, climate, and management of flushing rates.

The purpose of estimating production at high and low water elevation loss in Upper Quinsam and Wokas Lake is to show the relative differences within the operational rather than determining the precise capacity of the lake. If BC Hydro chose to maintain the reservoir near full pool during the summer growing season, the YCAP model predicts that fish productivity would be about 20% greater than if the reservoir was maintained at low pool. In reality, neither of these extreme scenarios is likely to occur, but the calculations indicate the potential magnitude of the effects of reservoir manipulation.

Obstructions and Effects of Drawdown at Stream Mouths

Upper Quinsam and Wokas Lakes.—Fish passage in and out of the main tributaries to the reservoir was found to be restricted during late-summer low flows. Assessments indicate that this probably has little effect on adult movements, since they occur primarily during periods of sustained higher flows. However, in many of the streams stranded juvenile trout were observed in pools of the de-watered sections, indicating that movements of juveniles may be hampered. Fish passage was not found to be restricted when the tributaries were re-visited during the spawning period in the spring, indicating that it is stream discharge, not reservoir water levels that cause access problems.

The greatest potential effect of BC Hydro operations at lake tributaries was potential for inundation of redds in the drawdown zone at the mouth of some streams. Redds on the gravel fan are subject to inundation and potentially reduced survivals if the level of the reservoir is raised (Lough 2000). As noted earlier, one would expect reservoir levels to generally decline over the spring incubation period, but the available data indicate that elevations may sometimes increase over this period (Figure 31).

An existing uncertainty is the adequacy of flows over the fans during the spawning and incubation period from February through June. Even if reservoir levels are maintained or reduced it is not known whether stream discharge in May and June is adequate to maintain flows over the redds. As noted earlier, the fans dewater at low flows. The condition of the streams during the incubation period has not been assessed.

Middle Quinsam and Lower Quinsam Lakes.—There was a common issue observed at the inlet and outlet of Middle and Lower Quinsam Lake, in relation to BC Hydro operations. Although no de-watered redds were observed, there was a general concern that if the stream flows were reduced during the remainder of the incubation period (June), then the redds will begin to de-water. Such dewatering would result in lower spawning and incubation success of salmonids.

Minimum flow recommendations for the lower Quinsam River were designed to meet fisheries requirements of downstream salmon and steelhead. The effectiveness of these water licence restrictions for resident species has not been investigated, but probably should be. The life history of resident species differs slightly, and issues regarding trout spawning or egg incubation at Middle Quinsam Lake may not be adequately reflected in the flows required by the license agreements.

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