WATER QUALITY OF THE CHEAKAMUS RIVER:
An Assessment and a Proposal for Future Monitoring

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SUMMARY

An application for increased discharge by the Municipality of Whistler for its sewage treatment plant was received by the Ministry of Environment's Waste Management Branch in 1982. A number of agencies expressed reservations regarding the effect of the increased discharge on the Cheakamus River, particularly the possibility of increased periphyton growth in portions of the river which are important for recreation and salmonid spawning and rearing. The Waste Management Branch requested that an interagency group undertake the task of preparing terms of reference for a monitoring program of the Cheakamus River. Monitoring would be carried out by a consultant or university group and would provide information on the effects of the sewage treatment plant on the aquatic environment.

This report includes an assessment of water quality data collected to date, from which the sampling strategy and a proposed monitoring program were drawn. On the basis of the existing data, the periods in which problems are likely to occur, the locations, and the parameters likely to measure the changes were identified. The monitoring program is designed to take place over a three-year period and utilize both one-year conventional monitoring and intensive investigation over three weeks during three key periods of the year. An experimental nutrient addition system to simulate the effect of higher nitrogen and phosphorus will be used. Sampling will also be carried out on the sewage treatment plant to characterize the input to the system. Ambient water chemistry, coliforms, sub-gravel dissolved oxygen in spawning areas and physical factors (light, stream velocity, temperature) will also be monitored.

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ACKNOWLEDGEMENTS

A preliminary report by George Gough (Waste Management Branch), Glen Carlson (Fish and Wildlife Branch) and Margaret Ross (Environmental Protection Service) was used as the basis of this assessment. Some parts of that report (Gough et al. 1982) have been incorporated into this report.

This document represents the collective ideas and assistance of a number of individuals who contributed to the preparation of this document as members of a committee by providing information, advice, and review of a draft copy: George Gough, Glen Carlson, Margaret Ross, Steve Samis, Chris Perrin, Ramona Helm. Assistance in the form of comments and suggestions were also received from Dale Wetter and Roland Rocchini.

1. INTRODUCTION

1.1 BACKGROUND

Rapid development of the Whistler ski resort area occurred in the early 1970's. One consequence of this development was the need for a sewage disposal system. A number of small sewage treatment plants and numerous septic tanks were installed. As a result of the concerns regarding the operation of the plants, the Regional District applied for a permit to consolidate the discharges via a trunk sewer and provide secondary treatment prior to discharge to the Cheakamus River (Wetter 1983). Discharge of sewage was begun in January 1975 but not without a number of agencies expressing concern that the discharge might cause deterioration of the Cheakamus River and Daisy Lake. Fishermen also began to complain about algae at this time. The Cheakamus River and Daisy lake are valuable as sources of domestic water, as fishery habitat and as recreational resources. The fishery on the lower Cheakamus is particularly important, and fears have been expressed that water quality deterioration might occur as a consequence of the sewage treatment plant discharge.

The area which is considered can be divided into four sections (Figure 1).

1.2 STUDY AREA

The upper Cheakamus River drains out of Cheakamus Lake, within Garibaldi Provincial park, and flows into Daisy Lake, after dropping 400 m in elevation over a 21 km length. The 11 km section from Cheakamus Lake down to the falls below the Millar Creek confluence has an average gradient of 2.0%, with mainly a boulder, bedrock substrate. The 11 km section from Millar Creek down to another falls, 0.5 km above Daisy Lake, has an average gradient of 1.4%, with some flat gravel areas. Callaghan Creek enters the upper Cheakamus River 5.5 km upstream from Daisy Lake. The Whistler Sewage

Treatment Plant (STP) is situated along the upper Cheakamus River, 100 m above the Millar Creek confluence and below a control monitoring site at the B.C. Rail bridge.

Daisy Lake Reservoir was formed by the damming of the Cheakamus River. Prior to the construction of the Daisy Lake dam in 1957, this area consisted of a number of small lakes that drained into the Cheakamus River. At full pool Daisy Lake has a surface area of 4.2 km^2, with a water storage capacity of 44 517 000 m^3. During high water storage Daisy Lake has an elevation of 378 m above sea level (ASL), which may drop to 369 m (ASL) at low lake levels.

The lower Cheakamus River begins at the Daisy Lake dam at an elevation of 351 m, and flows 26 km to enter the Squamish River near sea level, 13 km upstream from the estuary. The top 9 km section is a turbulent, bouldery section that ends at the falls in the Cheakamus Canyon. The bottom 17 km is composed of a series of long run-riffle areas that gradually level out as the river nears the confluence with the Squamish River. Its major tributaries all enter from the east and include Rubble Creek at 1 km, Culliton Creek at 14 km, Swift Creek at 18 km and Cheekye River at 23 km, downstream from the dam.

Most of the Daisy Lake water is diverted via a 12 km tunnel to the Squamish River system where it enters the 0.5 km powerhouse tailrace. This joins (approximately midway along) a 3 km long sidechannel, which flows into the Squamish River 40 km upstream from the Squamish Estuary. This section of the Squamish River contains some of its most productive fisheries habitat.

1.3 PREVIOUS STUDIES

Very little information is available with regard to water quality in the Cheakamus system. Most past investigations have been directed toward fisheries resources. Wrightman (1973) made an assessment of the possibilities for habitat improvement. Argue and Wilson (1978) described Coho tagging and recovery, and Hartman and Gill (1968) documented the distribution of rainbow and cutthroat trout in the area.

The Municipality of Whistler through an engineering consultant, Web Engineering, commissioned a study (EVS Consultants, 1976) to investigate the effects of the STP on the Cheakamus. A description of environmental resources, and in particular the water quality monitoring to that time was made. The data used were from permit related monitoring done by Pollution Control Branch (now Waste Management Branch). The report concluded that no significant impacts occurred.

2. WATER USES

2.1 FISHERIES RESOURCE

Resident fish species inhabit all the zones in the study area, whereas anadromous fish species only inhabit the lower Cheakamus River, and the Squamish River. Resident rainbow trout (Salmo gairdneri) are present in the upper Cheakamus River, where the best rearing and spawning habitat is situated between Millar Creek and 0.5 km upstream from Daisy Lake (Fish and Wildlife Branch, Unpublished Data). Both of the lower sections of Millar Creek and Callaghan Creek are accessible to the rainbow trout population of the upper Cheakamus River. This population is augmented yearly by displaced rainbow trout fry from the lakes at the head of each waterway (Figure 1).

Sportsfish populations in Daisy Lake, in order of decreasing abundance, include rainbow trout, kokanee salmon (Oncorhynchus nerka), and Dolly Varden char (Salvelinus malma). In a 1980 creel census these combined species gave angler catch per day of 2.2 fish. The lower sections of the three streams on the west side of Daisy Lake are utilized for spawning by these fish species.

The lower Cheakamus River contains both resident and anadromous fish species, with only the first 17 km of the river being accessible to the latter species. Resident fish species include rainbow and cutthroat trout (Salmo clarkii), Dolly Varden char and mountain whitefish (Prosopium willamsoni). Anadromous fish species include the five species of Pacific salmon genus Oncorhynchus, and steelhead trout (Salmo gairdneri). A small remnant population of sockeye salmon (O. nerka) entered as far as the Cheekye - Brohm river system, whereas an average number of 11,300 pink salmon (O. gorbuscha) spawned during each of the odd numbered years from 1965 to 1981 (Unpub. data, DFO). Between 1960 and 1981, the average estimated adult spawning returns for the other salmon species were: 21,000 chum salmon (*O. keta*); 4,700 coho salmon (*O. kisutch*); and 1,300 chinook salmon (*O. tshawytscha*).

The average estimated spawning return of adult steelhead trout during the late 1970's was 450 fish, with the majority of these spawning in the top section near the falls (Fish and Wildlife Branch, 1977b). In 1982, the steelhead fry density at five locations below the falls was estimated to be 0.5 fish per square meter (Tech. Memo, Fish and Wildlife Branch). Steelhead enhancement efforts are in progress and involve a hatchery on Tenderfoot Creek (tributary to the Cheakamus) and stocking of steelhead fry.

The Squamish River study zone is situated at the lower end of the most productive salmon and steelhead trout rearing and spawning areas on the Squamish River. Fish stocks include: chinook, coho, chum and pink salmon; and both resident and anadromous, rainbow (steelhead) and cutthroat trout and Dolly Varden char.

The average estimated adult spawning return of steelhead trout to the Squamish River during the late 1970's was 950 fish, with the majority of these spawning above the study zone (Fish and Wildlife Branch, 1977b). Adult steelhead first enter the Squamish and Cheakamus Rivers in December and spawn between April and July. Juvenile steelhead may rear in these rivers for up to four years before migrating to sea. The steelhead angler catch per day estimates for the Squamish watershed have decreased from 0.24 fish in 1972 to 0.16 fish in 1980. From March to May, 1978, a creel census estimated that there were 2 062 angler days, with 55% of the angler effort concentrated along the first 6 km of the Cheakamus River. Future enhancement of the steelhead stocks will need to rely on fry stocking and stricter regulations, since there is limited potential for habitat enhancement. The newly completed (1982) Federal Fisheries' Tenderfoot Creek hatchery, that is situated off the lower Cheakamus River 6 km from the mouth, will be used to enhance the chinook salmon and steelhead trout populations.

The salmon spawning period for the Squamish River lasts from August to December and the average estimated adult spawning returns between 1960 and 1981 were: 46 650 chum salmon; 14 650 coho salmon; 9 650 chinook salmon; and 18 500 pink salmon (in odd-numbered years), (Unpub. data, DFO). Juvenile pink, chum and chinook salmon depart for the sea between March and August, the following year, whereas most juvenile coho salmon remain in the freshwater one year longer. Prior to entering the Squamish watershed, all the anadromous stocks are subjected to a heavy Johnstone Strait commercial fishery. Within the watershed, coho and chinook salmon and steelhead trout stocks may be further depleted by either the Indian food fishery or by the heavy sports fishery. During the last decade these three stocks have shown the most serious population decreases.

Daisy Lake (before impoundment) was stocked with rainbow trout eggs in 1929, 1930, 1931 and 1932. Rainbow trout fry were stocked in 1938 and 1946 and the reservoir was stocked in 1973 with 63 000 fish. Resident fish include kokanee, Dolly Varden char and sculpin (*Cottus asper*).

2.2 WATER LICENCES

There are several water licences on the Cheakamus system, the major ones are associated with B.C. Hydro's dam and power generation system, but three withdrawals for domestic water supply and irrigation could possibly be affected by increased sewage treatment plant discharge (taste/odour, bacterial contamination, algae clogging pumps or intake screens).

B.C. Hydro has three licences for water storages and hydro electric power generation (Table 1). The licenced withdrawals at 3 points amount to 863 437 dam^3/year (from Shadow Lake - an arm of Daisy Reservoir, from the Cheakamus and from Rubble Cr). The withdrawal locations are shown in Figure 2.

2.3 RECREATION

The Whistler area is oriented toward recreation with the emphasis on the ski facilities. However there have been recent efforts to expand the recreational opportunities and develop a summer recreational period. Summer recreation would be oriented toward outdoor activities. The Cheakamus River and Daisy Lake are presently used by numerous visitors and can be expected to be utilized even more in the future.

A campsite was established at Daisy Reservoir by B.C. Hydro but it was closed in 1981 as a result of Order-in-Council 1409. The Order-in- Council was made in response to potential rock avalanche - debris flow posed by the Barrier (a vertical rock face west of Garibaldi Lake). The Ministry of Forests also had provided camp sites near Daisy Reservoir and the Cheakamus River which were closed by the Order-in-Council.

Prior to 1981, B.C. Hydro's facilities at Daisy Reservoir were widely used for day-use activities such as picnicking, boating, fishing and swimming. After the OIC in 1981 the access was blocked off. However, the facilities were not dismantled. The closure of these facilities did not eliminate their use, rather they continued to be used by visitors who parked their cars on both sides of Highway 99. From the viewpoint of many recreationists and the Outdoor Recreation Council of B.C., this situation posed greater safety problems than did the potential collapse of the Barrier. For this reason, as well as the high potential of Daisy Lake for a variety of lake uses, there was considerable pressure to re-open the area for recreational purposes (Barker, 1982) and this has been recently done (1983).

The Cheakamus is also used for kayaking, however, the relationship between water quality and suitability for kayaking is difficult to establish, and limited to bacterial concentrations which could limit body contact recreation.

In terms of general recreation potential, Barker (1982) noted that the attractiveness of the valley and consequently the marketability of a summer resort will be adversely affected if river carrying capacity is exceeded and water quality significantly reduced. A specific recommendation of the report was to maintain the streams, lakes and rivers of the Whistler corridor at drinking water standards (Recommendation 22). For some parameters this may be an admirable but difficult goal to achieve (such as fecal coliform bacteria). Other parameters of concern (nutrients and algal biomass) have no established applicable criteria.

3. HYDROLOGY

An understanding of the patterns and volumes of flow is a prerequisite to evaluating a number of key water quality parameters. These include effluent dilution and projecting future contaminant concentrations.

The lower portions of the system have their flows regulated by B.C. Hydro. Hydro constructed a 27 m dam in 1955-57 forming Daisy Lake Reservoir. Prior to construction, the area consisted of a number of small lakes including Daisy Lake, that drained into the Cheakamus River.

Daisy Lake, since it is a storage reservoir, varies considerably in its morphometric characteristics depending on the time of year and the way it is operated. At full pool the surface area is approximately 5 km^2, the volume is 44 517 dam^3 and the maximum depth is 24 m. Other data are given below.

DAISY RESERVOIR MORPHOMETRY

Volume	52 000 dam^3 (Waste Management Branch)
	52 423 dam^3 (EVS Consultants, 1976)
Max. pool level	378.25 m (1 241.5 feet)
Normal high pool	373.4 m (1 225 feet)
Normal low pool	368.8 m (1 210 feet)
Min. pool level	364.5 m (1 196 feet)
Surface area	4.2 km^2
Maximum depth	24 m
Watershed area	804 km^2

Water is released from Daisy Lake dam in two ways. For generation of power, the water is released via a 5.5 m diameter diversion tunnel to the Squamish Valley powerhouse 11 km to the southwest. The drop in elevation is 274 m and the hydroelectric energy capacity is 140 megawatts. The water discharged to the powerhouse is, on an annual basis, about 80% of the water leaving Daisy Lake.

Water may also be discharged to the lower Cheakamus from the dam by way of the small generator outlet; a hollow cone release valve; two radial spill gates; or over the top whenever the reservoir exceeds 378 m (last occurred in January, 1977). The Water Licences to B.C. hydro stipulate that there must be a flow of 500 cfs in the Cheakamus River below its confluence with Rubble Creek. To ensure this flow, it was calculated that the minimum outflow through the dam must be 2.24 m^3/s (80 cfs), consisting of 0.56 m^3/s (20 cfs) from the generator outlet and approximately 1.68 m^3/s (60 cfs) from the 0.8 diameter hollow cone valve, which is situated near the bottom of the reservoir at 357 m ASL. During high flow periods, varying amounts of water are released from the 11 m high by 12 m wide radial spill gates, which are placed at the upper 11 m of the dam. The flow in the lower Cheakamus has been gauged near Brackendale (08GA043) close to the confluence with the Squamish River. From October to April less than 50% of the total river flow at Brackendale originates from Daisy Reservoir, but in the May to September period, the largest portion of the flow originates from Daisy Reservoir. At Brackendale, peak flows generally occur in June (mean monthly flow 1957-1979 was 86.1 m^3/s) and low flow generally in March or April (mean March flow 1957-1979 was 15.9 m^3/s). There is also partial flow information for the Cheakamus at Garibaldi (08GA017) 1916-1957 (before dam construction) and 1958-1969 (after the dam) and for Rubble Creek (08GA023). The data for Rubble Creek are old (1924-1934) and may or may not be representative, but would indicate a mean annual flow of about 4.9 m^3/s. Thus Rubble Creek would likely contribute about 17% of the total flow below the confluence. Water flow gauging stations are shown in Figure 3.

Flow on the upper Cheakamus has been measured between 1924 and 1948 near Mons (08GA024). From those data, the mean flow is given as 19.7 m^3/s with the peak flow in July (49.4 m^3/s) and low flow in March (4.4 m^3/s). There are flow records for at least two other inflow creeks - Brandywine Creek (08GA016), and Cheekeye Creek (08GA039) which flows into the lower Cheakamus. The mean annual hydrographs for three stations on the Cheakamus are shown as Figures 4, 5 and 6. At present only one hydrologic station is active. This is the station upstream from Millar Creek on the Cheakamus which is operated by B.C. Hydro. A request to reactivate a station on the lower Cheakamus has been made.

Daisy Reservoir has a relatively short flow through (flushing) time. With a mean outflow of 1.2 million dam^3, the mean water residence time would be 15 days using full pool volume. However, the range is considerable; from 5 days or less at a high discharge rate to 138 days at a very low flow.

Because of the small volume of the reservoir, the elevation (and volume) vary through the year. The typical operation is to have the reservoir full in June, July and August, emptying in the fall and winter (September through March) and refilling in April or May (Figure 7).

Water Temperatures have also been recorded at two flow stations (Brackendale, Garibaldi) and are shown in Figure 8 (Environment Canada, 1977).

4. WASTE DISCHARGES

The Whistler sewage treatment plant is the major waste discharge in the system. However, there are two smaller permits which have been issued by Waste Management Branch which may have some effect on the Cheakamus system (Figure 3). Permit PE-6412 was issued in January 1982 to the Ministry of Lands, Parks and Housing for a residential subdivision. The effluent (maximum of 196 m^3/day) would be discharged to Daisy Lake and has effluent limits of 30 mg/L of BOD, 40 mg/L of suspended solids and 1.5 mg/L of total phosphorus. The second permit is for a laundromat and domestic sewage issued to Daisy Lake Holdings in September, 1973 as PE-2651. The discharge is to ground via septic tank of a maximum of 650 gal/day (2.9 m^3/day). The discharge is near Lake Lucille, which drains to the Cheakamus, however the discharge is unlikely to have a significant effect on water quality. An application has been received for a discharge of 109 m^3/d for a residential development to discharge to Daisy Reservoir (AE-6330). No permit has been issued at present for this discharge.

The Squamish-Lillooet Regional District supports the concept of further residential and recreational development in a number of areas, one of which is the east side of Daisy Lake (Barker, 1982).

4.1 SEWAGE TREATMENT PLANT

4.1.1 OPERATION

The Whistler effluent at present receives secondary treatment and phosphorus removal with alum. New works proposed in the 1983 permit amendment consist of an equalization tank, primary clarifier, rotating biological contactors, final clarifier, phosphorus removal facility, chlorine contact tank, anaerobic digestor and sludge belt press. The present facilities consist of an extended aeration activated sludge plant which will be phased out. The tanks will be used for flow equalization (Wetter, 1983).

4.1.2 PERMIT

The permit for the sewage treatment plant was issued February 4, 1972 as PE 1452 to the Squamish-Lillooet Regional District. The permitted discharge volume was 1 818 m^3/d (400 000 gallons/day) with a 5-day BOD of 40 mg/L, suspended solids of 40 mg/L and chlorination. The Letter of Transmittal required that a chlorine residual of less than 0.05 mg/L be maintained in the effluent with at least one hour chlorine contact time at average flow rates. Approval for discharge was contingent on the available effluent dilution being 40:1 or better (Wetter, 1983). The discharge was to be to the Cheakamus River above Millar Creek. The plant commenced operation in January, 1975. The permit was amended April 30, 1976 by extending the time specified for completion of the works and transferring the title from the Regional District to the Resort Municipality of Whistler.

Phosphorus removal was not a permit requirement, but facilities were built into the plant and phosphorus has been removed since 1975.

The growth of the Municipality has resulted in increased flows. In February, 1981, Whistler applied for an amendment of PE 1452 to discharge 12 800 m^3/day. By 1982, peak average daily flows (2 500 m^3/day) exceeded permitted volumes. The population served by the treatment plant was estimated to be 9 200, but facilities exist for approximately 13 800 with some hotels and subdivisions not yet connected.

The permit amendment which was issued in mid-1983 approved an increase to 8 182 m^3/day, which should service a population of 24 000. The permit also specified that an extensive environmental monitoring program be undertaken and a waste management program be developed. The following Table shows the anticipated population and discharge volumes to 1992.

WHISTLER POPULATION PROJECTIONS AND ESTIMATED SEWAGE DISCHARGE

Population (December)	Connected Population	Flow (0.34 m^3/person/day)
1982	13 800	4 705
1983	14 900	5 080
1984	16 000	5 455
1985	17 100	5 830
1986	18 200	6 205
1987	19 300	6 578
1988	20 400	6 955
1989	21 500	7 328
1990	22 600	7 705
1991	23 700	8 080
1992	24 800	8 456

The new permit specifies a maximum phosphorus concentration of 1.5 mg/L in the effluent after alum treatment.

In the future, flows from the treatment plant would be expected to increase in proportion to the population increases noted in the above Table. With the new permit, a significant change has been made specifying tertiary treatment and a maximum discharge concentration of 1.5 mg/L phosphorus. Since the effluent previously averaged approximately 3 mg/L total phosphorus, it would be expected that if effluent concentrations of 1.5 mg/L can be achieved, the loadings would at first be reduced but would increase after the time when present flow rates are doubled.

4.1.3 EFFLUENT DILUTION

In response to the original pollution control permit application of 1972, the Federal Government (Dept. of Fisheries and Forestry) had specified that the available dilution for the effluent should exceed 40:1. The Pollution Control Objectives specify a minimum dilution of 20:1. This dilution should be calculated by using "the lowest week's streamflow anticipated during the discharge period in an average year and the highest estimated hourly discharge rate" (Pollution Control Board, 1975). An hourly peaking factor of double the daily flow is generally used. Using a mean 7-day average low flow of 2.86 m^3/s (101 cfs) from station 08GA024 - Cheakamus near Mons, the dilution for the effluent under these low flow conditions for old permit conditions (1 818 m^3/day) is 136:1, for peak hourly discharge 68:1, for new permit conditions (8 182 m^3/day) 30.2:1 and for the new peak hourly discharge 15:1. Table 2 shows dilutions at a larger variety of river and effluent flows.

Because of low dilutions such as are present in the upper Cheakamus, and the present fish populations, dechlorination should be investigated.

The total phosphorus discharged had a mean concentration of approximately 3 mg/L and the total dissolved phosphorus a concentration of approximately 2.2 mg/L in the effluent. Too few ortho phosphorus values are available to estimate concentrations of this fraction but ortho and total dissolved phosphorus should be nearly equal.

4.1.4 EFFLUENT FLOW RECORDS

Whistler sewage treatment plant serves a resort population and the flows which the sewage treatment plant handles has patterns of flow characteristic of a resort village. The flows can be divided into a period of high population (high STP inflow) in the winter ski season and a lower population in the summer season. Within these two periods there are variations in flow according to weekday, weekend and long weekend. The flows in 1982 and 1983 are summarized below.

SEASONAL VARIATION IN FLOWS FROM WHISTLER STP

1982	summer	- weekdays 200 000 gpd (909 m^3/day)
		- weekends 250 000 gpd (1 137 m^3/day)
	ski season	- weekdays 250 000-300 000 gpd (275 000 gpd =1 250 m^3/day)
		- weekend and holidays 400-600 000 gpd (500 000 gpd = 2 274 m^3/d)
		- maximum daily flow 750 000 gpd (3 409 m^3/day)
1983	summer	- weekdays 180 000 gpd (818 m^3/day)
		- weekend 210 000 gpd (955 m^3/day)
		- long weekend 250 000 gpd (1 137 m^3/d)
	ski season	- weekdays 550 000 gpd (2 500 m^3/d)
		- weekends 600 000-700 000 gpd (650.000 gpd = 2 955 m^3/d)
		- long weekend 700 000 gpd (3 182 m^3/d)

4.1.5 EFFLUENT QUALITY

Data were collected for five years between 1977 and 1982 and can be used to evaluate the effluent quality of the treatment plant and its consequent effect on the Cheakamus River. A summary table of the important parameters (Table 3) shows that the suspended solids and BOD are on average well below the permit limits. For suspended sediments only 3 of 66 values exceeded 40 mg/L and for BOD only 2 of 65 exceeded 40 mg/L. The specified standard for chlorine residual of 0.05 mg/L was not met routinely. The mean chlorine residual reported was 0.44 mg/L and the majority of values exceeded 0.05 mg/L. Another notable result is the low concentration of fecal coliform bacteria. The mean concentration for the period was a MPN of 225/100 mL. The three samples with the highest values were associated with one particular test method.

With regard to the potential problem of stimulation of periphyton growth, nutrients are of primary concern. The mean effluent concentration of nitrate nitrogen was about 2 mg/L and ammonia nitrogen about 10 mg/L. The mean concentrations of phosphorus reflect the tertiary treatment which Whistler has carried out voluntarily since discharge began. The reduction is by alum precipitation, and results in phosphorus values which are relatively low: 2.2 mg/L for total dissolved phosphorus and 3.0 mg/L for total phosphorus.

4.1.6 SEWAGE TREATMENT PLANT LOADING AND RIVER NUTRIENT INCREASES

Using the available flow data for the discharge from the sewage treatment plant and the river flow at the point of discharge, the increase in the concentrations of nutrients as a consequence of the STP discharge can be calculated . Table 4 was created to ascertain the increase in concentration at the point of discharge which might be expected as a consequence of the STP effluent. Table 4 indicates that for a loading level typical of 1983, the increases can cover a wide range of values. Volumes of effluent discharged vary considerably during the year. Maximum population served is during long weekends, somewhat reduced for regular weekends and reduced again for weekdays. A lower population is present during the summer with variation between weekdays, weekends and long weekends.

Against these loading conditions, three levels of river flow were chosen, noted as mean (M), low (L), high (H). The flows which were used were the mean monthly flow, the lowest mean monthly flow on record (e.g. for February the lowest mean monthly flow was in 1937) and the highest mean monthly flow (i.e. in 1935 for February).

For total dissolved phosphorus, it would appear that theoretically with a loading equal to that which was produced in 1983, the river concentration in February would increase from 4.8 µg/L over background for a weekday discharge volume and high flow, to 51 µg/L over background for a long weekend discharge volume and low flow. An intermediate situation would be a weekend discharge volume and mean flow which would hypothetically cause an increase of 13 µg/L total phosphorus. This increase is significant (more than doubling the ambient concentration). However, from the river monitoring data (Section 5.2) available, no increase has been evident although the very limited sampling does not provide a sufficient data set on which to make any strong conclusions. It also is unclear why no noticeable algal growth occurs in the Cheakamus downstream from the STP since there are sufficient nutrients to support heavy algal growth. It may be that stream velocities are too high, the substrate unstable or that water clarity may be insufficient for algal growth. A similar projection for inorganic nitrogen concentration (ammonia + nitrate) is also given in Table 7.

To predict the potential increases in nitrogen and phosphorus concentrations in the two areas where heavy algal growth has been noted (Cheakamus downstream from Rubble Creek and in the tail race of the power house), the following rationale was used. The increases in concentrations at Daisy Lake will be proportional to those downstream from the sewage treatment plant. The outflow from Daisy Lake is about 1.7 million dam^3 (mean 1979-82) in comparison to the volume flowing past station 08GA024 (621 000 dam^3). Thus the projected concentrations of nitrate and phosphate (Table 4) would be reduced to 37 percent of the values in Table 4 by the time the water reached Daisy Reservoir and had been diluted by the creeks which enter the Cheakamus below the STP and flow into Daisy Reservoir. This diminution excludes sedimentation in Daisy Reservoir and it is not clear if the high volume of "glacial flour" would increase sedimentation of nutrients. Assuming that sedimentation of nutrients is not significant, the concentration of phosphorus in February below the power plant would be increased by 3-5 µg/L above background for an average flow year. For July or October the increase would be negligible (<1 µg/L) and for December 2-4 µg/L above background for a year of average flow.

Predicting the increases in nutrients for the lower Cheakamus River requires a series of estimates. First for February, a typical discharge from the dam is about 2.1 m^3/s and a typical flow for the Cheakamus at Garibaldi (08GA017) is about 8 m^3/s (1959-1968) so nutrient increases would be only about one-quarter those experienced at Daisy Reservoir. In July more water is spilled to the Cheakamus (20-60 m^3/sec) and this water comprises a much larger proportion of the flow of the Cheakamus. The mean flow at Garibaldi in July was about 60 m^3/s, so a fairly high percentage of the flow could be from Daisy Reservoir and the increases in nutrients could be proportional to those below the sewage treatment plant. However, these are generally fairly small increase at this time of year (<1 µg/L P, 2-3 µg/L N) although the effect on algal growth may still be significant.

This basic analysis shows that the hydrology is a very important component of this assessment. To determine the effect of the STP on water quality, adequate flow data will be necessary during periods of potential algal growth (i.e. times when the STP is likely to have a major effect which is when monitoring should take place). Discharges through the power tunnel and changes in storage should be included to determine the total inflow to Daisy Reservoir, and the consequent dilution in the outflow to the Cheakamus River.

5. WATER QUALITY

A number of water quality monitoring sites have been established on the Cheakamus system. The locations are given in Table 5. Station 0300116 serves as a control/upstream for the sewage treatment plant. Three sites downstream from the STP (405, 406, and 595) are for evaluation of the discharge at various stages downstream. Two other stations exist on the lower Cheakamus and one station has been established on Daisy Reservoir.

A variety of parameters have been measured over the period of record, the most important ones bearing on the problem of the effect of the sewage treatment plant on nutrients. However several other parameters have relevance and are considered briefly below. Changes are interpreted either over time (annual cycles, changes over the sampling period) or between stations (increases which occur downstream).

5.1 STATION SUMMARIES

The existing data are summarized in Table 6. Data for the river sites where data have been collected show few differences between stations (nutrients are considered in more detail separately below, Table 7).

The stations above Daisy Reservoir can be characterized as a group. The water was low in dissolved minerals (mean total residue 26-34 mg/L, specific conductance 32-40 µS/cm, alkalinity 12-15 mg/L, hardness 13-16 mg/L), well oxygenated (generally greater than 10 mg/L), low in nutrients, and moderately clear (suspended sediments 4-5 µg/L, turbidity 2.7-4.3 NTU.). There were some differences associated with time of year, e.g. higher suspended sediments in summer, but insufficient data exist to discern annual trends in other parameters.

Differences between stations which are a consequence of the sewage treatment plant are difficult to note in the data. Even the station in the dilution zone showed no differences over the long term from the upstream station for parameters such as suspended sediments, dissolved oxygen or nutrients. Fecal coliform numbers were very low for all four of these stations. There was some increase in fecal coliform concentration downstream from the sewage treatment plant but values were very low and pose no particular concern except if the water were used for drinking water without any treatment.

There have been very few data collected for Daisy Reservoir (summary in Table 6). The general water quality was similar to the upper Cheakamus. Temperature and dissolved oxygen profiles have been taken in July 1979 and July 1981 with associated water chemistry. They showed little temperature stratification (1979 15° surface, 12.5° at 3 m, 10.8° at 10 m, and 10° at 15 m; 1981 was 12° surface, 11° at 3 m, and 10° at 13 m). No vertical dissolved oxygen gradient existed (1979 10.2 mg/L at surface, 9.5 at 15 m; 1981 was 9 mg/L through the water column). Water clarity at the 1979 sampling (Secchi disc) was 1.45 m and 1% light intensity was 3 m below the surface. Compared to lakes in general, clarity is relatively low and due to the relatively heavy load of fine suspended material ("glacial flour"). No data exist to define the impact of this suspended material. The reservoir, on the basis of this limited sampling, is quite biologically unproductive; chlorophyll _a_ values averaged 2 µg/L and nutrients were low (ammonia 7 µg/L, nitrate 28 µg/L, organic nitrogen 100 µg/L, ortho phosphorus less than 3 µg/L and total phosphorus about 8 µg/L).

The two water quality stations on the Cheakamus below Daisy Reservoir (Table 6) showed values which are very similar, with generally the downstream station (0300095) having slightly higher values for most parameters. One parameter with a significantly higher value at the downstream station was suspended residue (mean 3.4 mg/L at 0300096 and 17 mg/L at 0300095). Silica was higher at the two Lower Cheakamus stations (7.5 and 8.9 mg/L) than at the upper Cheakamus stations (3.4-4.2 mg/L) however, the biological significance of this is unclear. Diatoms (a class of algae) require silica but 3 mg/L should provide an adequate supply.

5.2 NUTRIENTS

Nutrients are central to the problem of environmental effects from the Whistler STP. The data were examined for patterns which might help to elucidate whether the algal growth is caused, in part, by nutrient factors.

There do not appear to be any trends in concentration through the year for any stations for nutrients. This may reflect the limited sampling since there should be an increase in total phosphorus or total nitrogen at high effluent flows. However, most of this 'total' fraction would not be expected to be biologically available.

A more important trend would be spatial changes, particularly those changes which may be caused by the sewage treatment plant. In examining the nutrient data, it was noted that no increase was evident below the STP or along the river in general. In light of the projected increases in concentrations which were made earlier (Section 4.1.6), the absence of any noticeable increase was surprising. The reason for this lack of increase is unclear. However, no significant increases in either phosphorus or nitrogen occurred outside the initial dilution zone according to the present data base. This may partially be a reflection of the sampling which was largely done in the periods of higher river flow (i.e. high dilution) from May through September when elevated concentrations would not be very apparent.

Another important consideration for any future monitoring should be the question of which is the limiting nutrient. The most common way of assessing which of the two major macronutrients, nitrogen or phosphorus is limiting is by calculating the ratio of the concentrations. A number of methods of calculating ratios is possible: total nitrogen to total phosphorus, total dissolved phosphorus to total dissolved nitrogen or mineral dissolved nitrogen to mineral dissolved phosphorus. These different calculations reflect different levels of availability of nutrients.

Nitrogen to phosphorus mass ratios were calculated (see below) using total N to total P and inorganic nitrogen (nitrate + ammonia) to total dissolved phosphorus. Using the criteria that mass ratios greater than 12:1 indicates phosphorus limitation and less than 5:1 indicates nitrogen limitation of algal growth, most ratios fell into the intermediate or co-limitation zone and no clear limitation by either nitrogen or phosphorus was evident. However, it would be simplistic to expect that nutrients by themselves control periphyton in the system. Other factors such as stream velocity, available light (winter versus summer and attenuation of light by particulate matter in the water) or even temperature or substrate type may be factors controlling algal production and/or biomass. There is some evidence of this in the nutrient data, as frequently there were reported significant levels of both nitrogen and phosphorus in the water in a form which would be expected to be biologically available and readily taken up by periphyton. The presence of these biologically available concentrations implies other factors limit uptake.

NITROGEN TO PHOSPHORUS RATIOS FOR WATER SAMPLES
TAKEN AT THREE LOCATIONS ON THE CHEAKAMUS

	Total N: Total P	Inorganic Nitrogen:Total Dissolved Phosphorus
0300116 (u/s STP)	8.5:1	11.4:1
0301595 (d/s STP)	8.3:1	9.4:1
0300096 (d/s dam)	12.1:1	6.4:1

5.3 PERIODICITY OF ALGAL GROWTH

Very little information is available to assess where and when growth of periphyton occurred. Observations of visible algal growth have been made for several years by Waste Management Branch (Gough *et al.*, 1982). One significant observation was of heavy algae ("considerable green slime") noted at station 0300096 (Cheakamus River downstream from the dam) in August 1973. This was before the sewage treatment plant began discharge. This indicates that when conditions are suitable even very low concentrations of nutrients can cause algal growth. At this station non-quantitative observations were made during 1979 to determine the pattern of biomass of algae during the year. In April some visible growth (*Zygnema*) was noted. In May, heavy biomass was present (approximately 80% *Zygnema*, 20% *Ulothrix*). Heavy biomass was also present in June. In July there was accumulation of filamentous algae, however this was predominantly in pools. In August, the river was observed on three dates with moderate to heavy biomass present. No visible algae were present in September, very small amounts in October and no visible amounts in November.

In August 1981, observations were made of the distribution of algae along the Cheakamus system. At that time there was heavy biomass downstream from Daisy Dam, the dominant components being *Gomphonema* and *Ulothrix*. Rubble Creek had no visible algae and the Cheakamus upstream and downstream from Rubble Creek was also clear of algae. Near Alpine Lodge there was a noticeable green filamentous algal biomass and on the Squamish River below the generating station a heavy accumulation of algae occurred.

Observations of algal growth were also compiled by Ross (1983). In August 1981 some algal biomass was noted between the STP outfall and Daisy Lake. In March 1982 some minor algal biomass was noted downstream from Daisy Lake. In July algae were noted in the Squamish and lower Cheakamus, similar to algal growth noted in previous years.

In August 1982 algae in the form of bright green streaming clumps or fringes on rocks (Ulothrix) were noted along a 3 km section of the Cheakamus above and below the old Garibaldi townsite (1-4 km downstream from Daisy Lake Dam), and in Rubble Creek below the highway bridge. Below the flood-gates, a noticeable slippery film of diatoms was noted. The Squamish River had no noticeable algae except immediately below the power house.

In October 1982, no visible algae were present in the Cheekeye River. In the Cheakamus, below the confluence with the Cheekeye where silt had collected in pool areas, thick mats of decaying algae (probably Ulothrix) were present. Decaying algal mats were found 6 km upstream from the mouth and 19.5 km upstream from the mouth (4 km downstream from Daisy Lake Dam). At the latter site noticeable amounts of Spirogyra were noted to be growing.

For Daisy Reservoir, very little information regarding phytoplankton standing crop or growth patterns is available. Chlorophyll a values were low, averaging 2 µg/L, and may reflect the high light attenuation by suspended particulate material ("glacial flour") during much of the year.

The algal growth below Rubble Creek may be due to nutrients from the two watersheds complementing each other (Gough, 1983 pers. comm.).

6. DISCUSSION

The evaluation of the data has identified several problems.

1. There is significant algal growth in the lower Cheakamus below Daisy Dam and particularly below the confluence with Rubble Creek; and in the tail race of the power station. This algal growth may affect fish spawning and rearing habitat, water supply and the aesthetic attractiveness of this area which is oriented to outdoor recreation.

2. There does not appear to be at present any clear relationship between the discharge from the STP and changes in stream water quality. This may be due to the infrequent (due to manpower constraints) receiving water monitoring done to date. Since the treatment plant has variable flows within the year (because of high winter populations), within the week (because of heavy weekend inputs) and within a day; detailed sampling of the effluent should be an important component of future monitoring. This should include flow proportional composite sampling. This detailed sampling, over perhaps 3 week periods could take place in several specified portions of the year: February/March, May, and August.

3. There is a possibility that Daisy Reservoir might be negatively affected by the STP discharge. It seems unlikely that the nutrients would be a problem in stimulating algal growth since physical factors (lack of light penetration, vertical mixing and short water residence time) are more likely to be factors controlling phytoplankton growth. However, of possible importance is dissolved oxygen depletion in the reservoir during ice cover. During winter, the river flow is lowest, the STP discharge is highest and no natural oxygenation of the reservoir is possible because of ice

cover. This would seem to be the period of highest risk for fish populations and possible problems for water withdrawals since coliforms may also be higher than normal. If low dissolved oxygen does occur then taste or odour problems might also occur.

In designing a monitoring program the major consideration is the questions that need to be answered.

1. Is algal biomass (or accumulation rate) affected by increases in stream nutrient levels?

2. What is the contribution of the sewage treatment plant to the river of nutrients, oxygen demand and fecal coliform bacteria?

3. In Daisy Reservoir, is there an oxygen depletion during ice cover?

4. As a consequence of growth and decay of periphyton in those sections of the Cheakamus used for fish spawning, is there a decrease in dissolved oxygen in gravel in the stream bed or a change in stream benthos?

The monitoring program, outlined in general below, is intended to provide data to answer these questions.

7. PROPOSED MONITORING PROGRAM

The overall intent of the water quality assessment was to identify the locations in which effects are likely to be noted, the components of the aquatic environment (water chemistry, benthos, fish, periphyton, aesthetics) which are likely to change and a method which could be used to assess present and future effects.

The monitoring program should be preceded by a literature search to determine if problems have occurred elsewhere under similar circumstances and the environmental conditions associated with those problems.

7.1 SAMPLING STATIONS

Existing water quality monitoring stations will serve as a base for future monitoring. However, several additional sites need to be established (see Section 7.3.1) in order to provide a complete set of data. Sites should be established on Rubble Creek, on the Cheakamus above the confluence with Culliton Creek and on the sidechannel of the Squamish River above and below the confluence with the tail race of the power house.

7.2 SAMPLING TIMES AND FREQUENCIES

For water quality it would be advantageous to carry out more intensive sampling over several short periods (rather than less frequent sampling over a long period), particularly during periods when significant effects are likely to occur. A major objective is to ascertain if the STP discharge to the river affects river nutrient concentrations which in turn affect algal biomass or growth rates. The most important periods are:

1. Late Winter (February/March). At this period, the STP discharge is high, and river flows are low so that the greatest increase in nutrients and BOD will likely be evident. Daisy Reservoir is ice-covered and would be in its most sensitive state in terms of oxygen depletion. At this period light intensity and day length are increasing so algal growth may be initiated. During this period, of low river flows, periphyton tissue may be decomposing and reducing dissolved oxygen in stream bottom gravels, this effect may also be enhanced by BOD in the streamwater.
2. Spring (May). During this period, STP flows are reduced, river flows are somewhat higher, but light and temperature are likely very suitable for algal growth.
3. Summer (August). Highest recreational use of the river and reservoir. Potential algal growth may be limited by relatively low nutrients or high stream velocities.

The sampling program would take place over a 3-year period. In the initial year, efforts should be directed toward filling data gaps and to establishing a basic understanding of some key parameters since no data on the periodicity of events exist. For example, no systematic sampling of algal biomass has been done to determine when peak growth or accumulations occur. There is unlikely to be significant growth in October through January but this should be confirmed with preliminary sampling. Similarly, it is possible that problems with depressed dissolved oxygen will occur in late summer, fall and winter when periphyton biomass is decaying in the gravel. This should also be confirmed. This period is particularly sensitive since it will be the period of salmonid egg deposition and development.

One task which should be undertaken before a monitoring program is undertaken is a review of the literature to locate published studies of the effects of municipal sewage effluent on mountain streams, particularly in the western U.S. Information may be available which might describe the effects of such discharges or the conditions under which problems have arisen.

7.3 MONITORING PROGRAM COMPONENTS

A number of different approaches can be used to evaluate the effects of the Whistler STP. Advantages and disadvantages are discussed below.

One major problem with the situation is that no data exist for the period before the STP began operation and no basis of comparison is possible for the parameters of concern (nutrients, algal biomass, oxygen depletion, coliforms, etc.). One way of predicting the future (i.e. higher discharge or loading) would be to discontinue tertiary treatment at the STP for an experimental period which could vary from a month to a year. During this period, measurements could be made which when compared to a period when the plant was operating normally, would approximate the effect (of nutrients) when the plant would be treating three times the present volume. It would be the best representation of future discharge effects although present deterioration could not be evaluated. It may not be acceptable since it might be viewed as intentional pollution of the river when treatment was available. A significant risk is involved with regard to fish spawning and rearing habitat in the lower Cheakamus and in the Squamish River sidechannel below the powerhouse. Since the present effect of the discharge is unknown, an increase in nutrient concentration may pose an undue risk and therefore this approach is not recommended. The risks of this type of experiment could be reduced to a minimum, however, by conducting the first tests at times of higher dilution flow, and proceeding to subsequent tests at progressively lower dilution flows when the results of higher-flow tests are known.

A second approach to this problem would be to use in-stream or stream bank experiments which add nutrients to approximate the effects of added STP nutrients. Investigations of this type have been described by Stockner and Shortreed (1978) Bothwell and Daley (1981) and Peterson et al., (1983). This type of approach could be used to determine whether nitrogen or phosphorus were a limiting nutrient and the effect of increased stream nutrient concentration. The disadvantage of this approach is that a fairly intensive effort is required and a large amount of manpower is necessary. However, an in situ measurement of algal biomass and growth appears to be the only practical way of assessing response of periphyton to present nutrient conditions. The program below combines a conventional monitoring program concentrated at certain times of the year, with an experimental component. The experiment is designed to provide information on future nutrient loading which would be difficult to obtain by conventional monitoring.

7.3.1 MONITORING PROGRAM

The program is designed to be carried out over a three-year period with general monitoring in the first year (Table 8) and some specific investigations (Table 9) in each of the three years. The monitoring stations are listed below.

SAMPLING STATIONS FOR PROPOSED MONITORING PROGRAM

River Station	1	0300116	Cheakamus River U/S STP
	2	0301405	Cheakamus River D/S STP #1
	3	0301406	Cheakamus River D/S STP #2
	4		Cheakamus River D/S dam U/S Rubble Cr.
	5		Rubble Creek at mouth
	6		Cheakamus River D/S Rubble Cr.
	7		Cheakamus River above Culliton Cr.
	8		Tailrace of power plant
Lake Stations	9		Daisy Reservoir, north end
	10	1130073	Daisy Reservoir, near dam

Year One. A general monitoring program in year one is designed to confirm the assumptions made regarding periodicity of algal growth, interstitial gravel dissolved oxygen, fecal coliform contamination, nutrient concentrations and suspended sediments. The first year will also be used to establish, test and refine the specific techniques to be used for the monitoring program. The program should be carried out so that the annual biological cycle and the annual hydrological cycle are included within the first (and subsequent) years. This would mean that sampling should begin (preferably) in November or December.

The monthly monitoring program during year one is designed to provide information on the periodicity of occurrence of nutrients, fecal coliforms, stream velocity, temperature, dissolved oxygen, turbidity, and the location, periodicity and amount of algal growth since this has not been done systematically in the past.

Flexibility should be a key component of the program. If a certain frequency should be reduced or a parameter dropped (or added) then this should be accomplished by referral to the steering committee (see 7.3.3). Details of the 1st year general monitoring are given in Table 8.

Years 1, 2 and 3. A separate set of activities will be directed toward answering more specific questions and carrying out more intensive monitoring. The monitoring will be carried out in three, three-week periods during times of the year when changes are expected or when the sensitivity of the environment is high. The first year will be used to develop and refine the techniques but will also be expected to provide useful and consistent data. Details of the specific monitoring program are outlined in Table 9 and the scheduling is shown in Figure 10.

Two parameters which would be measured on a continuing basis are stream velocity and gravel dissolved oxygen (every two days during the three week sampling period). Velocity should be measured with an accurate and reliable instrument and sub-gravel dissolved oxygen with an oxygen meter probe through a perforated pipe forced into the gravel or into wire mesh cages buried in the gravel with an access tube to the surface.

7.3.2 PROGRAM COSTS

Since the program is to be carried out by a consultant, the cost stated below may be significantly modified. The costs are based on the following prices for analytical services, labour and travel etc. The analytical costs given are for the Ministry of Environment, Environmental Lab for 1983, commercial analytical laboratory costs may be higher or lower.

ASSUMPTIONS USED IN ESTIMATING PROGRAM COST

total dissolved phosphorus (TDP)		\$ 12
ortho phosphorus (OP)		\$ 7
Kjeldahl nitrogen (TKN)		\$ 21
ammonia nitrogen (NH_3)		\$ 7
nitrate (NO_3)		\$ 14
turbidity		\$ 7
suspended sediments (SS)		\$ 18
chlorophyll a		\$ 32
tissue nitrogen		\$ 27
tissue phosphorus		\$ 15
fecal coliforms	est.	\$ 25
alkaline phosphatase	est.	\$ 40
periphyton identification and counts	est.	\$ 100
project technician/biologist		\$2 000/month
project supervisor		\$3 000/month

The cost of the program (Table 10) is fairly high. However it represents a basic level of investigation into a difficult problem: to define cause and effect and to quantify the magnitude of any changes which might take place as a consequence of the discharge. A number of parameters have been deleted due to cost (e.g. benthic invertebrates, species composition and measurement of number of salmonid fry in affected vs non affected areas, littoral periphyton in Daisy Reservoir, detailed monitoring of periphyton on natural substrates), and the sampling frequency of a number of parameters has been reduced. Since the Ministry of Environment is interested in the results of such a monitoring program, some contribution might be made to the major cost (analytical). This item could be negotiated.

7.3.3 OVERALL PROJECT SUPERVISION

The project will require technical input and direction as it is undertaken. An interagency committee should be formed to meet with and provide advice to the consultant who undertakes the project.

No provision has been made for the consultant to interpret the data which are gathered (this would add significantly to the project cost). Thus the project committee should be charged with the responsibility to prepare a report on the results of the monitoring within a reasonable length of time after the data gathering has been completed (one year). Interim reports at the end of each year's sampling should also be considered.

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TABLE 1

WATER LICENCES ON THE CHEAKAMUS RIVER

LICENCE #	WATER BODY	VOLUME	USE	LICENCEE
C 22284	Cheakamus R. Rubble Creek Shadow Lake	863,437 dam^3	power generation	B.C. Hydro
C 22285	Cheakamus R. Rubble Creek and tributaries	55,507 dam^3	storage	B.C. Hydro
F 06047	Cheakamus	2.27 m^3/d	domestic supply	Daisy Lk. Holdings
F 20209	Cheakamus	5884 m^3	irrigation	School District 44
C 52899	Cheakamus	2.72 m^3/d 7401 m^3	domestic supply irrigation	J.M. Cousins

TABLE 2

SEWAGE TREATMENT PLANT EFFLUENT DILUTION IN CHEAKAMUS RIVER

		River Flows (08GA024)				
	STP Flows**	1*	2*	3*	4*	5*
1.	1 818 m^3/day	35.2:1	136:1	210:1	865:1	9 362:1
	(3 636)	17.6:1	67.9:1	105:1	432:1	4 681:1
2.	4 705	13.5:1	52.5:1	81.1:1	334:1	3 618:1
	(9 410)	6.8:1	26.3:1	40.5:1	167:1	1 808:1
3.	5 830	10.9:1	42.4:1	65.5:1	270:1	2 920:1
	(11 660)	5.5:1	21.2:1	32.8:1	135:1	1 460:1
4.	8 182	7.8:1	30.2:1	46.7:1	192:1	2 080:1
	(16 364)	3.9:1	15.1:1	23.4:1	96:1	1 040:1

* flow condition (m^3/s) see below

1. 0.74 (minimum recorded daily flow)
2. 2.86 (7 day average low flow)
3. 4.42 (mean monthly discharge for March 1924-1948)
4. 18.2 (mean monthly discharge for October 1924-1948)
5. 197 (maximum recorded daily flow)

**1. maximum permitted discharge 1975-1983 and (estimated peak hourly flow)

2. estimated flow, December 1982-see Table on page 14
3. estimated flow, December 1985-see Table on page 14
4. maximum discharge as permitted in amended Waste Management Permit

TABLE 3

WHISTLER SEWAGE TREATMENT PLANT - EFFLUENT SUMMARY 1977-1982

	Max.	Min.	Mean	N=	
oil and grease			1	1	
field pH	7.7	7.4	7.55	2	
sample pH	7.7	6.7	7.15	17	
total solids	218	186	199	4	
organic solids			148	2	
dissolved solids			156	1	
suspended solids	57.8	1	18.1	66	3 values >40
specific conductance(μS/cm)	518	219	349	17	
chlorine residual	>3	0	0.44	18	majority >.05
total organic carbon			6	2	
chloride			20.7	1	
hardness	84.5	77.7	81.1	-	
ammonia	29.88	0.55	10.3	11	
nitrate/nitrite N	11.6	0.04	1.99	15	
nitrate (dissolved) N	19.4	0.01	2.09	49	
nitrate (total) N	11.58	0.03	1.95	15	
nitrite N	8.0	0.0006	0.49	64	
organic nitrogen	4	1	2.24	5	
Kjeldahl nitrogen	36	2	13.5	10	
total nitrogen	36	4	19.4	8	
biological oxygen demand	81	1.8	12.95	65	2 values >40
ortho phosphorus	4.28	1.51	2.46	4	
total dissolved phosphorus	7.29	0.022	2.23	59	
total phosphorus	10.6	0.059	3.01	65	
fecal coliform (MPN/100 mL)	9200	<2	225	68	prep. 0001: 490, 9200 2300 - 3 highest values

All values in mg/L except as noted

TABLE 4

HYPOTHETICAL INCREASES IN RIVER CONCENTRATIONS (μg/L) OF TOTAL DISSOLVED PHOSPHORUS AND INORGANIC NITROGEN NEAR THE POINT OF DISCHARGE DUE TO TO SEWAGE TREATMENT PLANT DISCHARGE

	February			July			October			December		
	M	L	H	M	L	H	M	L	H	M	L	H
tal Dissolved Phosphorus	5.6	1.6	13.2	49.4	39.1	69.8	18.2	6.0	38.5	7.3	3.1	21.7
										(river flow, m^3/s)		
) summer weekdays (1 800)*				0.4	0.5	0.3	1.1	3.4	0.5			
weekends (2 103)*				0.5	0.6	0.4	1.3	4.0	0.6			
long weekends (2 501)*				0.6	0.7	0.4	1.6	4.8	0.8			
) ski season weekdays (5 500)*	11.3	39.7	4.8							8.7	20.5	2.9
weekends (6 992)*	13.4	47.0	5.7							10.3	24.2	3.5
long weekends (7 000)*	14.5	50.6	6.1							11.1	26.1	3.7

ased on a STP effluent concentration of 2.2 mg/L)

trate + Ammonia

	February			July			October			December		
) summer weekdays (10 061)*				2.4	3.0	1.7	6.4	19.4	3.0			
weekends (11 747)*				2.8	3.5	2.0	7.5	22.7	3.5			
long weekends (13 985)*				3.3	4.1	2.3	8.9	27.0	4.2			
) ski season weekdays (30 750)*	63.6	22.2	27.0							48.8	114.8	16.4
weekends (36 347)*	75.1	26.3	31.8							57.6	135.7	19.4
long weekends (39 139)*	80.9	28.3	34.3							62.1	196.1	20.9

ased on a STP effluent concentration of 12.3 mg/L)

= mean flow
= low flow
= high flow
1983 STP loadings (gm/day)

TABLE 5

WATER QUALITY MONITORING STATIONS

EQUIS Station #	Site Description
0300116	Cheakamus River at the bridge above the sewage treatment plant
0301405	Cheakamus River immediately below STP discharge
0301406	Cheakamus River 100 m downstream of discharge
0301595	Cheakamus River 3.5 km downstream of discharge
1130073	Daisy Reservoir 30 m north of Dam, mid-reservoir at max. depth
0300096	Cheakamus River at picnic site
0300095	Cheakamus River at Cheekeye

TABLE 6

AMBIENT WATER QUALITY SUMMARY (1975-1982)

Parameter	0300116 Cheakamus U/S STP				0301405 Cheakamus D/S STP#1				0301406 Cheakamus D/S #2				0301595 Cheakamus D/S #3			
	mean	min.	max.	n=	mean	min.	max.	n=	mean	min.	max.	n=	mean	min.	max.	n=
pH	7.2	6.3	7.8	21	6.6	6.3	7.4	5	6.8	6.3	7.4	6	6.8	6.4	7.6	8
total residue	34	19	59	11	27	19	35	4	26.3	20	31	4	33	19	54	7
fixed residue	15.2	11	20	5	15.3	11	23	4	15	10	18	4	18.5	10	32	6
dissolved residue	33.5	26	42	8												
suspended residue	4.2	1	12	19	3.7	2	6	3	4	2	6	3	5.3	1	11	6
dissolved organic residue	3.5	<1	11	6	2.7	1	5	3	2.7	1	5	3	4	<1	8	6
specific conductance (μS/cm)	40	22	54	21	32	28	37	5	35	27	52	6	38	26	67	8
field temperature (C)	8.9	3	15.1	16	8.9	6.4	12.5	3	8.0	6.3	9.6	2	10.5	7.8	13	4
field dissolved oxygen	11.5	9.3	15.8	17	11.1	11	11.4	3	11	11	11	2	12	10	16.7	5
turbidity (NTU)	2.7	0.8	5.4	5	4.2	2.8	5.6	2	4.3	3	5.6	2	2.9	0.4	5.8	5
total alkalinity	15.1	9.6	20.3	17	12.5	11.7	13.6	3	12.2	11.4	13.3	3	14.4	11.6	22.6	6
organic carbon	1	<1	1	5	1	<1	1	4	1.25	<1	2	4	1.4	<1	4	7
chloride	0.51	<0.5	0.7	13	<.5	<.5	<.5	3	1.25	<1	0.5	3	0.57	<.5	0.8	6
hardness	15.8	8.3	20.2	12	13.5	11.4	15.5	2	13.3	11.8	14.8	2	13.9	11.8	15.9	2
ammonia-N	0.0059	<0.005	0.013	20	0.005	<0.005	0.005	4	0.010	<0.005	0.028	5	0.005	<.005	0.007	8
nitrate-nitrite N	0.040	<0.02	0.08	18	0.03	<0.02	0.04	5	0.03	<0.02	0.06	6	0.03	<.02	0.07	8
organic nitrogen	0.050	<0.01	0.11	19	0.07	<0.01	0.12	4	0.07	0.01	0.14	5	0.05	<.01	0.09	8
total nitrogen	0.09	<0.02	0.14	5	0.04	0.04	0.04	1	0.14	0.1	0.18	2	0.05	<.01	0.11	3
ortho phosphorus	0.0033	<0.003	0.005	14	0.009	0.003	0.019	4	<0.003	<0.003	<0.003	4	0.003	<.003	0.003	7
total dissolved phosphorus	0.0044	<0.003	0.009	17	0.010	0.003	0.023	5	0.004	0.003	0.005	5	0.0045	0.004	0.005	8
total phosphorus	0.009	0.005	0.015	13	0.018	0.009	0.028	4	0.01	0.006	0.02	5	0.013	0.009	0.019	4
silica	4.2	3	6.6	6	3.45	3	3.9	4	3.4	3	3.8	4	3.7	2.7	5.3	8
carbon inorganic	3.2	2	5	5	2.5	2	3	4	2.5	2	3	4	3.3	2	6	7
calcium (diss)	5.7	3	7.1	12	4.9	4.4	5.7	4	4.8	4.4	5.4	4	4.9	4	5.8	5
magnesium (diss)	0.4	0.19	0.6	12	0.24	0.11	0.31	4	0.29	0.22	0.32	4	0.3	0.11	0.43	5
fecal coliform (MPN)		<2	<20	19	12.8	<2	20	5	11	<2	20	6	6.4	<2	20	4

All data from EQUIS (data collection by Waste Management)

TABLE 6 (Continued)

AMBIENT WATER QUALITY SUMMARY

Parameter	0300096 Cheakamus R.				0300095 Cheakamus R.				1130073 Daisy Reservoir							
	mean	min.	max.	n=	mean	min.	max.	n=	mean	min.	max.	n=	mean	min.	max.	n=
pH	7.3	6.5	7.7	31	7.3	6.9	7.7	25	7.35	7.3	7.4	4				
total residue	37	26	50	20	53	40	72	12	36.7	32	45	4				
fixed residue	18	10	34	11					23	19	32	4				
dissolved residue	36	22	58	21	38	22	60	22	31	30	32	3				
suspended residue	3.4	<1	23	28	17	1	178	20	2.75	2	3	4				
dissolved organic residue	1.8	<1	6	12					2	1	3	4				
specific conductance (µs/cm)	47	30	75	31	54	26	108	26	44	37	65	4				
field temperature (C)	9.3	2	15.6	30	8.3	0	16.8	28								
field dissolved oxygen	11.5	9.1	14.6	30	11	1.3	16.8	28								
turbidity (NTU)	1.3	.3	4.5	16	6	0.5	14	7	3.8	0.8	5.3	4				
total alkalinity	16.7	11	23.5	31	17.5	11	23.8	28	13.5	13.3	13.6	3				
organic carbon	1.15	<1	2	13					2	2	2	2				
chloride	1.38	< .5	4.3	31	1.9	0.5	3.8	28	1.03	< .5	2.6	4				
hardness	17.7	11.9	25.6	20	19	12.6	26.1	28	13.5	10.8	15.3	3				
ammonia-N	0.006	<.005	0.009	27	0.011	< .005	0.029	20	0.007	< .005	0.009	6				
nitrate-nitrite N	0.025	<.02	0.05	20	0.031	< .02	0.05	10	0.028	0.02	0.03	6				
organic nitrogen	0.05	<.01	0.19	26	0.05	< .01	0.13	18	0.10	< .01	0.26	6				
total nitrogen	0.07	0.02	0.19	11	0.12	0.04	0.28	4	0.13	0.04	0.29	6				
ortho phosphorus	0.003	<.003	0.004	25	0.004	<.003	0.011	18	< .003	< .003	< .003	6				
total dissolved phosphorus	0.005	<.003	0.008	22	0.007	0.004	0.014	11	.003	<.003	0.005	6				
total phosphorus	0.008	0.003	0.030	24	0.023	0.005	0.149	19	0.0077	0.007	0.009	4				
silica	7.5	4.1	9.9	15	8.95	3.8	10.9	5	3.9	3.3	5.4	4				
inorganic carbon	2.8	1	5	12					1	1	1	2				
calcium (diss)	6.2	4.3	8.9	21	6.6	4.2	9.2	28	4.9	3.8	5.6	3	0.0017	0.0012	0.002	3
magnesium (diss)	.55	.26	.82	20	0.59	0.37	0.84	25	0.31	0.31	0.31	3				
fecal coliform (MPN)	6.9	<2	20	29	15.5	<2	90	20								

TABLE 7

SPATIAL AND TEMPORAL TRENDS IN NITROGEN AND PHOSPHORUS
(concentration in μg/L)

	Date																		
	5-79	6-79	7-79	8-79	9-79	10-79	11-79	7-80	9-80	1-81	2-81	3-81	7-81	8-81	9-81	2-82	5-82	7-82	8-82
total phosphorus																			
0300116	7	9		9		11	10	15				17			10		15		8
0301405																			18
0301406																			9
0301595	11	10		10		9	10	17				14					19		9
1130073															11		12		9
0300096		6	7	5	8	9	8										15		6
total dissolved phosphorus																			
0300116	5	4		3		6	7	5	5	3	6	7	4		4		4	3	3
0301405																		5	12
0301406																		3	3
0301595	5	9		9		4	7	4	5	4	7	11	4	5		4	5	5	4
1130073														4	5		5	3.5	3.5
0300096		3	<3	<3		5	7										3	4	6
organic nitrogen																			
0300116	70	40		30		20	20	<10	130	40	10	50	70		70		60	70	50
0301405																		<10	30
0301406																		140	50
0301595	70	40		20		23	30	240	30	40	50	30	10	20		<10	60	70	80
1130073														20	70		80	<10	80
0300096		190	70	20	60	90	<10										80	<10	90
ammonia+nitrate																			
030016	50	45		<25		59	47	90	26	60	60	29	50		50		80	40	26
0301405																		40	25
0301406																		40	20
0301595	40	40		<25		57	49	40	36	65	68	74	50			<25	77	40	25
1130073															29		75	35	<25
0300096		<25	<25	<25	20	30	28										50	20	<25

TABLE 8

YEAR ONE GENERAL MONITORING PROGRAM

(see stations - Figures 9, 10 Table 4)

1. Monthly sampling at all stations for the following parameters: water chemistry (November - October)
   - total dissolved phosphorus (field filtered)
   - ortho phosphorus
   - total dissolved nitrogen (field filtered)
   - nitrate - nitrogen
   - ammonia - nitrogen
   - turbidity
   - suspended sediments

   field measurements
   - water velocity (stream flow meter)
   - water temperature
   - interstitial gravel dissolved oxygen

   biota
   - fecal coliform bacteria (5 stations-2,3,4,6 and lake stations)
   - periphyton standing crop (chlorophyll _a_) and species composition - at 4 stations (#4,6,7,8)
   - tissue N and P (April, June, August only) at 4 stations (#4,6,7,8)

Notes:
1. nutrient detection limits: phosphorus 1 µg/L, nitrate 5 µg/L, ammonia 1 µg/L
2. dissolved oxygen measurements, if taken with a meter should be calibrated with a Winkler titration or alternative acceptable technique.

TABLE 9

SPECIFIC MONITORING PROGRAM

(See Figures 9, 10)

(a) February:(i) detailed sampling of STP effluent (flow proportional composite sampling over 24 hours). Daily samples for total phosphorus, total dissolved phosphorus, ortho-phosphorus total nitrogen, total dissolved nitrogen, nitrate, ammonia and fecal coliforms plus effluent flow over 24 hours each sampling day.

(ii) water chemistry at eight river stations: total dissolved phosphorus, ortho phosphorus, total dissolved nitrogen, nitrate, ammonia, turbidity, suspended sediments every second day over three weeks (~10 samples)

(iii) dissolved oxygen profile at two locations in Daisy Reservoir (one near dam (station #9) one near inlet) to be done once in early February and once in late February

(iv) establish specific sampling locations for periphyton (two stations #6,#8) and gravel dissolved oxygen (3 stations). Dissolved oxygen in gravel to be measured twice a week over the 3 week period.

(v) set up periphyton nutrient addition experiment. Use design of Peterson *et al.*, (1983) but use styrofoam D-B as the substrate instead of glass microscope slides. Nutrient additions should be such that the phosphorus concentration increases by 10 μg/L and nitrogen by 100 μg/L. The experiment should run for a three week period with surfaces being sampled every two days for chlorophyll a, and at the end of the experiment for tissue N and P and alkaline phosphatase and algal species composition.

(b) May:repeat program described above.

(c) August:repeat program described above.

For years two and three repeat specific monitoring programs as outlined.

TABLE 10
ESTIMATED PROGRAM COSTS

General Monitoring

12 samples of	TDP ($12)	times 8 stations	$1 152
	OP ($7)		672
	TDN ($21)		2 016
	NH_3 ($7)		672
	NO_3 ($14)		1 344
	Turbidity($7)		672
	S.S. ($18)		1 728
	Coliforms($25)	times 5 stations	1 500
	chlorophyll a ($32)	(4 stations)	1 536
(April to Sept. only)	- tissue N and P	(4 stations)	1 008
(April to Sept. only)	- alkaline phosphatase	(4 stations)	960
(April to Sept. only)	- periphyton species composition	(4 stations)	2 400
			15 660

Specific Monitoring (Years 1, 2 and 3)

(i) STP effluent TP, OP, TDP, TN, TKN, NO_3, NH_3, coliforms = $115/sample 20 samples, 3 periods of the year = $5 900/year

(ii) water chemistry TDP, OP, TKN, NO_3, NH_3, turbidity, S.S., coliforms = $111/sample, 10 samples, 3 periods of the year = $3 330/year

(iii) field measurements - maintenance and repair, calibration chemicals etc. $500/year

(iv) gravel DO - equipment fabrication, misc. sampling year $500/year

(v) periphyton - equipment - 2 sets apparatus $3000

(vi) periphyton analysis: chlorophyll a

5 tubes/10 samples per period/3 periods/2 apparatus @ $32 = $9 600/year

:tissue N and P

5 tubes/1 sample per period/3 periods/2 apparatus @$42 = $1 260/year

:alkaline phosphatase

5 tubes/1 sample per period/3 periods/2 apparatus @$40 = $1 200/year

:species composition

5 tubes/1 sample per period/3 periods/2 apparatus @$100 = $3 000

(vii) labour

first year	4 man months technician/biologist	$8 000
	2 man months project leader	$6 000
second year	3 man months technician/biologist	$6 000
	1 man month project leader	$3 000
third year	3 man months technician/biologist	$6 000
	1 man month, project leader	$3 000

(viii) travel/accomodation/meals - first year - $3 000
second year - $2 000
third year - $2 000

cost first year $57 950

cost second and third year $36 290/year

Total cost $130 530

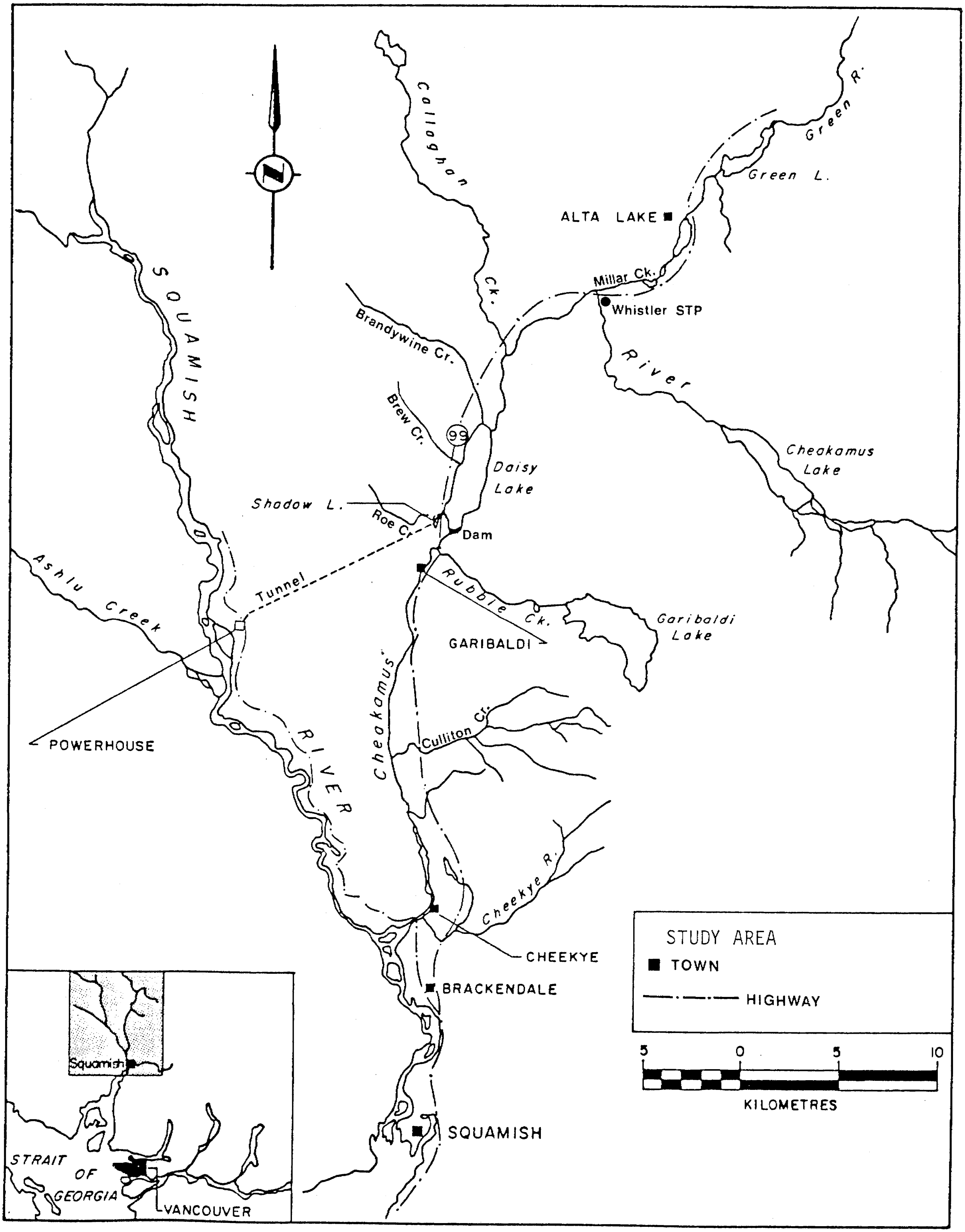


Figure 1 Study area for Cheakamus monitoring program.

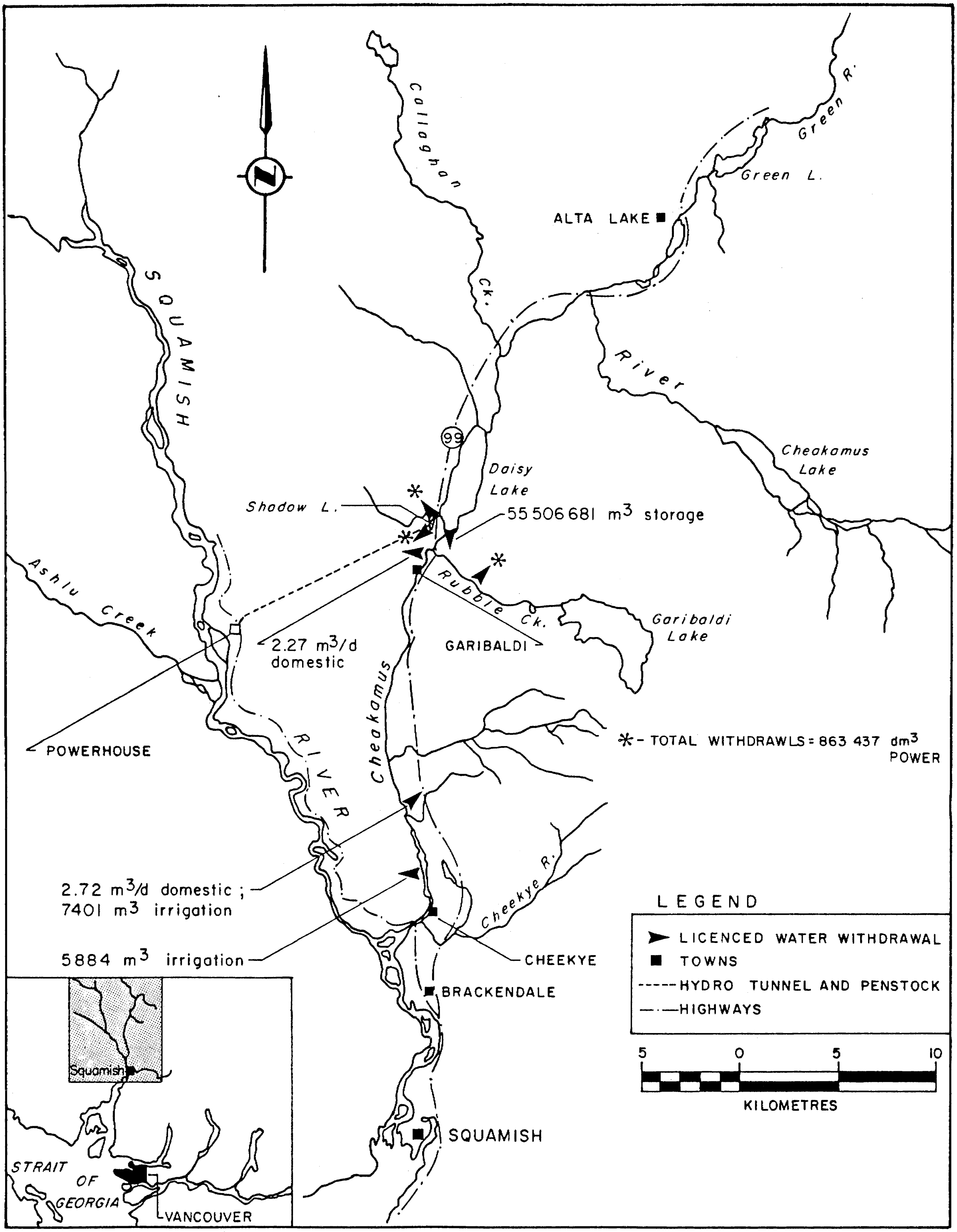


Figure 2 Water licences on the Cheakamus system

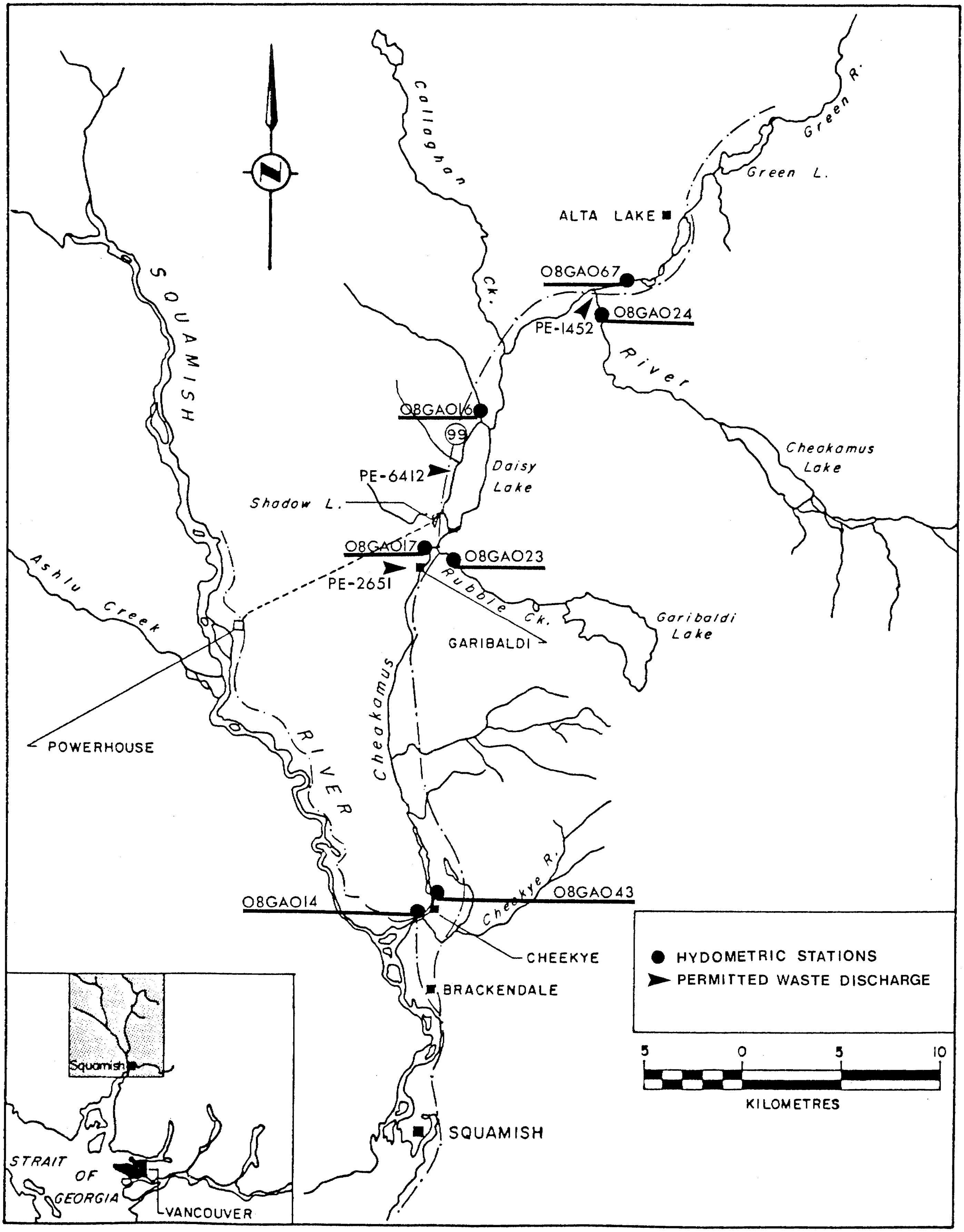


Figure 3 Hydrometric stations and waste discharge points on the Cheakamus system.

Figure 4

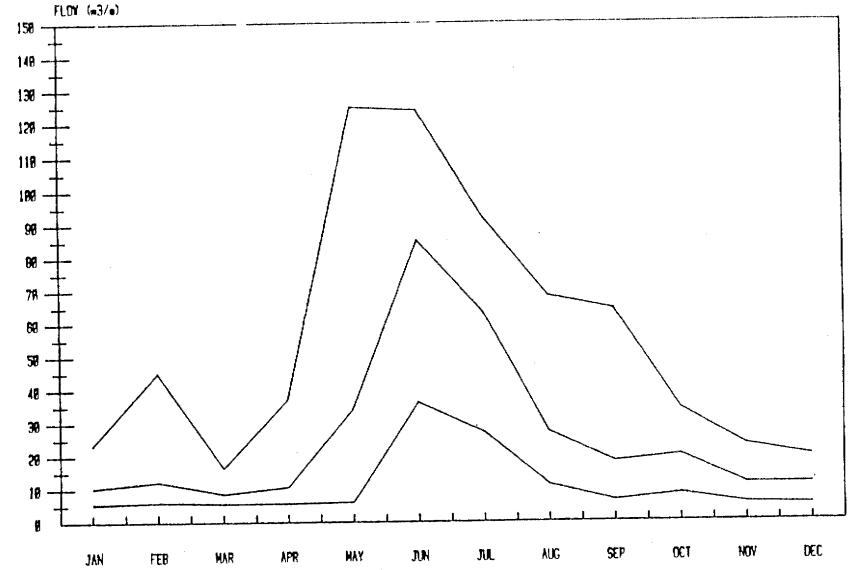


Figure 5

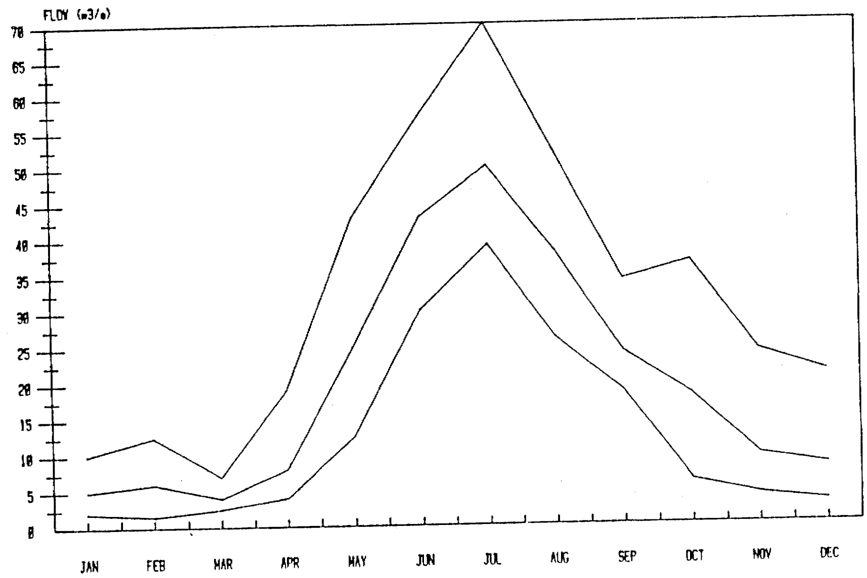
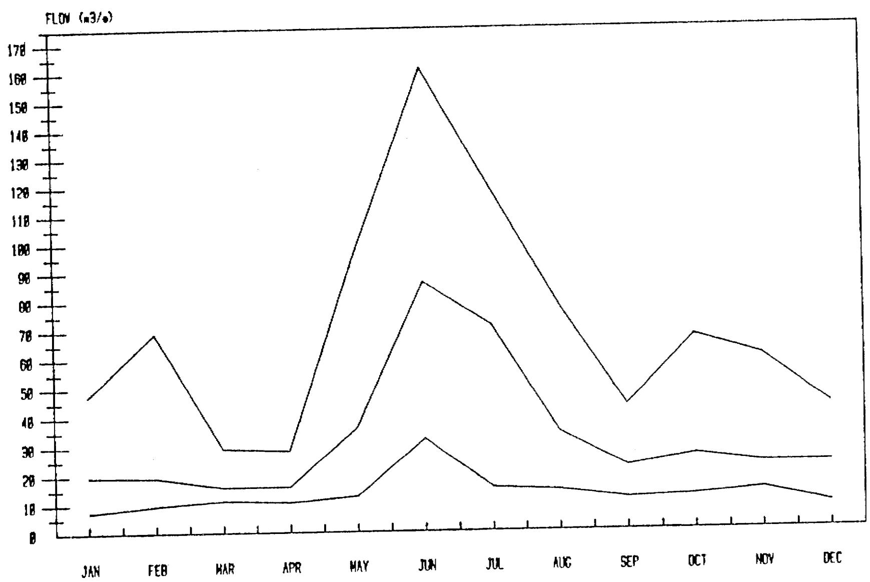


Figure 6



Hydrographs for three stations on the Cheakamus River. Figure 4 is 08GA017 (1957-1969), Figure 5 is 08GA024 (1925-1948) and Figure 6 is 08GA043 (1957-1979). Lines represent mean monthly, lowest mean monthly and highest mean monthly flows (M^3/S) for the period of record indicated.

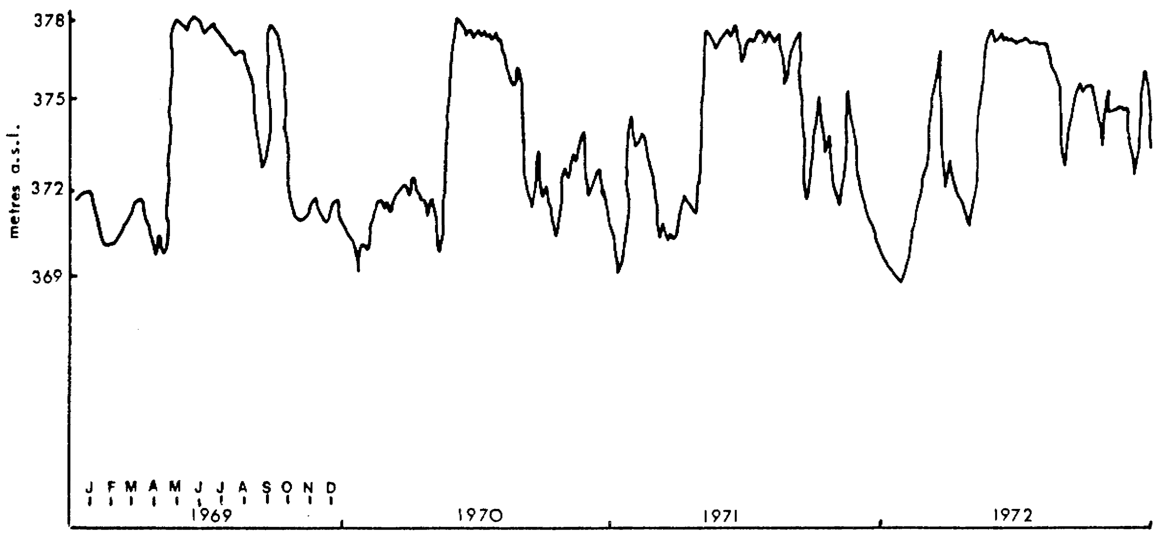
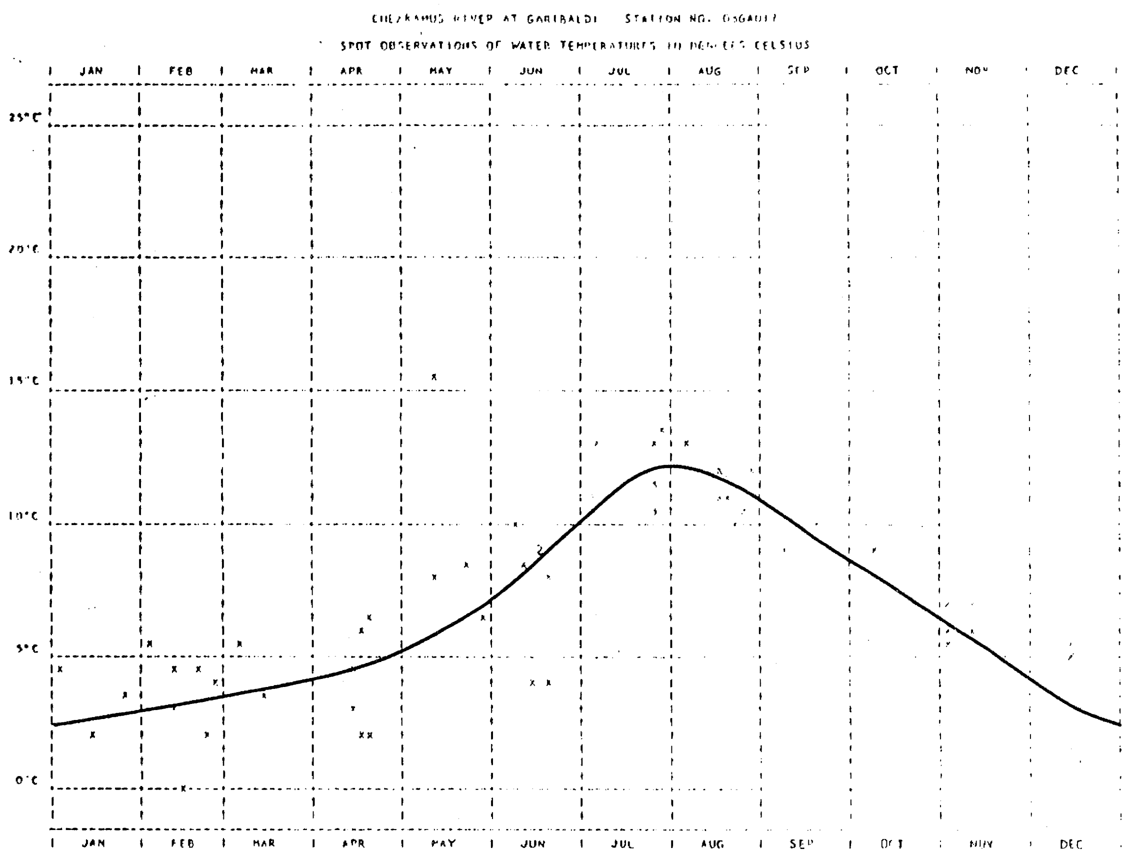


Figure 7 Daisy Reservoir surface elevation changes 1969-1972 (adapted from Wightman, 1973)



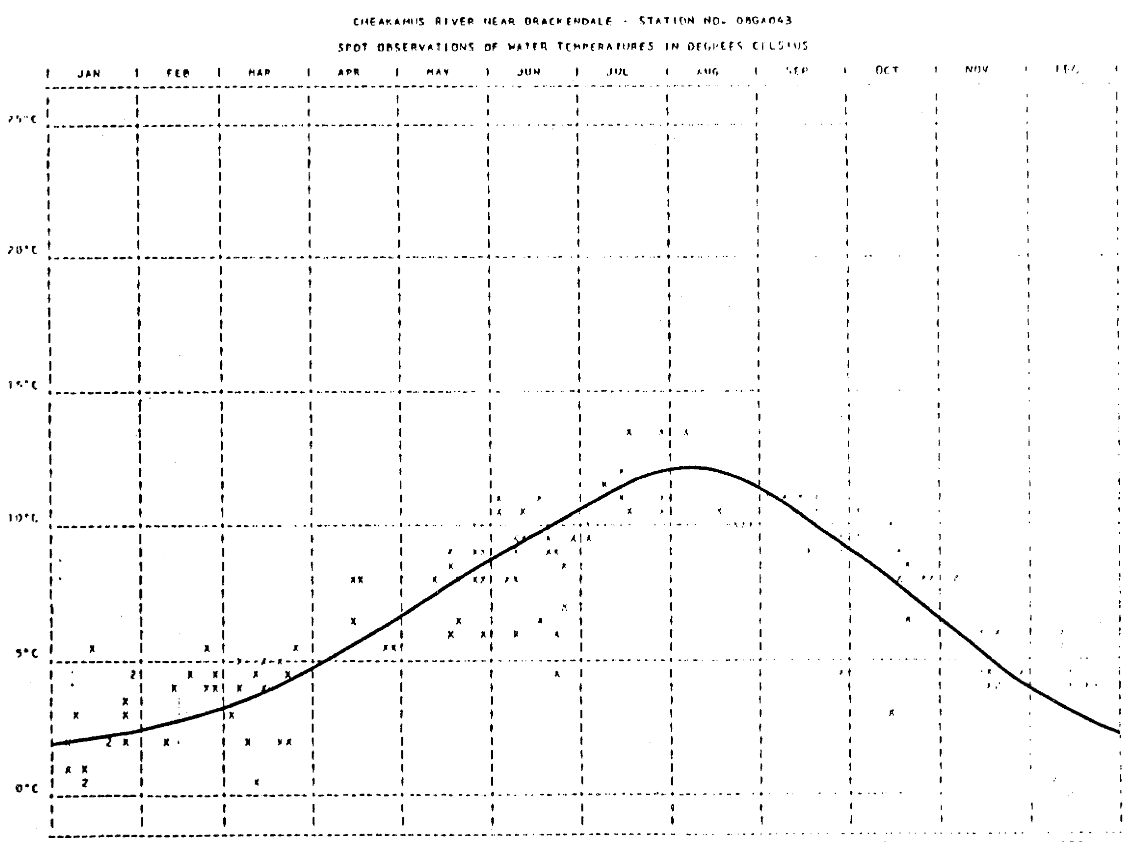


Figure 8 River water temperatures for the Cheakamus at Brackendale and Garibaldi.

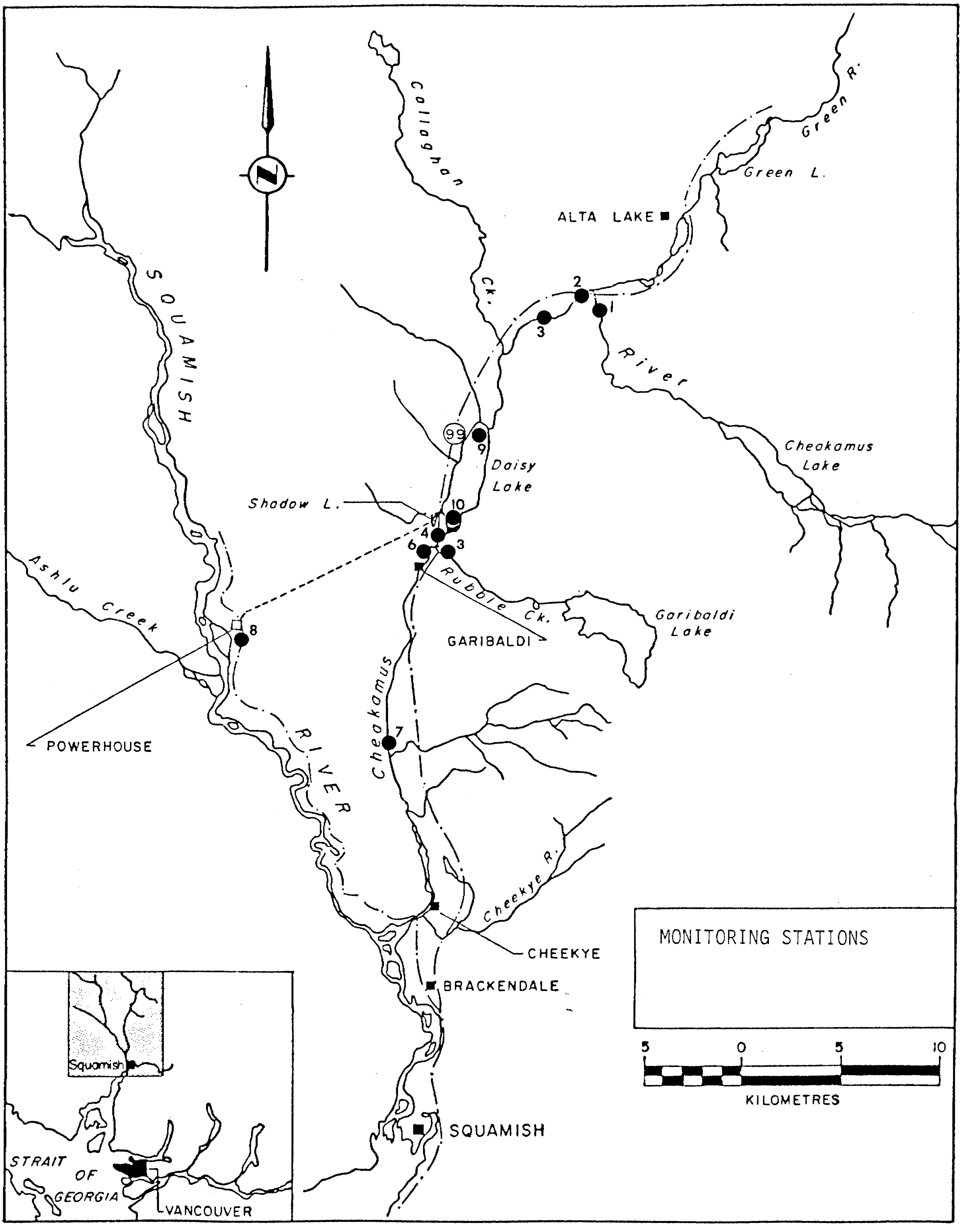


Figure 9 Proposed water quality monitoring stations on the Cheakamus River system (see Tables 8, 9)