Water Quality and Aquatic Ecosystem Monitoring in the Toboggan Creek Watershed: 2001-2002

By:
D. REMINGTON AND J. LOUGH
REMINGTON ENVIRONMENTAL[1]

Prepared for:
Northwest Institute for Bioregional Research
Box 2781
Smithers, BC V0J 2N0

March 31, 2002

[1] Site 59 Comp 9 RR#2, Smithers, BC V0J 2N0 Email: remingtn@bulkley.net

Executive Summary

(This summary of study results was mailed to Toboggan Creek residents in June 2002)

Introduction—

The Toboggan Creek, a small glacier-fed tributary of the Bulkley River near Smithers, British Columbia, supports highly valued fisheries resources, including coho salmon and rainbow/steelhead trout. A DFO Salmon Enhancement Program 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 watershed is traversed by both the railway and Highway 16, and has a long history of forestry and agriculture. Because of its close proximity to the community of Smithers, many rural residences are also present in the watershed.

A DFO Habitat Restoration and Salmon Enhancement Program water quality monitoring study was conducted in 1996-98 due to concerns regarding water quality and health of juvenile wild and hatchery salmon. The study suggested early signs of eutrophication: elevated bacterial and nutrient concentrations and excess stream-bottom algae (periphyton). The report suggested watershed stewardship initiatives be undertaken and recommended periodic trend monitoring of water quality and ecosystem health.

A water quality and aquatic ecosystem trend monitoring study was initiated in August 2001, sponsored by the Northwest Institute for Bioregional Research. This research was funded by Fisheries Renewal BC.

Methods—

Monthly water quality sampling was carried out August 2001 through March 2002 at eight locations in the watershed, shown in Figure 1. Site 1, Upper Toboggan Creek, is considered the 'control' site because it is upstream of most human influences, such as livestock over-wintering operations and permanent residences. Site 2 is downstream of the confluence of Upper Toboggan and Glacier Gulch creeks and downstream of Toboggan Lake. Three sites bracketed the fish hatchery: Site 4, upstream of the hatchery; Site 5, the hatchery outflow channel; and Site 6, downstream of the hatchery outflow. Site 3, Elliot Creek, and Site 7, Owens Creek, are the next two largest tributary streams. The final monitoring location is Site 8, the mouth of Toboggan Creek just upstream of Highway 16. Aquatic ecosystem monitoring included collection of the accumulated periphytic algae at four sites and aquatic insects (benthic invertebrates) at one site during September 2001.

A Ministry of Water, Land and Air Protection (MWLAP) Drinking Water Protection Plan monitoring study was conducted in October 2001 at 20 locations in the Skeena Region. Toboggan Creek at Site 8, upstream of Highway 16, was sampled weekly for five consecutive weeks.

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 and mailed to residents of the Toboggan Creek watershed in October 2001.

The results are summarized in the following three sections: 1) water quality and aquatic ecosystem monitoring results, 2) drinking water quality monitoring results and 3) land and water use survey results.

1 Water quality and aquatic ecosystem monitoring results—

Water temperature— Water temperatures exceeding MWLAP weekly average water quality guidelines for salmonid spawning were recorded during summer-early fall periods in 1996-1998 and again in 2001. Elevated water temperatures are a concern to fisheries managers in Toboggan Creek and other upper Skeena watershed streams. Toboggan Creek has been identified in Watershed Restoration Program studies as a priority watershed for riparian restoration activities such as riparian fencing and planting of shade trees.

Ammonia— 1996-1998 ammonia concentrations in the Toboggan mainstem did not exceed maximum or 30-day average guideline concentrations. However, a seasonal trend in ammonia concentrations was observed, with a spike in the period of mid-February to mid-April, coincident with low elevation snowmelt. An ammonia concentration higher than the 30-day average guideline was recorded immediately downstream of a livestock overwintering operation on a small fish-bearing tributary. Because of concern for the health of juvenile salmon, a DFO fish protection order was issued and the winter feedlot was subsequently relocated.

In 2001-2002, mean ammonia concentrations increased downstream of the lake compared to the Upper Toboggan Creek control site, which is likely due to natural biological activities in the wetlands surrounding the lake. Ammonia concentrations at all sites were consistently less than guideline concentrations for the protection of aquatic life.

Upstream-downstream trends— Statistical analysis of data for the five Toboggan mainstem sites indicates a slight increase in mean soluble phosphorus concentrations as one moves downstream. It should be noted that soluble phosphorus concentrations measured were very low and that any increase was slight. There was no evidence for a change in mean concentrations of the other highly bioavailable nutrients, ammonia and dissolved inorganic nitrogen.

Trends over time 1996-98 versus 2001-02—A series of statistical analyses were conducted using data from three sites that were duplicated in the two studies (Site 2, Site 4 and Site 8). Analysis of data from Site 8, Toboggan Creek at Highway 16, indicated that ortho-phosphate concentrations decreased from the 1996-1998 mean of 9.7 µg/L-P to a 2001-2002 mean of 1.6 µg/L-P. Known ratios of nitrogen to phosphorus indicate that algae growth in Toboggan Creek is strongly limited by low bioavailable phosphorus. We strongly suggest that any possible trend in phosphorus concentrations be viewed with caution until the completion of the remainder of the 2002 water quality sampling, which is ongoing.

Periphytic algal biomass and community composition— In 1996 and 1997, periphyton biomass in lower Toboggan Creek equaled or exceeded the guideline for protection of recreation and aesthetics. In 2001, periphyton biomass, measured at four sites, did not exceed water quality guidelines. Diatoms (the brownish-gray algae that coat stream-bottom rocks) were the dominant algal division at all sites, comprising 92-100% of biovolume. The exception was Site 6, downstream of the hatchery, where filamentous green algae comprised about ¼ of biovolume.

Toboggan Creek fish hatchery— Statistical tests were conducted with data for Site 4, upstream, and Site 6, downstream of the hatchery, in order to assess possible effect of the outflow on water quality in the Toboggan mainstem. Tests for ammonia, dissolved inorganic nitrogen, fecal coliform bacteria, and dissolved oxygen gave no evidence for any effect. There was very weak evidence that soluble phosphorus levels may be very slightly increased in Toboggan Creek due to the hatchery outflow. However, we strongly suggest that any possible trends be viewed with caution until the completion of water quality sampling in 2002.

2 Drinking water quality monitoring results—

In Toboggan Creek, eight of the 30 domestic drinking water intakes in the watershed are located on mainstem within 6 km of the mouth. 1996 and 1997 studies in the Toboggan watershed found fecal coliform and fecal streptococci concentrations to exceed MWLAP drinking water protection guidelines on late summer sampling dates.

A MWLAP Drinking Water Protection Plan monitoring study was conducted in October 2001 in the Skeena Region which included five samples in a 30-day period at Site 8, Toboggan Creek upstream of Highway 16. Indicator organisms, such as coliform bacteria, provide an estimate of the degree of fecal contamination from human and animal wastes that are in the water. The general philosophy associated with using an indicator organism is that if it can be shown that fecal contamination of the water has occurred, then disease-causing organisms, such as *Giardia* and *Cryptosporidium*, may also be present. The maximum acceptable concentration for coliforms in drinking water is zero organisms detectable per 100 mL. The BC Ministry of Health recommends that all drinking water supplies derived from surface waters receive disinfection such as boiling.

In October 2001, Toboggan Creek at the mouth exceeded the drinking water quality guidelines for all three indicator organisms measured. According to MWLAP guidelines, partial treatment, in addition to disinfection, is recommended prior to using the water for drinking, brushing teeth etc.

Fecal coliform concentrations at Site 8 exceeded drinking water quality guidelines in six of the eight monthly samples. At the other sites, microbiological quality varied somewhat depending upon location in the watershed and seasonally, with the lowest bacterial counts in tributary streams and during the winter low-flow period. Since fish are cold-blooded creatures, the hatchery fish are not contributors to fecal coliform loadings.

3 Land and water use survey results—

A land and water use survey was designed and mailed to residents of the Toboggan Creek watershed in October 2001. Of the ten surveys returned, only one represented the agricultural community, resulting in a gap in information regarding this land use type.

In an attempt to fill this gap, we interviewed several provincial and federal government sources. The total number of breeding cows in the Toboggan watershed is estimated at 1000 head and has varied little in recent years. Authorized animal unit months on crown range in the Bulkley Cassiar Forest District tend to vary somewhat depending on cattle prices, but are generally lower than they were in the early 1980s.

A number of positive changes have taken place in agricultural management practices in the Toboggan watershed since the 1996-1998 monitoring study. A cattle herd, which had been overwintered next a dugout pond in an unnamed tributary, has been relocated (see *Ammonia—* above). A cattle herd, which had been overwintered along Glass Creek at the head of Toboggan Lake, has been relocated to the other side of Highway 16. Riparian fencing has been constructed along Toboggan Creek, Owens Creek and Hopps Brook and some riparian planting completed. The herd, which has been over-wintered along Toboggan and Owens creeks, will be relocated in 2002-03 to an upper fenced pasture utilizing a dugout water supply and ice-free stock trough system.

Changes have also taken place at the Toboggan Creek fish hatchery. Fish densities at the hatchery have decreased from a total of 1,680 kg at historical peak winter biomass to roughly 720 kg in 2001-02.

The land and water use survey was more successful in eliciting response from the rural residential community, with a 27% response rate. Fifty percent of respondents had a stream on their property that was often used for household water supply and garden irrigation. Most of the residents reported that less than 50% of the stream on their property had been cleared of trees up to the streambank. Most residents reported a 30+ foot band of riparian shrubs and trees along the remainder of the stream on their property. Several residents responded that their entire property was in a forested, natural state.

Eighty percent of respondents utilized septic tanks and drain fields for household sewage disposal and 20% utilized sewage lagoons. Half of septic drain fields were over 25 years old. However, 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.

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 boiled or otherwise treated their drinking water. Half of the respondents using surface water sources either boil or filter their water prior to drinking or 'pack' drinking water from another source and one half drink raw surface water. Several residents expressed concern over agricultural fertilizer use, livestock concentrations, and livestock access to streams.

Conclusions—

We are aware that a number of positive changes in agricultural management practices occurred in the Toboggan watershed between the 1996-98 and the 2001-02 monitoring. A reduction in overwintering density at the Toboggan Creek fish hatchery has also occurred during that time. Comparison of the August to March water quality data between the two studies indicates that a reduction in soluble phosphorus levels occurred throughout the Toboggan mainstem. This is significant because our study indicates that periphytic algae growth in this system is controlled by phosphorus levels.

An overall reduction in periphytic algae biomass was found in the 2001 compared to 1996-97. In 1996 and 1997, periphyton biomass equaled or exceeded the water quality guidelines for aesthetics and recreation in the lower watershed. Algae biomass did not exceed the guidelines in 2001.

The initial impression is that nutrient levels have lowered resulting in a reduction in periphytic algal biomass and this is good news for a watershed that was thought to show early signs of eutrophication. However, caution in drawing conclusions is advised until the results are available from the entire year of water quality monitoring, which is underway.

MWLAP drinking water source monitoring of Toboggan Creek found levels of fecal coliforms, *E. coli*, and Enterococci to exceed drinking water protection 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. Sixty percent of survey 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 might lead some to reconsider the need for disinfection and partial treatment. The Bulkley Valley Community Health Council office in Smithers is a source for further information on disinfection and treatment options for surface waters.

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.

Cooperation between several levels of government and landowners will be necessary in order to implement much-needed watershed 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.

In order to compile one year of monitoring data, Environment Canada and MWLAP are sponsoring the continuation of water quality sampling through summer 2002. When complete, the water quality, drinking water, benthic algae and benthic invertebrate-IBI data collected in these studies will provide a solid baseline dataset for long-term trend monitoring in this watershed.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Background

Toboggan Creek watershed is a small system flowing into the Bulkley River roughly 21 km north of Smithers (Figure 1). The headwaters and major tributaries emanate from the eastern slopes of the Hudson Bay Range. Glacier Gulch Creek emanates from Hudson Bay Glacier and flows into the head of small, shallow Toboggan Lake on the valley bottom. Upper Toboggan Creek emanates from Toboggan Glacier and joins with Glacier Gulch Creek just below 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.

The Toboggan system supports highly valued fisheries resources, including coho salmon and rainbow/steelhead trout. A DFO Salmon Enhancement Program hatchery has operated on Toboggan Creek since 1985. The watershed is traversed by both the railway and Highway 16, providing many access points, and has a long history of forestry and agriculture. The entire mainstem Toboggan Creek and Toboggan Lake are on private (largely agricultural) lands. Because of its close proximity to the community of Smithers, many rural residences are present in the watershed.

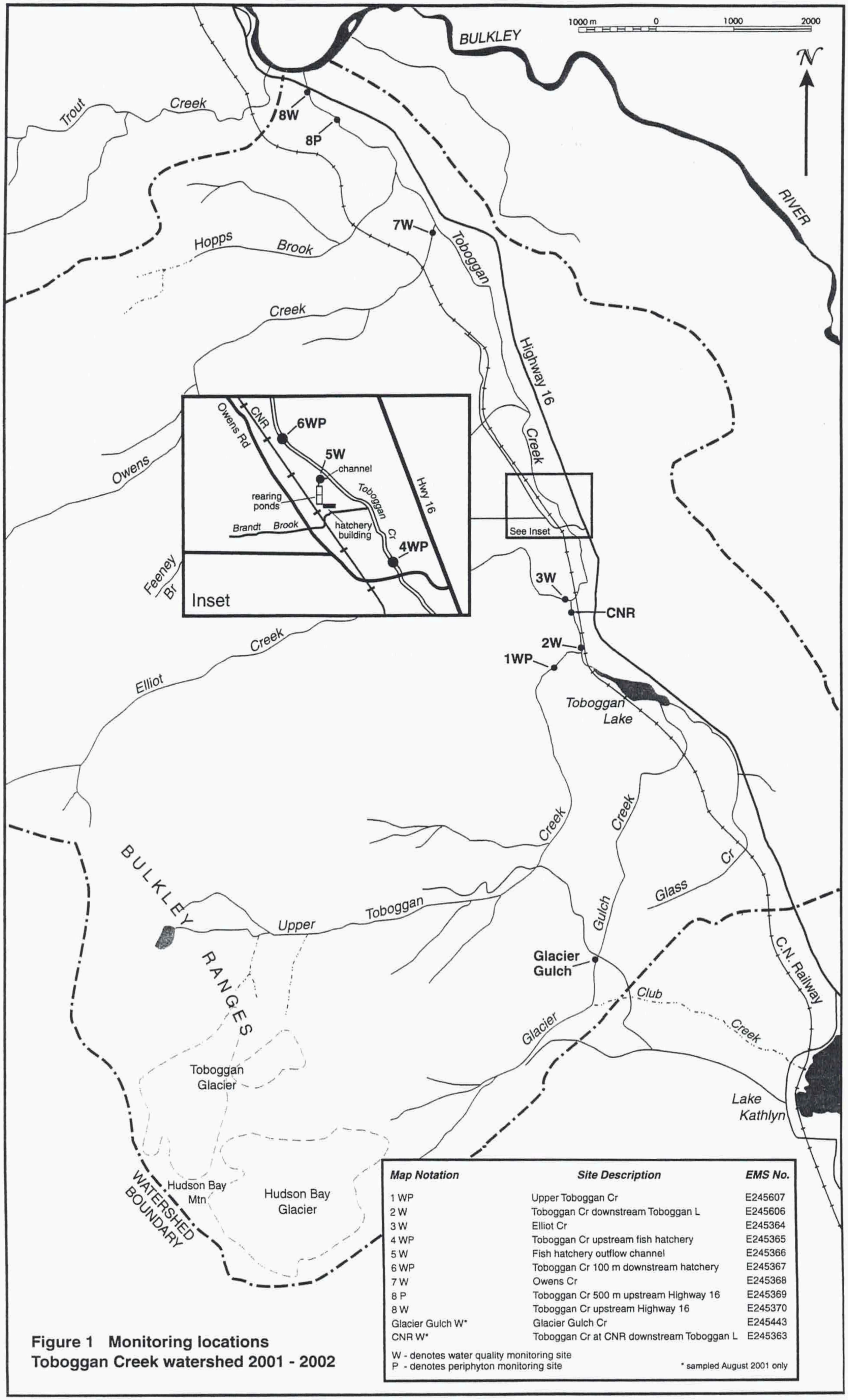
DFO Habitat Restoration and Salmon Enhancement Program initiated water quality monitoring in Toboggan Creek watershed in early 1996, due to concerns regarding water quality and health of juvenile wild and hatchery salmon. This work was reported in *Water quality in the Toboggan Creek watershed 1996-1998: are land use activities affecting water quality and salmonid health?* (Remington and Donas 1999). The study suggested early signs of eutrophication: elevated bacterial and nutrient concentrations and excess periphytic algae growth. A seasonal spike in ammonia and other nutrient concentration coinciding with early freshet suggested valley-bottom surface runoff as the source of nutrients. There was no indication that the degree of eutrophication at that time was having a negative impact on fisheries resources. However, the report suggested watershed stewardship initiatives be undertaken and recommended periodic trend monitoring of water quality and ecosystem health.

Remington Environmental was contracted to conduct water quality and ecosystem trend monitoring in the Toboggan Creek watershed during 2001-2002. Many people are thanked for their contributions to this project. Greg Tamblyn, Watershed Stewardship Coordinator CFDC Nadina, and Pat Moss, Executive Director of the Northwest Institute for Bioregional Research, for technical and administrative support. Ian Sharpe, Ministry of Water, Land and Air Protection (MWLAP), for technical advice and for contributing the analytical laboratory services for this project. Remi Odense, MWLAP, for technical advice and for providing drinking water source quality data.

1.2 Objectives

Specifically, the contract required the following:

- Water quality sampling at eight sites in the Toboggan Creek watershed on a monthly basis and immediately after heavy rainfall, 'rain on snow' and following runoff events adhering to standard water quality sampling protocols starting August 2001 and finishing March 2002.
- A landowner contact portion of the contract involves developing a water use survey with the residents and/or water license holders in the Toboggan Creek watershed. The water use survey will be designed to help determine quantities of water used in the watershed and what license holders feel are key issues associated with their water licenses and the local streams.
- The consultant will write a report summarizing and discussing the findings of the water quality and periphyton sampling and the water use survey. Results will be compared with provincial and federal water quality standards and with results from previous water quality sampling in the Toboggan Creek watershed. Information gained from the benthic index of biological integrity work to be conducted in the watershed during 2001 will be incorporated into the report.
- The report will include a non-technical executive summary that can be distributed to interested residents in the Toboggan Creek watershed.



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 Fisheries Resources

2.1.1 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).

2.1.2 Toboggan Creek

Fish species present with 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).

2.2 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. As well, local P.I.P. projects and school classroom incubators were provided with another 10,000 coho eggs and fry. 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 (Parasite S) 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 decreased 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 over-wintered 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. Over-wintering 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).

2.3 Land Use

2.3.1 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. At that time, the main road through the Bulkley Valley was the Telkwa High Road, which runs on the opposite side of the Bulkley River. A minor road linked Lake Kathlyn and Evelyn to Smithers.

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).

2.3.2 Mining

The Glacier Gulch mineral deposit lies partially beneath Hudson Bay (locally known as Kathlyn) glacier at 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 the large low-grade molybdenum deposit. This large porphyry deposit is suitable for open pit mining much to the dismay of Smithers residents who admire the spectacular view of the glacier west of town (Gottesfeld 1985).

2.3.3 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.

2.3.4 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 34 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.

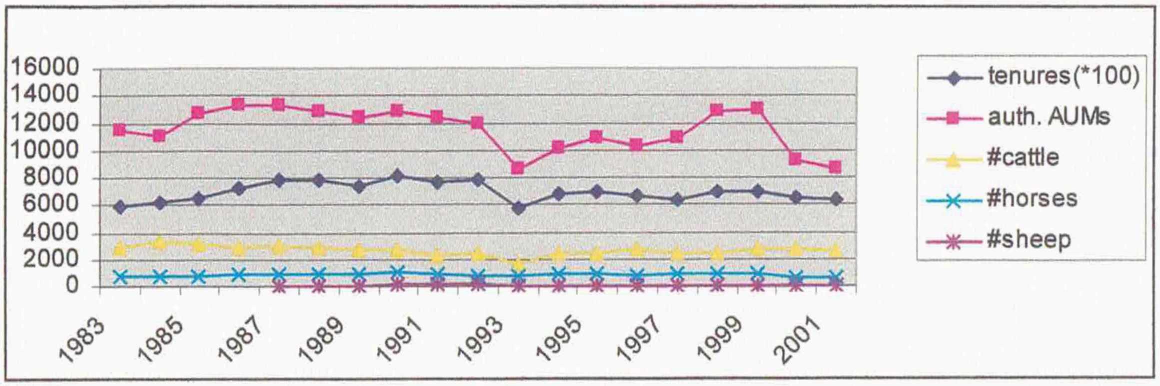
Septic system effluent has high nutrient and microorganism concentrations derived from human feces and phosphorus-rich detergents. Many studies have shown that, where septic tanks are located on well drained mineral soils set back an approved distance from receiving waters, there is little likelihood of contamination. Generally, only areas with highly permeable soils or high groundwater levels are susceptible to problems. In these situations, septic discharges can seep into underground water sources, contaminating both well water and nearby streams.

2.3.5 Agriculture

Soon after the construction of the railway in 1914, Evelyn became a center of farming activity. Today essentially the entire valley bottom is private land devoted to agriculture. Four beef cattle operations and two dairies are located in the Toboggan Creek watershed. The total number of breeding cows in the Toboggan Creek watershed is estimated at 1000 head and has varied little in recent years (D. Riendeau, District Agriculturist, personal communication). 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 1 Table 1 and charted in Figure 2. Figure 2 illustrates that livestock numbers in the Bulkley valley tend to vary somewhat depending on cattle prices, but are generally lower than they were in the early 1980's.

Figure 2. Trends in MOF grazing tenures, livestock headage and AUMs in the Bulkley Cassiar Forest District 1983-2001



2.3.5.1 Review of cattle-community watershed conflicts in the Skeena Region

Gaherty and others (1996) describe the typical 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 over-winter 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.

Grazing— Well drained slopes with a herbaceous vegetation cover have a low susceptibility to surface runoff and erosion, 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 grazing lands to water quality concerns to not be significant. Cattle densities on rangelands are very low and with very limited 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.

Livestock wintering areas— 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, both nitrogen and phosphorus.

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 this latitude that do not facilitate further bacterial breakdown of ammonia to nitrate.

2.4 Licensed Water Use

43 water use licenses are registered in the Toboggan Creek watershed (MWLAP Water Management Branch). Detailed water license information is found in Appendix 1 Table 2. There are 34 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

2.5 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).

2.5.1 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, a Nortec Consulting report (Mitchell, 1997) on the Bulkley River riparian assessment found that riparian areas within the watershed had been heavily impacted by non-forestry related sources including road, railway and powerline crossings and extensive land clearing. 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 degraded.

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. In addition to these works, the Water Rights Branch installed four stream gauges in 1978.

2.5.2 Water quality data analysis

Toboggan Creek water quality data, collected by DFO-HRSEP in 1996, were reported and assessed in Section 1.4.1 of the Gibson (1997) report. Erroneous nitrite concentrations were reported for April 7 to May 20th period at all sites downstream of Toboggan Lake. The levels reported were actually the concentrations of nitrate+nitrite. This led the author to conclude that federal and provincial criteria for the protection of aquatic life had been exceeded, when this was not the case. See Remington and Donas (1999) for a detailed assessment of the HRSEP 1996-98 water quality data.

2.5.3 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 in 1997 and broken up into reaches. 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 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 powerline right of way. Prescriptions for the lower end include bridge removal, placement of large woody debris, and bank stabilization. Upstream from the powerline 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 powerline right of way, extensive braiding above the powerline 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.

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

On January 5, 1998, Nortec Consulting attended a meeting with the Toboggan Creek Landowners Association. Details about the contract including its objectives were discussed. 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.

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

B. Donas, 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 over-wintered next to a dugout pond on a small unnamed fish-bearing tributary of Toboggan Creek, has been relocated away from the tributary.
- A cattle herd which had been over-wintered along Glass Creek at the head of Toboggan Lake has been relocated to the other side of the highway.

Recently agricultural management changes have been carried out in the Toboggan Creek watershed, as described by G. Tamblyn, Watershed Stewardship Coordinator (personal communication). Riparian fencing has been constructed along the confluence of Toboggan and Owens creeks. A cattle ranch will be relocating its overwintering and calving from lower Owens Creek to an upper pasture near Hopps Brook in the upcoming winter. 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. Sampling and Analytical Methods

3.1 Water Quality and Periphyton Monitoring Sites

Originally, ten monitoring sites were envisioned. This was reduced to eight sites due to budgetary constraints. The sites consist of an upstream 'control' site, a site downstream of Glacier Gulch Creek, the largest tributary; and one site each in Elliot and Owens Creeks, the next largest tributaries. Sites were established for the fish hatchery outflow channel and immediately upstream and downstream of the hatchery. The final site is Toboggan Creek upstream Highway 16 and the Bulkley River.

Monitoring site locations are shown in Figure 1. Water quality and periphyton site photos and location notes are found in Figures 3 and 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, the 1996-1998 study lacked a 'control' site which was upstream of most human influence. This resulted in difficulty in assessing the results without the use of comparative statistical techniques.

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; in addition, there would be difficulties in 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 1WP was established on Upper Toboggan Creek and sampled from September on. At this location, Upper Toboggan Creek passes between two hay fields with mature riparian cover. Although the hay is cut annually, cattle are not pastured or over-wintered on these fields and there is no permanent habitation on this property. Although there is open-range grazing during the summer months in the Glacier Gulch and Upper Toboggan Creek watersheds, the impact of this on water quality is expected to be minimal compared to confined seasonal feeding areas located lower in the watershed (Gaherty et al. 1996).

In August, Toboggan Creek, downstream of Glacier Gulch Creek and lake and upstream of the Elliot Creek confluence, was reached for sampling via the CNR grade. This site was relocated to Site 2W 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.

3.2 Water Monitoring and Analytical Methods

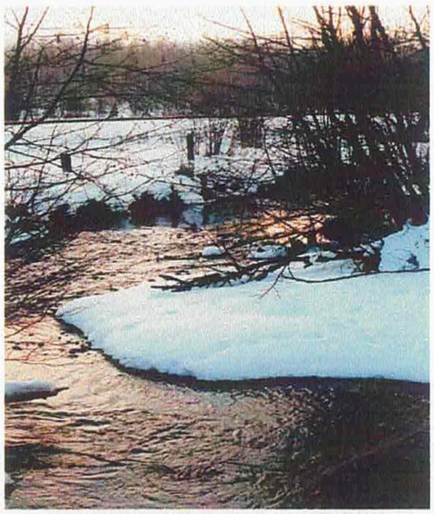
Water and bacterial sampling methods followed MELP standards: *Ambient freshwater and effluent sampling manual* (Cavanagh et al. 1994*a*) and *Biological sampling manual* (Cavanaugh et al. 1994*b*). Field parameters monitored included specific conductance, pH, water temperature and dissolved oxygen. Iced water samples were immediately shipped via air courier to North Vancouver for analysis by Pacific Environmental Science Centre laboratory. One set of triplicate samples was submitted for analysis each sampling date.

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.*

Figure 3 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.

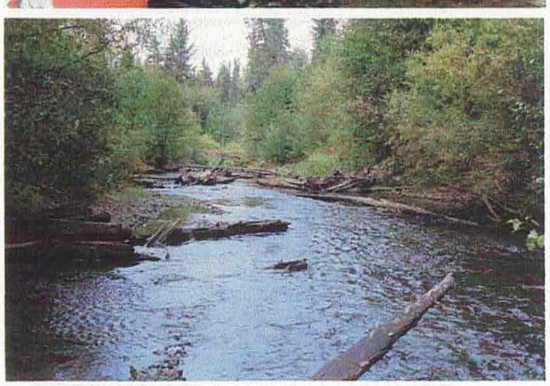


Site 2W **Toboggan Cr downstream Toboggan Lake** E245606 N54.8783 W127.2617

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.



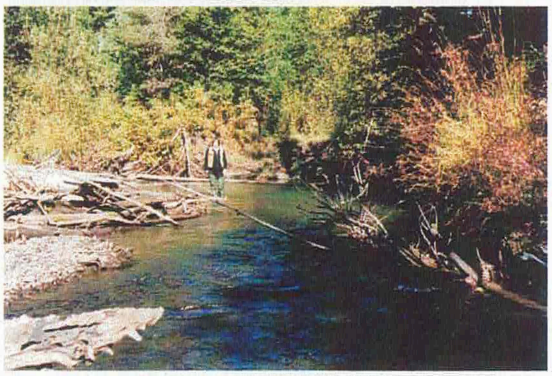
Site 4WP **Toboggan Creek upstream of fish hatchery** E245365 N54.8892 W127.2644

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.

Figure 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.

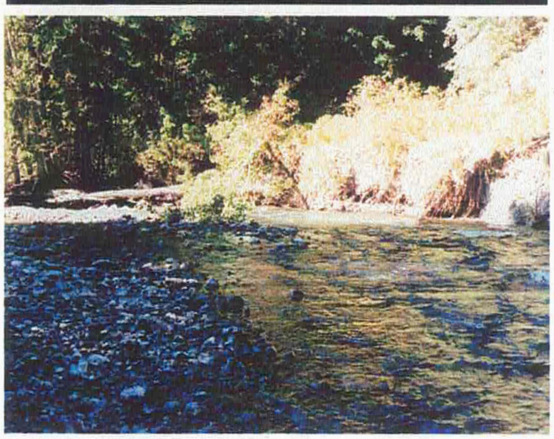


Site 6WP Toboggan Cr 100m downstream fish hatchery E245367 N54.8936 W127.27

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.

3.3 Periphyton Monitoring and Analytical Methods

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

Table 1 Physical characteristics of periphyton sampling locations Toboggan Creek September 2001

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

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 Pacific Environmental Science Centre.

Three periphyton samples for community analysis were collected at each site. 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. 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.

3.4 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 1 Table 3) and mailed to residents of the Toboggan Creek watershed in October 2001. The mailing list was derived from the MWLAP water license database.

4. Results and Comparison with Federal and Provincial Water Quality Guidelines

4.1 Water Quality Guidelines and Objectives

The Ministry of Water, Land and Air Protection (WLAP) 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 (CCREM 1999 with periodic updates) were developed in order to harmonize water quality guidelines used by provinces throughout Canada. The Canadian drinking water quality guidelines were most recently updated in March 2001.

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 criteria that have been adopted for the most sensitive designated use; and 3) the local conditions, including the actual measured water quality in the area. 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 criteria or guidelines, taking local circumstances into account. Objectives can be chosen above or below the criteria, 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.

4.2 Water Quality Results

4.2.1 Water quality QA/QC

Water quality data for each site are found in Appendix 2 Tables 1-10. 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, as shown in the Appendix 2 tables. Analysis of the replicate samples is found in Appendix 2 Table 11.

When three of 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* (Nagpal et al. 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 low for the replicate samples. Exceptional is October 15, where relative standard deviations for replicate TSS (total suspended sediments) and total phosphorus samples were 51% and 43%. A great deal of variation in suspended sediments is normal in streams, particularly during rainy fall weather, so result is not unexpected. Phosphorus-containing mineral particles are common, and total phosphorus levels are known to generally follow TSS levels. On the other hand, this could have been an example of a small amount of benthic sediment accidentally being collected with the water sample. The location, Owens Creek, is very shallow during low water making sampling difficult. On December 10, the relative standard deviation for replicate ammonia samples was 33%. Again, ammonia is known to adsorb readily to particulates (*Standard Methods*), thus concentrations of this substance will tend to show higher variability depending on TSS levels. Since no significant QA-related problems were noted in this data, blank samples were retained but not analyzed.

4.2.2 Water quality summary August 2001 –March 2002

Water analysis summary statistics for August through March are found in Table 2. The February water shipment to PESC for chemical analysis was lost by the courier so, unfortunately, an entire month of chemical data was lost. The microbiological shipment was not affected. On dates when triplicate samples were taken for QA/QC, the mean of the replicates was used in the calculation of summary statistics.

4.2.3 Water temperature

The BC water quality guidelines (WQGs) for water temperature for salmonids are:

- 18-19°C, maximum weekly average, adults and juveniles,
- 22-24°C, maximum, adults and juveniles
- 8-10°C, maximum weekly average for spawning, and
- 13-15°C, maximum for embryo survival.

The highest water temperature recorded in the 1996-98 study was 18°C in Glass Creek where it crosses a large field upstream of Toboggan Lake in late June 1996. The complete removal of riparian cover from this stream undoubtedly has 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 this study were on the late August to Early September sampling dates. On these dates, the temperature in Upper Toboggan and Glacier Gulch Creeks were 7 and 7.5°C. The Glacier Gulch Creek site is higher in elevation and both of these tributaries are well shaded by mature riparian forest. Water temperatures in both these streams are no doubt influenced by their glacial headwaters. The two smaller tributaries sampled, Elliot and Owens creeks, were both 8°C.

Water temperature in Toboggan Creek downstream of Toboggan Lake was 10°C (Site 2 and CNR). This increase is interpreted to be largely due to solar heating of the lake and the wetlands (beaver dams) along the CNR downstream of the lake. Water temperature was 11.2°C at Site 4 upstream of the fish hatchery, 10.5° C at Site 5 the hatchery outflow and Site 6 downstream of the hatchery, and 9.5°C at the Highway 16 crossing. Temperatures throughout the Toboggan mainstem equaled the maximum weekly average WQG for spawning on the two sampling dates. Pink and coho spawning, in the lower Toboggan mainstem, starts in the late-August to mid-September period so water temperatures are of concern to fisheries managers and may require further monitoring.

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). The maximum temperature recorded in the hatchery outflow channel was 10.5°C on 29-Aug-01. 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).

4.2.4 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, dissolved oxygen concentrations detrimental to salmonid survival were documented in a dug-out pond excavated in an unnamed fish-bearing tributary of Toboggan Creek. See Section 4.2.7 for further discussion.

Table 2 Water analysis summary Toboggan Creek watershed August 2001 to March 2002

Monitoring Site		Temp. water	Diss. Oxygen	Fecal coliform	TSS	pH	Specific Conduct-ance	Total Nitrogen	Ammonia (N)	Nitrite + Nitrate (N) LL	Diss. Inorg. Nitrogen	Nitrate (N)	Nitrite (N)	Phosphorus Total	Ortho-Phosphate (P) LL
		°C	(mg/L)	(CFU/100ml)	(mg/L)	(pH units)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	(mg/L)	(mg/L)	(mg/L)
Site 1 Upper Toboggan Cr	*Maximum*	7	15.9	19	10	7.94	150	0.88	0.009	0.670	0.678	0.668	< 0.002	0.020	0.001
	Minimum	0.3	11.6	< 1	< 5	7.39	41	0.11	< 0.005	0.091	0.096	0.194	< 0.002	< 0.002	< 0.001
	Average	2.8	12.8	6	6	7.71	98	0.52	0.007	0.363	0.370	0.429	< 0.002	0.007	< 0.001
	St. Dev.	2.8	1.8	8	2	0.23	48	0.29	0.001	0.227	0.228	0.195	0	0.008	*Median*
Glacier Gulch Cr		7.5	11.4	1	211	6.20	19	0.06	< 0.005	0.032	0.037			0.167	< 0.001
Site 2 Toboggan Cr downstream Toboggan Lake	*Maximum*	9.9	12.4	113	< 6	7.66	122	0.43	0.08	0.187	0.237	0.185	0.002	0.017	0.001
	Minimum	0.5	10.3	< 1	< 5	6.71	46	0.09	< 0.005	0.036	0.042	0.056	< 0.002	0.006	< 0.001
	Average	3.2	11.3	18	< 5	7.32	77	0.32	0.032	0.134	0.166	0.152	< 0.002	0.011	< 0.001
	St. Dev.	3.6	0.7	42	0	0.34	27	0.13	0.029	0.069	0.089	0.055	*Median*	0.004	*Median*
Toboggan Cr at CNR		10.0	10.8	13	< 5	6.91	60	0.08	< 0.005	0.027	0.032			0.006	< 0.001
Site 3 Elliot Cr	*Maximum*	8.0	15.8	118	< 5	8.03	160	0.13	0.008	0.142	0.147	0.140	< 0.002	0.003	< 0.001
	Minimum	1.5	11.2	< 1	< 5	7.46	116	0.05	< 0.005	0.048	0.053	0.046	< 0.002	< 0.002	< 0.001
	Average	4.1	12.2	16	< 5	7.79	141	0.09	0.006	0.069	0.075	0.074	< 0.002	< 0.002	< 0.001
	St. Dev.	2.4	1.6	41	0	0.20	13	0.03	0.001	0.034	0.033	0.038	0	*Median*	0
Site 4 Toboggan Cr upstream fish hatchery	*Maximum*	11.2	14.4	38	< 5	7.82	138	0.45	0.058	0.188	0.229	0.186	0.002	0.015	0.002
	Minimum	0.5	10.2	< 1	< 5	6.81	59	0.09	< 0.005	0.031	0.036	0.052	< 0.002	0.005	< 0.001
	Average	4.20	11.8	8	< 5	7.48	91	0.26	0.029	0.114	0.142	0.143	< 0.002	0.010	0.001
	St. Dev.	4.16	1.4	13	0 0	0.35	28	0.13	0.022	0.069	0.088	0.053	*Median*	0.004	0.0005
Site 5 Fish hatchery outflow channel	*Maximum*	10.5	15.6	11	19	7.87	124	0.44	0.122	0.194	0.260	0.192	0.002	0.078	0.009
	Minimum	0.5	8.9	< 1	< 5	7.42	90	0.30	0.049	0.063	0.125	0.074	< 0.002	0.015	0.002
	Average	4.1	11.4	5	7	7.57	111	0.38	0.076	0.128	0.204	0.151	< 0.002	0.029	0.006
	St. Dev.	4.0	2.2	4	5	0.17	13	0.05	0.029	0.057	0.045	0.045	*Median*	0.022	0.003
Site 6 Toboggan Cr 100m down-stream hatchery	*Maximum*	10.5	16.4	47	8	7.82	137	0.39	0.050	0.196	0.237	0.194	0.002	0.017	0.004
	Minimum	0.5	10.3	< 1	< 5	7.43	18	0.10	0.006	0.037	0.045	0.061	< 0.002	0.007	< 0.001
	Average	4.0	12.2	8	6	7.60	83	0.26	0.026	0.122	0.148	0.152	< 0.002	0.012	0.002
	St. Dev.	3.9	2.1	16	1	0.14	42	0.12	0.018	0.070	0.087	0.052	*Median*	0.003	0.001
Site 7 Owens Cr	*Maximum*	8.0	16.4	17	9	7.99	160	0.29	0.009	0.202	0.208	0.200	< 0.002	0.009	< 0.001
	Minimum	0.8	10.7	< 1	< 5	7.44	99	0.08	< 0.005	0.031	0.036	0.029	< 0.002	0.002	< 0.001
	Average	3.1	12.8	6	6	7.75	145	0.19	0.006	0.124	0.130	0.149	< 0.002	0.004	< 0.001
	St. Dev.	2.9	1.8	7	2	0.22	21	0.08	0.001	0.073	0.074	0.069	0	0.003	0
Site 8 Toboggan Cr upstream Highway 16	*Maximum*	9.5	17.8	59	11	7.96	153	0.58	0.032	0.253	0.285	0.251	0.002	0.035	0.003
	Minimum	0.3	10.6	< 1	< 5	6.85	60	0.10	< 0.005	0.044	0.049	0.067	< 0.002	0.004	< 0.001
	Average	3.5	13.3	17	7	7.66	109	0.32	0.015	0.153	0.169	0.193	< 0.002	0.013	0.002
	St. Dev.	3.9	2.3	19	2	0.39	31	0.18	0.011	0.094	0.103	0.074	Median	0.011	0.001

Dissolved oxygen was 10 mg/L or higher at all locations but the hatchery outflow channel in the 2001-2002 study period. The hatchery outflow had DO of 8.9 and 9.4 mg/L 29-Aug-01 and 17-Sep-01. The DO levels at all locations were above the criteria for post hatch and free-swimming stages of salmonids recommended by Davis (1975).

4.2.5 Total suspended sediments (TSS)

The glacial origins of Glacier Gulch Creek were very apparent in the TSS concentration of 211 mg/L on 30-Aug-01. Upper Toboggan Creek appears to be much less glacially influenced, with a TSS concentration of <5 mg/L on the first date it was sampled on 17-Sep-01. Toboggan Lake is interpreted to act as a settling pond, and average TSS concentrations are low downstream of the lake. Visually, glacial flour (comprised of very finely ground silt and clay particles) is apparent the length of Toboggan Creek.

4.2.6 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 low in Upper Toboggan Creek and downstream of the lake, ranging from 75-88 µS/cm. The two tributaries, Elliot and Owens Creeks, have higher average Specific conductance, each averaging 142 µS/cm. 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 (J. Veenstra, personal communication). Groundwater inflow is believed to significantly augment Toboggan Creek flows throughout its length (M. O'Neill, Toboggan Creek Fish Hatchery Manager, personal communication).

4.2.7 Ammonia and nitrite

Drainage from a dug-out pond, which had been excavated in a small unnamed tributary, was the subject of a DFO HRSEP investigation during the 1996-1998 study. 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 slough with cattle watering through the ice. An ammonia concentration higher than the provincial 30-day average guideline for ammonia was recorded during freshet, March 1998. Dissolved nitrogen and phosphorus concentrations in this tributary were elevated compared to other Toboggan watershed sites. Because of concern for the health of juvenile coho and rainbow trout/steelhead in the slough and downstream, a DFO fish protection order was issued and the winter feedlot was subsequently relocated.

Mean ammonia concentrations were 6 µg/L-N in Upper Toboggan/Glacier Gulch Creek, combined, and 6 µg/L-N in both Elliot and Owens Creeks (Table 4). Student's t test provides weak evidence for an increase in mean ammonia concentrations downstream of Toboggan Lake (at Site 2 and CNR combined) to average 19 µg/L-N (P=0.07). Student's t test of Site 1 and Site 4 (upstream of the hatchery) provides stronger evidence (P=0.04) for an increase in mean ammonia from 6 µg/L-N at Site 1 to 23 µg/L-N at Site 4.

An increase in ammonia concentration downstream of Toboggan Lake may be due to agricultural operations upstream, but could also simply result from biological activities in the extensive 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 this study was 122 µ/L-N in the hatchery 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 the temperature and pH recorded on that date is 1.84 mg/L-N. In order words, the 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 criteria. 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 an order of magnitude higher than recorded in this study.

Nitrite concentrations were consistently equal to or less than the detection limit of 2 µg/L-N at all 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.

4.3 Water Quality Trend Assessment

4.3.1 Upstream-downstream trends in water quality

In order to assess changes in water quality down the downstream gradient in Toboggan Creek, ANOVA was conducted on the data for the five mainstem sites. In this analysis, the data for Glacier Gulch Creek was combined with Upper Toboggan Creek (Site 1) and CNR was combined with Toboggan Creek downstream of the lake (Site 2). Table 3 shows 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 of no site effect. This analysis, using the data from all the mainstem sites, provides evidence for a slight increase in ortho-phosphate concentrations over the downstream gradient (P=0.04). It should be noted that this increase is very small, from 1 to 2 µg/L.

Table 3 Mean concentrations of selected nutrients and fecal coliform bacteria at five Toboggan Creek sites August 2001-March 2002 and probability of no site effect

mean concentration (µg/L) ± SE	Site 1 Upper Toboggan Cr + Glacier Gulch Cr	Site 2 Toboggan Cr downstream T. Lake + CNR	Site 4 Toboggan Cr upstream hatchery	Site 6 Toboggan Cr downstream hatchery	Site 8 Toboggan Cr upstream Hwy 16	probability of no site effect (P)
Ammonia (N)	7 ± 0.7	28 ± 11	29 ± 8	26 ± 7	15 ±4	0.19
DIN[1]	314 ± 100	147 ± 36	142 ± 33	148 ± 33	169 ± 39	0.14
Ortho-phosphate (P)	1 ± 0	1 ± 0	1.3 ± 0.2	2 ± 0.4	1.6 ± 0.3	0.04
Fecal coliform[2]	5 ± 3	17 ± 14	8 ± 4	8 ± 6	17 ± 7	0.71

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

[2] CFU/100 mL

4.3.2 Trends upstream and downstream of the fish hatchery

Student's *t* tests were conducted with the data for Site 4, upstream of the hatchery, and Site 6, 100 metres downstream of the hatchery outflow channel, in order to assess if the outflow had any effect on water quality in the mainstem. Student's *t* tests for ammonia (P=0.41), dissolved inorganic nitrogen (DIN) (P=0.46), fecal coliform bacteria (P=0.47), and dissolved oxygen (P=0.33) gave no evidence for a site effect. The Students *t* test for ortho-phosphate (P=0.08) provides weak evidence that ortho-phosphate levels may be increased in Toboggan Creek due to the hatchery outflow from mean 1.3 upstream to 2 µg/L-P downstream.

4.3.3 Temporal trends in water quality 1996-1998 and 2001-2002

Remington and Donas (1999) reported 1996-1998 water quality data for five sites in the Toboggan Creek mainstem. Student's *t* tests were conducted to compare data from the 1996-1998 study months August - March and this study months August - March. Note that the 1996-1998 study documented a peak in nutrient concentrations during early freshet (April) and this significant period for sampling is not included in this report. Three sites in the 1996-1998 study were essentially identical to sites in this study: Toboggan Creek at CNR and Site 2, Toboggan Creek at Evelyn and Site 4, and Toboggan Creek at Highway 16 and Site 8.

- Toboggan Creek at CNR (1996-1998) and Site 2 (2001-2002): Student's *t* tests for ammonia (P=0.46), nitrate+nitrite (P=0.29) and total phosphorus (P=0.48) do not provide evidence for a temporal effect at this site. The Student's *t* test for ortho-phosphate (P=0.07) provides weak evidence that a decrease in ortho-phosphate concentrations occurred from mean 19 µg/L-P in 1996-98 to mean 1 µg/L-P in 2001-2002.

- Toboggan Creek at Evelyn (1996-1998) and Site 4 (2001-2002): Student's *t* tests for ammonia (P=0.29) and nitrate+nitrite (P=0.28) provided no evidence for a temporal effect at this site. Student's *t* test for ortho-phosphate (P=0.08) provided weak evidence that ortho-phosphate concentrations decreased at this site from mean 10 µg/L-P in 1996-98 to mean 1.3 µg/L-P in 2001-2002.

- Toboggan Creek at Highway 16 (1996-1998) and Site 8 (2001-2002): Student's *t* tests for ammonia (P=0.17) and nitrate+nitrite (P=0.43) did not provide evidence for a temporal effect at this site. Student's *t* test for ortho-phosphate provided evidence (P=0.04) that ortho-phosphate concentrations decreased from the 1996-1998 mean of 10 µg/L-P to a 2001-2002 mean of 1.6 µg/L-P.

4.4 Comparison with other Skeena Watershed Streams 1983-1987

In 1982, MOELP Waste Management Branch initiated a 5 year monitoring program on major drainages of the Skeena River watershed. Data were collected monthly 1983-1987 and a summary published in 1990. Mean nutrient data (Wilkes and Lloyd 1990) are compared with August 2001-March 2002 mean data from this study's control Site 1, Upper Toboggan Creek, in Table 4. Total nitrogen levels are more than double in Upper Toboggan than the other streams. Most of the nitrogen is in the form of dissolved inorganic nitrite+nitrate. Nitrite+nitrate 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 agricultural overwintering operations, this cause is considered unlikely. The seasonal variation in nitrite+nitrate concentrations, with highest levels in late fall and winter (Appendix 2 Table 1), indicate that soil-water chemistry during passage through the riparian zone to the stream channel is responsible. This is a lesson in the importance of having an uninfluenced upstream control site for all water quality studies.

Table 4 Comparison of mean nutrient concentrations in Upper Toboggan Creek (August 2001 – March 2002) and other Skeena watershed streams (monthly 1983-1987)

µg/L	Total Nitrogen	Ammonia (N)	Nitrite+nitrate (N)	Total phosphorus	Ortho-phosphate
Upper Toboggan Creek (Site 1)	515	7.2	362.7	6.8	<1
Bulkley River at Quick	200	13.7	43.8	6.9	4.8
Telkwa River	152	10.2	73.8	5.1	3.7
Kispiox River	180	12.6	73.8	5.7	4.5
Morice River	120	8.2	37.5	5.2	<3

Source: Wilkes and Lloyd 1990

4.5 Water Quality Guidelines for Nutrients and Algae

The MELP 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.

4.5.1 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.

4.5.2 Protection of aquatic life guideline

A value of less than 100 mg/m^2 chlorophyll *a* is the MELP 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.
- 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.

4.5.3 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 orthophosphorus. The average N:P ratios for Toboggan Creek (Table 5) indicate strong P-limitation.

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 determining the development of nuisance algal growths. Nordin determined that inorganic nitrogen greater than 25 μg/L (for N-limited streams) or ortho-phosphorus greater than 3 μg/L (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 75 µg/L (Elliot Creek) to 370 µg/L (Upper Toboggan Creek) indicating that nitrogen is abundantly available, even at the control site upstream of agricultural and rural residential influences. Average ortho-phosphorus concentrations between 1 to 2 µg/L-P indicate that algal growth rates are limited by low bioavailable phosphorus.

Table 5 Mean N:P ratios[1] in Toboggan Creek August 2001 - March 2002

Site 1 Upper Toboggan Creek	Site 2 Toboggan Cr downstream Toboggan Lake	Site 3 Elliot Cr	Site 4 Toboggan Cr upstream fish hatchery	Site 5 Fish hatchery outflow channel	Site 6 Toboggan Cr 100m downstream hatchery	Site 7 Owens Cr	Site 8 Toboggan Cr upstream Highway 16
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)

4.6 Periphytic Algae Biomass and Community Composition Results

4.6.1 Periphytic algae biomass as chlorophyll *a*

Periphytic algae biomass measurements from Toboggan Creek in 1996, 1997 and 2001 are found in Appendix 3 Table 1. Mean periphytic algae biomass in 1996, 1997 and 2001 is found in Table 6. In the 1996 and 1997 studies, Reiseter Creek, which is a Bulkley River tributary of roughly the same size as Toboggan, 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 1996-97, periphyton sampling was conducted at the DFO assessment fence, which is located just downstream of the confluence of Owens Creek. The streambank has been armored with large rock in this location, resulting in a somewhat artificial 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.

Table 6 Mean periphytic algae biomass (chlorophyll *a)* on natural substrates in Toboggan Creek and control sites in September 1996, 1997 and 2001

1996	Reiseter Cr at Telkwa High Road (control)	Toboggan Cr upstream fish hatchery	Toboggan Cr at DFO assessment fence	probability of no site effect
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
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 (control)	Site 4 Toboggan Cr upstream fish hatchery	Site 6 Toboggan Cr downstream hatchery	Site 8P Toboggan Cr upstream Hwy 16	probability of no site effect
Chlorophyll *a* (mg/m^2) ± SE	1.27 ± 0.48	6.62 ± 4.67	8.17 ± 1.85	18.03 ± 5.3	0.03

QA/QC: Mean periphyton biomass was lower at all sites, including controls, in Toboggan Creek in 2001 than 1996 and 1997. As stated earlier, samples were collected according to WLAP sampling protocols, were stored frozen with activated desiccant and were shipped with dry ice. Samples were frozen upon arrival at Pacific Environmental Science Centre the next day (Larry Ye, PESC Sample Submission, personal communication). The samples were stored frozen at PESC until analysis on 4-Dec-01 (2.5 months). *Standard Methods* states that chlorophyll *a* samples may be stored frozen for as long as 30 days if kept in the dark, so perhaps storage time prior to analysis was a bit long resulting in some degradation of the pigments.

On the other hand, it was the author's visual estimation while doing the sampling that periphyton biomass at all sites was lower than in previous years. Possibly we missed the peak biomass of the growing season and some algal sloughing had occurred. The 2001 growing season was not particularly warm, so annual variability must also be considered.

4.6.2 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^3 chlor *a* and exceeded the guideline in 1997 with a mean biomass of 74 mg/m^3 chlor *a*. Periphyton biomass was lower in 2001, with a maximum at Site 8P of 18 mg/m^3 chlor *a*.

Student's *t* test conducted for Site 4 upstream of the hatchery and Site 6 downstream of the hatchery does not provide evidence for a change in mean periphyton biomass downstream of the hatchery compared to upstream (P=0.38).

ANOVA was conducted for each sampling year providing evidence (P≤0.05) for an increase in mean periphyton biomass along the downstream gradient in every year (Table 6). The river continuum concept (Vannote et al. 1980) states that a downstream pattern of increasing benthic algal biomass should occur from headwater to midcatchment reaches as streams coalesce, the channel becomes wider, and riparian shading is reduced. On the other hand, ortho-phosphate was shown to increase along the downstream gradient (Table 3) and Toboggan Creek is strongly phosphorus-limited with abundant background nitrogen concentrations to support algal growth.

4.6.3 Periphytic algae community composition

Periphytic algae 2001 community composition and biovolume is found in Appendix 3 Table 2. In 1996 and 1997, periphytic algal community composition was assessed as percent composition of the most common taxa (Appendix 3 Table 3). Mean periphytic algal biovolume by Division and genera richness in 2001 is found in Table 7. In the calculation of summary statistics, the taxon *Dinobryon sertularia* was omitted. D. *sertularia* is a non-diatom Chrysophte 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 7 Mean periphytic algal biovolume by Division and genera richness measured on natural substrate in Toboggan Creek September 2001

Algal Division	algal biovolume (μm^3 x 10^9 /m$^{2)}$ ± SE				probability of no site effect
	Site 1 Upper Toboggan	Site 4 Upstream Hatchery	Site 6 Downstream Hatchery	Site 8 Upstream Hwy 16	
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. Student's *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 (blue green algae) comprised less than 5% of biovolume at any site. Chlorophytes (green algae) 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).

Diatoms were the dominant algal division at all sites, comprising 92 to 100 % of algal biovolume at all sites except Site 6, where diatoms comprised 76%. Diatom biovolume and relative abundance are shown in Table 8. The dominant diatom taxa at Site 1 were *Gomphonema olivaceum* (64%) followed by *Achnanthes minutissima* (17%) and *Fragilaria* sp. (11%). The diatom found in greatest biovolume at the three sites downstream of the lake, *Gomphonema geminatum*, was completely absent at Site 1. *Gomphonema geminatum* was responsible for 75 to 85% of diatom biovolume at Sites 4, 6 and 8, followed by *Fragilaria* sp. *Gomphonema* has been found to represent a significant portion of diatom biomass in streams that have low soluble phosphorus concentrations (Chetelat et al. 1999).

Table 8 Diatom biovolume and relative abundance on natural substrates in Toboggan Creek in September 2001

Algal biovolume u3x109/m2	Mean Site 1 Upper Toboggan	Site 1 Relative abundance (percent)	Mean Site 4 Upstream Hatchery	Site 4 Relative Abundance (percent)	Mean Site 6 Downstream hatchery	Site 6 Relative Abundance (percent)	Mean Site 8P Upstream Hwy 16	Site 8 Relative Abundance (percent)
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	

4.7 Benthic Invertebrate Index of Biological Integrity (B-IBI) Assessment of Toboggan Creek 2001

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 benthic invertebrate 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 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 *draft* 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.

1. 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
2. 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.
3. Non Point Source (NPS) Agriculture: land clearing and crop harvest in the watershed, may include rural residential dwellings, or fish hatcheries
4. Municipal: Runoff from urban communities in direct proximity to sampling site.
5. Industrial: some type of non-point source discharge from an industrial operation
6. 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 9.

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 high biological condition.

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.

Table 9 Stream sites, human influence classification, average sample size and B-IBI score for 26 streams in the Bulkley TSA (Bennett and Hewgill *draft* 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

4.8 Drinking Water Source Quality Monitoring Summary

4.8.1 BC and Canadian drinking water quality guidelines

BC and Canadian drinking water quality guidelines for microbiological organisms are summarized in Table 10. Because microbiological organisms tend to adsorb to particulates (TSS), they are not uniformly distributed in water column and are subject to considerable sampling variation. Drinking water that fulfils the conditions outlined in Table 10 is considered to comply with federal and provincial guidelines.

Table 10 BC and Canadian Drinking Water Quality Guidelines (colonies/100mL) for microbiological indicators

<table>
<tr><th colspan="2">BC Guidelines for Raw Drinking Water</th><th>Canadian Drinking Water Quality Guidelines</th></tr>
<tr><td>-no treatment
-disinfection only
-partial treatment</td><td>Fecal coliforms
0
≤10 (90th perc.)
≤100 (90th perc.)</td><td rowspan="4">1. No sample should contain >10 total coliform organisms/100 mL; none of which should be Escherichia coli or thermotolerant coliforms: or

2. No consecutive sample from the same site should show the presence of coliform organisms; and

3. For community drinking water supplies:
a) not more than one sample from a set of samples taken from the community on a given day should show the presence of coliform organisms; and
b) not more than 10% of samples based on a minimum of 10 samples should show the presence of coliform organisms.</td></tr>
<tr><td>-no treatment
-disinfection only
-partial treatment</td><td>Escherichia coli
0
≤10 (90th perc.)
≤100 (90th perc.)</td></tr>
<tr><td>-no treatment
-disinfection only
-partial treatment</td><td>Enterococci
0
≤3 (90th perc.)
≤25 (90th perc.)</td></tr>
<tr><td>-no treatment</td><td>Pseudomonas aeruginosa
0</td></tr>
</table>

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.

Indicator organisms, such as coliform bacteria, provide an estimate of the degree of fecal contamination from human and animal wastes that are in the water (Warrington 1988). The general philosophy associated with using an indicator organism is that if it can be shown that fecal contamination of the water has occurred, then disease-causing organisms, such as *Cryptosporidium* and *Giardia*, may also be present. The maximum acceptable concentration for coliforms in drinking water is zero organisms detectable per 100 mL. The BC Ministry of Health recommends that all drinking water supplies derived from surface waters receive disinfection such as boiling.

4.8.2 Drinking water source quality results

In Toboggan Creek, eight of the 30 domestic drinking water intakes in the watershed are located on mainstem within 6 km of the mouth. Remington (1996, 1997) found fecal coliform and fecal streptococci concentrations in Toboggan Creek to exceed provincial drinking water protection guidelines on late summer sampling dates and suggested further monitoring.

A provincial Drinking Water Protection Plan initiative was undertaken in late 2001 by the Water Management Branch to monitor drinking water source quality in BC. The Lower Mainland, Vancouver Island and Skeena Region were chosen priorities for monitoring because heavy precipitation is typical during the fall months in coastal BC. A review was conducted of drinking water sources in Skeena region, including water sources for which BC water quality objectives and objectives monitoring locations have been established. A monitoring plan for 20 locations, including Toboggan Creek, encompassing bacteriological and chemical parameters was developed.

The water analysis data for Toboggan Creek from the MWLAP *Drinking Water Source Quality Monitoring: Skeena Region 2001* (Remington 2002) is found in Appendix 2 Tables 12 and 13 (reprinted with permission of R. Odense, Environmental Protection, Smithers). Summary Toboggan Creek results from this study are found in Table 11. The 4-Oct-01 bacteriology sample was delayed in shipment for longer than the recommended holding time for microbiological analysis. Therefore, the October 4 data was not used in calculation of the summary found in Table 11. Monthly and summary fecal coliform data from this study are found in Table 12.

Table 11 Drinking water source quality summary (five samples in a 30-day period) at Site 8W Toboggan Creek upstream Highway 16 (E245370) October 2001

Fecal coliform maximum	Fecal coliform 90th perc.	E. coli maximum	E. coli 90th perc.	Enterococci maximum	Enterococci 90th perc.	pH mean	Specific Conductance mean	True Color mean	Turbidity mean	Nitrate + Nitrite (N) mean	Nitrate (N) mean	Nitrite (N) mean
		(CFU/100ml)				(pH units)	(uS/cm)	(Col.unit)	(NTU)	(mg/L)	(mg/L)	(mg/L)
37	31.6	37	31.3	12	8.7	7.67	100.6	11.8	1.185	0.0681	0.0661	<0.002

Source: Remington, D. 2002. *Drinking Water Source Quality Monitoring: Skeena Region 2001*. Prepared for BC Ministry of Water, Land and Air Protection, Smithers, BC.

Table 12 Monthly and summary fecal coliform concentrations (CFU/100 ml) in the Toboggan Creek watershed August 2001-March 2002

	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
90th percentile	16	48	39	19	9	18	16	37
Average	6	18	16	8	5	8	6	17

4.8.3 Comparison to federal and provincial drinking water quality guidelines

Microbiological guidelines— Fecal coliform and *E. coli* concentrations during October 2001 (Table 11) were 31.6 and 31.3 CFU/100 mL (90^{th} percentile), respectively. An Enterococci concentration of 12 CFU/100 mL was recorded on one sampling date. Enterococci were not detectable in the remaining samples. Toboggan Creek was the only one of the 20 Skeena Region sites studied to have Enterococci present in the samples.

Toboggan Creek in October 2001 exceeded the WQGs, summarized in Table 10, for all three indicator organisms. Thus partial treatment, in addition to disinfection, is recommended prior to using the water for drinking, brushing teeth etc. Fecal coliform concentrations at the mouth of Toboggan Creek exceeded 10 CFU/100mL in six of the eight samples taken August 2001 through March 2002 (Table 12). The summary data presented in Table 12 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. Since fish are cold-blooded creatures, the hatchery fish are not contributors to fecal coliform loadings.

Physical and chemical guidelines— Mean turbidity, at 1.19 NTU, slightly 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 coloured but, on average, did not exceed the True Colour guideline of 15 TCU. Iron slightly exceeded the WQG on one sampling date, 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 drinking water quality guidelines.

4.9 Land and Water Use Survey Summary

Land and water use surveys were mailed to residents of the Toboggan Creek watershed in October 2001. Two 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 used their property primarily for rural residential use, with gardening and forestry also reported.

4.9.1 Rural residential land and water use information

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

Most of the residents reported that less than 50% of the stream on their property had been cleared of trees up to the streambank. Most residents reported 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 2.5.3 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 boiled or otherwise treated their drinking water. Half of the respondents using surface stream water sources did not boil or treated their drinking water. Half of the respondents using surface stream water sources either boiled or filtered their water prior to drinking or 'packed' drinking water from another source.

Eighty percent of respondents utilized septic tanks and drain fields for household sewage disposal and 20% utilized sewage lagoons. Half of septic drain fields were 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.

4.9.2 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.

4.9.3 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."

5. Discussion

5.1 Water Quality and Aquatic Ecosystem Monitoring Review

Several changes recommended in Remington and Donas (1999) were implemented in the 2001-2002 study design. A control site was added (Site 1 Upper Toboggan Creek) which is upstream of livestock over-wintering operations and permanent residences. The Toboggan Creek hatchery outflow (Site 5) and a site 100 m downstream of the outflow (Site 6) were added in order to isolate any influence of the hatchery from other NPS discharges. Elliot Creek and Owens Creek were added as monitoring locations in order to establish a baseline dataset and to assess possible NPS influences. The monthly water quality monitoring will be continued through July 2002 under the sponsorship of Environment Canada. This year of regularly collected water quality data, plus the periphyton and benthic-IBI data, will serve as a reproducible baseline dataset for future trend monitoring in this watershed.

The following question has been raised: Could the many salmon which spawn and subsequently die in Toboggan Creek affect measured nutrient levels this monitoring study? During the course sampling during the fall-early winter 2001, we paid attention to the number of salmon carcasses remaining in the stream at the monitoring sites. The signs of bears, including grizzlies, foraging in the creek for spawned-out salmon was intense through mid-November and well after early snow. There were also canine tracks along the creek, probably a dog pack, in the vicinity of Evelyn. Consequently, there were no visible salmon carcasses in the water at our monitoring sites by December. While these observations do not constitute a survey of the entire stream, they lead to author to doubt that rotting salmon in the stream had any significant affect on nutrient measurements.

Water temperature— Water temperatures exceeding provincial weekly average WQGs for spawning were recorded during summer-early fall periods in 1996-1998 and 2001. Elevated water temperatures are a concern to fisheries managers in Toboggan Creek and other upper Skeena watershed streams (T. Pendray, DFO Habitat Biologist, Skeena-Nass Area, personal communication). Research has shown that 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. To some extent, this is unavoidable in the Toboggan system, due to solar heating of shallow Toboggan Lake and associated wetlands. An increase in water temperature usually results from forestry and agricultural practices of removing mature riparian vegetation from streambanks. Stream segments lacking riparian cover have been documented throughout the lower watershed in Watershed Restoration Program (WRP) studies. Toboggan Creek has been identified as a priority watershed for riparian restoration activities.

Dissolved oxygen— DO was found at a safe level for protection of salmonids throughout the 2001-2002 study period.

Ammonia— 1996-1998 ammonia concentrations in the Toboggan mainstem did not exceed maximum or 30-day average ammonia WQGs. However, a seasonal trend in ammonia concentrations was observed, with a spike in the period of mid-February to mid-April, coincident with low elevation snowmelt.

In 2001-2002, mean ammonia concentrations increased downstream of the lake compared to the Upper Toboggan Creek control site, from 6 μg/L at Site 1 to 23 μg/L at Site 4. An increase in ammonia downstream of the lake may be due to agricultural operations upstream, but may also result from natural biological activities in the wetlands surrounding the lake (Section 4.2.7). Ammonia concentrations during the study period were consistently less than WQG concentrations for the protection of aquatic life. This study is not complete however, and data for the critical low elevation freshet period is not yet available.

Nitrite— Gibson (1997) reported erroneous nitrite concentrations for several Toboggan Creek sites during April-May 1996. The levels reported as nitrite were actually nitrate+nitrite. This led Gibson to conclude that WQGs had been exceeded, when this was not the case. The mistake was discovered following examination of the original 1996 laboratory reports. See Remington and Donas (1999) for the HRSEP 1996-1998 data.

In the 2001-2002 study period, nitrite concentrations were consistently ≤ the minimum detectable concentration of 2 μg/L-N at all sites and were well below WQG concentrations for the protection of aquatic life.

Upstream-downstream trends— ANOVA was conducted with the data for the five Toboggan mainstem sites. This analysis provides evidence for a slight increase in ortho-phosphate concentrations over the downstream gradient. It should be noted that the ortho-phosphate levels are very low and that any increase is slight: from 1 to 2 µg/L-P. There was no evidence for a change in mean concentrations of the other highly bioavailable nutrients, ammonia and dissolved inorganic nitrogen (DIN).

Temporal trends 1996-1998 Vs 2001-2002— A series of Student's *t* tests were conducted using data from three sites which were duplicated in the two studies (Site 2, Site 4 and Site 8). There was weak evidence ($P \leq 0.08$) of a decrease in ortho-phosphate concentrations at all three sites. Student's *t* test using ortho-phosphate data from Site 8, Toboggan Creek at Highway 16, provided evidence that ortho-phosphate concentrations decreased from the 1996-1998 mean of 9.7 µg/L-P to a 2001-2002 mean of 1.6 µg/L-P.

We strongly suggest that any possible trend in ortho-phosphate concentrations be viewed with caution until the completion of water quality sampling in 2002. The 1996-98 sampling was targeted toward the freshet period, so there were only three August-March dates which included ortho-phosphate data which we could use in trend analysis.

Mean ortho-phosphate concentrations (µg/L) and probability of no site effect

	1996-1998 mean	2001-2002 mean	probability of no site effect
Site 2	19	1	0.07
Site 4	10.4	1.3	0.08
Site 8	9.7	1.6	0.04

Nutrient control of periphytic algae growth— Nutrient information for the bulk of the 2001-2001 growing season is not available because this study was not initiated until late August. However, N:P ratios from 1996-1998 and this study indicate that Toboggan Creek is strongly P-limited. Experts in BC have estimated that inorganic nitrogen greater than 25 µg/L (for N-limited streams) or ortho-phosphate greater than 3 µg/L (for P-limited streams) to be factors contributing to high risk of excessive stream algal biomass (Nordin 1985). Average DIN concentrations in the Toboggan Creek mainstem (Table 3) ranged from 142 to 314 µg/L-N, indicating that nitrogen is abundantly available, even at the control site upstream of most agricultural and residential influences. Average ortho-phosphate concentrations of between 1 to 2 µg/L-P in 2001-2002 indicating that algal growth rates are limited by low bioavailable phosphorus concentrations.

Periphytic algal biomass and community composition— In 1996, periphyton biomass in lower Toboggan Creek roughly equaled the WQG for protection of recreation and aesthetics of ≤50 mg/m^3 chlor *a* and exceeded the guideline in 1997 with a mean biomass of 74 mg/m^3 chlor *a*. Periphyton biomass in 2001, with a maximum biomass at Site 8P of 18 mg/m^3 chlor *a*, was well below the WQGs for nutrients and algae.

ANOVA was conducted for each sampling year providing evidence ($P \leq 0.05$) for an increase in mean periphyton biomass along the downstream gradient (Table 6). A downstream pattern of increasing benthic algal biomass normally occurs from headwaters to midcatchment. However, in the Toboggan watershed linear developments and agricultural land clearing have resulted in less shading and possibly increased temperatures, which can stimulate algae growth as well. On the other hand, ortho-phosphate was shown to increase slightly along the downstream gradient and algae growth in Toboggan Creek is strongly phosphorus-limited.

Analysis of periphytic algal biovolume showed a similar trend, but with highest biovolume recorded at Site 6 downstream of the hatchery. Periphyton 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. Diatoms were the dominant algal division at all sites, comprising 92 to 100 % of algal biovolume at all sites except Site 6 downstream of the hatchery, where Chlorophytes comprised 24% of periphytic algal biovolume. Most of the green algae at Site 6 were the filamentous *Cladophora* sp. *Cladophora* is known to strongly respond to increases in bioavailable phosphorus concentrations.

Toboggan Creek fish hatchery— The Toboggan Creek fish hatchery is the only point source discharge in the watershed, and was monitored monthly in the 2001-2002 study. The highest ammonia concentration recorded in this study was 122 µ/L-N in the hatchery outflow channel 29-Aug-01. The maximum ammonia WQG at the temperature and pH on that date is 12.6 mg/L-N. The average 30-day WQG for the temperature and pH recorded on that date is 1.84 mg/L-N. In order words, the WQGs are one to two orders of magnitude higher than the maximum found in the hatchery outflow. At the temperature recorded 29-Aug-01, 10.5°C, the DO, at 8.9 mg/L, was roughly equal to the criteria level specified by Davis (1975) for salmonids at temperatures less than 15°C.

Student's *t* tests were conducted with data for Site 4, upstream of the hatchery, and Site 6, 100 metres downstream of the hatchery outflow channel, in order to assess possible effect of the outflow on water quality in mainstem. Student's *t* tests for ammonia, DIN, fecal coliform bacteria, and dissolved oxygen gave no evidence for a site effect. The Students *t* test for ortho-phosphate (P=0.08) provides weak evidence that ortho-phosphate levels may be increased in Toboggan Creek due to the hatchery outflow from mean 1.3 upstream to 2 µg/L-P downstream. We strongly suggest that any possible trend in ortho-phosphate concentrations be viewed with caution until the completion of water quality sampling in 2002.

Student's *t* test conducted with chlorophyll *a* data for Site 4 and Site 6 does not provide evidence for a change in mean periphyton biomass downstream of the hatchery compared to upstream. The mean periphyton biomass downstream of the hatchery was moderate, averaging 8.17 mg/m^2 chlor *a*. The periphytic algae community composition downstream of the hatchery was somewhat different from the other sites, with Chlorophytes comprised 24% of periphytic algal biovolume.

Benthic-IBI— 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). Streams that were uninfluenced reference sites had B-IBI scores ranging from 33 to 45 points. Trichoptera taxa richness in Toboggan Creek was comparable to uninfluenced sites in the Bulkley Timber Supply Area, 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, and a good sign for ecosystem health.

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.

Drinking water source quality monitoring— In Toboggan Creek, eight of the 30 domestic drinking water intakes in the watershed are located on mainstem within 6 km of the mouth. 1996 and 1997 studies in the Toboggan watershed found fecal coliform and fecal streptococci concentrations to exceed provincial drinking water protection guidelines on late summer sampling dates.

A provincial Drinking Water Protection Plan monitoring study was conducted in October 2001 in the Skeena Region which included five samples in a 30-day period at Site 8, Toboggan Creek upstream of Highway 16. Toboggan Creek in October 2001 exceeded the WQGs for all three indicator organisms. Thus partial treatment, in addition to disinfection, is recommended prior to using the water for drinking, brushing teeth etc.

Fecal coliform concentrations at Site 8 exceeded 10 CFU/100mL in six of the eight monthly samples taken August 2001 through March 2002. At the other sites, microbiological quality varied somewhat depending upon location in the watershed and seasonally, with the lowest bacterial counts in tributary streams and during the winter low-flow period. Since fish are cold-blooded creatures, the hatchery fish are not contributors to fecal coliform loadings.

5.2 Land and Water Use Review

A number of WRP studies have been conducted in the Toboggan Creek watershed in recent years. 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 (Section 2.5). Of 68 Bulkley River tributaries studied, Toboggan Creek was assessed as one of the five most severely degraded. Prescriptions for priority restoration works were prepared and presented to the Toboggan Creek Farmers Association during meetings in 1998. The association responded with support for an initial limited program: including repairing erosion areas on the creek with riprap; removing some problem obstacles; removing beavers and problem beaver dams; and opening some low areas with trenches. Fencing of creeks was not supported at that time. Possible works on other creeks were supported for future years.

When conducting water quality monitoring studies, such as this one, 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 and mailed to residents of the Toboggan Creek watershed in October 2001. Of the ten surveys returned, only one represented the agricultural community, resulting in a gap in information regarding this land use type.

In an attempt to fill this gap, we interviewed several provincial and federal government sources (Section 2.3.5). The total number of breeding cows in the Toboggan watershed is estimated at 1000 head and has varied little in recent years. Authorized animal unit months (AUMs) on crown range in the Bulkley Cassiar Forest District tend to vary somewhat depending on cattle prices, but are generally lower than they were in the early 1980s.

A number of positive changes have taken place in agricultural management practices in the Toboggan watershed since the 1996-1998 monitoring study. A cattle herd, which had been overwintered next a dug-out pond in an unnamed tributary, has been relocated (See Section 4.2.7 for discussion of aquatic impacts). A cattle herd, which had been overwintered along Glass Creek at the head of Toboggan Lake, has been relocated to the other side of Highway 16. Riparian fencing has been constructed along Toboggan Creek, Owens Creek and Hopps Brook and some riparian planting completed. The herd, which has been over-wintered along Toboggan and Owens creeks, will be relocated in 2002-03 to an upper fenced pasture utilizing a dugout water supply and automated stock trough system.

Changes have also taken place at the Toboggan Creek fish hatchery (Section 2.2). Overall, since 1997 fish densities at the hatchery have decreased. 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 over-wintered 153,000 smolts compared to 122,000 in 2001/02. Fry releases in 2001 were 38,500 compared to 38,600 in 1996. This resulted in over-wintering fish biomass of roughly 720 kg, down from a total of 1,680 kg at historical peak winter biomass.

The land and water use survey was successful in eliciting response from the rural residential community. Fifty percent of respondents had a stream on their property that was often used for household water supply and garden irrigation. Most of the residents reported that less than 50% of the stream on their property had been cleared of trees up to the streambank. Most residents reported a 30+ foot band of riparian shrubs and trees along the remainder of the stream on their property. Several residents responded that their entire property was in a forested, natural state.

Eighty percent of respondents utilized septic tanks and drain fields for household sewage disposal and 20% utilized sewage lagoons. Half of septic drain fields were over 25 years old. However, 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.

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 boiled or otherwise treated their drinking water. Half of the respondents using surface water sources either boil or filter their water prior to drinking or 'pack' drinking water from another source and one half drink raw surface water. Several residents expressed concern over agricultural fertilizer use, livestock concentrations, and livestock access to streams.

6. Conclusions

We are aware that a number of positive changes in agricultural management practices occurred in the Toboggan watershed between the 1996-98 and the 2001-02 monitoring. A reduction in overwintering density at the Toboggan Creek fish hatchery has also occurred during that time. Comparison of the August to March water quality data between the two studies indicates that a reduction in ortho-phosphate levels occurred throughout the Toboggan mainstem. This is significant because N:P ratios and overall nutrient levels indicate that periphytic algae growth in this system is strong controlled by phosphorus levels.

An overall reduction in periphytic algae biomass was found in the 2001 compared to 1996-97. In 1996 and 1997, periphyton biomass equaled or exceeded the WQG for aesthetics and recreation in the lower watershed and several blue-green algae considered as indicator species for eutrophication were present. Periphytic algae biomass did not exceed guidelines in 2001 but the presence (24% of total algal biovolume) of filamentous Chlorophytes was noted at Site 6 downstream of the hatchery.

The initial impression is that nutrient levels have lowered resulting in a reduction in periphytic algal biomass and this is good news for a watershed that was thought to show early signs of eutrophication. However, caution in drawing conclusions is advised until the results are available from the entire year of water quality monitoring, which is underway.

MWLAP drinking water source monitoring of Toboggan Creek (Site 8 upstream Highway 16) conducted in October 2001 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.

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 might 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.

Cooperation between several levels of government and landowners will be necessary in order to implement much-needed watershed 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.

In order to compile one year of monitoring data, Environment Canada and MWLAP are sponsoring the continuation of water quality sampling through the summer of 2002. The 1996-98 sampling was targeted toward the springtime surface runoff period; and a robust dataset is available for comparative analysis for these months. When complete, the water quality, drinking water, benthic algae and benthic invertebrate-IBI data collected in these studies will provide a solid baseline dataset for long-term trend monitoring in this watershed. The data collected in this study should also be valuable for fish hatchery management planning, particularly regarding stocking densities.

As promised, the information gained in this study will be shared and the Executive Summary of the study results will be mailed to Toboggan Creek watershed residents.

7. Recommendations

- Because of administrative delays in 2001, water quality data is not available for most of the growing season prior to periphyton biomass sampling in September. Due to the recent decision by Environment Canada and MWLAP to sponsor continued sampling, water quality data will be available for the 2002 growing season. We therefore recommend that periphyton biomass and community composition monitoring be conducted in late August 2002. Like most environmental parameters, periphytic algae biomass demonstrates a certain amount of annual variation. Several consecutive years of monitoring will help to establish a dataset useful for long-term management purposes.

- When the monitoring is complete, an addendum should be written that includes, at a minimum: summary data, comparison with WQGs, upstream/downstream trends and comparison with the 1996-98 study.

- There is a delicate line between a very productive watershed and a watershed that is tending to become eutrophic. An environmental impact study, particularly for nutrients and algae, would be appropriate coincident with any future major developments in this watershed, such as: a major increases in fish densities at the hatchery, major agricultural expansion, or new housing subdivisions.

8. References Cited

Barbour, M.T., J.L. Plafkin, B.P. Bradley, C.G. Graves, and R.W. Wisseman. 1992. Evaluation of EPA's rapid bioassessment benthic metrics: metric redundancy and variability among reference stream sites. *Environ. Toxicol. Chem.* **11**: 437-449.

BC Environment. 1999 ed. *Guidelines for interpreting water quality data.* Water Quality Section, Water Management Branch, MOELP, Victoria, BC.

____________. 1999 ed. *British Columbia water quality guidelines (criteria).* Water Quality Section, Water Management Branch, MOELP, Victoria, BC. http://www.elp.gov.bc.ca/wat/wq/BCguidelines/approved.html

Bennett, S. 2001. *A benthic invertebrate index of biological integrity for streams in the Bulkley TSA: field season 2000.* Prepared for Pacific Inland Resources, Bulkley Forest District and BC Environment, Smithers, BC.

Bennett, S. and K. Hewgill. 2002 *draft. The development of a benthic invertebrate index of biological integrity for streams in the Bulkley Timber Supply Area: field season 2001.* Prepared for Pacific Inland Resources, Bulkley Forest District and Ministry of Water Land and Air Protection, Smithers, BC.

Biggs, B.J.F. 1996. *Patterns in benthic algae of streams. In* R.J. Stevenson, M.L. Bothwell and R.L. Lowe, Editors, *Algal Ecology: Freshwater Benthic Ecosystems.* Academic Press 753pp.

Canadian Council of Resource and Environment Ministers (CCREM). 1999 and periodic updates. *Canadian Environmental Quality Guidelines.* CCREM, Winnipeg. http://www.mbnet.mb.ca/ccme/

Cavanagh, N., R.N. Nordin, L.G. Swain and L.W. Pommen. 1994*a*. *Ambient freshwater and effluent sampling manual.* MOELP, Water Quality Branch, Victoria.

Cavanagh, N., R.N. Nordin and P.D. Warrington. 1994*b*. *Biological sampling manual* (Field test edition). MOELP, Water Quality Branch, Victoria, BC.

Chetelat, J., F.J. Pick, A. Morin and P.B. Hamilton. 1999. *Periphyton biomass and community composition in rivers of different nutrient status.* Can. J. Fish. Aquat. Sci. **56**: 560-569.

Cooke, S.E. and E.E. Prepas. 1998. *Stream phosphorus and nitrogen export from agricultural and forested watersheds on the Boreal Plain.* Can.J. Fish. Aquat. Sci. **55**: 2292-2299.

Cooper, C.M. 1993. *Biological effects of agriculturally derived surface water pollutants on aquatic systems-a review.* Journal Environmental Quality **22**:402-408.

Davis, J.C. 1975. *Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review.* J.Fish. Res. Board Can. **32**(12):2295-2332.

Dillon, P.J., L.A. Molot and W.A. Scheider. 1991. *Phosphorus and nitrogen export from forested stream catchments in Central Ontario.* J. Environ. Qual. **20**:857-864.

Dykens, T. and S. Rysavy. 1998. *Operational inventory of water quality and quantity of river ecosystems in the Skeena Region (SB96-190INV): 1997 field season interim report.* Prepared for Ministry of Environment, Lands and Parks, Pollution Prevention Program, Skeena Region, Smithers, BC.

Fisheries Information Summary System (FISS) website: http://www.bcfisheries.gov.bc.ca/fishinv/fiss.html.

Galherty, W., H. Timmenga, G. Higginson, and G. Johnstone. 1996. *Review of cattle-community watershed conflicts in the Skeena Region.* Contract report prepared for MELP, Smithers, BC.

Gibson, L. 1997. *Toboggan Creek watershed restoration project Level 1 and 2 detailed assessment.* Prepared by Nortec Consulting for Watershed Restoration Program Ministry of Environment, Lands and Parks, Skeena Region, Smithers, BC.

Gottesfeld, A. 1985. *Geology of the northwest mainland.* Kitimat Centennial Museum Association, Kitimat, BC.

Hancock, M.J., A.J. Leaney-East and D.E. Marshall. 1983. *Catalogue of salmon streams and spawning escapements of Statistical Area 4 (Upper Skeena River).* Can. Data Rep. Fish. & Aquat. Sci. 394 324pp.

Karr, J.R. and E.W. Chu. 1999. *Restoring Life in Running Waters: Better Biological Monitoring.* Island Press, Washington, DC.

Kerans, B.L. and J.R. Karr. 1994. *A benthic index of biotic integrity (B-IBI- for rivers of the Tennessee Valley.* Ecol. Appl. 4: 768-785.

Kleindl, W.J. 1995. *A benthic index of biotic integrity for Puget Sound lowland streams, Washington, USA.* MS thesis, University of Washington, Seattle.

Loeher, R.C. 1974. *Characteristics and comparative magnitude of non-point sources.* Journal of Water Pollution Control Federation 46(8): 1849-1871.

Mackay, S. 1998. *EWET: The ecological watershed evaluation toolbox guidebook, V 1.* Prepared for Ministry of Environment, Lands and Parks, Pollution Prevention Program, Skeena Region, Smithers, BC.

Mitchell, S. 1997. *Riparian and in-stream assessment of the Bulkley River System: An examination and prioritization of impacts on the tributaries to the Bulkley River Mainstem.* Prepared by Nortec Consulting for the Department of Fisheries and Oceans, Smithers, BC.

Mould, J. 1976. *Stump farms and broadaxes.* Hancock House 101pp.

Nijman, R. 1986. *Bulkley River basin: water quality assessment and objectives.* Water Manage. Branch, MOELP, Victoria, BC.

Nordin, R.N. 1985. *Water quality criteria for nutrients and algae.* Water Manage. Branch, MOELP, Victoria, BC.

Nordin, R.N. and L.W. Pommen. 1986. *Water quality criteria for nitrogen (nitrate, nitrite and ammonia): Technical appendix.* Water Manage. Branch. MOELP, Victoria BC.

O'Neill[a], M. 1995, 1996, 1997. *Annual report for Toboggan Creek hatchery operations.* Toboggan Creek Salmon and Steelhead Enhancement Society, Smithers, BC.

O'Neill[b], M. 1994, 1995, 1996. *Toboggan Creek steelhead assessment.* Toboggan Creek Salmon and Steelhead Enhancement Society, Smithers, BC.

Prepas, E.E., D. Planas, J.J. Gibson, D.H. Vitt, T.D. Prowse, W.P. Dinsmore, L.A. Halsey, P.M. McEachern, S. Paquet, G.J. Scrimgeour, W.M. Tonn, C.A. Paszkowski and K. Wolfstein. 2001. *Landscape variables influencing nutrients and phytoplankton communities in Boreal Plain lakes of northern Alberta: a comparison of wetland-and upland-dominated catchments.* Can. J. Fish. Aquat. Sci. **58**:1286-1299.

Remington, D. 1997. *Survey of water quality and periphyton (algal) standing crop in the Bulkley River and tributaries, 1996.* Prepared for DFO Habitat & Enhancement Branch, Skeena/Nass, Smithers, BC.

__________. 1998. *Water quality and accumulation of periphyton (attached algae) in the Bulkley River and tributaries, 1997: relationship with land use activities in rural watersheds.* Prepared for DFO Habitat & Enhancement Branch, Skeena/Nass, Smithers BC.

_________. 2002. *Drinking water source quality monitoring: Skeena Region 2001.* Prepared for Environmental Protection, Ministry of Water, Land and Air Protection, Smithers, BC.

Remington, D. and B. Donas. 1999. *Water quality in the Toboggan Creek watershed 1996-1998: are land use activities affecting water quality and salmonid health?* Prepared for DFO-HRSEP and Community Futures Development Corporation of Nadina, Houston, BC.

Rysavy, S. 2000a. *Calibration of multimetric benthic invertebrate index of biological integrity for the Kispiox River Watershed: A tool for assessing & monitoring stream condition.* Prepared for the Kispiox Forest District Small Business Forest Enterprise Program, Hazelton, BC.

Rysavy, S. 2000b. *Calibration of multimetric benthic invertebrate index of biological integrity for the Upper Bulkley River Watershed: A tool for assessing & monitoring stream condition.* Prepared for the Community Futures Development Corporation of Nadina, Houston, BC.

Saimoto, R.K. *Toboggan Creek coho smolt enumeration.* 1995, 1996, 1997. Prepared for Pacific Biological Station by SKR Environmental Consultants for DFO, Smithers, BC.

Shervill, R.L. 1981. *Smithers, from swamp to village.* Town of Smithers, BC.

Sigma Environmental Consultants Ltd. 1983. *Summary of water quality criteria for salmonid hatcheries.* Department of Fisheries and Oceans. SECL 8067 Revised Edition 1983.

Silvicon Services Inc. 2000. *Summary report for Toboggan Creek stream rehabilitation and Silvern Lakes Road deactivation.* Prepared for Pacific Inland Resources (A Division of West Fraser Mills Ltd.), Smithers BC.

Stein, J. 1975. *Freshwater algae of British Columbia: the Lower Fraser Valley.* Syesis **8:**119-184.

Tredger, D. 1979. *An evaluation of fish habitat and fish populations in Toboggan Creek, near Smithers, relevant to steelhead enhancement opportunities.* Fish and Wildlife Branch, Min. Environment, Lands & Parks, Smithers, BC.

Triton Environmental Consultants Ltd. 1998. *Reconnaissance level fish and fish habitat inventory in the Bulkley TSA (Working unit #14-Toboggan).* Report and GIS (maps). Prepared for Pacific Inland Resources and FRBC, Smithers, BC.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. *The river continuum concept.* Can J. Fish. Aquat. Sci. **37**: 130-137.

Warrington, P.D. 1988. *Water quality criteria for microbiological indicators: technical appendix.* Resource Quality Section, Water Management Branch, MELP, Victoria BC.

Webb, B.W. and D.E. Walling. 1992. Water quality II. Chemical characteristics. Pp 73-100 *In* P. Calow and G.E. Petts, Eds. *Rivers Handbook: Hydrological and Ecological Principles* V.1. Blackwell Scientific Publications, Oxford.

Welch, E.B. 1980. *Ecological effects of waste water.* Cambridge University Press 337 pp.

Wilkes, B. and R. Lloyd. 1990. *Water quality summaries for eight rivers in the Skeena River drainage, 1983-1987: the Bulkley, upper Bulkley, Morice, Telkwa, Kispiox, Skeena, Lakelse and Kitimat Rivers.* Environmental Section Report 90-04. Skeena Region MELP, Smithers BC.

Appendix 1 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(*100)	5900	6200	6500	7200	7800	7800	7400	8100	7700	7900	5800
auth. AUMs	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*	2001
tenures(*100)	6800	7000	6700	6300	6900	6900	6500	6400
auth. 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

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

Appendix 1 Table 2. Water Use Licenses in the Tobbogan Creek watershed

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
	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	Domestic	Lychak, P.	RR1 Smithers, BC,V0J 2NO
			23.00 AF	Irrigation		
	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	Domestic	Van Alphen, K.J.	Box 3814 Smithers, BC,V0J 2NO
			50.00 AF	Irrigation		
	F010351	1929	500.00 GD 50.00 AF	Domestic Irrigation	Mott, D.C. & J.A.	RR1 C21 S25 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 1 Table 2 (continued). Water Use Licenses in the Tobbogan Creek watershed

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
	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 80.00 AF	Stock Watering Irrigation	Lychak Enterprises Ltd.	Box 621 Smithers, BC,V0J 2NO
	C106257	1993	500.00 GD 9.90 AF	Domestic Irrigation	Glass, D.G. & J.	Box 2042 Smithers, BC,V0J 2NO
	C105947	1992	40.0 AF	Irrigation	Huisman, O. & C.	RR1 Box 7 Site 25 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 1 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 1 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 2 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. Conductance (uS/cm)	Fecal coliform (CFU/100ml)	Residue Non filterable (TSS) (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
17-Sep-01	7.0	11.6	7.6	30	13	< 5	7.54	41
17-Sep-01						< 5	7.34	41
17-Sep-01						< 5	7.3	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
10-Dec-01	frozen - unable to sample							
08-Jan-02	0.25	12.7			< 1	< 5	7.82	150
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.25	15.9	8.0	120	< 1	< 5	7.94	144

Date	Total Nitrogen (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
17-Sep-01	0.11	< 0.005	0.092	0.097			0.002	< 0.001
17-Sep-01	0.11	< 0.005	0.092	0.097			< 0.002	< 0.001
17-Sep-01	0.10	< 0.005	0.090	0.095			< 0.002	< 0.001
15-Oct-01	0.38	0.007	0.196	0.203	0.194	< 0.002	0.003	< 0.001
12-Nov-01	0.88	0.008	0.670	0.678	0.668	< 0.002	0.02	0.001
10-Dec-01	frozen - unable to sample							
08-Jan-02	0.67	0.007	0.452	0.459	0.450	< 0.002	0.007	< 0.001
11-Feb-02	lost shipment							
11-Mar-02	0.54	0.009	0.404	0.413	0.402	< 0.002	< 0.002	0.001

Appendix 2 Table 2 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 (TSS) (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)	DIN (mg/L)	(mg/L)	Total Organic Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
30-Aug-01	0.06	< 0.005	0.032	0.037		0.023	0.167	< 0.001

Appendix 2 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 (TSS) (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
12-Nov-01						< 5	7.59	69
12-Nov-01						7	7.58	69
10-Dec-01	1.0	11.3	8.4	60	1	< 5	7.42	82
08-Jan-02	0.75	10.3			5	< 5	7.66	122
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.5	12.4	7.1	70	1	6	7.20	88

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N). (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
17-Sep-01	0.09	0.006	0.036	0.042			0.006	< 0.001
15-Oct-01	0.32	< 0.005	0.058	0.063	0.056	< 0.002	0.008	< 0.001
12-Nov-01	0.27	0.015	0.179	0.194	0.177	< 0.002	0.011	< 0.001
12-Nov-01	0.27	0.018	0.183	0.201	0.181	< 0.002	0.011	0.001
12-Nov-01	0.26	0.017	0.176	0.193	0.174	< 0.002	0.010	0.001
10-Dec-01	0.43	0.038	0.187	0.225	0.185	< 0.002	0.010	0.001
08-Jan-02	0.40	0.044	0.187	0.231	0.185	0.002	0.009	< 0.001
11-Feb-02	lost shipment							
11-Mar-02	0.39	0.080	0.157	0.237	0.155	< 0.002	0.016	0.001

Appendix 2 Table 4 Water analysis data Toboggan Cr at CNR downstream 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 (TSS) (mg/L)	pH (pH units)
30-Aug-01	10.0	10.8	7.4	50	13	< 5	6.91

Date	Specific Conduct ance (uS/cm)	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
30-Aug-01	60	0.08	< 0.005	0.027	0.032	0.006	< 0.001

Appendix 2 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. Conductance (uS/cm)	Fecal Coliform (CFU/100ml)	Residue Non-filterable (TSS) (mg/L)	pH (pH units)	Specific Conductance (uS/cm)
30-Aug-01	8.0	11.4	8.1	120	1	< 5	7.71	143
30-Aug-01						< 5	7.97	145
30-Aug-01						< 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	7.8	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
08-Jan-02	3.0	11.6			< 1	< 5	7.46	116
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	1.5	15.8	7.6	110	< 1	< 5	7.61	138

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
30-Aug-01	0.08	< 0.005	0.048	0.053			< 0.002	< 0.001
30-Aug-01	0.06	< 0.005	0.047	0.052			< 0.002	< 0.001
30-Aug-01	0.09	< 0.005	0.048	0.053			< 0.002	< 0.001
17-Sep-01	0.09	0.006	0.054	0.060			< 0.002	< 0.001
15-Oct-01	0.13	< 0.005	0.064	0.069	0.062	< 0.002	< 0.002	< 0.001
12-Nov-01	0.11	< 0.005	0.142	0.147	0.140	< 0.002	< 0.002	< 0.001
10-Dec-01	0.08	0.008	0.048	0.056	0.046	< 0.002	0.003	< 0.001
08-Jan-02	0.05	0.007	0.051	0.058	0.049	< 0.002	< 0.002	< 0.001
11-Feb-02	lost shipment							
11-Mar-02	0.07	< 0.005	0.075	0.080	0.073	< 0.002	< 0.002	< 0.001

Appendix 2 Table 6 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 (TSS) (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	7.4	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
10-Dec-01						< 5	7.69	96
10-Dec-01						< 5	7.71	96
08-Jan-02	1	11.6	n/a		3	< 5	7.82	138
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.5	14.4	7.2	90	2	< 5	7.41	110

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
29-Aug-01	0.09	0.005	0.031	0.036			0.008	0.001
17-Sep-01	0.10	0.018	0.039	0.057			0.005	< 0.001
15-Oct-01	0.22	< 0.005	0.054	0.059	0.052	< 0.002	0.007	0.001
12-Nov-01	0.28	0.020	0.160	0.18	0.158	< 0.002	0.013	0.002
10-Dec-01	0.52	0.073	0.171	0.244	0.169	< 0.002	0.014	0.001
10-Dec-01	0.37	0.043	0.172	0.215	0.170	< 0.002	0.013	0.001
10-Dec-01	0.45	0.043	0.171	0.214	0.169	< 0.002	0.010	0.001
08-Jan-02	0.34	0.041	0.188	0.229	0.186	0.002	0.01	< 0.001
11-Feb-02	lost shipment							
11-Mar-02	0.34	0.058	0.154	0.212	0.152	< 0.002	0.015	0.002

Appendix 2 Table 7 Water analysis data Site 5 Fish hatchery outflow channel (E245366) 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 (TSS) (mg/L)	pH (pH units)	Specific Conductance (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
08-Jan-02	1.0	12.0	n/a		7	< 5	7.46	116
08-Jan-02						< 5	7.45	115
08-Jan-02						< 5	7.48	115
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.5	15.6	7.3	100	2	< 5	7.44	122

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
29-Aug-01	0.40	0.122	0.063	0.185			0.078	0.006
17-Sep-01	0.30	0.112	0.065	0.177			0.024	0.009
15-Oct-01	0.40	0.049	0.076	0.125	0.074	< 0.002	0.024	0.008
12-Nov-01	0.34	0.062	0.162	0.224	0.160	< 0.002	0.023	0.006
10-Dec-01	0.44	0.057	0.173	0.23	0.171	< 0.002	0.015	0.003
08-Jan-02	0.40	0.062	0.193	0.255	0.191	0.002	0.020	0.005
08-Jan-02	0.39	0.068	0.195	0.263	0.193	0.002	0.021	0.005
08-Jan-02	0.42	0.068	0.195	0.263	0.193	0.002	0.021	0.005
11-Feb-02	lost shipment							
11-Mar-02	0.34	0.063	0.161	0.224	0.159	< 0.002	0.021	0.002

Appendix 2 Table 8 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
08-Jan-02	1.0	12.5			3	< 5	7.55	137
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.5	16.4	7.6	110	4	< 5	7.63	128

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
29-Aug-01	0.1	0.008	0.037	0.045			0.010	< 0.001
17-Sep-01	0.11	0.006	0.044	0.050			0.007	< 0.001
15-Oct-01	0.22	0.009	0.063	0.072	0.061	< 0.002	0.013	0.004
12-Nov-01	0.32	0.031	0.163	0.194	0.161	< 0.002	0.017	0.003
10-Dec-01	0.39	0.038	0.178	0.216	0.176	< 0.002	0.010	0.002
08-Jan-02	0.38	0.041	0.196	0.237	0.194	0.002	0.012	0.002
11-Feb-02	lost shipment							
11-Mar-02	0.31	0.050	0.170	0.220	0.168	< 0.002	0.015	0.001

Appendix 2 Table 9 Water analysis data Site 7 Owens Cr (E245368) 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	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
15-Oct-01						< 5	7.80	147
15-Oct-01						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
08-Jan-02	1.0	12.9			< 1	< 5	7.44	99
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	1.0	16.4	8.0	130	< 1	< 5	7.83	160

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
29-Aug-01	0.08	< 0.005	0.049	0.054			0.006	< 0.001
17-Sep-01	0.11	< 0.005	0.061	0.066			0.003	< 0.001
15-Oct-01	0.18	< 0.005	0.030	0.035	0.028	< 0.002	0.013	< 0.001
15-Oct-01	0.23	< 0.005	0.032	0.037	0.030	< 0.002	0.005	< 0.001
15-Oct-01	0.15	< 0.005	0.031	0.036	0.029	< 0.002	0.010	< 0.001
12-Nov-01	0.22	0.009	0.188	0.197	0.186	< 0.002	0.003	< 0.001
10-Dec-01	0.29	0.007	0.162	0.169	0.160	< 0.002	0.003	< 0.001
08-Jan-02	0.27	0.006	0.202	0.208	0.200	< 0.002	0.003	< 0.001
11-Feb-02	lost shipment							
11-Mar-02	0.19	0.007	0.172	0.179	0.170	< 0.002	< 0.002	0.001

Appendix 2 Table 10 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 (TSS) (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
08-Jan-02	0.3	13.5			27	9	7.61	113
11-Feb-02	n/a				< 1	lost shipment		
11-Mar-02	0.25	17.8	8.3	130	2	< 5	7.91	153
11-Mar-02						< 5	7.90	154
11-Mar-02						< 5	7.92	153

Date	Nitrogen Total (mg/L)	Ammonia (N) (mg/L)	Nitrite + Nitrate (N) LL (mg/L)	Diss. Inorg. Nitrogen (mg/L)	Nitrate (N) (mg/L)	Nitrite (N) (mg/L)	Phosphorus Total (mg/L)	Ortho-Phosphate (P) LL (mg/L)
29-Aug-01	0.10	0.005	0.044	0.049			0.010	< 0.001
17-Sep-01	0.11	< 0.005	0.053	0.058			0.005	< 0.001
15-Oct-01	0.22	< 0.005	0.069	0.074	0.067	< 0.002	0.004	< 0.001
12-Nov-01	0.58	0.020	0.200	0.22	0.198	< 0.002	0.035	0.003
10-Dec-01	0.40	0.027	0.214	0.241	0.212	< 0.002	0.008	0.002
08-Jan-02	0.46	0.032	0.253	0.285	0.251	0.002	0.019	0.002
11-Feb-02	lost shipment							
11-Mar-02	0.35	0.009	0.240	0.249	0.238	< 0.002	0.008	0.001
11-Mar-02	0.35	0.016	0.242	0.258	0.240	< 0.002	0.007	0.001
11-Mar-02	0.35	0.016	0.240	0.256	0.238	< 0.002	0.007	0.002

Appendix 2 Table 11 Data quality assessment: analysis of triplicate sequential water samples

	Residue Non-filterable (TSS)	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	7.9	144.3333	0.076667	0.005	0.047667		0.002	0.001
St. Dev.	0	0.166433	1.154701	0.015275	8.23E-11	0.000577		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 Cr	5	7.34	41	0.11	0.005	0.092		0.002	0.001
17-Sep-01	5	7.3	42	0.10	0.005	0.090		0.002	0.001
Mean	5	7.393333	41.33333	0.106667	0.005	0.091333		0.002	0.001
St. Dev.	0	0.128582	0.57735	0.005774	8.23E-11	0.001155		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	7.806667	146	0.186667	0.005	0.031	0.002	0.00933333	0.001
St. Dev.	4.582576	0.011547	1	0.040415	8.23E-11	0.001	0	0.00404145	0
Relative St. Dev.	51%	0%	1%	22%	0%	3%	0%	43%	0%
Site 2 TC	5	7.63	69	0.27	0.015	0.179	0.002	0.011	0.001
d/s 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	5.666667	7.6	69	0.266667	0.016667	0.179333	0.002	0.01066667	0.001
St. Dev.	1.154701	0.026458	0	0.005774	0.001528	0.003512	0	0.00057735	0
Relative St. Dev.	20%	0%	0%	2%	9%	2%	0%	5%	0%
Site 4 TC	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	7.776667	100	0.446667	0.053	0.171333	0.002	0.01233333	0.001
St. Dev.	0	0.133167	6.928203	0.075056	0.017321	0.000577	0	0.00208167	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	7.463333	115.3333	0.403333	0.066	0.194333	0.002	0.02066667	0.005
St. Dev.	0	0.015275	0.57735	0.015275	0.003464	0.001155	0	0.00057735	8.232E-11
Relative St. Dev.	0%	0%	1%	4%	5%	1%	0%	3%	0%

Appendix 2 Table 12 Water analysis data Toboggan Creek upstream Highway 16 (E245370) October 2001

Date	Fecal coliform (CFU/100ml)	*E. coli* (CFU/100ml)	Enterococci (CFU/100ml)	pH (pH units)	Specific Conductance (uS/cm)	Color True (Col.un	Turbidity (NTU)	Nitrite + Nitrate (N) Diss. (mg/L)	Nitrate (N) Diss. (mg/L)	Nitrite (N) Diss. (mg/L)
04-Oct-01	1*	1*	< 1*	7.41	90	8	1.15	0.048	< 0.046	< 0.002
10-Oct-01	19	18	12	7.69	100	< 13	0.1	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
22-Oct-01				7.78	105	11	1.51	0.081	< 0.079	< 0.002
29-Oct-01	17	8	< 1	7.94	112	< 16	1.9	0.096	< 0.094	< 0.002

Source: Remington, D. 2002. *Drinking Water Source Quality Monitoring: Skeena Region 2001*. Prepared for BC Ministry of Water, Land and Air Protection, Smithers, BC.

* Not analyzed within recommended holding times

Appendix 2 Table 13 Water analysis for total metals Toboggan Creek upstream Highway 16 (E245370) October 2001
mg/L

Date	Hardness-T	Ag-T	Al-T	As-T	B--T	Ba-T	Be-T	Bi-T	Ca-T	Cd-T
10/04/01	34.96267134 <	0.00002	0.0477	0.0006	0.004	0.00979	0.000004 <	0.00002	10.7 <	0.00001
10/10/01	43.4437 <	0.01	0.17 <	0.06 <	0.01	0.012 <	0.001		14.1 <	0.006
10/15/01	47.83732188 <	0.00002	0.036	0.0003	0.005	0.01113	0.000004 <	0.00002	15.4	0.00001
10/22/01	48.2625 <	0.01	0.06 <	0.06 <	0.01	0.011 <	0.001		15.7 <	0.006
10/22/01	49.0116 <	0.01	0.06 <	0.06 <	0.01	0.012 <	0.001		16 <	0.006
10/29/01	45.104 <	0.01	0.08 <	0.06 <	0.01	0.01 <	0.001		14.6 <	0.006

Date	Co-T	Cr-T	Cu-T	Fe-T	Li-T	K--T	Mg-T	Mn-T	Mo-T	Na-T
10/04/01	0.000071	0.009	0.00159	0.221	0.00013	0.3	2.00213	0.019855	0.01143	1.4
10/10/01 <	0.006 <	0.006 <	0.006	0.462		0.5	2	0.034 <	0.01	1.8
10/15/01	0.000047	0.0002	0.00127	0.258	0.00023	0.3	2.27866	0.02567	0.00545	1.8
10/22/01 <	0.006 <	0.006 <	0.006	0.255		0.4	2.2	0.027 <	0.01	1.8
10/22/01 <	0.006 <	0.006 <	0.006	0.256		0.4	2.2	0.026 <	0.01	1.9
10/29/01 <	0.006 <	0.006 <	0.006	0.278		0.4	2.1	0.025 <	0.01	2

Date	Ni-T	P--T	Pb-T	S--T	Sb-T	Se-T	Si-T	Sn-T	Sr-T	Ti-T
10/04/01	0.0007 <	0.1	0.00004	3.5	0.000077	0.0003	2.6 <	0.00001	0.044135	0.002
10/10/01 <	0.02 <	0.1 <	0.06	3.82 <	0.06 <	0.06	3.1 <	0.06	0.042	0.004
10/15/01	0.00066 <	0.1	0.00003	3.85	0.000087 <	0.0002	2.94 <	0.00001	0.061654 <	0.002
10/22/01 <	0.02 <	0.1 <	0.06	3.69 <	0.06 <	0.06	3.22 <	0.06	0.045	0.002
10/22/01 <	0.02 <	0.1 <	0.06	3.66 <	0.06 <	0.06	3.25 <	0.06	0.046	0.002
10/29/01 <	0.02 <	0.1 <	0.06	3.33 <	0.06 <	0.06	2.89 <	0.06	0.044 <	0.002

Date	Tl-T	U--T	V--T	Zn-T
10/04/01	0.000005	0.000012	0.0025	0.0003
10/10/01		<	0.01 <	0.002
10/15/01 <	0.000002	0.000024	0.00064	0.0001
10/22/01		<	0.01 <	0.002
10/22/01		<	0.01 <	0.002
10/29/01		<	0.01 <	0.002

Source: Remington, D. 2002. *Drinking Water Source Quality Monitoring: Skeena Region 2001*. Prepared for BC Ministry of Water, Land and Air Protection, Smithers, BC.

Appendix 3 Table 1 Periphyton biomass as chlorophyll *a* (mg/m²) on natural substrates in Toboggan Creek and control (Reiseter Cr) in September 1996, 1997 & 2001

	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

	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 (control) 12-Sep-01	Site 4 Toboggan Cr upstream fish hatchery 12-Sep-01	Site 6 Toboggan Cr 100 m downstream hatchery 13-Sep-01	Site 8P Toboggan Cr 500 m upstream Highway 16 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

Appendix 3 Table 2 Periphyton community composition analysis Toboggan Creek September 2001

Division	Species		U/S Lake Rep 1 12/09/01		U/S Lake Rep 2 12/09/01		U/S Lake Rep 3 12/09/01		at Hatchery Intake Rep 1 12/09/01		at Hatchery Intake Rep 2 12/09/01		at Hatchery Intake 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 3 Table 2 Periphyton community composition analysis Toboggan Cr

Division	Species		D/S Hatchery Rep 1 12/09/01		D/S Hatchery Rep 2 12/09/01		D/S Hatchery Rep 3 12/09/01		U/S HWY Rep 1 12/09/01		U/S HWY Rep 2 12/09/01		U/S HWY 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	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 3 Table 3 Periphyton taxonomic composition Toboggan and Reiseter creeks 1996 & 1997

Site 2 Toboggan Creek @ Evelyn 10-Sep-96

Taxon	%
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 %

* Large amount of inorganic sediment present in sample.

Site 2 Toboggan Creek @ Evelyn 18-Sep-97

Taxon	%
Chrysophyta	100 %
Bacillariophyceae	
Synedra ulna	60 %
Gomphonema sp.	20 %
Cymbella sp.	10 %
Tabellaria fenestrata	10 %

* Inorganic sediment present

Site 4 Toboggan Creek @ fence 11-Sep-96

Taxon	%
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 %

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

Site 4 Toboggan Creek @ fence 22-Sep-97

Taxon	%
Cyanophyta	5 %
Oscillatoria sp.	100 %
Chrysophyta	95 %
Bacillariophyceae	
Gomphonema geminatum	55 %
Synedra ulna	20 %
Achnanthes sp.	10 %
Cymbella sp.	15 %

* Algal mat:
Gomphonema geminatum on stalks
Spirogyra sp.
Ulothrix sp.
Oscillatoria sp.

Reiseter Creek @ High Road 11-Sep-96

Taxon	%
Chrysophyta	100 %
Bacillariophyceae	
Gomphonema geminatum	30 %
Synedra ulna	10 %
Hannaea arcus	10 %
Achnanthes spp.	20 %
Gomphonema spp.	20 %
Fragilaria spp.	10 %

Reiseter Creek @ High Road 17-Sep-97

Taxon	%
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 %

* Algal Clumps: Gomphonema geminatum on stalks