Water Quality Assessment and Objectives for Toboggan Creek and Tributaries: Technical Report

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Preface

1.1 Purpose of Water Quality Objectives

Water Quality Objectives are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the BC Water Land and Air Protection's mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

1.2 How Objectives Are Determined

Water Quality Objectives are based on scientific benchmarks called water quality guidelines (criteria).* Water quality guidelines (WQGs) relate the physical, chemical or biological characteristics of water, biota (plant and animal life) or sediment to their effects on water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the guidelines by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. A designated water use is one that is protected in a given location and is one of the following:

- Drinking source water, public water supply, and food processing
- Recreation and aesthetics
- Fisheries, aquatic life and wildlife
- Agriculture (livestock watering and irrigation)
- Industrial water supplies

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

1.3 How Objectives Are Used

Water Quality Objectives provide guidance for resource managers for the protection of water uses in specific waterbodies. Objectives are used to evaluate water quality, assist in issuing permits, licenses and orders to help manage fisheries and the province's land base. They also provide a reference against which the state of water quality

* The process for establishing water quality objectives is outlined more fully in *Developing Water Quality Objectives in British Columbia A User's Guide* and *Methods for Deriving Site-Specific Water Quality Objectives in British Columbia and Yukon*. Copies of these documents are available from the Water Quality Section, BCWLAP.

in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated. Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses.

1.4 Objectives and Monitoring

Water Quality Objectives are established to protect all uses which may take place in a waterbody. Monitoring (sometimes called sampling) is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less. The monitoring usually takes place during a five week period, which allows the specialists to measure the worst, as well as the average condition in the water. For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (i.e., mean value, maximum value).

Summary

Fed by glaciers on the slopes of the Hudson Bay Mountain Range overlooking Smithers, British Columbia, Toboggan Creek supports coho and pink salmon and rainbow/steelhead trout spawning and rearing. A Department of Fisheries and Oceans (DFO) fish hatchery has operated on Toboggan Creek since 1985. The Toboggan Creek watershed is traversed by both the railway and Highway 16, and has a long history of forestry and agriculture. Because of this, Toboggan Lake and the entire Toboggan Creek mainstem, downstream of the lake, traverse private properties. Precise livestock headage is unknown, but it is estimated that 1000 beef and dairy cattle overwinter in the watershed. Because of its close proximity to Smithers, many rural residences are also present in the watershed. Many residents draw their drinking water from Toboggan Creek and tributaries.

In early 2005, a mine was proposed for a large molybdenite deposit lying partially under Hudson Bay Glacier, the headwaters of Glacier Gulch Creek. Part of the flow of Glacier Gulch Creek is diverted into nearby Kathlyn Lake in the summer months.

DFO conducted water quality monitoring in the Toboggan Creek watershed in 1996-1998 in response to concerns regarding water quality of the hatchery source supply. The study suggested early signs of eutrophication: periphyton biomass and microbiological indicator organisms in exceedence of BC Water Quality Guidelines (WQGs) and Bulkley River Basin Water Quality Objectives for recreational and drinking water quality.

A number of ecosystem indicator tools were employed in this study. Monthly water quality monitoring was conducted at eight sites in the Toboggan Creek watershed August 2001-2002. Periphyton biomass and community composition monitoring was conducted September 2001 and again in September 2002. Benthic macroinvertebrate stream health index (formerly known as B-IBI) monitoring was completed in September 2001. A Land and Water Use Survey, which could be completed anonymously, was distributed to water license holders in the watershed in 2001. The survey was designed to help determine livestock headage and agricultural management practices, quantities of water used by agriculture and residents, and what license holders felt were key issues associated with their water licenses and the local streams.

The purpose of this report is to assess the water quality and aquatic ecosystem data gathered to date and to recommend water quality objectives specific to the watershed. Designated water uses, to be protected by water quality objectives, are drinking water, recreation, fisheries and aquatic life, livestock watering and irrigation.

Ecosystem indicator tools employed, key results and resulting 'level of concern' are summarized in the following table. Water quality objectives for Toboggan Creek and a detailed objectives monitoring program are proposed.

Water Quality and Ecosystem Health Summary and Concerns for Toboggan Creek and Tributaries

Ecosystem Indicators	Results	Level of concern
Water temperature	Water temperature in the Toboggan mainstem approached upper range of optimum for salmonid spawning in late summer. Solar heating of Toboggan Lake contributes to elevated water temperatures. Extensive riparian cover removal, resulting from transportation corridors, forestry and agricultural land clearing, was also identified as a contributing factor in Watershed Restoration Program studies.	Of concern to fisheries managers; important spawning stocks effected, contributes to eutrophication.
Dissolved oxygen (water column DO concentration over gravel)	Dissolved oxygen concentrations less than the minimum WQG to protect buried embryos or alevins were occasionally recorded in early spring. Likely due to ice cover, although anthropogenic loading of organic materials may further deplete winter DO concentrations.	Of concern, further monitoring needed.
Nitrate nitrogen	Elevated concentrations of nitrate nitrogen were found at the Upper Toboggan Creek control site, possibly due to geological sources within the drainage. Average nitrite+nitrate nitrogen concentrations in Upper Toboggan Creek are an order of magnitude greater than average concentrations in other regional streams for which a similar dataset is available.	Further monitoring needed.
Ammonia nitrogen, total & soluble phosphorus and fecal coliform bacteria	These parameters were significantly elevated in the Toboggan Creek mainstem compared to three tributary streams (Upper Toboggan, Elliot and Owens creeks). Ammonia and nitrite nitrogen concentrations in the mainstem did not exceed WQGs. A spike in ammonia concentrations recorded at first flush of freshet on the valley floor in 1998 is consistent with runoff from livestock areas in cold climates. The increases in nutrients and fecal coliform bacteria are consistent with runoff from livestock operations.	Of concern, can adversely affect aquatic systems and contribute to eutrophication. Important fish stocks, a hatchery, and domestic water users may be effected.
Concentrations & ratios of bioavailable nitrogen & phosphorus	High background inorganic nitrogen concentrations (possibly from geological sources) are present in this system. The ratios and concentrations of bioavailable nitrogen and phosphorus indicate that periphytic algae growth is strongly controlled by soluble phosphorus availability. Based on total phosphorus concentrations, the trophic status of Toboggan Creek ranges from oligo- or meso-trophic in the upper reaches to eutrophic in the lower mainstem.	Of concern, eutrophication can adversely affect aquatic systems.
Periphytic algae biomass (as chlorophyll *a*) and periphyton community composition	Periphytic algae biomass was elevated relative to control sites, and generally increased along the downstream gradient of the Toboggan mainstem. Biomass exceeded the WQG for aesthetics and recreation at lower mainstem sites in some years. At control sites, periphytic algae biomass was low and dominated by diatoms characteristic of cold, low nutrient streams. Filamentous green algae known to respond strongly to increased water temperatures and nutrient enrichment, such as *Cladophora*, were a significant proportion at some Toboggan mainstem sites.	Of concern, WQGs exceeded in some years, indicator species for eutrophication present.
Benthic macroinvertebrate stream health index: Benthic Index of Biological Integrity (B-IBI)	The maximum possible B-IBI score is 45 and minimum is 9, with lower scores indicating lower ecosystem health. The B-IBI score for the Toboggan Creek lower mainstem was 25. This metric can be compared to scores for sites uninfluenced by humans, which ranged from 33-43, and to other 'non-point source agriculture' category streams, which ranged from 13 to 35.	Of concern, overall score is lower than control sites uninfluenced by humans
Temporal trend analysis, water quality in 1996-98 versus 2001-02.	There was no evidence for a change in concentrations of total nitrogen, ammonia, nitrite+nitrate, total or soluble phosphorus over time, despite improvements in agricultural management practices.	Of concern to environmental managers. Further stewardship and outreach recommended.
Total metals	Some total metals concentrations approximated WQGs for aquatic life. Molybdenum equaled the WQG for forage crop irrigation water under certain conditions. A molybdenum mine has been proposed in the headwaters of Glacier Gulch Creek. Partial flow from Glacier Gulch Creek is diverted into Kathlyn Lake in the summertime.	Of concern for agricultural industry as well as downstream water users in Toboggan and Kathlyn watersheds. Further monitoring needed.
Microbiological indicators of drinking water source quality	In the lower Toboggan mainstem, concentrations of fecal coliform, *E. coli* and Enterococci bacteria exceeded drinking water source WQGs in October 2001, August 2002 and October 2002. Monthly data indicate that fecal contaminants may be present throughout the year, but generally are associated with periods of high surface runoff.	High concern, 31 licensed domestic water intakes draw from Toboggan Creek & tributaries.
Land and Water Use Survey	Response from rural residential community was good. Sixty percent of respondents draw their household water from streams and half of those do not boil or otherwise disinfect their drinking water. Response from agricultural community was very low.	Of concern, disinfection & partial treatment of drinking water is indicated. Lack of information regarding agriculture.

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1. Introduction

Fed by glaciers on the slopes of the Hudson Bay Mountain Range overlooking Smithers British Columbia, Toboggan Creek (Figure 1) supports highly valued fisheries resources, including coho and pink salmon and rainbow/steelhead trout spawning and rearing. A Department of Fisheries and Oceans (DFO) fish hatchery has operated on Toboggan Creek since 1985 and has been active in preserving and enhancing endangered stocks of coho and chinook salmon of the upper Skeena watershed. The Toboggan Creek watershed is traversed by both the railway and Highway 16, and has a long history of forestry and agriculture. Because of this, Toboggan Lake and the entire Toboggan Creek mainstem, downstream of the lake, traverse private properties. Precise livestock headage is unknown, but it is estimated that 1000 beef and dairy cattle overwinter in the lower watershed. Because of close proximity to Smithers, many rural residences are present in the Toboggan watershed and surrounding Kathlyn Lake. Many rural residents draw their drinking water from Toboggan Creek and tributaries.

In early 2005, a mine was proposed for a large molybdenite deposit lying partially under Hudson Bay Glacier, the headwaters of Glacier Gulch Creek. Part of the flow of Glacier Gulch Creek is diverted into nearby Kathlyn Lake in the summer months.

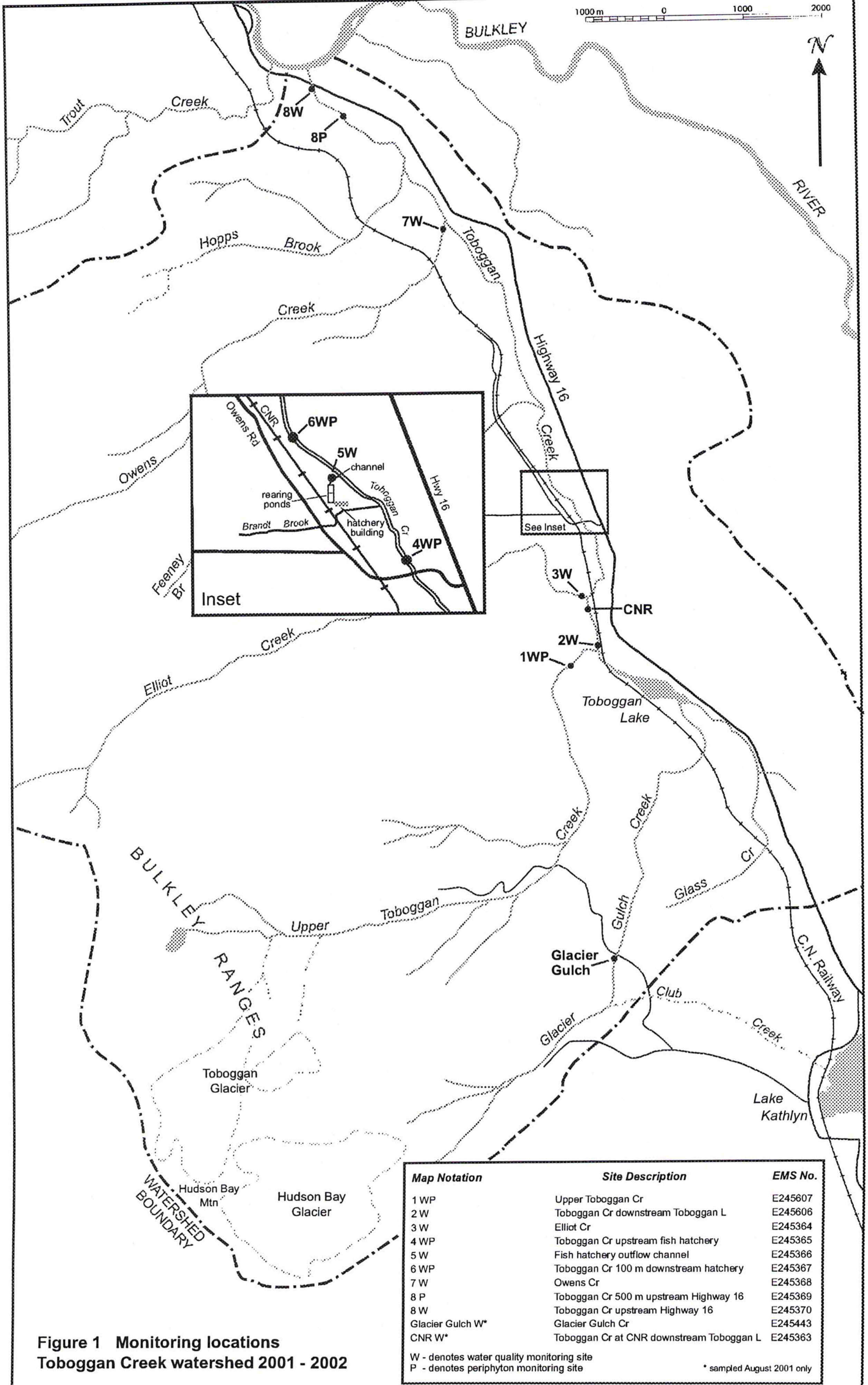
DFO conducted water quality monitoring in the Toboggan Creek watershed in 1996-1998 in response to concerns regarding water quality of the hatchery source supply (Remington and Donas 1999). The study suggested early signs of eutrophication: periphyton biomass and microbiological indicator organisms in exceedence of BC Water Quality Guidelines and Bulkley River Basin Water Quality Objectives for recreational and drinking water quality.

A number of positive changes in agricultural management practices occurred in the watershed after the 1996-1998 study. In 2001, one year of monthly water quality monitoring was approved under the sponsorship of Fisheries Renewal BC and BCWLAP. This work was scheduled to begin in April but, because of administrative delays, the first water samples were not taken until late August 2001. Periphyton biomass and community composition and benthic invertebrate Index of Biological Integrity (B-IBI) monitoring were completed in September 2001. A land and water use survey was distributed to water license holders in the watershed in October 2001. The survey was designed to help determine livestock headage and agricultural management practices, quantities of water used by agriculture and residents, and what license holders felt were key issues associated with their water licenses and the local streams.

Fisheries Renewal BC was terminated March 31st 2002, at which point eight months of sampling had been completed and an interim report was prepared (Remington and Lough 2002). The executive summary of the interim report was distributed to water license holders in the watershed.

In order to achieve the goal of collecting one full year of data, and to capture data during freshet, sponsorship was assumed by Environment Canada and BCWLAP for four additional months (April-July 2002). The final round of sampling in September 2002 and preparation of this report were sponsored by BCWLAP Water Protection Branch, Victoria.

The purpose of this report is to assess the water quality and aquatic ecosystem data gathered to date and to recommend water quality objectives specific to the watershed. Site specific water quality objectives are needed for this watershed to protect designated water uses, including: drinking and recreational water sources; fisheries and aquatic life and; livestock watering and irrigation.



Map Notation	Site Description	EMS No.
1 WP	Upper Toboggan Cr	E245607
2 W	Toboggan Cr downstream Toboggan L	E245606
3 W	Elliot Cr	E245364
4 WP	Toboggan Cr upstream fish hatchery	E245365
5 W	Fish hatchery outflow channel	E245366
6 WP	Toboggan Cr 100 m downstream hatchery	E245367
7 W	Owens Cr	E245368
8 P	Toboggan Cr 500 m upstream Highway 16	E245369
8 W	Toboggan Cr upstream Highway 16	E245370
Glacier Gulch W*	Glacier Gulch Cr	E245443
CNR W*	Toboggan Cr at CNR downstream Toboggan L	E245363

W - denotes water quality monitoring site
P - denotes periphyton monitoring site
* sampled August 2001 only

Figure 1 Monitoring locations
Toboggan Creek watershed 2001 - 2002

2. Summary of Existing Information

2.1 Description of Toboggan watershed

Toboggan Creek is 17 km long, the mouth of which is located 23 km north of Smithers, British Columbia. The watershed drains an area of approximately 112 km^2, and flows into the Bulkley River (Hatlevik 1978). The headwaters and major tributaries emanate from the eastern slopes of the Hudson Bay Range and flow in an easterly direction to coalesce as the mainstem Toboggan Creek. Glacier Gulch Creek emanates from Hudson Bay Glacier (locally known as Kathlyn Glacier) and flows into the head of small, shallow Toboggan Lake on the valley bottom. Upper Toboggan Creek emanates from Toboggan Glacier and an alpine lake and enters at the outlet of Toboggan Lake. From here mainstem Toboggan Creek flows in a northerly direction, parallel to the main valley, across low gradient till plain for approximately 8.5 km before entering the Bulkley River. Elliot Creek and Owens Creek, which also drain the eastern slopes of the Hudson Bay Range, join it along its length.

2.2 Hydrology

Hydrological data for this system is not available. Streamflow is estimated by staff gauge at the hatchery twice daily (M. O'Neill, Toboggan Creek Salmonid Hatchery Manager, personal communication), but the data has not been compiled or verified by Water Survey Canada. The hydrologic regime in Toboggan Creek is similar to that of the Bulkley River, with the lowest flows of the year during the winter months. Freshet occurs in March or April with the first snowmelt, and resulting surface runoff, occurring in the valley bottom. This is followed by much higher flows when the high elevation snowmelt occurs, usually in June. Peak flows generally occur before mid-July, followed by moderate and decreasing summertime flows. In most years, there may be a second minor peak with the onset of fall rains in late September or October.

2.3 Fisheries Resources

2.3.1 Toboggan Lake

Toboggan Lake is a small (14.9 ha), turbid, glacier fed lake. With a mean depth of 1.1 m (maximum depth 1.9 m), the lake probably does not stratify. Toboggan Lake has a sedge shoreline, extensive aquatic vegetation and is attractive to waterfowl. A large hay field lies upstream of the lake and inlet streams have been channelized in some areas. Water quality analysis, 15 September 1982, was unremarkable, except to note that low phosphorous/orthophosphorus concentrations limit productivity.

Coho salmon, rainbow/steelhead trout, cutthroat trout, Dolly Varden, kokanee, mountain whitefish, longnose sucker, sculpin and lamprey are present in the lake and it is considered an important rearing area for salmonids (Lake Files, BC Environment, Smithers).

2.3.2 Toboggan Creek

Fish species present in the Toboggan Creek system (watershed code: 460-242900) include pink and coho salmon, rainbow/steelhead trout, cutthroat trout, Dolly Varden, mountain whitefish, sculpin and lamprey. Pink salmon spawning takes place throughout the lower 8 km mainstem Toboggan Creek. Coho salmon spawning and rearing occurs in the mainstem up to the lake and in the lower reaches of Glacier Gulch Creek, Upper Toboggan Creek and the mouth of Elliot Creek. Steelhead spawning occurs in several areas of Glacier Gulch Creek and Upper Toboggan Creek (FISS website).

The low gradient and numerous side channels of Toboggan Creek and Toboggan Lake provide a substantial amount of suitable rearing habitat for coho salmon. Unlike pink salmon, coho remain in their natal streams for one year before smolting and migrating to sea. In Toboggan Creek, it is believed that some coho remain an additional year prior to smoltification (Saimoto 1997). The majority of steelhead young remain in freshwater for two or three years before migrating. Dolly Varden are resident throughout the system, and are found far up the mountain slopes in many tributary streams (Hancock et al. 1983, Triton 1998). The reader is directed to the FISS website for numerous other fisheries studies, including coho smolt enumeration and overwintering studies: http://www.bcfisheries.gov.bc.ca/fishinv/fiss.html.

Mean annual Toboggan Creek escapement for the 10 yr. period 1989-1998 is as follows (FISS website):

Coho	2,239
Pink (odd year)	8,001

The number of naturally spawning coho in Toboggan Creek has changed substantially over the years. In 1996 there were 1,185 coho adults estimated to have spawned in Toboggan, compared to over 6,000 in 2001. The three largest spawning escapements occurred in 1999, 2001 and 2000 respectively. 1997 showed the poorest escapement, which was a coastwide event, at 400 spawners.

A minor sport fishery is reported for cutthroat and Dolly Varden in Toboggan Creek itself. Historically, most of the angling for coho and steelhead destined for Toboggan Creek has occurred just downstream of the junction with the Bulkley River (Tredger 1979). For the past five years, when predicted coho returns were sufficient, a short-duration, monitored harvest of wild and/or hatchery coho has been specified downstream of the Toboggan Creek confluence (M. O'Neill, personal communication).

2.4 Land Use

2.4.1 Transportation corridors

The Grand Trunk Pacific Railway, now the Canadian National Railway, was constructed through the Bulkley Valley during 1907-1914. The rail line parallels Toboggan Creek for the length of the watershed, crossing it twice just below Toboggan Lake. Soon after, Evelyn Station became one of the early farming settlements in the valley. The small scattered community of Evelyn is located along Owens Road near the fish hatchery in Figure 1.

Highway 16 was completed from Hazelton to Prince Rupert in 1944 and the road link through the Toboggan watershed to Hazelton was established thereafter. In 1966, the old Bulkley River Bridge connecting Smithers to the Telkwa High Road was washed out by an ice jam. The existing bridge was built east of town and Highway 16 re-routed in the late 1960's. This established the present Highway 16 corridor, which closely parallels Toboggan Creek, but on the opposite side than the railway.

In the late 1960's or early 1970's, a major power transmission line was constructed the length of the Toboggan watershed, connecting Smithers to the power generation station at Kemano (Shervill 1981).

2.4.2 Mining

The Glacier Gulch mineral deposit lies partially beneath Hudson Bay Glacier, the headwaters of Glacier Gulch Creek. Numerous gold and silver vein deposits occur here, several of which were commercially developed in the 1930's to 1950's. More recent interest in Glacier Gulch has centered on a high-grade molybdenum deposit. This large porphyry molybdenite deposit has been considered for open pit mining in the past, much to the dismay of Smithers residents who admire the spectacular view of the glacier overlooking town (Gottesfeld 1985). For decades, exploration activity has taken place in the area of the 'York-Hardy project', including a 1.5 kilometre tunnel and nearly 200,000 feet of diamond drilling. A Toronto firm stated intention to purchase mining rights for the York-Hardy project in early 2005, citing the increase in value of molybdenum as their main motive. The firm states that the next steps will be finalizing the purchase agreement and commissioning studies on feasibility and environmental impact (Braverman 2005).

2.4.3 Forestry

Early settlers to the Bulkley Valley were employed in hewn tie making for the railway, in conjunction with land clearing for agriculture (Mould 1976). The hewn tie industry flourished through the 1920's and 1930's. With the introduction of portable sawmills in the 1940's there were hundreds of independently owned small scale selective and strip logging operations. The traces of these selective logging operations are still visible on the slopes above Evelyn. The small bush mills were gradually phased out and replaced with large mills at Smithers. Logging and milling operations have expanded rapidly since the 1960's, with expanded road systems and a shift to clearcut logging. Several sizeable clearcuts appeared in Elliot, Feeney and Owens Creek watersheds in the early 1970's. The Toboggan watershed is now within the Bulkley TSA. Clearcuts of various sizes and ages are present in all the major tributaries of Toboggan Creek.

2.4.4 Rural residences

It is not known exactly how many rural residences and hobby farms exist in the Toboggan watershed. There are a number of residences in the old subdivision at Evelyn Station; in addition, newer subdivisions have appeared in recent years on Glass Creek. The close proximity to Smithers makes the Toboggan watershed an attractive location.

There are 31 domestic-use water licenses registered on streams in the watershed. However, many more residents may have wells or groundwater springs as their water sources and therefore have not acquired water use licenses. All residences in the watershed utilize septic tanks or sewage lagoons for treating domestic wastes.

Septic system effluent has high nutrient and microorganism concentrations derived from human feces and phosphorus-rich detergents. Many studies have shown that, where septic tanks are located on well drained mineral soils at approved set back distance from receiving waters, there is little likelihood of contamination. The major soils of the low elevation (inhabited) portion of the Toboggan watershed are derived from glacial till, with small areas of alluvial, glacial fluvial and glacial lacustrine soils. The glacial till parent material is moderately fine textured, resulting in soils which are hard, compact, often stony and nearly impervious. These soils are arable, but have 'limited potential for effluent disposal' because of their impervious nature (Runka 1972). There is no current information regarding septic system location and function in this watershed.

2.4.5 Recreation

Recreational use of the headwater areas of Glacier Gulch and Toboggan Creeks is high. Old mining roads, now hiking and mountain bike trails, interconnect the headwaters. The BC Forest Service Twin Falls Recreational Site is located at the base of Hudson Bay Glacier, with a view of the two spectacular waterfalls which coalesce into Glacier Gulch Creek. In winter months, ice climbing is pursued on the twin ice falls. A sport fishery for cutthroat and Dolly Varden takes place in Toboggan Creek. Historically, most of the angling for coho and steelhead destined for Toboggan Creek has occurred just downstream of the junction with the Bulkley River (Tredger 1979).

A portion of Glacier Gulch Creek is diverted into Lake Kathlyn during the summer months. Lake Kathlyn is surrounded by residences and is a popular water-based recreational area.

2.4.6 Agriculture

Soon after the construction of the railway in 1914, Evelyn became a center of farming activity. Today, agricultural operations are found on private lands surrounding Glass Creek, Toboggan Lake and along the entire Toboggan mainstem downstream of the lake. An estimated four beef cattle operations and two dairies are located in the Toboggan Creek watershed (D. Riendeau, District Agriculturist, personal communication). According to Riendeau, the number of breeding cows in the Toboggan Creek watershed is estimated at 1000 head and has varied little in recent years. The beef cattle are fed forage crops during the winter months in confined feedlots on the valley bottom. The dairy herds generally are confined to valley bottom high-density grazing areas in the summer and are confined to dairy barns for much of the winter.

During the summer months, most of the beef cattle are placed on open range in the Toboggan Range Unit, administered by the Bulkley-Cassiar Forest District. The Toboggan Range Unit encompasses the tributary watersheds of Toboggan, Elliot and Owens Creeks. Grazing tenures, livestock numbers and Animal Unit Months (AUMs) in the Bulkley-Cassiar Forest District (R. Drinkwater, Prince Rupert Forest Regional Agrologist, personal communication) are found in Appendix 3 Table 1. In general, livestock numbers in the Bulkley valley tend to vary somewhat depending on cattle prices, but are somewhat lower than they were in the early 1980's.

Review of cattle-community watershed conflicts in the Skeena Region— Gaherty et al. (1996) describe the typical beef cattle operation in the Bulkley Valley as consisting of range or grazing areas, confined feedlot areas, and feed storage areas. Cattle are kept on free-range grazing areas and confined feedlot areas or in barns for part of the year. Perennial forage crops are grown for overwinter feed. Most farms use wood waste or straw as bedding material in the barn or calving grounds. High density grazing areas and confined feedlots may have accumulated manure, and soiled bedding is removed from the barn and stored outside on a regular basis.

Well drained slopes with herbaceous vegetation cover have a low susceptibility to surface runoff and, where manure is exposed to snowmelt runoff, it is widely distributed rather than concentrated as in livestock wintering areas. Gaherty assessed the contribution of free-range grazing lands to water quality concerns to not be significant. The authors considered cattle densities on rangelands to be low and with little or no winter use. The concerns identified related to the use of natural waters for watering. Cattle in the region generally have unlimited access to streams or lakes for watering, which may cause bank erosion and direct deposition of manure, a microbiological as well as nutrient hazard.

In agricultural areas nutrient losses from livestock wintering areas or feedlots generally exceed those from other agricultural sources by several orders of magnitude (Loehr 1974). Gaherty identified winter feedlots as an environmental risk to water bodies in the Skeena Region through manure runoff. Snowmelt runoff produced on the frozen surfaces of wintering areas entrains nutrients in manure in both particulate and dissolved forms. Where contaminated runoff reaches nearby streams high nutrient loads may result. Livestock manure is rich in nutrients, such as organic nitrogen and phosphorus, as well as organic carbon which may depress dissolved oxygen.

A comparative study of nutrient export from forested and agricultural watersheds on the Boreal Plain north of Edmonton was reported by Cooke and Prepas (1998). High ammonia export during spring runoff from the watershed with two cow-calf operations suggested that much of the organic nitrogen from livestock waste that accumulated over the winter was converted to ammonia in runoff. This is likely due to cold temperatures over winter and during spring runoff at northern latitudes that do not facilitate further bacterial breakdown of ammonia to nitrate. Ammonia can be directly toxic to aquatic life, as well as depress dissolved oxygen in the water column.

2.5 Toboggan Creek Fish Hatchery

The Toboggan Creek Salmon Hatchery was constructed just downstream of the Evelyn Road Bridge on land leased from the CNR in 1985. The goal of the operation has been to preserve and enhance endangered stocks of coho and chinook salmon of the upper Skeena watershed, particularly endangered upper Bulkley River stocks. During the 1996-1997 year, 100,000 coho and 92,000 chinook salmon from the 1995 brood year were reared and released to various natal streams. Over 187,000 chinook and coho from the 1996 brood year were reared and released in the spring of 1998.

In addition, approximately 150,000 steelhead fry were produced annually at the hatchery from 1985-1987 for stocking in nearby streams. In 1989-1990, approximately 14,000 steelhead yearling fish were produced. These fish were planted in nearby Trout Creek and the mainstem Bulkley near the confluence of Trout and Toboggan Creeks. Enhanced steelhead have never been stocked into Toboggan Creek itself (O'Neill[a] 1995, 1996, 1997).

The two main water sources for the hatchery are an intake in Toboggan Creek, and a groundwater infiltration system. A third water supply comes from Brandt Brook, a small spring-fed tributary. The hatchery uses the groundwater infiltration system and Brandt Brook mainly during the period of low elevation snowmelt in the spring. All of the water sources are gravity fed. About one cubic foot per second of flow is used over most of the year. (M. O'Neill, hatchery manager, personal communication).

Fish health and survival of fry and smolts over the years has remained consistently good. The main concern is for water-borne parasites that are common in surface flows, such as Trichodina and Costia. Fish are treated with Formalin and Chloramine-T to treat the ecto-parasites and bacterial infections. In some years, the myxobacterial infection goes systemic in which antibiotics are used for treatment (B. Donas personal communication). Survivals of adult coho held for broodstock purposes are also good.

Since the early 1990's, sludge from the rearing channel has been vacuumed out using a large pump. The sludge is deposited on land away from the creek and allowed to biofiltrate. This procedure has been carried out consistently since 1997. A separate outflow line was constructed after 1997 which bypasses the flow from the hatchery troughs past the rearing channel to improve water quality for smolts rearing outside of the hatchery. As well, three circular rearing tubs were plumbed in alongside the channel for use during the spring through fall period and are used for holding both fry and broodstock. Many more broodstock are now held through September and October compared to 1996.

M. O'Neill, hatchery manager, states that overall fish densities at the hatchery have been reduced since 1997. The number of smolts reared has been reduced while the number of fry reared at the hatchery has been maintained. In 1996/97, the hatchery overwintered 153,000 smolts compared to 122,000 in 2001/02. Fry releases in 2001 were 38,500 compared to 38,600 in 1996. At the present time, smolt densities are less than five kg/cubic metre in the outdoor rearing channel. Overwintering fish biomass was roughly 720 kg in 2001/02, down from a total of 1,680 kg at historical peak winter biomass (B. Donas personal communication).

2.6 *Licensed Water Use*

Forty water use licenses are registered in the Toboggan Creek watershed (BCWLAP Water Management Branch). Detailed water license information is found in Appendix 3 Table 2. There are 31 licensees in the watershed using surface streams for their domestic water source. The number of subdivisions in portions of the watershed, particularly around Glass Creek, indicates that many more households are probably utilizing wells. In addition, Glass Creek, Elliot Creek, Owens Creek and the Toboggan mainstem are licensed for irrigation (eleven licenses) and livestock watering (one license). One license is for ponds (Toboggan Creek). The Toboggan Creek Hatchery holds water use licenses on Toboggan Creek and Brandt Brook for fish culture.

The watershed also provides summertime flow (12 cubic feet per second) from Glacier Gulch Creek to Kathlyn Lake, via Club Creek. The water is diverted for the purpose of lake rehabilitation and the licensee is the Regional District of Bulkley Nechako. Kathlyn Lake is surrounded by residences, many which draw household drinking water from the lake. Provisional water quality objectives have been established for Kathlyn Lake, including drinking water objectives for fecal coliforms, turbidity and colour (Boyd et al. 1984). Objectives monitoring in Kathlyn Lake from 1987 to 1993 found that the objectives for Fecal coliforms were achieved in 83% of samples, while turbidity and colour objectives were achieved in 93% of samples (BC Environment 1994).

2.7 *Watershed Restoration Program Studies*

A number of Watershed Restoration Program (WRP) studies have been conducted in the Toboggan Creek watershed in recent years. The summary presented below was extracted from the Nortec Consulting Level 1 WRP Assessment (Gibson 1997).

2.7.1 Historical review

The historical review found that Toboggan Creek and its tributaries have been the focus of a number of studies. Overall, the studies found that Toboggan Creek is a highly productive system that is facing several different impacts including transportation corridors, logging and agricultural practices.

In 1997, an examination and prioritization of riparian and in-stream habitat damage was conducted on the Bulkley River and tributary streams (Mitchell, 1997). Mitchell found that riparian areas within the Bulkley watershed had been heavily impacted by non-forestry related sources including road, railway and power line crossings and extensive land clearing for agriculture. It was suggested that these impacts could lead to bank slumping, increased sediment loading, increased nutrient loading from agricultural practices, an increase of stream temperature, and a decrease of large woody debris recruitment in cleared areas. Of the 68 Bulkley River tributaries studied, Mitchell found Toboggan Creek to be one of the five most severely impacted Bulkley River tributaries.

Major historic in-stream works include the construction of a large berm across the valley floor in the early 1900's for railway development, diversion of Toboggan Creek into a historic channel in the 50's, large scale remedial works on Feeney Brook in the 70's, stream and bank restoration works in 1979 and construction of the Toboggan Creek hatchery in the mid 80's.

2.7.2 Habitat assessment summary and prescriptions

The Toboggan Creek mainstem and its main tributaries – Hopps Brook, Owens Creek, Feeney Brook, Brandt Creek, Elliot Creek, Glacier Gulch Creek and Glass Creek, were surveyed by Nortec Consulting (Gibson 1997) and broken up into reaches. Habitat assessments were carried out and prescriptions made for each reach.

Toboggan Creek— The Toboggan Creek mainstem was surveyed and broken up into nine reaches numbered from the mouth (reach 1) and extending to the headwaters (reach 9). A number of impacts were assessed over the entire mainstem including problems with overland flows as a result of rip rapped sections, lack of riparian cover, live stock trampling, numerous bank failures and extensive flooding in some areas due to beaver activity. The culvert at Highway 16 was suggested as being a possible obstacle for the passage of pink salmon during low flows. Old bridge decking in reach 4 was found to be accumulating sediment while further upstream in reach 8 an old bridge wash out and subsequent aggradation were causing problems. Portions of the bridge decking from the wash out continue to divert water down the road during moderate and high flows. In addition, newly constructed motorized vehicle trail bridges may be too low, possibly causing diversion of the creek during higher flows. Near the headwaters a large bank failure, a few minor slope failures and the old logging/mining road were found to be contributing a significant amount of sediment. A small, naturally iron-rich, tributary entering the mainstem was also cause for concern with regards to salmonid egg survival and toxicity to aquatic invertebrates. Prescriptions for the mainstem include investigation of the culvert at Highway 16, rip rapped sections, beaver control methodologies and removal of the old bridge decking. Recommendations were also made for riparian planting, large woody debris placement, fencing the creek off from livestock, placing structures and water bars to prevent overflow and excessive sediment loading, and ensuring new trail bridges are high enough to allow excess flows to pass under them.

Hopps Brook— Hopps Brook is a small creek approximately 3.6 km long and ephemeral in nature. A large portion of this creek runs through private land that has been cleared to provide grazing area. There is a small tributary entering towards mouth of creek. Lack of riparian cover, bank failures and livestock access were found to be the main impacts on this creek.

Owens Creek— Owens Creek, a major tributary, extends 7 km through five closely clustered cutblocks with the lower section flowing through farmland. Major impacts along the lower part of the creek include lack of riparian cover and large woody debris, numerous bank failures, one old bridge which requires removal and visible sediment transport at the power line right of way. Prescriptions for the lower end include bridge removal, placement of large woody debris, and bank stabilization. Upstream from the power line crossing, Owens Creek runs through a slightly wooded area and along a cutblock. Deciduous vegetation in the area attracts beavers and beaver activity. A collapsed bridge in this area may cause problems in the future once the decking falls into the creek. There were also a large number of debris jams found adjacent to the cutblock. A tributary entering Owens Creek in the upper section was found to be impacted by logging. In addition, an old road crossing the creek a number of times was causing aggradation and sediment loading.

Feeney Brook— Sometime in the early 1970's a large logging related gully failure on Feeney Brook occurred, contributing large quantities of sediment, which in turn caused extensive bank erosion and property damage. The Ministry of Environment undertook a number of restoration works including extensive channelization. Gully failure is still evident and continues to impact Feeney Brook. Prescriptions for individual property owners include large woody debris placement, riparian planting, fencing, building and maintaining access to rock falls, and re-establishing the main channel. Further upstream near the gully failure, prescriptions include slope stabilization through wattling, faggots, etc. Channelization done in the 70's did not follow the original course of Feeney Brook. Diverting the brook back to its original channel may limit prescriptions at private properties. The original channel runs through land belonging to the hatchery and could be used as a demonstration site, as well as provide better habitat to fish.

Brook/Brandt Creek— Brook/Brandt Creek is relatively unimpacted and, while this is not a high priority fish stream, its occasional use by fish and its use as a water supply for the Toboggan Creek Hatchery make the brook of concern. Efforts should be made to ensure this creek remains unimpacted. Recommendations were made for removal of an old rusted and deformed culvert approximately 300 m upstream from the mouth.

Elliot Creek— Elliot Creek extends from the mouth through lightly forested areas and farmland, through a wooded area to just below two cutblocks and continues between the cutblocks to the headwaters. Impacts to the lower portion of Elliot Creek include a lack of woody debris and pool presence, some bank sloughing, lack of riparian cover and livestock trampling. Future impacts to this portion of the creek may result from three small foot bridges that cross the creek. At high water these bridges may be flooded or washed out contributing to lateral channel movement and bank erosion. It has been recommended that these bridges be removed. The upper reach runs through a previously cleared, wooded area and contains a number of bank failures. Running along a large portion of the right hand bank is an old skid trail. At one point, the skid trail slopes steeply upwards causing a large bank failure, which continues to fail to this day. There is a dirt road ending at the creeks edge where a number of boulders have been placed in the creek. At the end of the road, the stream banks have been sandbagged, suggesting a problem at high flows. As the valley becomes narrower more debris and blow down is found sliding down the steep valley sides from the cutblocks causing aggraded and braided sections. 3.8 km upstream from the mouth of Elliot Creek a small high gradient tributary flows into the right hand side of the creek. This tributary carries a visible sediment load with cobble and angular boulders being carried out of the system. Roughly 200 metres upstream, there is a large slide, originating from the cutblock, which contributes a significant amount of fines and gravels to the system.

Glacier Gulch Creek— Glacier Gulch Creek is approximately 8.6 km in length including Toboggan Lake and ending at the outflow of Toboggan Lake and the confluence with Toboggan Creek. Historically the confluence occurred above the lake. Extensive channelization has moved Toboggan Creek such that it now joins Glacier Gulch Creek below the lake. This creek was divided into 6 reaches with the first reach beginning at the confluence with Toboggan Creek. The main impacts to Glacier Gulch creek include lack of riparian cover and structure, bank instability, the power line right of way, extensive braiding above the power line and several large slides and small bank erosions in the upper section. The Glacier Gulch Forest Service Recreation Site is located at the upper end of this creek and encompasses a hiking trail leading to the base of the Toboggan glacier as well as a mountain biking trail. The Toboggan FSR at the lower end of the reach is designated as a summer motorized vehicle trail. Mid-way along the reach is a diversion into Club Creek withdrawing water to Lake Kathlyn. The upper most reach encompasses Twin Falls and the headwaters of Glacier Gulch Creek. The main Glacier Gulch tributary originates just below the glacier and crosses the Toboggan Creek FSR. Below the road, the channel runs through a clear-cut, next to a large slash pile and is heavily impacted by recent logging. Prescriptions for Glacier Gulch Creek include adding structure and cover to the channelized section above the lake, large woody debris placement and bank stabilization. Recommendations were also made to conduct extensive survey and design work around the area of extensive channel braiding.

Glass Creek— Glass Creek is 4.2 km long and has one major tributary. Although not surveyed, air photos and the helicopter overview showed the creek running through farm fields and lacking in riparian cover. Prescriptions for this creek include a site survey of the area and riparian planting of cottonwood trees.

2.7.3 Summary of landowners meeting and response for Toboggan Creek Farmers Association

On January 5, 1998, Nortec Consulting attended a meeting with the Toboggan Creek Farmers Association. Nortec presented their habitat assessments and prescriptions for discussion. After reviewing a copy of Nortec's draft report, the Toboggan Creek Farmer's Association responded with unanimous support for a program to undertake works on Toboggan Creek for the first year. These works included repairing erosion areas on the creek with riprap, logs, etc.; removing some problem obstacles in the creek; removing beavers and problem beaver dams; and opening some low areas with trenches that leave water on farmers land and strand fingerlings after high water recedes. Fencing of creeks was not proposed at this time. Possible works on other creeks were proposed for year two.

2.7.4 Recent agricultural management changes and watershed restoration works in the Toboggan watershed

B. Donas, DFO-HRSEP Community Advisor (personal communication) described changes observed in agricultural management since the 1996-1998 water quality monitoring study:

A cattle herd, which had been overwintered next to a dugout pond on a small unnamed fish-bearing tributary of Toboggan Creek, has been relocated away from the tributary. (See Section 3.4.8 for further discussion.)

A cattle herd, which had been overwintered along Glass Creek and the wetlands heading Toboggan Lake, has been relocated to uplands on the other side of Highway 16.

Additional agricultural management changes in the Toboggan watershed are described by G. Tamblyn, CFDC Nadina Watershed Stewardship Coordinator (personal communication). Riparian fencing has been constructed along the confluence of Toboggan and Owens creeks. A cow-calf operation will be relocating its overwintering and calving from lower Owens Creek to an upper pasture near Hopps Brook in the winter of 2002-03. Fences have been constructed along Hopps Brook to exclude cattle from the watercourse and some riparian planting was completed in 2001. An off-channel watering system was developed using a 'thermodrinker' trough and dugout to supply water year-round to the new overwintering area.

In 2000, a hardened cattle ramp constructed of gravel and GeoWeb was built to allow cattle to cross Glacier Gulch Creek without adding sediment to the stream. This project was done on crown land to allow cattle to access Crown range.

As part of a watershed restoration project funded by FRBC, Pacific Inland Resources, a division of West Fraser Mills Ltd., carried out some rehabilitation work of Toboggan Creek at the Silvern Lakes Road crossing site in 2000/01. Several years ago an old bridge located at this site collapsed into the creek and diverted the main stream channel out of its natural course. Consequently the stream washed over its banks and ran down the road during high flows potentially causing excessive siltation and debris accumulation. A riprap berm was constructed to protect the stream banks and included approaches over the berm to maintain four-wheel drive access across the stream. A deflector groin was installed to protect the berm and approach from the full force of the stream and cottonwood root wads were placed at the waterline for fish habitat and potential revegetation. (Silvicon Services Inc., 2000)

3. Water Quality Assessment

3.1 Sampling and Analytical Methods

3.1.1 Water Quality and Periphyton Monitoring Sites

Monitoring site locations are shown in Figure 1. Water quality and periphyton site photos and location notes are found in Appendix 4. In the site names, W denotes a water quality monitoring site and P denotes a periphyton monitoring site.

Because of difficulties in finding road access and private land ownership, the 1996-1998 study lacked a control site that was upstream of most human influence. This resulted in inability to assess results using comparative statistical techniques.

We were unable to obtain permission to cross private land to sample Glacier Gulch Creek upstream of Toboggan Lake. The August 2001 control sample was taken from Glacier Gulch Creek on an old mining road at considerable elevation above the valley floor. This was not a satisfactory site for comparative purposes because of the elevation and impossibility of winter access. We were grateful, therefore, to be allowed access to a private road and property to sample Upper Toboggan Creek as a control site. Site 1 was established on Upper Toboggan Creek in September 2001 and sampled for the remainder of the study. Upstream of Site 1, Upper Toboggan Creek passes between two hay fields. A riparian zone of mature cottonwood, willow and spruce provides bank stability and shading. Although the hay is cut annually, cattle are not pastured or overwintered and there has been no fertilizer application to this property. There is no permanent habitation on this property.

One site each was established on the next largest tributaries, Elliot Creek (Site 3) and Owens Creeks (Site 7). A confined overwinter feeding and calving yard is located at the confluence of Owens and Toboggan creeks, but a drainage ditch directs surface runoff into Toboggan rather than Owens Creek. Sites 1, 3 and 7 are believed to be relatively unimpacted by human activities and diffuse sources, compared to the Toboggan mainstem.

In August, Toboggan Creek, downstream of the Glacier Gulch Creek confluence and upstream of the Elliot Creek confluence, was reached for sampling via the CNR grade. This site was relocated to Site 2 in September, for sampling convenience. Toboggan Creek is constrained and channelized throughout this section by the CNR berm. Beaver dams and ponding are also prominent throughout this section. Sites were established in the fish hatchery outflow channel (Site 5) and upstream and 100 m downstream of the hatchery (Sites 4 and 6). The final site is Toboggan Creek upstream of Highway 16 and the Bulkley River confluence (Site 8).

3.1.2 Water Monitoring and Analytical Methods

Water and bacterial sampling methods followed MELP standards: *Ambient freshwater and effluent sampling manual* (Cavanagh et al. 1994*a*) and *Biological sampling manual* (Cavanaugh et al. 1994*b*). Field parameters monitored included specific conductance, pH, water temperature and dissolved oxygen. Low-level nitrite-nitrate-N and ortho-phosphate-P samples were field filtered into specially washed amber glass bottles. Iced water samples were immediately shipped via air courier to the BCWLAP designated laboratory (Pacific Environmental Science Center in 2001 and PSC Analytical Services in 2002).

QA/QC: One set of triplicate sequential samples was submitted for analysis each sampling date. Trip and filtration blank samples were collected each field trip. Blank samples were retained but not analyzed.

Analyses were performed using procedures based on those described in BC Environmental Laboratory Manual For the Analysis of Water, Wastewater, Sediment and Biological Materials and Standard Methods for the Examination of Water and Wastewater. Water analysis data is stored in the BCWLAP EMS database.

3.1.3 Periphyton Monitoring and Analytical Methods

Periphyton sampling was conducted at four locations: Site 1WP Upper Toboggan Creek (control), Site 4WP (upstream of the hatchery), Site 6WP (downstream of the hatchery) and Site 8P. Site 8P is 500 m upstream of Site 8W at the Highway 16 crossing where water samples were taken. A slightly different site was chosen for periphyton and benthic invertebrate sampling because Site 8W had a steep gradient and boulder substrate that was unsuitable for biological sampling. The physical characteristics of the periphyton sampling locations are found in Table 1.

Periphyton sampling methods followed Cavanaugh et al. (1994*b*). Six replicate periphyton samples were collected at each site. Periphyton was scraped and washed from 2-3 randomly selected rocks into a glass container, which was immediately placed on ice in a darkened cooler. A waxed paper tracing of the sampled area was taken from each rock for areal determination. Later each day, the individual samples were filtered onto a 0.45 μm filter, and 2-3 drops of $MgCO_3$ suspension added as pH buffer. The sample filters were placed in a darkened thermos containing activated desiccant and were frozen immediately. Frozen samples were shipped via air courier and with dry ice, to ensure they remained frozen, to the designated BCWLAP analytical laboratory.

Table 1 Physical characteristics of periphyton sampling locations Toboggan Creek 2001 and 2002

Site	Location	EMS ID	Latitude/ Longitude	Sampling date	Water temp. °C	Sampling depth cm	Substrate	Current velocity m/s	Wetted width m	Percent shade %
1WP	Upper Toboggan Cr	E245607	N54.8733 W127.265	12-Sep-01 03-Sep-02	8	15	30% cobble 50% gravel 20% sand	0.53	4.5-5	75
4WP	Toboggan Cr upstream fish hatchery	E235365	N54.8892 W127.2644	12-Sep-01 02-Sep-02	11	15-20	75% gravel 15% sand 10% silt	0.44	9.4	15
6WP	Toboggan Cr 100m downstream hatchery	E245367	N54.8936 W127.27	13-Sep-01 03-Sep-02	9	25	80% gravel 20% sand/silt	0.48	6.5	50
8P	Toboggan Cr 500m upstream Hwy 16	E245369	N54.9364 W127.313	13-Sep-01 03-Sep-02	10	15-20	2% boulder 8% cobble 70% gravel 20% sand/silt	0.67	6	35-40

Three periphyton samples for community analysis were collected at each site in 2001. In 2002, only one sample was collected at each site due to budgetary constraints. Scrapings were included from at least three rocks for each sample and preserved with Lugol's solution. Mary Bolin, algal taxonomist, Victoria, conducted the algal identification and enumeration in both years. Cell counts were made at 500x magnification after settlement in Utermohl chambers. An overall scan of the chambers at 200x magnification was made to ensure an even distribution of cells and that no large cells, filaments or colonies are missed. A minimum of 100 individuals of the most abundant species and a minimum of 300 cells in total were counted. Cells of filamentous taxa were separated from counts of unicellular taxa. Cell counts were extrapolated to biovolume using known volumes of algal taxa.

QA/QC: To confirm cell counts, 10% of all samples were enumerated twice. Variation within 10% is regarded as acceptable between repeated counts. A list of references for algal identification is available upon request.

3.1.4 Land and Water Use Survey Methods

When conducting water quality monitoring studies, researchers generally attempt to document land use activities in the watershed at the time of the study. This 'snapshot' of land and water use practices at a point in time enables researchers to associate changes in land use over many years with changes in water quality. One inexpensive way to quantify land and water use in a particular watershed is a telephone or mail-in survey of landowners. A land and water use survey was designed (Appendix 3 Table 3) and mailed to residents of the Toboggan Creek watershed in October 2001. The mailing list was derived from the BCWLAP water license database.

3.2 Results and Comparison with Federal and Provincial Water Quality Guidelines

3.2.1 Water Quality Guidelines and Objectives

BCWLAP Water Quality Branch has developed province-wide water quality guidelines for use in assessing water quality data and preparing site-specific water quality objectives (BC Environment 1998 with periodic updates). Water quality guidelines (formerly referred to as 'criteria') are environmental benchmarks. They are safe levels of substances for the protection of a given water use, including drinking water, recreation, aquatic life and agriculture. They are intended to be used as a water quality data-screening tool. If the data do not exceed the guidelines, problems are unlikely. If the data lie outside the guidelines, then a detailed assessment of the data and the guidelines should be done to determine the extent of the problem.

The Canadian water quality guidelines (CCME 1999 with periodic updates) were developed in order to harmonize water quality guidelines used by provinces throughout Canada. The Canadian drinking water quality guidelines are also updated periodically and are based on Health Canada Guidelines.

Specific water quality objectives for the Bulkley and Morice Rivers were developed in anticipation of the Kemano Completion Project (Nijman 1986). Water quality objectives are environmental quality conditions set as targets for specific water bodies based on three main factors: 1) the designated use(s) for the water; 2) the water quality guidelines that have been adopted for the most sensitive designated use; and 3) the local conditions, including the actual measured water quality in the area and any observed toxic effects. For a specific drainage the appropriate priority uses for the water are chosen. This becomes the designated use to be protected by the objectives. Objectives are chosen for that waterbody based on the guidelines, taking local circumstances into account. Objectives can be chosen above or below the guidelines, depending on the situation and what is at risk. The objectives are policy guidelines for decision-makers who issue Water Licenses for water use and Waste Management Permits for waste disposal.

3.2.2 Water Quality Results

Water analysis data for each site are found in Appendix 1 Tables 1-18. There are two tables for each site. The first table contains all the data, including sequential replicate samples. The second table contains descriptive statistics for each site. The descriptive statistics were calculated using the mean of triplicate sequential samples on any given date. In many cases, the levels of substances present in stream water were observed to be below the minimum detectable concentration (MDC) used in the analyses. The MDC value was used for observations which were less than (<) the MDC when computing the mean and standard deviation.

Water quality QA/QC—
Replicate samples provide an estimate of the overall precision associated with field technique and laboratory analysis. Triplicate sequential samples were taken at one site on each sampling date. Analysis of the replicate samples is found in Appendix 1 Table 19.

When three or more replicates are collected, precision can be expressed as a percent relative standard deviation by dividing the standard deviation by the mean and then multiplying by 100. BC Environment *Guidelines for interpreting water quality data* (BCWAP 1997) suggests a 'rule of thumb' criteria for precision values (above which the data should be viewed with caution) is 18% for relative standard deviation for triplicates.

In general, the relative standard deviations were acceptable for the replicate samples. No single parameter or site was found to have an unusual amount of variability. Variability in the Residue Non-filterable, often referred to as total suspended solids (TSS), is normal in mountainous streams, particularly during the higher flow periods of freshet and autumn. Both major headwater branches of Toboggan Creek originate from glaciers, and a fine glacial flour is visible in the Toboggan mainstem except during the winter months. Phosphorus-containing mineral particles are common, and total phosphorus concentrations tend to be both higher and show more variation when TSS concentrations are elevated. Ammonia is known to adsorb readily to suspended solids (*Standard Methods*), thus concentrations of this substance will also tend to show higher variability depending on TSS levels. Since no significant QA-related problems were noted in this data, blank samples collected during each field trip were retained but not analyzed.

3.2.3 Water quality summary 2001 – 2002

Water analysis summary statistics for August through March are found in Table 2. On dates when triplicate sequential samples were taken for QA/QC, the mean of the replicates was used in the calculation of summary statistics. The MDC value was used for observations which were less than (<) the MDC when computing the mean and standard deviation. Once only samples from Glacier Gulch Creek and Toboggan Creek at the CNR bridge are not included in the summary table, but can be found in Appendix 1 Tables 17 and 18.

Table 2 Water analysis summary for eight sites in Toboggan Creek and tributaries 2001-02

Monitoring Site		Temp. water	Diss. Oxygen	Fecal coliform	Residue Non-filterable	pH	Specific Conduct-ance	Total Nitrogen	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrate (N)	Nitrite (N)	Diss. Inorganic Nitrogen	Phosphorus Total	Ortho-Phosphate (P) LL	N:P Ratio
		ºC	(mg/L)	(CFU/100ml)	(mg/L)	(pH units)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Site 1 Upper	*Maximum*	9.8	15.9	61	67	7.94	150	1.77	0.021	1.210	1.206	0.010	1.231	0.032	0.005	1231
Toboggan Cr	*Minimum*	0.1	9.8	< 1	< 4	7.20	26	0.09	< 0.005	0.033	0.031	< 0.002	0.038	< 0.002	< 0.001	8
E245607	*Average*	3.78	12.15	13.3	15.4	7.519	76.0	0.685	0.0078	0.4922	0.5288	0.0035	0.5000	0.0128	0.0018	338.4
	St. Dev.	3.38	1.53	20.2	18.3	0.278	42.1	0.595	0.0047	0.4544	0.4570	0.0027	0.4573	0.0105	0.0013	408.1
Site 2 Toboggan	*Maximum*	12.2	12.4	412	27	7.66	130	1.50	0.270	0.245	0.238	0.010	0.515	0.134	0.024	237
Cr downstream	*Minimum*	0.5	8.8	< 1	< 5	6.71	32	0.09	< 0.005	0.032	0.030	< 0.002	0.037	0.006	< 0.001	13
Toboggan Lake	*Average*	4.87	10.59	46.5	9.1	7.313	70.7	0.422	0.0439	0.1225	0.1277	0.0041	0.1664	0.0280	0.0037	62.5
E245606	*St. Dev.*	4.02	1.19	114.3	6.8	0.252	33.3	0.420	0.0787	0.0767	0.0748	0.0028	0.1420	0.0367	0.0066	80.4
Site 3 Elliot Cr	*Maximum*	8.5	15.8	118	50	8.03	160	0.5	0.008	0.374	0.367	0.012	0.379	0.044	0.003	379
E245364	*Minimum*	1.5	10.2	< 1	< 4	7.46	87	< 0.02	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
	Average	4.71	11.75	13.1	8.1	7.820	133.6	0.128	0.0055	0.0906	0.0946	0.0034	0.0961	0.0055	0.0012	91.6
	St. Dev.	2.29	1.32	32.0	12.6	0.145	21.3	0.120	0.0010	0.0932	0.0991	0.0032	0.0929	0.0116	0.0006	113.1
Site 4 Toboggan	*Maximum*	11.2	14.4	508	37	7.82	138	1.35	0.184	0.657	0.650	0.008	0.662	0.141	0.024	662
Cr upstream fish	*Minimum*	0.5	9.4	< 1	< 5	6.81	45	0.05	< 0.005	0.026	0.020	< 0.002	0.031	0.005	< 0.001	8
hatchery	*Average*	5.32	10.96	49.4	11.5	7.491	82.5	0.411	0.0316	0.1516	0.1687	0.0041	0.1832	0.0253	0.0035	117.3
E245365	*St. Dev.*	4.00	1.39	134.0	9.8	0.255	29.1	0.401	0.0497	0.1661	0.1720	0.0024	0.1783	0.0362	0.0063	206.6
Site 5 Fish	*Maximum*	11.0	15.6	480	19	7.90	220	1.09	0.150	0.603	0.593	0.010	0.745	0.078	0.009	745
hatchery outflow	*Minimum*	0.5	8.4	< 1	< 4	7.42	70	0.20	0.013	0.062	0.055	< 0.002	0.075	0.015	< 0.001	20
channel	*Average*	5.38	10.30	59.8	7.5	7.613	119.8	0.487	0.0725	0.1854	0.2032	0.0043	0.2580	0.0321	0.0044	146.3
E245366	*St. Dev.*	3.71	2.04	136.5	4.2	0.153	41.3	0.275	0.0444	0.1497	0.1513	0.0030	0.1744	0.0186	0.0028	229.3
Site 6 Toboggan	*Maximum*	11.0	16.4	456	59	7.90	137	1.45	0.216	0.660	0.646	0.014	0.668	0.095	0.024	668
Cr 100m down-	*Minimum*	0.5	9.2	< 1	< 5	7.43	18	0.10	< 0.005	0.030	0.026	< 0.002	0.035	0.007	< 0.001	14
stream hatchery	*Average*	5.13	11.44	55.1	14.3	7.589	79.7	0.429	0.0329	0.1565	0.1729	0.0047	0.1895	0.0240	0.0035	141.3
E245367	*St. Dev.*	3.83	1.78	125.9	15.4	0.149	36.5	0.421	0.0574	0.1660	0.1701	0.0038	0.1821	0.0244	0.0062	210.9
Site 7 Owens Cr	*Maximum*	9.8	16.4	31	161	7.99	160	1.20	0.009	0.774	0.771	0.010	0.779	0.043	0.003	779
E245368	*Minimum*	0.5	9.6	< 1	< 4	7.44	68	0.08	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
	Average	3.75	12.38	7.9	18.2	7.750	124.9	0.337	0.0057	0.1992	0.2222	0.0033	0.2048	0.0094	0.0012	197.6
	St. Dev.	3.32	1.69	8.8	42.9	0.168	30.6	0.347	0.0013	0.2314	0.2430	0.0026	0.2314	0.0113	0.0006	255.4
Site 8 Toboggan	*Maximum*	10.8	17.8	168	97	7.96	153	1.76	0.198	0.591	0.583	0.009	0.598	0.152	0.031	212
Cr upstream	*Minimum*	0.3	9.7	< 1	< 5	6.85	57	0.10	< 0.005	0.037	0.032	< 0.002	0.042	0.004	< 0.001	18
Highway 16	*Average*	4.57	12.51	39.0	26.7	7.640	93.7	0.492	0.0256	0.1783	0.1973	0.0045	0.2039	0.0363	0.0039	88.2
E245370	*St. Dev.*	4.13	2.07	51.5	32.9	0.286	32.0	0.476	0.0526	0.1611	0.1638	0.0030	0.1877	0.0431	0.0082	78.2

3.2.4 Water temperature

The BC water quality guidelines (WQGs) for water temperature vary for species and their life history phase. In Toboggan Creek, the most sensitive species present in the Toboggan mainstem, where elevated water temperatures are of concern, are pink and coho salmon. Pink salmon spawning takes place throughout the lower 8 km mainstem Toboggan Creek. Coho salmon spawning and rearing occurs in the mainstem up to the lake and in the lower reaches of Glacier Gulch Creek, Upper Toboggan Creek and the mouth of Elliot Creek. In the lower Toboggan mainstem, pink and coho salmon spawning starts in the late August to mid-September period, this is when the lowest streamflows and highest water temperatures often occur.

The recommended temperature guideline is plus or minus one degree Celsius change beyond optimum temperature range for each life history phase of the most sensitive salmonid species:

The optimum temperature range for coho spawning is 4.4-12.8 °C

The optimum temperature range for pink spawning is 7.2-12.8 °C.

The highest water temperature recorded in the 1996-98 study was 18°C in Glass Creek where it crosses a large hay field upstream of Toboggan Lake in late June 1996. The complete removal of riparian cover from this stream undoubtedly had influenced the water temperature in this creek. No fish were found in Glass Creek in July 1997, although historical information indicates fish presence and suitable Dolly Varden and rainbow trout habitat was available (Triton 1998).

The highest water temperatures recorded in the 2001-02 study occurred on 22 July 2002. On this date, the temperatures in the Toboggan tributary streams were less than 10°C. Upper Toboggan Creek (Site 1) and Owens Creek (Site 7) were 9.8°C. The other tributary monitored, Elliot Creek (Site 3) was 8.5°C. Elliot Creek may be cooler as the result of groundwater inflow from natural springs found upstream of Site 3.

On 22 July 2002, water temperature in the Toboggan mainstem at Site 2, downstream of the Glacier Gulch Creek confluence and Toboggan Lake, was 12.2°C. Toboggan mainstem water temperature was 11.2°C at Site 4 upstream of the fish hatchery, 11° C at Site 6 downstream of the hatchery, and 10.8°C at Site 8 upstream of Highway 16. Water temperatures on July to September sampling dates throughout the Toboggan mainstem approached, but did not exceed, the upper limit of the optimum temperature range for coho and pink salmon spawning.

Water temperature in the hatchery outflow channel (Site 5) was 11°C on 22 July 2002. Water temperatures in the hatchery outflow channel exceeded 9°C on three July to early-September sampling dates. Water temperatures may be even higher in the hatchery rearing channels, which have no shading. The maximum recommended water temperature for hatchery production of salmon with respect to successful smoltification and migratory behavior is 15°C (13°C for steelhead). Temperature increases reduce allowable pond loadings per unit flow rate and a high temperature period in late summer could therefore be the factor controlling the maximum numbers of fry reared at a facility with a limited water supply (Sigma Env. Consult. 1983).

Numerous human activities in this watershed contribute to elevated water temperatures: forestry, transportation corridors and, particularly, agricultural land clearing. Upstream of Toboggan Lake, Glass Creek and Glacier Gulch Creek pass through a sizeable hay field in which all riparian cover has been removed. Further solar heating during water passage through Toboggan Lake and wetlands is unavoidable. Stream segments lacking riparian cover have been documented throughout the lower Toboggan watershed in WRP studies. Toboggan Creek has been identified as a priority watershed for riparian restoration activities.

3.2.5 Dissolved oxygen

The WQGs (instantaneous minimum concentration) for dissolved oxygen (DO) for the protection of salmonids are as follows:

All life stages (other than embryos or alevins still in gravel) 5 mg/l

Buried embryo/alevin (water column concentration over gravel) 9 mg/l.

The Bulkley River Objective dissolved oxygen concentration is 7.8 mg/L minimum.

In the 1996-98 study, DO concentrations detrimental to salmonid survival were documented in a dug-out pond excavated in an unnamed fish-bearing tributary of Toboggan Creek. DO concentrations of 7 and 8 mg/L were also recorded in lower Toboggan Creek in March and April 1998 when the stream was under ice cover.

In the 2001-02 period, DO concentrations at all locations were greater than the 7.8 mg/L criterion for post hatch and free-swimming stages of salmonids recommended by Davis (1975) and the Bulkley River Objective. Minimum DO concentrations were greater than the 9 mg/L DO objective for water column over buried embryo/alevins in gravel.

The exceptions were DO concentrations of 8.8 and 8.9 mg/L recorded at Site 2 April 15 and 22, 2002, respectively. The slightly depressed DO at this site during freshet may have been related to flushing of stagnant water from the wetlands upstream. A confined livestock winter feeding lot on the slope above Toboggan Lake likely contributes organic loading to the lake, which can result in DO depression.

The lowest DO concentrations seen in this study were in the hatchery outflow channel (Site 5). DO concentrations ranging from 8.4 to 8.9 mg/L were recorded on summer to early fall sampling dates. The DO levels in the hatchery outflow channel did remain above the 7.8 mg/L criterion for salmonid hatcheries (Sigma Environmental Consultants 1983). No depression of DO was seen at Site 6, Toboggan Creek 100 metres downstream of the hatchery outflow.

3.2.6 Residue, Non-filterable

Non-filterable Residue is a measure of the total suspended solids (TSS) within the water column. The glacial origins of Glacier Gulch Creek were very apparent in the TSS concentration of 211 mg/L on 30-Aug-01. This sample was taken at high elevation and close to the glacier. Although Toboggan Lake acts as a settling pond, visually, glacial flour (comprised of very finely ground silt and clay particles) is apparent the length of Toboggan Creek for much of the summer.

During the high water flows of freshet, TSS was elevated in the entire system. The highest TSS recorded during this study was 161 mg/L at Site 7, Owens Creek, on 18-Jun-02.

Elliot Creek, Site 3, was notable in having TSS concentrations less than the minimum detectable concentration (MDC) for all but one sampling date (18-Jun-02). This is likely because much of the water flow in lower Elliot Creek is derived from groundwater springs.

3.2.7 Specific conductance

Specific conductance provides a good indication of the water's composition, especially in its mineral concentration. It is particularly sensitive to variations of dissolved solids. Specific conductance is relatively low in Upper Toboggan Creek and at Site 2 downstream of the lake, averaging 76 and 71 µS/cm respectively. The two tributaries, Elliot and Owens Creeks, have higher Specific conductance, averaging 134 and 125 µS/cm respectively. This is interpreted to be due to prolific groundwater springs, emanating from the lower slopes of Evelyn Mountain, which feed these watersheds. Brant Brook, which is the domestic water source for many households in the community of Evelyn, is entirely spring-fed. Groundwater inflow is believed to significantly augment Toboggan Creek flows throughout its length (M. O'Neill, Toboggan Creek Salmonid Hatchery Manager, personal communication).

Specific conductance is higher throughout the watershed during the winter months, reflecting the greater influence of groundwater flows during the winter.

3.2.8 Ammonia

Drainage from a dug-out pond, which had been excavated in a small unnamed tributary of Toboggan Creek, was the subject of a DFO investigation in 1996-98. The tributary was a known coho and rainbow trout/steelhead rearing stream. The 20 cow-calf operation was investigated because of the choice of winter feedlot location adjacent to the stream, with cattle watering through the ice on the dug-out pond. The manure which collected on the ice during the winter directly entered the stream in the spring. An ammonia concentration higher than the provincial 30-day average guideline for ammonia was recorded during freshet, March 1998. Histological analysis of juvenile salmonids captured in the pond showed gill, liver and kidney pathologies similar to those reported for ammonia toxicity. Because of concern for the health of juvenile coho and rainbow trout/steelhead in the pond and downstream, a DFO fish protection order was issued and the winter feedlot was subsequently relocated.

Average ammonia concentrations during 2001-02 were 7.8 μg/L-N in Upper Toboggan Creek (Site 1), 5.5 μg/L-N in Elliot Creek (Site 3) and 5.7 and μg/L-N in Owens Creek (Site 7). These three tributaries can be considered to be control sites. (A cow-calf confined winter feeding area is located at the confluence of Owens and Toboggan creeks, but drainage ditches have been constructed to direct most surface runoff into Toboggan Creek rather than Owens Creek.)

Average ammonia concentrations were 43.9 μg/L-N downstream of the lake (Site 2) and 31.6 μg/L-N upstream of the hatchery (Site 4). Student's t test provides evidence for an increase in mean ammonia concentrations from 7.8 μg/L-N at Site 1 to 43.9 μg/L-N at Site 2 ($P=0.07$). Likewise, a Student's t test provides evidence for an increase in mean ammonia concentrations from 7.8 μg/L-N at Site 1 to 31.6 μg/L-N at Site 4 ($P=0.06$).

Ammonia concentrations demonstrated a sharp increase on 15-Apr-02 at all Toboggan mainstem sites: 270 μg/L-N (Site 2), 184 μg/L-N (Site 4), 216 μg/L-N (Site 6) and 198 μg/L-N (Site 8). A jump of this magnitude was not seen on this date at the three control sites, Site 1 (Upper Toboggan), Site 3 (Elliot) and Site 7 (Owens). (These data are found in Appendix 1 Tables 1- 16). A similar event was noted during the 1996-98 study, in which ammonia concentrations throughout the Toboggan mainstem peaked with the first flush of freshet and surface runoff on the valley floor. The average 30-d concentration WQG for ammonia at 1 °C and 7.5 pH (on 15-Apr-02) is 2.05 mg/L-N (an order of magnitude greater).

An increase in ammonia concentration downstream of the confluence of Glacier Gulch Creek and the lake may be due to runoff from agricultural operations near Toboggan Lake; but could also be influenced by biological activities in the wetlands surrounding the lake. Wetlands and waterlogged soils favor the export of reduced nitrogen species such as ammonia (Dillon 1991). A recent study in northern Alberta (Prepas et al. 2001) found that the percentage wetland cover explained 40% of ammonia variability when comparing nutrient export from wetland-dominated versus upland-dominated catchments.

The highest ammonia concentration recorded in the hatchery outflow channel (Site 5) was 0.150 mg/L-N on 15-Apr-02 (Appendix 1 Table 10). Toxicity of ammonia increases with water temperature and pH. An ammonia concentration of 0.122 mg/L-N was recorded in the outflow channel 29-Aug-01. On that date, the water temperature was 10.5°C and pH 7.46. The maximum instantaneous ammonia WQG (Nordin and Pommen 1986) at that temperature and pH is 12.6 mg/L-N. The average 30-day WQG for 10.5°C and pH 7.46 is 1.84 mg/L-N. In other words, the 30-day WQG is an order of magnitude higher than the hatchery outflow ammonia concentration.

The *Summary of water quality criteria for salmonid hatcheries* (Sigma Environ. Consult. 1983) recommends a slightly more stringent criterion. The maximum level of ammonia in hatchery water supporting fish (i.e. effluent criteria) should be less than 1.71 mg/L-N at 10°C and 7.5 pH. Again, this is approximately an order of magnitude higher than recorded in this study.

Ammonia concentrations recorded in this study did not exceed WQGs for the protection of freshwater aquatic life. Nonetheless, the Toboggan Creek Salmonid Hatchery diverts its water supply to groundwater sources during early freshet each year for perceived water quality concerns (M. O'Neill, hatchery manager, personal communication). The DFO Summary of Water Quality Criteria for Salmonid Hatcheries (Sigma Env. Consult. 1983) states that the ideal concentrations for ammonia and nitrite in hatchery inflow water are 'non detectable'.

3.2.9 Nitrite

The maximum nitrite concentration recorded at any site was 14 µg/L-N. The average nitrite concentration ranged from ≤3.5 µg/L-N at the three tributary sites (1WP, 3W and 7W) to ≤4.7 µg/L-N at Toboggan mainstem sites. The WQG for nitrite is 60 µg/L-N (maximum) and 20 µg/L-N (30-day average).

Further discussion of nitrogen species is found in the Trend Assessment and WQGs for Nutrients and Algae sections that follow. Microbiological quality results follow in the Drinking Water Source Quality Monitoring (Section 3.11).

3.2.10 Metals

Analyses for total metals were completed as part of the drinking water quality studies. Four were high-level analyses with an MDC appropriate for drinking water quality guidelines. Four were low-level analyses (ICP-MS) appropriate for aquatic life guidelines. Some total metals concentrations (e.g. cadmium and iron) approximated the working WQGs for protection of aquatic life (BCWLAP 1998*a*).

The mean molybdenum concentration (ICP-MS) approximated the molybdenum irrigation water guideline of 0.01 mg/L when the water is used for forage crops on poorly drained soils and the copper to molybdenum ratio is <2:1. The Cu:Mo ratio in 2001-02 was 0.3:1. Further monitoring of total and dissolved metals concentrations (ICP-MS) is needed to assess the significance of these findings.

3.3 Water Quality Trend Assessment

3.3.1 Upstream-downstream trends in water quality

In order to assess water quality along the downstream gradient of Toboggan Creek, ANOVA was conducted on the data for Upper Toboggan Creek and the four mainstem sites. ANOVA and the Student's *t* test are statistical methods used for deciding if two or more sample means are significantly different. The null hypothesis is that there is no difference between the two sites ('no site effect'). If the P-value is large, we accept that there is no difference in chemical composition between sites. If the P-value is small (typically $P \leq 0.05$), we accept that the chemical composition is different depending on location. The significance level is a subjective decision. Common choices are 0.10, 0.05 and 0.01; the most standard choice is the 5% significance level, $P=0.05$. Table 3 contains the mean concentration ± standard error for the most biologically available nutrients and fecal coliform bacteria in Upper Toboggan Creek and the four downstream Toboggan Creek mainstem sites and the probability (P) of no site effect.

Table 3 Mean concentrations of selected nutrients and fecal coliform bacteria at five Toboggan Creek sites 2001-02 and probability of no site effect

Parameter	Site 1 Upper Toboggan Cr (E245607)	Site 2 Toboggan Cr d/s T. Lake (E245606)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8 Toboggan Cr u/s Hwy 16 (E245370)	Probability of no site effect (P) ANOVA
			Mean concentration (μg/L) ± SE			
Total Nitrogen	685.2 ± 179.4	422.4 ± 126.6	411.3 ± 111.2	429.2 ± 116.7	491.5 ± 131.9	0.60
Ammonia (N)	7.8 ± 1.4	43.9 ± 23.7	31.6 ± 13.8	32.9 ± 15.9	25.6 ± 14.6	0.62
Nitrate (N)	528.8 ± 144.5	127.7 ± 23.6	168.7 ± 51.9	172.9 ± 51.3	197.3 ± 49.4	0.003
DIN[1]	500.0 ± 137.9	166.4 ± 42.8	183.2 ± 49.4	189.5 ± 50.5	203.9 ± 52.0	0.01
Total Phosphorus	12.8 ± 3.2	28.0 ± 11.1	25.3 ± 10.0	24.0 ± 6.8	36.3 ± 11.9	0.53
Ortho-phosphate (P)	1.8 ± 0.4	3.7 ± 1.9	3.5 ± 1.8	3.5 ± 1.7	3.9 ± 2.3	0.94
Fecal coliform[2]	13.3 ± 5.8	46.5 ± 31.7	49.4 ± 35.8	55.1 ± 33.6	39.0 ± 13.8	0.86

[1] Dissolved Inorganic Nitrogen: Ammonia + Nitrate + Nitrite (N)

[2] CFU/100 mL

ANOVA provides strong evidence for a locational effect for nitrate (P=0.003) and dissolved inorganic nitrogen (DIN)(P=0.01). The high concentration of nitrate (and, consequently, DIN and total nitrogen) in Upper Toboggan Creek compared to the rest of the system is an unexpected anomaly. A *t*-test using nitrate data for Site 1 and Site 2, downstream of the Glacier Gulch Creek confluence, also provides strong evidence for a difference in nitrate concentration from average of 529 μg/L-N at Site 1 to 128 μg/L-N at Site 2 (P=0.007). Lower average nitrate concentrations are also found in Elliot and Owens creeks: 95 and 222 μg/L-N, respectively.

According to the property owner, there has been no livestock grazing or overwintering and no fertilizer application on the fields adjacent to the Upper Toboggan Creek monitoring site. Without anthropogenic inputs, most surface waters have less than 300 μg/L of nitrate (BC Environment 1999). If there is an anthropogenic source for nitrate in the Upper Toboggan watershed, it is not apparent to the authors.

Nitrate concentrations in Upper Toboggan Creek were elevated during the winter months, November to May, when groundwater input is proportionally greater (Appendix 1 Tables 1 -2). Igneous rocks and volcanic emanations may provide localized sources of nitrates to water (McNealy et al. 1979), so perhaps there is a localized geologic source for the nitrate in this tributary.

3.3.2 Comparison of nutrient and fecal coliform concentrations in tributary streams with the Toboggan mainstem

Livestock density in the Toboggan watershed, particularly in confined overwintering feedlots, is concentrated on private properties surrounding Toboggan Lake and along the mainstem downstream of the lake. In order to assess any possible effect of this activity on water quality in the mainstem, the data for the three tributary streams, Upper Toboggan, Elliot and Owens creeks (Sites 1, 3 and 7) were combined. This was compared with the combined data for the mainstem (Sites 2, 4, 6 and 8) using a *t*-test. Because of the anomalous nitrate concentration in Upper Toboggan Creek, nitrate, DIN and total nitrogen are omitted from the analysis found in Table 4. The *t*-tests provide strong evidence that higher concentrations of ammonia, total and orthophosphorus and fecal coliform bacteria are found in mainstem Toboggan Creek compared to three tributary streams.

Table 4 Mean concentrations of selected nutrients and fecal coliform bacteria in three tributaries and four Toboggan Creek mainstem sites 2001-02 and probability of no site effect

Parameter	Toboggan Cr tributaries: Site 1 Upper Toboggan (E245607), Site 3 Elliot (E245364) and Site 7 Owens (E245368) combined	Toboggan Cr mainstem: Site 2 (E245606), Site 4 (E245365), Site 6 (245367) and Site 8 (E245370) combined	Probability of no site effect (P)
	mean concentration (µg/L) ± SE		
Ammonia (N)	6.2 ± 0.5	33.1 ± 8.2	0.003
Total Phosphorus	9.0 ± 1.8	28.4 ± 4.9	0.0008
Ortho-phosphate (P)	1.4 ± 0.1	3.7 ± 0.9	0.02
Fecal coliform[2]	11.3 ± 3.5	47.5 ± 14.6	0.02

[2] CFU/100 mL

3.3.3 Trends upstream and downstream of the fish hatchery

t-Tests were conducted with water quality data for Toboggan Creek at Site 4, upstream of the Toboggan Creek Salmonid Hatchery and Site 6, 100 m downstream of the hatchery outflow channel. Mean concentrations of selected parameters and probability of no site effect are found in Table 5. This dataset provides no evidence that the hatchery has an effect on concentrations of nutrients, dissolved oxygen or fecal coliform bacteria in the Toboggan mainstem.

Table 5 Mean concentrations of selected nutrients, dissolved oxygen and fecal coliform bacteria in Toboggan Creek upstream and downstream of the fish hatchery 2001-02 and probability of no site effect

Parameter	Site 4 Toboggan Cr u/s fish hatchery (245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Probability of no site effect (P) *t*-Test
	Mean concentration (µg/L) ± SE		
Total Nitrogen	411.3 ± 111.2	429.2 ± 116.7	0.46
Ammonia (N)	31.6 ± 13.8	32.9 ± 15.9	0.48
DIN[1]	183.2 ± 49.4	189.5 ± 50.5	0.46
Total Phosphorus	25.3 ± 10.0	24.0 ± 6.8	0.46
Ortho-phosphate (P)	3.5 ± 1.8	3.5 ± 1.7	0.49
Dissolved Oxygen (mg/L)	11 ± 0.38	11.4 ± 0.49	0.23
Fecal coliform[2]	49.4 ± 35.8	55.1 ± 33.6	0.45

[1] Dissolved Inorganic Nitrogen: Ammonia + Nitrate + Nitrite (N)

[2] CFU/100 mL

3.3.4 Temporal trends in water quality 1996-98 and 2001-02

In 1996-1998, water quality monitoring took place at five sites in the Toboggan Creek mainstem (Remington and Donas 1999). The main difference from this study is that, in 1996-98, over half of the samples were gathered during freshet (April-June) while, in 2001-02, sampling was generally once per month throughout the calendar year.

t-Tests were conducted to compare the 1996-1998 data with that from 2001-02. In the 1996-98 study, nitrite+nitrate was mistakenly reported as nitrate by the DFO Cultus Lake laboratory (E. MacIsaac, DFO West Vancouver Lab, personal communication). This error was corrected in the dataset used for the temporal trend analysis.

Three sites in the 1996-1998 study were essentially identical to sites monitored in this study: Toboggan Creek at CNR (1996-98) and Site 2; Toboggan Creek at Evelyn (1996-98) and Site 4; and Toboggan Creek at Highway 16 (1996-98) and Site 8.

Toboggan Creek at CNR and Site 2: *t*-Tests comparing total nitrogen (P=0.18), ammonia (P=0.22), total phosphorus (P=0.18) and ortho-phosphate (P=0.13) do not provide evidence for a temporal effect at this site. The *t*-test for nitrite+nitrate (P=0.08) provides weak evidence that a decrease occurred from 1996-98 mean of 210 µg/L-N to a 2001-02 mean of 123 µg/L-N. Positive changes in agricultural practices, implemented after the 1996-98 study (Section 2.7.4), could have affected a decrease in nitrogen concentrations downstream.

Toboggan Creek at Evelyn and Site 4: *t*-Tests for total nitrogen (P=0.26), ammonia (P=0.42), nitrite+nitrate (P=0.32), total phosphorus (P=0.22) and ortho-phosphate (P=0.15) do not provide evidence for a temporal effect at this site.

Toboggan Creek at Highway 16 and Site 8: *t*-Tests for total nitrogen (P=0.35), ammonia (P=0.46), nitrite+nitrate (P=0.32), total phosphorus (P=0.15) and ortho-phosphate (P=0.17) do not provide evidence for a temporal effect at this site.

3.4 Comparison with other Skeena Watershed Streams 1983-1987

In 1982, BC Environment Waste Management Branch initiated a water quality monitoring program on major drainages of the Skeena River watershed (Wilkes and Lloyd 1990). Monitoring occurred monthly for five consecutive years. Table 6 contains mean nutrient concentrations in the Morice, Telkwa, Kispiox and Bulkley rivers, 1982-88, and Upper and lower Toboggan Creek, 2001-02. Major human activities in the catchment areas of the monitoring locations are also noted.

Table 6 Mean nutrient concentrations in Toboggan Creek (2001-2002) and other Skeena watershed streams (1982-1988) (Wilkes and Lloyd 1990)

Waterbody	Major human activities	Total Nitrogen	Ammonia (N)	Nitrite+nitrate (N)	Total Phosphorus	Ortho-phosphate (P)	*Ortho-P MDC*[2]
				Mean [1] µg/L			
Morice River	Forestry	120	8.2	37.5	5.2	<3	<3
Telkwa River	Forestry	152	10.2	73.8	5.1	3.7	<3
Kispiox River	Agriculture / Forestry	180	12.6	73.8	5.7	4.5	<3
Bulkley River at Quick	Municipal / Agriculture	200	13.7	43.8	6.9	4.8	<3
Upper Toboggan Cr (Site 1)	Forestry	685	10.1	492.2	15.1	2.3	*<1*
Toboggan Creek at Hwy 16 (Site 8)	Agriculture / Rural Residential / Forestry	492	43.2	178.3	36.3	5.8	*<1*

[1] Mean calculated as in Wilkes and Lloyd: observations below the MDC were excluded from the calculation.

[2] The minimum detectable concentration (MDC) for ortho-phosphate differed between the 1982-87 and 2001-02 studies. The higher MDC in the earlier study has the effect of making the calculated mean reported by Wilkes and Lloyd somewhat higher than it likely was.

Mean total nitrogen and nitrite+nitrate levels are two to three times higher at the Upper Toboggan Creek control (Site 1) than the other Skeena watershed streams. Likewise, mean total phosphorus concentration at the Upper Toboggan Creek control (Site 1) was two to three times that of the other streams. As noted previously, the nitrate levels in Upper Toboggan Creek are remarkable. Nitrate and phosphorus levels have been strongly related to the intensity of agricultural activity in other watersheds (Nordin 1985; Webb and Walling 1992; Cooper 1993; Cooke and Prepas 1998). However, since Site 1 is upstream of livestock overwintering operations and other soluble nutrients (ammonia and ortho-phosphate) are low, this relationship is considered unlikely.

3.5 Phosphorus Concentrations and Trophic Status

Currently, BC has only defined phosphorus water quality guidelines for lakes. Likewise, no national environmental quality guidelines exist for phosphorus. The Protocol for the Derivation of Guidelines for the Protection of Aquatic Life (CCME 1991) is intended to deal with toxic substances, and provide numerical limits based on the most current, scientifically defensible toxicological data. Phosphorus does not fit this model because it is non-toxic to aquatic organisms at levels and forms present in the environment; however, secondary effects, such as eutrophication and oxygen depletion are serious concerns. Because aquatic communities are generally adapted to ambient conditions, it is not feasible to establish a single guideline value for phosphorus. Some of the effects of phosphorus are aesthetic and thus include an element of subjectivity. Based on these realities, guidelines for phosphorus have not been derived, rather a guidance framework that is consistent with CCME guideline principles has been developed. The framework accommodates the non-toxic endpoints associated with phosphorus loading and permits site-specific management of phosphorus.

The framework provides a tiered approach where water bodies are marked for further assessment by comparing their trophic status to predefined 'trigger ranges'. Internationally accepted Organization for Economic Co-operation and Development (OECD) trophic status values (Vollenweider and Kerekes 1982) are the recommended trigger ranges for both rivers and lakes (Table 7). Also found in Table 7 are the mean total phosphorus concentrations in the Toboggan watershed and the corresponding trophic status.

Table 7 Total phosphorus trigger ranges for Canadian lakes and rivers and Toboggan Creek trophic status

Trophic status	Canadian trigger ranges total phosphorus (µg/L)
Ultra-oligotrophic	<4
Oligotrophic	4-10
Mesotrophic	10-20
Meso-eutrophic	20-35
Eutrophic	35-100
Hyper-eutrophic	>100

Toboggan Creek locations	Mean total phosphorus 2001-2002 (µg/L)	Trophic status
Site 3 Elliot Cr	5.5	Oligotrophic
Site 7 Owens Cr	9.4	Oligotrophic
Site 1 Upper Toboggan Cr	12.8	Mesotrophic
Site 2 Toboggan Cr d/s T. Lake	28	Meso-eutrophic
Site 4 Toboggan Cr u/s fish hatchery	25.3	Meso-eutrophic
Site 6 Toboggan Cr 100m d/s hatchery	24	Meso-eutrophic
Site 8 Toboggan Cr u/s Hwy 16	36.3	Eutrophic

3.6 Water Quality Guidelines for Nutrients and Algae

The BCWLAP water quality criteria for nutrients and algae (Nordin 1985) are proposed to protect water resources from degradation by excessive amounts of algae. Eutrophication is the process by which lakes and streams become biologically more productive due to increased supply of nutrients (phosphorus and/or nitrogen). If sufficiently large amounts of nutrients enter lakes and streams, man's use of waters can be impaired by the algal biomass present. Eutrophication at low levels and in some habitats may benefit sport fisheries. However as the eutrophication process accelerates, negative consequences, such as changes in fish food benthic organism communities and habitat conditions, can result in a shift in fish species away from salmonids and toward more tolerant species.

3.6.1 Protection of aesthetics and recreation guideline

The Bulkley River watershed objective value of less than 50 mg/m^2 chlorophyll *a* was established for protection of uses related to recreation and aesthetics (Nijman 1986). Nordin (1985) discusses the difficulty in assessing a level of algal biomass that is acceptable from the perspective of aesthetics. He cites examples in other British Columbia rivers in which algal biomass in the range of 35-100 mg/m^2 caused complaints about the appearance of the river, and reduced enjoyment of use of the river by fishermen. The growth, predominantly filamentous algae, was brown or brownish green, slimy and often occurred as long trailing strands. The growth coated the rocks, making footing hazardous and fouled fishing lures, making angling difficult.

Under the right conditions of light and temperature, nutrient enrichment can promote a shift in community composition from predominantly diatoms to a predominance of certain prolific blue green or green filamentous algae species. This is often considered a 'nuisance' condition for the following reasons (Welch 1980):

An undesirable change in the appearance of the river and reduced enjoyment of use of the river by fishermen.

The clogging of water intakes with floating clumps of filaments occurs.

Many of the nuisance species of green and blue green algae that thrive in enriched environments produce undesirable tastes and odors if the affected stream is used for drinking water supply.

3.6.2 Protection of aquatic life guideline

A value of less than 100 mg/m^2 chlorophyll *a* is the BCWLAP guideline to protect against undesirable changes in aquatic life. To define what levels of algal biomass in a stream represent an impairment of use for aquatic life, the scientific literature and the experience of environmental biologists working in BC were surveyed. Excessive amounts of algal biomass accumulation can be detrimental to fish in streams by causing the following problems:

A secondary biological oxygen demand is created that can deplete oxygen downstream as the filaments break off, or are dislodged, float away and decompose in shallow backwater areas.

Change in oxygen concentration in streambed gravels. With heavy algal biomass, algal respiration or the decomposition of algal tissue in the gravel can damage or destroy incubating eggs. The oxygen concentration can also be affected by restriction of water flows through the gravel.

A shift in community composition from diatoms to green and blue green filamentous algae, which are believed to be less appealing to the invertebrate food species of salmonid juveniles and fry.

A shift in community composition from diatoms to green and blue green filamentous algae, which are believed to be less appealing to the invertebrate food species of salmonid juveniles and fry.

Heavy algal biomass may provide additional shelter for stream invertebrates from fish, and consequently affect fish growth and survival rates.

Fry rearing and overwintering may be impaired by algal growth as well. Excellent habitat for fry (such as cobble) where fry rear and overwinter in the spaces between the cobbles provides high survival. Reduction in oxygen could reduce survival particularly for some species.

3.6.3 Nitrogen to phosphorus ratios and availability

Algae require nitrogen and phosphorus in specific proportions to meet their metabolic needs. A number of investigators have proposed, on the basis of variety of physiological and environmental data, ranges of N:P ratios which are representative of conditions for algal growth under different circumstances. Nordin (1985) made the interpretation that ratios of N:P in water (in available forms) of less than 5:1 are indicative of nitrogen limitation, ratios of 5-15:1 indicate no limitation or co-limitation and ratios of greater than 15:1 indicate phosphorus limitation. For streams, N:P ratios should be calculated using dissolved inorganic nitrogen (DIN) (ammonia+nitrite+nitrate) and ortho-phosphate. The average growing season N:P ratios for the Toboggan watershed, which are found in Table 8, indicate strong P-limitation.

Table 8 Average growing season N:P ratios[1] at eight sites in the Toboggan watershed 2001-02

Site 1 Upper Toboggan Cr (E245607)	Site 2 Toboggan Cr d/s T. Lake (E245606)	Site 3 Elliot Cr (E245365)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 5 Fish hatchery outflow channel (E245366)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 7 Owens Cr (E245368)	Site 8 Toboggan Cr u/s Highway 16 (E245370)
370:1	166:1	70:1	114:1	49:1	89:1	130:1	101:1

[1] Calculated according to Nordin (1985): Dissolved inorganic nitrogen (N) : ortho-phosphate (P)

If all of the physical factors, such as light and temperature, are within a suitable range for algal growth, nutrient concentrations alone can be the determining factor in the development of nuisance algal growths. Nordin determined that inorganic nitrogen greater than 25 μg/L-N (for N-limited streams) or ortho-phosphorous greater than 3 μg/L-P (for phosphorus-limited streams) to be factors contributing to high risk of excessive stream algal biomass in BC. Average DIN concentrations in Toboggan Creek mainstem (Table 2) range from 96 μg/L-N (Elliot Creek) to 500 µg/L-N (Upper Toboggan Creek) indicating that nitrogen is abundantly available from a source in Upper Toboggan Creek. Average ortho-phosphate concentrations between 1.2 to 3.9 µg/L-P indicate that algal growth rates are limited by phosphorus availability.

3.7 Periphytic Algae Biomass and Community Composition Results

3.7.1 Periphytic algae biomass

Periphytic algae biomass measured as chlorophyll *a* (chlor *a*) in Toboggan Creek 1996, 1997, 2001 and 2002 are found in Appendix 2 Table 1. The means of the six replicates taken each year are found in Table 9.

Table 9 Mean periphytic algae biomass (chlorophyll *a)* on natural substrates in Toboggan Creek and control sites in September 1996, 1997, 2001 and 2002

1996	Reiseter Cr at Telkwa High Road (control)	Toboggan Cr upstream fish hatchery	Toboggan Cr at DFO assessment fence	probability of no site effect (P) ANOVA
Chlorophyll *a* (mg/m^2) ± SE	2.13 ± 0.22	11.38 ± 3.46	46.27 ± 15.88	0.01

1997	Reiseter Cr at Telkwa High Road (control)	Toboggan Cr upstream fish hatchery	Toboggan Cr at DFO assessment fence	probability of no site effect (P) ANOVA
Chlorophyll *a* (mg/m^2) ± SE	13.67 ± 2.96	33.63 ± 21.76	74.26 ± 15.9	0.05

2001	Site 1 Upper Toboggan Cr (E245607)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)	probability of no site effect (P) ANOVA
Chlorophyll *a* (mg/m^2) ± SE	1.27 ± 0.48	6.62 ± 4.67	8.17 ± 1.85	18.03 ± 5.3	0.03

2002	Site 1 Upper Toboggan Cr (E245607)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)	probability of no site effect (P) ANOVA
Chlorophyll *a* (mg/m^2) ± SE	<5 ± 0	7.17 ± 0.87	<5 ± 0	5.67 ± 0.42	[1]

[1] ANOVA cannot be used when all the observations for a site are less than the MDC.

In the 1996 and 1997 studies, Reiseter Creek, a nearby Bulkley River tributary, was designated as a 'control' site. Reiseter Creek emanates from the Babine Ranges and has a watershed with little human activity other than forestry. In 1996 and 1997, periphyton sampling was conducted at the DFO assessment fence, which is located just downstream of the confluence of Owens Creek. The stream bank has been armored with large rock in this location, resulting in a somewhat unnatural substrate. In 2001, the sampling location was moved 2 km downstream to near the Highway 16 crossing (Site 8P). Site 8P has suitable natural substrate characteristics (gravel, riffles and runs) for periphyton and benthic invertebrate sampling.

Toboggan Creek upstream of the fish hatchery is the same location in all years. In 1996 and 1997, Toboggan Creek upstream of the fish hatchery sampling was between the Owens Road bridge and the hatchery intake weir. In 2001 and 2002, samples were taken along a gravel bar immediately downstream of the weir. In the intervening years, the cobble and gravel substrate upstream of the weir had been blanketed with fine sediments unsuitable for periphyton sampling.

3.7.2 Comparison with Water Quality Guidelines for nutrients and algae and Bulkley Basin Objectives

Periphyton biomass in 1996 roughly equaled the WQG for protection of recreation and aesthetics of ≤50 mg/m^2 chlor *a* and exceeded the guideline in 1997, with a mean biomass of 74 mg/m^2 chlor *a* (Table 8). Periphyton biomass was lower in 2001 and 2002, with a maximum of 18 mg/m^2 chlor *a* at Site 8P.

ANOVA was conducted with chlor *a* data for each sampling year providing evidence ($P \leq 0.05$) for site effect. With the exception of 2002, an increase in mean periphyton biomass occurred along the downstream gradient.

In 2001, periphyton biomass was higher at Site 6, 100 m downstream of the hatchery, than Site 4, upstream of the hatchery. A *t*-test, however, does not provide evidence for a change in mean periphyton biomass downstream of the hatchery compared to upstream (P=0.38). Biomass was slightly higher upstream of the hatchery in 2002.

3.7.3 Periphytic algae community composition 1996, 1997, 2001 and 2002

Samples of periphytic algae were collected for identification and enumeration in each of the four study years, but the number of samples collected and enumeration methods differed depending on budgetary constraints. In 1996 and 1997, one sample was taken at each site and periphytic algal community composition was assessed as percent composition of the most common taxa. In 2001, three samples were taken at each site and assessed as cells/m^2 and biovolume. In 2002, one sample was taken at each site and assessed as cells/m^2 and biovolume. Algae identification and enumeration was completed by the same taxonomist, Mary Bolin, in all four years. Periphytic algae community composition analysis for 1996-97 is found in Appendix 2 Table 2. Community composition analysis for 2001 and 2002 are found in Appendix 2 Tables 3 and 5, respectively. Biovolume and relative abundance of Chrysophyta (diatoms) in 2001 and 2002 are found in Appendix 2 Tables 4 and 6, respectively. Periphytic algae percent biovolume by division and Genera Richness statistics 1996 through 2002 are found in Table 10.

Table 10 Periphytic algae percent biovolume by division and Genera Richness in Toboggan Creek and controls 1996[1], 1997, 2001 and 2002

	1996			
Algal Division	Reiseter Cr at Telkwa Highroad	Toboggan Cr u/s fish hatchery	Toboggan Cr at DFO assessment fence	
Cyanophyta (bluegreens)				
Chlorophyta (greens)			25%	
Chrysophyta (diatoms)	100%	100%	75%	
Genera Richness	5	7	7	
	1997			
Algal Division	Reiseter Cr at Telkwa Highroad	Toboggan Cr u/s fish hatchery	Toboggan Cr at DFO assessment fence	
Cyanophyta (bluegreens)			5%	
Chlorophyta (greens)				
Chrysophyta (diatoms)	100%	100%	95%	
Genera Richness	6	4	7	
	2001			
Algal Division	Site 1 Upper Toboggan Cr (E245607)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)
Cyanophyta (bluegreens)	1%	3%	1%	
Chlorophyta (greens)	0%	5%	24%	
Chrysophyta (diatoms)	99%	92%	76%	100%
Genera Richness	7	11	11	7
	2002			
Algal Division	Site 1 Upper Toboggan Cr (E245607)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)
Cyanophyta (bluegreens)	1%	6%	3%	23%
Chlorophyta (greens)		34%	2%	
Chrysophyta (diatoms)	99%	60%	95%	77%
Genera Richness	6	14	8	10

[1] Periphyton biovolume was visually estimated in 1996-97. Source: Remington (1997 and 1998)

Control sites— Chrysophyta (diatoms) comprised 99%+ of periphytic algal biovolume at the control sites, Reiseter Creek and Site 1 Upper Toboggan Creek, in all years. *Gomphonema* spp. were the dominant diatom taxa, comprising over 50% of diatom biovolume at each site. *Gomphonema* has been found to represent a significant portion of diatom biomass in streams that have low soluble phosphorus concentrations (Chetelat et al. 1999). Other dominant taxa included *Achnanthes* spp., *Synedra ulna*, *Cymbella* sp. and *Epithema sorex*.

Site 4 Toboggan Cr upstream fish hatchery— Diatoms comprised nearly 100% of algal biovolume at this site in 1996 and 1997. *Gomphonema* was not the dominant diatom at this site, being displaced by *Synedra ulna, Fragilaria* or *Achnanthes* in most years. In 2001, in addition to 92% diatoms, the filamentous Cyanophytes, *Lyngbya* and *Oscillatoria* and the filamentous Chlorophyte *Cladophora* were found. In 2002, 40% of algal biovolume at Site 4 was *Lyngbya, Oscillatoria* and *Cladophora.*

Site 6 Toboggan Cr 100m downstream the fish hatchery outflow— Diatoms comprised 76% and 95% of periphytic algal biovolume in 2001 and 2002, respectively. Chlorophytes comprised 24% of biovolume at this site in 2001, primarily filamentous *Cladophora*. In 2002, approximately 5% Cyanophytes and Chlorophytes were found at this site.

Toboggan Cr at DFO assessment fence— In 1996 and 1997, diatoms comprised 75% and 95% of periphytic algal biovolume, respectively. In 1996, 25% was primarily the filamentous Chlorophyte *Spirogyra*. In 1997, 5% Cyanophytes and Chlorophytes were present, primarily *Oscillatoria*.

Site 8 Toboggan Cr 500 m upstream Highway 16— In 2001 and 2002, diatoms comprised 100% and 77% of periphytic algae biovolume at this site, respectively. In 2002, 23% filamentous Cyanophytes *Lyngbya* and *Oscillatoria* were present.

3.7.4 Periphytic algal community at four Toboggan Creek sites in 2001

In 2001 three periphyton samples were collected and analyzed for each of four sites. This allows for further statistical analysis of the data for this year. Mean periphytic algal biovolume by Division and genera richness in 2001 is found in Table 11. In the calculation of summary statistics, the taxon *Dinobryon sertularia* was omitted. D. *sertularia* is a non-diatom Chrysophyte that is generally planktonic in BC (Stein 1975). A low biovolume of this species was found at one site and considered to have been accidentally captured.

Table 11 Mean periphytic algal biovolume by Division and genera richness measured on natural substrates in Toboggan Creek September 2001

Algal Division	Mean algal biovolume (μm^3 x 10^9 /$m^{2)}$ ± SE				Probability of no site effect (P) ANOVA
	Site 1 Upper Toboggan Cr (E245607)	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)	
Cyanophyta (blue greens)	0.09 ± 0.07	14.86 ± 10.09	11.82 ± 4.64	0	0.2
Chlorophyta (greens)	0.03 ± 0.03	22.49 ± 18.68	392.77 ± 245.26	0	0.14
Chrysophyta (diatoms)	8.49 ± 2.51	424.17 ± 191.11	1258.92 ± 611.23	1542.50 ± 539.24	0.1
Total	8.6 ± 2.48	461.51 ± 176.74	1663.51 ± 719.9	1542.50 ± 539.24	0.09
Genera Richness	6.67 ± 0.33	11.33 ± 1.86	10.67 ± 0.88	7 ± 0.58	0.03

ANOVA was conducted with the total biovolume data. ANOVA provided weak evidence (P=0.09) that, similar to the chlorophyll *a* analysis, total periphytic algae biovolume increased along the downstream gradient. A *t*-test was conducted with total biovolume data for Site 4, upstream, and Site 6, 100 m downstream, of the hatchery outflow channel. This provided weak evidence (P=0.09) for an increase in biovolume from 462 μm^3 x $10^9/m^2$ at Site 4 to 1664 μm^3 x $10^9/m^2$ at Site 6.

ANOVA was conducted with the genera richness data. ANOVA provides evidence for a site effect (P=0.03) and genera richness was greatest at Sites 4 and 6, with roughly 11 genera each, compared to Sites 1 and 8 with roughly 7 genera each. Cyanophytes comprised less than 5% of biovolume at any site. Chlorophytes comprised less than 5% at any site except Site 6, downstream of hatchery, where Chlorophytes comprised 24% of periphytic algal biovolume. Most of the green algae at Site 6 was the filamentous *Cladophora* sp. Periphyton biomass and composition are strongly related to ambient nutrient concentrations, and *Cladophora* growth is known to accelerate strongly in response to increasing soluble phosphorus concentrations (Biggs 1996; Chetelat et al. 1999).

3.8 Macroinvertebrate Stream Health Index Assessment

Since 1997, MWLAP led projects designed to assess the impact of forest harvesting on streams in the Skeena Region have taken a toolbox approach (Dykens and Rysavy 1998, Mackay 1998). In this approach, there are three broad categories of monitoring and assessment tools: chemical, physical and biological.

One of the biological monitoring tools chosen is the macroinvertebrate stream health index, also known as the benthic index of biological integrity (B-IBI), developed by Dr. James Karr at the University of Washington. The benthic invertebrate multimetric index approach has been implemented as an effective biological monitoring strategy in many US states and Japan (Barbour et al. 1992, Kerans and Karr 1994, Kleidl 1995, Karr and Chu 1999).

The B-IBI is a multimetric approach that relies on biological data to assess the condition of a stream. The benthic invertebrate community in a stream should reflect the aquatic integrity and the cumulative effects of any impacts to the stream and its surrounding environment. A metric is a descriptive statistic of the invertebrate community (e.g. number of different mayfly taxa). The ideal index would comprise a number of metrics that are sensitive to a variety of human induced stresses placed on a system.

Not all metrics respond to increasing human influence the same way in different geographic areas, therefore a unique set of metrics must be identified for each geographic region. In the Skeena Region, B-IBI calibration began in the Kispiox and Morice Timber Supply Areas (TSA) in 1999 (Rysavy 2000a, 2000b). Eight of the ten metrics tested in the Kispiox responded predictably with increasing human influence and clearly distinguished uninfluenced sites from heavily influenced sites.

In 1999, a partnership was initiated between MWLAP, the Ministry of Forests and Pacific Inland Resources to develop a B-IBI specific to the Bulkley TSA. Calibration of the B-IBI in the Bulkley TSA began in the 2000 field season by sampling benthic invertebrates in a number of streams with varying human influence; from uninfluenced, pristine watersheds, to watersheds with heavy human influence (Bennett 2001). Additional fieldwork was conducted in 2001 in order to further refine and calibrate the proposed B-IBI for the Bulkley TSA (Bennett and Hewgill 2002).

During August 2001, 26 streams with similar attributes, including stream order, elevation and gradient were sampled using a modified 250 micron Surber sampler. Toboggan Creek was one of the 26 streams sampled (Figure 1 Site 8P). Site 8P, approximately 500 m upstream of Highway 16 and the Toboggan confluence with the Bulkley River, has suitable habitat attributes for both benthic invertebrate and periphyton monitoring (this report).

In-stream and riparian conditions were assessed at each site. Twenty-one different metrics were calculated for each sampling location. Particular attention was paid to the proper classification of streams as either reference (unimpacted) streams or heavily influenced streams because the validity of the multimetric index is reliant on the selection of individual metrics that discriminate between the two extremes and have a predictable response.

Streams were classified as reference sites if they met the following criteria:

Less than 5% harvesting or cleared land in catchment

No road crossings upstream of site

No mining in watershed

No channelization

No upstream impoundments

No known point or non-point source discharges

No urban land use in catchment.

All other sites were considered to be human influenced and classified as one of six impact types.

Livestock access:

A. Forested riparian zone and livestock have direct access to the stream

B. Disturbed riparian zone (riparian vegetation has been removed or is dominated by a shrub/herb layer) and livestock have direct access to the stream

Forest harvested sites

A. Low: A low level of forest harvesting has occurred

B. Moderate: A moderate level of forest harvesting has occurred in the watershed

Non Point Source (NPS) Agriculture: land clearing and crop harvest in the watershed, may include rural residential dwellings, or fish hatcheries

Municipal: Runoff from urban communities in direct proximity to sampling site

Industrial: some type of non-point source discharge from an industrial operation

Channelized/Flow alteration: extensive channelization at sampling site, impoundment upstream or known flow alteration

There were no streams in the 2001 dataset that fit the Industrial or Channelized/Flow alteration impact types. Toboggan Creek was classified NPS Agriculture, with a Moderate degree of human influence.

Development of a B-IBI for the Bulkley TSA required identification of a core set of metrics that reliably reflect changes attributable to human influence. Each metric should contribute valuable and non-redundant information. Therefore, a variety of metrics were tested that had successfully been included in other multimetric indices. To facilitate identification of useful metrics, a subset of sampling sites were selected for metric testing that were grouped by human influence as either reference site, sites with moderate forest harvesting influences, or heavily influenced sites. Generally, these were the sites with the most disturbed riparian zones at the sampling area.

Metric scores were plotted against human influence for each of the twenty-one 'test' metrics. Twelve of the twenty-one metrics tested were found to respond predictably over a gradient of human influences and nine of those could clearly distinguish uninfluenced sites from heavily influenced sites.

The nine metrics chosen for inclusion in the multimetric index included;

Plecoptera (Stonefly) taxa richness,

Trichoptera (Caddisfly) taxa richness,

Relative abundance of Dipterans and non-insects,

Intolerant taxa richness,

Hilsenhoff Biotic Index

Relative abundance of sediment intolerant individuals,

Relative abundance of predators,

Clinger taxa richness, and

% Dominance (3 taxa).

For each of the nine selected metrics, scoring cutoffs were determined. Metrics were scored 5 points if values were similar to uninfluenced streams, 3 points if values were similar to moderately influenced streams, and 1 point if values were similar to heavily influenced streams.

Finally, the B-IBI scores for all the streams sampled in the Bulkley TSA were summarized and scored using cutoff points identified above. Individual metric scores were added to give one final index score, shown in Table 12.

The maximum possible B-IBI score is 45 and minimum is 9, with lower scores indicating lower ecosystem health. B-IBI scores at uninfluenced reference sites ranged from 33 to 45 points. Sites influenced by non-point source agriculture ranged from 13 to 35, while sites with livestock access influences ranged from 13 to 31. Sites classified with municipal human influences scored from 13 to 33, and sites influenced by forest harvesting scored between 27 and 45 points. Sites with low levels of human influences generally scored higher than sites with moderate and high levels of influence. The distribution of B-IBI scores suggests that the majority of streams assessed in the Bulkley TSA in 2001 have a relatively high ecosystem health score.

Among the NPS Agriculture category streams, Toboggan Creek, with a B-IBI score of 25, can be compared to the Gramophone Creek (35), nearby Lower Trout Creek (33), Canyon Creek (31), and Lemieux Creek (13). Trichoptera taxa richness in Toboggan Creek was comparable to uninfluenced sites in the BTSA, while Plecoptera taxa richness was low. Plecoptera are thought to be more sensitive and decline at lower levels of human influence than Trichoptera. Taxa richness can increase with human influence where nutrient loading may be occurring. There were three intolerant taxa present in the Toboggan Creek samples, a relatively high result for the metric.

Rigorous testing of the B-IBI has been completed in many areas of the US, to ensure that the selected metrics respond predictably and accurately across a gradient of human influences. However, calibrating the B-IBI for the Bulkley TSA is still an iterative process that involves testing metric response to specific types of human influence and adjusting metric scores until we are confident that they accurately reflect local biological conditions. For this reason, the benthic invertebrate dataset and B-IBI score for Toboggan Creek should be considered as a baseline dataset for long-term trend monitoring (S. Bennett, personal communication).

Table 12 Stream sites, human influence classification, average sample size and B-IBI score for 26 streams in the Bulkley TSA (Bennett and Hewgill 2002)

Site Name	Human Influence Type	Degree of Human Influence	Average # of Individuals per Sample	B-IBI Score
Reiseter West (u/s)	Reference	None	974	43
Driftwood Ref.	Reference	None	1554	41
Reiseter East (trib)	Reference	None	945	41
Reiseter ab. Bridge	Reference	None	428	41
Arnett	Reference	None	758	39
Mulwain	Reference	None	506	33
Gramophone d/s	NPS Agriculture	Moderate	1468	35
Lower Trout	NPS Agriculture	Low	1974	33
Canyon d/s	NPS Agriculture	Moderate	1318	31
Toboggan	NPS Agriculture	Moderate	863	25
Lemieux d/s	NPS Agriculture	High	1149	13
John Brown	Municipal	V. Low	983	33
Chicken	Municipal	Moderate	535	27
Kathlyn	Municipal	High	398	19
Bigelow (Dahlie)	Municipal	High	1105	13
Upper Trout	Livestock Access / Forest Harvest	Moderate	2744	31
Lemieux u/s	Livestock Access	Low	5550	27
Robin	Livestock Access	High	4488	13
Coal	Forest Harvest	Low	2119	45
Kwun	Forest Harvest	Low	953	41
Sinclair	Forest Harvest	Low	734	41
Jonas	Forest Harvest	Moderate	799	39
Gramophone u/s	Forest Harvest	Low	703	37
Caribou	Forest Harvest	Low	507	35
Cumming	Forest Harvest	Moderate	2069	31
Goathorn u/s	Forest Harvest	Moderate	944	27

3.9 Drinking Water Source Quality Assessment

3.9.1 Drinking water source quality results

Eight of the 30 licensed domestic drinking water intakes in the Toboggan Creek watershed are located on the mainstem within 6 km of the mouth (water license information is found in Appendix 3 Table 2). Remington (1996, 1997) found fecal coliform and fecal streptococci concentrations in Toboggan Creek to exceed provincial drinking water protection guidelines on isolated late summer sampling dates and suggested further monitoring.

BCWLAP drinking water source quality monitoring was conducted throughout the Skeena Region in 2001-2002 (the 2001 data was previously reported in Remington 2002). Toboggan Creek upstream of Highway 16 and confluence with the Bulkley (Site 8) was chosen as a monitoring location because of the many domestic drinking water intakes on this system. The 2001-02 drinking water source quality data for Toboggan Creek is found in Appendix 1 Tables 20 and 21.

Summary of Toboggan watershed drinking water source quality results is found in Table 13. Monthly, maximum, 90^{th} percentile and geometric mean fecal coliform data from this study are found in Table 14.

Table 13 Drinking water source quality summary (five samples in a 30-day period) at Site 8W Toboggan Creek upstream Highway 16 (E245370) 2001-02

Date Range	Fecal coliform maximum	Fecal coliform 90th %	*E. coli* maximum	*E. coli* 90th %	Enterococci maximum	Enterococci 90th %	pH	Specific Conduct-ance	True Color	Turbidity
			(CFU/100ml)				(pH units)	(uS/cm)	(Col.unit)	(NTU)
Oct 4-29 2001	37	31.6	37	31.3	12	8.7	7.67	100.6	11.8	1.19
Aug 8-Sep 3 2002	100	81.2	78	60.4	93	72.9		68	6.0	12.13
Oct 7-Nov 3 2002	37	29	15	13.8	14	13.6	7.6	66	9.0	2.30

Table 14 Monthly, maximum, 90th percentile and geometric mean fecal coliform concentrations at eight sites in the Toboggan Creek watershed 2001-2002

(CFU/100 ml)	Site 1 Upper Toboggan Cr	Site 2 Toboggan Cr downstream T. Lake	Site 3 Elliot Cr	Site 4 Toboggan Cr upstream fish hatchery	Site 5 Fish hatchery outflow channel	Site 6 Toboggan Cr 100m down-stream hatchery	Site 7 Owens Cr	Site 8 Toboggan Cr upstream Highway 16
30-Aug-01			1	3	11	3	17	14
17-Sep-01	13	4	118	11	8	6	15	14
15-Oct-01	1	1	2	1	2	2	2	12
12-Nov-01	19	113	5	38	6	47	9	59
10-Dec-01		1	< 1	3	1	1	< 1	10
08-Jan-02	< 1	5	< 1	3	7	3	< 1	27
11-Feb-02	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
11-Mar-02	< 1	1	< 1	2	2	4	< 1	2
15-Apr-02	48	412	< 1	508	244	456	8	168
22-Apr-02	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
13-May-02	61	46	41	87	38	193	2	139
18-Jun-02	3	8	4	14	480	24	7	43
22-Jul-02	4	4	2	16	18	18	14	30
3-Sep-02	7	8	4	4	18	12	31	26
Maximum	61	412	118	508	480	456	31	168
90th percentile	45.1	99.6	30.2	72.3	182.2	149.2	16.4	115.0
Geometric mean	4.5	5.9	2.8	7.1	9.0	8.4	3.9	15.8

3.9.2 Comparison to federal and provincial drinking water quality guidelines

A summary of federal and provincial water quality guidelines which are the 'best fit' for this study area (raw drinking water/private drinking water supplies) is found in Table 15.

Table 15 Selected BC and Canadian Drinking Water Quality Guidelines for Microbiological Indicators (Colonies/100 mL)

<table>
<tr><th colspan="2">BC Guidelines for Raw Drinking Water</th><th>Canadian Drinking Water Quality Guidelines for Semi-Public and Private Drinking Water Supply Systems Revised April 2002 (There are no federal guidelines for raw drinking water.)</th></tr>
<tr><td></td><td>Fecal coliforms[1]</td><td rowspan="16">1. No sample should contain Escherichia coli. E. coli indicates recent fecal contamination and the possible presence of enteric pathogens, therefore the water is unsafe to drink. If E. coli is detected, a boil water advisory should be issued and corrective actions taken.
2. No sample should contain total coliform bacteria. In non-disinfected well water, the presence of total coliform bacteria in the absence of E. coli indicates the well is prone to surface water infiltration and therefore at risk of fecal contamination.</td></tr>
<tr><td>-no treatment</td><td>0</td></tr>
<tr><td>-disinfection only</td><td>≤10 (90th perc.)</td></tr>
<tr><td>-partial treatment</td><td>≤100 (90th perc.)</td></tr>
<tr><td></td><td>Escherichia coli</td></tr>
<tr><td>-no treatment</td><td>0</td></tr>
<tr><td>-disinfection only</td><td>≤10 (90th perc.)</td></tr>
<tr><td>-partial treatment</td><td>≤100 (90th perc.)</td></tr>
<tr><td></td><td>Enterococci</td></tr>
<tr><td>-no treatment</td><td>0</td></tr>
<tr><td>-disinfection only</td><td>≤3 (90th perc.)</td></tr>
<tr><td>-partial treatment</td><td>≤25 (90th perc.)</td></tr>
<tr><td></td><td>Pseudomonas aeruginosa</td></tr>
<tr><td>-no treatment</td><td>0</td></tr>
</table>

Source: BCWLAP (1998b) and CCREM (1999)

[1] Fecal coliform criteria which presently exist will apply on an interim basis until use of the other preferred indicators is adopted.

Medians and geometric means are calculated from at least 5 samples in a 30-day period. Ten samples are required for 90th percentiles.

Canadian Drinking Water Quality Guidelines microbiological guidelines for private drinking water supply systems— Canadian Drinking Water Quality Guidelines (CCME Revised April 2002) for bacteria state that no sample should contain E. coli. The presence of E. coli indicates fecal contamination and possible presence of enteric pathogens; therefore, the water is unsafe to drink. Data reported in Appendix 1 Table 20 shows that E. coli was present in every sample collected at Site 8 October 2001, August 2001 and October 2002.

BC Water Quality Guidelines for microbiological indicators for raw drinking water— The BC guideline for raw water with no treatment is 0 for each of the three indicator organisms. The fecal coliform and E. coli 'no treatment' guidelines were exceeded in every sample and the Enterococci guideline was exceeded in 10 of 13 samples at Site 8. Water quality monitoring at Site 8 indicates that disinfection should be employed prior to drinking raw water drawn from the lower Toboggan mainstem. The concentration of Enterococci (90th %) during the Aug 8 to Sep 2 2001 period (73 CFU/100 mL 90th %) indicates the need for partial treatment in addition to disinfection.

The data for eight sites in Toboggan Creek and tributaries, presented in Table 14, indicates that microbiological quality varies somewhat depending upon location in the watershed and seasonally, with the lowest bacterial counts in tributary streams and during the winter low flow period. In general, drinking water quality worsens along the downstream gradient. Since fish are cold-blooded creatures, the hatchery fish are not considered contributors to fecal coliform loadings.

Physical and chemical guidelines— Physical and chemical drinking water source quality data is found in Appendix 1 Table 20 and total metals data is found in Table 21. Mean turbidity in each of the study periods exceeded the turbidity WQG concentration of 1 NTU. The headwaters of Toboggan Creek emanate from glaciers on the slopes of the Hudson Bay Ranges, so some background glacial turbidity is natural for this stream. Toboggan Creek waters are slightly coloured but, on average, did not exceed the True Colour guideline of 15 TCU. Iron slightly exceeded the WQG on two sampling dates, but was not in exceedence on average. The iron guideline is an aesthetic guideline based on the taste of the water, and is not health related. No other physical or chemical parameters exceeded BCWLAP drinking water quality guidelines.

3.10 Salmon Histological Analysis 1996

As a part of DFO investigations in 1996, juvenile wild salmonids, mostly coho, were captured in minnow traps at several locations (Remington and Donas 1999). All fish samples were iced and shipped on the day of capture to the fish pathology lab at the DFO Pacific Biological Station for histological examination.

The most common pathology observed in Toboggan watershed salmonids was mild to severe lamellar hyperplasia of the gills, sometimes accompanied by sloughing of the lamella or secondary infection. Most of the fish submitted for examination were from upstream of the hatchery. Gill damage was most common in June and July, although some damage was observed later in the season.

Degenerative changes in the liver were also observed in the upper watershed, mainly in the June and July samples. Liver sections showed degenerative changes including nuclear pleomorphism and pyknosis, uneven vacuolation, indistinct cytoplasmic detail and necrotic cells. Some liver sections contained basophilic striae in the hepatic cytoplasm indicating increased cellular activity and suggesting detoxifying activity. Necrotic cells were observed in the anterior kidney in many samples as well.

It is impossible to identify any particular toxicant by histological examination alone (J. Bagshaw, histologist, Pacific Biological Station, personal communication). The gill damage appears to be the result of an immediate sub-acute irritant. The liver and kidney damage appears to represent the process of detoxification as the result of longer-term chronic exposure to low levels of a toxicant.

3.11 Land and Water Use Survey Summary

A Land and Water Use Survey (Appendix 3 Table 3) was mailed to each water license holder in the Toboggan Creek watershed in October 2001. The survey, which could be returned anonymously, was designed to help determine livestock headage and agricultural management practices, quantities of water used by agriculture and residents, and what license holders felt were key issues associated with their water licenses and the local streams. Two surveys were returned 'Address Unknown'. Of the remaining 34 surveys, 10 were completed and returned for an overall 29% response rate.

Of the ten surveys returned, only one represented the agricultural community, resulting in a gap in information regarding this land use type. The remaining respondents indicated rural residential use, with gardening and forestry also reported.

3.11.1 Rural residential land and water use information

The response rate from the rural residential community was 27%, which is considered good for this type of survey. Rural residential property sizes range from 0.5 to 140 acres. One respondent has a summer cabin. Fifty percent of respondents have a stream on their property, and the stream is often used for household water supply and garden irrigation.

Most of the residents report that less than 50% of the stream on their property has been cleared of trees up to the stream bank. Most residents report a 30+ foot band of riparian shrubs and trees along the remainder of the stream on their property.

To a question regarding flooding on their property, three residents responded that flooding due to logging practices upstream of them had caused property damage in the past. In one case, the property damage resulted in considerable cost to the resident (see Section 2.7.2 for discussion of Feeney Brook).

Sixty percent of respondents draw their household water from streams (surface water sources) and 40% from wells or springs (groundwater sources).

None of those utilizing groundwater boil or otherwise treat their drinking water. Half of the respondents using surface stream water sources do not boil or treat their drinking water. Half of the respondents using surface stream water sources either boil or filter their water prior to drinking or 'pack' drinking water from another source.

Eighty percent of respondents utilize septic tanks and drain fields for household sewage disposal and 20% utilize sewage lagoons. Half of septic drain fields are over 25 years old. Seventy-five percent of the septic tanks are pumped annually or every 3-5 years. No one reported a wet, swampy area at the end of the septic drain field.

3.11.2 Agricultural land and water use information

The single respondent in this category reported having a beef cattle operation with about 250-head total and 190 breeding cows. This operation does not employ irrigation. All livestock watering is from stock troughs, rather than from streams or dugouts.

3.11.3 Concerns and comments regarding land or water use in the Toboggan Creek watershed

In response to the question, "*Do you have any other concerns or comments regarding land or water use in the Toboggan Creek watershed?* ", all of the comments received are repeated verbatim as follows:

Rural residential—

- "Lack of an adequate riparian zone on stream banks through some of the farms"
- "Too much fertilizer use by farmers. Too much livestock concentration on many farms"
- "I have a concern with farmers clearing their land right to the creek and allowing farm animals full access to the creek within the pastures"

Agricultural—

- "Water is certainly a lot better than it was 50-60 years ago when I was young. All the cattle and horses were watered by Toboggan Creek. It was a mess in the spring. It's much better now. Agriculture is an excellent steward of the land. I wish I could say the same for residences and Highways. As the multitude of residences clean up their act, agriculture will do its part."

3.12 Discussion

1996-98 vs. 2001-2002– We are aware that several positive changes in agricultural management practices occurred in the Toboggan watershed after the 1996-98 monitoring. A reduction in overwintering density at the Toboggan Creek fish hatchery also occurred during that time. However, a distinct temporal trend in water quality was not identified, partially because of differences in study design (springtime vs. monthly monitoring, parameter choice, etc.).

Water temperature— Late summer water temperatures in the Toboggan mainstem approached the upper range of optimum temperatures for salmonid spawning. Flow through Toboggan Lake and wetlands contributes to solar heating in the Toboggan mainstem. However, many kilometers of stream having little or no riparian cover have been identified by WRP studies of this watershed. Riparian cover removal has resulted from transportation corridors, forestry and agricultural land clearing.

Stream reaches with dense canopy riparian zones tend to have lower water temperatures, due to shading, than stream areas without riparian canopies. Riparian zone grasses and trees also filter runoff and retain nutrients and sediment in the riparian zone. Riparian zone vegetation directly affects biotic communities by influencing cover, habitat and instream temperature (Gregory et al. 1991). Locally, the riparian zone is particularly important to water quality conditions in agricultural basins because the riparian vegetation can directly mediate the effects of agricultural activities (Stauffer et al. 2000). Stauffer assesses that wooded riparian cover could be effective in maintaining and improving fish community composition in streams in agricultural basins.

Dissolved oxygen– Instantaneous minimum water column concentration over gravel DO water quality guideline concentrations to protect buried embryos or alevins were exceeded in early spring 1998 in lower Toboggan Creek and again in April 2002 at Site 2 downstream of the lake. Depression of DO during winter is a common occurrence in lakes and rivers that experience ice cover (Pietroniro et al. 1998), although anthropogenic loading of organic material from confined livestock feedlots may further deplete winter DO concentrations.

Upper Toboggan Creek nitrate concentrations– Concentrations of nitrate in stream water throughout the world are reported to be elevated relative to natural background levels. This enrichment is commonly attributed to human activities such as livestock feeding, agricultural runoff and municipal/industrial effluent discharge. Elevated concentrations of nitrate in Upper Toboggan Creek (the 'control' site upstream of most human influences) confounded analysis of upstream/downstream trends in inorganic nitrogen species in this study. Nitrate concentrations in Upper Toboggan were highest during winter months and early freshet, suggesting a groundwater source of the nitrate. Average nitrite+nitrate concentrations in Upper Toboggan Creek are nearly an order of magnitude greater than average concentrations in other regional streams for which a similar year-round dataset is available.

Holloway et al. (1998) found that bedrock containing appreciable concentrations of fixed nitrogen contribute a surprisingly large amount of nitrate to surface waters in certain California watersheds, contributing to periodic fish kills in downstream reservoirs. Elevated stream water nitrate concentrations were closely associated with metasedimentary and metavolcanic lithologies, particularly phylite, shale, biotite schist, meta-volcanic breccia and greenstone. Relatively high nitrogen occurs in both organic and inorganic forms in slate, whereas it is dominantly in inorganic forms in the other lithologies. Mass balance calculations showed that much nitrogen is released into groundwaters during the rock-to-soil transformation in these watersheds. Skeena Group shales, Cretaceous age, are exposed up the main Toboggan drainage starting very approximately 1.5 km above Site 1, and extending up the drainage for about 6.7 km (T. L'Orsa, consulting geologist, personal communication). Average and maximum nitrate concentrations in Upper Toboggan were within the range reported by Holloway for streams with geological nitrate sources. The source of nitrate to Upper Toboggan Creek is unknown, but may be weathering of the Skeena Group shales.

Upstream/downstream trends– There is strong evidence that there are higher concentrations of ammonia, total and orthophosphorus and fecal coliform bacteria in the Toboggan mainstem than the three tributary streams monitored. There was no evidence of a change in nutrient or bacterial concentrations downstream of the hatchery. Since there are no other point sources in this watershed, we conclude that this increase is the result of diffuse nutrient sources prevalent along the mainstem, particularly agriculture.

Based on total phosphorus concentrations, the OECD trophic status values for Toboggan Creek range from oligo- or mesotrophic in the upper watershed, to eutrophic in the lower mainstem

Ammonia and bacterial concentrations in hatchery intake water are of concern to hatchery management, and the hatchery diverts to groundwater supplies during early freshet each year. At Toboggan mainstem sites, neither ammonia nor nitrite exceeded WQGs for aquatic life during the 1996-98 or 2001-02 studies. Average fecal coliform concentration at Site 4, the hatchery water intake, was 49 CFU/100ml (maximum 508 CFU/100mL).

Salmonid histological analysis– In 1996, DFO histological analysis found gill hyperplasia, as well as other damage or secondary infection, in some wild juvenile salmonids captured, mainly, upstream of the hatchery. The specific toxicant was not identified and the study was discontinued. Ammonia has been found to produce histopathological changes in fish gill structure in numerous studies (reviewed in Haywood 1983). The usual effects appear as a general thickening of the epithelial membrane with associated hyperplasia. This general disruption of branchial structure effectively reduces the surface area of the gill membrane, with resultant reduction in oxygen-diffusing capacity. The susceptibility of salmonids to bacterial fish disease is closely linked with gill hyperplasia caused by ammonia. The exact concentrations of ammonia reported to produce gill damage in various studies has varied depending on other (known and unknown) variables, including dissolved oxygen, CO_2, temperature, ionic gradients, species, life stage and size, acclimation and stress.

Ideally, hatchery water supplies will have non-detectable ammonia and nitrite concentrations. These metabolites will increase inside the rearing facility and will dictate the ultimate stocking density. In the crowded conditions found in salmon hatcheries, evidence of gill damage, similar to that described as characteristic of ammonia poisoning, as well as reduced growth and increased bacterial disease, have been associated with ammonia at concentrations far below that recommended as 'safe' (Meade 1985).

Toboggan Creek Salmonid Hatchery– Data analysis for monitoring sites upstream and downstream of the Toboggan Creek Salmonid Hatchery provided no evidence for an increase in either nutrients or fecal coliform bacteria in the Toboggan mainstem as a result of the hatchery discharge. Water quality data for the hatchery intake and discharge should be useful for fish culture management planning, particularly regarding stocking densities.

N:P ratios, periphytic algae biomass and community trends– Nitrogen to phosphorus ratios and availability indicate that periphytic algae growth is strongly controlled by low phosphorus availability in this watershed. In 1996 and 1997, periphyton biomass equaled or exceeded the WQGs for aesthetics and recreation in the lower watershed. An overall reduction in periphytic algae biomass, to levels not exceeding guidelines, was found in the 2001-02. A trend in increasing periphyton biomass occurred along the downstream gradient in most years.

At control sites in all years, periphytic algae biomass was low, and dominated by diatoms that are characteristic of cold, low nutrient streams. In 1996-97, filamentous blue-green and green algae considered as indicator species for eutrophication were present in the Toboggan mainstem. Although overall biomass was lower in 2001-02, filamentous green algae, known to respond strongly to increased water temperatures and nutrient enrichment such as *Cladophora*, were a significant proportion at some mainstem sites.

Studies of periphyton responses to temperature (DeNicola 1996) have found that cold water control sites are dominated by diatoms, primarily *Gomphonema* and *Achnanthes* spp. Sites where the ambient temperatures were higher in the summer and fall (or with the addition of heated discharges), a shift in dominance from diatoms to *Oscillatoria*, *Spirogyra* and *Cladophora* occurred.

Periphyton biomass and composition are also strongly related to ambient nutrient concentrations. In many catchments (particularly those with little forest cover), there is a downstream increase in nutrient loading that can lead to gradients in community composition and biomass. Headwater reaches are frequently dominated by diatoms. As enrichment increases down the catchment (e.g., with high intensity land use), nutrient-demanding taxa such as the *Cladophora* become more prominent and can form a high biomass (Biggs 1996). *Cladophora* growth is known to accelerate strongly in response to increasing soluble phosphorus concentrations (Biggs 1996; Chetelat et al. 1999) and can reach nuisance proportions at highly enriched sites.

B-IBI– Calibration of a benthic invertebrate index of biological integrity (B-IBI) for the Bulkley timber supply area has been underway since 1999. B-IBI was assessed at Site 8P in lower Toboggan Creek in 2001, as a part of this initiative. The maximum possible B-IBI score is 45 and minimum is 9, with lower scores indicating lower ecosystem health. The final B-IBI score for Toboggan Creek was 25. This metric can be compared to scores for sites uninfluenced by humans, which ranged from 33 to 43, and to other 'non-point source agriculture' category streams, which ranged from 13 to 35. B-IBI shows great promise as an ecosystem health indicator, however several more years of assessment will be required to establish baseline conditions for this watershed.

Drinking water source quality– BCWLAP conducted drinking water source monitoring of Toboggan Creek at Site 8, upstream of Highway 16, in October 2001, August 2002 and October 2002. WQGs for microbiological indicators call for sampling five times in a 30-day period. These studies found levels of fecal coliforms, *E. coli*, and Enterococci to exceed drinking water guidelines and, thus, disinfection and partial treatment is recommended. Monthly monitoring indicates that fecal contaminants may be present throughout the year but generally are associated with periods of high surface runoff. Drinking water source quality is of concern in this watershed because there are 31 licensed domestic water intakes on Toboggan Creek and tributaries.

Land and Water Use Survey– The attempt at using a mail-in survey approach to describing current land and water use in the watershed was partly successful. Response from the agricultural community was poor. The response from the rural residential community was considered good, with a 27% response rate. Rural residents generally seemed to be conscious of riparian protection and reported good, but not perfect, maintenance of septic systems.

Sixty percent of respondents draw their household water from streams and half of those do not boil or otherwise disinfect their drinking water. Depending upon individual situations, the microbiological quality reported in this study may lead some to reconsider the need for disinfection and partial treatment.

Several rural residents expressed concern over livestock density and livestock access to creeks in the watershed. The agricultural respondent to the survey expressed willingness on the part of the agricultural community to be good stewards of the watershed and suggested that everyone, including rural residents and highways, should do their part.

Proposed molybdenum mine– A molybdenum mine was proposed for the headwaters of Glacier Gulch Creek in early 2005. Molybdenum, copper, zinc and other minor metallic elements, collectively referred to as micronutrients, could be released in the course of mining or leached from disturbed rock. Relative concentrations of these elements in fresh waters can have a significant effect on the competitive abilities of species in algal communities (Wetzel 1983). Ammonia is one of the starting raw materials of explosives used in the mining industry. Nitrogen losses into watersheds from use of ammonium nitrate-based explosives at mines in BC has been investigated by Pommen (1983). The Toboggan watershed is currently showing signs of eutrophication, and therefore would be highly sensitive to the addition of nutrients (or micronutrients) as a result of mining.

Molybdenum is a growth promoter for phytoplankton, periphyton and macrophytes at low concentrations, but becomes inhibiting to growth at higher concentrations. At high concentrations, most metallic micronutrients are very toxic to plants and animals. Ruminants, as opposed to non-ruminants, are particularly subject to copper deficiency and to a copper-molybedenum-sulphur imbalance. Cattle are the most sensitive animal to molybdenum toxicity, especially when consuming molybdenum in forage and in drinking water. Molybdenosis has been reported ruminants in Ireland, England, Nevada, Colorado, Oregon, California and Manitoba. This disease is characterized by diarrhea (scouring), discolouration of hair, loss of appetite, joint abnormalities, osteoporosis, reproductive difficulties, lack of sexual activity, testicular degeneration and, occasionally, death in animals. Molybdenosis is in part a copper deficiency since signs and lesions of molybdenosis are almost identical to copper deficiency. Also, the condition can be successfully prevented and treated with copper supplements (Swain 1986).

The principal problem related to irrigating with water which has high molybdenum concentrations is that molybdenum is absorbed and concentrated by plants. High molybdenum concentrations seldom retard plant growth, but can be toxic to ruminant animals that feed on the plants. Soils often associated with a copper/molybdenum problem in ruminants are poorly drained soils that allow most applied molybdenum to remain within the root zone. Soil associations in the agricultural zone along the Toboggan mainstem are derived from glacial till parent materials that are moderately fine textured, resulting in soils which are hard, compact, and nearly impervious. The C.L.I. Land Inventory Soils and Landforms Map 93L/NW (Runka 1972) indicates the predominant soils in the agricultural portions of the watershed are Barrett Association, which are well to moderately well drained on convex ridges and poorly drained in moisture receiving swales, flat plains and seepage channels. Forage crops are generally grown on the flattest land available. Irrigation water objectives for molybdenum are proposed applicable to differing Cu:Mo ratios, soil drainage characteristics and forage or non-forage crops. Available information indicates that the Toboggan watershed may require the most stringent objective, because baseline Cu:Mo concentrations are much lower than 2:1 and irrigation water is used to produce forage crops fed to cattle.

3.13 Recommendations

Monitoring future developments— There is a delicate line between a very productive watershed and a watershed that is tending to become eutrophic. An environmental assessment would be appropriate coincident with any future major developments in this watershed which could affect water quality, such as: an increase in fish production at the hatchery, new or expanded agricultural operations, or new housing subdivisions.

Any environmental effects assessment carried out for the proposed molybdenum mine should include the concentrations and fate of discharged metals in the aquatic environment of Toboggan Lake and Toboggan Creek, taking into account that the system is already showing signs of eutrophication and further nutrient or micronutrient additions could be detrimental to ecosystem health. Further assessment is needed on the extent of irrigation of forage crops fed to cattle in the watershed, in order to establish the appropriate water quality objective.

Outreach/stewardship publications— An interim report of this study was prepared (Remington and Lough March 2002). A non-technical summary was mailed to Toboggan Creek water license holders in June 2002, with cover letter from the Northwest Institute for Bioregional Research. A second outreach publication, summarizing the final ecosystem health and drinking water source quality assessment, is recommended. Dissemination of the microbiological quality assessment and recommendations for water treatment is of particular importance in this watershed, in which there are many domestic surface water intakes. This would also be an opportunity to explain the purpose of Water Quality Objectives in British Columbia and describe the proposed future objectives monitoring program for Toboggan Creek and tributaries. Emphasis would be placed on stewardship opportunities for government, the fish hatchery, rural residents, agriculture and forestry.

Cooperation between several levels of government and landowners will be necessary in order to implement much-needed riparian restoration prescriptions. The implementation of Best Management Practices on the part of the hatchery and agricultural operations and heightened awareness of watershed stewardship on the part of residents will help ensure water quality does not degrade in the future.

3.14 Data gaps/research needs

3.14.1 Hydrometric, temperature and dissolved oxygen data

A staff gauge for collecting hydrometric data has been in place at the hatchery for many years, and twice-daily readings recorded by hatchery personnel (M. O'Neill, personal communication). This data should be collated and validated to provide stage discharge information. This would be of value for many purposes related to water engineering and environmental management.

Elevated water temperatures in the Toboggan system, as well as other upper Skeena streams, are of concern to fisheries managers. Morrison et al. (2002) analyzed historic flows and water temperatures in the Fraser River watershed and detected trends in both the annual flow profile and summer temperatures. These trends are expected to continue with the change in climate predicted by global circulation models. For the period 2070-2099, the summer mean water temperature for the Fraser is predicted to increase by 1.9 °C. The potential exposure of salmon to water temperatures above 20 °C is predicted to increase by a factor of 10 in the Fraser basin.

Water temperature increases during the critical late summer-early fall spawning period can significantly increase mortality of spawning adult salmon due to increased incidence of disease as well as other factors (T. Pendray, DFO Habitat Biologist Skeena-Nass Area, personal communication). Further temperature monitoring to determine mean weekly maximum temperatures (MWMT) during the summer low flow period is needed.

Historical photographs document the retreat of the Hudson Bay Glacier, which feeds Glacier Gulch Creek, as the result of climate change. It is likely that Toboggan Glacier, which feeds Upper Toboggan Creek, is retreating in a similar manner. Long-term hydrometric and temperature monitoring stations are required to detect any effect glacial retreat/climate change may have on the magnitude and timing of streamflows and temperatures. It is important to gain a better understanding of the extent of future impact of climate change on the streamflow profile and water temperature so that appropriate management strategies may be proposed.

In some years, depressed dissolved oxygen concentrations have been recorded in the early spring. The extent or duration of this phenomenon is unknown. Nor is it clear if organic matter in runoff from agricultural winter feedlot operations are a contributing factor. Hatchery personnel could monitor DO concentrations, either at critical times of the year, or on a daily or weekly basis.

3.14.2 Licensed water withdrawals and instream flow assessment for fisheries

Irrigation is a major licensed water withdrawal volume in the Toboggan Creek system. Concern has been raised by fisheries managers that instream flows may be less than ideal for salmonids during late summer in some years. Low streamflows secondarily influence water temperature, which is at seasonal maximum during the period of peak irrigation demand.

In the Bulkley Valley, the volume of water licensed for irrigation purposes and the amount actually used may differ by up to 50% (D. Riendeau, District Agriculturist, personal communication). This is because rainfall often provides sufficient moisture for forage crop production. The Toboggan Creek Land and Water Use Survey was designed to document actual water volumes used for irrigation in the past five years, but was unsuccessful. The information gap regarding water use by the agricultural sector remains and should be addressed.

3.14.3 Trophic status and trends in nutrients and algae

Phosphorus plays a major role in biological metabolism, and when compared to other macronutrients required by biota, phosphorus is the least abundant and commonly the first nutrient to limit biological productivity (Wetzel 1983). Elevated nitrate concentrations emanating from Upper Toboggan Creek, believed to be from geologic sources, make the Toboggan mainstem particularly sensitive to eutrophication when anthropogenic phosphorus is available.

BC water quality guidelines for lakes are defined as total phosphorus concentrations during spring turnover. Toboggan Lake has only been sampled once, in September 1982, when it was described as oligotrophic, with a total phosphorus concentration of 11 μg/L. Further monitoring of Toboggan Lake is needed to assess future trends in trophic status and to establish baseline conditions prior to development of the proposed Glacier Gulch molybdenum mine. Likewise, monitoring of Glacier Gulch Creek is needed to assess nutrient loadings and to establish baseline water quality conditions prior to mining.

The BC water quality guideline for chlorophyll *a* represents the biomass of naturally growing periphytic algae on the stream bed. Our studies to date have shown considerable variation in periphytic biomass at the same locations between years. This may be because, in a shallow stream such as Toboggan Creek, sudden changes in water levels and other disturbance of the substrate can cause the algae to slough. For this reason, we suggest that accrual of periphyton biomass on artificial substrates may be a more reliable monitoring method. Periphyton community composition has proven to be a more reliable indicator of environmental change in Toboggan Creek. The Periphyton Index of Biotic Integrity (PIBI), developed by Hill et al. (2000), was found to correlate well with 27 chemical, 12 physical habitat, and 3 landscape variables. It is recommended that P-IBI be adapted to the Toboggan system and evaluated as a long term monitoring tool.

CCME (2003) has proposed a guidance framework for phosphorus in lakes and streams. Because aquatic communities are generally adapted to ambient conditions, it is neither feasible nor desirable to establish a single guideline value for phosphorus. The framework permits site-specific management of phosphorus. The framework offers a tiered approach where phosphorus concentrations should not (i) exceed predefined 'trigger ranges', and (ii) increase more than 50% over the baseline (reference) levels. If the upper limit of the range is exceeded, or is likely to be exceeded, further assessment is required. When assessment suggests the likelihood of undesired change in the system, management decisions must be made. It is recommended that objectives based on the guidance framework be established for the Toboggan system when sufficient data are available. These would incorporate such data as phosphorus concentration, chlorophyll *a* and Secchi depth, for the lake, and phosphorus concentration, chlorophyll *a*, periphyton and macroinvertebrate stream health indexes, for streams.

3.14.4 Drinking water source quality assessment

The drinking water source quality reported in this study is cause for concern, because there are many domestic water intakes on this system. Further investigation of the sources of contaminants is warranted. This study attempted, unsuccessfully, to document livestock headage, watering practices, and riparian condition in the Toboggan watershed using a mail-out survey. An information gap remains regarding agricultural management practices near watercourses and possible effects on microbiological water quality. Because of the density of both livestock and domestic water users in the watershed, Toboggan Creek would be an excellent candidate for regional drinking water studies into the prevalence of *Giardia* and *Cryptosporidium* in drinking source water.

3.14.5 Total and dissolved metals

Total metals scans were completed as part of the drinking water quality studies. Some of the total metals concentrations (e.g. cadmium and iron) were close to the working WQGs for protection of aquatic life (BCWLAP 1998*a*). Further monitoring of dissolved metals concentrations (using low-level ICP-MS analysis) is needed to assess the significance of this finding. Low level analysis for dissolved and total metals will provide baseline data for environmental effects assessment for the proposed Glacier Gulch molybdenum mine as well.

3.14.6 Environmental effects monitoring of herbicide use on CN rail grade

The Canadian National railway runs the length of the Toboggan watershed. In some places Toboggan Creek has been channelized to run parallel with, and very close to, the rail grade. There are two stream crossings just below Toboggan Lake. No information is available on herbicide use along the rail grade, although it would be very difficult to avoid exposing the stream to herbicide over-spray or runoff, due their close proximity. The CNR herbicide use is administered under a pesticide use plan, which is reviewed periodically by the province. Consideration should be given to requiring an assessment of environmental effects of herbicide application in the Toboggan watershed under the pesticide use plan.

4. Proposed Water Quality Objectives

4.1 Water Use Designations

Water quality objectives are set to protect the most sensitive designated water use at a specific location. The most sensitive water uses in this system are:

Drinking and recreational water sources— The Toboggan mainstem and all major tributaries are drinking and recreational water sources for the agricultural and rural residential communities. Due to proximity to Smithers, rural residential subdivisions have expanded into the eastern portions of the watershed in recent years, and this trend will likely continue. A BC Forest Service Recreational Site is located at the head of Glacier Gulch Creek. In addition, water is diverted from Glacier Gulch Creek into Lake Kathlyn, which is a drinking water source and a popular recreational area. Although existing water withdrawals are found at low elevation, drinking water source quality objectives will apply to higher elevation reaches, in order to protect downstream users. Objectives are proposed by microbiological parameters and turbidity, as well as iron and colour (Table 16).

Fisheries and freshwater aquatic life— Toboggan Creek is an important rearing area for salmonids, particularly coho and pink salmon and rainbow/steelhead trout. The Toboggan Creek Salmonid Hatchery has operated on the mainstem since 1985. Objectives are proposed for temperature, dissolved oxygen, suspended solids, ammonia and nitrite for the protection of aquatic life, particularly wild and hatchery salmonids (Table 16).

Our data has shown that Toboggan mainstem is exhibiting signs of eutrophication, which is detrimental to drinking and recreational water quality as well as to aquatic life. This system apparently has a geologic source of nitrogen in the headwaters and algal productivity is limited by phosphorus. An objective for phosphorus is proposed for Toboggan Lake. A periphyton biomass as chlorophyll *a* objective is proposed for the stream for the protection of recreation, particularly angling. Benthic macroinvertebrate assessment techniques employed to date show great promise as an ecosystem health indicator and their use should be continued.

Livestock watering and irrigation— The Toboggan watershed has supported a stable cattle industry since settlement in the early 1900's. Today four beef cattle operations, two dairies, and additional small holdings are located in the watershed. Cattle are the most sensitive animal to molybdenum toxicity, especially when consuming molybdenum in forage and in drinking water. Molybdenosis can be successfully prevented through limiting molybdenum uptake and treated with copper supplements (Swain 1986).

The principal problem related to irrigating with water which has high molybdenum concentrations is that molybdenum is absorbed and concentrated by plants. High molybdenum concentrations seldom retard plant growth, but can be toxic to ruminant animals that feed on the plants. Soils often associated with a copper/molybdenum problem in ruminants are poorly drained soils that allow most applied molybdenum to remain within the root zone. Irrigation water objectives for molybdenum are proposed applicable to differing Cu:Mo ratios, soil drainage characteristics and forage or non-forage crops. Available information indicates that the Toboggan watershed will require the most stringent objective, because baseline Cu:Mo concentrations are much lower than 2:1 and irrigation water is used to produce forage crops.

The following designated water uses, to be protected by water quality objectives, apply to Toboggan Creek and tributaries: (i) **drinking water**, (ii) **recreation**, (iii) **fisheries,** (iv) **(other) aquatic life,** (v) **livestock watering** and (vi) **irrigation.**

4.2 Toboggan Creek Salmonid Hatchery Discharge Registration

Registration of the Toboggan Creek Salmonid Hatchery under the land-based fin fish waste control regulation of the Waste Management Act is in process. No water quality guidelines were exceeded in the hatchery discharge during this study. Monitoring approximately 100 m downstream of the hatchery discharge channel did not document an effect on water quality in the Toboggan mainstem. Unless future monitoring indicates otherwise, the definition of an initial dilution zone for this discharge is considered unnecessary.

Table 16 Proposed Water Quality Objectives for Toboggan Creek and Tributaries

Parameter	Treatment or Conditions	Recommended WQO	Comment
Fecal coliforms[1,2]	-no treatment -disinfection only -partial treatment	0 ≤10/100 mL (90th percentile) ≤100/100 mL (90th percentile)	The most sensitive use for this parameter is drinking water. This objective will protect all other water uses as well.
Escherichia coli	-no treatment -disinfection only -partial treatment	0 ≤10/100 mL (90th percentile) ≤100/100 mL (90th percentile)	The most sensitive use for this parameter is drinking water. This objective will protect all other water uses as well.
Enterococci	-no treatment -disinfection only -partial treatment	0 ≤3/100 mL (90th percentile) ≤25/100 mL (90th percentile)	The most sensitive use for this parameter is drinking water. This objective will protect all other water uses as well.
Pseudomonas aeruginosa	-no treatment	0	The most sensitive use for this parameter is drinking water. This objective will protect all other water uses as well.
Turbidity	-no treatment -treatment	1 NTU when background is ≤ 5 NTU 5 NTU when background is ≤ 50 NTU, or 10% of background when background is greater than 50 NTU	The most sensitive use for this parameter is drinking water. This objective will protect all other water uses as well.
Iron		≤0.3 mg/L	The most sensitive use for this parameter is drinking water (aesthetic objective). This objective will protect all other water uses as well.
Colour (true)		≤15 TCU	The most sensitive use for this parameter is drinking water (aesthetic objective). This objective will protect all other water uses as well.
Phosphorus (total)	-Lakes	10 µg/L (maximum)[3]	The most sensitive uses for this parameter are drinking water and recreation. This objective will protect all other water uses as well.
Water temperature		+ or - 1 degree Celsius change from optimum temperature range of 4.4-12.8 °C	The most sensitive use for this parameter is fisheries (recommended temperature range for coho and pink salmon spawning).

Table 16 (continued) Proposed Water Quality Objectives for Toboggan Creek and Tributaries

Parameter	Treatment or Conditions	Recommended WQO	Comment
Dissolved Oxygen	Buried embryo/alevin life stages[4] All life stages other than buried embryo/alevin	9 mg/L (instantaneous minimum)[5] 11 mg/L (30-day mean) 5 mg/L (instantaneous minimum)[5] 8 mg/L (30-day mean)	The most sensitive use for this parameter is fisheries. This objective will protect all other water uses as well.
Suspended solids		Maximum induced level of 10 mg/L above background if background is ≤ 100 mg/L	The most sensitive use for this parameter is aquatic life. This objective will protect all other water uses as well.
Ammonia nitrogen		See tables 4 and 5 in :British Columbia Water Quality Guidelines (Criteria): 1998 Edition	The most sensitive use for this parameter is aquatic life. This objective will protect all other water uses as well.
Nitrite nitrogen		0.06 mg/L (maximum) when chloride is less than 2 mg/L ≤ 0.02 mg/L (average)[6] when chloride is less than 2 mg/L See table 16 in: British Columbia Water Quality Guidelines (Criteria): 1998 Edition	The most sensitive use for this parameter is aquatic life. This objective will protect all other water uses as well.
Periphyton		50 mg/m^2 Chlorophyll *a* (maximum)[7]	The most sensitive use for this parameter is recreation (particularly angling). This objective will protect all other water uses as well.
Molybdenum (total)	Poorly drained soils used for forage crops and Cu:Mo ratio is <2:1 in irrigation water Well drained soils used for forage crops, or, poorly drained soils used for forage crops and Cu:Mo ratio is ≥2:1 in irrigation water	0.01 mg/L average 0.05 mg/L maximum[8] 0.02 mg/L average 0.05 mg/L maximum[8]	The most sensitive use for this parameter is irrigation water. This objective will protect all other water uses, including human and livestock drinking water.

[1] Fecal coliform criteria which presently exist will apply on an interim basis until use of the other preferred indicators is adopted.

[2] Medians and geometric means are calculated from at least 5 weekly samples in a 30-day period. Ten samples are required for 90th percentiles.

[3] Total phosphorus in lakes is either the spring overturn concentration, if the residence time of the epilimnetic water is greater than 6 months, or the mean epilimnetic growing season concentration, if the residence time of epilimnetic water is less than 6 months.

[4] For the buried embryo/alevin life stages, these are in-stream concentrations for spawning to the point of yolk sac absorption or 30 days post-hatch for fish.

[5] The instantaneous minimum level is to be maintained at all times.

[6] Average value is calculated from at least 5 weekly samples taken in a period of 30 days.

[7] Chlorophyll *a* guidelines in streams apply to naturally-growing periphytic algae.

[8] Maximum and average values apply during the irrigation season, with average values calculated from at least 5 weekly samples taken in a period of 30 days.

5. Proposed Water Quality Objectives Monitoring Program

The proposed annual water quality objectives monitoring program is found in Table 17. It is suggested that the annual program be implemented for three consecutive years, in order to establish baseline conditions and to assess annual variability of all parameters. Following this, the three-year monitoring cycle should be repeated after five years. Monitoring of Toboggan Lake is recommended, although access to the lake through private property has been restricted in the past.

Table 17 Proposed Annual Water Quality Objectives Monitoring Program for Toboggan Creek and Tributaries

EMS ID	Location	Time of Year	Frequency	Variables
New site	Toboggan Lake	Spring breakup and mid-August	Once	DO profile, temperature profile, pH, specific conductance, Secchi disc, suspended solids, true colour, chloride, total nitrogen, TKN, ammonia-N, nitrite+nitrate-N, nitrite-N, total phosphorus, ortho-phosphate-P, total and dissolved metals (ICP-MS)
		Mid-August	Once	Suspended chlorophyll a, phytoplankton ID and enumeration
New site	Glacier Gulch Creek u/s Toboggan L.	Freshet (Mar-Apr)	Twice/month	DO, temperature, pH,
E245607	Upper Toboggan Creek	May to September	Once/month	specific conductance, turbidity
E245365	Toboggan Cr u/s fish hatchery			suspended solids, true colour, chloride,
E245367	Toboggan Cr 100m d/s fish hatchery			total nitrogen, TKN, ammonia-N,
E245369	Toboggan Cr 500m u/s Highway 16			nitrite+nitrate-N, nitrite-N, total phosphorus, ortho-phosphate-P, total and dissolved metals (ICP-MS)
E245607	Upper Toboggan Creek	August/September	Once/year	Benthic chlorophyll *a*, periphyton ID and enumeration
E245365	Toboggan Cr u/s fish hatchery			
E245367	Toboggan Cr 100m d/s fish hatchery			
E245369	Toboggan Cr 500m u/s Highway 16			
E245369	Toboggan Cr 500m u/s Highway 16	August/September	Once/year	Benthic-IBI
E245365	Toboggan Cr u/s fish hatchery	Freshet (Mar/Apr)	5 times	*Fecal coliforms*, *E. coli*, Enterococci,
New site	Domestic water intake lower Toboggan Cr	and fall rainy	weekly	*Pseudomonas aeruginosa*
New site	Domestic water intake lower Toboggan Cr	period (Sep)	in 30-days	turbidity, true colour
E245370	Toboggan Cr u/s Highway 16		Once/month	Total metals (ICP)

The preferred monitoring tool for dissolved oxygen is the 30-day mean DO. The preferred monitoring tool for water temperature is the mean weekly maximum temperature (MWMT) during the warmest week of each year. Automated DO and/or temperature monitors are available. Alternatively, it may be possible to partner with Toboggan Creek Salmonid Hatchery personnel for manual collection of DO and temperature data.

A WQO has not been proposed for benthic macroinvertebrate stream health index as yet. Two more years of baseline data are required to set objectives.

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Appendix 1 Table 1 Water analysis data Site 1 Upper Toboggan Cr (E245607) 2001 - 2002

Date	Temp. water (°C)	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
17-Sep-01	7.0	11.6	7.6	30	13	< 5	7.54	41
Replicate2						< 5	7.34	41
Replicate3						< 5	7.30	42
15-Oct-01	3.5	12.0	8.2	50	1	< 5	7.55	62
12-Nov-01	3.0	11.6	7.6	50	19	10	7.87	92
8-Jan-02	0.25	12.7			< 1	< 5	7.82	150
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.25	15.9	8.0	120	< 1	< 5	7.94	144
15-Apr-02	0.1	12.3	7.5	70	48	10	7.50	92
22-Apr-02	0.5	12.9	7.7	70	< 1	17	7.70	82
13-May-02	3.7	12.6	7.5	60	61	23	7.60	74
Replicate2						22	7.10	73
Replicate3						20	7.00	73
18-Jun-02	6.5	11.3	7.6	30	3	67	7.20	39
22-Jul-02	9.8	9.8	7.4	20	4	20	7.20	26
3-Sep-02	7.0	11.0	7.6	20	7	< 4	7.30	34

Date	Total Nitrogen (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen[1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
17-Sep-01	0.11	< 0.005	0.092	N/A	N/A	0.097	0.002	< 0.001	97
Replicate2	0.11	< 0.005	0.092	N/A	N/A	0.097	< 0.002	< 0.001	97
Replicate3	0.10	< 0.005	0.090	N/A	N/A	0.095	< 0.002	< 0.001	95
15-Oct-01	0.38	0.007	0.196	0.194	< 0.002	0.203	0.003	< 0.001	
12-Nov-01	0.88	0.008	0.670	0.668	< 0.002	0.678	0.020	0.001	
8-Jan-02	0.67	0.007	0.452	0.450	< 0.002	0.459	0.007	< 0.001	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.54	0.009	0.404	0.402	< 0.002	0.413	< 0.002	0.001	413
15-Apr-02	1.77	0.021	1.210	1.206	0.004	1.231	0.032	< 0.001	1231
22-Apr-02	1.27	< 0.005	0.995	0.993	0.002	1.000	0.019	0.002	500
13-May-02	1.45	0.015	1.180	1.170	0.010	1.195	0.015	0.004	299
Replicate2	1.53	< 0.005	1.180	1.172	0.008	1.185	0.010	0.003	395
Replicate3	1.49	< 0.005	1.180	1.169	0.011	1.185	0.015	0.003	395
18-Jun-02	0.21	< 0.005	0.123	0.116	0.007	0.128	0.027	0.002	64
22-Jul-02	0.13	< 0.005	0.033	0.031	0.002	0.038	0.011	0.005	8
3-Sep-02	0.09	< 0.005	0.060	0.058	< 0.002	0.065	0.004	0.002	33

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only.

Appendix 1 Table 2 Water analysis summary statistics Site 1 Upper Toboggan Cr (E245607) 2001 - 2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
17-Sep-01 [1]	7.0	11.6	7.6	30	13	< 5	7.39	41
15-Oct-01	3.5	12.0	8.2	50	1	< 5	7.55	62
12-Nov-01	3.0	11.6	7.6	50	19	10	7.87	92
8-Jan-02	0.25	12.7			< 1	< 5	7.82	150
11-Feb-02					< 1			
11-Mar-02	0.25	15.9	8.0	120	< 1	< 5	7.94	144
15-Apr-02	0.1	12.3	7.5	70	48	10	7.50	92
22-Apr-02	0.5	12.9	7.7	70	< 1	17	7.70	82
13-May-02 [1]	3.7	12.6	7.5	60	61	22	7.23	73
18-Jun-02	6.5	11.3	7.6	30	3	67	7.20	39
22-Jul-02	9.8	9.8	7.4	20	4	20	7.20	26
3-Sep-02	7.0	11.0	7.6	20	7	< 4	7.30	34
Maximum	9.8	15.9	8.2	120	61	67	7.94	150
Minimum	0.1	9.8	7.4	20	< 1	< 4	7.20	26
Average	3.78	12.15	7.67	52.0	13.3	15.4	7.519	76.0
St. Dev.	3.38	1.53	0.25	30.5	20.2	18.3	0.278	42.1

Date	Total Nitrogen (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
17-Sep-01 [1]	0.11	< 0.005	0.091			0.096	< 0.002	< 0.001	96
15-Oct-01	0.38	0.007	0.196	0.194	< 0.002	0.203	0.003	< 0.001	
12-Nov-01	0.88	0.008	0.670	0.668	< 0.002	0.678	0.020	0.001	
8-Jan-02	0.67	0.007	0.452	0.450	< 0.002	0.459	0.007	< 0.001	
11-Feb-02									
11-Mar-02	0.54	0.009	0.404	0.402	< 0.002	0.413	< 0.002	0.001	413
15-Apr-02	1.77	0.021	1.210	1.206	0.004	1.231	0.032	< 0.001	1231
22-Apr-02	1.27	< 0.005	0.995	0.993	0.002	1.000	0.019	0.002	500
13-May-02 [1]	1.49	0.008	1.180	1.170	0.010	1.188	0.013	0.003	363
18-Jun-02	0.21	< 0.005	0.123	0.116	0.007	0.128	0.027	0.002	64
22-Jul-02	0.13	< 0.005	0.033	0.031	0.002	0.038	0.011	0.005	8
3-Sep-02	0.09	< 0.005	0.060	0.058	< 0.002	0.065	0.004	0.002	33
Maximum	1.77	0.021	1.210	1.206	0.010	1.231	0.032	0.005	1231
Minimum	0.09	< 0.005	0.033	0.031	< 0.002	0.038	< 0.002	< 0.001	8
Average	0.685	0.0078	0.4922	0.5288	0.0035	0.5000	0.0128	0.0018	338.4
St. Dev.	0.595	0.0047	0.4544	0.4570	0.0027	0.4573	0.0105	0.0013	408.1

[1] Mean of triplicate sequential samples

Appendix 1 Table 3 Water analysis data Site 2 Toboggan Cr downstream Toboggan Lake (E245606) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
17-Sep-01	9.9	10.8	7.3	40	4	< 5	6.71	46
15-Oct-01	3.9	11.6	8.0	40	1	< 5	7.35	54
12-Nov-01	3.0	11.6	7.6	50	113	< 5	7.63	69
Replicate 2						< 5	7.59	69
Replicate 3						7	7.58	69
10-Dec-01	1.0	11.3	8.4	60	1	< 5	7.42	82
8-Jan-02	0.75	10.3			5	< 5	7.66	122
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.5	12.4	7.1	70	1	6	7.20	88
15-Apr-02	0.7	8.8	7.1	110	412	11	7.40	130
22-Apr-02	3.8	8.9	7.1	60	< 1	7	7.30	77
13-May-02	7.2	11.5	7.3	60	46	Bottle broken during transit		
18-Jun-02	6.5	10.9	7.1	30	8	27	7.40	43
22-Jul-02	12.2	9.2	7.0	20	4	16	7.20	32
Replicate 2						14	7.20	32
Replicate 3						16	7.20	31
3-Sep-02	9.0	9.8	6.9	20	8	8	7.20	35

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N). (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen[1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
17-Sep-01	0.09	0.006	0.036			0.042	0.006	< 0.001	42
15-Oct-01	0.32	< 0.005	0.058	0.056	< 0.002	0.063	0.008	< 0.001	
12-Nov-01	0.27	0.015	0.179	0.177	< 0.002	0.194	0.011	< 0.001	
Replicate 2	0.27	0.018	0.183	0.181	< 0.002	0.201	0.011	0.001	
Replicate 3	0.26	0.017	0.176	0.174	< 0.002	0.193	0.010	0.001	
10-Dec-01	0.43	0.038	0.187	0.185	< 0.002	0.225	0.010	0.001	
8-Jan-02	0.40	0.044	0.187	0.185	0.002	0.231	0.009	< 0.001	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.39	0.080	0.157	0.155	< 0.002	0.237	0.016	0.001	237
15-Apr-02	1.50	0.270	0.245	0.238	0.007	0.515	0.134	0.024	21
22-Apr-02	0.86	0.008	0.157	0.153	0.004	0.165	0.042	0.007	24
13-May-02	Bottle broken during transit				0.007			0.001	
18-Jun-02	0.20	< 0.005	0.076	0.066	0.010	0.081	0.026	< 0.001	81
22-Jul-02	0.18	< 0.005	0.026	0.030	0.004	0.031	0.027	0.002	16
Replicate 2	0.06	< 0.005	0.039	0.034	0.005	0.044	0.025	0.004	11
Replicate 3	0.06	< 0.005	0.030	0.025	0.005	0.035	0.020	0.003	12
3-Sep-02	0.09	< 0.005	0.034	0.032	0.002	0.039	0.022	0.002	20

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 4 Water analysis summary statistics Site 2 Toboggan Cr downstream Toboggan Lake (E245606) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
17-Sep-01	9.9	10.8	7.3	40	4	< 5	6.71	46
15-Oct-01	3.9	11.6	8.0	40	1	< 5	7.35	54
12-Nov-01 [1]	3.0	11.6	7.6	50	113	6	7.60	69
10-Dec-01	1.0	11.3	8.4	60	1	< 5	7.42	82
8-Jan-02	0.75	10.3			5	< 5	7.66	122
11-Feb-02					< 1			
11-Mar-02	0.5	12.4	7.1	70	1	6	7.20	88
15-Apr-02	0.7	8.8	7.1	110	412	11	7.40	130
22-Apr-02	3.8	8.9	7.1	60	< 1	7	7.30	77
13-May-02	7.2	11.5	7.3	60	46			
18-Jun-02	6.5	10.9	7.1	30	8	27	7.40	43
22-Jul-02 [1]	12.2	9.2	7.0	20	4	15	7.20	32
3-Sep-02	9.0	9.8	6.9	20	8	8	7.20	35
Maximum	12.2	12.4	8.4	110	412	27	7.66	130
Minimum	0.5	8.8	6.9	20	< 1	< 5	6.71	32
Average	4.87	10.59	7.35	50.9	46.5	9.1	7.313	70.7
St. Dev.	4.02	1.19	0.47	25.9	114.3	6.8	0.252	33.3

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N). (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
17-Sep-01	0.09	0.006	0.036			0.042	0.006	< 0.001	42
15-Oct-01	0.32	< 0.005	0.058	0.056	< 0.002	0.063	0.008	< 0.001	
12-Nov-01 [1]	0.27	0.017	0.179	0.177	< 0.002	0.196	0.011	0.001	
10-Dec-01	0.43	0.038	0.187	0.185	< 0.002	0.225	0.010	0.001	
8-Jan-02	0.40	0.044	0.187	0.185	0.002	0.231	0.009	< 0.001	
11-Feb-02									
11-Mar-02	0.39	0.080	0.157	0.155	< 0.002	0.237	0.016	0.001	237
15-Apr-02	1.50	0.270	0.245	0.238	0.007	0.515	0.134	0.024	21
22-Apr-02	0.86	0.008	0.157	0.153	0.004	0.165	0.042	0.007	24
13-May-02					0.007			0.001	
18-Jun-02	0.20	< 0.005	0.076	0.066	0.010	0.081	0.026	< 0.001	81
22-Jul-02 [1]	0.10	< 0.005	0.032	0.030	0.005	0.037	0.024	0.003	13
3-Sep-02	0.09	< 0.005	0.034	0.032	0.002	0.039	0.022	0.002	20
Maximum	1.50	0.270	0.245	0.238	0.010	0.515	0.134	0.024	237
Minimum	0.09	< 0.005	0.032	0.030	< 0.002	0.037	0.006	< 0.001	13
Average	0.422	0.0439	0.1225	0.1277	0.0041	0.1664	0.0280	0.0037	62.5
St. Dev.	0.420	0.0787	0.0767	0.0748	0.0028	0.1420	0.0367	0.0066	80.4

[1] Mean of triplicate sequential samples

Appendix 1 Table 5 Water analysis data Site 3 Elliot Cr (E245364) 2001-2002

Date	Temp. water (°C)	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduc (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
30-Aug-01	8.0	11.4	8.1	120	1	< 5	7.71	143
Replicate 2						< 5	7.97	145
Replicate 3						< 5	8.02	145
17-Sep-01	7.0	11.6	8.1	130	118	< 5	7.85	145
15-Oct-01	3.0	11.9	8.3	120	2	< 5	7.80	147
12-Nov-01	2.5	11.9	8.2	130	5	< 5	8.03	160
10-Dec-01	4.0	11.2	7.6	100	< 1	< 5	7.91	137
8-Jan-02	3.0	11.6			< 1	< 5	7.46	116
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	1.5	15.8	7.6	110.0	< 1	< 5	7.61	138
15-Apr-02	4.0	10.8	7.6	120.0	< 1	< 4	7.90	141
Replicate 2						< 4	7.90	143
Replicate 3						< 4	7.80	142
22-Apr-02	3.2	11.5	7.6	120.0	< 1	< 4	7.80	147
13-May-02	4.0	12.2	7.6	120.0	41	< 4	7.80	145
18-Jun-02	5.0	11.7	8.0	70.0	4	50	7.90	87
22-Jul-02	8.5	10.2	8.0	80.0	2	< 4	7.80	96
3-Sep-02	7.5	11.0	8.2	110.0	4	< 4	7.90	133

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen[1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
30-Aug-01	0.08	< 0.005	0.048			0.053	< 0.002	< 0.001	53
Replicate 2	0.06	< 0.005	0.047			0.052	< 0.002	< 0.001	52
Replicate 3	0.09	< 0.005	0.048			0.053	< 0.002	< 0.001	53
17-Sep-01	0.09	0.006	0.054			0.060	< 0.002	< 0.001	60
15-Oct-01	0.13	< 0.005	0.064	0.062	< 0.002	0.069	< 0.002	< 0.001	
12-Nov-01	0.11	< 0.005	0.142	0.140	< 0.002	0.147	< 0.002	< 0.001	
10-Dec-01	0.08	0.008	0.048	0.046	< 0.002	0.056	0.003	< 0.001	
8-Jan-02	0.05	0.007	0.051	0.049	< 0.002	0.058	< 0.002	< 0.001	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.07	< 0.005	0.075	0.073	< 0.002	0.080	< 0.002	< 0.001	80
15-Apr-02	0.14	< 0.005	0.111	0.109	< 0.002	0.116	0.004	0.004	29
Replicate 2	0.15	< 0.005	0.111	0.109	< 0.002	0.116	< 0.002	0.003	39
Replicate 3	0.14	< 0.005	0.111	0.109	< 0.002	0.116	< 0.002	0.002	58
22-Apr-02	0.17	< 0.005	0.121	0.119	< 0.002	0.126	< 0.002	< 0.001	126
13-May-02	0.50	< 0.005	0.374	0.367	0.007	0.379	< 0.002	< 0.001	379
18-Jun-02	0.16	< 0.005	0.052	0.04	0.012	0.057	0.044	< 0.001	57
22-Jul-02	< 0.02	< 0.005	< 0.002	< 0.002	< 0.002	0.007	0.003	< 0.001	7
3-Sep-02	0.07	< 0.005	0.036	0.034	< 0.002	0.041	0.003	0.002	21

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only.

Appendix 1 Table 6 Water analysis summary statistics Site 3 Elliot Cr (E245364) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
30-Aug-01 [1]	8.0	11.4	8.1	120	1	< 5	7.90	144
17-Sep-01	7.0	11.6	8.1	130	118	< 5	7.85	145
15-Oct-01	3.0	11.9	8.3	120	2	< 5	7.80	147
12-Nov-01	2.5	11.9	8.2	130	5	< 5	8.03	160
10-Dec-01	4.0	11.2	7.6	100	< 1	< 5	7.91	137
8-Jan-02	3.0	11.6			< 1	< 5	7.46	116
11-Feb-02					< 1			
11-Mar-02	1.5	15.8	7.6	110	< 1	< 5	7.61	138
15-Apr-02 [1]	4.0	10.8	7.6	120	< 1	< 4	7.90	142
22-Apr-02	3.2	11.5	7.6	120	< 1	< 4	7.80	147
13-May-02	4.0	12.2	7.6	120	41	< 4	7.80	145
18-Jun-02	5.0	11.7	8.0	70	4	50	7.90	87
22-Jul-02	8.5	10.2	8.0	80	2	< 4	7.80	96
3-Sep-02	7.5	11.0	8.2	110	4	< 4	7.90	133
Maximum	8.5	15.8	8.3	130	118	50	8.03	160
Minimum	1.5	10.2	7.6	70	< 1	< 4	7.46	87
Average	4.71	11.75	7.91	110.8	13.1	8.1	7.820	133.6
St. Dev.	2.29	1.32	0.28	18.8	32.0	12.6	0.145	21.3

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
30-Aug-01 [1]	0.08	< 0.005	0.048			0.053	< 0.002	< 0.001	53
17-Sep-01	0.09	0.006	0.054			0.060	< 0.002	< 0.001	60
15-Oct-01	0.13	< 0.005	0.064	0.062	< 0.002	0.069	< 0.002	< 0.001	
12-Nov-01	0.11	< 0.005	0.142	0.140	< 0.002	0.147	< 0.002	< 0.001	
10-Dec-01	0.08	0.008	0.048	0.046	< 0.002	0.056	0.003	< 0.001	
8-Jan-02	0.05	0.007	0.051	0.049	< 0.002	0.058	< 0.002	< 0.001	
11-Feb-02									
11-Mar-02	0.07	< 0.005	0.075	0.073	< 0.002	0.080	< 0.002	< 0.001	80
15-Apr-02 [1]	0.14	< 0.005	0.111	0.109	< 0.002	0.116	0.003	0.003	42
22-Apr-02	0.17	< 0.005	0.121	0.119	< 0.002	0.126	< 0.002	< 0.001	126
13-May-02	0.50	< 0.005	0.374	0.367	0.007	0.379	< 0.002	< 0.001	379
18-Jun-02	0.16	< 0.005	0.052	0.04	0.012	0.057	0.044	< 0.001	57
22-Jul-02	< 0.02	< 0.005	< 0.002	< 0.002	< 0.002	0.007	0.003	< 0.001	7
3-Sep-02	0.07	< 0.005	0.036	0.034	< 0.002	0.041	0.003	0.002	21
Maximum	0.50	0.008	0.374	0.367	0.012	0.379	0.044	0.003	379
Minimum	< 0.02	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
Average	0.128	0.0055	0.0906	0.0946	0.0034	0.0961	0.0055	0.0012	91.6
St. Dev.	0.120	0.0010	0.0932	0.0991	0.0032	0.0929	0.0116	0.0006	113.1

[1] Mean of triplicate sequential samples

Appendix 1 Table 7 Water analysis data Site 4 Toboggan Cr upstream fish hatchery (E245365) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conductance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
29-Aug-01	11.2	10.2	7.5	40	3	< 5	6.81	59
17-Sep-01	8.6	10.6	7.6	50	11	< 5	7.40	61
15-Oct-01	4.1	11.3	7.8	60	1	< 5	7.42	77
12-Nov-01	3.0	11.8	8.0	70	38	< 5	7.75	88
10-Dec-01	1.0	12.6	7.6	80	3	< 5	7.93	108
Replicate 2						< 5	7.69	96
Replicate 3						< 5	7.71	96
8-Jan-02	1	11.6	n/a		3	< 5	7.82	138
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.5	14.4	7.2	90	2	< 5	7.41	110
15-Apr-02	1.0	10.0	7.1	100	508	23	7.50	124
22-Apr-02	3.8	9.7	7.1	70	< 1	17	7.40	79
13-May-02	6.8	10.8	7.4	70	87	11	7.60	86
18-Jun-02	7.8	10.1	7.4	50	14	37	7.60	55
22-Jul-02	11.2	9.4	7.4	40	16	18	7.40	45
3-Sep-02	9.2	10.0	7.3	40	4	9	7.50	50

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen [1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
29-Aug-01	0.09	0.005	0.031			0.036	0.008	0.001	36
17-Sep-01	0.10	0.018	0.039			0.057	0.005	< 0.001	57
15-Oct-01	0.22	< 0.005	0.054	0.052	< 0.002	0.059	0.007	0.001	
12-Nov-01	0.28	0.020	0.160	0.158	< 0.002	0.18	0.013	0.002	
10-Dec-01	0.52	0.073	0.171	0.169	< 0.002	0.244	0.014	0.001	
Replicate 2	0.37	0.043	0.172	0.170	< 0.002	0.215	0.013	0.001	
Replicate 3	0.45	0.043	0.171	0.169	< 0.002	0.214	0.010	0.001	
8-Jan-02	0.34	0.041	0.188	0.186	0.002	0.229	0.01	< 0.001	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.34	0.058	0.154	0.152	< 0.002	0.212	0.015	0.002	106
15-Apr-02	1.35	0.184	0.205	0.197	0.008	0.389	0.141	0.024	16
22-Apr-02	0.82	< 0.005	0.168	0.164	0.004	0.173	0.041	0.003	58
13-May-02	1.00	0.005	0.657	0.650	0.007	0.662	0.018	< 0.001	662
18-Jun-02	0.22	< 0.005	0.077	0.070	0.007	0.082	0.032	0.001	82
22-Jul-02	0.05	< 0.005	0.026	0.020	0.006	0.031	0.016	< 0.001	31
3-Sep-02	0.09	0.007	0.04	0.037	0.003	0.047	0.011	0.006	8

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only.

Appendix 1 Table 8 Water analysis summary statistics Site 4 Toboggan Cr upstream fish hatchery (E245365) 2001-2002

Date	Temp. water	Diss. Oxygen	Field pH	Field Sp. Conduct-ance	Fecal Coliform	Residue Non-filterable	pH	Specific Conduct-ance
	°C	(mg/L)	(pH units)	(uS/cm)	(CFU/100ml)	(mg/L)	(pH units)	(uS/cm)
29-Aug-01	11.2	10.2	7.5	40	3	< 5	6.81	59
17-Sep-01	8.6	10.6	7.6	50	11	< 5	7.40	61
15-Oct-01	4.1	11.3	7.8	60	1	< 5	7.42	77
12-Nov-01	3.0	11.8	8.0	70	38	< 5	7.75	88
10-Dec-01 [1]	1.0	12.6	7.6	80	3	< 5	7.78	100
8-Jan-02	1	11.6			3	< 5	7.82	138
11-Feb-02					< 1			
11-Mar-02	0.5	14.4	7.2	90	2	< 5	7.41	110
15-Apr-02	1.0	10.0	7.1	100	508	23	7.50	124
22-Apr-02	3.8	9.7	7.1	70	< 1	17	7.40	79
13-May-02	6.8	10.8	7.4	70	87	11	7.60	86
18-Jun-02	7.8	10.1	7.4	50	14	37	7.60	55
22-Jul-02	11.2	9.4	7.4	40	16	18	7.40	45
3-Sep-02	9.2	10.0	7.3	40	4	9	7.50	50
Maximum	11.2	14.4	8.0	100	508	37	7.82	138
Minimum	0.5	9.4	7.1	40	< 1	< 5	6.81	45
Average	5.32	10.96	7.45	63.3	49.4	11.5	7.491	82.5
St. Dev.	4.00	1.39	0.27	20.2	134.0	9.8	0.255	29.1

Date	Nitrogen Total	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrate (N)	Nitrite (N)	Diss. Inorganic Nitrogen	Phosphorus Total	Ortho-Phosphate (P) LL	N:P Ratio
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
29-Aug-01	0.09	0.005	0.031			0.036	0.008	0.001	36
17-Sep-01	0.10	0.018	0.039			0.057	0.005	< 0.001	57
15-Oct-01	0.22	< 0.005	0.054	0.052	< 0.002	0.059	0.007	0.001	
12-Nov-01	0.28	0.020	0.160	0.158	< 0.002	0.180	0.013	0.002	
10-Dec-01 [1]	0.45	0.053	0.171	0.169	< 0.002	0.224	0.012	0.001	
8-Jan-02	0.34	0.041	0.188	0.186	0.002	0.229	0.010	< 0.001	
11-Feb-02									
11-Mar-02	0.34	0.058	0.154	0.152	< 0.002	0.212	0.015	0.002	106
15-Apr-02	1.35	0.184	0.205	0.197	0.008	0.389	0.141	0.024	16
22-Apr-02	0.82	< 0.005	0.168	0.164	0.004	0.173	0.041	0.003	58
13-May-02	1.00	0.005	0.657	0.650	0.007	0.662	0.018	< 0.001	662
18-Jun-02	0.22	< 0.005	0.077	0.070	0.007	0.082	0.032	0.001	82
22-Jul-02	0.05	< 0.005	0.026	0.020	0.006	0.031	0.016	< 0.001	31
3-Sep-02	0.09	0.007	0.040	0.037	0.003	0.047	0.011	0.006	8
Maximum	1.35	0.184	0.657	0.650	0.008	0.662	0.141	0.024	662
Minimum	0.05	< 0.005	0.026	0.020	< 0.002	0.031	0.005	< 0.001	8
Average	0.411	0.0316	0.1516	0.1687	0.0041	0.1832	0.0253	0.0035	117.3
St. Dev.	0.401	0.0497	0.1661	0.1720	0.0024	0.1783	0.0362	0.0063	206.6

[1] Mean of triplicate sequential samples

Appendix 1 Table 9 Water analysis data Site 5 Fish hatchery outflow channel (E245366) 2001-2002

Date	Temp. water	Diss. Oxygen	Field pH	Field Sp. Conduct-ance	Fecal Coliform	Residue Non-filterable	pH	Specific Conduct-ance
	°C	(mg/L)	(pH units)	(uS/cm)	(CFU/100ml)	(mg/L)	(pH units)	(uS/cm)
29-Aug-01	10.5	8.9	7.0	80	11	19	7.46	90
17-Sep-01	8.6	9.4	7.4	90	8	< 5	7.42	97
15-Oct-01	4.1	10.7	7.7	100	2	< 5	7.59	124
12-Nov-01	3.0	11.4	7.6	90	6	< 5	7.87	119
10-Dec-01	1.0	12.0	7.7	90	1	< 5	7.72	112
8-Jan-02	1.0	12.0	n/a		7	< 5	7.46	116
Replicate 2						< 5	7.45	115
Replicate 3						< 5	7.48	115
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.5	15.6	7.3	100	2	< 5	7.44	122
15-Apr-02	4.0	8.7	7.1	160	244	10	7.70	182
22-Apr-02	3.0	9.8	7.1	110	< 1	7	7.60	129
13-May-02	7.0	9.6	7.2	90	38	7	7.60	104
18-Jun-02	7.2	8.5	7.6	220	480	< 4	7.90	220
22-Jul-02	11.0	8.4	7.1	60	18	12	7.60	70
3-Sep-02	9.1	8.9	7.2	60	18	9	7.60	73
Replicate 2						10	7.60	73
Replicate 3						8	7.60	73

Date	Nitrogen Total	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrate (N)	Nitrite (N)	Diss. Inorganic Nitrogen [1]	Phosphorus Total	Ortho-Phosphate (P) LL	N:P Ratio[2]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
29-Aug-01	0.40	0.122	0.063			0.185	0.078	0.006	31
17-Sep-01	0.30	0.112	0.065			0.177	0.024	0.009	20
15-Oct-01	0.40	0.049	0.076	0.074	< 0.002	0.125	0.024	0.008	
12-Nov-01	0.34	0.062	0.162	0.160	< 0.002	0.224	0.023	0.006	
10-Dec-01	0.44	0.057	0.173	0.171	< 0.002	0.23	0.015	0.003	
8-Jan-02	0.40	0.062	0.193	0.191	0.002	0.255	0.020	0.005	
Replicate 2	0.39	0.068	0.195	0.193	0.002	0.263	0.021	0.005	
Replicate 3	0.42	0.068	0.195	0.193	0.002	0.263	0.021	0.005	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.34	0.063	0.161	0.159	< 0.002	0.224	0.021	0.002	112
15-Apr-02	0.81	0.150	0.278	0.274	0.004	0.428	0.062	0.008	54
22-Apr-02	0.93	0.036	0.300	0.296	0.004	0.336	0.044	0.002	168
13-May-02	1.09	0.142	0.603	0.593	0.010	0.745	0.028	< 0.001	745
18-Jun-02	0.44	0.043	0.207	0.198	0.009	0.25	0.017	0.003	83
22-Jul-02	0.24	0.013	0.062	0.055	0.007	0.075	0.032	< 0.001	75
3-Sep-02	0.20	0.028	0.068	0.065	0.003	0.096	0.028	0.005	19
Replicate 2	0.21	0.029	0.066	0.063	0.003	0.095	0.029	0.004	24
Replicate 3	0.20	0.027	0.065	0.062	0.003	0.092	0.028	0.002	46

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 10 Water analysis summary statistics Site 5 Fish hatchery outflow channel (E245366) 2001-2002

Date	Temp. water	Diss. Oxygen	Field pH	Field Sp. Conduct-ance	Fecal Coliform	Residue Non-filterable	pH	Specific Conduct-ance
	°C	(mg/L)	(pH units)	(uS/cm)	(CFU/100ml)	(mg/L)	(pH units)	(uS/cm)
29-Aug-01	10.5	8.9	7.0	80	11	19	7.46	90
17-Sep-01	8.6	9.4	7.4	90	8	< 5	7.42	97
15-Oct-01	4.1	10.7	7.7	100	2	< 5	7.59	124
12-Nov-01	3.0	11.4	7.6	90	6	< 5	7.87	119
10-Dec-01	1.0	12.0	7.7	90	1	< 5	7.72	112
8-Jan-02 [1]	1.0	12.0			7	< 5	7.46	115
11-Feb-02					< 1			
11-Mar-02	0.5	15.6	7.3	100	2	< 5	7.44	122
15-Apr-02	4.0	8.7	7.1	160	244	10	7.70	182
22-Apr-02	3.0	9.8	7.1	110	< 1	7	7.60	129
13-May-02	7.0	9.6	7.2	90	38	7	7.60	104
18-Jun-02	7.2	8.5	7.6	220	480	< 4	7.90	220
22-Jul-02	11.0	8.4	7.1	60	18	12	7.60	70
3-Sep-02 [1]	9.1	8.9	7.2	60	18	9	7.60	73
Maximum	11.0	15.6	7.7	220	480	19	7.90	220
Minimum	0.5	8.4	7.0	60	< 1	< 4	7.42	70
Average	5.38	10.30	7.33	104.2	59.8	7.5	7.613	119.8
St. Dev.	3.71	2.04	0.26	44.6	136.5	4.2	0.153	41.3

Date	Nitrogen Total	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrate (N)	Nitrite (N)	Diss. Inorganic Nitrogen	Phosphorus Total	Ortho-Phosphate (P) LL	N:P Ratio
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
29-Aug-01	0.40	0.122	0.063			0.185	0.078	0.006	31
17-Sep-01	0.30	0.112	0.065			0.177	0.024	0.009	20
15-Oct-01	0.40	0.049	0.076	0.074	< 0.002	0.125	0.024	0.008	
12-Nov-01	0.34	0.062	0.162	0.160	< 0.002	0.224	0.023	0.006	
10-Dec-01	0.44	0.057	0.173	0.171	< 0.002	0.230	0.015	0.003	
8-Jan-02 [1]	0.40	0.066	0.194	0.192	0.002	0.260	0.021	0.005	
11-Feb-02									
11-Mar-02	0.34	0.063	0.161	0.159	< 0.002	0.224	0.021	0.002	112
15-Apr-02	0.81	0.150	0.278	0.274	0.004	0.428	0.062	0.008	54
22-Apr-02	0.93	0.036	0.300	0.296	0.004	0.336	0.044	0.002	168
13-May-02	1.09	0.142	0.603	0.593	0.010	0.745	0.028	< 0.001	745
18-Jun-02	0.44	0.043	0.207	0.198	0.009	0.250	0.017	0.003	83
22-Jul-02	0.24	0.013	0.062	0.055	0.007	0.075	0.032	< 0.001	75
3-Sep-02 [1]	0.20	0.028	0.066	0.063	0.003	0.094	0.028	0.004	30
Maximum	1.09	0.150	0.603	0.593	0.010	0.745	0.078	0.009	745
Minimum	0.20	0.013	0.062	0.055	< 0.002	0.075	0.015	< 0.001	20
Average	0.487	0.0725	0.1854	0.2032	0.0043	0.2580	0.0321	0.0044	146.3
St. Dev.	0.275	0.0444	0.1497	0.1513	0.0030	0.1744	0.0186	0.0028	229.3

[1] Mean of triplicate sequential samples

Appendix 1 Table 11 Water analysis data Site 6 Toboggan Cr 100m downstream hatchery (E245367) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
29-Aug-01	10.5	10.3	7.5	40	3	< 5	7.43	50
17-Sep-01	8.3	10.6	7.7	60	6	< 5	7.53	67
15-Oct-01	4.0	11.0	7.9	70	2	8	7.51	87
12-Nov-01	3.0	11.7			47	6	7.82	97
10-Dec-01	1.0	13.0	8.0	90	1	< 5	7.76	18
8-Jan-02	1.0	12.5			3	< 5	7.55	137
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.5	16.4	7.6	110	4	< 5	7.63	128
15-Apr-02	1.0	11.0	7.3	110	456	27	7.50	129
22-Apr-02	3.5	10.7	7.3	70	< 1	16	7.50	82
Replicate 2						19	7.40	82
Replicate 3						20	7.40	82
13-May-02	6.8	11.4	7.6	70	193	12	7.90	90
18-Jun-02	7.2	10.5	7.5	50	24	59	7.60	56
22-Jul-02	11.0	9.2	7.5	40	18	23	7.50	45
3-Sep-02	8.9	10.4	7.4	40	12	7	7.50	50

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen [1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
29-Aug-01	0.1	0.008	0.037			0.045	0.010	< 0.001	45
17-Sep-01	0.11	0.006	0.044			0.050	0.007	< 0.001	50
15-Oct-01	0.22	0.009	0.063	0.061	< 0.002	0.072	0.013	0.004	
12-Nov-01	0.32	0.031	0.163	0.161	< 0.002	0.194	0.017	0.003	
10-Dec-01	0.39	0.038	0.178	0.176	< 0.002	0.216	0.010	0.002	
8-Jan-02	0.38	0.041	0.196	0.194	0.002	0.237	0.012	0.002	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.31	0.050	0.170	0.168	< 0.002	0.220	0.015	0.001	220
15-Apr-02	1.45	0.216	0.205	0.197	0.008	0.421	0.095	0.024	18
22-Apr-02	0.84	0.006	0.177	0.172	0.005	0.183	0.049	< 0.001	183
Replicate 2	0.84	0.005	0.174	0.17	0.004	0.179	0.049	0.001	179
Replicate 3	0.84	0.008	0.174	0.169	0.005	0.182	0.057	0.001	182
13-May-02	1.04	0.008	0.660	0.646	0.014	0.668	0.019	< 0.001	668
18-Jun-02	0.19	0.005	0.078	0.07	0.008	0.083	0.033	0.002	42
22-Jul-02	0.13	0.005	0.030	0.026	0.004	0.035	0.014	< 0.001	35
3-Sep-02	0.10	< 0.005	0.036	0.033	0.003	0.041	0.015	0.003	14

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only.

Appendix 1 Table 12 Water analysis summary statistics Site 6 Toboggan Cr 100m downstream hatchery (E245367) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conductance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
29-Aug-01	10.5	10.3	7.5	40	3	< 5	7.43	50
17-Sep-01	8.3	10.6	7.7	60	6	< 5	7.53	67
15-Oct-01	4.0	11.0	7.9	70	2	8	7.51	87
12-Nov-01	3.0	11.7			47	6	7.82	97
10-Dec-01	1.0	13.0	8.0	90	1	< 5	7.76	18
8-Jan-02	1.0	12.5			3	< 5	7.55	137
11-Feb-02					< 1			
11-Mar-02	0.5	16.4	7.6	110	4	< 5	7.63	128
15-Apr-02	1.0	11.0	7.3	110	456	27	7.50	129
22-Apr-02 [1]	3.5	10.7	7.3	70	< 1	18	7.43	82
13-May-02	6.8	11.4	7.6	70	193	12	7.90	90
18-Jun-02	7.2	10.5	7.5	50	24	59	7.60	56
22-Jul-02	11.0	9.2	7.5	40	18	23	7.50	45
3-Sep-02	8.9	10.4	7.4	40	12	7	7.50	50
Maximum	11.0	16.4	8.0	110	456	59	7.90	137
Minimum	0.5	9.2	7.3	40	< 1	< 5	7.43	18
Average	5.13	11.44	7.57	68.2	55.1	14.3	7.589	79.7
St. Dev.	3.83	1.78	0.22	26.0	125.9	15.4	0.149	36.5

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
29-Aug-01	0.10	0.008	0.037			0.045	0.010	< 0.001	45
17-Sep-01	0.11	0.006	0.044			0.050	0.007	< 0.001	50
15-Oct-01	0.22	0.009	0.063	0.061	< 0.002	0.072	0.013	0.004	
12-Nov-01	0.32	0.031	0.163	0.161	< 0.002	0.194	0.017	0.003	
10-Dec-01	0.39	0.038	0.178	0.176	< 0.002	0.216	0.010	0.002	
8-Jan-02	0.38	0.041	0.196	0.194	0.002	0.237	0.012	0.002	
11-Feb-02									
11-Mar-02	0.31	0.050	0.170	0.168	< 0.002	0.220	0.015	0.001	220
15-Apr-02	1.45	0.216	0.205	0.197	0.008	0.421	0.095	0.024	18
22-Apr-02 [1]	0.84	0.006	0.175	0.170	0.005	0.181	0.052	0.001	181
13-May-02	1.04	0.008	0.660	0.646	0.014	0.668	0.019	< 0.001	668
18-Jun-02	0.19	0.005	0.078	0.070	0.008	0.083	0.033	0.002	42
22-Jul-02	0.13	0.005	0.030	0.026	0.004	0.035	0.014	< 0.001	35
3-Sep-02	0.10	< 0.005	0.036	0.033	0.003	0.041	0.015	0.003	14
Maximum	1.45	0.216	0.660	0.646	0.014	0.668	0.095	0.024	668
Minimum	0.10	< 0.005	0.030	0.026	< 0.002	0.035	0.007	< 0.001	14
Average	0.429	0.0329	0.1565	0.1729	0.0047	0.1895	0.0240	0.0035	141.3
St. Dev.	0.421	0.0574	0.1660	0.1701	0.0038	0.1821	0.0244	0.0062	210.9

[1] Mean of triplicate sequential samples

Appendix 1 Table 13 Water analysis data Site 7 Owens Cr (E245368) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conductance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
29-Aug-01	8.0	10.7	7.9	130	17	< 5	7.45	149
17-Sep-01	6.2	11.5	8.1	140	15	< 5	7.76	156
15-Oct-01	2.9	12.2	8.2	120	2	14	7.80	145
Replicate 2						< 5	7.80	147
Replicate 3						8	7.82	146
12-Nov-01	2.0	12.6	8.0	120	9	< 5	7.97	154
10-Dec-01	0.75	13.5	7.9	120	< 1	< 5	7.99	148
8-Jan-02	1.0	12.9			< 1	< 5	7.44	99
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	1.0	16.4	8.0	130	< 1	< 5	7.83	160
15-Apr-02	0.5	12.9	8.0	90	8	9	7.70	109
22-Apr-02	1.0	13.2	8.0	90	< 1	6	7.70	107
13-May-02	2.5	13.2	7.9	70	2	14	7.70	86
18-Jun-02	4.5	11.7	7.9	50	7	147	7.70	68
Replicate 2						180	7.70	68
Replicate 3						155	7.70	68
22-Jul-02	9.8	9.6	8.0	90	14	4	7.80	104
3-Sep-02	8.6	10.6	8.0	110	31	< 4	7.90	138

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen [1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
29-Aug-01	0.08	< 0.005	0.049			0.054	0.006	< 0.001	54
17-Sep-01	0.11	< 0.005	0.061			0.066	0.003	< 0.001	66
15-Oct-01	0.18	< 0.005	0.030	0.028	< 0.002	0.035	0.013	< 0.001	
Replicate 2	0.23	< 0.005	0.032	0.030	< 0.002	0.037	0.005	< 0.001	
Replicate 3	0.15	< 0.005	0.031	0.029	< 0.002	0.036	0.010	< 0.001	
12-Nov-01	0.22	0.009	0.188	0.186	< 0.002	0.197	0.003	< 0.001	
10-Dec-01	0.29	0.007	0.162	0.160	< 0.002	0.169	0.003	< 0.001	
8-Jan-02	0.27	0.006	0.202	0.200	< 0.002	0.208	0.003	< 0.001	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.19	0.007	0.172	0.170	< 0.002	0.179	< 0.002	0.001	179
15-Apr-02	1.20	0.005	0.774	0.771	0.003	0.779	0.016	< 0.001	779
22-Apr-02	0.81	< 0.005	0.514	0.511	0.003	0.519	0.011	0.002	260
13-May-02	0.70	< 0.005	0.394	0.384	0.010	0.399	0.016	< 0.001	399
18-Jun-02	0.20	< 0.005	0.016	0.013	0.003	0.021	0.078	< 0.001	21
Replicate 2	0.17	< 0.005	0.020	0.012	0.008	0.025	0.030	< 0.001	25
Replicate 3	0.12	0.005	0.033	0.024	0.009	0.038	0.021	< 0.001	38
22-Jul-02	0.08	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
3-Sep-02	0.08	< 0.005	0.017	0.015	0.002	0.022	0.005	0.003	7

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 14 Water analysis summary statistics Site 7 Owens Cr (E245368) 2001-2002

Date	Temp. water (°C)	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conductance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
29-Aug-01	8.0	10.7	7.9	130	17	< 5	7.45	149
17-Sep-01	6.2	11.5	8.1	140	15	< 5	7.76	156
15-Oct-01 [1]	2.9	12.2	8.2	120	2	9	7.81	146
12-Nov-01	2.0	12.6	8.0	120	9	< 5	7.97	154
10-Dec-01	0.75	13.5	7.9	120	< 1	< 5	7.99	148
8-Jan-02	1.0	12.9			< 1	< 5	7.44	99
11-Feb-02					< 1			
11-Mar-02	1.0	16.4	8.0	130	< 1	< 5	7.83	160
15-Apr-02	0.5	12.9	8.0	90	8	9	7.70	109
22-Apr-02	1.0	13.2	8.0	90	< 1	6	7.70	107
13-May-02	2.5	13.2	7.9	70	2	14	7.70	86
18-Jun-02 [1]	4.5	11.7	7.9	50	7	161	7.70	68
22-Jul-02	9.8	9.6	8.0	90	14	4	7.80	104
3-Sep-02	8.6	10.6	8.0	110	31	< 4	7.90	138
Maximum	9.8	16.4	8.2	140	31	161	7.99	160
Minimum	0.5	9.6	7.9	50	< 1	< 4	7.44	68
Average	3.75	12.38	7.99	105.0	7.9	18.2	7.750	124.9
St. Dev.	3.32	1.69	0.09	27.1	8.8	42.9	0.168	30.6

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
29-Aug-01	0.08	< 0.005	0.049			0.054	0.006	< 0.001	54
17-Sep-01	0.11	< 0.005	0.061			0.066	0.003	< 0.001	66
15-Oct-01 [1]	0.19	< 0.005	0.031	0.029	< 0.002	0.036	0.009	< 0.001	
12-Nov-01	0.22	0.009	0.188	0.186	< 0.002	0.197	0.003	< 0.001	
10-Dec-01	0.29	0.007	0.162	0.160	< 0.002	0.169	0.003	< 0.001	
8-Jan-02	0.27	0.006	0.202	0.200	< 0.002	0.208	0.003	< 0.001	
11-Feb-02									
11-Mar-02	0.19	0.007	0.172	0.170	< 0.002	0.179	< 0.002	0.001	179
15-Apr-02	1.20	0.005	0.774	0.771	0.003	0.779	0.016	< 0.001	779
22-Apr-02	0.81	< 0.005	0.514	0.511	0.003	0.519	0.011	0.002	260
13-May-02	0.70	< 0.005	0.394	0.384	0.010	0.399	0.016	< 0.001	399
18-Jun-02 [1]	0.16	< 0.005	0.023	0.016	0.007	0.028	0.043	< 0.001	28
22-Jul-02	0.08	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
3-Sep-02	0.08	< 0.005	0.017	0.015	0.002	0.022	0.005	0.003	7
Maximum	1.20	0.009	0.774	0.771	0.010	0.779	0.043	0.003	779
Minimum	0.08	< 0.005	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.001	7
Average	0.337	0.0057	0.1992	0.2222	0.0033	0.2048	0.0094	0.0012	197.6
St. Dev.	0.347	0.0013	0.2314	0.2430	0.0026	0.2314	0.0113	0.0006	255.4

[1] Mean of triplicate sequential samples

Appendix 1 Table 15 Water analysis data Site 8 Toboggan Cr upstream Highway 16 (E245370) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
29-Aug-01	9.5	10.6	8.0	50	14	7	6.85	60
17-Sep-01	8.0	11.5	8.0	70	14	< 5	7.58	80
15-Oct-01	3.9	12.6	8.4	80	12	< 5	7.78	104
12-Nov-01	2.5	13.0	8.3	90	59	11	7.93	124
10-Dec-01	0.3	14.1	7.9	100	10	< 5	7.96	127
8-Jan-02	0.3	13.5			27	9	7.61	113
11-Feb-02	N/A equipment malfunction				< 1	Shipment lost in transit		
11-Mar-02	0.25	17.8	8.3	130	2	< 5	7.91	153
Replicate 2						< 5	7.90	154
Replicate 3						< 5	7.92	153
15-Apr-02	0.3	13.2	8.0	90	168	89	7.70	119
22-Apr-02	0.8	13.1	7.6	40	< 1	57	7.50	67
13-May-02	6.0	11.9	7.7	70	139	26	7.80	93
18-Jun-02	6.8	11.0	7.7	50	43	97	7.60	59
22-Jul-02	10.8	9.7	7.8	50	30	24	7.60	57
3-Sep-02	10.0	10.6	7.9	50	26	7	7.50	62

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen [1] (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio[2]
29-Aug-01	0.10	0.005	0.044			0.049	0.010	< 0.001	49
17-Sep-01	0.11	< 0.005	0.053			0.058	0.005	< 0.001	58
15-Oct-01	0.22	< 0.005	0.069	0.067	< 0.002	0.074	0.004	< 0.001	
12-Nov-01	0.58	0.020	0.200	0.198	< 0.002	0.22	0.035	0.003	
10-Dec-01	0.40	0.027	0.214	0.212	< 0.002	0.241	0.008	0.002	
8-Jan-02	0.46	0.032	0.253	0.251	0.002	0.285	0.019	0.002	
11-Feb-02	Shipment lost in transit								
11-Mar-02	0.35	0.009	0.240	0.238	< 0.002	0.249	0.008	0.001	249
Replicate 2	0.35	0.016	0.242	0.240	< 0.002	0.258	0.007	0.001	258
Replicate 3	0.35	0.016	0.240	0.238	< 0.002	0.256	0.007	0.002	128
15-Apr-02	1.76	0.198	0.357	0.348	0.009	0.555	0.152	0.031	18
22-Apr-02	0.85	< 0.005	0.152	0.146	0.006	0.157	0.066	< 0.001	157
13-May-02	1.01	0.007	0.591	0.583	0.008	0.598	0.036	0.003	199
18-Jun-02	0.27	< 0.005	0.068	0.059	0.009	0.073	0.089	0.002	37
22-Jul-02	0.17	< 0.005	0.037	0.032	0.005	0.042	0.025	< 0.001	42
3-Sep-02	0.11	< 0.005	0.039	0.036	0.003	0.044	0.016	0.002	22

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 16 Water analysis summary statistics Site 8 Toboggan Cr upstream Highway 16 (E245370) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
29-Aug-01	9.5	10.6	8.0	50	14	7	6.85	60
17-Sep-01	8.0	11.5	8.0	70	14	< 5	7.58	80
15-Oct-01	3.9	12.6	8.4	80	12	< 5	7.78	104
12-Nov-01	2.5	13.0	8.3	90	59	11	7.93	124
10-Dec-01	0.3	14.1	7.9	100	10	< 5	7.96	127
8-Jan-02	0.3	13.5			27	9	7.61	113
11-Feb-02					< 1			
11-Mar-02 [1]	0.25	17.8	8.3	130	2	< 5	7.91	153
15-Apr-02	0.3	13.2	8.0	90	168	89	7.70	119
22-Apr-02	0.8	13.1	7.6	40	< 1	57	7.50	67
13-May-02	6.0	11.9	7.7	70	139	26	7.80	93
18-Jun-02	6.8	11.0	7.7	50	43	97	7.60	59
22-Jul-02	10.8	9.7	7.8	50	30	24	7.60	57
3-Sep-02	10.0	10.6	7.9	50	26	7	7.50	62
Maximum	10.8	17.8	8.4	130	168	97	7.96	153
Minimum	0.3	9.7	7.6	40	< 1	< 5	6.85	57
Average	4.57	12.51	7.97	72.5	39.0	26.7	7.640	93.7
St. Dev.	4.13	2.07	0.26	26.7	51.5	32.9	0.286	32.0

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Diss. Inorganic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)	N:P Ratio
29-Aug-01	0.10	0.005	0.044			0.049	0.010	< 0.001	49
17-Sep-01	0.11	< 0.005	0.053			0.058	0.005	< 0.001	58
15-Oct-01	0.22	< 0.005	0.069	0.067	< 0.002	0.074	0.004	< 0.001	
12-Nov-01	0.58	0.020	0.200	0.198	< 0.002	0.220	0.035	0.003	
10-Dec-01	0.40	0.027	0.214	0.212	< 0.002	0.241	0.008	0.002	
8-Jan-02	0.46	0.032	0.253	0.251	0.002	0.285	0.019	0.002	
11-Feb-02									
11-Mar-02 [1]	0.35	0.014	0.241	0.239	< 0.002	0.254	0.007	0.001	212
15-Apr-02	1.76	0.198	0.357	0.348	0.009	0.555	0.152	0.031	18
22-Apr-02	0.85	< 0.005	0.152	0.146	0.006	0.157	0.066	< 0.001	157
13-May-02	1.01	0.007	0.591	0.583	0.008	0.598	0.036	0.003	199
18-Jun-02	0.27	< 0.005	0.068	0.059	0.009	0.073	0.089	0.002	37
22-Jul-02	0.17	< 0.005	0.037	0.032	0.005	0.042	0.025	< 0.001	42
3-Sep-02	0.11	< 0.005	0.039	0.036	0.003	0.044	0.016	0.002	22
Maximum	1.76	0.198	0.591	0.583	0.009	0.598	0.152	0.031	212
Minimum	0.10	< 0.005	0.037	0.032	< 0.002	0.042	0.004	< 0.001	18
Average	0.492	0.0256	0.1783	0.1973	0.0045	0.2039	0.0363	0.0039	88.2
St. Dev.	0.476	0.0526	0.1611	0.1638	0.0030	0.1877	0.0431	0.0082	78.2

[1] Mean of triplicate sequential samples

Appendix 1 Table 17 Water analysis data Glacier Gulch Cr (E245443) August 2001

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)		Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
30-Aug-01	7.5	11.4	6.5	10	1		211	6.20	19

Date	Nitrogen Total (mg/L)		Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorganic Nitrogen [1] (mg/L)	Phosphorus Total (mg/L)		Ortho-Phosphate (P) LL (mg/L)	N:P Ratio [2]
30-Aug-01	0.06	<	0.005	0.032	0.037	0.167	<	0.001	37

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 18 Water analysis data Toboggan Cr at CNR d/s Toboggan Lake (E245363) 2001-2002

Date	Temp. water °C	Diss. Oxygen (mg/L)	Field pH (pH units)	Field Sp. Conduct-ance (uS/cm)	Fecal coliform (CFU/100ml)		Residue Non-filterable (mg/L)	pH (pH units)	Specific Conduct-ance (uS/cm)
30-Aug-01	10.0	10.8	7.4	50	13	<	5	6.91	60

Date	Nitrogen Total (mg/L)		Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorganic Nitrogen[1] (mg/L)	Phosphorus Total (mg/L)		Ortho-Phosphate (P) LL (mg/L)	N:P Ratio [2]
30-Aug-01	0.08	<	0.005	0.027	0.032	0.006	<	0.001	32

[1] Dissolved Inorganic Nitrogen = Ammonia (N) + Nitrate (N) + Nitrite (N)

[2] Calculated according to Nordin (1985) N:P Ratio = Dissolved Inorganic Nitrogen (N) : Ortho-phosphate (P) for growing season only

Appendix 1 Table 19 Data quality assessment: analysis of triplicate sequential samples

	Residue Non-filterable	pH	Specific Conduct-ance	Nitrogen Total	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrite (N)	Phosphorus Total	Ortho-Phosphate (P) LL
Site 3	5	7.71	143	0.08	0.005	0.048		0.002	0.001
Elliot Cr	5	7.97	145	0.06	0.005	0.047		0.002	0.001
30-Aug-01	5	8.02	145	0.09	0.005	0.048		0.002	0.001
Mean	5	7.90	144.3	0.0767	0.005	0.0477		0.002	0.001
St. Dev.	0	0.166	1.2	0.0153	0	0.0006		0	0
Relative St. Dev.	0%	2%	1%	20%	0%	1%		0%	0%
Site 1 Upper	5	7.54	41	0.11	0.005	0.092		0.002	0.001
Toboggan (T) Cr	5	7.34	41	0.11	0.005	0.092		0.002	0.001
17-Sep-01	5	7.30	42	0.10	0.005	0.090		0.002	0.001
Mean	5	7.393	41.3	0.107	0.005	0.0913		0.002	0.001
St. Dev.	0	0.129	0.6	0.006	0	0.0012		0	0
Relative St. Dev.	0%	2%	1%	5%	0%	1%		0%	0%
Site 7	14	7.80	145	0.18	0.005	0.030	0.002	0.013	0.001
Owens Cr	5	7.80	147	0.23	0.005	0.032	0.002	0.005	0.001
15-Oct-01	8	7.82	146	0.15	0.005	0.031	0.002	0.010	0.001
Mean	9.0	7.807	146.0	0.187	0.005	0.0310	0.002	0.0093	0.001
St. Dev.	4.6	0.012	1.0	0.040	0	0.0010	0	0.0040	0
Relative St. Dev.	51%	0%	1%	22%	0%	3%	0%	43%	0%
Site 2 T Cr	5	7.63	69	0.27	0.015	0.179	0.002	0.011	0.001
d/s T Lake	5	7.59	69	0.27	0.018	0.183	0.002	0.011	0.001
12-Nov-01	7	7.58	69	0.26	0.017	0.176	0.002	0.010	0.001
Mean	5.7	7.60	69	0.267	0.0167	0.1793	0.002	0.0107	0.001
St. Dev.	1.2	0.026	0	0.006	0.0015	0.0035	0	0.0006	0
Relative St. Dev.	20%	0%	0%	2%	9%	2%	0%	5%	0%
Site 4 T Cr	5	7.93	108	0.52	0.073	0.171	0.002	0.014	0.001
u/s hatchery	5	7.69	96	0.37	0.043	0.172	0.002	0.013	0.001
10-Dec-01	5	7.71	96	0.45	0.043	0.171	0.002	0.010	0.001
Mean	5	7.777	100.0	0.447	0.0530	0.1713	0.002	0.0123	0.001
St. Dev.	0	0.133	6.9	0.075	0.0173	0.0006	0	0.0021	0
Relative St. Dev.	0%	2%	7%	17%	33%	0%	0%	17%	0%
Site 5	5	7.46	116	0.40	0.062	0.193	0.002	0.020	0.005
Hatchery outflow	5	7.45	115	0.39	0.068	0.195	0.002	0.021	0.005
8-Jan-02	5	7.48	115	0.42	0.068	0.195	0.002	0.021	0.005
Mean	5	7.463	115.3	0.403	0.0660	0.1943	0.002	0.0207	0.005
St. Dev.	0	0.015	0.6	0.015	0.0035	0.0012	0	0.0006	0
Relative St. Dev.	0%	0%	1%	4%	5%	1%	0%	3%	0%
Site 8 T Cr	5	7.91	153	0.35	0.009	0.240	0.002	0.008	0.001
u/s Hwy 16	5	7.90	154	0.35	0.016	0.242	0.002	0.007	0.001
11-Mar-02	5	7.92	153	0.35	0.016	0.240	0.002	0.007	0.002
Mean	5	7.910	153.3	0.35	0.0137	0.2407	0.002	0.0073	0.0013
St. Dev.	0	0.010	0.6	0	0.0040	0.0012	0	0.0006	0.0006
Relative St. Dev.	0%	0%	0%	0%	30%	0%	0%	8%	43%
Site 3	4	7.90	141	0.14	0.005	0.111	0.002	0.004	0.004
Elliot Cr	4	7.90	143	0.15	0.005	0.111	0.002	0.002	0.003
15-Apr-02	4	7.80	142	0.14	0.005	0.111	0.002	0.002	0.002
Mean	4	7.867	142.0	0.143	0.005	0.111	0.002	0.0027	0.0030
St. Dev.	0	0.058	1.0	0.006	0	0	0	0.0012	0.0010
Relative St. Dev.	0%	1%	1%	4%	0%	0%	0%	43%	33%

Appendix 1 Table 19 (continued) Data quality assessment: analysis of triplicate sequential samples

	Residue Non-filterable	pH	Specific Conduct-ance	Nitrogen Total	Ammonia (N)	Nitrite + Nitrate (N) LL	Nitrite (N)	Phosphorus Total	Ortho-Phosphate (P) LL
Site 6 T Cr 100m	16	7.50	82	0.84	0.006	0.177	0.005	0.049	0.001
d/s hatchery	19	7.40	82	0.84	0.005	0.174	0.004	0.049	0.001
22-Apr-02	20	7.40	82	0.84	0.008	0.174	0.005	0.057	0.001
Mean	18.3	7.433	82	0.84	0.0063	0.1750	0.0047	0.0517	0.001
St. Dev.	2.1	0.058	0	0	0.0015	0.0017	0.0006	0.0046	0
Relative St. Dev.	11%	1%	0%	0%	24%	1%	12%	9%	0%
Site 1 Upper	23	7.60	74	1.45	0.015	1.180	0.010	0.015	0.004
T Cr	22	7.10	73	1.53	0.005	1.180	0.008	0.010	0.003
13-May-02	20	7.00	73	1.49	0.005	1.180	0.011	0.015	0.003
Mean	21.7	7.233	73.3	1.490	0.0083	1.180	0.0097	0.0133	0.0033
St. Dev.	1.5	0.321	0.6	0.040	0.0058	0	0.0015	0.0029	0.0006
Relative St. Dev.	7%	4%	1%	3%	69%	0%	16%	22%	17%
Site 7	147	7.70	68	0.20	0.005	0.016	0.003	0.078	0.001
Owens Cr	180	7.70	68	0.17	0.005	0.020	0.008	0.030	0.001
18-Jun-02	155	7.70	68	0.12	0.005	0.033	0.009	0.021	0.001
Mean	160.7	7.70	68	0.163	0.005	0.0230	0.0067	0.0430	0.001
St. Dev.	17.2	0	0	0.040	0	0.0089	0.0032	0.0306	0
Relative St. Dev.	11%	0%	0%	25%	0%	39%	48%	71%	0%
Site 2 T Cr	16	7.20	32	0.18	0.005	0.026	0.004	0.027	0.002
d/s T Lake	14	7.20	32	0.06	0.005	0.039	0.005	0.025	0.004
22-Jul-02	16	7.20	31	0.06	0.005	0.030	0.005	0.020	0.003
Mean	15.3	7.2	31.7	0.100	0.005	0.0317	0.0047	0.0240	0.0030
St. Dev.	1.2	0	0.6	0.069	0	0.0067	0.0006	0.0036	0.0010
Relative St. Dev.	8%	0%	2%	69%	0%	21%	12%	15%	33%
Site 5	9	7.60	73	0.20	0.028	0.068	0.003	0.028	0.005
Hatchery outflow	10	7.60	73	0.21	0.029	0.066	0.003	0.029	0.004
3-Sep-02	8	7.60	73	0.20	0.027	0.065	0.003	0.028	0.002
Mean	9.0	7.60	73	0.203	0.0280	0.0663	0.003	0.0283	0.0037
St. Dev.	1.0	0	0	0.006	0.0010	0.0015	0	0.0006	0.0015
Relative St. Dev.	11%	0%	0%	3%	4%	2%	0%	2%	42%

Appendix 1 Table 20 Drinking water quality data Site 8 Toboggan Cr upstream Highway 16 (E245370) 2001-2002

Date	Fecal coliform (CFU/100ml)	*E. coli* (CFU/100ml)	Enterococci (CFU/100ml)	pH (pH units)	Specific Conductance (uS/cm)	Color True (Col.unit)	Turbidity (NTU)	Nitrite + Nitrate (N) Diss. (mg/L)	Nitrate (N) Diss. (mg/L)	Nitrite (N) Diss. (mg/L)
04-Oct-01				7.41	90	8	1.15	0.048	0.046	< 0.002
10-Oct-01	19	18	12	7.69	100	< 13	0.10	0.048	0.046	< 0.002
15-Oct-01	12	8	< 1	7.66	103	11	1.23	0.067	0.065	< 0.002
22-Oct-01	37	37	< 1	7.55	91	11	1.58	0.082	0.08	< 0.002
Replicate sample [1]				7.78	105	11	1.51	0.081	0.079	< 0.002
29-Oct-01	17	8	< 1	7.94	112	< 16	1.90	0.096	0.094	< 0.002
Maximum	*37*	*37*	*12*	*7.94*	*112*	*16*	*1.90*	*0.096*	*0.094*	*< 0.002*
90th percentile	*31.6*	*31.3*	*8.7*							
Average				*7.673*	*100.6*	*11.8*	*1.185*	*0.0681*	*0.0661*	*< 0.002*
8-Aug-02	8	3			68	< 5	9.66	0.047	0.043	0.004
12-Aug-02	25	21	9			< 5	11.5			
19-Aug-02	33	22	11			< 5	11.8			
27-Aug-02	100	78	93			5	13.3			
3-Sep-02	53	34	26			10	14.4			
Maximum	*100*	*78*	*93*		*68*	*10*	*14.40*	*0.047*	*0.043*	*< 0.004*
90th percentile	*81.2*	*60.4*	*72.9*							
Average						*6.0*	*12.132*			
7-Oct-02	37	15	14	7.6	66	5	5.95	0.081	0.078	0.003
15-Oct-02	14	8	13			10	1.44			
21-Oct-02	4	4	1			10	1.38			
28-Oct-02	17	12	4			10	1.30			
3-Nov-02	12	5	2			10	1.43			
Maximum	*37*	*15*	*14*	*7.6*	*66*	*10*	*5.95*	*0.081*	*0.078*	*< 0.003*
90th percentile	*29*	*13.8*	*13.6*							
Average						*9.0*	*2.30*			

[1] Average of replicate sequential samples used in calculation of summary statistics

Appendix 1 Table 21 Total metals data Toboggan Creek upstream Highway 16 (E245370) 2001-2002

mg/L

Date	Hardness	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Calcium
4-Oct-01	34.96	0.0477	0.000077	0.0006	0.00979	0.000004	< 0.00002	0.004	< 0.00001	10.7
10-Oct-01	43.44	0.17	< 0.06	< 0.06	0.012	< 0.001		< 0.01	< 0.006	14.1
15-Oct-01	47.84	0.036	0.000087	0.0003	0.01113	0.000004	< 0.00002	0.005	0.00001	15.4
22-Oct-01	48.26	0.06	< 0.06	< 0.06	0.011	< 0.001		< 0.01	< 0.006	15.7
22-Oct-01	49.01	0.06	< 0.06	< 0.06	0.012	< 0.001		< 0.01	< 0.006	16
29-Oct-01	45.10	0.08	< 0.06	< 0.06	0.01	< 0.001		< 0.01	< 0.006	14.6
8-Aug-02	31.20	0.29	0.000078	0.0008	0.0126	< 0.00002	0.00003		0.00003	9.97
7-Oct-02	30.50	0.172	0.000088	0.0007	0.0109	< 0.00002	< 0.00002		0.00002	9.92

Date	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Molybdenum	Nickel
4-Oct-01	0.009	0.000071	0.00159	0.221	0.00004	0.00013	2.00213	0.019855	0.01143	0.0007
10-Oct-01	< 0.006	< 0.006	< 0.006	0.462	< 0.06		2	0.034	< 0.01	< 0.02
15-Oct-01	0.0002	0.000047	0.00127	0.258	0.00003	0.00023	2.27866	0.02567	0.00545	0.00066
22-Oct-01	< 0.006	< 0.006	< 0.006	0.255	< 0.06		2.2	0.027	< 0.01	< 0.02
22-Oct-01	< 0.006	< 0.006	< 0.006	0.256	< 0.06		2.2	0.026	< 0.01	< 0.02
29-Oct-01	< 0.006	< 0.006	< 0.006	0.278	< 0.06		2.1	0.025	< 0.01	< 0.02
8-Aug-02	< 0.0002	0.000122	0.0044		0.00022	0.00046	1.52	0.0283	0.0104	< 0.00005
7-Oct-02	< 0.0002	< 0.000005	0.00294	0.596	0.00014	< 0.000005	1.4	0.0274	0.0104	< 0.00005

Date	Phosphorus	Potassium	Selenium	Silicon	Silver	Sodium	Strontium	Sulphur	Thallium	Tin
4-Oct-01	< 0.1	0.3	0.0003	2.6	< 0.00002	1.4	0.044135	3.5	0.000005	< 0.00001
10-Oct-01	< 0.1	0.5	< 0.06	3.1	< 0.01	1.8	0.042	3.82		< 0.06
15-Oct-01	< 0.1	0.3	< 0.0002	2.94	< 0.00002	1.8	0.061654	3.85	< 0.000002	< 0.00001
22-Oct-01	< 0.1	0.4	< 0.06	3.22	< 0.01	1.8	0.045	3.69		< 0.06
22-Oct-01	< 0.1	0.4	< 0.06	3.25	< 0.01	1.9	0.046	3.66		< 0.06
29-Oct-01	< 0.1	0.4	< 0.06	2.89	< 0.01	2	0.044	3.33		< 0.06
8-Aug-02	0.008		< 0.0002		< 0.00002		0.0307		0.00001	0.00001
7-Oct-02	0.013		< 0.0002		< 0.00002		0.0374		< 0.000002	0.00004

Date	Titanium	Uranium	Vanadium	Zinc
4-Oct-01	0.002	0.000012	0.0025	0.0003
10-Oct-01	0.004		< 0.01	< 0.002
15-Oct-01	< 0.002	0.000024	0.00064	0.0001
22-Oct-01	0.002		< 0.01	< 0.002
22-Oct-01	0.002		< 0.01	< 0.002
29-Oct-01	< 0.002		< 0.01	< 0.002
8-Aug-02		< 0.000002	0.00091	0.0016
7-Oct-02		0.000016	0.00079	0.0016

Appendix 2 Table 1 Periphyton biomass as chlorophyll *a* (mg/m^2) on natural substrates in Toboggan Creek 1996, 1997, 2001 and 2002

1	Reiseter Cr at Telkwa High Road (control) 11-Sep-96	Toboggan Cr upstream fish hatchery 10-Sep-96	Toboggan Cr at DFO assessment fence 11-Sep-96
Rep 1	1.9	14.5	11.9
Rep 2	2.2	5.8	70.1
Rep 3	3.1	7.1	108.0
Rep 4	1.7	2.8	12.6
Rep 5	2.3	11.7	56.5
Rep 6	1.6	26.4	18.5

2	Reiseter Cr at Telkwa High Road (control) 17-Sep-97	Toboggan Cr upstream fish hatchery 18-Sep-97	Toboggan Cr at DFO assessment fence 22-Sep-97
Rep 1	23.3	4.1	72.8
Rep 2	22.6	142.0	34.8
Rep 3	9.5	18.8	88.4
Rep 4	9.7	13.9	49.3
Rep 5	7.4	10.9	126.0
Rep 6	9.5	12.1	lost sample

	Site 1 Upper Toboggan Cr (E245607) 12-Sep-01	Site 4 Toboggan Cr upstream fish hatchery (E245365) 12-Sep-01	Site 6 Toboggan Cr 100 m downstream hatchery (E245367) 13-Sep-01	Site 8P Toboggan Cr 500 m upstream Highway 16 (E245369) 13-Sep-01
Rep 1	0.3	1.3	1.6	3.0
Rep 2	0.3	0.7	5.0	38.3
Rep 3	3.3	0.5	13.8	16.3
Rep 4	1.2	5.1	10.9	10.7
Rep 5	1.9	2.4	6.7	11.5
Rep 6	0.6	29.7	11.0	28.4

	Site 1 Upper Toboggan Cr (E245607) 03-Sep-02	Site 4 Toboggan Cr upstream fish hatchery (E245365) 02-Sep-02	Site 6 Toboggan Cr 100 m downstream hatchery (E245367) 03-Sep-02	Site 8P Toboggan Cr 500 m upstream Highway 16 (E245369) 03-Sep-02
Rep 1	<5	7	<5	<5
Rep 2	<5	6	<5	<5
Rep 3	<5	11	<5	<5
Rep 4	<5	8	<5	7
Rep 5	<5	6	<5	<5
Rep 6	<5	<5	<5	7

[1] Source: Remington, D. 1997. *Survey of water quality and periphyton (algal) standing crop in the Bulkley River and tributaries 1996* Prepared for DFO North Coast Division, Smithers B.C.

[2] Source: Remington, D. 1998. *Water quality and accumulation of periphyton (attached algae) in the Bulkley River and tributaries 1997*. Prepared for DFO North Coast Division, Smithers B.C.

Appendix 2 Table 2 Periphyton community composition (as percentage) in Toboggan Creek and Reiseter Creek 1996 & 1997

Reiseter Creek at Telkwa High Road (control)[1] 11-Sep-96	
Chrysophyta	100 %
Bacillariophyceae	
Gomphonema geminatum	30 %
Synedra ulna	10 %
Hannaea arcus	10 %
Achnanthes spp.	20 %
Gomphonema spp.	20 %
Fragilaria spp.	10 %

Reiseter Creek at Telkwa High Road (control)[2] 17-Sep-97	
Chrysophyta	100 %
Bacillariophyceae	
Synedra ulna	20 %
Gomphonema geminatum	20 %
Gomphonema sp.	20 %
Cymbella sp.	15 %
Diatoma tenue v. elongatum	10 %
Cocconeis placentula	5 %
Hannaea arcus	5 %

Comment: Algal clumps composed of *Gomphonema geminatum* on stalks.

Toboggan Creek upstream fish hatchery[1] 10-Sep-96	
Chlorophyta	0.5 %
Cladophora sp.	100 %
Chrysophyta	99.5 %
Bacillariophyceae	
Synedra ulna	20 %
Achnanthes spp.	20 %
Cymbella caespitosa	10 %
Gomphonema spp.	10 %
Surirella angustata	10 %
Fragilaria spp.	20 %
Epithemia sorex	10 %

Comment: Large amount of inorganic sediment present in sample.

Toboggan Creek upstream fish hatchery[2] 18-Sep-97	
Chrysophyta	100 %
Bacillariophyceae	
Synedra ulna	60 %
Gomphonema sp.	20 %
Cymbella sp.	10 %
Tabellaria fenestrata	10 %

Comment: Inorganic sediment present.

Toboggan Creek at DFO assessment fence[1] 11-Sep-96	
Chlorophyta	25 %
Cosmarium sp.	2 %
Spirogyra sp.	98 %
Chrysophyta	75 %
Bacillariophyceae	
Fragilaria spp.	6 %
Gomphonema geminatum	70 %
Cymbella spp.	10 %
Achnanthes spp.	7 %
Gomphonema spp.	5 %
Stauroneis phoenicentron	2 %

Comment: Algal mats composed of *Gomphonema geminatum* on stalks and *Spirogyra* sp. Large amount of inorganic sediment present.

Toboggan Creek at DFO assessment fence[2] 22-Sep-97	
Cyanophyta	5 %
Oscillatoria sp.	100 %
Chrysophyta	95 %
Bacillariophyceae	
Gomphonema geminatum	55 %
Synedra ulna	20 %
Achnanthes sp.	10 %
Cymbella sp.	15 %

Comment: Algal mat composed of *Gomphonema geminatum* on stalks; *Spirogyra* sp.; *Ulothrix* sp. and *Oscillatoria* sp.

[1] Source: Remington, D. 1997. *Survey of water quality and periphyton (algal) standing crop in the Bulkley River and tributaries 1996* Prepared for DFO North Coast Division, Smithers B.C.

[2] Source: Remington, D. 1998. *Water quality and accumulation of periphyton (attached algae) in the Bulkley River and tributaries 1997*. Prepared for DFO North Coast Division, Smithers B.C.

Appendix 2 Table 3 Periphyton community composition (as cells/m^2 and biovolume) at four sites in Toboggan Creek 2001

Division	Species		Site 1 Upper Toboggan Cr (E245607) Rep 1 12/09/01		Site 1 Upper Toboggan Cr Rep 2 12/09/01		Site 1 Upper Toboggan Cr Rep 3 12/09/01		Site 4 Toboggan Cr u/s hatchery (E245365) Rep 1 12/09/01		Site 4 Toboggan Cr u/s hatchery Rep 2 12/09/01		Site 4 Toboggan Cr u/s hatchery Rep 3 12/09/01	
			cells x $10^6/m^2$	u^3x10^9/m^2	cells x $10^6/m^2$	u^3x10^9/m^2	cells x $10^6/m^2$	u^3x10^9/m^2	cells x $10^6/m^2$	u^3x10^9/m^2	cells x $10^6/m^2$	u^3x10^9/m^2	cells x $10^6/m^2$	u^3x10^9/m^2
CYANOPHYTA														
	Lyngbya sp.	/mm	0.04	0.23				0.03	5.62	33.73	0.34	2.01	0.33	1.97
	Oscillatoria sp.	/mm							0.12	1.23	0.12	1.24	0.44	4.39
CHLOROPHYTA														
	Cladophora sp.	/mm						0.08	0.20	7.89	1.49	59.57		
	Closterium sp.													
	Cosmarium sp.													
CHRYSOPHYTA														
	Dinobryon sertularia													
CHRYSOPHYTA - DIATOMS														
	Achnanthes minutissima		29.54	2.07	24.51	1.72	8.31	0.58	228.08	15.97	433.10	30.32	176.50	12.36
	Achnanthes sp.		0.96	0.06	0.26	0.02	0.20	0.01	2.47	0.15				
	Cocconeis placentula												2.19	1.97
	Cyclotella sp.								4.93	3.45				
	Cymbella caespitosa								1.23	1.49				
	Cymbella sp.												1.10	0.66
	Cymbella ventricosa		0.55	0.27	0.52	0.26	0.40	0.19	7.40	3.62			5.48	2.69
	Diatoma hiemale										1.24	0.79		
	Diatoma tenue v. elongatum													
	Eunotia pectinalis													
	Eunotia sp.													
	Fragilaria sp.		2.06	1.03	2.62	1.31	1.04	0.52	88.77	44.38	67.01	33.51	50.43	25.21
	Gomphonema geminatum								2.47	56.71	8.69	199.80	30.70	706.02
	Gomphonema intricatum								1.23	2.47				
	Gomphonema olivaceum		10.31	4.95	18.48	8.87	5.29	2.54	28.36	13.61	18.61	8.94	76.74	36.84
	Gomphonema parvulum												4.39	2.85
	Hannaea arcus		0.14	0.26	0.13	0.25	0.10	0.19	4.93	9.37			2.19	4.17
	Melosira granulata								9.86	8.88				
	Meridion circulare		0.14	0.07					3.70	1.81				
	Navicula sp.								3.70	1.85				
	Nitzschia acicularis								2.47	0.27			1.10	0.12
	Nitzschia palea				0.26	0.29			16.03	17.63				
	Stauroneis phoenicenton													
	Stauroneis sp.													
	Synedra ulna								1.23	3.67	1.24	3.70	3.29	9.80
	Tabellaria fenestrata								2.47	3.70	2.48	3.72		
TOTAL			43.70	8.71	46.78	12.72	15.34	4.03	409.33	189.03	532.37	280.78	354.11	802.69
TOTAL mm			0.04	0.23				0.11	5.94	42.85	1.95	62.82	0.77	6.36

Appendix 2 Table 3 Periphyton community co

Division	Species		Site 6 Toboggan Cr 100m d/s hatchery (E245367) Rep 1 12/09/01		Site 6 Toboggan Cr 100m d/s hatchery Rep 2 12/09/01		Site 6 Toboggan Cr 100m d/s hatchery Rep 3 12/09/01		Site 8P Toboggan Cr 500m u/s Hwy 16 (E245360) Rep 1 12/09/01		Site 8P Toboggan Cr 500m u/s Hwy 16 Rep 2 12/09/01		Site 8P Toboggan Cr 500m u/s Hwy 16 Rep 3 12/09/01	
			cells x $10^6/m^2$	$u^3 x 10^9/m^2$	cells x $10^6/m^2$	$u^3 x 10^9/m^2$	cells x $10^6/m^2$	$u^3 x 10^9/m^2$	cells x $10^6/m^2$	$u^3 x 10^9/m^2$	cells x $10^6/m^2$	$u^3 x 10^9/m^2$	cells x $10^6/m^2$	$u^3 x 10^9/m^2$
CYANOPHYTA														
	Lyngbya sp.	/mm	2.28	13.68	0.43	2.59	2.45	14.71						
	Oscillatoria sp.	/mm	0.37	3.66			0.08	0.82						
CHLOROPHYTA														
	Cladophora sp.	/mm			8.37	334.67	20.22	808.92						
	Closterium sp.						4.09	24.51						
	Cosmarium sp.						4.09	10.21						
CHRYSOPHYTA														
	Dinobryon sertularia												3.65	4.39
CHRYSOPHYTA - DIATOMS														
	Achnanthes minutissima		188.01	13.16	472.31	33.06	956.00	66.92	508.24	35.58	171.67	12.02	716.25	50.14
	Achnanthes sp.		3.48	0.21					21.63	1.30			29.23	1.75
	Cocconeis placentula				2.70	2.43					7.80	7.02		
	Cyclotella sp.													
	Cymbella caespitosa								10.81	13.08	2.23	2.70	10.96	13.27
	Cymbella sp.		1.74	1.04							1.11	0.67		
	Cymbella ventricosa						4.09	2.00	18.02	8.83	5.57	2.73	62.12	30.44
	Diatoma hiemale		1.74	1.11	2.70	1.73	4.09	2.61						
	Diatoma tenue v. elongatum				2.70	0.49								
	Eunotia pectinalis												3.65	4.39
	Eunotia sp.										1.11	0.78		
	Fragilaria sp.		62.67	31.33	242.90	121.45	163.42	81.71	508.24	254.12	118.16	59.08	445.83	222.92
	Gomphonema geminatum		3.48	80.08	94.46	2172.65	40.85	939.66	86.51	1989.70	17.84	410.21	58.47	1344.80
	Gomphonema intricatum													
	Gomphonema olivaceum		248.94	119.49			57.20	27.45	93.72	44.98	46.82	22.47	54.82	26.31
	Gomphonema parvulum		5.22	3.39										
	Hannaea arcus		6.96	13.23	8.10	15.38	8.17	15.52	3.60	6.85	3.34	6.35		
	Melosira granulata													
	Meridion circulare				2.70	1.32			3.60	1.77				
	Navicula sp.													
	Nitzschia acicularis						4.09	0.45						
	Nitzschia palea		3.48	3.83										
	Stauroneis phoenicenton				2.70	7.15								
	Stauroneis sp.				2.70	1.81								
	Synedra ulna				5.40	16.09			7.21	21.48	3.34	9.97	7.31	21.78
	Tabellaria fenestrata													
TOTAL			525.72	266.87	839.37	2373.56	1246.09	1171.04	1261.58	2377.69	378.99	534.00	1392.29	1720.19
TOTAL mm			2.65	17.34	8.80	337.26	22.75	824.45						

Appendix 2 Table 4 Mean biovolume and relative abundance of diatom taxa at four sites in Toboggan Creek September 2001

Algal biovolume u3x109/m2	Mean Site 1 Upper Toboggan Cr (E245607)	Site 1 Relative abundance	Mean Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 4 Relative abundance	Mean Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 6 Relative abundance	Mean Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)	Site 8 Relative abundance
Achnanthes minutissima	1.46	17.2%	19.55	4.6%	37.71	3.0%	32.58	2.1%
Achnanthes sp.	0.03	0.4%	0.05	0.01%	0.07	0.01%	1.02	0.1%
Cocconeis placentula			0.66	0.2%	0.81	0.1%	2.34	0.2%
Cyclotella sp.			1.15	0.3%				
Cymbella caespitosa			0.50	0.1%			9.68	0.6%
Cymbella sp.			0.22	0.1%	0.35	0.03%	0.22	0.0%
Cymbella ventricosa	0.24	2.8%	2.10	0.5%	0.67	0.1%	14.00	0.9%
Diatoma hiemale			0.26	0.1%	1.82	0.1%		
Diatoma tenue v. elongatum					0.16	0.01%		
Eunotia pectinalis							1.46	0.1%
Eunotia sp.							0.26	0.02%
Fragilaria sp.	0.95	11.2%	34.37	8.1%	78.16	6.2%	178.71	11.6%
Gomphonema geminatum			320.84	75.6%	1064.13	84.5%	1248.24	80.9%
Gomphonema intricatum			0.82	0.2%				
Gomphonema olivaceum	5.45	64.3%	19.80	4.7%	48.98	3.9%	31.25	2.0%
Gomphonema parvulum			0.95	0.2%	1.13	0.1%		
Hannaea arcus	0.23	2.7%	4.51	1.1%	14.71	1.2%	4.40	0.3%
Melosira granulata			2.96	0.7%				
Meridion circulare	0.02	0.3%	0.60	0.1%	0.44	0.0%	0.59	0.04%
Navicula sp.			0.62	0.1%				
Nitzschia acicularis			0.13	0.03%	0.15	0.01%		
Nitzschia palea	0.10	1.1%	5.88	1.4%	1.28	0.1%		
Stauroneis phoenicenton					2.38	0.2%		
Stauroneis sp.					0.60	0.0%		
Synedra ulna			5.72	1.3%	5.36	0.4%	17.74	1.2%
Tabellaria fenestrata			2.47	0.6%				
Total diatom biovolume	8.49		424.17		1258.92		1542.50	

Appendix 2 Table 5 Periphyton community composition (as cells/m^2 and biovolume) on natural substrates in Toboggan Creek 2002

Division	Species		Site 4 Toboggan Cr u/s hatchery (E245365) 2/9/2002		Site 1 Upper Toboggan Cr (E245607) 03/09/02		Site 6 Toboggan Cr 100m d/s hatchery (E245367) 03/09/02		Site 8P Toboggan Cr 500m u/s Hwy 16 (E245360) 03/09/02	
			cells x 10^6/m^2	u^{3}x10^9/m^2	cells x 10^6/m^2	u^{3}x10^9/m^2	cells x 10^6/m^2	u^{3}x10^9/m^2	cells x 10^6/m^2	u^{3}x10^9/m^2
CYANOPHYTA										
	Lyngbya sp.	/mm	0.50	3.03	0.01	0.04	1.16	6.96	2.08	12.50
	Oscillatoria sp.	/mm	0.95	9.46					1.19	11.86
CHLOROPHYTA										
	Ankistrodesmus sp.		1.26	0.19						
	Cladophora sp.	/mm	1.89	75.68						
	Cosmarium sp.						1.76	4.40		
CHRYSOPHYTA - DIATOMS										
	Achnanthes lanceolata						1.76	0.18		
	Achnanthes minutissima		142.54	9.98	20.82	1.46	175.88	12.31	165.61	11.59
	Achnanthes sp.				0.07					
	Cocconeis placentula								1.22	1.10
	Cymbella ventricosa		1.26	0.62					0.61	0.30
	Diatoma tenue v. elongatum		1.26	0.23						
	Epithemia sorex				0.07	0.09				
	Fragilaria capucina						1.76	1.48		
	Fragilaria sp.		114.79	57.39	0.57	0.28	49.25	24.62	23.83	11.92
	Fragilaria vaucheriae				0.07	0.02			1.83	0.62
	Gomphonema geminatum								1.83	42.17
	Gomphonema olivaceum		92.08	44.20	5.12	2.46	260.31	124.95	11.00	5.28
	Gomphonema parvulum						22.86	14.86		
	Gomphonema sp.				0.85	0.85				
	Hannaea arcus		2.52	4.79	0.14	0.27				
	Meridion circulare		1.26	0.62						
	Navicula sp.		1.26	0.63						
	Nitzschia linearis								0.61	1.99
	Nitzschia palea		3.78	4.16						
	Nitzschia sp.		20.18	4.84			8.79	2.11		
	Surirella ovata						1.76	8.99		
	Synedra sp.								0.61	1.10
	Synedra ulna						3.52	10.48	1.83	5.46
	Tabellaria fenestrata		3.78	5.68						
	Tabellaria flocculosa								0.61	0.55
TOTAL			385.97	133.33	27.71	6.24	527.65	204.38	209.59	82.08
TOTAL mm			3.34	88.17	0.01	0.04	1.16	6.96	3.27	24.36

Appendix 2 Table 6 Biovolume and relative abundance of diatom taxa on natural substrates in Toboggan Creek in September 2002

Algal biovolume u^3x109/m^2	Site 1 Upper Toboggan Cr (E245607)	Site 1 Relative abundance	Site 4 Toboggan Cr u/s fish hatchery (E245365)	Site 4 Relative abundance	Site 6 Toboggan Cr 100m d/s hatchery (E245367)	Site 6 Relative abundance	Site 8P Toboggan Cr 500m u/s Hwy 16 (E245369)	Site 8 Relative abundance
Achnanthes lanceolata					0.18	0.09%		
Achnanthes minutissima	1.46	23.40%	9.98	7.50%	12.31	6.45%	11.59	14.12%
Achnanthes sp.								
Cocconeis placentula							1.10	1.34%
Cymbella ventricosa			0.62	0.47%			0.30	0.37%
Diatoma tenue v. elongatum			0.23	0.17%				
Epithemia sorex	0.90	14.42%						
Fragilaria capucina					1.48	0.77%		
Fragilaria sp.	0.28	4.49%	57.39	43.11%	24.62	12.89%	11.92	14.52%
Fragilaria vaucheriae	0.02	0.32%					0.62	0.76%
Gomphonema geminatum							42.17	51.38%
Gomphonema olivaceum	2.46	39.42%	44.20	33.20%	124.95	65.43%	5.28	6.43%
Gomphonema parvulum					14.86	7.78%		
Gomphonema sp.	0.85	13.62%						
Hannaea arcus	0.27	4.33%	4.79	3.60%				
Meridion circulare			0.62	0.47%				
Navicula sp.			0.63	0.47%				
Nitzschia linearis							1.99	2.42%
Nitzschia palea			4.16	3.12%				
Nitzschia sp.			4.84	3.64%	2.11	1.10%		
Surirella ovata					8.99	4.71%		
Synedra sp.							1.10	1.34%
Synedra ulna					1.48	0.77%	5.46	6.65%
Tabellaria fenestrata			5.68	4.27%				
Tabellaria flocculosa							0.55	0.67%
Total diatom biovolume	6.24		133.14		190.98		82.08	

Appendix 3 Table 1 Trends in MOF grazing tenues, livestock headage and AUMs in the Bulkley-Cassiar Forest District 1983-2001

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Tenures	59	62	65	72	78	78	74	81	77	79	58
Authorized AUMs[1]	11513	10977	12657	13224	13339	12828	12309	12874	12314	11926	8566
#cattle	2934	3255	3194	2809	3050	2898	2769	2771	2206	2472	1632
#horses	689	695	797	876	926	974	894	1023	980	774	775
#sheep					45	45	47	147	147	147	47

	1994	1995	1996	1997	1998	1999	2000 [2]	2001
Tenures	68	70	67	63	69	69	65	64
Authorized AUMs	10094	10923	10276	10814	12792	12907	9150	8636
#cattle	2341	2455	2749	2351	2486	2699	2693	2541
#horses	956	894	769	870	887	919	614	667
#sheep	0	0	0	0	0	0	0	0

Source: R. Drinkwater, MOF Prince Rupert Forest Regional Agrologist, personal communication

1 An animal unit (AU) is defined as a mature 100 lb. cow and her calf or equivalent. Since different classes of livestock have different nutritional requirements, they must be converted to AU equivalents (below). An Animal Unit Month (AUM) is the amount of feed required by one AU for 1 month.

cow & calf	1.0
bull	1.3
horse	1.25
domestic sheep	0.2

[2] The Kechika and Turnagain clients moved to the Fort Nelson Forest District in 2000. This caused a significant drop in AUMS.

Appendix 3 Table 2 BCWLAP Water Use Licenses on Toboggan Creek and tributaries

Source	License No.	Year Issued	Quantity[1]	Use	Licensee	Address
Toboggan Creek	C115024	1980	2.00 CS	Ponds	Butz, T.J. & L.C.	Box 783 Smithers, BC, V0J 2NO
	C040409	1970	1000.00 GD	Domestic	Landrock, K.S. & K.A.	RR1 C9 S23 Smithers, BC, V0J 2NO
	C068089	1989	40.00 AF	Irrigation	Hopps, T & L.R.	RR1 C1 S23 Smithers, BC, V0J 2NO
	F038718	1965	500.00 GD	Domestic	Collingwood Sales Ltd.	Box 2408 Smithers, BC, V0J 2NO
	C060179	1983	3000.00 GD	Domestic	Evelyn Mountain View Farms Ltd.	RR1 Smithers, BC, V0J 2NO
	F041164	1965	2500.00 GD 150.00 AF	Domestic Irrigation	Reitsma, J. & S.	Box 754 Smithers, BC, V0J 2NO
	C031864	1966	1000 GD 30.00 AF	Domestic Irrigation	Benjamin, R.M. & B.A.	RR1 Smithers, BC, V0J 2NO
	F020874	1966	500.00 GD 23.00 AF	Domestic Irrigation	Lychak, P.	RR1 Smithers, BC, V0J 2NO
	F112281	1984	2.00 CS	Fish Culture	Toboggan Creek Salmon and Steelhead Enhancement Society	RR1 C23 S25 Smithers, BC, V0J 2NO
	F020452	1964	500.00 GD	Domestic	Headley, E.F.	RR1 C24 S25 Smithers, BC, V0J 2NO
Owens Creek	C110315	1995	98.00 AF	Irrigation	Huisman, O.	RR1 C7 S25 Smithers, BC, V0J 2NO
	F010352	1929	1000.00 GD 50.00 AF	Domestic Irrigation	Van Alphen, K.J.	Box 3814 Smithers, BC, V0J 2NO
	F010351	1929	500.00 GD 50.00 AF	Domestic Irrigation	Mott, D.C. & J.A.	RR1 C21 S25 Smithers, BC, V0J 2NO
Huisman Brook	C047325	1974	1500.00 GD	Domestic	Huisman, O.	RR1 C7 S25 Smithers, BC, V0J 2NO
Feeney Brook	C038402	1971	1000.00 GD	Domestic	Glass, D.G. & J.	Box 2042 Smithers, BC, V0J 2NO
	C107668	1970	500.00 GD	Domestic	Raufer, H. & G.	RR1 Raufer Rd, C6 S25

[1] CS indicates cubic feet per second
GD indicates gallons per day
AF indicates acre-foot

Appendix 3 Table 2 (continued) BCWLAP Water Use Licenses on Toboggan Creek and tributaries

Source	License No.	Year Issued	Quantity[1]	Use	Licensee	Address
Brandt Brook	F112281	1984	0.5 CS	Fish Culture	Toboggan Creek Salmon and Steelhead Enhancement Society	RR1 C23 S25 Smithers, BC,V0J 2NO
	C114835	1993	500.00 GD	Domestic	Klassen, D. & J.D.	Box 20113 Smithers, BC,V0J 2NO
	C114834	1979	500.00 GD	Domestic	Mettler, M. J.	Box 3716 Smithers, BC,V0J 2NO
	C029303	1963	500.00 GD	Domestic	Greengrass, P.C. & C.V.	RR1 C32 S25 Smithers, BC,V0J 2NO
	C048533	1976	500.00 GD	Domestic	Hartman, J.	RR1 Dunlop Street, C27 S25 Smithers, BC,V0J 2NO
	C051408	1977	500.00 GD	Domestic	Corneau,R.	Box 3793 Smithers, BC,V0J 2NO
	C058119	1981	500.00 GD	Domestic	Mager, J.C. & T.A.	Box 3822 Smithers, BC,V0J 2NO
	C058120	1981	500.00 GD	Domestic	Huisman, J.	Box 2226 Smithers, BC, V0J 2N0
	C110539	1995	500.00 GD	Domestic	Duguay, J.	RR1 C27 S25 Smithers, BC,V0J 2NO
	C114782	1999	500.00 GD	Domestic	Cook, A.D. & G	17 11229 232 St. Maple Ridge, B.C. V2X 2N4
Hobbs Brook	C057172	1966	1500.00 GD	Domestic	Veenstra, J. & S.	RR1 C22 S25 Smithers, BC,V0J 2NO
Elliot Creek	C110079	1970	500.00 GD	Domestic	Lychak, D.P. & J.	Box 621 Smithers, BC,V0J 2NO
	C110080	1970	1000.00 GD	Stock Watering	Lychak Enterprises Ltd.	Box 621 Smithers, BC,V0J 2NO
			80.00 AF	Irrigation		
	C106257	1993	500.00 GD	Domestic	Glass, D.G. & J.	Box 2042 Smithers, BC,V0J 2NO
			9.90 AF	Irrigation		
	C105947	1992	40.0 AF	Irrigation	Huisman, O. & C.	RR1 C7 S25 Smithers, BC, V0J 2N0
Fulda Spring	C115019	1989	1000.00 GD	Domestic	Butz, T. & L.	Box 783 Smithers, BC, V0J 2N0
Glacier Gulch	C068043	1988	12.00 CS	Land Improvement	Bulkley-Nechako Regional District	Box 820 Burns Lake, BC V0J 1E0
Glass Creek	C104619	1971	1000.00 GD	Domestic	Storeys Ranch Ltd.	RR1 Smithers, BC,V0J 2NO
	C104331	1992	70.00 AF	Irrigation	Storeys Ranch Ltd.	RR1 Smithers, BC,V0J 2NO
	F040688	1968	1000.00 GD	Domestic	Horlings, A. & L.	RR2 C8 S43 Smithers, BC,V0J 2NO
	C062049	1985	500.00 GD	Domestic	Van Der Meulen, E. & A.	RR1 C37 S27 Smithers, BC,V0J 2NO
	C047203	1973	500.00 GD	Domestic	Nordings, W.F.	Box 2732 Smithers, BC,V0J 2NO
	C114694		500.00 GD	Domestic	Steenhof, C. & H.	RR1 S27 C47 Smithers, BC, V0J 2N0
	C111915	1996	500.00 GD	Domestic	Edie, A. G. & Taugher, J.A.	RR1 C13 S27 Smithers, BC,V0J 2NO

Source: MELP Water Management, Smithers

[1] CS indicates cubic feet per second
GD indicates gallons per day
AF indicates acre-foot

Appendix 3 Table 3 Toboggan Creek Land and Water Use Survey

The purpose of this survey is to document land and water use in the Toboggan Creek drainage concurrently with an on-going water quality study. This is also your opportunity to let people know your concerns and opinions about land use and water use in your neighborhood. A summary of the survey results will be mailed to all respondents (be sure to include your name and address if you were not on our original mailing list.) A summary of the survey results will also be included in the technical report of the water quality study. Individual respondents will not be identified. You may complete this survey anonymously if you wish.

A Land use information:

1 Total property size: ______________________

2 Main land use and acreage dedicated to this use: ______________________

3 Other land use activities: Residential ☐ Agriculture ☐ Forestry ☐ Tourism ☐ Recreation ☐
Other (explain): ______________________

4 Please indicate if you have a stream, wetland or lake on your property: Stream ☐ Wetland ☐ Lake ☐

5 What do you use this waterbody for: Water supply ☐ Hunting ☐ Fishing ☐ Swimming ☐
Wildlife viewing ☐ Nothing ☐ Other (explain): ______________________

6 If you have a stream on your land, what percent of the stream has been cleared to the bank? 0-25% ☐
26-50% ☐ 51-75% ☐ 76-100% ☐

7 On the remainder of the stream, how wide is the riparian band of shrubs and trees on average?
0-5 ft ☐ 6-15 ft ☐ 16-30 ft ☐ 30+ft ☐

8 Are you experiencing losses of land to streambank erosion? Yes ☐ No ☐

9 Do you feel you experience increased flooding due to developments upstream of you in on your stream?
If so, please explain: ______________________

____

B Residential water use information:

10 What is the source of your household's drinking water?
Stream or brook (name): ______________________
Dugout or wetland ☐ Rainwater cistern ☐ Well ☐ Other ☐

11 Do you boil ☐, chemically treat ☐, or filter ☐ your water prior to drinking it? Do not treat ☐

12 Does your household utilize a septic tank and field or a sewage lagoon for sewage treatment?
Septic tank/field ☐ Sewage lagoon ☐

13 What is the age of your septic field? 0-5 years ☐ 6-15 years ☐ 16-25 yrs ☐ 25+ yrs ☐

14 How often is the septic tank pumped? Annually ☐ Every 3-5 yrs ☐ More than 5 yrs ☐

15 Is there a wet, swampy area at the end of your drain field? Yes ☐ No ☐

C Other comments:

16 Do you have any other concerns or comments regarding land or water use in the Toboggan Creek watershed? ______________________

____

____

This project is funded by Fisheries Renewal BC and Ministry of Water, Land and Air Protection

Appendix 3 Table 3 (continued) Toboggan Creek Land and Water Use Survey

D Agricultural land and water use information (*Only to be filled out by agricultural operators*):
Most of these questions were taken from the BC Ministry of Agriculture Environmental Evaluation of Agricultural Operations Checklists.

17 Do you have a beef or dairy operation? Beef ☐ Dairy ☐
How many cow-calf pairs do you own? ____________
How many bulls do you own? ____________
How many yearlings do you own? ____________
How many horses do you own? ____________
Other stock? ____________

18 How do you water your cattle?

Outdoor Feeding Areas are defined as follows:
Grazing Area - livestock sustained by feed growing on the area
Seasonal Feeding Area - crop land that is also used seasonally for wintering livestock with supplemental feed
Confined Livestock Area - an outdoor, non-grazing area where livestock are confined, such as corrals or feedlots

Check boxes below ↓

Outdoor Feeding Area	Water directly from stream	Water from confined area of stream	Water from dugout	Water from stock trough
Grazing Areas				
Seasonal Feeding				
Confined Feeding				

19 Have you made any changes in how you manage cattle watering in the last five years? Yes ☐ No ☐
If yes, please explain: ____________

20 Did you withdraw water from a watercourse for irrigation this year? Yes ☐ No ☐

21 How many times have you irrigated in the past five years? ____________

22 When was the last year you irrigated? ____________

23 How many acres did you irrigate and by what method? ____________

24 What crop did you irrigate? ____________

25 How many days did you irrigate in:

May	Jun	Jul	Aug	Sept

26 On average, how many hours per day did you irrigate? ____________

27 What is the rate of water removal used by your irrigation system (gallons per minute)? ____________

28 What total volume of water (gallons) did you use for irrigation? ____________

29 Do you have any other comments or concerns regarding agriculture or water use in the Toboggan Cr. watershed? ____________

30 Would you like to receive more information on stream stewardship for agriculture? Yes ☐ No ☐

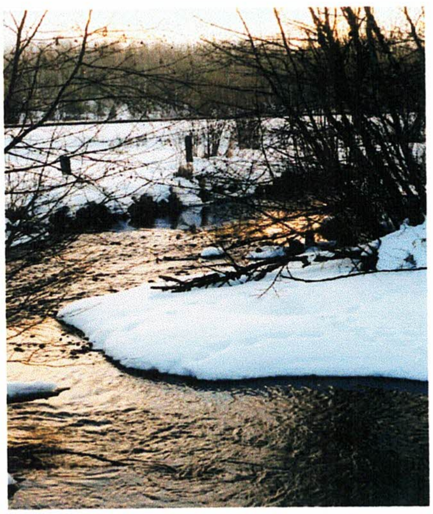
31 **OPTIONAL: Name and Address:** ____________

This project is funded by Fisheries Renewal BC and Ministry of Water, Land and Air Protection

Appendix 4 Water quality and periphyton site photographs and location notes Sites 1 - 4

Site 1WP **Upper Toboggan Creek** E245607 N54.8733
Watershed Code 460-242900 W127.265

Photo is looking upstream from private road bridge. Access to this site is via private road off Highway 16. This is the control site for both water quality and periphyton monitoring.

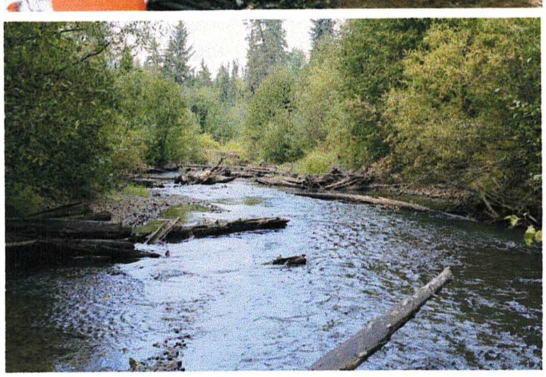


Site 2W **Toboggan Cr downstream Toboggan Lake** E245606 N54.8783 W127.2617

Photo is looking upstream from private road bridge with CNR in background. Access to this site is via private road off Highway 16. This site is downstream of the confluence of Upper Toboggan and Glacier Gulch creeks and downstream of the lake.

Site 3W **Elliot Creek** Watershed Code 460-242900-47700 E245364 N54.8881 W127.2639

Elliot Creek upstream of its confluence with Toboggan Creek is accessible by walking south along the CNR line from Owens Road.



Site 4WP **Toboggan Creek upstream of fish hatchery** E245365 N54.8892 W127.2644

Photo is looking downstream from the rock weir constructed for the hatchery water intake. This site is accessible from the hatchery driveway. This is a water quality and periphyton monitoring location.

Appendix 4 Water quality and periphyton site photographs and location notes: Sites 5 - 8

Site 5W Fish hatchery outflow channel E245366 N54.8925 W127.289

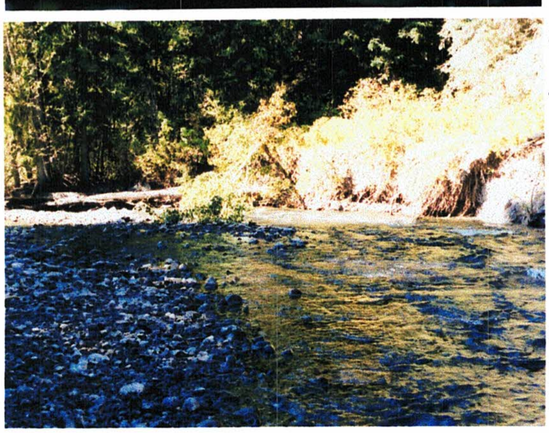
This site is downstream of the combined hatchery and rearing pond discharges and is accessed through the hatchery property.

Site 6WP Toboggan Cr 100m downstream fish hatchery E245367 N54.8936 W127.27

Photo is looking downstream with the CNR line just out of the photo to the left. This site is accessed by walking downstream on the hatchery property. This is a water quality and periphyton monitoring location.

Site 7W Owens Creek Watershed Code 460-242900-16100 E245368 N54.9222 W127.29

Owens Creek upstream of its confluence with Toboggan Creek is accessible by crossing private property.



Site 8P Toboggan Creek 500m upstream Hwy 16 E245369 N54.9364 W127.313

This site is 500m upstream of Highway 16 and is accessed via private driveway. This is a periphyton & benthic invertebrate monitoring location. Water quality monitoring took place at Site 8W.

Site 8W Toboggan Creek upstream Hwy 16 (E245370) is not pictured. The water quality monitoring location is immediately upstream of the Highway 16 culvert.