THE EFFECTS OF RECREATION ON DRINKING WATER QUALITY WITHIN THE LAMBLY, KELOWNA AND MISSION CREEK WATERSHEDS KELOWNA, BRITISH COLUMBIA 2000

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EXECUTIVE SUMMARY

A water quality monitoring project was undertaken in the spring of 2000 in three community watersheds (Lambly, Kelowna and Mission creeks) located near the City of Kelowna, BC, to determine the relative contribution of pathogens to the drinking water supply caused by recreational activities. Parameters included in the study were fecal coliforms and *E. coli*, *Giardia* and *Cryptosporidium*, and general water chemistry parameters including temperature, colour, pH, total suspended solids, turbidity, total inorganic carbon and total organic carbon. Water chemistry parameters and bacteriological analyses were conducted a total of five times between early May and late October. On seven other occasions, a total of five samples were collected from each of the three intake sites and analyzed specifically for *E. coli*. Whenever the presence of *E. coli* was confirmed in any of the water samples, the sample was plated and sent to the Department of Environmental Health at the University of Washington for ribosomal RNA analysis to determine the animal species from which the *E. coli* originated. Scat samples were also collected on a number of occasions in each watershed and analyzed for the presence of *Giardia* and *Cryptosporidium*. General findings and conclusions can be summarized as follows:

- colour levels were high in all three watersheds, with values exceeding the aesthetic drinking water guideline. Lambly Creek had colour concentrations considerably lower than either Mission or Kelowna creeks;
- pH values decreased with elevation in all three watersheds, and values at all sites were well within the acceptable range recommended by the drinking water guideline;
- turbidity and total suspended solids concentrations were generally low, although a slight increase was observed in both parameters during the spring freshet in all three watersheds;
- all three watersheds had relatively high levels of both total organic and total inorganic carbon;
- maximum summer temperatures in the three watersheds (especially Lambly and Mission creeks) either exceeded or were in danger of exceeding the aesthetic drinking water guideline of 15°C;

- all three watersheds had water samples that tested positive for both *Giardia* and *Cryptosporidium* on at least one occasion for at least one site;
- one cow scat sample collected in the Kelowna Creek watershed and two bear scat samples collected in the Mission Creek watershed tested positive for *Cryptosporidium*, and one cow scat sample from the Lambly Creek watershed tested positive for *Giardia*.
- high levels of fecal and total coliforms were present throughout the Kelowna and Mission creek watersheds, and lower levels were present in the Lambly Creek watershed;
- the results of the ribosomal RNA analyses of the *E. coli* samples showed a similar distribution in the three watersheds, with roughly 1/3 of the *E. coli* originating from each of the three groups (cattle, humans and domestic animals, and wildlife). The proportion of *E. coli* originating from cattle was lower in the Lambly Creek watershed, and the proportion of *E. coli* originating from wildlife was proportionately higher at this site. With regard to the concern that, in these watersheds, recreational use poses a significant risk to human health by contributing pathogens to the water supply, it appears that although the contribution from these sources is significant, other contributors (specifically, wildlife and cattle) are an equally high concern.

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1.0 INTRODUCTION

1.1 STUDY AREA

In May of 2000, a water quality monitoring project was undertaken in three community watersheds located near the city of Kelowna, located in the central Okanagan Valley in the interior of British Columbia (Figure 1). The purpose of this project was to determine the effects of recreational activities occurring within these watersheds on drinking water quality. In the 1998/99 Auditor General of British Columbia report on protecting drinking water sources (Office of the Auditor General of BC, 1999), concern was expressed regarding the lack of research on the effects of recreation on drinking-water quality. One of the recommendations made in this report suggested a necessity for the Province to gather information on the potential impacts of recreation on drinking water sources to guide future policy development. This study attempts to contribute some of the information necessary for future decision-making with regards to recreational access to community watersheds.

The watersheds chosen for this study were Lambly (Bear) Creek, Kelowna (Mill) Creek, and Mission Creek, all of which supply water for the purposes of domestic use and irrigation to various irrigation districts. Lambly Creek supplies water to the Lakeview Irrigation District (LID) through the Rose Valley Reservoir, Kelowna Creek supplies water to the Glenmore-Ellison Improvement District (GEID), and Mission Creek supplies water to both the Black Mountain Irrigation District (BMID) (through the mainstem of the creek) and the South-East Kelowna Irrigation District (SEKID) (through Hydraulic Creek, a major tributary to Mission Creek).

1.2 PROJECT GOALS

The primary focus of this project was to determine the effects of recreational activities on drinking water quality. In order to do this, it is necessary to be able to distinguish the effects of these activities from the effects of other impacts within the watersheds. The types of activities occurring in each of the study watersheds are very similar, although the intensity of the different activities varies between watersheds. Primary impacts stemming from human activities are associated with forestry and forestry related activities (road building and maintenance, etc.), cattle grazing, and recreation, while natural impacts include wildlife and natural landslides.

1.3 Determining the Source of Impacts

Both timber harvesting and road construction are most likely to impact water quality by increasing the amount of sediment reaching the creek. Water quality parameters affected by this type of impact include turbidity, total suspended solids, total dissolved solids, specific conductivity, and pH. Other impacts are associated with increased sunlight reaching the creek due to canopy openings, which can affect water temperature and biological productivity (chlorophyll *a* and periphyton concentrations). A summary of logging activities within each watershed is given in Appendix I.

Cattle grazing and recreation have the potential to impact water quality in a number of similar ways. One of the most important concerns associated with both of these types of activity is the potential contamination of the domestic raw water supply from biological wastes. The main health concerns related to the contamination of drinking water with animal or human feces are associated with water-borne diseases caused by bacteria (e.g., *Salmonella*, *Camplyobacter*, *E. coli*), viruses (e.g., various species that cause viral gastroenteritis, hepatitis A, poliomyelitis), or small parasites (e.g., *Cryptosporidium*, *Giardia*, *Toxoplasma*). A second potential influence that these activities can have on water quality relates to the contribution of nutrients (primarily nitrogen and phosphorus) from fecal materials that can increase biological activity within the creek, as well as in lakes and reservoirs below these impacts. Finally, both recreational activities and cattle grazing can cause bank destabilization and erosion resulting from traffic and/or removal of vegetation, which in turn can cause increased turbidity, total suspended solids and sedimentation within the creek. Other concerns associated with recreation activities include contamination from improperly disposed of garbage or hydrocarbons from a variety of sources (four-wheel drive vehicles, all-terrain vehicles, boat motors, etc.). A summary of both recreational activities and cattle grazing are included as Section 3.1 and 3.2, respectively.

Warm-blooded wildlife (including almost all mammal and bird species) can carry and disseminate many of the same diseases as cattle and humans. They will also contribute nutrients in their wastes, and may contribute to bank destabilization and erosion. In the case of nutrients and erosion it is generally a fairly simple matter to determine the source of the problem – the amount of nutrients contributed to the system are directly related to the volume of waste contributed by each species, and physical impacts are also related to the numbers of individuals involved as well as the intensity of use. Because both nitrogen and phosphorus are processed and incorporated into biological matter fairly rapidly in the environment, animal densities considerably greater than those generally seen naturally are necessary to have a significant impact on nutrient levels. While most wildlife species tend to be relatively far ranging and dispersed, cattle do not tend to move as much and are often concentrated in relatively small areas. For this reason, cattle are much more likely to contribute high levels of nutrients, as well as contribute to surface erosion and bank destabilization.

In general, relatively high numbers of individuals are necessary to cause problems with both nutrient levels and erosion. However, in some cases only small amounts of fecal material are necessary to cause a potential health problem. This is due to the extremely high concentration of bacteria (as well as viruses and parasites, in infected individuals) found in feces. For this reason, even a single animal can cause a potential health risk, especially if the contaminated water is improperly treated prior to consumption. Although it is possible to determine the source of a fecal sample through coprology, once the pathogens enter the watercourse a determination of their origins becomes much more difficult. In fact, we are able to determine the source of the pathogen only through deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) analysis, which enables us to identify the species of origin of a specific pathogen. A discussion of wildlife issues within the three watersheds is included in Section 3.3.

2.0 DESCRIPTION OF WATERSHEDS AND SAMPLING LOCATIONS

Four sampling locations were selected within each watershed. Locations were chosen to reflect both longitudinal changes along the creek resulting from natural variability within the watershed, as well as to identify and characterize potential impacts caused by the various land uses within the watershed. To accomplish both of these objectives, sites were selected as far apart as possible geographically (as high in the watershed as possible, down to the terminus of the creeks), as well as to represent various tributaries and reaches. A summary of general watershed characteristics is given in Table 1.

Table 1. Physical characteristics of Kelowna, Lambly and Mission Creek watersheds.

	Kelowna Creek	Lambly Creek	Mission Creek
Total watershed area (km^2)	223.5	244.1	810.0
Designated Community Watershed area (km^2)	76.6	223.0	601.5
Minimum elevation (m)	342	342	342
Maximum elevation (m)	1650	1870	1860
Length of main channel (km)	35.7	20.0	74.3
Mean annual discharge (near mouth) (dam^3/a)	17,597	49,000	199,623

2.1 KELOWNA CREEK

Kelowna Creek (also known locally as Mill Creek) serves as a supply of water for drinking and irrigation purposes to the districts of Glenmore and Ellison. There are three primary storage reservoirs located in the upper watershed (Moore (Bulman), Postill and South lakes) (Figure 1), each with control structures that regulate flows below the lakes. Together, these reservoirs hold approximately 9,000 dam^3 of water. Table 2 shows various physical characteristics for the major lakes in the Kelowna Creek watershed. The mainstem of Kelowna Creek flows through Postill Lake, South Lake drains into Morrison Creek (which enters Kelowna Creek upstream of the confluence with Bulman Creek), and Moore Lake drains into Bulman Creek.

Table 2. Limnological characteristics of significant lakes within the Kelowna Creek watershed.

	Elevation (m)	Surface Area (ha)	Perimeter (km)	Sports-fish species present*
Geen Lake	1646	15.0	4.4	RBT
Postill Lake	1326	96.8	8.4	BT, RBT (S)
South Lake	1400	21.2	3.5	RBT
Moore Lake	1280	24.2	2.9	RBT

*RBT = rainbow trout (*Oncorhynchus mykiss*); BT = brook trout (*Salvelinus fontinalis*); (S) indicates lake stocked for that species

Sampling sites within the Kelowna Creek watershed were located at the outlet of Postill Lake (E223643), on Bulman Creek at the confluence with Kelowna Creek (E241724), at the GEID Intake (E223217), and at the mouth of Kelowna Creek where it enters Okanagan Lake (0500039)(Figure 1). Water flow at the outlet of Postill Lake is primarily through a penstock that delivers water from near the bottom of Postill Lake. Between the GEID intake and Okanagan Lake, Kelowna Creek flows through large residential and commercial areas of the City of Kelowna, and is therefore subject to a wide variety of anthropogenic influences.

2.2 Lambly Creek

Lambly Creek is also referred to as Bear Creek. It is located on the western shore of Okanagan Lake, opposite the city of Kelowna, and supplies water to the Lakeview Irrigation District (LID) for public water supply (drinking water and irrigation). The watershed is composed of three major sub-basins: the North Fork of Lambly Creek, Terrace Creek, and Bald Range Creek. Reservoirs located in the upper watershed are the Esperon Lake, Tadpole Lake and the Big Horn reservoirs, all of which have control structures to regulate flows. The Big Horn Reservoir, located in the Terrace Creek sub-basin, has a 25-m high dam, providing a live storage volume of 3,200 dam^3 (UMA Engineering Ltd., 1993). A square slide gate controls flow on Esperon Lake, which has a live storage volume of 190 dam^3 (UMA Engineering Ltd., 1993). The LID intake consists of an 18.3-m long concrete weir with 1.9-m high sidewalls. A 34" diameter pipeline with a maximum capacity of 0.9 m^3/s conveys water approximately 6.4 km to the

Rose Valley Reservoir, which has a storage volume of 2,880 dam^3. Table 3 shows information pertaining to significant lakes within the watershed.

Table 3. Limnological characteristics of significant lakes within the Lambly Creek watershed.

	Elevation (m)	Surface Area (ha)	Perimeter (km)	Sports-fish species present*
Duo Via Lake		6.5	1.1	BT (S)
Esperon Lake	1615	20.1	2.4	RBT
Tadpole Lake		7.1	1.7	

*RBT = rainbow trout (*Oncorhynchus mykiss*); BT = brook trout (*Salvelinus fontinalis*); (S) indicates lake stocked for that species

There are also future plans for the diversion of Dunwaters Creek from an adjacent watershed into the Duo Via Lake area, which would provide an additional 620 dam^3 of water to the Lambly Creek watershed. This diversion is included in the LIDs 20-year capital works plan, and will be implemented when demand exceeds the current supply.

Lambly Lake is completely diverted out of the Lambly Creek watershed and into the Powers Creek watershed for domestic use by the Westbank Irrigation District (WID). Tadpole Lake is also diverted into the Powers Creek watershed between April 1 and June 15 by the WID.

Sites selected within the Lambly Creek watershed were both above and below the Big Horn Reservoir (Esperon Creek above the reservoir (E241725), and at the outlet of the Big Horn Reservoir (E241746)), at the diversion/intake on Lambly Creek (0500041) and at the Rose Valley Intake (E241402) (Figure 3).

2.3 Mission Creek

Mission Creek is considerably larger than the other two watersheds included in this study, carrying approximately 1/3 of all the water that reaches Okanagan Lake each year. It has a number of significant tributaries, including Hydraulic Creek (28.87 km long), Daves Creek (10.88 km long), Belgo Creek (31.21 km in length), Joe Rich Creek (17.03 km long), and Pearson Creek (22.08 km long) (Figure 3). Stevenson Creek (6.75 km long) is a tributary to Pearson Creek.

There are also a number of significant lakes within the watershed. Haynes, Minnow and Hydraulic lakes form a chain that drains into the upper reaches of Hydraulic Creek. Long Meadow Lake, Browne Lake and Fish Lake form another chain that drains into an unnamed tributary that meets Hydraulic Creek just downstream of Hydraulic Lake. Mission Lake drains into the upper portions of the mainstem of Mission Creek, and the Fish Hawk Lakes also drain into the mainstem via Fish Hawk Creek. Loch Lost drains into Stevenson Creek, Loch Long drains into Mission Creek via Stanley Creek (4.9 km in length), and Graystoke Lake drains into Mission Creek via Loch Katrine Creek (6.8 km long). In the lower portions of the watershed, Ideal (Belgo) Lake drains into Belgo Creek. Table 4 summarizes information about these lakes.

Of the lakes mentioned above, five have control structures that enable them to act as reservoirs. Storage volumes of these lakes (as opposed to actual lake volumes) is as follows: Hydraulic Lake holds about 17,300 dam^3, Graystoke Lake holds approximately 5,100 dam^3, Fish Hawk Lake holds 2,300 dam^3, Ideal Lake holds 6,800 dam^3, and Loch Long holds 500 dam^3.

The four sites selected within the Mission Creek watershed were: Hydraulic Creek at the outlet of McCulloch Reservoir (0500658); Hydraulic Creek at the Myra Forest Service Road Bridge (E241726); Hydraulic Creek at the SEKID intake (E241403); and Mission Creek at the confluence with Okanagan Lake (0500046). Between the SEKID intake and Okanagan Lake Mission Creek passes through both residential and commercial areas of the City of Kelowna (similar to Kelowna Creek), and is subject to a variety of anthropogenic influences.

Table 4. Limnological characteristics of significant lakes within the Mission Creek watershed.

	Elevation (m)	Surface Area (ha)	Perimeter (km)	Sports-fish species present*
Haynes Lake	1257	63.7	4.8	RBT (S)
Minnow Lake	1219	16.8	2.3	RBT (S)
Hydraulic Lake (McCulloch Reservoir)	1257	285.8	23.1	RBT (S)
Long Meadow Lake	1300	26.0	3.2	
Browne Lake	1300	22.5	2.6	RBT (S)
Fish Lake	1311	13.0	1.8	BT (S), RBT
Loch Lost		4.7	1.1	RBT
Loch Long	1829	27.4	3.3	RBT
Graystoke Lake		45.7	3.2	RBT
Mission Lake		31.2	3.5	
Fish Hawk Lakes	1814	48.0	4.4	RBT
Ideal (Belgo) Lake	1300	132.1	9.1	RBT (S)

*RBT = rainbow trout (*Oncorhynchus mykiss*); BT = brook trout (*Salvelinus fontinalis*); (S) indicates lake stocked for that species

3.0 POTENTIAL SOURCES OF FECAL COLIFORMS AND *E. COLI*

As mentioned in Section 1, the three primary sources of fecal coliforms and *E. coli* are: recreation (including domestic pets such as cats and dogs); cattle and other domestic grazing animals; and various warm-blooded wildlife species, including birds and mammals.

3.1 RECREATIONAL USE OF WATERSHEDS

All three of the watersheds included in this study are used on a regular basis for various recreational activities. During the summer, activities consist primarily of fishing in the various lakes, camping, hiking, boating, horseback riding, mountain biking and various motorized activities including all-terrain vehicles (ATV's) motorcycles and 4x4s (McEachnie and Klimuk, 1999). In the winter, snowmobiling occurs to some extent within all three watersheds.

The Kelowna Joint Water Committee (KJWC), working with the Water Quality Branch of the Ministry of Environment, Lands and Parks (MELP) and Youth Options BC, has sponsored a project for the past two years (1999 and 2000) called the Upper Watershed Program (McEachnie and Klimuk, 1999; Iandolo and MacLeod, 2000). The purpose of this program is to educate people that are using the Kelowna Creek, Mission Creek and Hydraulic Creek community watersheds for recreational purposes about the potential effects that their activities can have on drinking water quality. Activities include speaking to various groups (including schools and at various events and festivals), as well as travelling throughout the watersheds talking directly with people using the watersheds and distributing informational pamphlets. Table 5 shows the number of days spent in each district, as well as the number of people contacted directly and the number of vehicles "tagged" with brochures in 1999 and 2000. While this project did not include the Lambly Creek watershed, it is likely that similar results would have been seen there.

Table 5. Summary of activities conducted as part of the Upper Watershed Awareness Program.

	BMID	GEID	SEKID	Total
1999				
Days in District	16	13	19	**48**
# of people directly contacted	163	71	677	**911**
# of vehicles tagged	54	22	148	**224**
2000				
Days in District	15	10	15	**40**
# of people directly contacted	348	316	863	**1527**
# of vehicles tagged	27	3	92	**122**

There was considerable variability between the number of people contacted and number of vehicles tagged per day, both amongst watersheds and between the two sampling years, which makes accurate extrapolations of overall watershed usage throughout the summer difficult. The BMID and GEID upper watersheds had similar concentrations of recreational users, with an average of 16.7 people contacted for each day that educators spent in the BMID and 18.6 people contacted per day in the district for the GEID. This average was considerably higher in the SEKID, where an average of 46.6 people were contacted by educators per day over the two-year period. Assuming that the busiest periods for recreation in the watersheds occurs between July 1 and August 31 (a total of 62 days), it can be extrapolated on this basis that between 1,000 and 1,200 people utilize the BMID and GEID watersheds for recreation during this period, while close to 3,000 people may utilize the upper SEKID watershed over a similar period. These estimates are based on a number of assumptions, including that 1999 and 2000 were typical years, that the educators managed to contact everyone in the watershed during their visit, and that the days that educators chose to visit the watershed were typical days (and not, for example, primarily on weekends).

The majority of the lakes in these watersheds have populations of sports fish including rainbow trout and brook trout (see Section 2) that encourages recreational use. In addition, several lakes (especially in the Mission Creek watershed) are stocked with fish on an annual or semi-annual basis to further encourage fishing activities. There are a number of Forest Recreation Sites maintained by the BC Ministry of Forests (MOF) within each of the watersheds, as summarized in Table 6 (Source: www.for.gov.bc.ca/hfp/rec/brochure/sitelist.htm, 2001).

Table 6. Summary of BC MOF Forest Recreation Sites within the study watersheds.

	# of Vehicle Units	Access*	Activities	Boat Access**
Postill Lake	12	2WD	Fishing	Cartop
Moore Lake	6	2WD	Fishing	Cartop
Ideal Lake	30	RV	Fishing	Boat launch
Hydraulic Lake	12	RV	Fishing, boating, hiking, motor biking	Boat launch
Browne Lake	5	2WD	Boating, fishing, canoeing, private cabins	Boat launch

*2WD denotes two-wheel drive access, RV denotes access suitable for recreational vehicle (trailer or fifth-wheel)

**Cartop access indicates boats must be launched by hand, boat launch indicates that trailers can be used to launch boats

3.2 Cattle Grazing

Cattle grazing on Crown Lands is regulated by grazing permits administered by the BC Ministry of Forests. For each permit issued, a Range Use Plan is prepared which summarizes watershed-specific strategies and objectives for minimizing impacts on water quality and range by grazing cattle. Grazing permits have been issued for each of the three watersheds included in this study. In addition to contributing fecal coliforms, *E. coli* and other potential pathogens, cattle also result in significant nutrient inputs which are discussed in the following sub-sections.

3.2.1 Kelowna Creek

The Ministry of Forests Penticton District office has one grazing license issued to the Eldorado Ranch, allowing 900 cow/calf pairs to graze between Ideal and Postill lakes between August 22 and September 30, and in the Bulman Creek area from October 1 to October 30. The following table shows the potential nutrient contributions from this number of cattle to the watershed for a period of 2.5 months.

Potential nutrient loadings from cattle grazing in the Kelowna Creek watershed (based on 2.5 months, using Bangay's 1976 nutrient coefficients)

	Phosphorus (kg/a)	Nitrogen (kg/a)
Cows (including bulls)	1,485	12,750
Calves	41	339
Total	**1,526**	**13,089**

3.2.2 Lambly Creek

Two grazing leases have been issued for the Lambly Creek watershed. In the first, Dave and Mike Tutt (Licensee 1) are permitted to graze 320 cattle in the Bald Range Creek, Blue Grouse Mountain and Burnt Basin areas between May 7 and October 31. In actuality, they currently only graze 165 cow/calf pairs, 7 cows, 41 yearlings and 10 bulls. Under the second lease, Bert Sperling and Ken Casorso (Licensee 2) are allowed to graze 75 cattle (currently consisting of 60 cow/calf pairs, 12 yearlings and 3 bulls) from May 15 to October 31 in the Burnt Basin pastures.

Both tenures allow for approximately 6 months of grazing, and it is estimated that the Tutt's cattle spend approximately one-third of this time in the Lambly Creek watershed. Sperling and Casorso's cattle are in the watershed about one-half of the six-month grazing period. Based on this length of time, and using Bangays (1976) nutrient coefficients, the potential loading of phosphorous and nitrogen was predicted for each licensee and is shown below.

Estimate of potential loadings for cattle grazing in the Lambly Creek watershed (based on Bangay's (1976) estimates).

	Licensee 1		**Licensee 2**	
	Phosphorus (kg/a)	Nitrogen (kg/a)	Phosphorus (kg/a)	Nitrogen (kg/a)
Cows	227	1,950	119	1,020
Calves	6	50	3	27
Yearlings	22	273	10	120
Total	**255**	**2,273**	**132**	**1,167**

3.2.3 Mission Creek

The Ministry of Forests Penticton District office has one grazing license issued to James Weddel in the upper Mission Creek and the tributaries Pearson Creek, Foolhen Creek and Belgo Creek. It allows 150 cow/calf pairs, 44 yearlings and 6 bulls to graze in this area from May 7 to Oct 31. In the upper part of the watershed near Graystoke Lake, 125 cow/calf pairs are permitted to graze from July 15 to Sept 30 in the area bounded by Buck Mountain in the north to Loch Larson in the south and Long Lake to the west. In June and July, 150 cow/calf pairs are permitted to graze in the area north of Belgo Creek and east of Ideal Lake. Estimates of potential nutrient loadings from these cattle are given in the following tables.

Estimate of potential loadings for cattle grazing in Upper Mission, Pearson, Foolhen and Belgo creeks (based on Bangay's (1976) estimates for a six-month grazing period).

	Phosphorus (kg/a)	Nitrogen (kg/a)
Cows	618	5,304
Calves	17	136
Yearlings	70	878
Total	**705**	**6,318**

Estimate of potential loadings for cattle grazing near Graystoke Lake (based on Bangay's (1976) estimates, and for a 2.5 month grazing period).

	Phosphorus (kg/a)	**Nitrogen (kg/a)**
Cows	206	1,771
Calves	6	47
Total	**212**	**1,818**

Estimate of potential loadings for cattle grazing north of Belgo Creek and east of Ideal Lake (based on Bangay's (1976) estimates, and for a 2 month grazing period).

	Phosphorus (kg/a)	**Nitrogen (kg/a)**
Cows	198	1,700
Calves	6	45
Total	**204**	**1,745**

3.3 WILDLIFE

As mentioned in Section 1.3, all warm-blooded wildlife species (including birds and mammals) are capable of carrying and disseminating fecal coliforms and *E. coli*. In addition, virtually every mammal tested can carry both *Giardia* and *Cryptosporidium*. Obviously it is not possible to regulate the access of wildlife species to a watershed, and wildlife species occurring in each of the three watersheds are similar. In addition to a wide variety of large mammals (including white-tail and mule deer, moose, black bear and the occasional grizzly bear, coyotes, fox, cougar, bobcat and lynx) there are countless species of small terrestrial (e.g. raccoons, skunks, fishers, martens, mink, weasels, rabbits, mice, voles) and aquatic (e.g. beavers, muskrat, otter) mammals in each of the watersheds. There are also a wide variety of migratory (e.g. ducks and geese) and non-migratory bird species that inhabit these watersheds for much of the year. Potential surface-water contamination by these various wildlife species is inevitable and unpredictable, and is one of the primary reasons that all surface waters must be disinfected prior to consumption under the Safe Drinking Water Regulation of the BC Health Act.

4.0 Sampling Protocol

4.1 Sample Schedule

Samples were collected a total of five times at each site between May and October 2000 (see Table 7). Samples were then to a laboratory for analysis of a number of water chemistry parameters (colour, pH, total suspended solids (TSS), turbidity, total inorganic carbon (TIC) and total organic carbon (TOC)), and biological parameters (*Cryptosporidium* oocysts, *Giardia* cysts, total and fecal coliforms, *E. coli* and *Streptococci*). In addition, five water samples were collected on seven different occasions (June 13, June 27, July 25, August 9, August 28, September 13 and September 26) (for a total of 35 samples) at each of the three intake sites (the GEID Intake, SEKID Intake and Rose Valley Intake), and analyzed for *E. coli*. Whenever positive *E. coli* tests were confirmed, these samples were sent to the Department of Environmental Health at the University of Washington in Seattle, WA to determine their origin using ribosomal RNA analysis. Finally, scat samples were also collected at a number of times and locations in each of the three watersheds. Samples were either sent to the University of Washington as reference material for the genetic typing or to the laboratory of Dr. Corinne Ong at the BC Centre for Disease Control (BCCDC) in Vancouver to be examined for the presence of other parasites and identification of the animals from which they originated.

Table 7. Sampling schedule for general water chemistry and biological parameters.

Location	Round #1	Round #2	Round #3	Round #4	Round #5
Mill (Kelowna) Creek at the Mouth	May 8	May 29	July 10	Aug. 14	Oct. 16-D
GEID Intake	May 3	May 29	July 10	Aug. 14	Oct. 16-D
Bulman Creek at Kelowna Creek Confluence	May 8	May 29	July 10-B	Aug. 14	Oct. 16-D
Outlet of Postill Lake	May 8	May 29	July 10	Aug. 14-B	Oct. 16-D
Mission Creek at the Mouth	May 1	May 31	July 12	Aug. 16	Oct. 18-D
SEKID Intake	May 1-B	May 31	July 12	Aug. 16	Oct. 18-D
Outlet of McCulloch Reservoir	May 1	May 31	July 12	Aug. 16	Oct. 18-D
Hydraulic Creek @ Myra FSR Bridge	May 9	May 31	July 12	Aug. 16	Oct. 18-D
Rose Valley Intake	May 2	May 30	July 11	Aug. 15	Oct. 17-D
Diversion/Intake on Lambly Creek	May 1	May 30	July 11	Aug. 15	Oct. 24-D
Outlet of Big Horn Reservoir	May 2	May 30	July 11-B	Aug. 15	Oct. 17-D
Esperon Creek above reservoir	May 2	May 30	July 11	Aug. 15	Oct. 17-D

*D denotes duplicate sample collected on this date, B denotes field blank collected on this date

4.2 Sampling Methodology

General water chemistry samples were collected according to Resource Inventory Commission (RIC) standards, as outlined in Cavanagh (1997a), using a standard 1-L polyethylene sample bottle for general chemistry and a 250-mL polyethylene bottle for TIC and TOC. Samples were stored in a cooler with ice in the field, and shipped to the Pacific Environmental Science Centre (PESC) overnight with ice packs. Samples arrived at PESC on the day following their collection, and water temperature upon arrival was recorded. Specific conductivity (using a Fischer Model 152 conductivity meter) and water temperature were measured in the field when samples were collected, and this information was entered into the Environmental Monitoring System (EMS) (a Provincial database that stores water quality information). In addition, field notes documented adherence to procedures, and noted potential influences to water quality (the presence or evidence of wildlife, recreation activities, weather and water conditions, etc.).

Coliform samples (including total and fecal coliforms, *E. coli* and *Streptococci*) were collected in sterile 250 mL sampling bottles using aseptic sampling procedures as outlined by Cavanagh (1997b). Samples were stored in coolers during the day, and shipped on ice to CanTest Laboratories in Vancouver overnight.

Giardia cysts and *Cryptosporidium* oocysts were collected following USEPA method 1623 (USEPA, 1999), using a portable sampling apparatus consisting of a flow meter (to determine the volume of water filtered) and a generator-powered pump connected to a Gelman capsule filter with a 1 µm nominal porosity. Approximately 25 L of water was filtered through the sampling apparatus to collect the sample, and flow rates were maintained at about 1L per minute. Prior to sample collection, the apparatus was flushed with a minimum of 100 L of water. Once the requisite amount of water had been pumped through the system, the filter was removed and placed in a sealed zip-lock bag, which was in turn stored on ice in a cooler. The samples were shipped in this manner overnight to Hyperion Research Ltd.

When water samples collected at the three intake sites tested positive for the presence of *E. coli*, the number of colony-forming units per 100 mL (CFU/100 mL) were calculated, and the individual colonies were re-plated onto growing medium. The plates were then shipped to the University of Washington, where they were analyzed for ribosomal RNA differences in each isolate in order to generate characteristic data for that individual sample. Comparison of this information with results from reference scat samples enabled, in most instances, a determination of the genus or species of the animal from which the bacteria originated.

Samples of fresh scats were collected on a number of occasions within each watershed. Plastic sampling containers were used to collect the samples (ensuring that contamination did not occur), and the containers were then placed in labeled zip-lock bags and shipped to either the BCCDC or the University of Washington.

4.3 Quality Assurance / Quality Control

A Quality Assurance / Quality Control (QA/QC) program was implemented for this project both in the field during sample collection, and in the laboratory when samples were analyzed.

The field portion of the QA/QC program consisted of three parts: the use of trained, experienced personnel for all sample collection, strict adherence to RIC standards (see Section 4.2), and the collection of duplicate and field blank samples. A total of 12 duplicate samples and four field blanks were collected (see Table 7 above), using identical sampling bottles to those used for the original samples, and duplicates were collected as closely as possible to both the location and time of the original sample. Field blanks were collected by filling sampling bottles with deionized water at the various sampling locations in the same method that regular samples were collected. Samples were then sent to the laboratory for analysis along with the original samples. The purpose of the duplicate samples was to give some indication as to the variability between samples resulting from a number of possible factors, including sample contamination, sampling error, and laboratory error. To minimize the potential for contamination of the *Giardia/Cryptosporidium* filters, they were stored in new sealed zip-lock bags and flushed well between uses. In addition, the filtration apparatus was cleaned using hot soapy water after each sampling day.

The laboratory portion of the QA/QC program consisted of the use of methods based upon those found in "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, QC solution runs, duplicate runs, blank runs, and batch quality control for microbiological analyses in water. Satisfactory results were obtained for all of these analyses.

5.0 Results and Discussion

Water chemistry and bacteriological results from the various sampling locations are tabulated in Appendix II.

5.1 Colour

Typical of the Okanagan area, all three watersheds had relatively high colour levels, especially in the upper portions of the watersheds.

5.1.1 Kelowna Creek

In general, colour values were highest during the beginning of the sampling program and decreased gradually throughout the summer and early fall. The highest value (125 TCU) was recorded at the GEID intake in early May, although high values of 100 and 90 TCU were observed in Bulman Creek in early May and early July, respectively. Values at the GEID intake decreased to a minimum of 45 TCU by mid-October, still well above the aesthetic water quality guideline of 15 TCU for drinking water (Nagpal *et al.* 1998). True colour levels were consistent at the outlet of the Postill Lake Reservoir (between 50 and 55 TCU for the duration of the monitoring program), and therefore the source of the higher colour levels would appear to be the upper portion of the Bulman Creek sub-basin.

5.1.2 Lambly Creek

True colour levels at the Rose Valley intake were considerably lower than elsewhere in the watershed, as well as lower than those seen in both Kelowna and Mission creeks. Values at the intake ranged from 5 to 20 TCU, with an average of 15 TCU. The average colour value is at the threshold of the aesthetic guideline, but three of the five values (between July 10 and October 16) slightly exceeded that value. Mean values at the other three sampling locations in the Lambly Creek watershed ranged from 36.2 TCU at the Diversion to 62 TCU at the outlet of the Big Horn reservoir.

5.1.3 Mission Creek

Within the Mission Creek watershed, true colour values were lowest at the mouth of the creek, with values ranging from 15 TCU to 50 TCU and an average of 28 TCU. At the upstream sites, mean values ranged from 40 TCU at the outlet of Hydraulic Lake to 49.6 TCU at the SEKID intake. All values, with the exception of two late-summer measurements at the mouth of Mission Creek, exceeded the 15 TCU aesthetic guideline for true colour in drinking water.

5.2 PH

In all of the watersheds, pH values in the lower parts of the creeks was invariably slightly basic, ranging from about 7.5 pH units to 8.2 pH units. In the upper parts of the watersheds values were near-neutral, ranging from about 6.7 to 7.2 pH units. All values are well within the acceptable limits for drinking water (a range of 6.5 to 8.5 pH units) (Nagpal *et al.* 1998).

5.3 Total Suspended Solids and Turbidity

5.3.1 Kelowna Creek

Both turbidity and TSS values were highest in the May through July samples and decreased in the August and October samples at all of the sites within the watershed. This is as would be expected, since higher water levels and increased runoff associated with the spring freshet would cause elevated levels of both of these parameters. In addition, both parameters were consistently lower in the upper watershed (at the outlet of Postill Lake) and gradually increased in a downstream direction to maximum values near the mouth of Kelowna Creek. TSS values were consistently below detection limits (<5 mg/L) at the outlet of Postill Lake and the maximum turbidity recorded at this site was only 2.56 nephelometric turbidity units (NTU), while at the mouth of Kelowna Creek TSS values ranged from 10 mg/L in late summer to a high of 44 mg/L in early July. Similarly, the turbidity value at the lower site was only 0.62 NTU on October 16, and a maximum of 22 NTU was observed on July 10. The mean turbidity value measured at the intake (4.3 NTU) was slightly lower than the guideline for the protection of drinking water (5 NTU) (Nagpal *et al.* 1998). Only one of the five values (10.1 NTU, recorded on May 3) exceeded this guideline. No guideline exists for TSS concentrations in drinking water.

5.3.2 Lambly Creek

Total suspended solids concentrations were very low (below the detection limit of 5 mg/L) at all of the sampling sites in the Lambly Creek watershed between May 29 and October 16, 2000. On May 3, the three upper sites had TSS values ranging from 7 mg/L in Esperon Creek to 15 mg/L at the diversion on Lambly Creek. Turbidity values were also generally low (<2 NTU) at all of the sites for the duration of the program, with the exception of two values (3.3 NTU at the diversion on Lambly Creek, and 6.1 NTU at the outlet of the Big Horn Reservoir, both on May 3). The drinking water guideline was exceeded on only this single occasion, at the outlet of the Big Horn Reservoir.

5.3.3 Mission Creek

TSS levels were also generally low (below the detection limit of 5 mg/L) throughout the Mission Creek watershed for the duration of the sampling program. Exceptions included two samples in May at the mouth of Mission Creek (10 to 27 mg/L), and one value at the outlet of Hydraulic Lake in early May (11 mg/L). Turbidity values were similarly low, with maximum values of about 3.5 NTU at all of the sites except on Hydraulic Creek at the Myra FSR (the maximum value here was only 2 NTU). No samples had turbidity values exceeding the 5 NTU guideline for the protection of drinking water.

5.4 Total Organic and Total Inorganic Carbon

High water colour levels generally result from the decomposition of organic matter, and therefore when creeks have high concentrations of colour we would expect them to also have high organic carbon concentrations. Inorganic carbon concentrations result from the erosion of rocks and minerals containing carbon such as graphite and calcium carbonate.

In general, all three watersheds had relatively high concentrations of both organic and inorganic carbon, and the concentrations of both of these materials was proportional to water volume. However, while total organic carbon concentrations were generally directly proportional to water levels (with higher concentrations appearing in the spring and early summer, during freshet), inorganic carbon concentrations were generally inversely proportional to water levels. As such, they tended to increase over the summer as water levels dropped. This difference in relationships is likely due to the source of the different forms of carbon. Organic carbon is present primarily in the upper soil layers and is a result of the decomposition of organic materials. Therefore during spring runoff, water from snowmelt and precipitation will percolate through the upper levels of soils, carrying higher concentrations of organic carbon into the creeks. In contrast, the presence of inorganic carbon is due primarily to the weathering of rock, which occurs primarily within the creek (rather than being carried in from surrounding areas). Therefore, increased water levels in the spring would serve only to dilute the inorganic carbon present in the creeks, and as this dilution effect decreases with decreased water levels, inorganic carbon levels would increase concomitantly.

5.4.1 Kelowna Creek

Total organic carbon concentrations followed the same trend as colour levels in the Kelowna Creek watershed, with the highest values occurring in Bulman Creek at the confluence with Kelowna Creek. Concentrations at all sites generally decreased over the summer, with the exception of the outlet of Postill Lake, where concentrations remained fairly constant throughout the sampling program. The maximum recorded value (18.3 mg/L) occurred at the Bulman Creek site, and mean concentrations ranged from 7.1 mg/L at the mouth of Kelowna Creek to 16.2 mg/L in Bulman Creek at the confluence with Kelowna Creek. These values are all considerably higher than the guideline of 4 mg/L for the protection of surface drinking water (Nagpal *et al.* 1998).

Mean concentrations of total inorganic carbon were fairly consistent at the upper three sites in the Kelowna Creek watershed, ranging from 4.0 mg/L to 6.4 mg/L, but the mean concentration at the mouth was considerably higher (45.1 mg/L). The maximum recorded value within the watershed was 62.2 mg/L on August 14, at the mouth of Kelowna Creek.

5.4.2 Lambly Creek

TOC concentrations in Lambly Creek decreased in both a downstream direction, and over time as the summer progressed. The maximum mean concentration of TOC was 12.1 mg/L at the outlet of the Big Horn reservoir, while the minimum mean value of 5.5 mg/L occurred at the Rose Valley intake. All values measured within the watershed were considerably higher than the 4 mg/L guideline for the protection of drinking water.

Inorganic carbon concentrations behaved in the opposite manner to organic carbon, increasing in both a downstream direction and over the course of the sampling program. Mean values ranged from 6.0 mg/L at the outlet of the Big Horn reservoir to a maximum of 22.7 mg/L at the Rose Valley intake. There is no guideline for inorganic carbon concentrations in drinking water.

5.4.3 Mission Creek

Total organic carbon levels in Mission Creek did not follow the same trend as in the other two study watersheds. Moderate mean values of 9.7 and 8.5 mg/L were found at the outlet of Hydraulic Lake and in Hydraulic Creek at the Myra FSR, respectively, while the highest mean value of 11.4 mg/L was observed at the SEKID intake. The lowest mean value (5.7 mg/L) was measured at the mouth of Mission Creek. The likely reason for the sudden increase at the SEKID intake, rather than a gradual decline in TOC concentrations along the creek (as occurred in the other watersheds), is likely a reflection of higher concentrations in the mainstem of Mission Creek, above the confluence with Hydraulic Creek. This would result in the elevated levels measured at the SEKID intake before TOC concentrations gradually declined once again by the mouth of the creek.

The general trend of increased TIC both over time and in a downstream direction seen in Mission Creek was, however, consistent with trends in the other two watersheds. The mean TIC concentrations measured at the upper Hydraulic sites were 3.2 mg/L at the outlet of Hydraulic Lake and 2.8 mg/L at the Myra FSR. The mean increased to 4.9 mg/L at the SEKID intake, and jumped to 11.3 mg/L at the mouth of Mission Creek.

5.5 Water Temperature

Water temperatures generally increased in a predictable manner in all three watersheds, in both a downstream direction and towards the middle of summer. Maximum values at all sites were observed for the mid-July and mid-August samples, and the warmest temperatures were usually measured at the mouth of the creek. Exceptions to this were associated with the Postill and Hydraulic Lake reservoirs, where the relatively long retention times allowed temperatures to rise significantly, and groundwater seepage downstream of these sites resulted in lowered stream temperatures. The highest water temperatures recorded in each watershed were 16.5°C for Kelowna Creek at the mouth, 19.5°C in Hydraulic Creek at the outlet of Hydraulic Lake, and 20°C at the Rose Valley intake. Water temperatures exceeded the 15°C aesthetic guideline for drinking water at only one intake (Lambly Creek at the Rose Valley intake), although the maximum value at the SEKID intake was equal to the guideline and likely exceeded it between samples.

5.6 CONDUCTIVITY

Conductivity values were generally cumulative (increasing in a downstream direction) at all of the watersheds, reflecting the common trend of a gradual addition of ions along the length of a creek. Specific conductivity values were also usually inversely proportional to water flows: with increasing water levels, ions present in the creek are diluted, while during low flow periods these ions are concentrated. An exception to this was Lambly Creek at the Rose Valley Intake, where specific conductivity values actually declined slightly over the course of the sampling program. The reason for this discrepancy is unclear.

Mean specific conductivity values in the Kelowna Creek watershed increased from 32 μS/cm for the five values collected at Postill Lake to 399 μS/cm at the mouth of Kelowna Creek. A sudden and large increase was observed in specific conductivity levels at the mouth of Kelowna Creek between early spring and mid-summer, with values jumping from 190 μS/cm in late May to 620 μS/cm in mid-August. Specific conductivity values in Lambly Creek followed a similar trend, with a low mean of 44 μS/cm at the outlet of the Big Horn reservoir increasing to a maximum of 193 μS/cm at the Rose Valley intake. Finally, in Mission Creek, the mean specific conductivity increased from 27 μS/cm at the Myra FSR to 97 μS/cm at the mouth of Mission Creek.

5.7 *GIARDIA* AND *CRYPTOSPORIDIUM*

Most samples in all of the watersheds contained no *Giardia* cysts or *Cryptosporidium* oocysts. In Kelowna Creek, only one sample at one site tested positive for *Cryptosporidium*, with 11.4 oocysts/100 L at the mouth of Kelowna Creek on August 14. The two middle sites on Kelowna Creek tested positive on one instance each for *Giardia* (18.7 cysts/100 L at the GEID intake on May 3, and 3.8 cysts/100 L on October 16 in Bulman Creek), and the upper and lower site on the creek had two positive samples each. At the outlet of Postill Lake, 4 cysts and 8 cysts/100 L were found on May 29 and October 16, respectively, while at the mouth of the creek the last two samples collected had concentrations of 11.4 and 13.8 cysts/100 L, respectively.

A single sample (on October 16) in the Lambly Creek watershed was positive for *Cryptosporidium* oocysts, with a total of 16 oocysts/100 L. In contrast, the two lower sites on Lambly Creek tested positive for *Giardia* cysts on one occasion each (on May 29 at the diversion, and on October 16 at the intake), and the upper sites tested positive on two occasions each (August 14 and October 16 in Esperon Creek, and May 3 and October 16 at the outlet of the Big Horn reservoir). The maximum concentration of *Giardia* found in the Lambly Creek watershed was 16 cysts/100 L at the Esperon Creek site.

The presence of *Cryptosporidium* oocysts in Mission Creek was again limited to a single sample, with 4 oocysts/100 L found in the October 16 sample collected from Hydraulic Creek at the Myra FSR. A single instance of *Giardia* cysts were found at the outlet of Hydraulic Lake, with 8 cysts/100 L in the October 16 sample. Two samples tested positive for *Giardia* cysts at the mouth of Mission Creek (July 10 and October 16, with 8 cysts and 20 cysts/100 L, respectively), and three of five samples collected from Hydraulic Creek at the Myra FSR tested positive for *Giardia*. The three positive results were found in the July 10, August 14 and October 16 samples, with 16 cysts, 4 cysts and 24 cysts/100 L, respectively.

5.8 Bacteriology

Four different classes of bacteria were analyzed as part of this study. These consisted of total coliforms, fecal coliforms, *E. coli* and *Streptococci*. This section will discuss the presence of these bacteria at all sites within the watersheds, while section 5.9 will address only the *E. coli* sampling and results of the ribosomal RNA analyses for samples collected at the three intake sites (the GEID intake, the SEKID intake and the Rose Valley intake).

Total coliforms have many non-fecal sources, including soils and plants, and are therefore not necessarily indicative of fecal contamination. Coliform bacteria are specific to warm-blooded animals and are able to grow at elevated temperatures. While rarely pathogenic themselves, they are used as indicators of fecal contamination in water. Species such as *E. coli* and *Streptococci* are even more specific to fecal contamination. Coliforms generally do not survive long in cold, fresh water (Brettar and Höfle, 1992), but can survive for prolonged periods in stream sediment, soils or fecal material, when associated with particulate matter, or in warmer water (Howell *et al.*, 1996; Tiedemann *et al.*, 1987). Water quality guidelines for coliforms are based on 90th percentiles of a minimum of five samples collected in a 30-day period (and ideally 10 samples collected in this time period). Therefore, due to the sampling frequency used in this program, it is not possible to determine useful 90th percentile values or to compare results with drinking water guidelines.

5.8.1 Kelowna Creek

Concentrations of all types of coliforms were lowest in the samples collected at the outlet of Postill Lake. Due to the relatively long residence time of Postill Lake and the short survival time of coliforms in open water, this would be expected. Coliform concentrations then increased in a downstream direction, with the highest values occurring at the mouth of Kelowna Creek. The greatest increase occurred between the GEID intake and the mouth of Kelowna Creek, likely reflecting the higher concentration of people and domestic animals in this residential area. In general, coliform concentrations were higher in Kelowna Creek than in either Lambly or Mission creeks.

5.8.2 Lambly Creek

Coliforms levels were considerably lower in the Lambly Creek watershed than in either Kelowna or Mission creeks. At the outlet of the Big Horn reservoir and at the Rose Valley intake, values for all parameters were almost invariably below detection limits (<1 CFU/100 mL). Coliform levels (especially total coliforms) were slightly higher at the Esperon Creek site and higher again at the diversion on Lambly Creek, especially for the July and August samples. These elevated levels may be a result of increased cattle grazing during this time, increased recreational use, or simply because warmer water temperatures allowed a longer survival time for existing coliforms.

5.8.3 Mission Creek

Coliforms values were lowest at the outlet of Hydraulic Lake, likely due to the increased residence time of water in the lake. Values increased in a downstream direction much as they did in Kelowna Creek, with maximum values occurring at the mouth of Mission Creek. The reason for these increases is likely the same as that for Kelowna Creek, primarily the increased densities of both humans and domestic animals in this reach of the creek.

5.9 *E. coli* and Ribosomal RNA Analyses at the Intake Sites

Results for the *E. coli* and ribosomal RNA analyses are included in Appendix III. *E. coli* levels were consistently highest in the Kelowna Creek watershed, followed by Mission Creek and finally Lambly Creek, which had much lower levels than either Kelowna or Mission creeks. Coliforms concentrations were highest in all watersheds in the mid-summer, between late June and early August.

Table 8 shows the results of the ribosomal RNA analyses for samples collected at the three intake sites. Categories are based on the most precise analysis possible, which varied between samples. For example, for many samples it was possible to determine only that they were of avian (bird) origin, but some of the samples that were identified as avian were able to be further classified to their genus level (either duck or goose). Samples identified to only the avian level may in fact have originated from either ducks or geese, but may also have come from other species of birds. Similarly, while some samples were identified as coming from dogs, others were classified only as canine, which could also include coyotes or wolves. Samples labeled feline may have originated from domestic cats, but may also have come from cougars, bobcats, or lynx.

Table 8. Frequency distribution of the ribosomal RNA results for *E. coli* samples collected at the SEKID, GEID and LID intakes.

	SEKID		GEID		LID	
Cattle	46	27.7%	57	34.1%	3	12.0%
Sub-total	**46**	**27.7%**	**57**	**34.1%**	**3**	**12.0%**
Humans and Domestic Animals						
Humans	25	15.1%	13	7.8%	4	16.0%
Horses	6	3.6%	6	3.6%	1	4.0%
Dogs	2	1.2%	10	6.0%	2	8.0%
Canine	8	4.8%	8	4.8%		
Feline	6	3.6%	5	3.0%	1	4.0%
Pig			1	0.6%		
Sub-total	**47**	**28.3%**	**43**	**25.7%**	**8**	**32.0%**
Wildlife						
Birds	20	12.0%	25	15.0%	4	16.0%
Geese	3	1.8%	6	3.6%	3	12.0%
Ducks	6	3.6%	2	1.2%	2	8.0%
Rodent	4	2.4%	6	3.6%	1	4.0%
Rabbit			1	0.6%		
Deer	3	1.8%	12	7.2%	1	4.0%
Deer-Elk	15	9.0%				
Elk	1	0.6%				
Bear	1	0.6%	2	1.2%		
Sub-total	**53**	**31.9%**	**54**	**32.3%**	**11**	**44.0%**
Unknown	20	12.0%	13	7.8%	3	12.0%
Sub-total	**20**	**12.0%**	**13**	**7.8%**	**3**	**12.0%**
Total	**166**	**100.0%**	**167**	**100.0%**	**25**	**100.0%**

Trends were fairly consistent between watersheds. Humans and domestic animals accounted for between 1/4 and 1/3 of all *E. coli* found in each watershed. Cattle contributed between 12% (at the LID) and 34% (at the GEID) of *E. coli* coliforms collected, and various wildlife species contributed from 32% (SEKID and GEID) to 44% (LID) of *E. coli* coliforms. The sample size for *E. coli* analyzed in the Lambly Creek watershed was considerably smaller than at either of the other two sites, due to the low levels *E. coli* found in that watershed. For that reason, there is considerably less confidence in the actual distribution of *E. coli* origins for Lambly Creek compared to Mission and Kelowna creeks. However, the most significant difference between the *E. coli* origins for Lambly Creek versus Mission and Kelowna creeks relates to the relative contributions of cattle and wildlife. Based on the estimates of nutrient loadings (which would be relatively proportional to the contributions of fecal coliforms, including *E. coli*), Lambly Creek receives considerably lower contributions from cattle than the other two watersheds (see Section 3.2). In considering the nutrient contributions relative to the size of the watershed, estimates of total nitrogen loadings per square kilometer of watershed area for the three watersheds are: 15 kg N per km^2 in Lambly Creek; 16 kg N per km^2 in Mission Creek, and 170 kg N per km^2 in Kelowna Creek. Based on this estimate we might expect there to be similar contributions of *E. coli* from cattle in the Mission Creek and Lambly Creek watersheds and a considerably higher contribution in the Kelowna Creek watershed, assuming all other impacts (wildlife and recreation) are equal between watersheds. The fact that this is not the case suggests that cattle may be in closer proximity to the creek in the Mission Creek watershed, resulting in a higher proportion of their wastes entering the creek and being carried down to the intake.

Appendix IV contains figures showing the distribution of the different classes of *E. coli* (human and domestic animals, cattle and wildlife) as well as unknown samples over the course of the sampling period. No trend is evident with respect to the distribution of the various classes.

It is important to note that when the results of the ribosomal RNA analyses are inconclusive and identify the *E. coli* origins only to the level of canine or feline, they were attributed to domestic animals only for the sake of this study. Some or all of these coliforms may have originated from wildlife (e.g., coyotes, wolves, cougars, bobcats or lynx), which would change the relative distribution of the three categories by decreasing the number of coliforms attributed to humans and domestic animals and increasing the proportion of coliforms contributed by wildlife. This uncertainty is a by-product of the difficulty of identifying every sample to the species level, and is currently unavoidable.

5.10 Analysis of Scat Samples

The results of the scat analyses are given in Table 9. *Cryptosporidium* oocysts were found on three separate occasions, within both the Mission and Kelowna creek watersheds, and *Giardia* was found in one sample from the Lambly Creek watershed. *Cryptosporidium* was found in both bear and cow feces, while the positive *Giardia* result was found in a sample of cow feces. For this study, only presence/absence was determined, and so no comment can be made on the actual concentration of *Cryptosporidium* oocysts and *Giardia* cysts found in the samples.

Table 9. Results of scat sample analyses and presence/absence of *Cryptosporidium*, *Giardia* and intestinal parasites.

Date	Watershed	Sample location	Animal species	*Crypto.**	*Giardia**	Intestinal Parasites*
13-Jun-00	Lambly Creek	Rose Valley	Human			X
09-Jul-00	Kelowna Creek	Postill Road	Bear	X	X	X
09-Jul-00	Kelowna Creek	Postill Road	Cow	X	X	X
12-Jul-00	Kelowna Creek	Postill Road	Cow	X	X	X
15-Jul-00	Kelowna Creek	Postill Road	Cow	X	X	X
15-Aug-00	Lambly Creek	Big Horn Reservoir	Cow	X	Yes	
15-Aug-00	Lambly Creek	Big Horn Reservoir	Cow	X	X	X
18-Aug-00	Mission Creek	McCulloch Rd (8 km)	Bear	Yes	X	
21-Aug-00	Mission Creek	McCulloch Rd (8 km)	Bear	Yes		
22-Aug-00	Kelowna Creek	East of Postill Lake	Cow	X	X	X
22-Aug-00	Kelowna Creek	Postill Road (12 km)	Cow	Yes	X	X

X denotes absence of pathogen, Yes denotes presence of pathogen

5.11 QA/QC

Tables 10, 11 and 12 show a comparison of the laboratory results for duplicate samples collected at the twelve sites. For each sample, the percent relative mean difference was calculated by determining the absolute difference between the two samples, dividing this by the mean of the samples, and converting the result to a percentage. The Guidelines for Interpreting Water Quality Data (Cavanagh *et al.* 1998) indicate an acceptable relative difference of 25 % for duplicates and 18 % relative standard deviation for triplicates.

This method is not acceptable for interpreting bacteriological data due to the lack of homogeneity of coliforms in the water column and resulting high degree of variability between samples. However, these data give some indication of the degree of natural variability within the different systems. The majority of the parameters fell well within the 25% limit for acceptability, with the exception of turbidity. For each watershed, turbidity duplicate values were well outside of the maximum acceptable limit of 25%, with a maximum relative mean percent difference of 147.5% at the mouth of Kelowna Creek. Turbidity is a notoriously difficult parameter to measure as it is based on optical clarity, and can vary significantly between samples and within the water column. While turbidity meters often report results to within one-one hundredth of an NTU, the resolution of the probe is actually only reliable to within 2 NTU. Therefore, the variability found at these relatively low turbidity levels are probably not a serious cause for concern.

Table 13 shows the results of the laboratory analyses of the field blanks collected at the various sampling locations. The majority of the parameters were reported to be below detection limits. However, one turbidity value was reported to be 0.17 NTU, and the same sample (collected on August 14 at the outlet of Postill Lake) had a reported total organic concentration equal to the detection limit (0.5 mg/L). In addition, two of the pH values reported (the one collected at Postill Lake, and one collected at the SEKID intake) were higher than might be expected for deionized water. These results may be indicative of slight levels of contamination in either the field or laboratory, or may indicate errors in analytical methods, but do not occur at a high enough level to cause significant concern.

Table 10. Comparison of duplicate samples collected in Kelowna Creek watershed.

	Kelowna (Mill) Creek at the Mouth			GEID Intake			Outlet of Postill Lake			Bulman Creek at Kelowna Creek Confluence		
	16-Oct-00	Duplicate	**% rel. mean diff.**	16-Oct-00	Duplicate	**% rel. mean diff.**	16-Oct-00	Duplicate	**% rel. mean diff.**	16-Oct-00	Duplicate	**% rel. mean diff.**
Total Coliform	600	750	**22.2%**	22	27	**20.4%**	4	14	**111.1%**	21	20	**4.9%**
Fecal coliform	30	16	**60.9%**	12	11	**8.7%**	<1	<1	**0.0%**	<1	1	**0.0%**
E. Coli	20	16	**22.2%**	12	10	**18.2%**	<1	<1	**0.0%**	<1	1	**0.0%**
Streptococci	320	280	**13.3%**	22	18	**20.0%**	<1	<1	**0.0%**	7	12	**52.6%**
Colour TCU	17.5	15	**15.4%**	45	45	**0.0%**	55	55	**0.0%**	55	55	**0.0%**
pH	8.09	8.18	**1.1%**	7.45	6.95	**6.9%**	7.09	7.09	**0.0%**	7.52	7.32	**2.7%**
TSS mg/L	10	12	**18.2%**	<5	<5	**0.0%**	<5	<5	**0.0%**	6	<5	**18.2%**
Turbidity NTU	0.62	4.1	**147.5%**	0.42	0.23	**58.5%**	1.67	4.19	**86.0%**	0.48	0.77	**46.4%**
TIC mg/L	55.9	55.8	**0.2%**	8.7	8.7	**0.0%**	3.6	3.6	**0.0%**	6.0	5.9	**1.7%**
TOC mg/L	4.7	4.7	**0.0%**	9.5	9.5	**0.0%**	10.1	10.1	**0.0%**	13.5	13.7	**1.5%**

Table 11. Comparison of duplicate samples collected in Lambly Creek watershed.

	Diversion/Intake on Lambly Creek			Rose Valley Intake			Outlet of Big Horn Reservoir			Esperon Creek above reservoir		
	17-Oct-00	Duplicate	**% rel. mean diff.**	17-Oct-00	Duplicate	**% rel. mean diff.**	17-Oct-00	Duplicate	**% rel. mean diff.**	17-Oct-00	Duplicate	**% rel. mean diff.**
Total Coliform	22	12	**58.8%**	40	24	**50.0%**	7	18	**88.0%**	32	32	**0.0%**
Fecal coliform	<1	<1	**0.0%**	<1	<1	**0.0%**	<1	<1	**0.0%**	4	1	**120.0%**
E. Coli	<1	<1	**0.0%**	<1	<1	**0.0%**	<1	<1	**0.0%**	4	1	**120.0%**
Streptococci	1	1	**0.0%**	<1	1	**0.0%**	<1	<1	**0.0%**	2	5	**85.7%**
Colour TCU	16	17.5	**9.0%**	16	13	**20.7%**	55	55	**0.0%**	23	23	**0.0%**
pH	7.98	7.52	**5.9%**	7.49	7.87	**4.9%**	6.81	7.15	**4.9%**	7.39	6.89	**7.0%**
TSS mg/L	<5	<5	**0.0%**	<5	<5	**0.0%**	<5	<5	**0.0%**	<5	<5	**18.2%**
Turbidity NTU	0.2	0.21	**4.9%**	0.08	0.08	**0.0%**	0.24	0.66	**93.3%**	0.77	0.14	**138.5%**
TIC mg/L	24.6	24.4	**0.8%**	22.9	22.9	**0.0%**	5.9	5.8	**1.7%**	9.3	9.4	**1.1%**
TOC mg/L	4.5	4.7	**4.3%**	5.1	5.0	**2.0%**	10.6	10.4	**1.9%**	5.8	5.9	**1.7%**

Table 12. Comparison of duplicate samples collected in the Mission Creek watershed.

	Mission Creek at the Mouth			Outlet of McCulloch Reservoir			SEKID Intake			Bulman Creek at Kelowna Creek Confluence		
	18-Oct-00	Duplicate	**% rel. mean diff.**	18-Oct-00	Duplicate	**% rel. mean diff.**	18-Oct-00	Duplicate	**% rel. mean diff.**	18-Oct-00	Duplicate	**% rel. mean diff.**
Total Coliform	178	148	**18.4%**	13	13	**0.0%**	44	18	**83.9%**	50	30	**50.0%**
Fecal coliform	110	66	**50.0%**	<1	<1	**0.0%**	6	3	**66.7%**	9	11	**20.0%**
E. Coli	98	59	**49.7%**	<1	<1	**0.0%**	4	3	**28.6%**	9	10	**10.5%**
Streptococci	120	68	**55.3%**	<1	<1	**0.0%**	18	13	**32.3%**	<1	<1	**0.0%**
Colour TCU	15	15	**0.0%**	25	25	**0.0%**	28	25	**11.3%**	22	25	**12.8%**
pH	7.95	7.91	**0.5%**	7.52	7.4	**1.6%**	7.53	7.57	**0.5%**	7.75	7.55	**2.6%**
TSS mg/L	<5	<5	**0.0%**	<5	<5	**0.0%**	<5	<5	**0.0%**	<5	<5	**0.0%**
Turbidity NTU	0.39	0.41	**5.0%**	3.27	2.84	**14.1%**	2.78	3.77	**30.2%**	1.11	3.01	**92.2%**
TIC mg/L	16.2	16.2	**0.0%**	3	3.0	**0.0%**	6.0	6.0	**0.0%**	3.5	3.5	**0.0%**
TOC mg/L	2.9	3.0	**3.4%**	8.9	9.0	**1.1%**	8.3	8.2	**1.2%**	5.1	5.0	**2.0%**

Table 13. Results of laboratory analysis of field blanks collected in Kelowna, Lambly and Mission Creek watersheds.

	Outlet of Postill Lake	GEID Intake	Outlet of Big Horn Reservoir	SEKID Intake
Field results	14-Aug-00	10-Jul-00	11-Jul-00	01-May-00
Colour TCU	<2.5	<2.5	<2.5	<2.5
pH	7.32	5.67	5.74	6.65
TSS mg/L	<5	<5	<5	<5
Turbidity NTU	0.17	<0.05	<0.05	<0.05
TIC mg/L	<0.5	<0.5	<0.5	
TOC mg/L	0.5	<0.5	<0.5	<0.05

6.0 Summary and Conclusions

A number of general statements can be made regarding water quality in the three subject watersheds:

- colour levels were high in all three watersheds, with values exceeding the aesthetic drinking water guideline. Lambly Creek had colour concentrations considerably lower than either Mission or Kelowna creeks;
- pH values decreased with elevation in all three watersheds, and values at all sites were well within the acceptable range recommended by the drinking water guideline;
- turbidity and total suspended solids concentrations were generally low, although a slight increase was observed in both parameters during the spring freshet in all three watersheds;
- all three watersheds had relatively high levels of both total organic and total inorganic carbon;
- maximum summer temperatures in the three watersheds (especially Lambly and Mission creeks) either exceeded or were in danger of exceeding the aesthetic drinking water guideline of 15°C;
- all three watersheds had water samples that tested positive for both *Giardia* and *Cryptosporidium* on at least one occasion for at least one site;
- one cow scat sample collected in the Kelowna Creek watershed and two bear scat samples collected in the Mission Creek watershed tested positive for *Cryptosporidium*, and one cow scat sample from the Lambly Creek watershed tested positive for *Giardia*.
- high levels of fecal and total coliforms were present throughout the Kelowna and Mission creek watersheds, and lower levels were present in the Lambly Creek watershed;
- the results of the ribosomal RNA analyses of the *E. coli* samples showed a similar distribution in the three watersheds, with roughly 1/3 of the *E. coli* originating from each of the three groups (cattle, humans and domestic animals, and wildlife). The proportion of *E. coli* originating from cattle was lower in the Lambly Creek watershed, and the proportion of *E. coli* originating from wildlife was proportionately higher at this site. With regard to the concern that, in these watersheds, recreational

use poses a significant risk to human health by contributing pathogens to the water supply, it appears that although the contribution from these sources is significant, other contributors (specifically, wildlife and cattle) are an equally high concern.

There have been a number of recent studies that have attempted to analyze the relationship between public access to watersheds and the presence of various pathogens (including *Cryptosporidium*, *Giardia*, fecal coliforms and *E. coli*), primarily on Vancouver Island (Lucas 1997; Caron 1999; Westland Resource Group 2000). In each of these reports, low concentrations of both *Giardia* and *Cryptosporidium* were found in the various study watersheds, along with relatively high concentrations of both fecal coliforms and *E. coli.* Conclusions drawn from these reports suggest that while recreation and public access definitely play a role in the presence of various pathogens within a watershed, they are generally only one of a number of factors that contribute to this problem. The use of RNA analysis in this study to determine the actual origin of the pathogens contributes significantly to our understanding of the role that recreation plays in contributing pathogens to drinking water sources. For the three watersheds included in this study, recreation, cattle grazing and wildlife were near-equal contributors of *E. coli*, and likely of the other pathogens considered as well.

Figure 1. Map of study area, showing individual sampling locations.

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APPENDIX I SUMMARY OF LOGGING ACTIVITIES OCCURRING WITHIN KELOWNA, LAMBLY AND MISSION CREEK WATERSHEDS.

KELOWNA CREEK

Forestry activities within the Kelowna Creek watershed have occurred over the last 70 years. In the earlier years, lower elevation stands were harvested with selective harvesting techniques. Over the last 35 years, more clearcut harvesting has occurred in higher elevation even-aged lodgepole pine and Engelmann spruce-subalpine fir stands. A significant portion of the annual harvest over the past 15 years has been from salvage logging of lodgepole pine infested by mountain pine beetle.

The following information is based on the Interior Watershed Assessment Procedure for the Kelowna (Mill) Creek Watershed, produced in 1998 (Dobson Engineering, 1998a). As of 1997, Kelowna Creek had an equivalent clearcut area (ECA) of 14.4%. This was projected to increase to 22.3% by 2003. Within sub-basins, the ECA ranged from a low of 5.9% in the South Lake sub-basin to a high of 14.3% in the Postill Lake sub-basin. Above the H_{60}[1] line, the ECA for the total watershed was 7.2%. The total road density within the watershed was moderate to high, at 1.15 km/km^2 above the GEID Diversion. A total of 1.57 km of roads had been built on unstable slopes. There were 26 stream crossings within the watershed, most within the lower portion below the Bulman Creek confluence. Approximately 15% of the entire stream-length had been logged to the streambank (0.15 km/km), with values ranging from 0% in the South Lake sub-basin to 21% in Bulman Creek. About 10% of the stream length had an unstable channel (0.11 km of unstable channel per km of total stream length for the entire watershed), all within the lower portion of the watershed along Postill Lake Road. There have been eight historical landslides documented within the Kelowna Creek watershed area, all below the Bulman Creek confluence, and seven of the eight were associated with the Postill Lake Forest Service Road.

[1] The H_{60} is the elevation at which 60% of the watershed area lies above. This is an important characteristic because in the interior of B.C., snow typically covers the upper 60% of a watershed when streamflow levels begin to rise in the spring

To address concerns about terrain instability and soil erosion, a number of projects have been initiated. These include erosion control measures including relocation and rehabilitation of the section between 9 km and 13 km of the Postill Lake Road, and road deactivation and modification in the Bulman sub-basin.

LAMBLY CREEK

Timber harvesting in the Lambly Creek watershed dates back approximately 80 years, to the 1920's. Most of the early harvesting occurred at lower elevations and consisted of selective or diameter-limit harvesting. More recently, harvesting has advanced to higher elevations, with clearcutting being the primary harvest method over the past 40 years. Riverside Forest Products Ltd., under TFL 49, and the Small Business Forest Enterprise Program (SBFEP) of the Ministry of Forests are both actively operating within the Lambly Creek watershed.

The ECA for the Lambly Creek watershed above the LID Intake is 31%. The ECA for the three sub-basins are 35.6% (North Fork Creek), 38.1% (Terrace Creek), and 24.3% (Bald Range Creek). The ECA for the entire watershed is slightly higher than the maximum of 30% recommended by the Timber Harvesting Guidelines for any watershed, and considerably higher than the 20% maximum recommended for Community Watersheds (Kamloops Forest Region, 1992).

The Lambly Creek watershed also has a high surface erosion rating due to the extensive road network. There are approximately 800 km of roads in the watershed with a resulting road density of 3.2 km/km^2. However, only 1.72 km of roads of the 800 km total are considered high risk. These high-risk roads include the roads on potentially unstable slopes (1.1 km) and roads determined to be a high sediment source (1.62 km) (Dobson Engineering Ltd., 1998b).

Additional forestry-related impacts to the Lambly Creek watershed include landslides and the removal of riparian zones. Five forestry related landslides have occurred in the watershed, resulting in a low impact rating for the watershed. Approximately 799 of the

800 km of roads in the watershed are located on stable terrain and will most likely not contribute to further landslides. Finally, approximately thirty percent of fish bearing streams within the Lambly Creek watershed have been harvested (Dobson Engineering Ltd., 1998b).

MISSION CREEK

Forestry activities within the Mission Creek watershed have occurred since the turn of the century, with the majority of the harvesting occurring in the 1980's to control mountain pine beetle infestations. Three licensees, Riverside Forest Products Limited, Tolko Industries Limited and Gorman Brothers Lumber Limited operate within the watershed, and there are three woodlots within the watershed with an annual harvest of 1000 m^3 each.

The following information is based on the Interior Watershed Assessment Procedure for the Mission Creek Watershed Update Report (Dobson Engineering, 1998c). As of 1997, Mission Creek had an equivalent clearcut area (ECA) of 19.3%. This is projected to increase to 21.8% by 2003. Within sub-basins, the ECA currently ranges from a low of 10.4% in Joe Rich Creek to a high of 47.3% in Daves Creek. Above the H_{60} line, the ECA for the total watershed is 13.7%. The H_{60} line occurs at about the 1,300 m contour. The total road density within the watershed is moderate to high, ranging from 1.0 km/km^2 in Mission Creek above Pearson Creek to 3.0 km/km^2 in Daves Creek. Only about 0.3 km of roads have been built on unstable slopes. There are a very high number of stream crossings within the Mission Creek watershed however, with 153 in the Belgo Creek sub-basin, 120 in Mission Creek above Pearson Creek, and 504 crossings in total throughout the watershed. Approximately one-fifth of the entire stream-length has been logged to the streambank (0.21 km/km), with values ranging from 0.11 km/km in Pearson Creek to 0.57 km/km in Daves Creek. Over 40% of the stream length has an unstable channel (0.43 km/km for the total watershed). There have been 64 historical landslides documented within the total watershed area, with the vast majority (47 of the 64) occurring in Mission Creek above Pearson Creek. Of the 64 landslides, 11 appear to be related to forest development activities.

Landslides have caused problems for water quality in the past in Mission Creek, resulting in high turbidity levels and poor drinking water quality. Efforts are being made to decrease forestry impacts by deactivating high-priority sites identified in a road assessment completed in 1996. Thirteen of 37 high-priority sites were deactivated in 1997, along with 60 km of road. Long-term forestry plans are being developed for sensitive portions of the watershed (including Pearson Creek and Mission Creek above Pearson Creek) to minimize the risk of increased peak flows. In addition, no further harvesting is proposed for the Daves Creek watershed until at least 2004, to allow the 1997 ECA of 47.3% to decrease to 42.4%.

APPENDIX II. WATER CHEMISTRY AND BACTERIOLOGY RESULTS FOR THE TWELVE SAMPLING LOCATIONS.

Table 1. Water Chemistry and Bacteriology for Site 0500039, Kelowna (Mill) Creek at the Mouth.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	08-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	19.8	14.6	8.1	4.1	5.19	**10.4**
Air temperature °C	9	16	20.5	14	7.0	**13.3**
Water temperature °C	7	10	16.5	16	9.0	**11.7**
Conductivity µS/cm	180	180	425	620	590	**399**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	11.4	0.0	**2.3**
Giardia cysts/100 L	0.0	0.0	0.0	11.4	13.8	**5.0**
Total Coliform (CFU/100 mL)	3500	5	35000	620	600	**7945**
Fecal coliform (CFU/100 mL)	350	<2	1100	500	30	**396**
E. coli (CFU/100 mL)	350	<2	540	310	20	**244**
Streptococci (CFU/100 mL)	113	140	86	98	320	**151**
Colour (TCU)	80	55	20	15	17.5	**37.5**
pH	7.37	7.74	7.98	8.17	8.09	**7.87**
TSS (mg/L)	30	36	44	10	10	**26**
Turbidity (NTU)	15.1	13.4	22	3.15	0.62	**10.9**
TIC mg/L		18.5	43.6	62.2	55.9	**45.1**
TOC mg/L	14.3	11.1	3.2	2.3	4.7	**7.1**

Table 2. Water Chemistry and Bacteriology for Site E223217, Kelowna (Mill) Creek at the GEID Intake.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	10.7	4.89	3.4	4.55	1.31	**5.0**
Air temperature °C	9.5	12	18.5	14.5	8	**12.5**
Water temperature °C	5	8	12.5	12	4.5	**8.4**
Conductivity µS/cm	72	47	54	40	73	**57**
Lab results						
Cryptosporidium oocysts/100L	0	0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	18.7	0	0.0	0.0	0.0	**3.7**
Total coliform (CFU/100 mL)	17	21	1600	56	22	**343**
Fecal coliform (CFU/100 mL)	7	2	13	21	12	**11**
E. coli (CFU/100 mL)	7	2	13	20	12	**11**
Streptococci (CFU/100 mL)	1	<1	8	26	22	**12**
Colour (TCU)	125	55	60	55	45	**68**
pH	7.22	7.42	7.54	7.68	7.45	**7.46**
TSS (mg/L)	17	<5	<5	9	<5	**8.2**
Turbidity (NTU)	10.1	3.8	3.2	3.93	0.42	**4.3**
TIC mg/L		5.1	6.7	5.0	8.7	**6.4**
TOC mg/L	21.4	13.1	10.6	11.0	9.5	**13.1**

Table 3. Water Chemistry and Bacteriology for Site E241724, Bulman Creek at the Kelowna Creek confluence.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	6.04	2.65	11.5	4.4	1.52	**5.2**
Air temperature °C	10.0	9.5	18.5	21.5	5	**12.9**
Water temperature °C	5.0	8.5	13.5	10	5	**8.4**
Conductivity µS/cm	46	47	48	39	54	**46.8**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	0.0	0.0	0.0	3.8	**0.8**
Total coliform (CFU/100 mL)	11	228	350	9	21	**124**
Fecal coliform (CFU/100 mL)	<2	1	130	1	<1	**33**
E. coli (CFU/100 mL)	<2	1	130	1	<1	**33**
Streptococci (CFU/100 mL)	1	<1	110	5	7	**25**
Colour (TCU)	100	65	90	75	55	**77**
pH	6.86	7.37	7.54	7.9	7.52	**7.44**
TSS (mg/L)	8	<5	30	6	6	**11**
Turbidity (NTU)	4.74	2.4	18	4.09	0.48	**5.9**
TIC mg/L		5.2	6.1	5.1	6.0	**5.6**
TOC mg/L	18.3	17.7	15.6	16.0	13.5	**16.2**

Table 4. Water Chemistry and Bacteriology for Site E223643, Kelowna Creek at the outlet of Postill Lake.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	2.84	1.75	0.9	1.25	1.52	**1.7**
Air temperature °C	10	10.5	18.5	16	5	**12.0**
Water temperature °C	6	7.5	10.5	14.5	7	**9.1**
Conductivity µS/cm	40	32	28.5	31	26	**31.5**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	4.0	0.0	0.0	8.0	**2.4**
Total coliform (CFU/100 mL)	166	250	86	<1	4	**101**
Fecal coliform (CFU/100 mL)	<1	1	<1	<1	<1	**<1**
E. coli (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
Streptococci (CFU/100 mL)	1	1	<1	<1	<1	**<1**
Colour (TCU)	50	55	50	55	55	**53**
pH	6.79	6.97	7.04	6.79	7.09	**6.94**
TSS (mg/L)	<5	<5	<5	<5	<5	**<5**
Turbidity (NTU)	2.56	1.35	0.98	1.16	1.67	**1.5**
TIC mg/L		3.9	3.9	4.6	3.6	**4.0**
TOC mg/L	10.6	11.7	10.1	10.3	10.1	**10.6**

Table 5. Water Chemistry and Bacteriology for Site E241402, Lambly Creek at the Rose Valley Intake

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	0.51	0.55	0.58	0.62	0.63	**0.6**
Air temperature °C	11.5	10.5	16.5	17.5	9	**13.0**
Water Temperature °C	7.5	12.5	17	20	12.5	**13.9**
Conductivity µS/cm	210	205	180	180	190	**193**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	16.0	**3.2**
Giardia cysts/100 L	0.0	0.0	0.0	0.0	8.0	**1.6**
Total coliform (CFU/100 mL)	<2	21	77	<1	40	**28.2**
Fecal coliform (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
E. coli (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
Streptococci (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
Colour (TCU)	15	5	20	19	16	**15**
pH	7.99	7.99	8.03	7.97	7.49	**7.89**
TSS (mg/L)	<5	<5	<5	<5	<5	**<5**
Turbidity (NTU)	0.34	0.48	0.61	0.78	0.08	**0.5**
TIC mg/L			23.0	22.2	22.9	**22.7**
TOC mg/L	5.7	5.8	5.0	5.8	5.1	**5.5**

Table 6. Water Chemistry and Bacteriology for Site 0500041, Diversion on Lambly Creek

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	4.52	1.8	0.84	0.57	0.62	**1.7**
Air temperature °C	15	14.5	19	16.5	1	**13.2**
Water Temperature °C	4	7	12	11	3	**7.4**
Conductivity µS/cm	74	87	115	195	180	**130**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	6.5	0.0	0.0	0.0	**1.3**
Total coliform (CFU/100 mL)	1300	116	287	17	22	**348**
Fecal coliform (CFU/100 mL)	2	3	11	13	<1	**6.0**
E. coli (CFU/100 mL)	<1	<1	10	11	<1	**4.8**
Streptococci (CFU/100 mL)	3	1	22	10	1	**7.4**
Colour (TCU)	60	50	40	15	16	**36**
pH	7.5	7.69	8.00	8.22	7.98	**7.88**
TSS (mg/L)	15	<5	<5	<5	<5	**7.0**
Turbidity (NTU)	3.3	1.6	1.1	0.47	0.2	**1.3**
TIC mg/L		10.2	15.4	24.5	24.6	**18.7**
TOC mg/L	13.3	10.5	7.2	4.5	4.5	**8.0**

Table 7. Water Chemistry and Bacteriology for Site E241746, Lambly Creek at the outlet of the Big Horn Reservoir

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	6.64	1.66	1.25	1.15	1.75	**2.5**
Air temperature °C	10	12.5	23	22	7	**14.9**
Water Temperature °C	2.5	5	8	8	7.5	**6.2**
Conductivity µS/cm	64	35	30	n/a	46	**43.8**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	2.0	0.0	0.0	0.0	15.4	**3.5**
Total coliform (CFU/100 mL)	22	39	72	12	7	**30.4**
Fecal coliform (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
E. coli (CFU/100 mL)	<1	<1	<1	<1	<1	**<1**
Streptococci (CFU/100 mL)	<1	<1	1	<1	<1	**<1**
Colour (TCU)	70	65	60	60	55	**62**
pH	6.72	7.03	6.89	7.02	6.81	**6.89**
TSS (mg/L)	10	<5	<5	<5	<5	**10.0**
Turbidity (NTU)	6.1	1.63	1.1	1.11	0.24	**2.0**
TIC mg/L			6.0	6.2	5.9	**6.0**
TOC mg/L	14	10.5	13.0	12.5	10.6	**12.1**

Table 8. Water Chemistry and Bacteriology for Site E241725, Esperon Creek above the Reservoir.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	0.79	0.43	0.59	0.56	0.5	**0.6**
Air temperature °C	12	9	21.5	16.5	7.0	**13.2**
Water Temperature °C	3	6	12	11	4.0	**7.2**
Conductivity µS/cm	36	43	42	n/a	76	**49.3**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	0.0	0.0	8.0	16.0	**4.8**
Total coliform (CFU/100 mL)	24	46	240	22	32	**73**
Fecal coliform (CFU/100 mL)	<1	1	1	14	4	**4.2**
E. coli (CFU/100 mL)	<1	1	1	12	4	**3.8**
Streptococci (CFU/100 mL)	<1	<1	29	8	2	**8.2**
Colour (TCU)	80	45	50	20	23	**44**
pH	7.25	7.42	7.6	7.81	7.39	**7.49**
TSS (mg/L)	7	<5	<5	<5	<5	**5.4**
Turbidity (NTU)	0.62	0.73	1.0	0.65	0.77	**0.8**
TIC mg/L		4.4	5.8	8.8	9.3	**7.1**
TOC mg/L	14.5	11	10.1	4.8	5.8	**9.2**

Table 9. Water Chemistry and Bacteriology for Site 0500046, Mission Creek at the Mouth

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	8.4	4.85	1.8	1.25	1.47	**3.6**
Air temperature °C	12.0	14.0	17	17	9	**13.8**
Water Temperature °C	6.5	7	14	14	8	**9.9**
Conductivity µS/cm	66	51	68	140	160	**97.0**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	0.0	8.0	0.0	20.0	**5.6**
Total coliform (CFU/100 mL)	1700	205	37	200	178	**464**
Fecal coliform (CFU/100 mL)	32	26	32	100	110	**60**
E. coli (CFU/100 mL)	32	23	28	60	98	**48**
Streptococci (CFU/100 mL)	11	22	18	68	120	**48**
Colour (TCU)	50	35	25	15	15	**28.0**
pH	7.63	7.44	7.77	7.82	7.95	**7.72**
TSS (mg/L)	27	10	<5	<5	<5	**10.4**
Turbidity (NTU)	3.3	2	1.4	0.91	0.39	**1.6**
TIC mg/L		5.5	7.5	15.8	16.2	**11.3**
TOC mg/L	11	7.2	4.5	3.1	2.9	**5.7**

Table 10. Water Chemistry and Bacteriology for Site E241403, Mission Creek at the SEKID Intake

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	3.67	3.85	3.4	2.65	3.24	**3.4**
Air temperature °C	15.5	9	19	18.5	8.0	**14.0**
Water Temperature °C	6.0	11	15	15	8.0	**11.0**
Conductivity µS/cm	68	71	38	32	57	**53.2**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	0.0	0.0	0.0	0.0	**0.0**
Total coliform (CFU/100 mL)	186	297	30	16	44	**115**
Fecal coliform (CFU/100 mL)	1	47	18	3	6	**15**
E. coli (CFU/100 mL)	1	44	17	1	4	**13**
Streptococci (CFU/100 mL)	<1	<1	9	3	18	**6**
Colour (TCU)	80	50	50	40	28	**50**
pH	7.63	7.35	7.47	7.53	7.53	**7.50**
TSS (mg/L)	<5	<5	<5	6	<5	**<5**
Turbidity (NTU)	3.2	1.68	3.5	2.7	2.78	**2.8**
TIC mg/L		5.3	4.3	3.8	6.0	**4.9**
TOC mg/L	18.1	11.4	10.1	8.9	8.3	**11.4**

Table 11. Water Chemistry and Bacteriology for Site 0500658, Outlet of Hydraulic Lake

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	3.12	1.65	2.35	1.8	3.58	**2.5**
Air temperature °C	14.0	12	18.5	24	8.5	**15.4**
Water Temperature °C	6.5	10	14.5	19.5	7.5	**11.6**
Conductivity µS/cm	34	41	24	27	30	**31.2**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	0.0	**0.0**
Giardia cysts/100 L	0.0	0.0	0.0	0.0	8.0	**1.6**
Total coliform (CFU/100 mL)	3500	52	9	34	13	**722**
Fecal coliform (CFU/100 mL)	2	<1	3	1	<1	**1.6**
E. coli (CFU/100 mL)	<1	<1	3	<1	<1	**1.4**
Streptococci (CFU/100 mL)	2	<1	<1	1	<1	**1.2**
Colour (TCU)	25	45	55	40	25	**38**
pH	6.81	7.02	7.17	7.26	7.52	**7.16**
TSS (mg/L)	11	<5	<5	<5	<5	**6.2**
Turbidity (NTU)	2.8	1.34	2.2	1.19	3.27	**2.2**
TIC mg/L		3.3	3.3	3.2	3	**3.2**
TOC mg/L	9.1	10.9	10.4	9.4	8.9	**9.7**

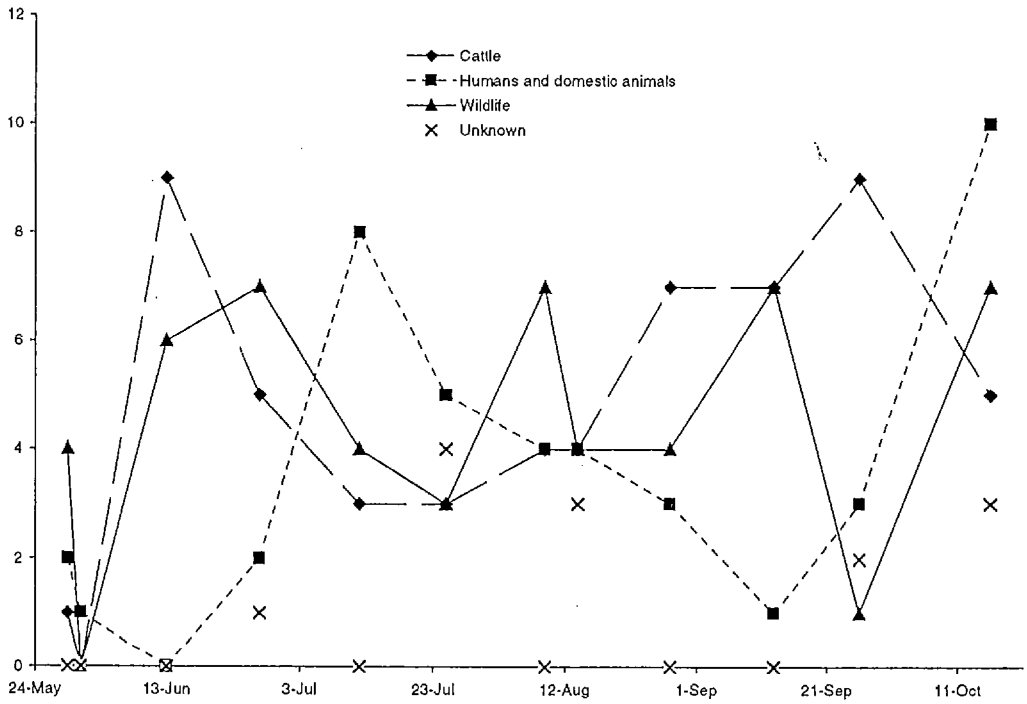
Table 12. Water Chemistry and Bacteriology for Site E241726, Hydraulic Creek at the Myra FSR.

	Round 1	Round 2	Round 3	Round 4	Round 5	
Field results	03-May-00	29-May-00	10-Jul-00	14-Aug-22	16-Oct-00	**Mean**
Turbidity NTU	2.25	2.12	2.1	1.5	1.66	**1.9**
Air temperature °C	3.0	11.0	20	17.5	10.5	**12.4**
Water Temperature °C	1.0	8.0	14.5	16	6.5	**9.2**
Conductivity μS/cm	21	30	20	29	33	**26.6**
Lab results						
Cryptosporidium oocysts/100L	0.0	0.0	0.0	0.0	4.0	**0.8**
Giardia cysts/100 L	0.0	0.0	16.0	4.0	24.0	**8.8**
Total coliform (CFU/100 mL)	64	82	6	40	50	**48**
Fecal coliform (CFU/100 mL)	1	2	<1	15	9	**5.6**
E. coli (CFU/100 mL)	1	2	<1	<1	9	**2.8**
Streptococci (CFU/100 mL)	1	<1	9	12	<1	**4.8**
Colour (TCU)	60	50	50	30	22	**42**
pH	6.65	6.94	7.29	7.37	7.75	**7.20**
TSS (mg/L)	<5	<5	<5	<5	<5	**<5**
Turbidity (NTU)	1.55	1.14	2	0.29	1.11	**1.2**
TIC mg/L		1.6	2.3	3.7	3.5	**2.8**
TOC mg/L	12.2	10.7	8.5	6.2	5.1	**8.5**

Appendix III. Results of *E. coli* Sampling at the GEID, SEKID and LID Community Watershed Intakes.

Field results	3-May	29-May	13-Jun	27-Jun	10-Jul	25-Jul	9-Aug	14-Aug	28-Aug	13-Sep	26-Sep	16-Oct	Mean
GEID													
E. coli #1	7	2	3	12	13	15	12	20	6	8	2	12	**10.1**
E. coli #2			3	14		28	12		4	5	3		**9.9**
E. coli #3			3	12		12	10		3	3	2		**6.4**
E. coli #4			6	13		25	14		4	7	1		**10.0**
E. coli #5			5	14		29	7		4	9	1		**9.9**
SEKID													
E. coli #1	1	44	9	9	17	3	4	1	2	3	2	4	**5.6**
E. coli #2			7	10		6	5		4	3	2		**5.3**
E. coli #3			9	15		2	2		4	2	1		**5.0**
E. coli #4			13	13		2	4		5	6	1		**6.3**
E. coli #5			11	10		2	2		3	3	1		**4.6**
LID													
E. coli #1	<1	<1	1	1	<1	15	<1	<1	<1	<1	<1	<1	**2.6**
E. coli #2			<1	<1		4	<1		<1	<1	<1		**<1**
E. coli #3			<1	<1		1	<1		1	<1	<1		**<1**
E. coli #4			<1	2		2	<1		<1	<1	<1		**<1**
E. coli #5			<1	2		5	<1		<1	<1	<1		**1.7**

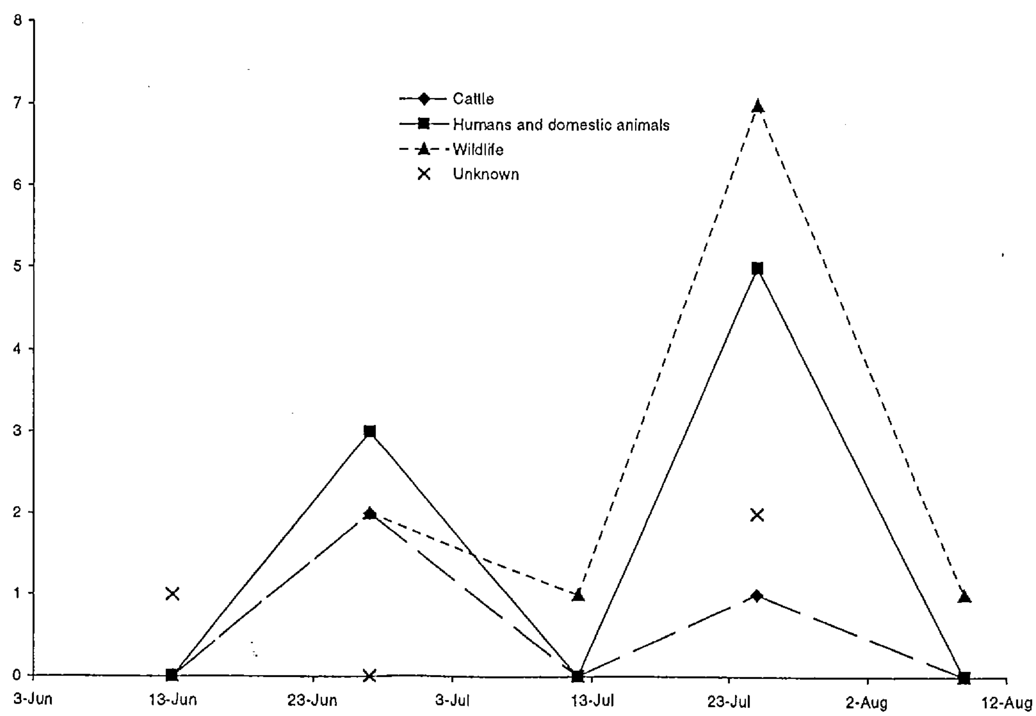
APPENDIX IV. GRAPHICAL REPRESENTATION OF THE ORIGINS OF *E. COLI* SAMPLES COLLECTED IN THE THREE



WATERSHEDS.

Figure 1. Distribution of *E. coli* samples at the GEID intake

Figure 2. Distribution of *E. coli* samples at the LID intake.



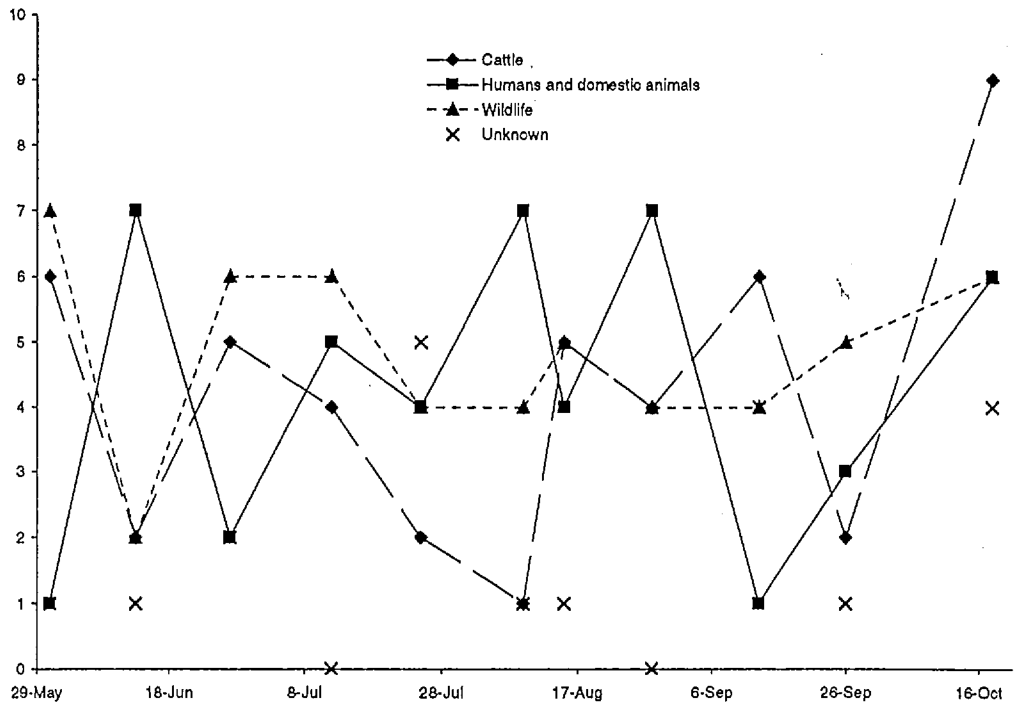


Figure 3. Distribution of *E. coli* samples at the SEKID intake.