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A Biological Assessment of Five Streams in Glacier and Yoho National Parks, British Columbia, with Regards to Domestic Sewage Discharges

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A BIOLOGICAL ASSESSMENT OF FIVE STREAMS IN GLACIER AND YOHO NATIONAL PARKS, BRITISH COLUMBIA, WITH REGARDS TO DOMESTIC SEWAGE DISCHARGES

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ABSTRACT

The water quality of the Illecillewaet River, Beaver River, Connaught Creek and Loop Creek in Glacier National Park and the Kicking Horse River in Yoho National Park was found to be well within the limits considered necessary for fish survival. A combined stream macroinvertebrate diversity of 2.18 was obtained for Glacier National Park and 2.41 for Yoho National Park. These values are higher than those recorded in several other British Columbia streams. The standing crop of periphytic algae compared favourably with that recorded in other British Columbia streams.

Two areas requiring further study have been identified: Connaught Creek in Glacier National Park and the Kicking Horse River, near the townsite of Field in Yoho National Park. Appreciably higher nutrient concentrations were obtained in Connaught Creek (under a heavy forest canopy) downstream of a domestic sewage discharge along with a comparably high algal standing crop. Reduction in dissolved oxygen and increases in turbidity, heavy metals, and total phosphate were observed downstream of Field and may be associated with a gravel operation.

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SUMMARY AND CONCLUSIONS

1. The chemical and physical characteristics of water quality for the Illecillewaet River, Beaver River, Connaught Creek and Loop Creek in Glacier National Park and the Kicking Horse River in Yoho National Park compare with values reported as necessary for fish survival.

2. Two areas requiring further surveillance have been identified:
   - Connaught Creek in Glacier National Park
   - Kicking Horse River near Field, B.C., in Yoho National Park.

3. Monthly chemical and biological sampling over the period between ice break-up and winter freeze-over are necessary to determine the impact of the Rogers Pass sewage discharge and the townsite of Field sewage discharge on their respective receiving streams.

4. Campsite septic-tank and absorption-field disposal systems adjacent to streams are not considered likely to be a problem if suitably located and properly maintained.

5. The direct discharge of septic-tank effluent (chlorinated) should be phased out as soon as possible and replaced with ground-disposal systems so that the streams may be maintained in as natural a state as possible.

6. Where disinfection is shown to be necessary and chlorination is used, dechlorination is recommended.

7. Macroinvertebrate populations and periphytic algal standing crop compare favourably with that recorded for comparable British Columbia streams.

1 INTRODUCTION

A water quality investigations program involving the Environmental Protection Service and Inland Waters Directorate (Water Quality Branch) of Environment Canada and Parks Canada is in the formation stage for some British Columbia National Parks.

The need for biological and chemical assessments of the main streams in the British Columbia National Parks has resulted due to the increased use of present park sewage treatment facilities. Baseline levels of water quality at various times of the year are needed. Monitoring stations are to be established on major streams to determine the impact of discharges from present sewage waste disposal facilities and plan future waste disposal requirements.

The Environmental Protection Service conducted a preliminary field survey in Glacier and Yoho National Parks from October 1 to 5, 1974. This period was deemed suitable to measure any biological effects related to sewage discharges of the previous summer tourist season. The scope of the study included the measurement of the macroinvertebrate densities, periphytic algal standing crop, and chemical and physical characteristics of the receiving streams.

2 DESCRIPTION OF THE STUDY AREA

2.1 Glacier National Park

Glacier National Park is located 28 miles (45 km) east of Revelstoke and encompasses a 521 square mile area (1350 square km) of the Selkirk Mountain Range and, to a lesser extent, the Purcell Range of interior British Columbia. The park is characterized by steep-sided glacial valleys and swift-flowing mountain streams. The geologic characteristics of the park are reviewed by Baird, 1971.

The extent of the study area in Glacier National Park is shown in Figure 1 and included part of the Illecillewaet River, Beaver River, Connaught Creek and Loop Creek systems. A description of the sample locations and a listing of the park domestic-sewage disposal facilities are given in Appendices I and II, respectively.

2.2 Yoho National Park

Yoho National Park is located 16 miles (25.5 km) east of Golden, British Columbia, and encompasses 500 square miles (1295 square km) of the Van Horne, Ottertail, Waputik, and President ranges of the Rocky Mountains. It is also characterized by steep-sided glacial valleys and swift-flowing rivers. The geologic characteristics of the park are reviewed by Baird, 1962.

The study area in Yoho National Park was the Kicking Horse River near Field, British Columbia (Figure 2). The Kicking Horse River is a fast-flowing river and for an approximate 3 mile (4.8 km) stretch of the river, extending approximately 1.5 miles (2.4 km) either side of the townsite of Field, the river runs in a braided pattern and because of scouring related to sediment movement, it can be considered an unstable environment. A description of the sample locations and a listing of the park domestic-sewage disposal facilities are given in Appendices I and II, respectively.

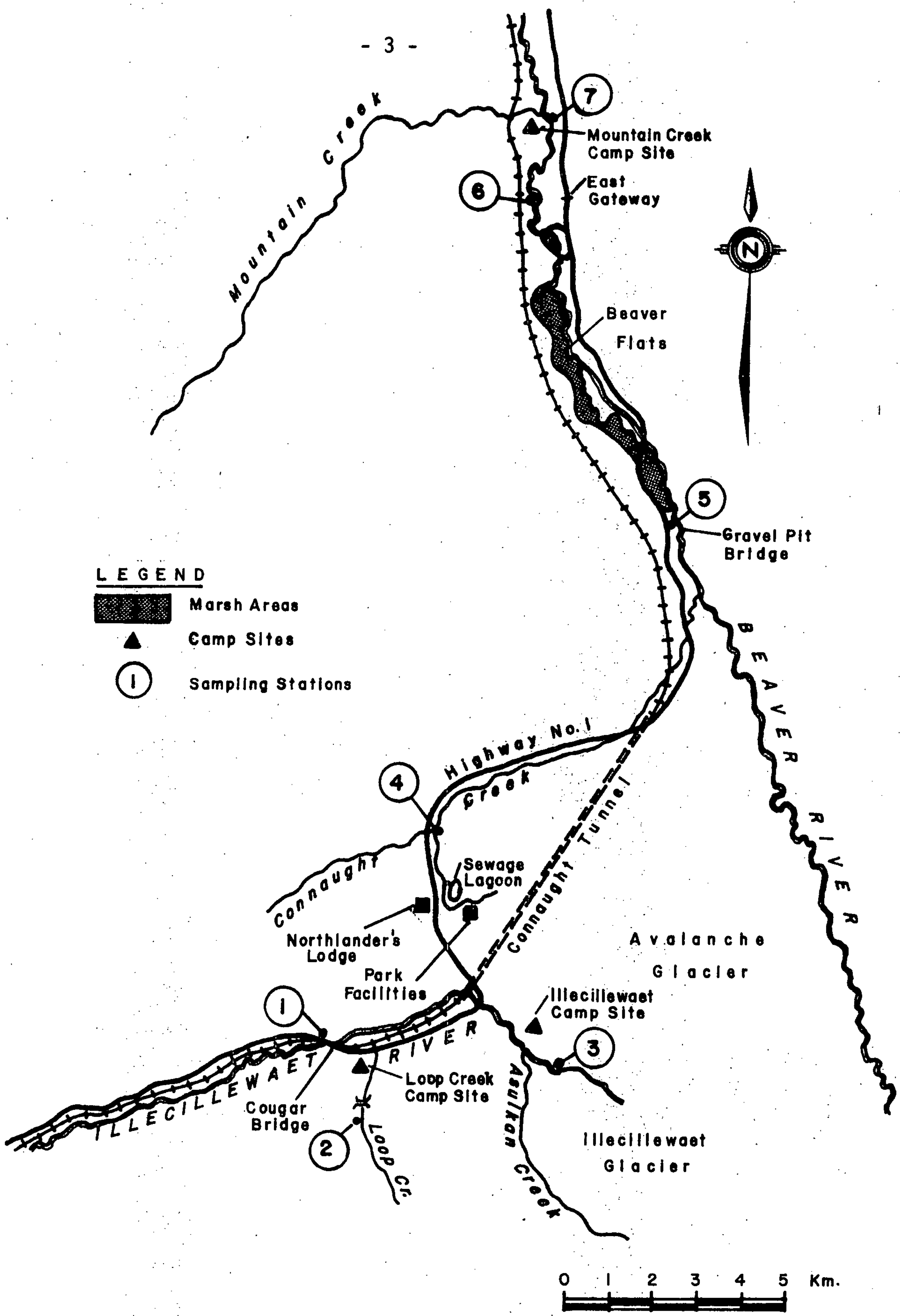

FIGURE I SAMPLING STATIONS AT GLACIER NATIONAL PARK

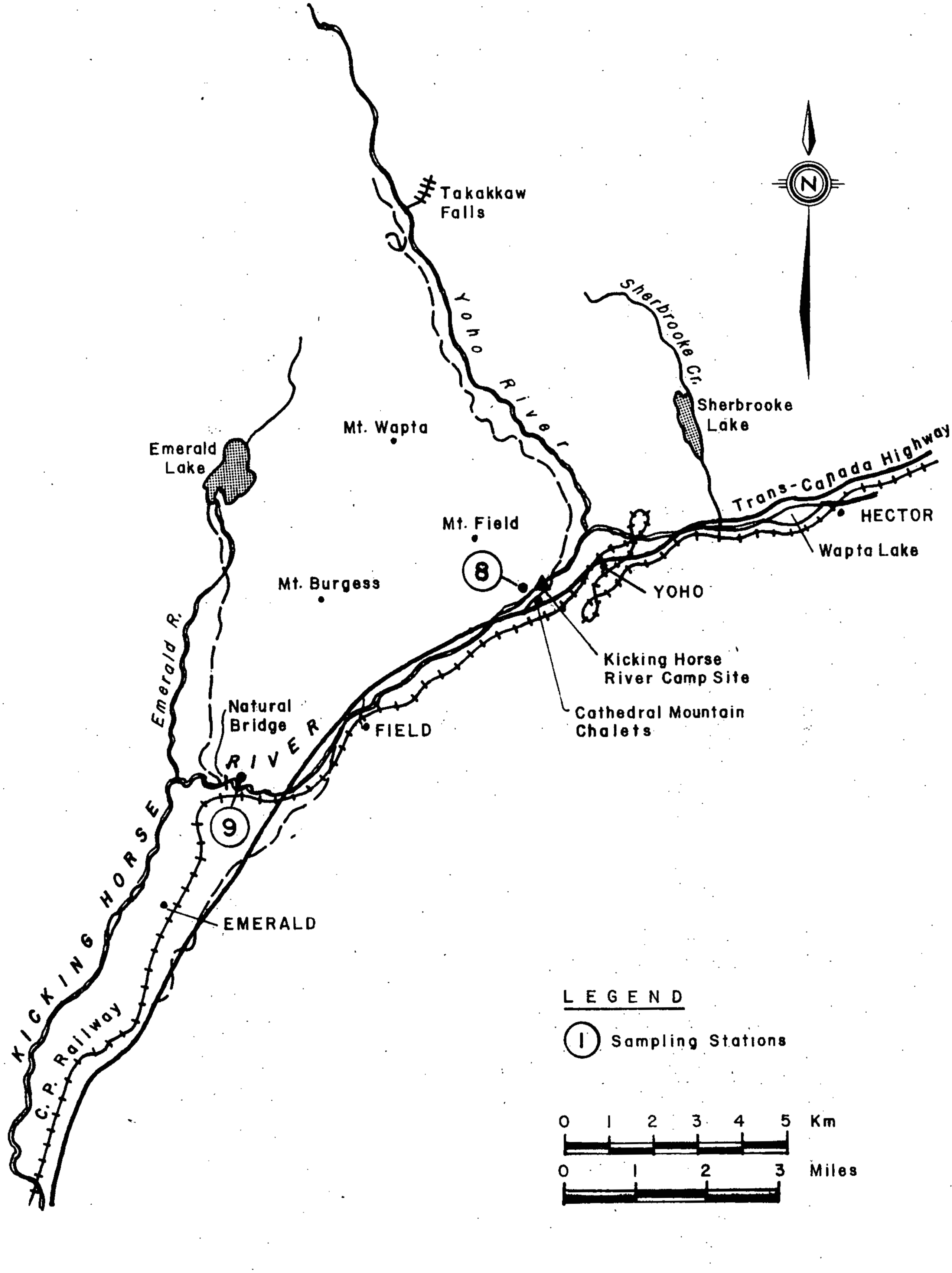

FIGURE 2 SAMPLING STATIONS AT YOHO NATIONAL PARK

3 METHODS AND MATERIALS

3.1 Water Quality

All water samples were collected with a 6-litre Van Dorn bottle. Water samples for dissolved oxygen were transferred to 300 ml BOD bottles, preserved immediately with manganese sulfate and alkali-iodide-azide reagents and titrated with 0.025 N sodium thiosulphate within 24 hours. The samples for total organic carbon, cyanide and heavy metal analysis were stored in 100 ml, 1 litre and 500 ml polyethylene sample bottles, respectively, and those for phosphate analysis in 50 ml glass sample bottles. The total organic carbon samples were frozen over dry ice; the heavy metal samples were preserved with 1 ml HNO_3 and the cyanide samples were preserved with sodium hydroxide at a pH of 11. An untreated sample for hardness, alkalinity, turbidity, conductivity, colour, reactive silica and pH was stored in a 2.5 litre polyethylene bottle and kept cool with wet ice. The samples for total dissolved phosphate were immediately filtered through a distilled water-washed 0.45μ cellulose acetate membrane filter. All the samples were returned within 72 hours to the Inland Waters Directorate, Water Quality Laboratory, in North Vancouver for analysis utilizing the methods outlined in the Inland Waters Directorate, Analytical Methods Manual, 1974. Temperature was recorded with a standard centigrade thermometer.

3.2 Biological

3.2.1 Macroinvertebrates

Three quantitative samples of macroinvertebrates were collected at each station using a ($0.093m^2$) modified Hess circular sampler with a 351μ cloth. The samples were preserved with formaldehyde to a 10% solution and returned to the Environmental Protection Service Laboratory in North Vancouver for sorting, identification and enumeration. A Wild M5 Stereo Microscope was used for identification along with the following biological keys: Pennak, 1953; Ward and Whipple, 1959; and Usinger, 1968. The data obtained were analyzed statistically on a Hewlett-Packard Model 9830A computor for diversity ($\bar{d}$) as described by Wilhm and Dorris, 1968, and for evenness of distribution (J) as described by Pielou, 1966. The formulas used in the calculations of these pollution indices are as follows:

$$\bar{d} = - \sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n}{n}$$

$$J = - \frac{\frac{n_i}{n} \log_2 \frac{n_i}{n}}{\log_a}$$

n_i = total number of individuals per taxon
n = total number of individuals per sample
s = total number of taxa
a = total number of species sampled

In addition, the data was grouped with respect to sensitivity to pollution in accordance with Cairns and Dickson, 1971.

3.2.2 Periphyton. At each station, six periphyton samples were collected with a "Toothbrush Sampler" with a 5.3 cm^2 surface area (Stockner and Armstrong, 1971). The six samples were combined, thoroughly mixed and the resulting composite sample was split in half. One-half was preserved with Lugol solution and returned to the Environmental Protection Service Laboratory, North Vancouver, for enumeration and identification with the aid of a Wild M40 inverted microscope and the following biological keys: Prescott, 1970, and Patrick and Reimer, 1966. The remaining half was filtered through a 0.45μ cellulose nitrate membrane filter, treated with $MgCO_3$, then frozen over dry ice and returned to Laboratory Services, Pacific Region (Environmental Protection and Fisheries Service) in West Vancouver for chlorophyll^a and pheopigment analysis by the methods outlined in the Fisheries Service - Environmental Protection Service, Laboratory

Manual, 1974.

3.2.3 Fish. An unsuccessful attempt was made to catch fish for pesticide analysis at Station 5.

4 RESULTS AND DISCUSSION

4.1 Water Quality

4.1.1 Glacier National Park. Alkalinity, total inorganic carbon (TIC) and water hardness are all parameters associated with identifying water type, buffering capacity and productivity. Based on the U.S. Geological Survey classification of water hardness ($CaCO_3$ equivalent), the Illecillewaet River, Loop Creek and Connaught Creek would be considered soft water (0-69 mg/ℓ) while the Beaver River would be termed moderately soft water (61-120 mg/ℓ) (Table 1). The streams tested reflect an overall low buffering capacity and productivity. McKee and Wolfe, 1963, report that it is generally recognized that the best waters for the support of diversified aquatic life are those having a total alkalinity of 100 - 120 mg/ℓ or more and that the hardness of water of good quality should not exceed 270 mg/ℓ ($CaCO_3$ equivalent).

TABLE 1 CHEMICAL AND PHYSICAL MEASUREMENTS OF WATER QUALITY - OCTOBER, 1974

Sample Site	Turb. JTU's	Specific Conductance μmhos/cm^{-1}	TIC mg/ℓ	Total Alkalinity mg/ℓ	Hardness mg/ℓ	pH
Glacier National Park						
1 (Illecillewaet River)	1.4	50.6	4.4	15.2	23.0	7.1
2 (Loop Creek)	2.0	78.1	6.9	28.0	38.9	7.2
3 (Illecillewaet River)	1.2	31.8	2.2	8.6	14.3	6.9
4 (Connaught Creek)	1.0	49.2	4.0	14.7	22.6	6.9
5 (Beaver River)	3.5	121.0	11.7	49.9	61.7	7.5
6 (Beaver River)	4.4	130.0	13.0	55.4	67.5	7.3
7 (Beaver River)	4.3	151.0	13.4	58.1	77.8	7.5
Yoho National Park						
8 (Kicking Horse River)	7.6	169.0	15.6	68.8	91.5	7.9
9 (Kicking Horse River)	26.0	174.0	18.0	72.2	93.7	7.9

The specific conductance ranged between 31.8 - 151 μmhos-cm^{-1} with the higher values being found in the Beaver River (Table 1). These values indicate an overall low ion content for the streams tested. McKee and Wolfe, 1963, report that the specific conductance of streams supporting a good mixed fish fauna lay, in general, between 150 - 500 μmhos/cm^{-1}. Turbidity values were all below 5.0 JUT's and are indicative of clean water (Table 1).

Base metals are important parameters when identifying water quality. Within the streams tested the heavy metal concentrations all fell within acceptable standards for good water quality as reviewed by McKee and Wolfe, 1963, and Water Quality Criteria, 1972 (Table 2).

TABLE 2 TOTAL EXTRACTABLE HEAVY METAL CONTENT - OCTOBER, 1974 (ppm)

Sample Site	Cu	Fe	Pb	Zn	Cd
Glacier National Park					
1 (Illecillewaet River)	0.001	0.045	0.003	0.001	<0.001
2 (Loop Creek)	0.001	0.019	0.001	0.001	<0.001
3 (Illecillewaet River)	0.001	0.009	<0.001	0.001	<0.001
4 (Connaught Creek)	0.001	0.090	0.001	0.002	<0.001
5 (Beaver River)	0.002	0.150	0.003	0.002	<0.001
6 (Beaver River)	0.001	0.270	0.002	0.002	<0.001
7 (Beaver River)	0.001	0.250	0.001	0.003	<0.001
Yoho National Park					
8 (Kicking Horse River)	0.001	0.160	0.002	0.003	<0.001
9 (Kicking Horse River)	0.004	0.380	0.007	0.020	<0.001

Only iron showed any appreciable difference between rivers with the higher values being found in the Beaver River. The species and solubility of metals in water is strongly governed by the hydrogren ion concentration (pH) in the water; at a high pH many metals form hydroxides or basic carbonates that are relatively insoluble and tend to precipitate out (Water Quality Criteria, 1972). The sensitivity of fish to toxic metals increases in soft waters (McKee and Wolfe, 1963).

There were no appreciable dissolved-oxygen, percent-saturation differences between any of the control and downstream of treatment facility stations (Table 3). Percent-saturation values ranged between 98.6 (11.3 mg/ℓ DO) and 101.4 (11.6 mg/ℓ DO) percent. Temperature values ranged between 1.5 - 4.0^{o}C (Table 3). Dissolved oxygen, temperature and pH all fall well within the limits considered necessary for fish survival.

TABLE 3 DISSOLVED OXYGEN AND TEMPERATURE - OCTOBER, 1974

Sample Site	Temperature (^{o}C)	Dissolved Oxygen mg/ℓ	Percentage Saturation
Glacier National Park			
1 (Illecillewaet River)	2.0	11.6	100.4
2 (Loop Creek)	2.0	11.5	100.0
3 (Illecillewaet River)	1.5	11.6	99.4
4 (Connaught Creek)	2.0	11.3	98.7
5 (Beaver River)	2.5	11.6	101.4
6 (Beaver River)	4.0	11.2	98.8
7 (Beaver River)	4.0	11.3	99.7
Yoho National Park			
8 (Kicking Horse River)	2.5	-	108.0
9 (Kicking Horse River)	2.0	-	87.5

McKee and Wolfe, 1963, report that to maintain a varied fish fauna in good condition the dissolved oxygen should remain >5.0 mg/ℓ and that for trout in soft water the lower limit is set at 6.0 mg/ℓ. Gaufin, 1973, recommends that to maintain a well-rounded, diversified population of cold water aquatic insects, maximum temperatures, minimum dissolved-oxygen levels and the pH range should not exceed the requirements of cold water fishes. He also states that while some aquatic insects can tolerate dissolved oxygen levels as low as 1.6 mg/ℓ for short periods, concentrations of 6.0 mg/ℓ are required for long-term survival. In addition, temperatures during the winter months must be maintained at normal seasonal levels to prevent premature emergence and during the summer months temperatures above 65°F (18°C) are considered maximum for maintaining many species of stoneflies, mayflies, and caddisflies.

Sewage effluent contains nitrate-nitrogen (NO_3-N), ammonia (NH_3-N), and phosphate (PO_4) all of which are recognized as important nutrients for algal growth and are identified with the eutrophication of freshwater bodies. Nitrogen in the form of NO_3 is completely free to move through the soil unless intercepted by plants, while NH_3-N may be adsorbed for a short period in soils through ion exchange phenomena; however, it is inevitably nitrified to NO_3-N and becomes highly mobile (Oldham, 1975). Nitrogen in the soil can be removed through plant uptake, soil storage, denitrification, volatization and leaching to ground water or surface water.

Phosphorous in sewage effluent is primarily in the form of dissolved ortho-phosphate which is the form that can be absorbed directly by algal cells. Phosphorous is readily adsorbed to surface particles of soil (provided it is not previously saturated) and is not generally made available again by biological means, thus the likelihood of ground-water contamination with phosphorous is not as great as with nitrogen.

Nutrient levels detected within the streams tested are shown in Table 4. Station 4, downstream of the Rogers Pass Park facilities' sewage discharge into Connaught Creek, had the highest concentrations of NO_3-N, NH_3-N, TPO_4, and dissolved TPO_4 (0.138 mg/ℓ, 0.051 mg/ℓ, 0.038 mg/ℓ, and 0.026 mg/ℓ, respectively). Dissolved phosphate and NH_3-N are an order of magnitude higher than other streams sampled in this survey. Although a sample was not collected upstream of the sewage source, it seems likely that the high nutrient levels recorded are a result of the park facilities' discharge.

TABLE 4 BIONUTRIENT CONTENT - OCTOBER, 1974 (Mg/ℓ)

Sample Site	TOC	NO_3-N	NH_3-N	TPO_4	TPO_4 Diss.	SO_4^{--}	SiO_2
Glacier National Park							
1 (Illecillewaet River)	<1.0	0.091	<0.004	0.007	0.004	7.6	2.3
2 (Loop Creek)	<1.0	0.111	0.005	0.024	-	9.9	1.9
3 (Illecillewaet River)	<1.0	0.054	0.004	0.007	-	6.0	1.9
4 (Connaught Creek)	<1.0	0.138	0.051	0.038	0.026	6.7	2.7
5 (Beaver River)	1.4	0.091	0.007	0.008	0.007	11.6	3.0
6 (Beaver River)	1.0	0.086	0.009	0.012	0.008	12.2	3.2
7 (Beaver River)	1.6	0.083	0.008	0.012	0.006	19.5	3.3
Yoho National Park							
8 (Kicking Horse River)	1.7	0.080	0.005	0.010	0.006	20.0	2.1
9 (Kicking Horse River)	1.4	0.075	0.006	0.052	0.018	20.0	2.0

A major concern in the use of ground-disposal systems (septic-tank and absorption-field) is the potential for groundwater contamination with nutrients. A detailed study of the ground-disposal systems in Glacier National Park with regard to groundwater and stream contamination was beyond the scope of this survey but if properly installed and maintained, these systems should prove satisfactory.

Sulphate concentrations are reported in Table 4. McKee and Wolfe, 1963, report that in the United States, of rivers supporting good game fish, 50% had SO_4 concentrations <32 mg/ℓ and that experiments indicate water containing <0.5 mg/ℓ sulfate will not support algal growth.

Total organic carbon (TOC) measurements afford a quick and simple method of monitoring organic pollution levels and provide insight regarding the accumulation of non-biodegradable or refractory organic materials. Values of <1.0 mg/ℓ were reported for the Illecillewaet River, Loop Creek, and Connaught Creek while the Beaver River had slightly higher values ranging between 1.0 - 1.6 mg/ℓ TOC (Table 4). Maier and McConnell, 1974, report that river waters have a marked seasonal variation in organic carbon concentrations with the highest concentrations usually corresponding to periods of low stream-flow and high photosynthetic productivity, both in the water and on land. Lowest carbon concentrations are observed in spring and seem to coincide with periods of high flow.

4.1.2 Yoho National Park. The Kicking Horse River can be classified as moderately soft water (61 - 120 mg/ℓ, $CaCO_3$ equivalent). Generally, the chemical parameters tested were higher downstream of the townsite of Field than upstream (Tables 1 - 4) but still within the limits of good water quality discussed earlier. These higher levels may reflect the addition of suspended sediment to the water at a gravel operation on the river bank opposite the townsite of Field.

The dissolved-oxygen content of the water dropped from 12.0 mg/ℓ (100% saturation) at Station 8 to 8.8 mg/ℓ (88% saturation) at Station 9. The reason for this reduction in dissolved-oxygen has yet to be ascertained.

There were no appreciable differences between the control and downstream station for NO_3-N, NH_3-N, TOC, or SO_4^{--}, while TPO_4 and filtered TPO_4 increased from 0.010 mg/ℓ to 0.052 mg/ℓ and from 0.006 mg/ℓ to 0.018 mg/ℓ, respectively. The significance of this TPO_4 increase in relation to the gravel operations and domestic-waste discharge at Field requires further study.

4.2 Biological

4.2.1 Macroinvertebrates. The sensitivity of freshwater macroinvertebrates to stress (pollution) and their use as indicators to reflect environmental conditions and community structure are well documented: Gaufin, 1973; Cairns and Dickson, 1971; Egloff and Brakel, 1973; Wilhm and Dorris, 1968; and Pielou, 1966. Certain taxonomic groups have been categorized as tolerant, facultative, and intolerant (sensitive) to various types of pollution (Cairns and Dickson, 1971). Resh and Unzicker, 1975, and Gaufin, 1973, discuss the variability in tolerance to various parameters at the species level.

For the purpose of this report, the macroinvertebrates have been identified to the taxonomic level of family (Table 5), categorized in indicator groups (Figure 3) and the community structure determined using diversity $\overline{d}$ and evenness of abundance J (Table 6). Wilhm, 1970, described $\overline{d}$ as varying between 3 - 4 in clean water streams and is usually less than 1 in polluted streams. The value of J ranges between 0 - 1 with the higher value representing a more desirable distribution. Hughes, 1975, has shown $\overline{d}$ varies with the type of sampler used and Egloff and Brakel, 1973, indicated some sensitivity is sacrificed when diversity indices are based only on higher taxa. However sufficient sensitivity is retained even at the family level to demonstrate the impact of waste-water discharges.

4.2.1.1 Glacier National Park. Within the four streams sampled in Glacier National Park (Stations 1 to 7) $\overline{d}$ ranged between 1.85 to 2.73 (Table 6) with a combined stream average of 2.18. Evenness (J) ranged between 0.56 - 0.82. The low value of 1.85 was

TABLE 5 MACROINVERTEBRATE DATA FOR YOHO AND GLACIER NATIONAL PARKS - OCTOBER, 1974

Identification (family)	Number of Individuals per Station*								
	1	2	3	4	5	6	7	8	9
	[----------Glacier Park						----------]	[-Yoho Park-]	
'SENSITIVE'									
Plecoptera									
Nemouridae	6	38	10	30	8	12	1	11	35
Chloroperlidae	-	8	51	35	41	51	10	2	5
Perlodidae	-	29	-	-	-	-	-	4	-
Ephemeroptera									
Heptageniidae	22	104	103	168	47	46	1	9	3
Baetidae	6	4	11	23	17	7	2	4	1
Trichoptera									
Psychomyiidae	-	-	-	15	-	1	-	-	-
Hydropsychidae	-	-	-	1	-	1	-	-	-
Rhyacophilidae	5	-	26	4	2	1	-	3	-
Coleoptera									
Staphylynidae	-	-	-	-	-	-	1	-	-
'FACULTATIVE'									
Diptera									
Simulidae	-	-	-	1	-	-	-	-	-
Nematocera	-	-	2	1	-	-	-	-	-
Culicidae	15	-	1	-	-	-	-	-	-
Tendipedidae	4	3	19	7	2	2	2	4	4
Dolichopodidae	1	-	7	1	-	-	-	-	-
Helelidae	-	1	1	-	-	-	-	-	1
Psychodidae	-	1	3	-	-	-	-	-	2
Rhagionidae	1	-	5	3	2	-	1	2	2
Unconfirmed	-	-	2	-	-	-	-	-	-
Arachnida									
Hydracarina	-	-	-	1	-	-	-	1	1
'TOLERANT'									
Hirudinea									
Glossiphoniidae	2	-	1	2	-	-	-	-	-
Oligochaeta	3	-	-	-	-	-	-	1	-

* Total of 3 circular samples

obtained from Loop Creek at Station 2 upstream of the Loop Creek campsite septic tank discharge. Values of $\bar{d}$ = 2.14 and J = 0.56 were obtained from Connaught Creek at Station 4, downstream of a sewage discharge. A macroinvertebrate sample was not collected above the Connaught Creek discharge site for comparison.

TABLE 6 DIVERSITY INDICES FOR MACROINVERTEBRATES, YOHO AND GLACIER NATIONAL PARKS - OCTOBER, 1974

Parameter	Sample Station 1	2	3	4	5	6	7	8	9
	[---------------Glacier Park						]	[-Yoho Park-]	
Total Individuals	65	188	242	292	119	121	18	41	54
Total Taxa	10	8	14	14	7	8	7	10	9
Diversity ($\bar{d}$)	2.73	1.85	2.58	2.14	2.01	1.89	2.10	2.93	1.90
Evenness (J)	.82	.61	.68	.56	.72	.63	.74	.88	.60

A value of 2.18 according to Wilhm and Dorris, 1968, would indicate an area of moderate pollution. As the streams tested are of good water quality, the values of $\bar{d}$ are likely suppressed due to the high taxonomic level used. The variation in $\bar{d}$ may reflect natural community structure differences resulting from bottom substrate conditions, sampling methods, or the autumn season at which time most insects have emerged and not pollution sources. It can be seen from Figure 3 that the pollution sensitive invertebrates are well represented with only limited representation of the facultative and tolerant groups.

4.2.1.2 Yoho National Park. A considerable reduction in diversity occurred between the control and station downstream of the townsite of Field (2.93 to 1.90, respectively) (Table 6). The decrease may possibly be accounted for by the difference in bottom substrate. Station 8 had a typical boulder-to-sand river bottom, compared to a bedrock and irregular sized limestone slabs substrate at Station 9. The value of J also decreased from 0.88 to

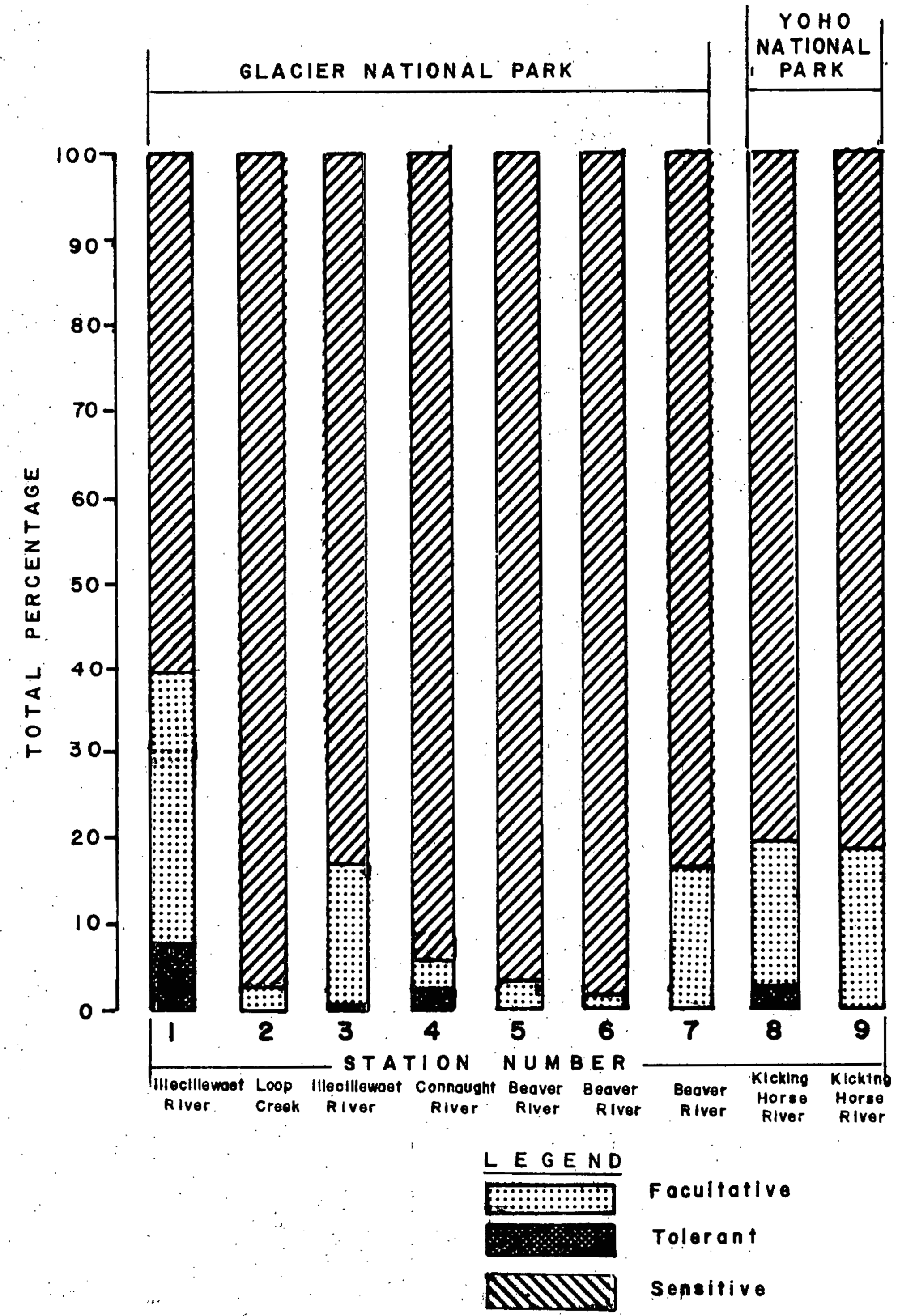

FIGURE 3 THE ACCUMULATIVE PERCENT DISTRIBUTION OF INDICATOR GROUPS S, F and T. - OCTOBER 1974

0.60 for Stations 8 to 9 and indicates a disproportionate distribution at Station 9 which may reflect the substrate dissimilarity. Hynes, 1970, states that in general the more complex the substratum the more diverse is the invertebrate fauna. Current speed is also a factor of major importance in running water and it controls the occurrence and abundance of species and hence the whole structure of the animal community. From Figure 3 it can be seen that the relative proportions of sensitive to tolerant macroinvertebrates are not appreciably different, thus the difference in diversity has not likely resulted from any domestic waste discharge at Field. Further sampling will be necessary to confirm this. For comparison purposes, Hallam, 1975, and Derksen (unpublished data) using identical sampling methods found control station ($\bar{d}$, J) values of 1.99, 0.51, and 1.45, 0.38, respectively, for two British Columbia streams. The former stream was a remote, clean, mountain stream, while the latter stream can be considered eutrophic.

4.2.2 Periphyton. Algae are arranged on stems and other fixed objects in a definite way in relation to the current and because of this detailed local distribution quantitative sampling becomes difficult (Hynes, 1970). Usually diatoms dominate the list of species, and in stony streams and rivers they are also the most abundant forms.

4.2.2.1 Glacier National Park. Algal identifications are shown in Table 7 and for the streams tested, diatoms were the dominant group. Samples from Stations 1, 3, 6 and 7 were too silty for quantification, thus an absence or presence of genera are given. For Stations 2, 4 and 5 the number of cells per cm^2 are given. The dominant genera were found to be *Achnanthes spp.*, *Navicula spp.*, *Fragilaria spp.*, and *Hannaea arcus*. The absence of Chlorophyceae can be attributed to the autumn season by which time these species have died down.

TABLE 7 PERIPHYTON IDENTIFICATION - OCTOBER 1974

Identification	Number of Cells per cm^2 per Station*								
	1	2	3	4	5	6	7	8	9
	[----------Glacier Park						----------]	[-Yoho Park-]	
<u>Bacillariophyceae</u>									
Achnanthes spp.	+	30	+	2152	2299	+	+	+	+
Navicula spp.	+	840	+	1177	1470	+	+	-	+
Fragilaria spp.	+	1861	+	908	1018	+	+	+	+
Gomphonema spp.	+	180	-	706	264	+	+	+	+
Tabellaria spp.	+	90	+	202	302	-	-	+	+
Hannaeaarcus	+	1201	+	370	792	+	+	+	+
Cyclotella spp.	-	2071	+	134	151	-	-	+	+
Cymbella spp.	+	90	+	101	188	+	+	+	+
Diatoma spp.	-	120	-	34	-	-	-	-	+
Nitzschia spp.	+	-	-	-	-	-	-	-	-
Synedra spp.	+	30	-	-	-	-	-	+	+
Rhoicosphenia spp.	-	30	-	-	-	-	-	-	-
Amphora spp,	-	-	-	-	-	+	-	+	+
Epithemia spp.	-	-	-	-	38	-	-	-	-
Diploneis spp.	+	-	-	-	-	+	+	-	-
Girdle view c.f.	-	240	-	202	490	-	-	-	-
<u>Bartramiaceae</u> (moss)	-	-	-	-	+	-	-	-	-
Catoscopium nigritium c.f.	-	-	-	-	-	-	-	-	+

Chlorophyll[a] values are shown in Table 8 and the values ranged between 0.65 μg/Chla/cm^2 at Station 1 to 3.04 μg/Chla/cm^2 at Station 3. Station 4 on Connaught Creek which was the only location under a heavy forest canopy had a comparably high chlorophyll[a] value of 2.97 μg/Chla/cm^2 and may reflect a nutrient enrichment situation as light might be expected to be a limiting factor to algal growth at this station.

TABLE 8 CHLOROPHYLL[a] AND PHEOPIGMENTS - OCTOBER, 1974

Parameter	Sample Station								
	1	2	3	4	5	6	7	8	9
	[---------------Glacier Park						------------------]	[-Yoho Park-]	
Chlorophyll[a]	0.65	0.57	3.04	2.97	1.94	2.57	0.84	0.81	7.78
Pheopigment	-	0.07	0.59	-	-	1.14	-	0.24	0.95

Stockner and Shortreed, 1975, utilizing artificial substrates in two Vancouver Island, B.C., streams found a maximum value of 0.95 $\mu g/Chla/cm^2$ in October for Carnation Creek and a maximum value of 1.38 $\mu g/Chla/cm^2$ in July for Ritherdon Creek. The forest canopy over Carnation Creek ranged between heavy to moderate while Ritherdon Creek is clearcut-logged. Both streams are considered phosphate poor and oligotrophic. Diatoms were the dominant algal group in both creeks. Stockner and Shortreed, 1975, further state that during high flow situations (>200 cfs) stream bed movement will scour gravel and small rocks, effectively removing or burying most attached algae. Derksen (unpublished data) found control station chlorophyll[a] values as high as 1.13 to 5.01 $\mu g/Chla/cm^2$ occurring between August and October in three North Vancouver, British Columbia, streams. The chlorophyll[a] values obtained in this survey compare favorably with those of other streams in British Columbia. A mean stream chlorophyll[a] value calculated from monthly recording over a summer's growth are required to fully evaluate the streams sampled.

4.2.2.2 Yoho National Park. The periphytic algae of the Kicking Horse River are similar to that observed in Glacier National Park. Chlorophyll[a] values ranged from 0.81 $\mu g/Chla/cm^2$ at Station 8 to 7.78 $\mu g/Chla/cm^2$ at Station 9. The higher value at Station 9 is attributed to an abundant growth of the moss Catoscopium nigritum cf. on the bottom substrate. Additional sampling is required to fully evaluate the algal community of the Kicking Horse River.

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APPENDICES

APPENDIX I SAMPLE STATION DESCRIPTIONS

Sample Site	River	National Park	Description: Forest Canopy	Description: Substrate	Description: General
1	Illecillewaet	Glacier	Light	Sand/pebble/ cobble/ boulder	Approximately 50 ft. downstream of Cougar Bridge. Sampling restricted to river's edge. Fast flow.
2	Loop Creek	Glacier	Light/ moderate	Sand/pebble/ cobble/ boulder	Upstream of Loop Creek Campsite and approximately 50 ft. upstream of small footbridge. Loop Creek drains into Illecillewaet River.
3	Illecillewaet	Glacier	Light/ Moderate	Sand/pebble/ cobble/ boulder	Immediately upstream of top end of Illecillewaet River Campsite. Samples restricted to river's edge.
4	Connaught Creek	Glacier	Moderate/ heavy	Sand/pebble/ cobble	Approximately 20 ft. downstream of confluence of unnamed creek which contains sewage effluent from Rogers Pass Lagoon.
5	Beaver	Glacier	Light	Sand/pebble/ cobble	South end of Beaver Flats. Riffle area upstream of the bridge into gravel pit.

APPENDIX I SAMPLE STATION DESCRIPTIONS (Continued)

Sample Site	River	National Park	Description		
			Forest Canopy	Substrate	General
6	Beaver	Glacier	Light	Silt/sand/ pebble	North end of Beaver Flats at East Gateway Complex. River broadens here.
7	Beaver	Glacier	Moderate	Sand/cobble/ large boulders	Downstream of Mountain Creek Campsite and approximately 100 ft. upstream of confluence with Mountain Creek. Sampling restricted to river's edge.
8	Kicking Horse	Yoho	Light	Sand/cobble/ large boulders	Immediately upstream of Kicking Horse River Campsite and Cathedral Mountain Chalets. Sampling restricted to river's edge.
9	Kicking Horse	Yoho	Light	Sand/cobble/ bedrock and limestone rock slabs of various sizes	Upstream of Natural Bridge on north side of river. Sampling restricted to river's edge.

APPENDIX II DOMESTIC SEWAGE DISPOSAL FACILITIES

Park Facility	Park	Type of Disposal
Loop Creek Campsite	Glacier	Chlorinated septic tank effluent discharged to Loop Creek.
Illecillewaet River Campsite	Glacier	Chlorinated septic tank effluent discharged to Illecillewaet River.
Park Facilities	Glacier	Single-cell lagoon servicing staff housing, offices, Northlander Hotel and Service Station and discharged to Connaught Creek.
East Gateway Complex	Glacier	Septic tank followed by a lagoon.
Mountain Creek Campsite	Glacier	Septic tanks plus absorption fields.
Cathedral Mountain Chalets	Yoho	Septic tanks plus absorption fields or rock pit with overflow to Kicking Horse River.
Townsite of Field*	Yoho	Septic tank (13,200 gallons) with average 29,400 Igpd discharge to Kicking Horse River.
Kicking Horse Campsite	Yoho	Septic tank plus absorption field.
CPR Operations*	Yoho	Septic tanks connected to oil separator tank with a recorded discharge of 12,000 Igpd.

*Information from Strong, Lamb and Nelson, 1975.