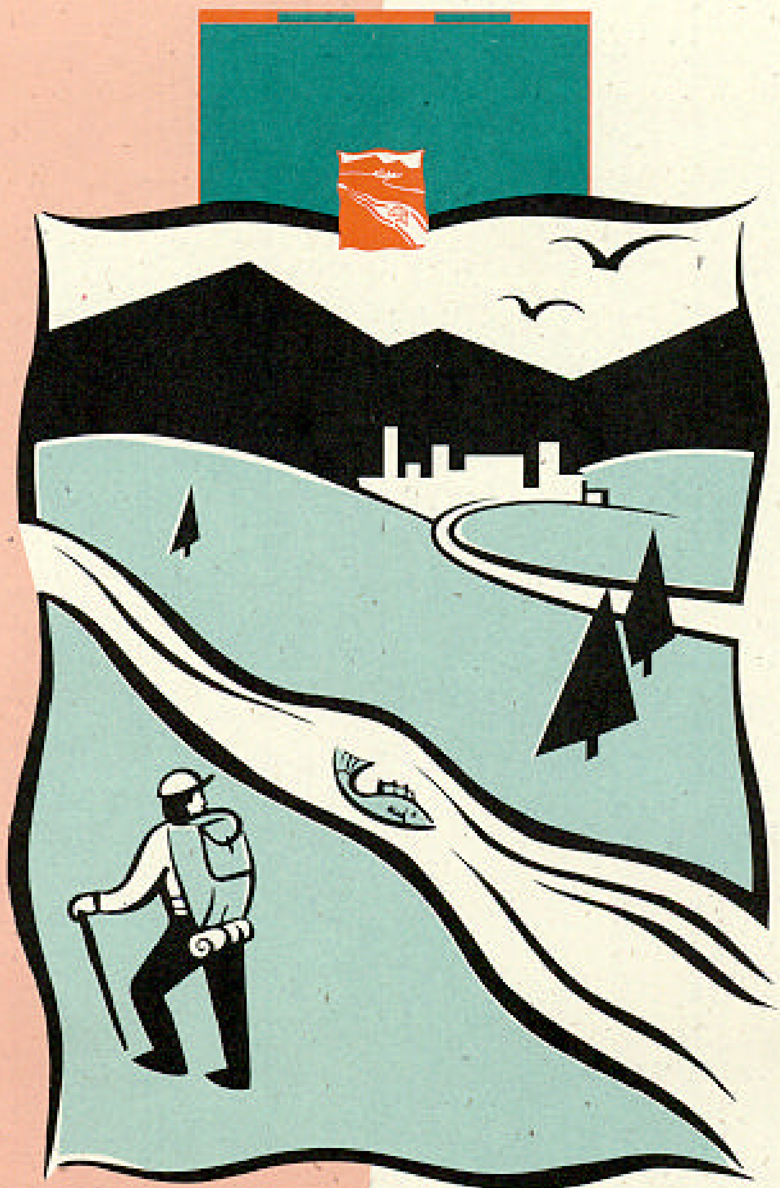
Fraser River Action Plan



Landuse and Water Quality Management in the Bridge Creek Basin

DOE FRAP 1994-25

BC Environment

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LAND USE AND WATER QUALITY MANAGEMENT IN THE BRIDGE CREEK BASIN

Prepared for: Water Quality Branch
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BC Environment
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and

Fraser Pollution Abatement Office
Fraser River Action Plan
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January, 1995.

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TABLE OF CONTENTS

TABLE OF CONTENTS, cont'd.

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This project could not have been carried out without the assistance of many individuals in the Ministry of Environment, Lands and Parks, the Ministry of Forests, the Ministry of Health, the Ministry of Agriculture, Fisheries and Food, the Cariboo Regional District, and the District of 100 Mile House. Projects of this nature depend to a large degree on information available from government agencies and on detailed discussions with resource managers.

I would like to acknowledge in particular the considerable contribution to this report made by the 100 Mile House Forest District. Andy Hall (Resource Officer, Integrated Resource Management) provided very useful information concerning forest practices and lake management in the basin and made available his department's G.I.S. capability for forest cover map database analysis. Lew Greentree (G.I.S. Operator, Integrated Resource Management) very ably undertook the task of analyzing the forest cover database to map the extent of clearcutting and cleared land in the basin. This map and the accompanying analysis of land tenure, tree height in clearcut areas, and cleared land classes could not have been produced without their efforts and the Forest District's resources.

SUMMARY

This study was initiated as a result of long-standing public health and environmental concerns about the quality of water in the Bridge Creek basin. Bridge Creek is the principal water source for the District of 100 Mile House; there are many, highly-valued recreational lakes throughout the basin; and the watercourses provide critical fish habitat as well as domestic and irrigation water supplies.

The effects of a range of basin land uses on water quality are evaluated - including roads, agriculture, forestry, rural residences, cottages and resorts, and urban and industrial development. The most detailed evaluations were of the impact of snowmelt runoff from livestock wintering areas to receiving waters, a source of phosphorus that has had an impact on lakes elsewhere in the Cariboo region.

The most significant land use impacts on water quality are considered to be:

- urban and industrial development in the vicinity of 100 Mile House;
- residential and cottage development along lakeshores; and agricultural land development, livestock wintering, and forestry in the lake drainage basins; and
- agricultural land development, grazing, livestock wintering, and, to a lesser extent, forestry along the Bridge Creek floodplain from the Deka Creek confluence to Canim Lake.

The potential water quality problems in the Bridge Creek basin - such as discharge of toxic substances, stream sedimentation, nutrient loading, and bacterial contamination - are produced by many, individually minor sources dispersed throughout the watershed. Such impacts do not lend themselves to easy identification or control. To maintain water quality, comprehensive watershed planning with active public participation is required.

The central recommendations for water quality management made in this report are summarized as follows:

- for the built-up area of 100 Mile House, develop and implement measures for pollutant control in the urban and industrial source areas and along ditch and storm sewer systems;
- investigate the feasibility of constructing wetlands to treat urban runoff;
- conduct water quality monitoring to determine the trophic status of the most developed lakes;

- for individual lake basins in the upper watershed, develop and implement land use plans based on lake sensitivity, lakeshore suitability for development, and potential impacts related to lakeshore development, livestock wintering areas, agricultural land development, and forestry;

- for areas along the Bridge Creek floodplain, develop and implement plans to minimize the impacts of roads, livestock wintering area runoff, and riparian zone disturbance by agriculture and forestry activities; and

- establish a long-term monitoring programme to evaluate water quality change at the basin scale.

1.0 INTRODUCTION

Bridge Creek drains a 1,550 km^2 area of the Fraser River basin upstream from Canim Lake (Figure 1). The largest community within the basin is the District of 100 Mile House located 80 km southeast of Williams Lake.

As the primary drinking water source for 100 Mile House, the quality of Bridge Creek water has been a long-standing concern for residents. A 1981 outbreak of giardiasis ('beaver fever') attributed to waterborne *Giardia lamblia* cysts (Fogel, 1990), as well as other public health concerns resulted in construction of a slow sand water filtration plant at 100 Mile House in 1985. Leakage and accidental spills from the municipal sewage lagoons adjacent to Bridge Creek also threatened water quality until the 1993 opening of new lagoons at Stephenson Lake (Zirnhelt, 1991; Vath, pers. comm.).

Other water quality issues that have been raised by basin residents include the impact of contaminated runoff from livestock wintering areas, leakage of lakeside septic systems, and impacts of forestry activities on water quality and quantity. There is particular concern for the quality of the numerous, highly-valued recreational lakes in the basin. The shorelines of many of the larger lakes are occupied by cottages and resorts and their drainage areas are in use for logging and ranching.

This study is the second phase of a project directed towards development of a watershed management plan for the Bridge Creek watershed. In the first phase, conducted by Hart (1993), the existing water uses were described and the available water quality data were analyzed. The present study was designed to identify the basin land uses that may affect water quality and to consider management approaches to maintain water quality.

Given the large basin area, and budget and time constraints, many of the land use impacts are treated in a general way. The most detailed evaluation was carried out of the potential impact of livestock wintering areas on water quality. Field work was conducted between October, 1993 and April, 1994.

In addition to this study, BC Environment, the Cariboo Health Unit, and the District of 100 Mile House are currently cooperating on a water quality study of the Bridge Creek watershed upstream from 100 Mile House. Water quality is being monitored at the water supply intake for 100 Mile House, at the outlet of Horse Lake, at three sites in Horse Lake, and at the mouths of all the streams flowing into Horse Lake. The purpose of the study is to assess the water quality of the water supply for 100 Mile House and, ultimately, to establish water quality objectives for Bridge Creek/Horse Lake to guide the management of the watershed. Monitoring began in the fall of 1993, and continued until the fall of 1994.

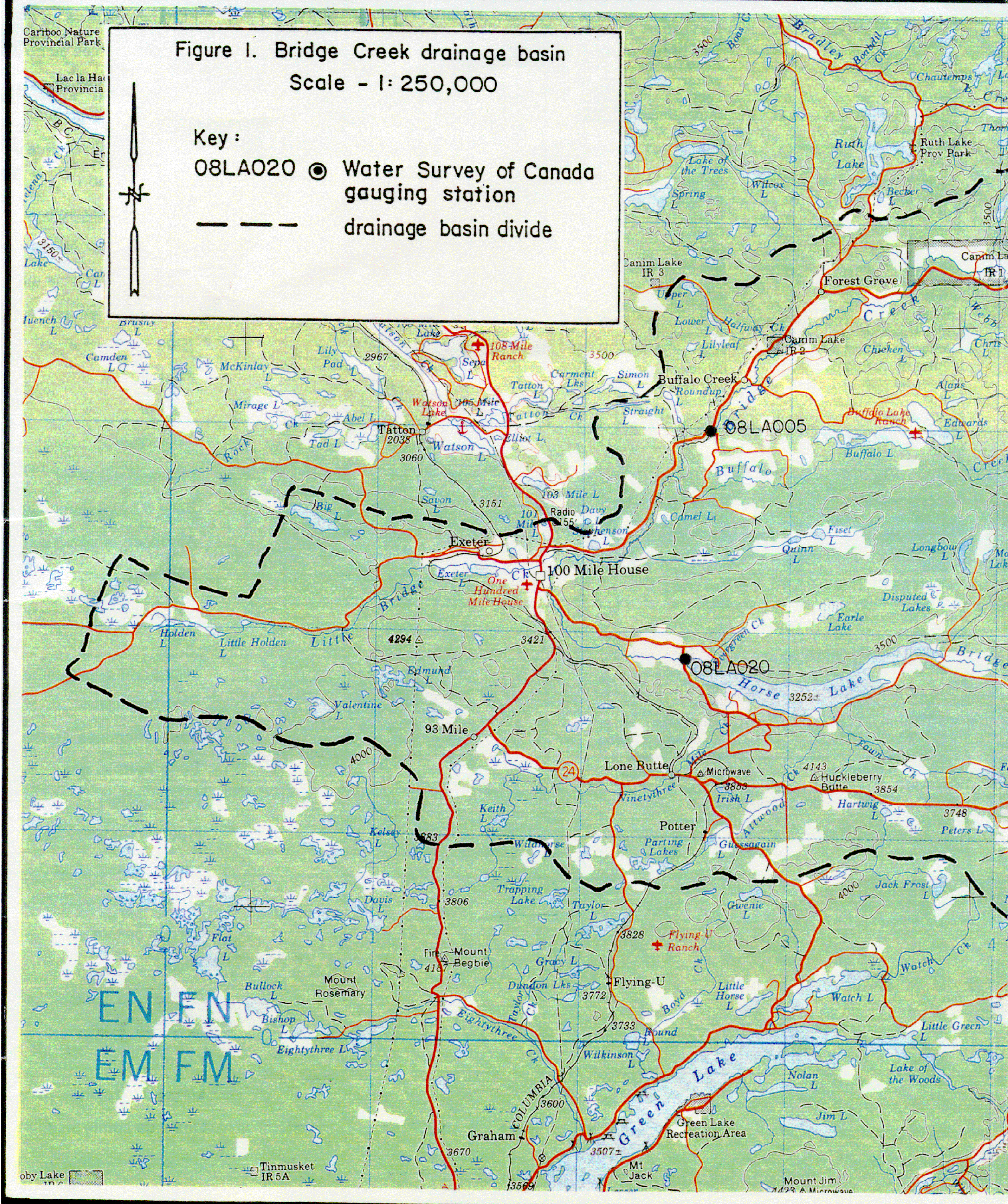


Figure 1. Bridge Creek drainage basin
Scale - 1:250,000


Location of study area
Prince George
Study Area
Vancouver
Wells Gray
Eagle Creek
Canim Lake
Paul Pt
Eagle I
Schoolhouse Lake
Hawkins
Greenlee L
Canim Beach Provincial Park
Round I
Howard Lake
McNeil L
Dorrit L
Drewry Lake
Balfour L
Dragonfly L
Parks L
Duckling L
Hathaway L
Dombey L
Marais Lake
Apollo L
Sulphurous L
Sutherland L
Higgins L
Deka Ck
Manning L
French L
Needa L
Jim Creek
English L
Judson Ck
Lonely L
Fawn L
Sheridan L
Roe Lake
Lesser Fish L
Bridge Lake
Long I
Reichmuth L
Otter L
Faulkner L
West King L
East King Lake
Wavey L
Stack L
Bridge Lake Centennial Provincial Park
Bridge Lake Provincial Park
Lac des Roches
West Twin L
East Twin L
Little Muskrat L
Rutherford L
Muskrat L
Raspberry L
Crescent L
Knight L
Montana L
North Bonaparte
Graham Ck
Hooligan Ck
Peel L
Machete Lake
Machete
Eagan
Willow L
Phinetta L
Birch L
Tortoise L
Toby L
Nomans L
Thuya Lakes
NEHALLISTON
NORTH NEHALLISTON
FOREST
Taweel L
Moosehead L
Friendly L
Ta Hoola L
Poomi Mtn
Monticola L
Meadow L
Lost Horse L
Hardcastle L
Crater L
Rock Island
Deer L
Laurel L
Long Island L
Lynn L
Emar L
Latremouille L
Moose L
Heger
KAMLOOPS DIVISION OF YALE LAND DISTRICT
LILLOOET LAND DISTRICT
Mount Mahood
Italia L
Ejas L

2.0 DESCRIPTION OF BRIDGE CREEK BASIN

2.1 PHYSICAL SETTING

The Bridge Creek basin is situated within the Fraser Plateau, a subdivision of the Interior Plateau (Holland, 1976). Most of the basin is subdued, undulating to gently rolling topography with steeper slopes in the eastern headwaters. Elevations range from 772 m (2,534 ft) at Canim Lake to a headwater summit of 1,643 m (5,390 ft) near Deka Lake (Figure 1).

Fine-grained volcanic bedrock (mainly basalt and andesite) underlays the basin (Campbell and Tipper, 1971) and is covered, throughout most of the uplands, by medium- to coarse-textured glacial till with coarse colluvial materials (products of mass wasting) on steeper slopes. Fine-textured, fluvial deposits occur along the Bridge Creek valley bottom and medium-textured lacustrine materials are extensive on adjacent valley slopes (Valentine and Schori, 1980; Gough, 1988). Moderately-decomposed organic deposits (fens) have developed along stream valleys and in scattered depressions.

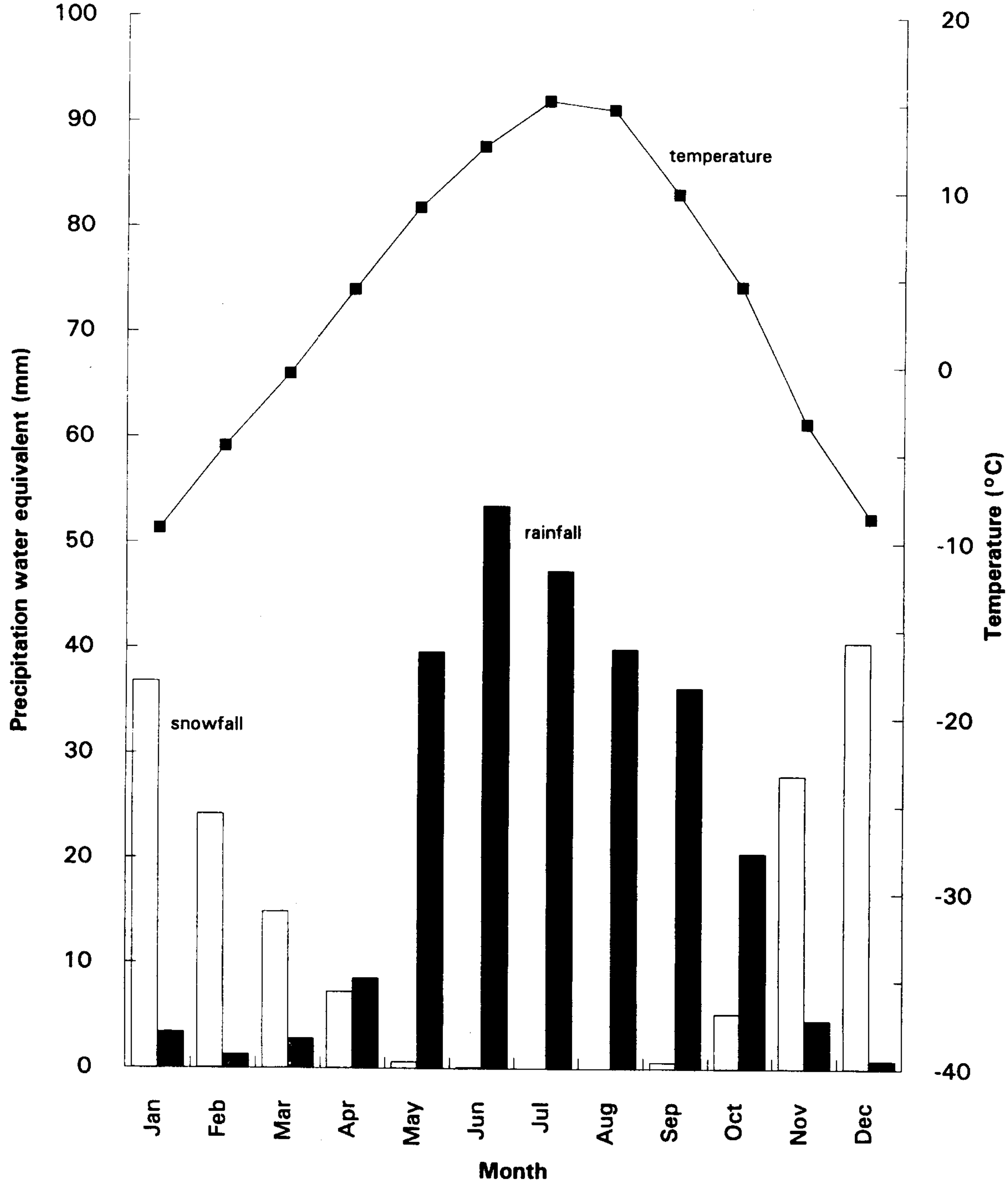
2.2 CLIMATE

The Bridge Creek drainage basin has a moderate, relatively dry continental climate. A climate station maintained at 100 Mile House (937 m elevation) records a mean annual temperature of 3.7°C and a mean annual precipitation of 416 mm (Atmospheric Environment Service; 1970-85 unpublished data). Precipitation occurs primarily as snow through the winter (November-March); peak monthly rainfall is during the summer; and spring and fall months are relatively dry (Figure 2).

2.3 DRAINAGE SYSTEM

In the southeastern portion of the basin numerous large lakes, including Deka, Bridge, and Sheridan Lakes are drained in a westerly direction to Horse Lake by Bridge Creek and its headwater tributaries (Figure 1). Downstream from Horse Lake, Bridge Creek flows west to its confluence with Little Bridge Creek at 100 Mile House and thence northeastward to its confluence with Buffalo Creek and its outlet at Canim Lake. Little Bridge Creek flows from low-lying headwater terrain, east through several small lakes to Bridge Creek. Buffalo Creek flows west into Bridge Creek through Drewry, Edwards, and Buffalo Lakes.

Figure 2. 100 Mile House mean monthly temperature and precipitation (1970-1985).



2.4 HYDROLOGY

Figures 3 and 4 illustrate the mean monthly mean flows[1] for the two Water Survey of Canada gauging stations on Bridge Creek. The station at the outlet of Horse Lake drains a 912 km^2 basin area; and the station near 100 Mile House drains a 1330 km^2 area (see Figure 1). At both stations flows are low during the winter when most precipitation is stored as snow, rise to monthly maxima with spring snowmelt, and then decline through the summer and early fall. A slight late fall flow increase is apparent at Bridge Creek near 100 Mile House and is related to reduced evapotranspiration and lower municipal and irrigation water use.

The peak monthly flow is during May at the lower station (near 100 Mile House), and during June at the upper station (at the Horse Lake outlet). Upstream high flows are protracted by the effects of water storage in the numerous large lakes. Downstream flows are dominated to a greater extent by runoff from lower elevations less regulated by lake storage.

Rainstorms may also generate peak flows in Bridge Creek. Through the 27-year record of Bridge Creek near 100 Mile House, on four occasions summer rainstorms accounted for the maximum daily flows recorded for the year. The peak daily discharge on record at both gauging stations was produced by rainfall (in June, 1990). Rain-on-snow events may also cause floods, although climate and discharge records have not been analyzed to determine their frequency.

A comparison of the mean monthly and the 1-in-5 year 7-day low flow hydrographs[2] (Figures 3 and 4) indicate the flow variation from year to year. The 1-in-5 year low flow is used by the Water Management Branch (BC Environment) for calculations of water availability for licensing. Many of the tributary creeks in the Bridge Creek basin dry up during the summer in low flow years. A low flow study conducted by the Water Management Branch during the summer of 1987 (a drought year) recorded no flow in Attwood Creek, Buffalo Creek, Deka Creek, Hathaway Creek, 93 Mile Creek (at Horse Lake Rd. and Hwy. 24), Bridge Creek downstream from Roe Lake, Judson Creek, and Little Bridge Creek (Gale, pers. comm.).

[1]For a given month the mean daily discharges are averaged to determine the monthly mean flow and these values are averaged for the months on record to give the mean monthly mean flow. These data were recorded by the Water Survey of Canada (1991).

[2]For a given month the lowest mean daily discharge in any seven-day period is determined to give the 7-day low flow. The 1-in-5 year 7-day low flow is the 7-day low flow estimated to recur on average one out of 5 years. This low flow frequency analysis was carried out by Todd Gale, Water Management Branch, Williams Lake, based on Water Survey of Canada data.

Figure 3. Bridge Creek flow at outlet of Horse Lake (Water Survey of Canada station 08LA020)

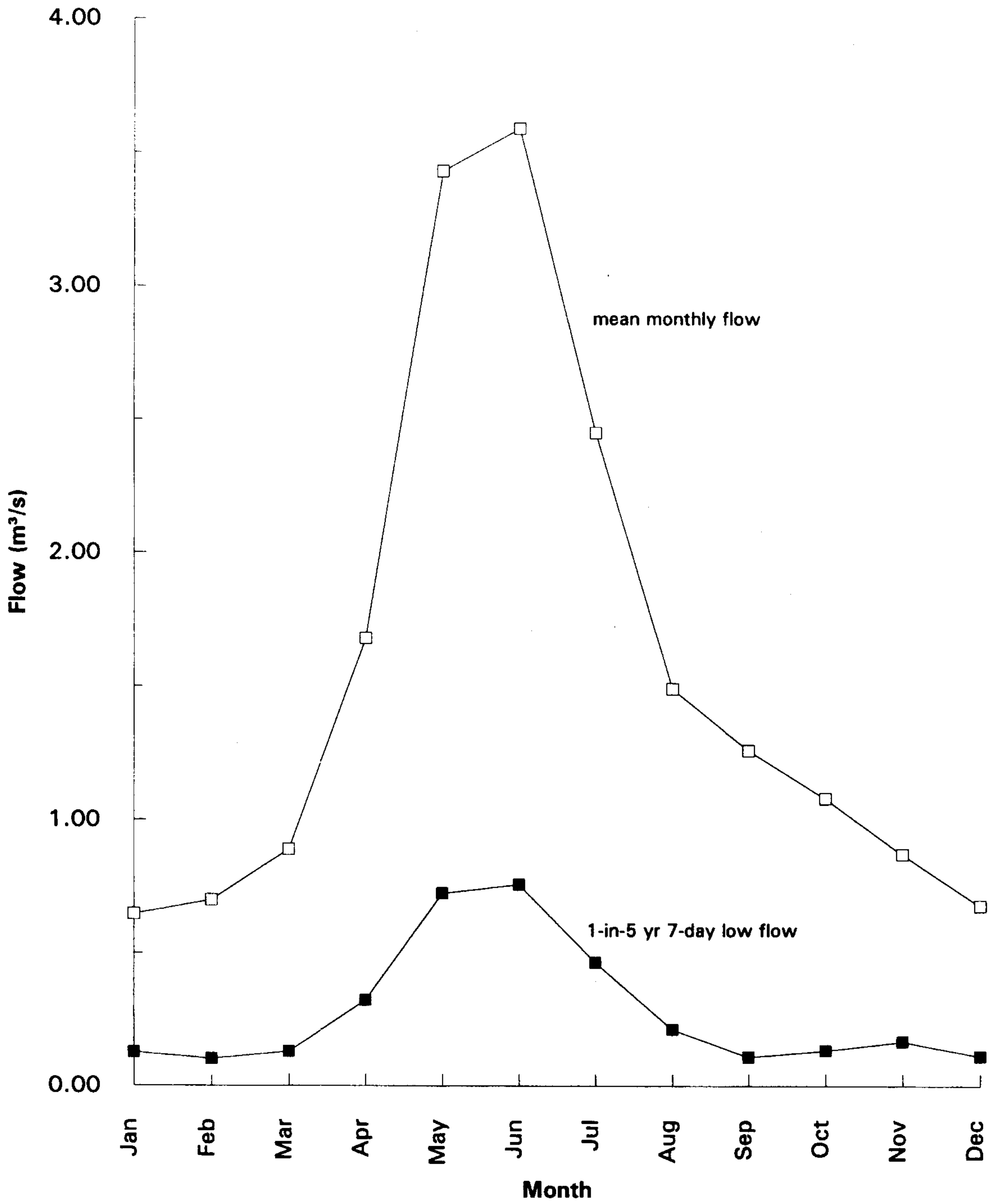
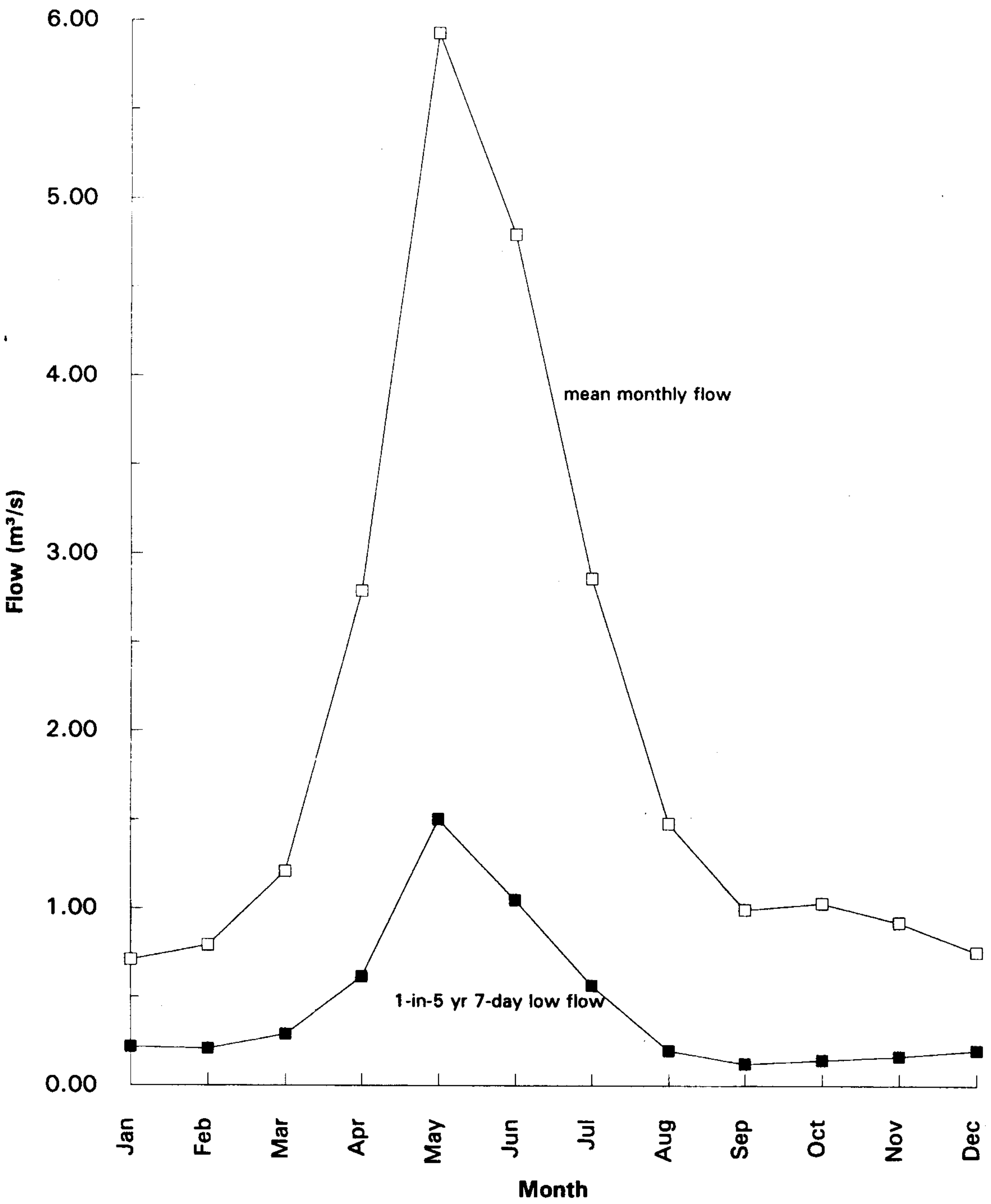


Figure 4. Bridge Creek flow near 100 Mile House (Water Survey of Canada station 08LA005)



The monthly total discharge measured at both gauging stations is shown in Figure 5. Discharge near 100 Mile House is less than upstream at Horse Lake during the low flow period of August, September, and October. This downstream decrease is a result of municipal and irrigation water withdrawals and very low flows in Little Bridge Creek and Buffalo Creek during late summer and early fall.

2.5 FISH[1]

Many of the lakes within the Bridge Creek basin support important populations of rainbow trout, kokanee, lake char and, in Sheridan Lake, Eastern brook trout. Many of the larger lakes and numerous smaller lakes are stocked by the Fisheries Branch.

Sports fishing is the primary recreational use of study area lakes. Based on aerial boat counts, Table 1 provides estimates of angler use for a selection of lakes. This survey method underestimates the actual use (perhaps by 50%), but provides a useful measure for comparative purposes.

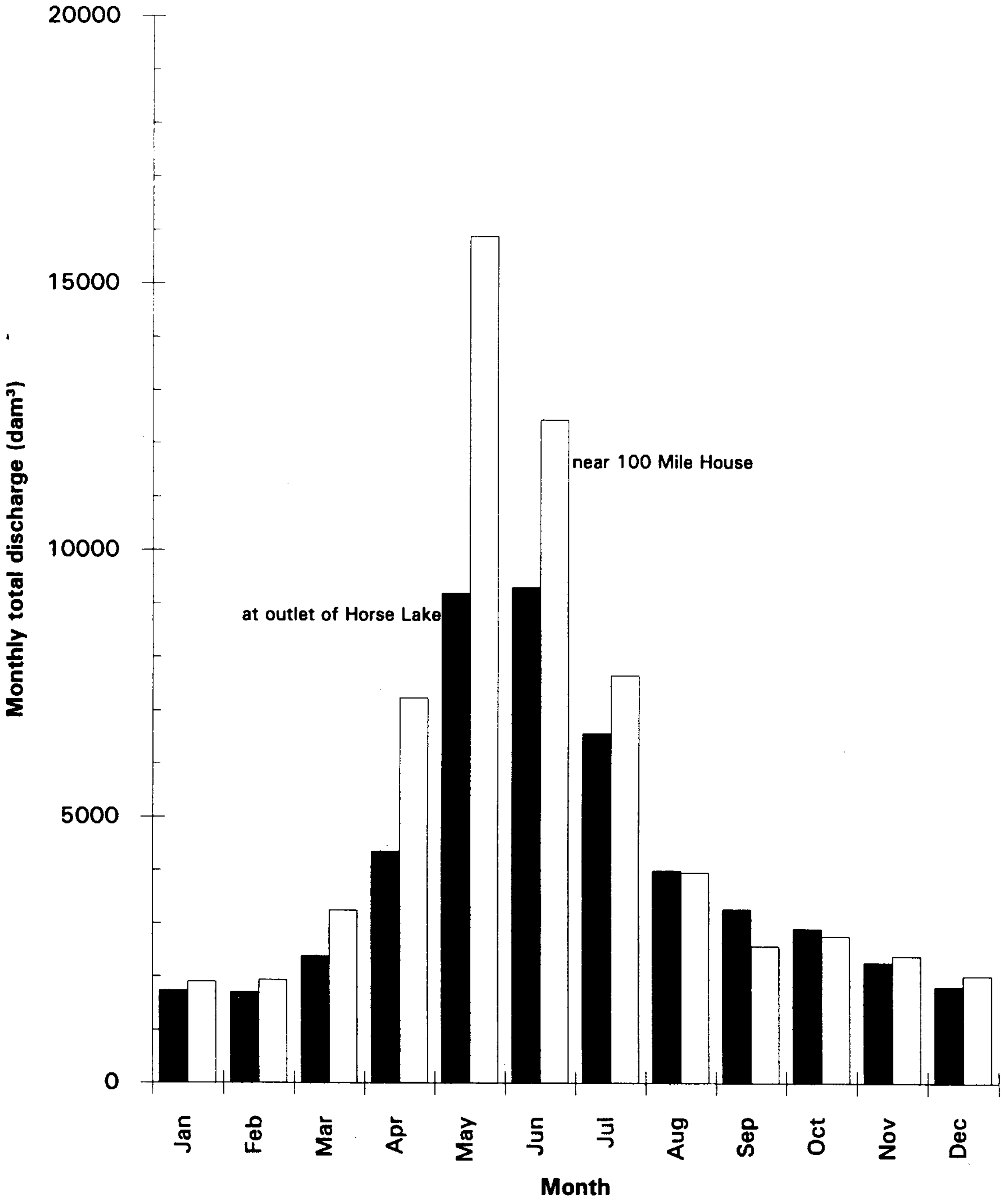
Sheridan Lake angler use is the highest in the Cariboo-Chilcotin region. A creel census carried out in 1986 recorded angler effort between May and October of 29,147 days. The Sheridan Lake fishery alone is estimated to generate approximately one million dollars annually for the Provincial economy (Westover and George, 1987).

Table 1. Angler effort estimates for selected lakes in 1989. (from Recreational Fisheries Branch, 1989)

LAKE	ESTIMATED SUMMER EFFORT (days)
Bobbs	263
Bridge	5 581
Deka	3 319
East King	1 593
Exeter	398
Fawn	3 467
Hathaway	931
Horse	9 298
Sheridan	17 867
Sulphurous	3 119
Valentine	1 174
West King	1 720

[1]Information in this section is mainly from the Fisheries Branch, BC Environment, Williams Lake (Chapman; Wilders, pers. comm.).

Figure 5. Bridge Creek monthly total discharge (Water Survey of Canada stations 08LA005 and 08LA020)



The larger creeks throughout the Bridge Creek system provide rainbow trout spawning and rearing habitat and, in many cases, over-wintering habitat. Rainbow trout reside along the lower length of Bridge Creek to Canim Lake, but upstream migration is blocked by a small waterfall near 100 Mile House. In Little Bridge Creek there are reported to be trout upstream to a waterfall above 'Five Mile Meadow' (L. 5310), but not in the upstream lakes (Castonguay, pers. comm.). Kokanee spawn in Bridge Creek above and below Horse Lake, in the lower reach of 93 Mile Creek, and in the Bridge Lake inlet and outlet creeks.

More detailed fisheries information will soon be available for creeks in the study area. In a joint project with the Canim Lake Indian Band, the Fisheries Branch is currently carrying out a biophysical inventory of fish habitat and impediments to migration along the major watercourses in the Bridge Creek basin (Lirette, pers. comm.).

3.0 WATER QUALITY OF UNDISTURBED AREAS

There are only limited water quality data available which are representative of undisturbed areas of the Bridge Creek basin (Hart, 1993), however, the water quality of low relief, forested watersheds is typically very high. Sediment transport rates are generally low, with minerals being transported primarily as solution load regulated by groundwater contributions. Phosphorus - the limiting nutrient for primary productivity (algal growth) in aquatic ecosystems in the study area - is strongly conserved in forest soils. Pathogenic organisms (such as bacteria and viruses) which derive from wildlife, although present in undisturbed streams, have fewer health consequences than does contamination from human wastes.

The steeper, forested slopes of the basin are underlain mainly by stable glacial till deposits and exhibit little evidence of slope failures such as debris avalanches or slumps which can rapidly deliver large quantities of sediment to channels. The slopes most subject to mass wasting and gullying are the steep, lacustrine deposits flanking the valley bottom along Bridge Creek downstream from 100 Mile House.

There is little surface runoff across the well-drained forest soils of the basin. Runoff source areas which might contribute sediment, phosphorus, and pathogenic organisms to streams are the wetlands and lower-lying saturated zones along channels. Precipitation cannot infiltrate these wetter areas and produces runoff as 'saturation overland flow'. Where phosphorus and pathogenic organisms are able to infiltrate better-drained soils, they normally travel only a few metres before being adsorbed. In saturated soils travel is further, but still generally less than 50 metres (Brown, 1980).

The channels tributary to Bridge Creek are generally confined by valley slopes with only narrow, fragmentary floodplains; ponds and wetland fens are common along their lengths, in many cases controlled by beaver dams. Bank erosion rates are naturally very low, both in wetlands and along the intervening entrenched reaches. The frequent ponds, lakes and wetlands throughout the upper watershed serve as effective sediment traps and regulate downstream nutrient transport.

Downstream from its confluence with Deka Creek, Bridge Creek flows generally in an irregularly meandering pattern, within a moderately wide floodplain. Bank erosion rates are low where not affected by land use activities, the banks being well stabilized by riparian shrubs and trees. The slow, progressive shifting of the channel across its valley flat would nevertheless be an important sediment source along the valley. Occasional sites where the channel is undermining steep valley walls are also principal sediment sources (e.g., sites 12-16 in Figure 6).

Although streamwater may remain clear and unaffected by human activity, organisms can be present that are hazardous to human health. Outbreaks of giardiasis ('beaver fever'), a type of dysentery caused by the *Giardia lamblia* cyst, have occurred in the Bridge Creek basin. This cyst is carried by warm-blooded animals and is transported by water. Occurrences of giardiasis are often attributed to beaver and muskrat, but are also related to other aquatic mammals, birds, and human wastes (Fogel *et al.*, 1993). Beaver activity was observed in streams throughout the study area.

Cryptosporidium oocysts, the parasites which cause the gastrointestinal disease cryptosporidiosis, have also been found in Bridge Creek water (Fogel *et al.*, 1993), although no disease occurrences have been reported in the area (Vath, pers. comm.). *Cryptosporidium* oocysts are transmitted by domestic livestock and aquatic mammals.

4.0 LAND USE EFFECTS ON WATER QUALITY

The land use activities in the Bridge Creek watershed which might affect water quality are discussed in this section. An effort is made to determine the relative significance of the potential pollution sources, however, there are no data available upon which to base a quantitative analysis. Most of the land uses (such as roads and septic systems) have been treated in a general way, in the absence of site-specific information for these dispersed sources.

More detailed information was collected concerning the potential impact of livestock wintering areas. These sites have been found to account for a majority of the elevated phosphorus loading in nearby watersheds (Stitt *et al.*, 1979; McKean *et al.*, 1987; Hart and Mayall, 1990; Hart and Mayall, 1991).

Figure 6 illustrates potential water quality impact sites and basin land uses including agricultural clearing, urban and residential development and four classes of tree heights in clearcut areas. The information on this map was compiled mainly by the 100 Mile House Forest District using their forest cover map database and G.I.S. capability.

4.1 ROADS

There is a relatively dense network of roads in the study area comprised of public roads (managed by the Ministry of Transportation and Highways), Forest Service roads, and private roads. In Figure 6 major and minor roads are differentiated (irrespective of ownership); skidroads and trails (available in the database) are excluded.[1]

4.1.1 Erosion and sedimentation

In the literature addressing the water quality impacts of forestry practices, road-related erosion is typically identified as the principal source of clastic sediment delivered to watercourses (excepting steep terrain subject to mass wasting). Road erosion rates often exceed natural rates by an order of magnitude. In Washington state, Reid (1981) found that rates of erosion of gravel-surfaced roads vary directly with frequency of use and maintenance activities. Sediment production from logging roads travelled by more than four trucks per day was three orders of magnitude greater than rates from deactivated roads. Gravel-surfaced roads and ditches constructed for other purposes similarly act as significant sediment sources, although logging roads are often on steeper terrain.

[1]The 100 Mile House Forest District is in the process of updating their road database; some discrepancies may be noted.

Road ditches are the conduits for mobilized road sediment as well as significant sediment sources themselves. Ditches are primarily designed to remove surface runoff efficiently while maintaining road and ditch integrity; control of sediment transport is generally a secondary consideration. Routine ditch cleaning work, for example, may maintain ditch efficiency, yet it exposes mineral soils to erosion.

Road surface erosion has not hitherto been regarded as a major problem in gently rolling Interior Plateau terrain as found throughout much of the Bridge Creek basin. Applying a erosion hazard rating system adopted by the Ministry of Forests (Lewis *et al.*, 1991) the basin soils are generally in the low to moderate range, varying mainly with slope length and gradient. The higher erosion hazard areas are in the more steeply sloping terrain in the eastern basin headwaters, in the vicinity of Drewry and Deka Lakes; however, there has been little road construction in these areas to date.

In the subdued topography of the Bridge Creek basin much of the sediment produced along roads does not make its way to channels. Deposition occurs along ditches, in depressions, on slopes, and along drainage lines that are not connected to the continuous channel network. The sites that deliver sediment are generally close to streams, although sediment may be carried considerable distances along drainage lines and ditches connected to downslope channels (section 4.5).

Above Horse Lake there are many sites where roads cross streams or encroach upon riparian zones; however, preliminary inspections indicate that sediment losses from roads to streams in this area are low. Sedimentation impacts may be identified along individual stream reaches, but they are not expected to be extensive. The numerous lakes and ponds in the upper basin would also help to curtail downstream effects.

In the upper basin, roads serving residential subdivisions adjacent to lakes may have the most significant impact on water quality. Subdivisions on Deka Lake, Horse Lake, Sheridan Lake, and Bridge Lake have the most extensive road networks. Road ditches are designed to efficiently remove runoff and typically discharge to lakes or to streams and drainage lines draining directly to lakes. Pollutants from residential developments may include sediment from exposed soils, fertilizer, herbicides, pesticides, chemical spillages, petroleum products, and domestic animal wastes.

The most extensive areas of developed land in proximity to watercourses are located along lower Little Bridge Creek and along Bridge Creek between Horse Lake and Canim Lake. The industrial zone on the north slope of the Little Bridge Creek valley is a major source of sediment which is transported along road ditches to the channel (section 4.5). Along Bridge Creek below Horse Lake there are numerous private and public roads close to the channel and an estimated 22 road bridges. Increased sediment losses would likely result from this encroachment. At one site near the community of Buffalo Creek (site 1, Figure 6), a length of private road accessing a gravel pit is located on the Bridge Creek floodplain and is being actively undercut by the channel.

4.1.2 De-icing chemicals

Sodium chloride is the main de-icing chemical used in the 100 Mile House area. Snowmelt runoff and spray of road salt causes widespread roadside tree mortality in B.C. (Davis *et al.*, 1992) and can contaminate both groundwater and surface water supplies (Jones and Jeffrey, 1986; Whitfield, 1993). Whitfield (1993) suggests that short-term peaks in salt concentration during snowmelt may harm aquatic vegetation, invertebrates, and fish, but that there is little information concerning the severity of this problem in British Columbia. Road salt may also release cyanide from compounds used as an anti-caking agent, and other contaminants such as lead, with potentially toxic effects to aquatic biota (Whitfield, 1993).

In the Bridge Creek basin, the 100 Mile House area would likely produce the greatest elevation of stream or lake sodium and chloride concentrations. The area has the highest road density in the study area and is drained by a storm sewer system which rapidly delivers snowmelt runoff to receiving waters (section 4.5).

4.1.3 Dust abatement chemicals

The dust abatement chemicals currently approved for use by the Ministry of Transportation and Highways are magnesium chloride, calcium chloride, calcium lignosulphonate, and sodium lignosulphonate. The Ministry has general guidelines concerning methods of handling and application of these chemicals for protection of the aquatic environment: the chemicals cannot be applied within 6 metres of a water crossing; roadside windrows are to be graded to confine any product runoff; and there are stipulations regarding weather and proximity of chemical mixing and equipment cleaning operations. With these relatively limited restrictions there is still a hazard of dust control chemicals reaching a watercourse, particularly in the event of a rainstorm during or soon after an application.

A brief review of the literature and discussions with Ministry of Environment and Environment Canada researchers have provided indications of the environmental hazards associated with these chemicals. There is less concern about the use of calcium or magnesium chlorides, concentrations in receiving waters being less than those that result from road salt runoff, but research to date is scant (Acres, 1988; Ontario Ministry of Environment and Energy, 1993; Whitfield, pers. comm.; van Barneveld, pers. comm.). The lignosulphonates have been identified as possibly having toxic effects to aquatic organisms and fish, although the research results vary widely (Techman, 1982; Acres, 1988; Ministere de l'Environnement, 1990). As Acres (1988: p. 21) concluded: 'in view of the research findings to date, it would appear prudent to recommend avoiding application of lignosulphonates as a dust suppressant in the vicinity of spawning sites and cold water streams supporting trout'.

During the period of field study a dust suppressant had not been selected for 1994, however, Whiteline Road Maintenance Ltd., the former road maintenance contractor in the study area, has used calcium chloride in recent years (Lee, pers. comm.).

4.2 AGRICULTURE

Agricultural land use is widely reported to modify watershed hydrology and reduce stream and lake water quality. Hydrologic effects include: more snow accumulation in cleared than forested areas; lessened infiltration of snowmelt and storm runoff into cultivated fields and the compacted and exposed surfaces of roads, yards, and livestock confinement areas; and more efficient runoff due to the extension of the surface drainage network by irrigation, drainage and road ditches. Water quality deterioration is typically related to accelerated erosion of exposed soils; encroachment of agricultural activities upon stream channels; and the delivery to streams and lakes of livestock wastes and agricultural chemicals such as fertilizer, herbicides, and pesticides.

In Cariboo Regional District Electoral Areas H and L (encompassing much of the study area), agriculture is the largest employer of the primary resource industries (McDaniels Research Ltd., 1993). The major agricultural activity is beef cattle ranching, although there are significant numbers of horses, bison, sheep and other small livestock. There are also numerous producers of perennial forage crops who do not maintain livestock, but supply the cattle industry and other producers in the region.

4.2.1 Agricultural land development

The 'cleared land' in Figure 6 provides a first estimate of the extent of agricultural development in the basin. This category covers 6.2 per cent of the basin and includes land cultivated for forage production and pastures, but also clearings for non-agricultural purposes such as those in residential areas and along rights-of-way. On the other hand, some of the larger wetland fens in the basin are managed for hay production but, being natural openings, are not mapped as cleared land.

Almost all land cultivation in the study area is for perennial forage production; annual crops (e.g., oats or barley) are normally grown only as land is being developed or as a 'cover crop' during re-establishment of the perennial crop. Without the soil exposure of annual cropping practices, the erosion rates in the basin are much lower than those commonly ascribed to agricultural land use.

Agricultural land development could nevertheless constitute a significant sediment source within the basin. Particularly along riparian zones, land cultivation, ditching, equipment operation close to or in stream channels, channel realignment and bank erosion control works, and numerous other incidental ranch operations can all increase erosion and impair stream water quality and habitat. The main agricultural areas in the basin are in the vicinity of Bridge and Sheridan Lakes (the 'Interlakes' area); in the southern area of the watershed along Highway 24; along Bridge Creek just upstream and downstream from Horse Lake; in the lower Little Bridge Creek valley near 100 Mile House; and along Bridge Creek and its tributaries between 100 Mile House and Canim Lake. The most extensive agricultural land use in proximity to a watercourse is along the floodplain of Bridge Creek, from its confluence with Deka Creek to Canim Lake.

4.2.2 Irrigation water withdrawal

The Water Management Branch indicates that all watercourses in the Bridge Creek system are 'fully recorded' - that is, no further water is available for use during the irrigation season unless water storage can be provided (Gale, pers. comm.). Water is withdrawn for storage during the period October 1 to June 15. Since many creeks in the basin have very low summer flows (section 2.4), they are vulnerable to impacts by irrigation water withdrawals. No observations have been made during this study relating to this concern; however, the fish habitat study being undertaken by the Fisheries Branch and the Canim Lake Indian Band will identify streams that are susceptible to depletion by irrigation water use (Lirette, pers. comm.).

4.2.3 Livestock wintering

Site assessment methodology

Contaminated snowmelt runoff from livestock wintering grounds can significantly increase phosphorus loading of streams and enrich downstream lakes. In this study a system devised by Hart and Mayall (1990; 1991) is used, with some modification, to determine the potential for phosphorus delivery from livestock wintering grounds to receiving waters and to evaluate the potential impact of this process relative to other classified sites. The general approach taken to determine the potential impact of a livestock wintering area is illustrated in Figure 7 and described below.

Six terrain factors listed in Table 2 are classified to indicate how they might induce surface runoff to a low, moderate, or high degree. These terrain factors are inherent to the site that has been selected for livestock feeding and they are assessed independently of the influence exerted by livestock feeding practices themselves. In this rating the terrain conditions are considered both at the feeding site and along the drainage pathway from feeding site to receiving water.

Having evaluated the influence of terrain conditions upon runoff, the control exerted by specific wintering area characteristics are

Table 2. Phosphorus delivery rating of livestock wintering areas.

CONTROLLING VARIABLE	RATING Low	Moderate	High
Terrain factors:			
Slope (%)	<5	5-15	>15
Vegetation cover	forest	herbaceous	bare or annual crop
Drainage conditions	rapidly or well drained	imperfectly or moderately well drained	very poorly or poorly drained
Flood frequency	nil or rare	occasional	frequent
Depression storage	good	limited	absent
Slope position	upper	mid-slope	lower
Wintering area factors:			
Setback distance (m)	>200	100-200	<100
Wintering area - size (ha)	<1	1-4	>4
- orientation	across slope	intermediate	downslope
- livestock density (animal-unit months/ha)	<40	40-200	>200

Table 3. Potential impact rating of livestock wintering areas.

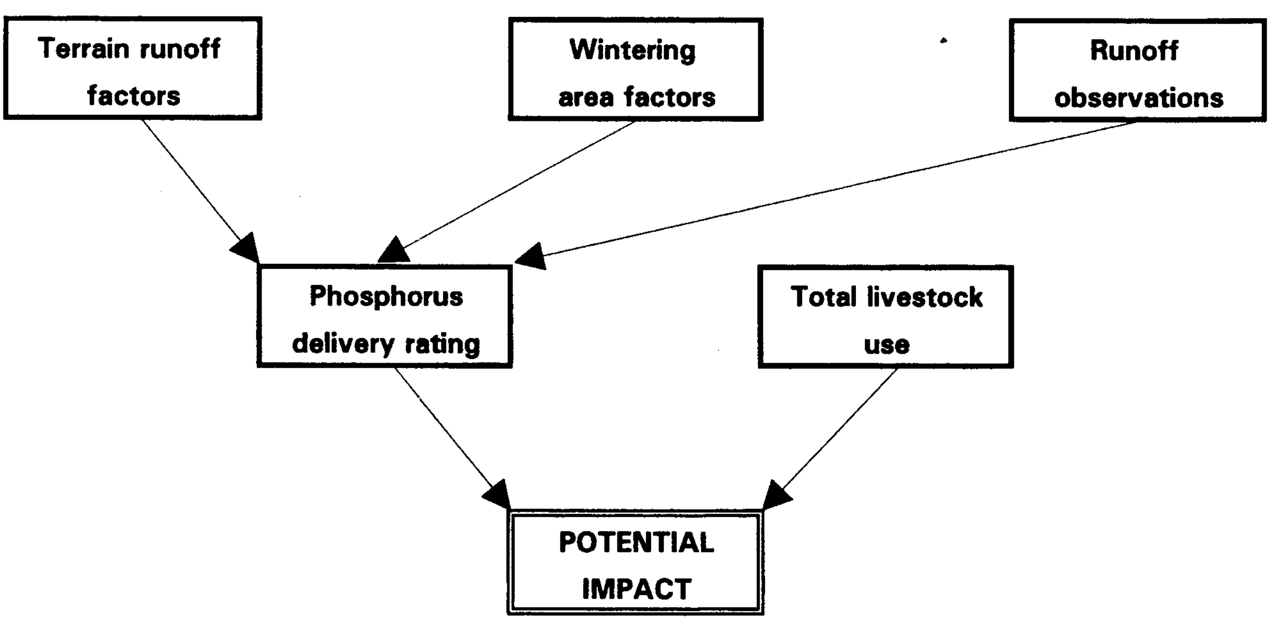
PHOSPHORUS DELIVERY RATING	TOTAL LIVESTOCK USE (animal-unit months) <200	200-400	>400
Low	low	low-moderate	low-moderate
Moderate	low-moderate	moderate	moderate-high
High	moderate	moderate-high	high

considered. The distance to receiving water and the wintering area size, orientation on the slope, and livestock density are categorized to indicate their degree of control of runoff production (Table 2). The terrain factors, the wintering area factors, and field observations are then evaluated together to yield a 'phosphorus delivery rating' for each feeding site (Figure 7). Because of the subjective nature of this approach, direct observations of snowmelt runoff are particularly important.

The potential impact of the snowmelt runoff from a wintering area is determined by combining the phosphorus delivery rating and the total livestock use of the wintering area - that is, at the same site a larger number of animals would be assigned a higher impact (Table 3; Figure 7). Low, moderate, and high classes of livestock use of a wintering area are less than 200, 200-400, and greater than 400 animal-unit months, respectively.

In some cases, general approaches to correct problems are suggested; however, specific management practices would be determined by detailed consultation with the rancher.

Figure 7. Approach to determine potential impact of livestock wintering areas.



Observations

All ranches feeding more than 25 animal units[1] of livestock were inspected during the late winter and spring. In total, 37 ranches were visited and 82 individual wintering sites were evaluated. On these ranches 2,700 animal units of livestock were wintered, comprised mainly of cattle, but including horses, bison, and sheep. The distribution of ranches is shown in Figure 6 and the site assessment coding forms completed for each wintering area are in a separate appendix volume. Of the 82 wintering sites the potential impact of phosphorus delivery to the fluvial system is rated as follows: 42 low, 15 low-moderate, 21 moderate, and 4 moderate-high impact sites.

These results indicate somewhat better wintering conditions in the study area than were reported by Hart and Mayall (1990; 1991) in the basins drained by Williams Lake and Lac la Hache. In the Bridge Creek basin the livestock herds are smaller, averaging 33 animal units per wintering site, and the ranches are distributed throughout the rolling terrain of the basin, and less confined to major stream valleys. The absence of high impact sites is due to the smaller herd sizes - there are 16 sites where the susceptibility to phosphorus delivery to the fluvial system is rated as high yet the low or moderate levels of livestock use reduce the overall impact.

As well as the livestock wintered on the larger ranches in the study area, there are many smaller farms and rural residences with only a few animals. A first estimate based on road counts adds about 300 horses, 250 cows, and 250 sheep, equivalent to 675 animal units in total. Except where livestock feeding is in close proximity to a lake or stream, the water quality impact of these smaller operations is expected to be low.

4.2.4 Agricultural chemicals

Of the 37 ranches visited in the course of this study, 18 ranchers reported use of chemical fertilizer; however, in 14 cases the fertilizer was applied only to better-drained upland soils. On these sites there would be little risk of phosphorus losses to streams and lakes. Phosphorus is relatively immobile in well-drained soils, particularly in the moderately alkaline soils prevalent in the study area.

In four cases the ranchers surveyed reported routine application of chemical fertilizer to their hayfields on wetland fens and, at three of these, phosphorus fertilizer was used. There are also a few commercial hay producers who harvest wetlands; they were not interviewed during this study, but they could be assumed to be using

[1]An animal unit is a standard defined as one mature cow with or without an unweaned calf. Animal unit equivalents include: weaned calves - 0.60; yearlings - 0.67; bulls and mature horses - 1.30; ewes with or without lambs - 0.20 (McLean, 1979).

chemical fertilizer. There is a potential for phosphorus losses from these wetlands since they drain directly to channels or lakes in most cases; because phosphorus is more mobile in saturated soils; and because organic matter itself has little capacity to fix phosphorus. On the other hand, the calcium content of these organic soils would promote phosphorus retention, and the removal of plant nutrients by forage harvesting would reduce downstream losses. Given the low incidence of fertilizer use, the buffering capacity of the soils, and the annual harvesting, wetland hayfields are not expected to be a significant phosphorus source.

There is very little use of other agricultural chemicals in the study area (Awmack, pers. comm.). Forage production does not generally require use of herbicides or pesticides.

4.2.5 Grazing

The majority of the ranchers surveyed maintain their cattle on Crown range from May 16 to October 31. Livestock graze mainly upland terrain, including open sidehills, mixed forest, and logged areas. There is limited use of wetlands. Range stocking rates are relatively low, with approximately 2,200 head of cattle distributed throughout the basin (Hayes-Van Vliet, pers. comm.).

Dispersed grazing of upland livestock range generally has little effect on phosphorus concentrations in streams (Miner and Willrich, 1970; Loehr, 1974; Tiedemann *et al.*, 1989). Where snowmelt runoff flows to channels it is across surfaces having widely distributed manure, not the concentrated accumulations as in livestock wintering areas. For all but the highest intensity rainstorms, runoff infiltrates undisturbed upland soils and phosphorus would be assimilated by the soil.

More intensive grazing occurs on private land along Bridge Creek downstream from 100 Mile House. Manure accumulations in intensively grazed floodplain areas may have some effect on Bridge Creek nutrient loadings; however, a more significant impact may be the loss of bank stability caused by shrub removal and livestock trampling along the streambank. Bank erosion rates accelerated by pasture development and livestock use were observed (incidentally) along several stream reaches (e.g., sites 2 and 3, Figure 6).

4.3 FORESTRY

Table 4 is a summary of the logging history in the Bridge Creek basin derived from the Ministry of Forests database (which extended to 1989 when these data were generated). It is apparent that much of the timber harvesting in the basin took place more than 20 years ago. Excluding the undated logging, 80 per cent of the total clearcut and selectively logged area was cut prior to 1973. The total area logged to 1989 (excluding land permanently cleared for other uses) is 23 per cent of the basin area with approximately 70 per cent being on Crown Land. The proportion of private land

Table 4. Bridge Creek basin logging history.[1]

Logging history	Private land (ha)	Crown land (ha)	Total (ha)
Mature forest[2]:			
- pre-1973 logging	2,656	7,513	10,169
- 1974-78 logging	no record	14	14
- 1979-83 logging	11	44	55
- 1984-89 logging	no record	no record	no record
- undated logging	4	7	11
Immature forest:			
- pre-1973 logging	5,509	11,036	16,545
- 1974-78 logging	113	3,591	3,704
- 1979-83 logging	51	767	818
- 1984-89 logging	no record	96	96
- undated logging	87	94	181
Logged (N.S.R.)[3]:			
- pre-1973	525	357	882
- 1974-78	20	574	594
- 1979-83	249	645	894
- 1984-89	22	773	795
- undated	1,185	91	1,276
Logged total	>10,432	>25,602	>36,034
Unlogged			
- mature forest	10,708	41,787	52,495
- immature forest	9,567	24,654	34,221
Unlogged total	20,275	66,441	86,716

[1]Data provided by 100 Mile House Forest District (Andy Hall, Planning) and Cariboo Forest Region (Lloyd Wilson, Inventory)
[2]Logging in mature forest refers to selective logging.
[3]The logged (non-immature) category refers mainly to not satisfactorily restocked land.

(including agricultural leases) in the study area is 25.4 per cent (Greentree, pers. comm.).

In Figure 6, the existing clearcuts are mapped based on four tree height classes less than 9 metres. The total area of this recently logged or not satisfactorily restocked land is 9.7 per cent of the basin area, with about 80 per cent of it being on Crown Land.

Future timber harvesting in the basin will supply the established lumber mills as well as the oriented strand board (OSB) plant which has recently been completed by Ainsworth Lumber Co. Ltd. This plant will use pulp quality stands on both Crown and private land, including deciduous forest types and other low value stands that have been excluded from the annual allowable cut (Ryan *et al.*, 1994).

4.3.1 Lakeside and riparian zone disturbance

A principal means by which forestry activities affect streamflow and stream and lake water quality is by disturbance of terrain in proximity to the waterbody. Mechanical disturbance of soils and slashpile burning in riparian or lakeside areas can increase delivery of sediment and nutrients. Removal of streamside forest can increase stream temperatures, reduce the food supply to aquatic organisms and fish, and reduce streambank stability. Streams are also directly affected by machine traffic across the channel and by removal of large woody debris (e.g., fallen trees) which provide channel stability and critical fish habitat.

The majority of the clearcut logging mapped in Figure 6 is on upland sites removed from lakes and streams. Logging adjacent to watercourses is most extensive in the eastern basin headwaters in the drainage basins of Judson Creek and Bridge Lake. Deka, Sulphurous, and Hathaway Lakes and numerous smaller lakes have minor areas of logging extending to their shorelines. Drewry Lake is an exception, with a logged area extending 3 km along its north shore; however, this logging was carried out from 1967 to 1971 and would not be expected to be affecting present lake water quality.

With completion of Ainsworth's OSB plant at 100 Mile House (see section 4.5) the rate of timber harvesting may increase throughout the watershed, possibly including increased use of riparian stands on private land.

4.3.2 Effects on streamflow

Clearcutting is normally found to increase groundwater flow and surface water yield due to a reduction of water loss to the atmosphere by transpiration of trees. The common view that clearcutting reduces low flows in streams may be related to the fact that the surface 30 cm or so of well drained soils are normally drier after logging, being more exposed to sun and wind. In contrast, moist sites frequently become wetter with the increased groundwater supply. Given the present low rate of cut in the Bridge

Creek basin, low flow increases are not expected to be apparent.

Timber harvesting can also affect the timing and quantity of peak flows, with the most pronounced effect occurring during the snowmelt runoff period. More snow accumulates in clearcuts than adjacent forest; snow melts in these areas one to two weeks earlier; and groundwater recharge by snowmelt occurs more quickly, a result of the higher antecedent soil moisture contents. At the basin scale the result is larger runoff volumes which can cause higher and earlier peak flows, depending on the location of clearcuts in the watershed.

Because channels are adjusted to the size of floods which they convey, higher peak flows may increase channel erosion, thereby increasing sediment yields. The Ministry of Forests (1993) is currently developing a 'watershed assessment procedure' to evaluate the susceptibility to such changes. This will normally be applied only where the proportion of disturbed land in a basin exceeds 20 per cent, the hydrologic effects generally not being significant for smaller proportions.

The watershed assessment procedure involves determination of the extent to which regrowth in clearcut acts, hydrologically, as an established forest. A preliminary relationship defined for second growth forests in the Southern Interior indicates full 'hydrologic recovery' when average tree height attains 9 metres. The four tree height classes in Figure 6 were defined to permit estimates to be made of the degree of hydrologic recovery of basins within the Bridge Creek watershed, expressed as the proportion of a basin which acts as a clearcut or the 'equivalent clearcut area'.

Two basins in the Bridge Creek basin with apparently higher rates of cut were evaluated to determine the degree of hydrologic recovery of the logged areas. The equivalent clearcut area in the Little Bridge Creek basin was estimated to be 9 per cent of the basin and the logged area of the Judson Creek basin is equivalent to a 14 per cent clearcut area (Figure 6). At the scale of these larger basins the impact of clearcutting on snowmelt peaks is not expected to be apparent. For smaller sub-basins, such as those draining to smaller lakes in the basin headwaters, there may be a potential for flow regime alteration. These smaller basins were not assessed.

4.3.3 Forest chemical use

Forest fertilization projects are not routinely conducted in the study area. There have been several aerial applications of urea ammonium and sulphate blend fertilizer in trial areas in recent years, mainly on slopes well back from receiving waters. There has been no use of herbicides or pesticides (Raatz, pers. comm.).

4.4 RURAL RESIDENCES, COTTAGES, RESORTS

Rural residences, cottages, and commercial resorts adjacent to lakes or streams are often sources of water pollutants. The severity of water quality impact varies with the intensity and character of development and with the sensitivity of the receiving water.

In conventional, higher-density[1] subdivisions:

drainage patterns are altered by roads, ditches, excavation and land-filling;

surface contaminants such as petroleum products, fertilizer, pesticides, herbicides, animal wastes are more readily transported to waterbodies during snowmelt and storm runoff periods;

sediment production is increased by soil exposure in cultivated areas, construction sites, roads, and ditches;

channel bank and lakeshore erosion may be increased by soil disturbance and vegetation removal;

and, with smaller lot size, there is less flexibility for septic system installation, and leakage of nutrients, bacteria, and other pathogenic organisms to waterbodies is more likely.

In lower-density developments, with less soil disturbance and lower drainage density, surface runoff impacts are reduced; and, with larger lots, there is less likelihood of development encroachment on channel banks and lakeshores and of pollution from septic systems. There is also greater opportunity for design of developments explicitly to minimize water quality impacts.

For a given development the water quality impact will vary with site conditions such as water table depth, soil texture, flood susceptibility, and terrain slope. Well-drained upland soils are preferable both for septic systems, building sites, and control of surface runoff. Being lower-lying and less well-drained, many sites along lakes and streams are unsuitable for septic systems and more prone to surface runoff and flooding.

Along streams, there is a particular hazard of bank erosion which is accelerated by vegetation removal and mechanical disturbance. Removal of streamside vegetation can also bring about an increase in streamwater temperature, often an undesirable change for cold-water fish such as rainbow trout.

[1]For the Cariboo Regional District's lakeshore management strategy low density refers to lots of 0.4 ha or larger (Urban Systems Ltd., 1983).

4.4.1 Lakeshore development

The water quality of lakes for aesthetic, recreational and domestic consumption purposes varies directly with its degree of nutrient enrichment, expressed as its 'trophic state'. Nutrient-poor lakes are classified as 'oligotrophic', moderately-enriched lakes are 'mesotrophic', and nutrient-rich lakes are 'eutrophic'. Eutrophic lakes have more aquatic weed growth and lower water clarity related to the presence of algae. In Bridge Creek basin lakes, phosphorus is the nutrient which limits lake productivity; increases in phosphorus supply would bring about an increase in growth of aquatic weeds and algae.

Another critical water quality concern is the presence of pathogenic organisms such as bacteria (e.g., *Campylobacter* and *E. coli*), parasites (e.g., *Giardia lamblia* cysts), and viruses (e.g., *Hepatitis A*) which can be discharged from leaking septic systems.

Urban Systems Ltd. (1983) has determined the trophic state and rated the water quality sensitivity for the principal recreational lakes in the study area (Table 5). This evaluation is based on limited water quality and hydrologic data, but it does identify the lakes that would be susceptible to development impacts.

For this study an aerial photo count of the number of lakeshore habitations was made to provide an indication of lakeshore development. The estimated numbers of cottages, residences and commercial resorts situated within 100 metres of the lakeshore are tallied in Table 5.[1] Bridge, Deka, Horse, Sheridan, and Sulphurous Lakes have the most lakeshore development, and with the exception of Horse Lake, they are classified as having high water quality sensitivity. Horse Lake is assigned a moderate water quality sensitivity, primarily because of an estimated water residence time which, at 3 to 4 years, is decades less than its upstream counterparts. Bridge, Deka, Sheridan, and Sulphurous Lakes are in headwater locations and have little outflow.

There is no detailed information available concerning the water quality impacts of the existing lakeshore developments. Site-specific soil surveys and lake carrying-capacity analyses would be required to determine impacts. The Ministry of Health (Vath; pers. comm) and the Cariboo Regional District (D'Avignon; Winters, pers. comm.) - the agencies regulating lakeshore septic systems - have provided general information about potential problem areas.

The Deka Lake Subdivision was established in the early 1970's at the lake outlet. More than 1,000 lots were subdivided, but the majority remain vacant due to poor drainage conditions, fine-textured soils, near-surface bedrock, and small lot size. Considering these site limitations, and that the disposal systems are aging, there are

[1]Being based on counts using 1992 aerial photos without field verification, these totals are first estimates only.

Table 5. Lake sensitivity and lakeshore development.

Lake	Trophic state	Flushing period[1]	Water quality sensitivity[2]	Lakeshore development[3]
Bridge	mesotrophic	50 to 60 yr	high	195
Buffalo	n/a*	n/a	n/a	1
Burn	n/a	n/a	n/a	8
Deka	mesotrophic	47 yr	high	141
Drewry	eutrophic	11 yr	moderate	0
Edwards	n/a	n/a	n/a	4
Eugene	n/a	n/a	n/a	5
Fawn	n/a	n/a	n/a	5
Hansen	n/a	n/a	n/a	2
Hathaway	n/a	n/a	n/a	22
Henley	n/a	n/a	n/a	2
Horse	mesotrophic	3 to 4 yr	moderate	297
Knight	n/a	n/a	n/a	2
Lesser Fish	oligotrophic	<2 yr	low	17
Lower	n/a	n/a	n/a	1
Marius	n/a	n/a	n/a	2
Otter	mesotrophic	>10 yr	high	5
Roe	mesotrophic	2 months	moderate	15
Sheridan	mesotrophic	250 yr	high	479
Sulphurous	oligotrophic	'very long'	high	100
Upper	n/a	n/a	n/a	1
Wavey	n/a	n/a	n/a	1
Webb	n/a	n/a	n/a	8
Whitley	n/a	n/a	n/a	1
Wilson	n/a	n/a	n/a	12

*not available
[1]Flushing periods are based on limited flow data and are approximations only.
[2]Water quality sensitivity and flushing periods from Urban Systems Ltd. (1983).
[3]Estimated number of cottages, residences and resorts within 100 m of lakeshore.
- based on 1992 aerial photography.

doubtless failing systems that affect lake water quality.

The lots on Sulphurous Lake are also more than two decades old now and occupy fine-textured soils. With approximately 100 houses or cottages within 100 m of the lake, the potential exists for septic system leakage to the lake.

Sheridan Lake is the most developed of the lakes, with an estimated 479 houses or cottages within 100 m of the shore. Potential problems are related to the aging septic systems, small lot size, low-lying sites, and soil texture.

On Horse Lake much of the development was during the 1960's and septic system functioning may be a problem at some sites. The lots are generally larger and buildings are set back on well-drained upland sites; however, there are some smaller, lower-lying lots which may pose problems, notably in the Anderson Subdivision.

On Bridge Lake most of the lots were developed later than those described above; the lots are larger and there was tighter regulatory control by the Ministry of Health and the Cariboo Regional District as they were developed. In general, fewer problems are expected, although there are some small, older lots along the north shore which may pose problems.

On all these lakes, there are lots created for seasonal recreational use that are now being occupied permanently. With this conversion, additional stress is placed on the capacity of existing disposal systems, larger systems are installed, or new systems replace outhouses. The rate of new housing development is also increasing - primarily as a result of an influx of people from outside the area - with development pressure being greatest along lakeshores. In the 100 Mile House area, for the period January to June in each year: 94 new home permits were recorded in 1993; 74 permits in 1992; and 37 permits in 1991 (McDaniels Research Ltd., 1993).

4.4.2 Streamside development

In the study area upstream from Horse Lake there are only a few residential subdivisions adjacent to streams, lakeside locations being preferred for homes and cottages. The community of Lone Butte is situated on 93 Mile Creek; Deka Lake Subdivision is located at the lake outlet; and Imperial Ranchettes Subdivision flanks the lower reach of Evergreen Creek. As well, there are scattered individual residences along Bridge Creek, Fawn Creek, and 93 Mile Creek, but very few situated close to their riparian zones.

Downstream from Horse Lake there are numerous subdivisions including Creek Heights Subdivision, Gateway, Buffalo Creek, Forest Grove, and Canim Lake Indian Reserve 1. Housing within these developments is mostly on well drained sites above the Bridge Creek floodplain. Altogether there are 80 residences within 100 m of Bridge Creek, but only four which appear to be situated on the floodplain.

4.5 URBAN AND INDUSTRIAL DEVELOPMENT

Historically, there has been an engineering rather than an environmental approach to management of surface runoff in urban areas. The emphasis has been on efficient runoff removal with little attention to downstream impacts. Runoff which is rapidly shed by roofs, pavement, and exposed and compacted soils is collected by networks of ditches and storm sewers for conveyance to receiving waters.

Surface runoff from urban areas is widely reported to be contaminated by elevated concentrations of suspended solids, trace elements and metals, pathogenic organisms, nutrients, synthetic organic compounds, and oxygen-demanding substances. There is a lengthy list of sources of such contaminants which includes: tree leaves; fertilizer; pesticides; herbicides; animal wastes; building materials and coatings; street litter; chemical spillage; illegal discharges; car washes; petroleum spillage and leakage; products of vehicle wear, leakage, and exhaust; road materials; de-icing chemicals; atmospheric fall-out from industrial emissions; construction sites; and surface and ditch erosion.

Although it's difficult to generalize about pollutant quantities, the relative contributions from various urban zones has been differentiated in numerous studies (e.g., Fam, *et al.*, 1987; Hall and Anderson, 1988). In general, stormwater pollutant loadings are greater from commercial, industrial, and high traffic areas than from residential areas and landscaped open space. These former areas are the primary sources of heavy metals, trace elements, and organic compounds, whereas nutrients, oxygen-demanding substances, and pathogenic bacteria derive more from residential areas and open spaces such as golf courses and parks. The exposed soils of construction areas have been identified as the major source of sediment transported to streams from urban areas.

The District of 100 Mile House is 5,715 ha in area and encompasses all the commercial, industrial, and higher-density residential areas within the vicinity. The District population is estimated to be 1,990 people, but it serves a market area of about 20,000 people in the south Cariboo (Haggstrom, pers. comm.). 100 Mile House is also a major service point along Hwy. 97: the 'summer average daily traffic' travelling north from 100 Mile House is 11,500 vehicles per day, somewhat less than half of which is estimated to be non-local traffic (Penner, pers. comm.).

No water quality sampling has been conducted to determine snowmelt or storm runoff pollutant loadings specifically from 100 Mile House to Bridge Creek or Little Bridge Creek. One can only make assumptions based on the character of urban development and the known waste discharges.

There are currently no licensed effluent discharges to Bridge Creek or its tributaries. Until September, 1993 however, 100 Mile House discharged sewage to lagoons located beside Bridge Creek immediately above its confluence with Little Bridge Creek (site 11, Figure 6). Slow leakage occurred from these lagoons through a narrow berm to the creek (Dayton and Knight, 1990) and, on several occasions, the lagoon berms have been breached and spilled sewage directly to the creek (Fogel, pers. comm.), notably on the occasion of a large spill in March, 1991 (Zirnhelt, 1991). These lagoons were closed in 1993 and the stored effluent pumped to the District's new sewage lagoons at Stephenson Lake (site 4, Figure 6).

The Stephenson Lake facility is in a natural depression about 500 m from Bridge Creek. It consists of primary and secondary treatment lagoons plus a permanent storage lagoon. Seepage from the lagoons would be to Stephenson Lake. Since the lake maintains a level at about the elevation of Bridge Creek, no groundwater flow of contaminants to Bridge Creek is expected (Hill, pers. comm.). Treated effluent will be pumped from the permanent storage lagoon to spray irrigation sites on the surrounding slopes and on pasture and hayfield sites between Stephenson Lake and 100 Mile House. The hayfield is adjacent to Little Bridge Creek and there is a limited risk of pollution due to groundwater flow and accidental surface runoff. A condition of the District's waste management permit is that the effluent meet specific limits of biochemical oxygen demand (BOD) and fecal coliform count at the irrigation discharge point (Hill, pers. comm.).

Having rectified the problem of sewage lagoon leakage, the potential pollution sources in 100 Mile House are dispersed throughout the built-up area. A high-traffic commercial zone extends along Hwy. 97 and adjacent streets with residential zones on the eastern and northern sides; and an industrial zone is located along Exeter Station Rd., running west from Hwy. 97 on the north slope of the Little Bridge Creek valley.

Based on mapping by T.R. Underwood Engineering (1993), an estimated 165 ha of 100 Mile House is served by storm sewers. Of this area about 35 per cent drains north to outfalls along Little Bridge Creek; 46 per cent drains west to 100 Mile Marsh (in the Little Bridge Creek basin, Figure 6); and 19 per cent drains east to Bridge Creek. The area draining directly to Bridge Creek is mainly residential; most of the commercial and highway drainage is from the areas flowing to Little Bridge Creek and 100 Mile Marsh.

From 100 Mile House one might expect the range of pollutants reported in other commercial and residential drainage areas. At present there are no specific practices in place to treat contaminated runoff in the source areas (e.g., vegetated filter strips and infiltration basins). 100 Mile Marsh is a 30 ha pond which serves as an effective trap for particulate matter; outflow from the pond follows a ditch west to Exeter Lake.

One singular sediment source area was created during the study period (spring, 1994) with expansion of the Overwaitea store onto a site close to Little Bridge Creek (site 17, Figure 6). Construction activities disturbed a 2 ha area within 10 m of both sides of the creek. At the time of inspection there had been little provision for control of erosion and stream sedimentation. Final project design involves confining Little Bridge Creek to a culvert along its 140 m traverse of the site (Wilders, pers. comm.).

The industrial zone along Exeter Station Rd. is occupied by numerous service and retail outlets (site 5, Figure 6) along the length of road closest to the village; and two sawmills, Weldwood of Canada Ltd. (site 6) and Ainsworth Lumber Co. Ltd. (site 7) to the west. The service and retail area and the majority of the Weldwood mill site drain to Little Bridge Creek downstream from Exeter Lake.

The Weldwood mill site has extensive areas of exposed soils in log storage and lumber yards and parking areas. Untreated runoff from such sources might deliver high suspended solids, nutrients, petroleum products, oxygen-demanding substances, metals, and other trace elements to Little Bridge Creek. Snowmelt runoff from the mill site was sampled on one occasion along Exeter Station Rd. at Jens Rd. to provide an indication of sediment and phosphorus transport; the suspended sediment concentration was 846 mg/L and total phosphorus was 0.006 mg/L. This runoff flowed the 350 m downstream to the inundated wetland fen along Little Bridge Creek. A second sample of snowmelt runoff taken at an Exeter Station Rd. culvert one kilometre to the east had a sediment concentration of 973 mg/L and 0.546 mg/L total phosphorus. This culvert drained portions of the Weldwood mill and the light industrial and retail zone (site 5).

The Ainsworth Lumber sawmill is adjacent to Little Bridge Creek upstream from Exeter Lake. As noted above, snowmelt and storm runoff from the mill yards may deliver sediment and other contaminants to the creek.

Ainsworth has recently completed construction of an oriented strand board (OSB) plant at a site to the west of its lumber mill (site 8, Figure 6) and also adjacent to Little Bridge Creek. During a brief inspection of the access road to the OSB plant construction site in early March, turbid snowmelt runoff was observed flowing to the creek at two locations. Ainsworth has designed a detention pond to store pumped groundwater and to trap surface runoff (Lewis, pers. comm.); however, peripheral areas of the site may still act as sources of sediment and other contaminants delivered to Little Bridge Creek.

At the Ainsworth OSB plant there is an additional concern related to the storage of aspen logs that are to be used by the mill. Leachate from stored aspen logs has been found to be very toxic to all forms of aquatic life (Taylor, 1994). Given the mill's proximity to Little Bridge Creek, the Ministry of Environment, Lands and Parks is requiring Ainsworth to implement measures to contain logyard runoff (Lewis, 1994).

The Cariboo Regional District maintains a refuse site for 100 Mile House (at site 9, Figure 6), 200 m upslope from the OSB plant site and about 800 m from Little Bridge Creek. In spite of this distance, turbid spring runoff was observed flowing from the disturbed soils of the refuse site to the creek, initially along a natural drainage line, but converging with road ditch flow along the western periphery of the OSB plant. A single sample of this flow taken above the plant site contained 952 mg/L suspended sediment and 0.467 mg/L total phosphorus.

Although no water quality monitoring has been carried out to determine pollutant loadings from the built-up area of 100 Mile House, it would be the major source of water quality pollution in the Bridge Creek basin. The downstream effects can only be speculated upon without knowledge of runoff water quality and existing stream conditions. They might include impacts such as toxicity to fish and other aquatic organisms from metals, trace elements, salts and organic compounds; sedimentation of spawning beds; reduction of dissolved oxygen; promotion of aquatic plant and algae growth; and bacterial contamination of recreational water and domestic water supplies.[1]

[1]Canim Lake Indian Reserve 1 residents have complained of reduced water clarity in lower Bridge Creek and attribute health problems to deteriorating water quality (Dixon, pers. comm.).

5.0 WATER QUALITY MANAGEMENT

5.1 CUMULATIVE IMPACTS

5.1.1 Bridge Creek basin upstream from Horse Lake outlet
(sub-basins E, F, G, and H; Table 6)

In the Bridge Creek basin upstream from Horse Lake, it is the cumulative impacts of many, individually minor land uses that determine the quality of surface waters. The primary potential sources that have been identified are livestock wintering area runoff, leakage from lakeside septic systems, snowmelt and storm runoff from residential developments and roads, and logging and agricultural development of riparian zones. In Table 9, the specific sources which have been identified in the course of this project are listed.

The upper basin is dominated by numerous large lakes whose water quality is dependent on land use within their drainage areas and on their individual sensitivity to water quality change. Since pollutants such as phosphorus, bacteria, and sediment would primarily influence those lakes, their combined effects are discussed for the main lake basins.

Bridge Lake is a mesotrophic lake with high water quality sensitivity. It is potentially affected by upstream forestry and agricultural activities and lakeshore development. Bridge Lake has one low-moderate, one moderate, and one moderate-high impact livestock wintering site along its north shore; four other sites were considered to have low potential impacts. There are 195 residences or cottages within 100 m of the lake, although the majority are set back sufficiently from the shore to not pose water quality problems. Forestry activities are relatively extensive in the Bridge Lake basin. Disturbance of riparian and lakeside areas, road-related erosion, and high rates of cut in sub-basins may affect the quality of water draining to Bridge Lake and the many, smaller lakes upstream.

Sheridan Lake is a high-sensitivity, mesotrophic lake which would be mainly affected by lakeshore development. At an estimated 479 cottages and residences within 100 m of the lakeshore, it is the most developed of the lakes in the study area. There are no ranches near the lake and only limited recent logging within its drainage area.

Deka Lake is a high-sensitivity, mesotrophic lake subject to water quality impacts from a residential subdivision near the lake outlet. Potential impacts would be septic system leakage and snowmelt and storm runoff transport of pollutants. There are no ranches near the lake and very little logging in the basin.

Although oligotrophic, Sulphurous Lake is considered to have a high sensitivity due to its low flushing rate. There are approximately 100 residences or cottages within 100 m of the lakeshore, some of

Table 6. Potential water quality impact sites in Bridge Creek sub-basins[1].

Sub-basin	Site description	Potential impact evaluation
A - Bridge Ck. basin below Little Bridge Ck. (Bridge Ck. valley, Halfway Ck., Exeter Ck; excluding Buffalo Ck.)	livestock wintering sites	8 low impact sites 4 low-moderate impact 2 moderate
	road along Bridge Ck. channel bank - site 1	example of erosion due to road encroachment on channel
	pasture sites along Bridge Ck. floodplain - sites 2, 3	examples of channel bank instability related to intensive grazing and shrub removal
	private land logging on slope adjacent to Bridge Ck. - site 10	slope instability and probable sediment source
	Stephenson Lake sewage treatment facility - site 4	low impact
	channel eroding steep valley slopes - sites 13, 14, 15, 16	examples of natural sediment sources
B - Buffalo Ck. basin (Buffalo, Edwards, Drewry Lks.)	livestock wintering sites	3 low impact 2 low-moderate 4 moderate
C - Little Bridge Ck. basin (Exeter, Holden Lks.)	livestock wintering site	moderate impact
	light industrial and retail sites - site 5	potential source of sediment and other contaminants
	Weldwood of Canada Ltd. - site 6	source of sediment and potentially other contaminants
	Ainsworth Lumber Co. Ltd. - site 7	potential source of sediment and other contaminants
	Ainsworth oriented strand board plant - site 8	source of sediment and potentially other contaminants including poplar leachate
	Cariboo Regional District landfill - site 9	source of sediment and potentially other contaminants
	Overwaitea expansion - excavation adjacent to creek - site 17	potential sediment source
	100 Mile House townsite	source of wide range of contaminants discharged by storm sewers

...continued

[1]This table summarizes site-specific potential impacts noted in the text - other, dispersed sources such as logging and agricultural impacts are not listed.

Table 6. Potential water quality impact sites in Bridge Creek sub-basins, continued.

Sub-basin	Site description	Potential impact evaluation
D - Bridge Ck. basin above Little Bridge Ck. and below Horse Lake	100 Mile House townsite	source of wide range of contaminants discharged by storm sewers
	livestock wintering sites	2 low impact 2 moderate impact
	deactivated 100 Mile House sewage lagoons adjacent to Bridge Ck. - site 11	formerly a source of sewage leakage and spillage to creek
	channel eroding steep valley slope - site12	natural sediment source
E - Horse Lake basin (Evergreen, Fawn, Attwood, 93 Mile, Longbow Cks.)	livestock wintering sites	11 low impact 2 low-moderate impact 4 moderate impact 1 moderate-high
	Anderson Subdivision; Imperial Ranchettes; and other lakeside housing development	potential for septic system leakage and transport of contaminants by surface runoff
F - Bridge Ck. basin above Horse Lake and below Deka Ck. (O'Neil Ck., Sheridan Lk.)	livestock wintering sites	2 low impact 1 low-moderate 6 moderate
	Sheridan Lake housing development	potential for septic system leakage and transport of contaminants by surface runoff
G - Deka Ck. basin (Deka, Sulphurous Hathaway Lks.)	Deka Lake Subdivision	potential for septic system leakage and transport of contaminants by surface runoff
	Sulphurous Lk. housing development	potential for septic system leakage and transport of contaminants by surface runoff
H - Bridge Ck. basin above Deka Ck. (Roe, Bridge Lks.; Judson Ck.)	livestock wintering sites	17 low impact 5 low-moderate 2 moderate 3 moderate-high
	Bridge Lk. housing development	potential for septic system leakage and transport of pollutants by surface runoff

which are expected to have septic system leakage problems. There are no ranches located on the lake nor in the upstream basin. Logging is limited, although one cutblock extends to the lakeshore.

Roe Lake, a moderate-sensitivity, mesotrophic lake, is subject to runoff from a low-moderate impact livestock wintering site, a moderate site, and a moderate-high site adjacent to the lake. There are also four wintering sites upstream along Bridge Creek between Roe Lake and Lesser Fish Lake, but they are rated as low impact. A large proportion of the lakeshore is cleared for agriculture and there are an estimated 15 residences within 100 m of the shore.

Along Bridge Creek between Roe Lake and Horse Lake, there are three ranches with 3 low impact livestock wintering sites, 2 low-moderate sites, and 6 moderate impact sites. There is very little residential development along this length of channel. Clearcut areas along the valley are on upland terrain set back from the riparian zone.

The smaller creeks flowing into Horse Lake - Longbow, Fawn, Attwood, 93 Mile and Evergreen Creeks - have only a few livestock wintering areas which pose a significant hazard. Longbow Creek has one site rated moderate; Attwood Creek has one low-moderate, two moderate, and one moderate-high potential impact site; 93 Mile Creek has one low-moderate impact site; and Evergreen Creek has a single moderate impact site. However, the combined impacts of residential and agricultural development and, to a lesser extent, logging activities may affect stream and lake water quality.

Horse Lake is a moderate-sensitivity, mesotrophic lake. There is considerable residential development along the lake, and more underway. Approximately 300 houses are within 100 m of the lakeshore. There are no large ranches beside the lake, but there are numerous small farms which maintain a few animals each.

5.1.2 Bridge Creek basin downstream from Horse Lake
(sub-basins A, B, C, D; Table 6)

Along Bridge Creek between Horse Lake and 100 Mile House, there is considerable agricultural and residential development, but no source that is a singular concern. A ranch near the lake outlet has four livestock wintering areas: the two areas of highest use are considered to have a low impact; and two areas with only limited use have moderate potential impact. There are also at least two sites downstream at which horses are fed on or close to the Bridge Creek floodplain. Most of the residential development is on upland sites along Horse Lake Road, although there are 16 homes within 100 m of the creek. There is no recent logging close to the creek.

In section 4.5, the potential impact of snowmelt and storm runoff from urban and industrial development at 100 Mile House is discussed. This development is the most significant source of water quality pollutants in the basin. An earlier review of the available data by the writer revealed that Little Bridge Creek - which drains

81 per cent of the area of 100 Mile House that is served by storm sewers - had the poorest water quality of the Bridge Creek basin streams (Hart, 1993). Pollutants are transported by snowmelt and storm runoff from sources dispersed throughout the built-up area; no point sources such as industrial and municipal waste discharges have been identified.

Downstream, between 100 Mile House and Canim Lake, potential water quality impacts are related mainly to agricultural and residential development in proximity to Bridge Creek and its tributaries.

Little Bridge Creek has a single, moderate impact livestock wintering area downstream from Exeter Lake. Exeter Creek has two livestock wintering areas which may have a small water quality impact. There are two ranches on Buffalo Lake - with one low-moderate and three moderate impact sites - at which livestock feeding area runoff to the lake was observed. Halfway Creek has a single low-moderate impact feeding area. Ravine Creek has one low-moderate and one moderate impact site. Along Bridge Creek itself there are two low-moderate sites and one moderate impact site. Other significant agricultural impacts are related to land development and intensive pasture use adjacent to channels, notably along the Bridge Creek floodplain.

There are only a few cases along lower Bridge Creek and its tributaries where recent logging has encroached on streams or riparian zones. In the course of a helicopter inspection of the basin, mass wasting of a recently-logged slope on private land along Bridge Creek was observed (site 10, Figure 6). This logging was carried out on erodible lacustrine materials and appeared to have resulted in sediment delivery to the channel.

A gravel pit access road flanking Bridge Creek near Buffalo Creek (site 1, Figure 6) has been noted as a significant sediment source. Detailed inspection may reveal additional road-related sediment sources along this more developed length of valley.

There are also significant natural sediment sources along lower Bridge Creek. Bridge Creek erodes its own floodplain deposits as well as occasional sites where it is deflected by valley slopes.

5.2 REGULATION OF WATER QUALITY

The Province of British Columbia is preparing Community Watershed Guidelines to govern Crown land use in community watersheds, including forestry, mining, agriculture, range, recreation, and residential development. The Guidelines are expected to be advisory in nature for private land. They will apply to community watersheds up to 500 km^2, although larger watersheds could be included by agreement between provincial government ministries. At about 900 km^2, the area drained by Horse Lake (the 100 Mile House watershed) would not automatically be designated a community watershed.

Guidelines and regulations pertaining to specific land uses are discussed below.

5.2.1 Roads

To date, the Ministry of Transportation and Highways has had only brief guidelines for environmental aspects of highway construction. Since 1991 the Ministry has been working on detailed environmental procedures guidelines to apply to highway planning, design, construction, and maintenance practices. These guidelines (to be completed in the fall, 1994) are to address aspects such as erosion and storm runoff control, use of de-icing and dust control chemicals, and protection of streams and lakes (Buckingham, pers. comm.).

The Ministry of Forests and the Ministry of Environment, Lands and Parks are proposing new standards and regulations to control the environmental effects of public forest roads in a *Forest Practices Code*. The Code will address concerns such as road system planning, management of erodible terrain, maintenance of natural drainage lines, revegetation of disturbed areas, and protection of streams. Assuming adequate enforcement, these new practices should considerably enhance water quality protection.

On both public and private land the Water Act (British Columbia) and the Fisheries Act (Canada) have authority over activities that directly affect streams such as installation of culverts or bank protection works and addition of 'deleterious substances' to streams. These Acts provide effective control where a clear case can be made that water pollution has taken place. The less obvious environmental effects of private roads such as surface erosion are effectively unregulated, although the cumulative impact of such dispersed sources may be significant.

5.2.2 Agriculture

Standards for grazing areas and winter livestock feeding areas are set out in the *Code of Agricultural Practice for Waste Management*. The Code regulates storage, composting, and use of agricultural waste; agricultural emissions; disposal of mortalities; and feeding areas and access to water. Violators of the Code are liable to prosecution under British Columbia's Waste Management Act.

The key provisions of the Code which address livestock wintering areas are: feeding areas must have 'berms where necessary to prevent agricultural waste runoff from causing pollution'; feeding must be at least 30 m from a watercourse without written permission from the Regional Manager (Environmental Protection); feeding must be conducted in a manner that manure is distributed as a fertilizer or soil conditioner and that no accumulation of manure causes pollution; and written permission from the Regional Manager (Environmental Protection) must be obtained for location of permanent feed bunks. The main requirement pertaining to livestock grazing and access to water is that pollution is prevented.

Certain other agricultural practices affecting water resources in the study area are regulated by the Water Act and the Fisheries Act. The Water Act regulates changes in or about a stream, waterworks, water diversions, and water use. The Fisheries Act regulates fish habitat protection, channel obstruction, and deposition of deleterious substances in watercourses. Other land use activities such as land clearing and cultivation to streambanks, construction, chemical fertilization, intensive streamside pasture use are unregulated, unless a case can be made that a specific activity is causing pollution.

5.2.3 Forestry

The *Forest Practices Code* now in preparation will significantly strengthen the Ministry of Forests and Ministry of Environment, Lands and Parks authority to manage forestry activities on Crown Land for water quality protection. Detailed regulations are being prepared to control forestry activities within and adjacent to riparian zones and beside lakes and wetlands; soil conservation measures guiding timber harvesting and silvicultural practices will be put in place; and the watershed assessment procedure will set rates of timber harvesting to restrict changes in streamflow regime and impacts on channels. In designated 'community watersheds' - which will normally be less than 500 km^2 in area - forestry activities will be most strictly regulated for maintenance of water quality and quantity.

Private land forestry practices will not be regulated under the Code and they are not currently subject to environmental regulation other than by the Fisheries Act (Canada) and the Water Act (B.C.) (section 5.2.1).

The Ministry of Forests and the Ministry of Environment, Lands and Parks (1994), in cooperation with user groups, is currently developing lake management guidelines and a lake classification system to be used to guide forestry activities in the 100 Mile House Timber Supply Area (Hall, pers. comm.). The intent of the programme is to protect fisheries, wildlife, recreation, tourism, aesthetics and other values of the area's lakes, although investigation of lake water quality will not be carried out. Management strategies will apply to Crown land only.

5.2.4 Residential, cottage and resort development

The Ministry of Health regulates domestic sewage disposal system installation by permit to control discharge of pathogenic organisms to receiving waters under the authority of the Health Act and BC Environment issues waste management permits for sewage disposal systems exceeding discharges of 5,000 gallons/day, normally for commercial purposes.

The Cariboo Regional District has 'lakeshore management guidelines' which prescribe sewage system installation requirements to control discharge of phosphorus to lakes and streams flowing to downstream lakes. These guidelines, however, only apply to subdivisions requiring rezoning. Many subdivisions are proposed and passed that are not subject to the rezoning process and may thus result in violations of the lakeshore management guidelines. This problem could be rectified by amending the Subdivision Regulation administered by the Ministry of Highways to address eutrophication impacts of septic systems and other concerns such as storm drainage and erosion control or by expanding the powers of the Cariboo Regional District's management strategy to apply to all lakeshore subdivisions, regardless of whether they require rezoning (Andrews, pers. comm.).

With adequate enforcement, these measures would provide effective control of new sewage systems installation. However, there are no routine procedures to identify or improve existing systems which may be leaking wastes to groundwater or surface water.

Other residential impacts such as land clearing of streamsides and accelerated storm runoff to receiving waters are not regulated. Urban Systems Ltd. (1983) developed storm runoff control guidelines as a component of the Cariboo Regional District's lakeshore management strategy, but these guidelines have not been enforced (Gillette, pers. comm.). *Land Development Guidelines for the Protection of Aquatic Habitat* prepared by the Department of Fisheries and Oceans and the Ministry of Environment, Lands and Parks (1992) provide comprehensive information concerning riparian vegetation protection, erosion control, stormwater management, instream work, and fish habitat protection. However, BC Environment hasn't the legislative authority to require application of many of these practices, nor to require regional district or municipal governments to adopt them as by-laws for new development.

5.2.5 Urban and industrial development

Specific waste discharges such as municipal sewage or industrial effluent are regulated by permit by BC Environment under the authority of the Waste Management Act. However, there is no legislated control of pollutants transported by snowmelt and storm runoff from dispersed urban and industrial sources unless the source is large and identifiable. BC Environment (1992) has produced excellent *Urban Runoff Quality Control Guidelines for British Columbia* which could be adopted by municipalities and regional districts, but they are not required to do so.

5.3 MANAGEMENT RECOMMENDATIONS

The most significant land uses affecting water quality in the Bridge Creek basin are:

- urban and industrial development in the vicinity of 100 Mile House;

- residential and cottage development along lakeshores and agriculture and forestry in the major lake drainage basins; and

- agricultural land development, grazing, livestock wintering, and forestry along the Bridge Creek floodplain from the Deka Creek confluence to Canim Lake.

General recommendations are listed below for management of these water quality concerns; however, detailed discussion of government agency responsibility and mechanisms for managing land use is beyond the scope of this report. Close, inter-agency cooperation and considerable public involvement are clearly indicated.

5.3.1 Urban and industrial development

Having opened a new sewage treatment facility at Stephenson Lake, the remaining water quality problems in the 100 Mile House vicinity are posed by snowmelt and storm runoff transport of pollutants. The industrial area west of 100 Mile House drains through ditches to Little Bridge Creek; and 46 per cent of the urban storm sewers drain to 100 Mile Marsh (thence to Little Bridge Creek), 35 per cent discharge directly to Little Bridge Creek, and 19 per cent to Bridge Creek.

100 Mile Marsh would trap some particulate matter and other pollutants, although the merits of use of this wetland have not been assessed. The 100 Mile House District may consider construction of wetlands at the site of the old sewage lagoons along Bridge Creek (site 11) for use as a storm runoff treatment facility (Haggstrom, pers. comm.) and there are other possible sites for constructed wetlands.

Many other measures can be taken within the built-up area itself to reduce delivery of pollutants to streams. BC Environment's (1992) *Urban Runoff Quality Control Guidelines for the Province of British Columbia* and the Dept. of Fisheries and Oceans and the Ministry of Environment, Lands, and Parks' (1992) *Land Development Guidelines for the Protection of Aquatic Habitat* detail many approaches to controlling pollutant transport - measures such as reducing use of contaminants, promotion of runoff infiltration, and surface erosion control.

The following recommendations are made for management of urban and industrial area runoff water quality:

- develop a municipal government plan for pollutant control in the urban and industrial source areas and along the established ditch and sewer systems;

- incorporate runoff treatment practices in design of new storm drainage systems;

- consider adoption of Land Development Guidelines and Urban Runoff Quality Control Guidelines in municipal and regional district by-laws; and

- investigate the feasibility of constructing wetlands to treat urban runoff.

5.3.2 Lake basin development

Residential use of lakeshores can affect lake water quality by septic system leakage, by runoff of pollutants such as herbicides, pesticides, and chemical fertilizer, and by accelerated surface and lakeshore erosion. Agricultural land development, livestock wintering, and logging in proximity to upstream watercourses can increase transport of sediment and nutrients to lakes.

The following recommendations are made to control land use impacts on lake and stream water quality:

- monitor water quality to evaluate trophic status and sensitivity of the more developed lakes including Horse (in progress), Sulphurous, Deka, Bridge, and Sheridan Lakes;

- investigate site suitability for housing, septic systems, and roads in lakeside areas based on terrain characteristics (such as soil texture, slope, and drainage conditions), vegetation cover, and drainage pathways;

- survey lakeshore residential development to identify septic systems having the greatest potential to threaten water quality and quantify the actual potential for contamination;

- identify other forms of land development that may threaten water quality;

- the Cariboo Regional District should devise plans to manage streamside and lakeshore residential development to sustain water quality, fish and wildlife, recreational resources, and other aesthetic values - e.g., avoid foreshore development; retain buffer strips of undisturbed vegetation along lakeshores and riparian zones; maintain natural drainage patterns; avoid land-filling and other site development practices within runoff source areas and other sensitive areas; design road ditches to promote runoff infiltration and avoid discharge to lakes and streams; encourage alternate patterns of lakeshore development such as cluster rather than linear development - in the upper Bridge Creek basin, watershed management plans could be made at the scale of the individual lake basins (e.g., Deka Creek, Bridge Lake, and Sheridan Lake basins);

- private land development should be planned in conjunction with the Ministry of Forests and Ministry of Environment, Lands and Parks lake classification and management strategy being developed for Crown land (section 5.2.3);

- programmes should be carried out to inform the public of environmental concerns such as impacts of fertilizer, herbicide, pesticide, and household chemical and detergent use; the impact of leaking septic systems; the importance of regular septic system maintenance; the value of lakeside and riparian buffer strips; the importance of maintaining natural drainage systems;

- work individually with ranchers: to design controls to minimize agricultural land development impacts, to implement low impact livestock wintering practices, and to enforce the *Code of Agricultural Practice for Waste Management*; and

- strict management of forestry activities in riparian zones and adjacent areas is advised - on Crown land this can be accomplished largely by the *Forest Practices Code*; for the 25 per cent of the basin which is private land, public awareness programmes and enforcement of (revised) Water Act and Fisheries Act provisions and Regional District by-laws or guidelines will be required.

In the recently-released Cariboo-Chilcotin Land Use Plan, the Interlakes area is designated as a Special Resource Development Zone. The Plan specifies that timber harvesting, mining, and grazing on Crown Land will take place in a manner that respects the significant fish, wildlife, ecosystem, recreation, or tourism values that exist in these zones. It is expected that detailed subregional planning will be required to accommodate the range of Crown land resource uses in the Interlakes area.

5.3.3 Bridge Creek floodplain development

There is relatively intensive use of the Bridge Creek floodplain (from Deka Creek to Canim Lake) for hayland, pasture, livestock wintering and, to a lesser extent, logging. These activities can all bring about increased stream sedimentation and nutrient loading. Since most of this land is private, mitigative measures to control water quality impacts will have to be planned and carried out in close cooperation with land owners.

The following recommendations are made for water quality management in this zone:

- identify slopes along the Bridge Creek valley that are potentially unstable if disturbed by logging, roads, or other development and consider use of zoning and development restrictions for such sites;

- identify channel reaches where bank erosion may be accelerated by land development, grazing, or logging (in progress by Fisheries Branch) and implement measures such as buffer strips, fencing, and revegetation to mitigate impacts;

- design road ditches to promote runoff infiltration and avoid discharge to Bridge Creek and tributary streams;
- for areas along Bridge Creek and its tributary streams, work with ranchers to design and implement low impact livestock wintering practices and enforce the *Code of Agricultural Practice for Waste Management*; and
- the Cariboo Regional District, with the participation of provincial government agencies, should establish a public process to plan private land use for protection of water quality and other resource values.

5.3.4 Watershed management planning

Individual land use planning processes have been recommended above to address the potential urban and industrial, lake basin, and floodplain development impacts. These 'sub-watershed' management plans should be integrated as components of a management plan for the entire watershed. At this scale, watershed land use would be planned to ensure protection of water quality as well as other resource values such as fisheries, wildlife, and recreation.

In the watershed management planning process, potential impacts should be investigated and prioritized and areas of the basin requiring further assessment should be identified.

To evaluate water quality change at the basin scale, it is recommended that a long-term monitoring programme be established.

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