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BRITISH COLUMBIA MINISTRY OF ENVIRONMENT

THE WATER QUALITY OF THE TRIBUTARIES OF NICOLA LAKE

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I. **INTRODUCTION**

Previous studies conducted in the Nicola River watershed have generally categorized the water quality of Nicola Lake and tributaries (M.O.E, 1983; Holmes, 1979). These studies have shown that Nicola Lake has high nutrient levels and extensive algal blooms. Although previous data are not extensive, what is available has shown that some tributaries also have high nutrient levels that may contribute to the problem.

Historic observations indicate that the water quality of Nicola Lake, at least in the mid 20th century, was not of high quality (Rawson, 193?). Personal observations of long time residents appear to corroborate these studies. However, there appears to have been a rapid deterioration of the existing water quality in recent years. Scientific proof of this is lacking, but local residents and M.O.E. staff have observed what appears to be increasing algal blooms in the lake.

In 1983, in response to complaints, and as a result of the Nicola Strategic Plan, the Waste Management Branch initiated a study to determine the nutrient loading rates from the major tributaries to Nicola Lake and the source of the nutrients in the tributaries.

II. **METHODS AND MATERIALS**

Upper Nicola River, Chapperon Creek, Spahomin Creek, Quilchena Creek, Moore Creek and Nicola River at the outlet of Nicola Lake were chemically sampled from June, 1983 to June, 1984. Although there are other tributaries within the basin, these were chosen either for their size, and/or because they were thought to be impacted by land use activities. Fifteen samples from up to thirteen sites were obtained. Samples from all the sites were obtained either on the same day or within two days and immediately sent to the Environmental Lab. in Vancouver for analysis. Total and faecal coliform samples were only taken between Nov. 16/83 and April 25/84.

Field analyses consisted of water temperature, pH, and detailed field notes. Parameters measured in the lab included:

- total and dissolved phosphorus
- total nitrogen
- Kjeldahl nitrogen
- organic nitrogen
- ammonia nitrogen
- nitrate-nitrite nitrogen
- non-filterable residue
- specific conductance and pH

Methodologies used for parameter analyses are denoted in the Ministry of Environments's Lab Manual (MOE, 1976).

Monitoring sites used in this study were (Fig. 1):

C-1	Chapperon Cr. u/s Lake
C-2	" " d/s Lake
S-1	Spahomin Cr. u/s Douglas Lake
N-1	Nicola River u/s Chapperon Cr.
N-2	Nicola River u/s Douglas Lake
N-3	Nicola River d/s Douglas Lake
N-4	" " @ Power Station
N-5	" " u/s Nicola Lake
M-1	Moore Cr. u/s Nicola Lake
Q-1	Quilchena Cr. @ Paradise
Q-2	" " u/s Wasley Cr.
Q-3	Quilchena Cr. u/s Ranch
Q-4	" " @ Mouth
W-1	Wasley Cr. d/s Minnie Lake
NL-1	Nicola River @ Nicola Lk. Outlet

III. **WATERSHED DESRIPTION**

1. Chapperon Creek

Upper Chapperon Creek (site C-1) drains the eastern section of the Upper Nicola watershed and drains into Chapperon Lake. Just prior to entry into the lake is one of the ranches associated with the Douglas Lake Cattle Co. At this site are enclosed pens holding various numbers of cattle depending on time of year. Another major tributary, which was not monitored in this study, enters the south end of Chapperon Lake. This is an area of forested lands interspersed with grazing areas. Chapperon Cr. (site C-2), exits the west end of the lake, travels through irrigated alfalfa fields and enters Upper Nicola River at a major feedlot.

2. Upper Nicola River

This river has its headwaters in the Thompson Plateau, runs 30 km through the Barton Hills Forest and Nicola Forest, and another 10 km through grazing land prior to its confluence with Chapperon Creek. In the area of the confluence is a major cattle holding and feeding area. In places, the pens are situated right adjacent to the river and the animals have direct access to the river. Site N-1 is situated just upstream of the feedlot area. About 10 km downstream, the Nicola River enters Douglas Lake. Site N-2 is situated just prior to the lake. In this stretch, the river has been diverted in places for irrigation purposes and the river flow varies greatly depending on time of year. Site N-3 is situated at the outlet of Douglas Lake. From Douglas Lake, the Nicola flows for 20 km to Nicola Lake. Site N-4 is situated halfway between the lakes and Site N-5 is located at the inlet to Nicola Lake. The area between the lakes is used for both cattle grazing and irrigated alfalfa production. Numerous small tributaries which were not monitored enter the Nicola River along its course.

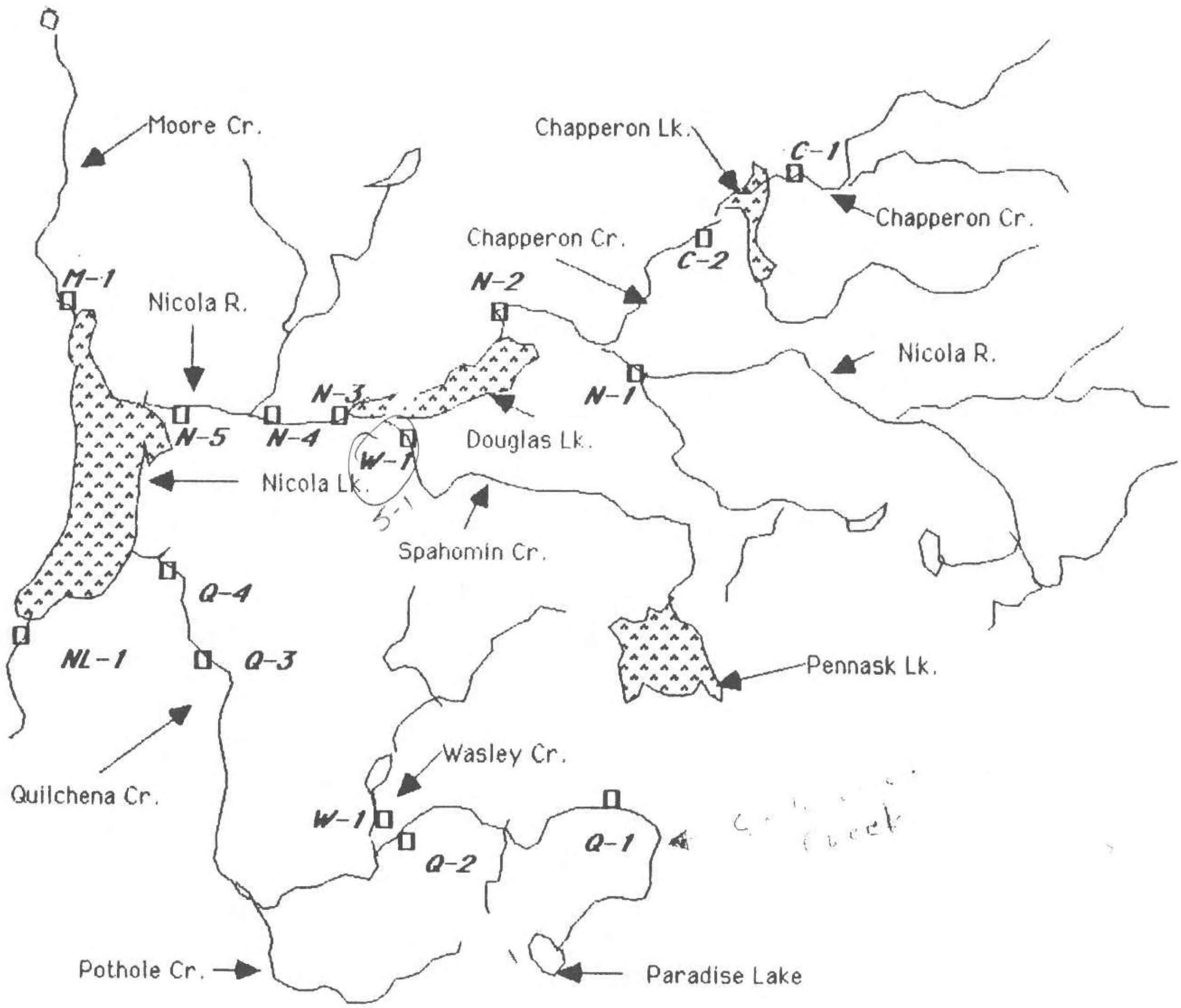


Fig. 1. Schematic diagram of sampling sites on tributaries of Nicola Lake.

3. Spahomin Creek

This creek drains Pennask Lake 25 km to the south and enters the extreme west end of Douglas Lake. A small native settlement is situated on the creek near Douglas Lake. The upper end of the watershed is heavily forested while the lower portion is grazed rangeland. The only site on this creek, S-1, is situated just upstream of the entrance to the lake.

4. Moore Creek

Moore Creek drains a large watershed to the north of Nicola Lake. This watershed contains a mixture of forested land, some small lakes and fairly extensively grazed rangeland. The last few km prior to the lake is inhabited by the Guichon Ranch. Just upstream of the ranch, the land is used for extensive grazing and feeding of cattle. The only site monitored on the system, M-1, is located within the ranch property one km upstream of the lake.

5. Quilchena Creek

Quilchena Creek has the largest watershed of the five tributaries monitored. It arises from Paradise Lake, an oligotrophic lake in a forested area, then flows through two smaller lakes. This is a forested area interspersed with marshes. The first site (Q-1) is located 30 km downstream of Paradise Lake prior to entering rangeland. Subsequent to leaving this area, the creek enters a more open range area utilized for cattle grazing. It then picks up a major tributary, Wasley Creek, and angles in a southerly direction through predominately rangeland interspersed with some forests. Site Q-2 is located 28 km downstream of Q-1 just prior to the confluence with Wasley Creek. Wasley Creek drains an area heavily used for cattle grazing and forage production. The Wasley site, W-1, is situated just upstream of the confluence with Quilchena Cr. and just downstream of Minnie Lake. After travelling south for some km's, Quilchena Creek turns abruptly north and empties into Nicola Lake. Site Q-3 is 30 km downstream of Q-2 and just prior to the grazing land of the Quilchena Ranch. Site Q-4 is situated just upstream of Nicola Lake approximately 3 km downstream of Q-3 and below Quilchena Ranch and Quilchena Golf Course.

IV. RESULTS AND DISCUSSION

Chapperon Creek

Results

1. Phosphorus

The two Chapperon Cr. stations, C-1 (u/s Lake) and C-2 (d/s Lake), had radically different P concentrations (Table 1). Total P above the lake increased with increasing river flow, however, except for one date, increases were fairly low (Fig. 2). On that one date (May 30,1984), maximum runoff was occurring. The mean total P upstream of Chapperon Lake was the lowest of all sites in the Upper Nicola watershed (Table 2). In contrast, P concentrations below Chapperon Lake were by far the highest of any site on the system. Also, highest concentrations occurred during low flow while the lowest concentrations occurred during the highest flows (Fig. 3).

Upstream of the lake, phosphorus was mostly in the dissolved form during low water but contained a lot of particulate during runoff. Phosphorus below the lake followed the same pattern but there was less in the dissolved form.

Table 1. Phosphorus concentrations and % composition sites C-1 and C-2.

DATES	SITES					
	C-1			C-2		
	Total P	Diss. P	% TDP/TP	Total P	Diss. P	% TDP/TP
6-Jun	36	22	61.0	194	42	21.7
15-Jun	39	11	28.2	639	74	11.6
28-Jun	33	20	60.6	604	168	27.8
19-Jul	31	17	54.8	460	304	66.1
22-Aug	23	20	87.0	490	378	77.1
27-Sep	27	17	63.0	640	451	70.5
16-Nov	24	19	79.2	388	289	74.5
6-Dec	22	19	86.4	319	247	77.4
30-Jan	32	24	75.0	353	318	90.1
28-Feb	31	25	80.7	344	130	37.8
19-Mar	27	23	85.2	339	82	24.2
25-Apr	38	30	79.0	233	91	39.1
16-May	59	35	59.3	145	85	58.6
30-May	133	28	21.1	140	84	60.0
13-Jun	35	22	62.9	114	66	57.9
Mean	39.3	22.1	65.6	347.2	187.3	53.0

2. Nitrogen

Total nitrogen concentrations upstream of the lake (C-1) ranged from 240 - 690 ug/l with a mean of 330 (Table 2). During high water and growth periods, the nitrogen was mainly in the organic form. Ammonia remained low above the lake with slight increases in mid-winter (Fig. 4). Also, during the low water months and especially in the winter, nitrite-nitrate concentrations peaked, rising from non-detectable to a high of 170 ug/l. Conversely, organic nitrogen decreased during this period. Nitrogen concentrations were generally higher at higher flows. The maximum value of 690 ug/l occurred at peak flows in May, 1984. During the winter months, the organic portion comprised only a little more than half of the total nitrogen. During the remainder of the year, the organic portion comprised from 75% to 100%.

Downstream of the lake, (C-2) nitrogen was extremely high (Table 2). Total nitrogen reached a maximum of 8460 ug/l with a mean of 3330 and a standard deviation of 2170 ug/l. The extremely high values were reached in June, 1983 on a receding flow rate in the river (Fig.5). This same high peak was not reached in 1984 since the monitoring program did not continue on a receding flow rate. Organic comprised the majority of the total nitrogen ranging from 82% to

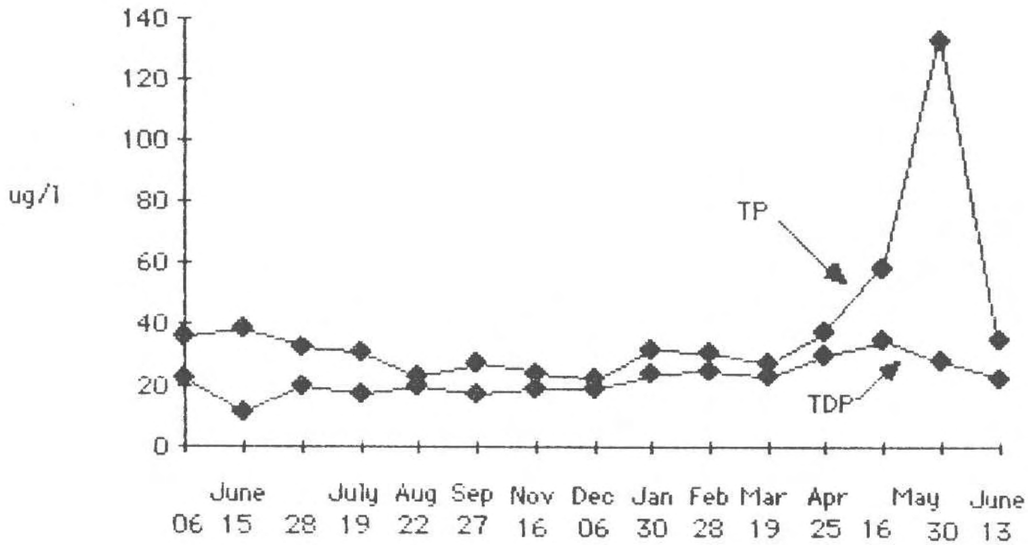


Fig. 2. Total and total dissolved phosphorus at site C-1, Chapperon Creek upstream Chapperon Lake.

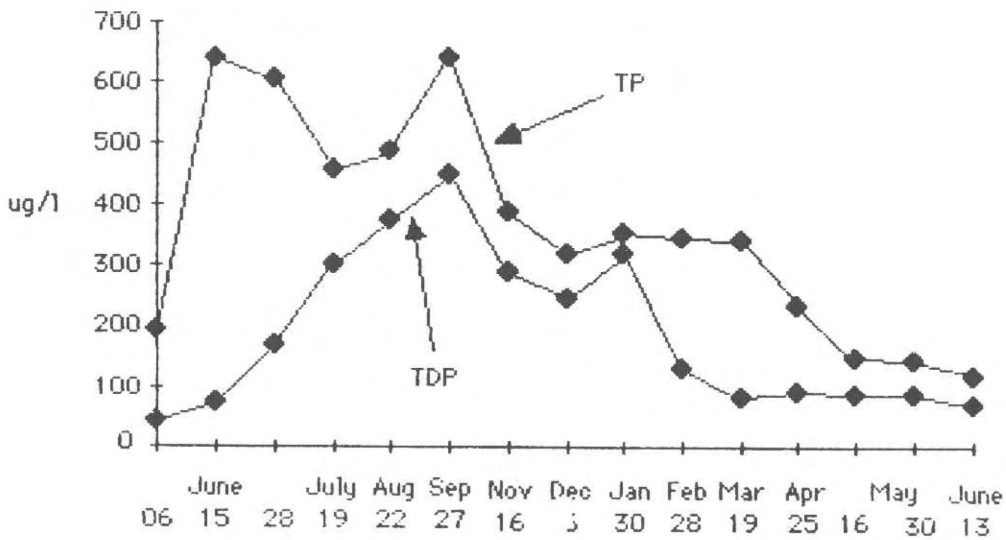


Fig. 3. Total and total dissolved phosphorus at site C-2, Chapperon Creek downstream Chapperon Lake.

100% with a mean of 95.5%. The lower percentages were obtained during winter when ammonia concentrations rose. Ammonia concentrations were extremely high during winter reaching a maximum of 1510 ug/l. Nitrite-nitrate followed the same pattern as ammonia but concentrations were generally lower.

Table 2. Comparisons of means and ranges of parameters at all sites on Upper Nicola system and Moore Creek.

SITES	TOTAL PHOSPHORUS			DISS. PHOSPHORUS →			TOTAL NITROGEN →		
	N	MEAN	RANGE	N	MEAN	RANGE	N	MEAN	RANGE
C-1	15	39.3	22-133	15	22.1	8-62	15	367	240-690
C-2	15	360.1	114-640	15	187.3	42-451	15	3329	1010-8460
S-1	15	48.6	29-90	15	22.9	16-32	15	349	180-660
N-1	8	76.0	18-297	8	15.9	13-30	8	318	180-830
N-2	10	134.2	40-515	10	48.0	24-125	10	685	380-1310 →
N-3	15	60.2	26-98	15	37.4	44-89	15	693	380-2400
N-4	15	70.0	35-158	15	34.9	35-98	15	746	410-3140
N-5	15	83.1	35-187	15	33.2	21-45	15	666	390-2320
M-1	13	61.2	32-279	13	30.8	25-48	13	378	230-910
	AMM. NITROGEN			NON-FILT. RESIDUE			SPECIFIC CONDUCTANCE		
C-1	15	8.1	L5-11	14	10.1	1-51	15	146.7	76-232
C-2	15	373.8 →	28-1510	14	17.9	4-53	15	190.8	155-246
S-1	15	6.7	L5-14	14	19.3	3-114	15	106.3	82-179
N-1	8	7.5	L5-16	8	25.5	2-163	8	98.1	60-130
N-2	10	34.1	L5-70	10	48.4	2-313	10	161.7	84-216
N-3	15	22.9	L5-92	14	6.1	3-19	15	134.3	119-145
N-4	15	14.2	5-68	14	13.9	3-43	15	151.1	124-170
N-5	15	12.5	L5-50	14	26.1	3-118	15	157.9	129-185
M-1	13	9.5	L5-31	13	16.8	2-125	13	297.2	137-380

3. General Ions

The pH above the lake (C-1) remainded relatively constant varying only from 7.6 to 8.1 (Table 3). It decreased during winter and freshet and increased during summer growth months and spring low flow. Below the lake (at C-2), pH had a much greater variation from 7.6 to 9.2. The general pattern of variation followed that of the upstream lake site.

At site C-1, specific conductance ranged from 76 to 232 umhos/cm and non-filterable residue from 1 to 51 mg/l. The two parameters were inversely proportional to each other in concentration versus river flow (Fig. 6). Below the lake, the same pattern was evident but concentations and ranges were greater. Mean specific conductance was 146.7 umhos/cm at site C-1 and 190.8 at site C-2. Mean non-filterable residue was 10.1 ug/l at site C-1 and 17.9 at site C-2.

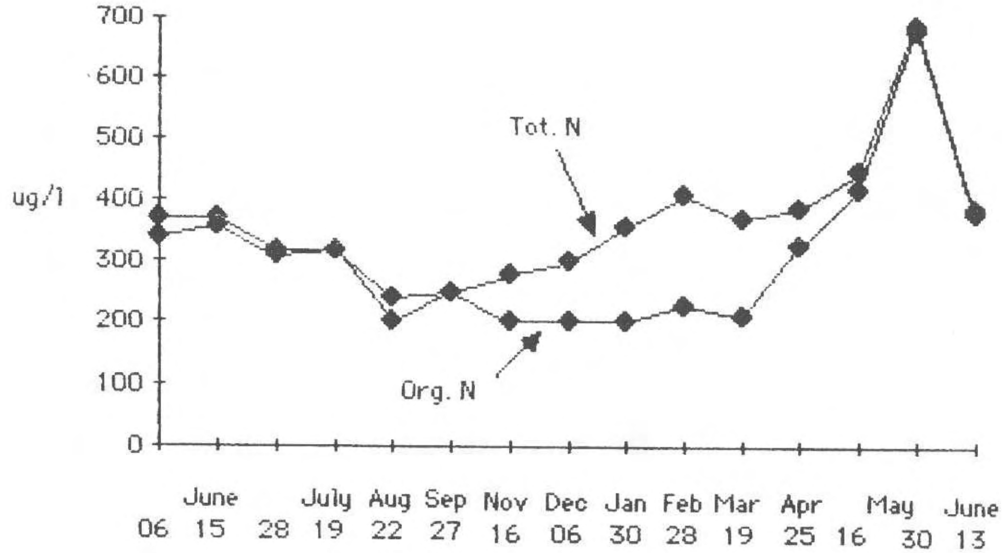


Fig. 4. Total and organic nitrogen at site C-1, Chapperon Creek upstream Chapperon Lake.

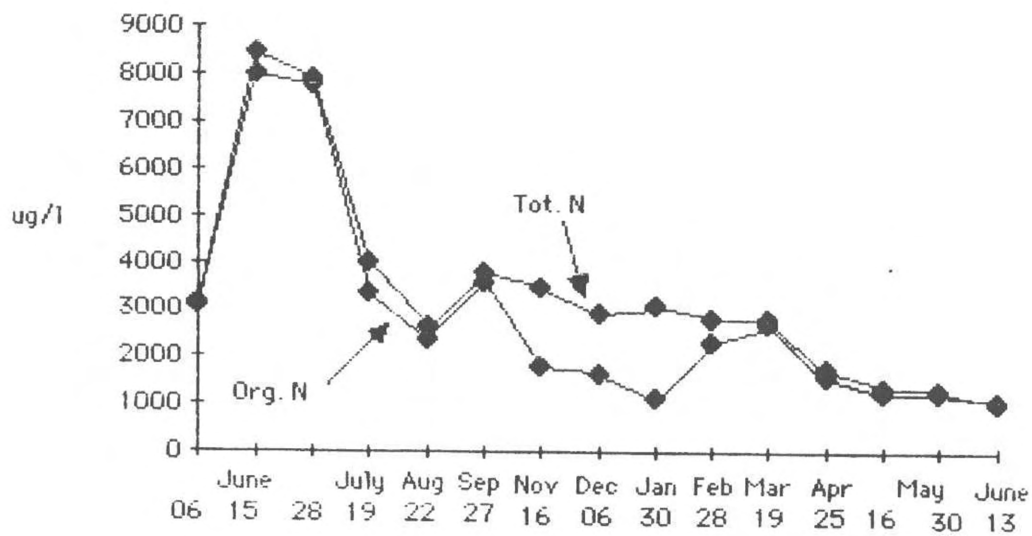


Fig. 5. Total and organic nitrogen at site C-2, Chapperon Creek downstream Chapperon Lake.

Table 3. General ions at sites C-1 and C-2.

DATES	SITES					
	C-1			C-2		
	NFR	pH	COND	NFR	pH	COND.
June 6	-	7.9	88	-	9.2	155
June 15	9	7.9	109	53	8.4	161
June 28	5	8.0	118	45	8.9	169
July 19	5	8.1	123	18	8.3	179
Aug. 22	1	8.0	188	17	8.6	184
Sept. 27	3	8.0	150	16	8.8	185
Nov. 16	4	7.7	145	7	7.8	201
Dec. 6	4	7.9	166	4	8.2	209
Jan. 30	2	7.7	182	4	7.7	246
Feb. 28	2	8.1	223	15	8.0	224
Mar. 19	4	8.0	232	15	9.1	187
Apr. 25	7	8.0	186	16	9.1	200
May 16	12	7.9	127	12	8.9	200
May 30	51	7.6	87	25	8.4	196
June 13	33	7.7	76	4	8.4	166
Mean	10.1	7.9	146.7	17.9	8.5	190.8

Discussion

The water quality of the upstream station, C-1, was very good. Phosphorus concentrations were generally low and increases were directly related to increasing river flows. There were substantial concentrations of cattle above the monitoring site on some sampling occasions. The data did not indicate large nutrient input from these concentrations. Either the cattle wastes did not enter the creek or the sampling dates missed the impact. Nitrogen concentrations were much lower at C-1 than C-2. Non-filterable residues were generally low as was the specific conductance. Again, the highest non-filterable residue occurred during runoff and indicated some land use impacts.

Water exiting Chapperon Lake was extremely poor. Phosphorus, and especially nitrogen, had the highest concentrations recorded in the entire region. The variations over the year were a direct result of the dynamics of Chapperon Lake. The results show that the lake is extremely eutrophic and sometime in the past had large nutrient imputs. Large concentrations of cattle have been known to overwinter on the lands surrounding Chapperon Lake (Fig. 7). A major tributary, which was not monitored, enters the southern end of the lake. Numerous cattle have overwintered here and this tributary may contribute quantities of nutrients to Chapperon Lake.

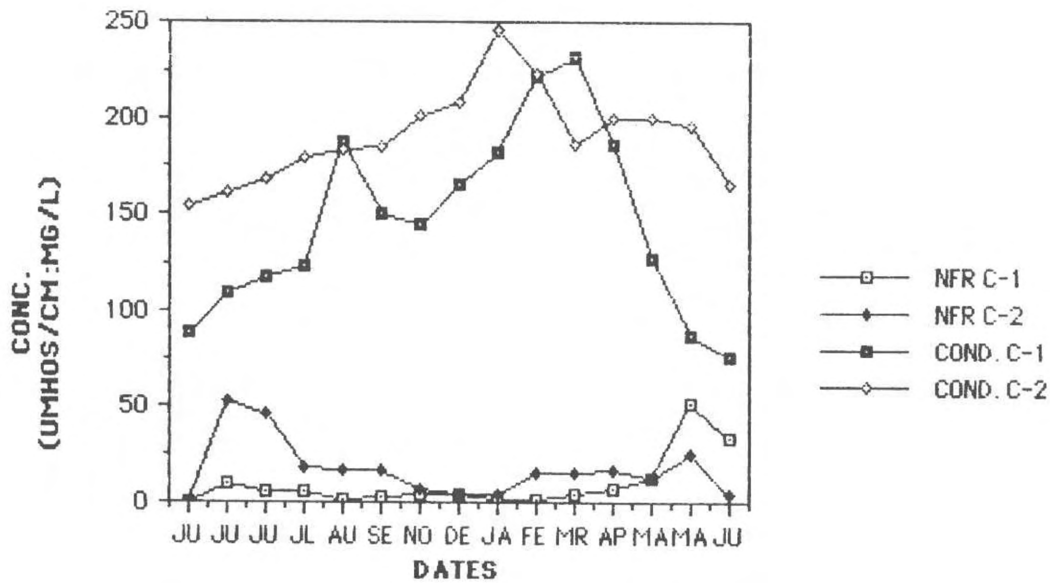


Fig. 6. General ions at sites C-1 and C-2 in 1983 and 1984.

Upper Nicola River

Results

1. Phosphorus

Five stations were sampled on the Upper Nicola River. During freshet, large concentrations of total phosphorus were present at the upstream station, N-1 and the inlet to Douglas Lake, N-2 (Table 4). Except for one sample, total P was lower at site N-1 than at site N-2. On that date, river flows were at their maximum. Concentrations at the lowest station on the system, N-5, were higher than upstream during higher flows and lower during lower flows (Fig. s 8&9).

The concentration decreased drastically at the outlet of the lake, N-3, however considerable increases were noted at the downstream stations, N-4 and N-5. The concentration at site N-2 varied from 42 to 515 ug/l, while at site N-3 it varied from 26 to 98 ug/l.

During high water, there was a general increase in total P concentration between Douglas Lake (site N-3) and Nicola Lake (site N-5). This section of river is utilized quite heavily for winter feeding of cattle (Fig. 7). [NEED SOMETHING ON SITE 68].

Total dissolved P showed a noticeable increase between sites N-1 and N-2 throughout the sampling period. Concentrations at site N-1 were uniformly low with the maximums occurring during higher flows. Dissolved P leaving Douglas Lake (N-3) was generally higher

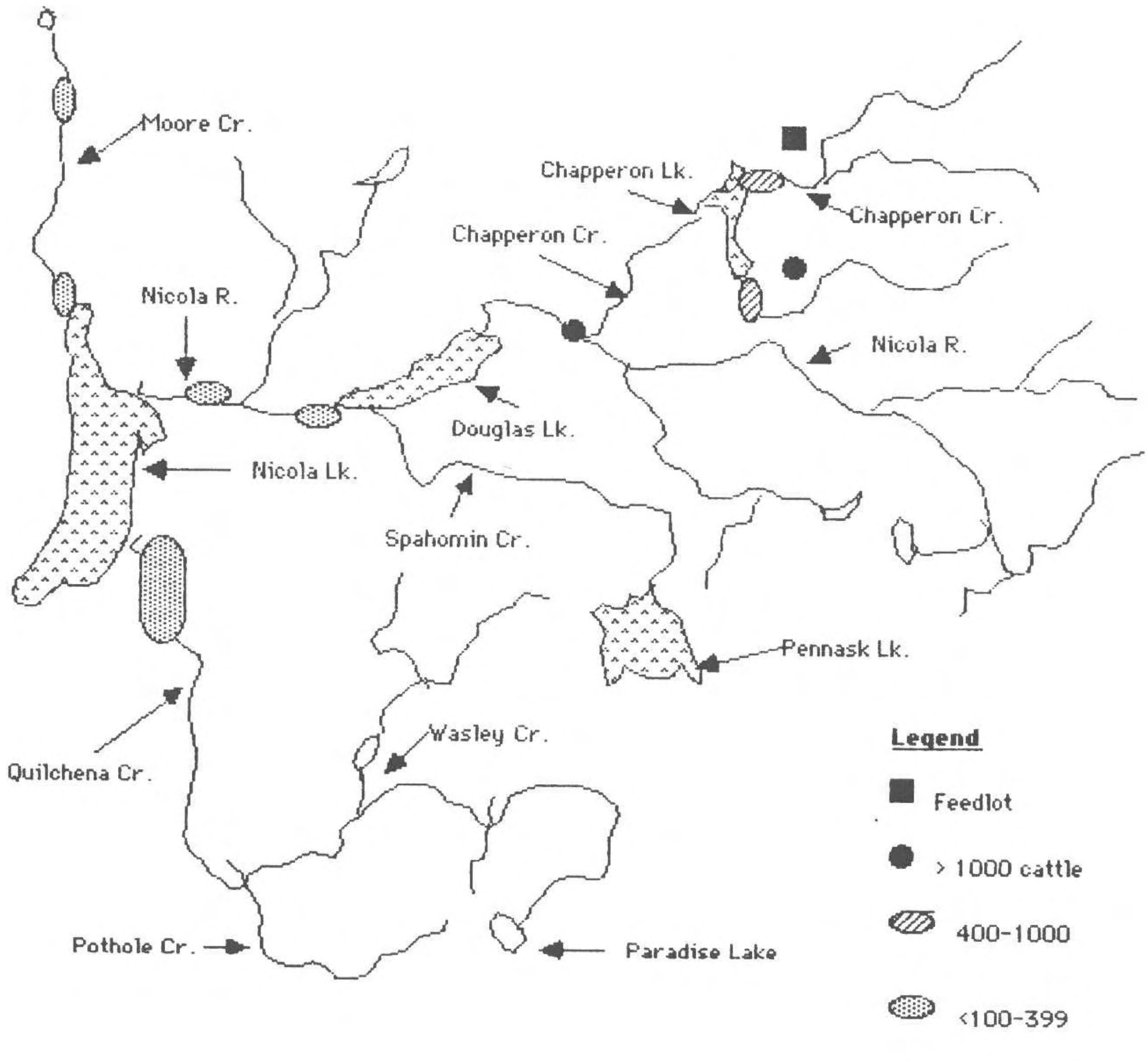


Fig. 7. Major cattle wintering areas in the Nicola watershed as taken from aerial surveys on Feb. 8, 1982.

than that entering except during freshet and once during a bloom in Douglas Lake. Through the lower part of the Upper Nicola R. (sites N-3 to N-5), dissolved P decreased during low flow but increased slightly during freshet.

Table 4. Mean nutrient concentrations during freshet and non-freshet at Upper Nicola River sites.

SITES	FRESHET			NON-FRESHET		
	Tot. P	TDP	Tot. N	Tot. P	TDP	Tot. N
N-1	132.5	22.5	437.5	19.5	14.0	198.0
N-2	200.8	31.3	590.0	89.8	59.2	748.3
N-3	45.9	22.3	530.0	76.6	54.6	880.0
N-4	62.4	22.1	583.8	78.7	49.6	931.4
N-5	87.3	22.9	540.0	78.3	45.0	810.0

2. Nitrogen

The upstream station, N-1, had the lowest total nitrogen concentrations in the Upper Nicola R. throughout the year except for one runoff date, May 30, 1984. There was invariably an increase between sites N-1 and N-2 regardless of water level (Fig. 10). Site N-3, the outlet of Douglas Lake, varied in nitrogen levels during the study. On seven of ten sampling dates, total nitrogen was less at the outlet than the inlet of the lake. This occurred during early winter (Sept. - Dec.) and spring (May - June). In late winter, total nitrogen increased between the inlet and outlet. During the growth period in summer, there was large amounts of N exiting the lake in the form of algae. Between Douglas and Nicola Lakes, total nitrogen tended to increase during high water and decrease during low water.

Ammonia nitrogen varied considerably throughout the sample period. During Nov. and Dec., a large increase occurred between sites N-1 and N-2 with a rapid drop at the remainder of the stations. Nitrite-nitrate followed the same pattern. The ammonia pattern in January was similar on a smaller scale, however nitrite-nitrate increased with an ammonia decrease. Little variation in ammonia occurred from station to station in February and March. There were large increases in nitrite-nitrate at the Douglas Lake inlet and outlet stations as opposed to the upstream station N-1, with decreases at the downstream stations. Ammonia and nitrite-nitrate increased at the lake outlet in April.

3. General Ions

The lowest mean specific conductance was measured at the upstream site, N-1, with the highest at the inlet to Douglas Lake, site N-2 (Table 5). Large increases occurred between these two sites on all sampling dates. Maximum concentrations and increases were evident during low flow colder months (Fig. 11). On all fifteen sampling dates, conductance increased from the

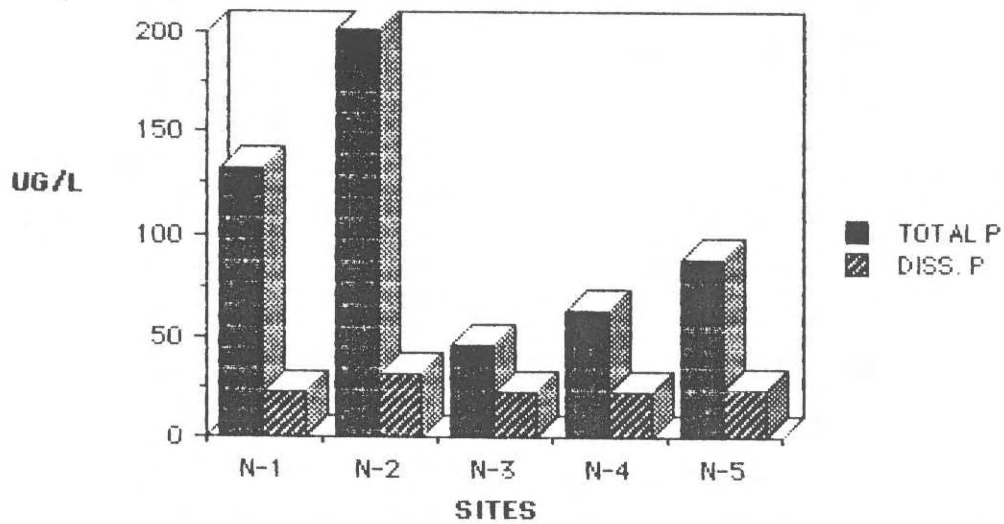


Fig. 8. Total and dissolved phosphorus at Upper Nicola sites during freshet.

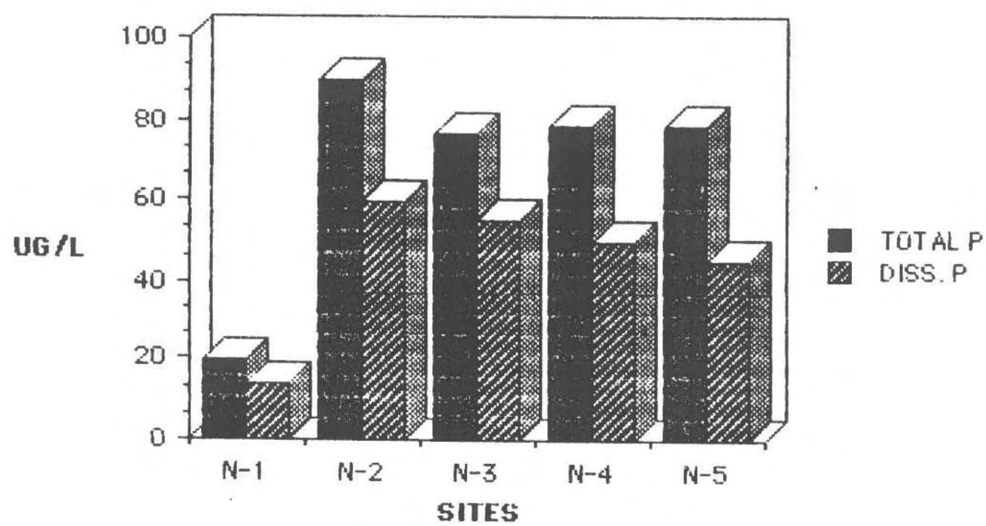


Fig. 9 Total and dissolved phosphorus at Upper Nicola sites during non-freshet.

Douglas Lake outlet to Nicola Lake. The highest concentrations and increases occurred during the low flow colder months.

Very little change occurred in pH between the upper two sites (Table 5). The only significant downstream change occurred on August 22/83, when the pH dropped from 9.0 at site N-3 to 8.1 at site N-4.

Non-filterable residue showed extreme variation at the upstream sites, N-1 and N-2, with increases on seven of eight sampling dates. Major increases occurred during freshet, for example, from 17 to 92 mg/l and 163 to 313 mg/l. Between N-3 and N-4, increases occurred on most dates again with maximums occurring during freshet. The maximum concentration between N-3 and N-5, 118 mg/l was reached on June 13/84 at N-5. Maximum readings at N-1 and N-2 were 163 and 313 mg/l respectively. Large increases were noted between N-3, N-4, and N-5 during freshet.

I don't understand this. Perhaps a table or graph might help.

Table 5. Mean general ion concentrations at Upper Nicola sites.

SITES	FRESHET			NON-FRESHET		
	Cond.	pH	NFR	Cond.	pH	NFR
N-1	78.0	7.7	47.8	118.3	7.8	3.3
N-2	109.3	7.7	113.8	196.7	7.8	6.2
N-3	129.5	8.0	6.3	139.9	7.9	6.0
N-4	138.5	8.0	20.4	165.4	8.0	7.4
N-5	142.4	8.1	41.7	175.7	8.1	10.4

4. Coliforms

Coliform data at site N-1 showed some faecal contamination arising in the headwaters of the Nicola system. On three of the five sampling dates, the total was comprised entirely of faecal coliforms.

is this the right word for an increase in pathogens.

Site N-2 showed a healthy increase in both total and faecal concentrations. The mean total at N-1 was 53 MPN while the mean at N-2 was 132. The mean faecal at N-1 was 18 while at N-2 it was 102. Coliforms were virtually eliminated in Douglas Lake with only one real positive result at N-3 of 8 total coliforms and no real positive faecals recorded. Between Douglas Lake and Nicola Lake, there was a major increase in both total and faecal coliforms. Total means increased from 3 MPN at site N-3 to 241 at N-5, Nicola Lake inlet. Faecals increased from a mean of 2 MPN at N-3 to 208 at N-5.

Discussion

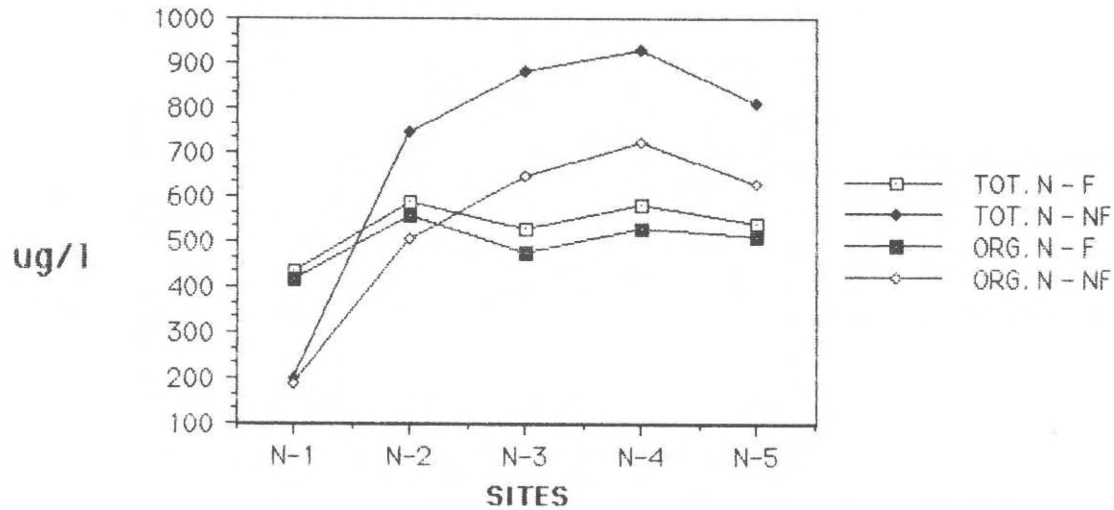


Fig. 10. Mean total and organic nitrogen at Upper Nicola sites during freshet and non-freshet.

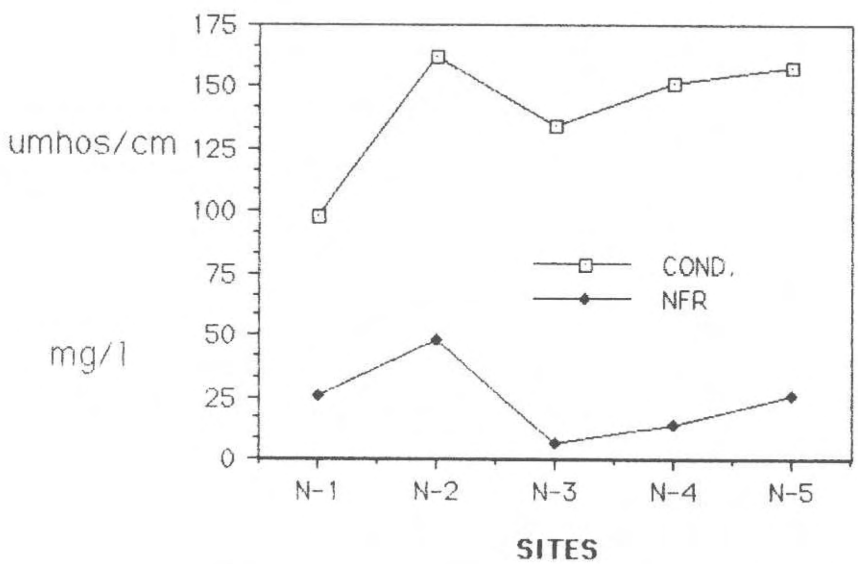


Fig. 11. Mean specific conductance and non-filterable residue at Upper Nicola sites.

The increase in phosphorus and nitrogen between sites N-1 and N-2 during freshet was caused by the influx of nutrient rich Chapperon Cr. water and runoff from surrounding land between the two sites. There is considerable usage of these lands by cattle with attendant wastes (Fig. 7). The total P almost doubled between the two sites even though the Chapperon Cr. water had less P than the upstream Nicola station. These increases were also mirrored in the non-filterable results which lends added support to the belief that degradation was caused by land use activities.

Although at times Douglas Lake acted as a P "sink", it was a source of total P during certain months. Downstream increases occurred during January and February, 1984. Heavy algal blooms in the summer of 1983 resulted in in high total P concentrations exiting the lake. Also, at that time, there was evidence of blue-green algal accumulations, of which the breakdown products are known to be toxic (REF). Douglas Lake controlled the release of nitrogen resulting in a retention and utilization by algae. Nitrogen concentrations exiting the lake increased during periods of algal decomposition and also when summer algal blooms occurred. Non- filterable residues decreased due to settling in the lake.

Considerable amounts of nutrients entered the river between Douglas Lake and Nicola Lake during high water due to winter feeding and grazing by cattle. Non-filterable residue increases in this section of the river were the result of overland run-off of wastes and probably increased river bank erosion caused by destabilization. of the banks by vegetation removal and trampling by cattle.

Coliform data, though sparse and lacking results during high flow periods, confirm heavy contamination by cattle. The greatest increases occurred between N-1 & N-2 and N-3 & N-5 which were also the areas of largest cattle concentrations.

Spahomin Creek

Results

1. Phosphorus

Total phosphorus ranged from 29 - 90 ug/l and was directly related to river flow (Fig. 12). Total dissolved phosphorus varied from 16 - 32 ug/l but was not as directly affected by water levels. The percent of total P that was in the dissolved form decreased during high water. During low water, the dissolved portion ranged up to 80% of the total.

2. Nitrogen

Total nitrogen was generally high during freshet but decreased during low water (Fig. 13). However, in the winter months (Dec., Jan. and Feb.), the concentration increased. These increases correlated to increases in ammonia and nitrite-nitrate.

Total nitrogen ranged from 180 - 660 ug/l with a mean of 350 ug/l. These values were

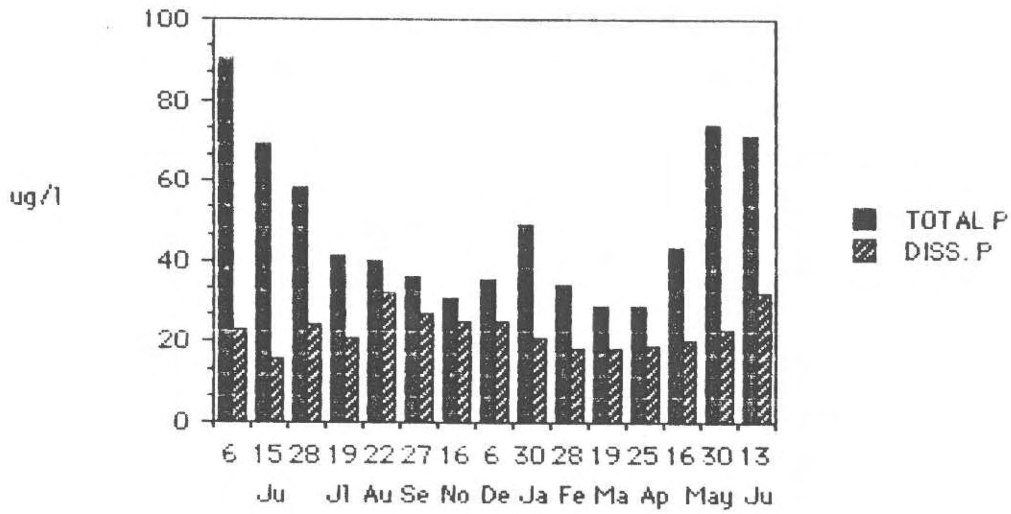


Fig. 12. Total and dissolved phosphorus at S-1, Spahomin Creek on all sampling dates.

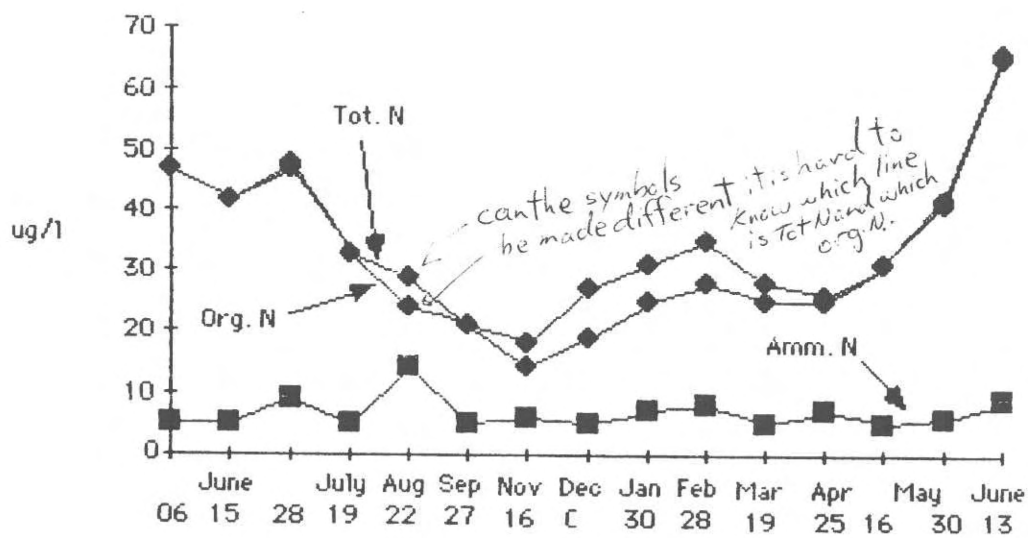


Fig. 13. Total, organic and ammonia nitrogen at site S-1, Spahomin Creek upstream Douglas Lake.

similar to the upstream station on the Nicola but less than the other stations on the system (Table 2). The organic nitrogen portion of the total varied from 70.4 - 100%, the lower values occurring during winter and also on the August sampling date.

Ammonia varied considerably over the year with increases evident during winter months, maximum flow, and the growth period in August. Nitrite-nitrate was detectable only during winter and the August date. Both ammonia and nitrite-nitrate concentrations were low relative to the other sites.

3. General Ions

Non-filterable residue ranged from 3 - 114 mg/l with maximum values being reached during freshet conditions (Fig. 14). The 114 mg/l value was much higher than the next highest value, 32 mg/l. Conductance varied inversely with flow ranging from 82 - 179 umhos/cm with a mean of 106. These concentrations were similar to the upstream station on the Nicola and lower than the remaining stations on the system (Table 2). pH varied slightly between 7.5 and 7.9 with no apparent pattern.

4. Coliforms

Total coliforms varied between 5 and 49 MPN while faecals ranged from L2 to 11 MPN. On only one of the sampling dates did faecals comprise all of the totals.

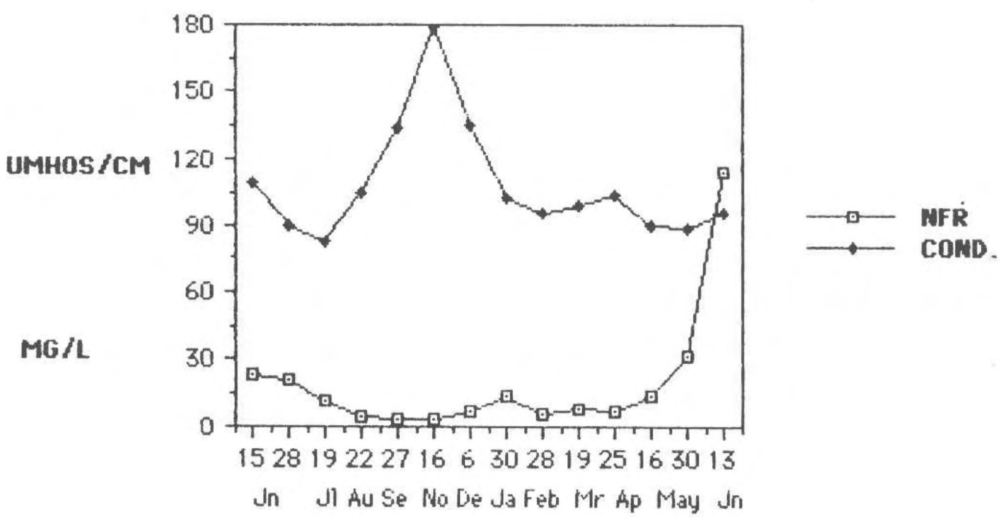


Fig. 14. Non-filterable residue and specific conductance on all sampling dates on Spahomin Creek.

Discussion

Both total P and total nitrogen peaked with non-filterable residue during high water. High water P, being in the particulate form, may indicate the P came from suspended solids such as from soil loss. The source of nitrogen may have been animal wastes, however this cannot be proven since no upstream station was present on the creek to show changes. It is possible that the higher nitrogen and phosphorus could have come from the headwaters, Pennask Lake. This is thought to be unlikely since the water quality of Pennask Lake is thought to be quite good. The small number of coliform samples indicate a small amount of faecal contamination but none were taken during the high water period. The total amount of nutrients present in Spahomin Creek is generally less than the rest of the watershed. Basically, the dynamics of this system is probably, for most of the year, a product of Pennask Lake processes.

Ron should I sample Pennask Lake to check this?

Moore Creek

Results

1. Phosphorus

Concentration of total P was directly related to stream flow (Fig. 15). Twelve of the thirteen values obtained were below 79 ug/l with one outlier at 279 ug/l. The mean total P (61.2 ug/l), was similar to the lower means on the remainder of the Upper Nicola system (Table 2).

Total dissolved phosphorus generally followed the same pattern as total P. The percent of total P comprised of dissolved P varied from 17.2% to 86%. The 17.2% value occurred during high water when the total P reached 279 ug/l. The next lowest percent was 43.5%, which also occurred during high water. During rising water a large amount of particulate P was present.

2. Nitrogen

Total nitrogen correlated well to rising water in Moore Creek (Fig. 16). Increasing water flows resulted in higher nitrogen concentrations and decreasing water flows resulted in lower concentrations. The mean total nitrogen reading of 378 ug/l was similar to the lower means on the Upper Nicola system (Table 2). Organic nitrogen made up the majority of the total, never dropping below 80%.

Ammonia ranged from L5 - 31 ug/l with a mean of 9.5. These readings were similar to the lower values obtained on the Upper Nicola stations (Table 2). The higher values were obtained during freshet conditions, usually on rising water. Even during freshet, when waters were dropping, ammonia levels were low or non-detectable. Nitrite-nitrate was non-detectable in nine of the thirteen samples. The only noticeable concentrations were obtained during rising water, similar to the ammonia pattern.

ug/l

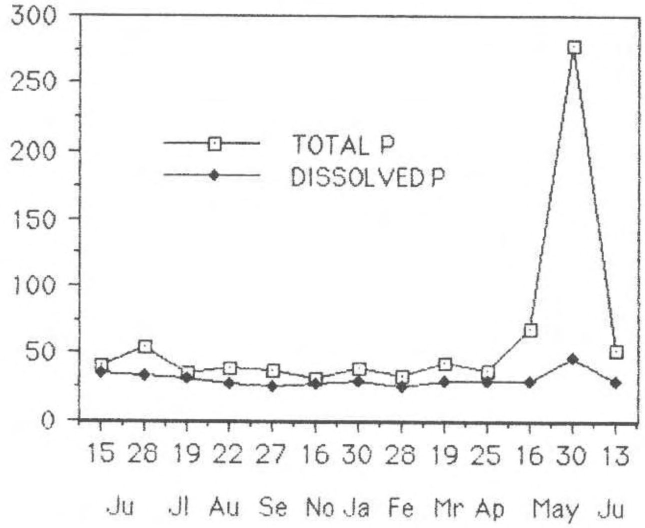


Fig. 15. Total and total dissolved phosphorus at site M-1, Moore Creek upstream Nicola Lake.

ug/l

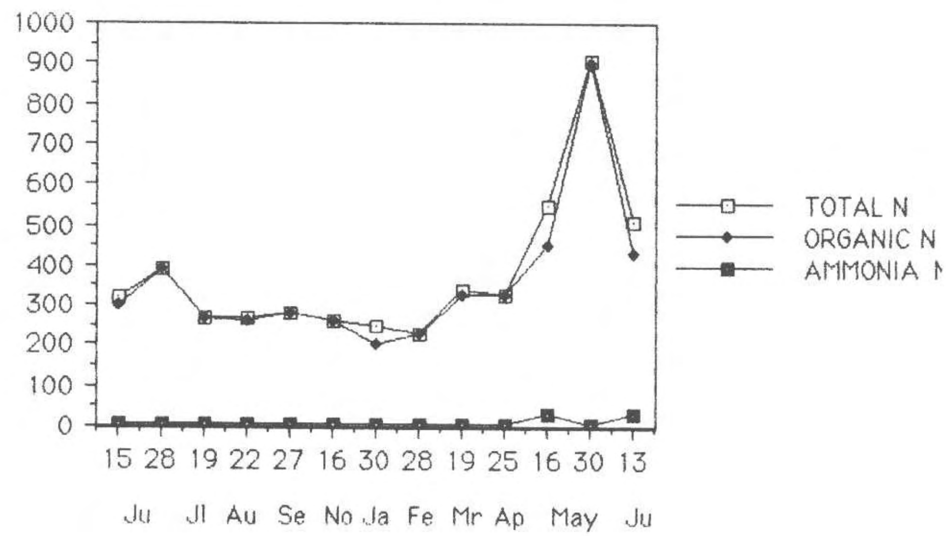


Fig. 16. Total, organic and ammonia nitrogen at site m-1, Moore Creek upstream Nicola Lake.

3. General Ions

Non-filterable residue in Moore Creek ranged from 2 - 125 mg/l with a mean of 16.8. The 125 mg/l value was obtained on May 30/84 at maximum high water (Fig. 18). The next highest value was 30 mg/l, also obtained at very high water on the next sampling date. These values corresponded to maximum readings on other parameters such as phosphorus and nitrogen. The mean value ranked fourth out of nine stations on the Upper Nicola system.

The mean specific conductance of 297.2 umhos/cm was by far the highest of all the stations in this system. As was expected, the conductance was inversely proportional to the flow rate of the river. The lowest conductance was obtained during the highest water levels.

The pH ranged from 7.8 - 8.4 with no apparent pattern relating to river flow. These waters were slightly more alkaline than the Upper Nicola stations but less than the Chapperon outlet site.

4. Coliforms

Six total and faecal coliform samples were taken between November 16, 1983 and April 25, 1984. In all cases the total was comprised entirely of faecal. Concentrations varied from 110 MPN to G2400 MPN.

Discussion

The four-fold increase between the highest and second highest total P readings indicates the large amount of phosphorus which enters the system during run-off. Non-filterable residue and total nitrogen also reached their highest levels on the same day as total P. These data indicate the input probably originates as overland run-off. The coliform samples show that cattle wastes do enter the system during the winter months.

Quilchena Creek/Wasley Creek

Results

1. Phosphorus

During low water, total phosphorus did not appreciably increase throughout the length of Quilchena Creek except for one date in February, 1984 (Table 6). This increase, from 57 - 130 ug/l occurred between sites Q-3 and Q-4. This increase was in the form of particulate P since little change was recorded in dissolved P on this date. Total phosphorus concentrations in Wasley Creek during low water were always much higher than Quilchena Creek concentrations. Mean phosphorus during low water ranged from 48.0 ug/l at Q-1 to 153.0 at W-1 (Fig. 17). There was an increase between Q-1 and Q-2 and another slight increase between Q-3 and Q-4.

All Quilchena station concentrations were much less than Wasley Creek.

Total phosphorus concentration changes during high water were generally quite dramatic and usually occurred between sites Q-2 and Q-4. On June 6/83, it increased from 43 ug/l at site Q-1 to 304 ug/l at Q-4 and on June 13/84, phosphorus increased between those two sites from 30 - 755 ug/l (Table 6). Much smaller increases were noted between sites Q-1 and Q-2. Mean total phosphorus concentrations during freshet ranged from a low of 41.1 ug/l at Q-1 to 216.8 ug/l at Q-4 (Fig. 17).

Total dissolved phosphorus generally declined downstream during low flows except for some individual small increases between sites Q-3 and Q-4 (Table 6). The mean phosphorus during low water at the Quilchena stations varied from 28.7 ug/l at Q-3 to 40.0 at Q-2 Fig. 18). Wasley Creek had a much higher mean of 100.3 ug/l. Greater downstream increases occurred during high water with highest readings noted during maximum flows on a rising water table. Slightly higher increases occurred between Q-3 and Q-4 similar to total phosphorus results. The Quilchena stations mean phosphorus during freshet ranged from 26.9 ug/l at Q-1 to 35.0 at Q-4. There was a gradual increase from the top of the watershed to the bottom. Again, as for low water, Wasley Creek had the highest mean at 73.9 ug/l.

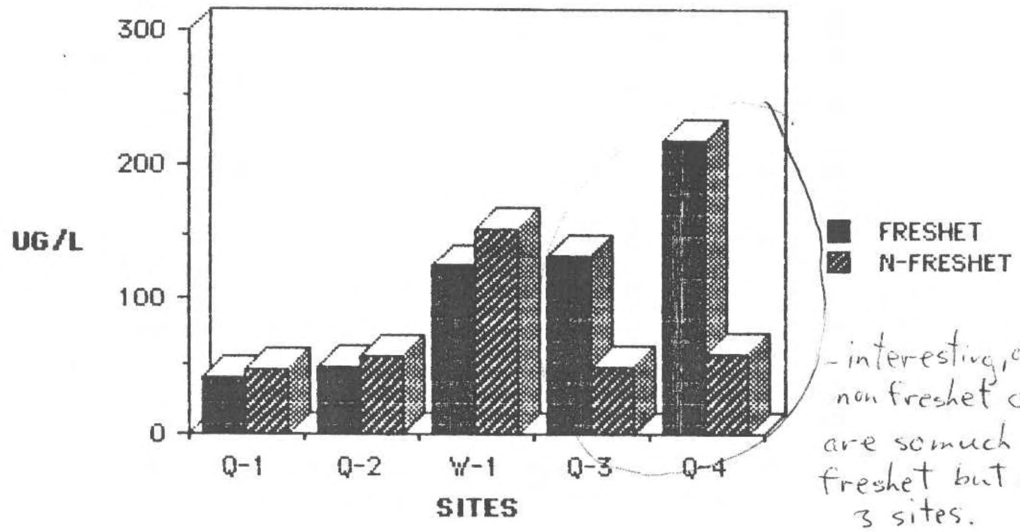
Table 6. Total and dissolved phosphorus at Quilchena sites during 1983 and 1984.

DATES	TOTAL PHOSPHORUS					DISSOLVED PHOSPHORUS				
	Q-1	Q-2	W-1	Q-3	Q-4	Q-1	Q-2	W-1	Q-3	Q-4
1983										
June 6*	43	57	-	232	304	23	33	-	38	31
June 15*	36	51	150	85	82	27	32	66	35	35
June 28*	42	-	100	64	89	26	-	59	33	41
July 19*	40	-	110	54	51	31	-	32	36	29
Aug. 22	50	-	-	34	36	43	-	-	25	29
Sept 27	41	-	172	43	40	31	-	106	27	26
Nov. 16	46	-	116	36	39	31	-	95	26	27
Dec. 6	36	-	-	44	43	32	-	-	26	25
1984										
Jan. 30	-	-	-	57	59	-	-	-	33	34
Feb. 28	48	50	76	57	130	34	37	50	29	32
Mar. 19	67	65	248	69	71	47	43	150	35	30
Apr. 25*	52	51	164	84	84	36	37	106	30	32
May 16*	41	53	133	182	216	28	28	94	31	34
May 30*	45	49	164	117	153	21	22	119	23	30
June 13*	30	37	60	255	755	23	26	41	34	48

* denotes freshet condition

2. Nitrogen

Total nitrogen increased downstream during high water (Fig. 19). The largest increases



- interesting, any idea why non freshet concentrations are so much lower than freshet but not for other 3 sites.

Fig. 17. Mean total phosphorus at Quilchena sites during freshet and non-freshet.

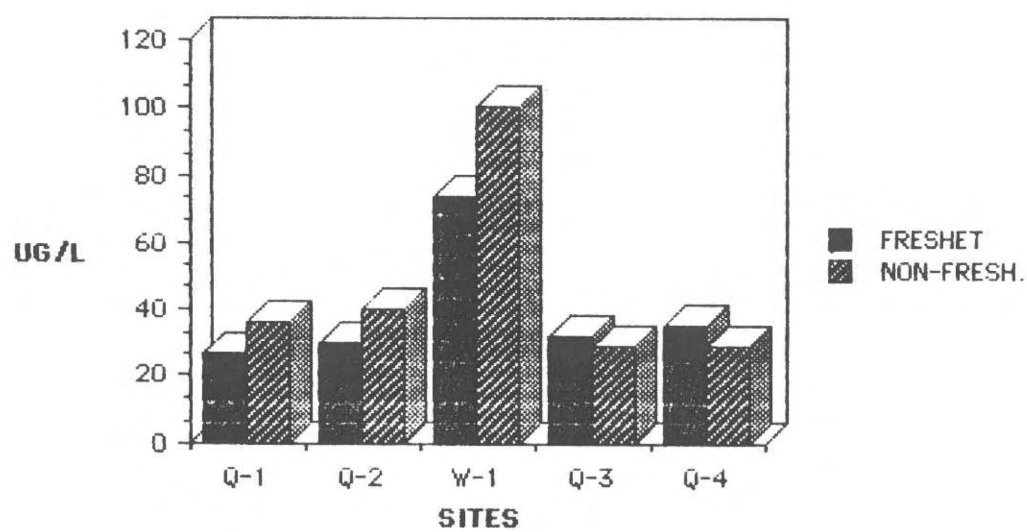


Fig. 18. Mean dissolved phosphorus at Quilchena sites during freshet and non-freshet.

occurred during maximum flows. No increases were noted between sites Q-1 and Q-2 (Table 7). Major increases were noted between Q-2 and Q-3, and Q-3 and Q-4. During low flows, total nitrogen generally declined between stations except for the Feb. 28th sampling date when a large increase occurred between Q-3 and Q-4. Except for ~~on sampling date,~~ June 13/84, nitrogen concentrations in Wasley Creek were in the range of three times greater than the Quilchena site.

Ammonia did not correlate as well with water flows as did total nitrogen (Table 7). In fact, some of the highest ammonia results were obtained during low flow. On Aug. 22/83 and Feb. 28/84, large increases occurred between sites Q-3 and Q-4. The Feb. increase also occurred in total nitrogen but not the August sample. These increases did not occur in nitrite-nitrate concentrations. Ammonia increases were also noted at various times between stations Q-1 and Q-2 with subsequent decreases on those dates between the next two sites, Q-2 and Q-3. Wasley Creek ammonia concentrations were much greater than all Quilchena sites except for the Feb. sample, similar to the total nitrogen pattern (Table 7).

Total nitrogen was comprised mainly of organic, averaging 95% over the study period at the Quilchena sites (Fig. 19 $ 20). The Wasley Cr. site averaged 86.6% organic nitrogen. In Quilchena Cr. during winter, The ~~%~~ percent of organic declined and ammonia increased. Ammonia comprised a much larger part of the total nitrogen in Wasley Cr. than Quilchena Cr.

Table 7. Total and ammonia nitrogen on all sampling dates at Quilchena sites during 1983 and 1984.

DATES	TOTAL NITROGEN					AMMONIA NITROGEN				
	Q-1	Q-2	W-1	Q-3	Q-4	Q-1	Q-2	W-1	Q-3	Q-4
1983										
June 6	470	540	-	780	890	7	19	-	8	7
June 15	450	450	1470	510	50	L5	8	28	7	12
June 28	530	-	1320	490	490	6	-	33	5	L5
July 19	460	-	1590	380	380	5	-	33	L5	5
Aug. 22	330	-	-	360	330	7	-	-	L5	31
Sept. 27	510	-	2210	380	380	L5	-	161	L5	L5
Nov. 16	580	-	2200	51	45	L5	-	112	L5	L5
Dec. 6	480	-	-	390	380	6	-	-	L5	L5
1984										
Jan. 30	-	-	-	520	500	-	-	-	13	14
Feb. 28	500	370	1400	400	640	11	11	66	10	21
Mar. 19	600	380	2190	340	380	6	L5	122	L5	L5
Apr. 25	500	450	1610	450	480	7	8	163	7	6
May 16	520	480	1310	590	630	5	L5	87	L5	5
May 30	560	510	1630	600	660	5	L5	161	L5	5
June 13	390	410	420	770	990	L5	L5	6	28	10

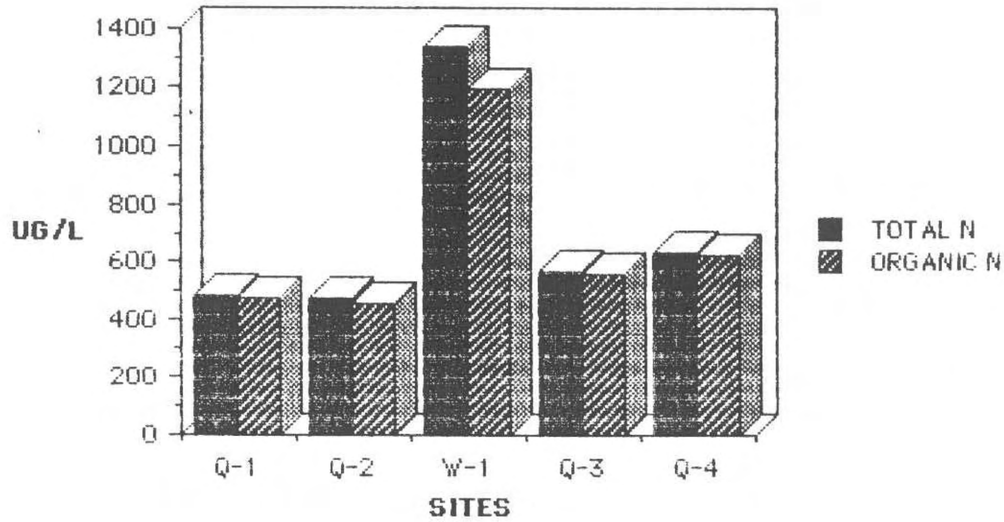


Fig 19. Total and organic nitrogen at all Quilchena sites during freshet.

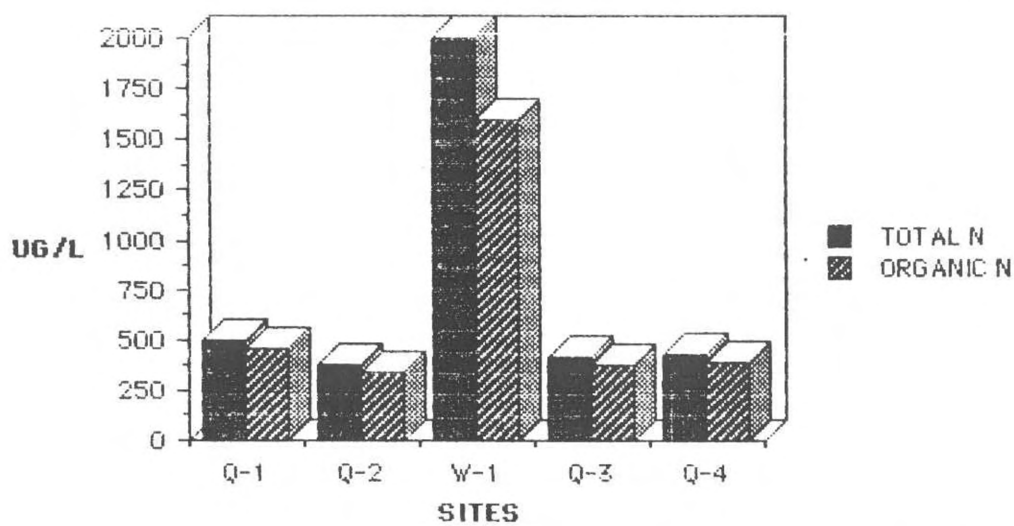


Fig. 20. Total and organic nitrogen at all Quilchena sites during non-freshet.

3. General Ions

Mean non-filterable residue showed a regular increase from site Q-1 to Q-4 (Fig. 21). The smallest increase occurred between Q-1 and Q-2, while the largest increase occurred between Q-2 and Q-3. Wasley Cr. mean non-filterable residue was intermediate between the four Quilchena sites. The maximum increase between Q-1 and Q-2 (5 mg/l) occurred on May 16/84. The maximum concentration at Q-1 was 11 mg/l with a mean of 5.2 while the maximum at Q-2 was 12 mg/l with a mean of 6.8 mg/l. Of the eight comparative sampling dates at Q-1 and Q-2, there were four increases and four decreases. Between Q-2 and Q-3, increases were small or non-existant during low flow. However, during high flow at these sites, the increases were extreme. For example, there were recorded increases of 215 mg/l and 272 mg/l. The mean residue at Q-3 was 58.5 mg/l with a maximum of 278 while Q-4 had a mean of 89.1 and a maximum of 586 mg/l. The mean increase between Q-2 and Q-3 was 123 mg/l between Q-3 and Q-4 was 34.4 mg/l.

Specfic conductance changes mirrored non-filterable residue at the Quilchena sites (Fig. 22)œ. The Wasley site, however, had a much higher specific conductance than the Quilchena sites. The conductance change between Q-2 and Q-3 was just as dramatic as the non-filterable residue increase. The means increased from 67.2 umhos/cm at Q-1 to 236.2 umhos/cm at Q-4. Mean pH's also increased between Q-2 and Q-3 from 7.6 to 8.1. Mean pH at Q-1 was also 7.6 while at Q-4, it was 8.2. The highest mean pH was at Wasley Cr. with a mean of 8.3.

4. Coliforms

Coliforms generally increased with distance downstream at the Quilchena sites (Table). Major increases occurred in Nov., Feb. and March between Q-3 and Q-4. There were smaller increases between Q-2 and Q-3 while in April, the largest concentration was found at the uppermost station, Q-1. In most samples, the total was comprised entirely of faecal. Wasley Creek had significant readings on only one of the four sample dates.

DISCUSSION

Total phosphorus did not vary greatly during low flows except on February 28th between Q-3 and Q-4. Field notes taken then noted a large concentration of cattle below Q-3 with access to the river. The water at Q-3 was clear while the water at Q-4 was very murky. It was evident that the P increase was a result of the cattle impacting the creek.

In contrast, during high water, increases occurred also between sites Q-2 and Q-3. The distance between Q-2 and Q-3 is very large and the area has poor accessibility so no samples could be obtained between the sites. In addition to the P increases, non-filterable residue also increased greatly during high water. Subsequently, an aerial survey was undertaken to observe these area of the watershed. Mid-way between the sites is an area of silt banks which are heavily eroded during freshet. Obviously, a major part of the increased silt (and probably particulate P) load is caused by the erosion.

The increases during freshet between Q-3 and Q-4 could be attributed to two sources. Field p@

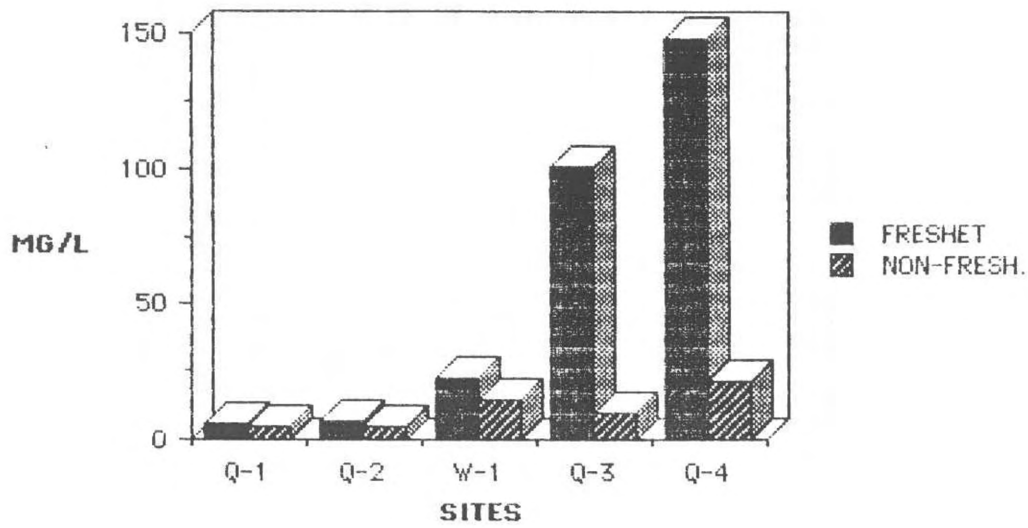


Fig. 21. Mean non-filterable residue at all Quilchena sites.

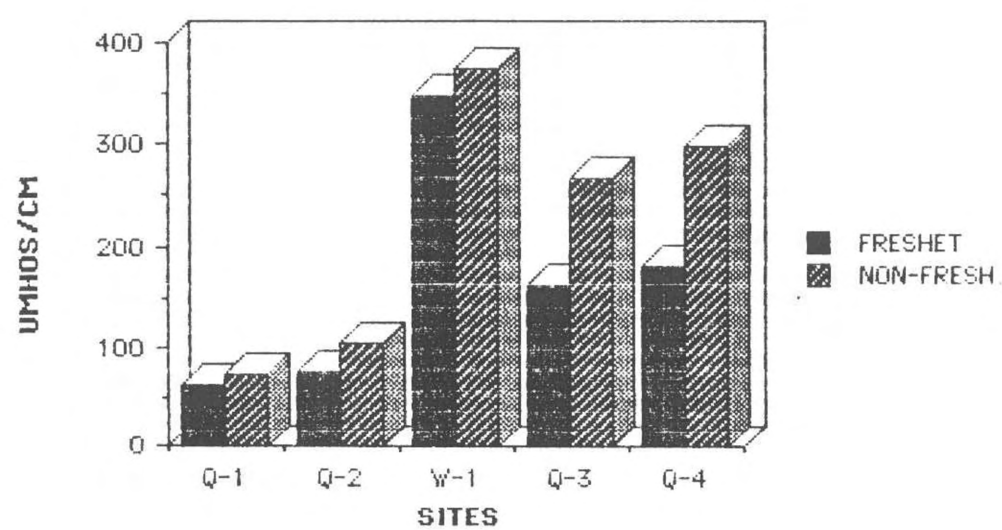


Fig. 22. Mean specific conductance at all Quilchena sites.

notes indicated concentrations of cattle between the sites had access to the stream. Cattle wastes and bank erosion caused by the cattle were evident between these two sites. A golf course also exists between these sites. On the day of maximum P increase, the golf course was flooded. It is conceivable that P additions could come from the fertilizer applied to the land. It is impossible to quantify this source. Total dissolved phosphorus increases during freshet were probably the result of the same factors as for total P.

Wasley Creek P readings were generally much higher than the Quilchena sites. The water chemistry of this creek is a result of the watershed entering Minnie Lake since the downstream Wasley site is only a kilometer in length. Although some cattle may graze the area surrounding Wasley Creek, no large concentrations were noted during the study. No data were obtained for the upper Wasley watershed so the source of nutrients cannot be stated.

The nitrogen concentration changes were generally similar to phosphorus. As for phosphorus, the large nitrogen increase during February was the result of the large cattle concentrations. Wasley Creek's much larger concentrations are again a reflection of the organic enrichment of Minnie Lake. The downstream decrease in nitrogen concentrations during low water reflects the lack of organic imput without overland runoff. Nitrogen stripping occurs in the streams during this time period.

The faecal coliform increases at the lower sites indicate the contamination by cattle. The paucity of data prevents a detailed appraisal of the system.

NICOLA RIVER AT OUTLET OF NICOLA LAKE

1. Phosphorus

Total phosphorus concentrations ranged from 33 to 51 ug/l except for one anomalous result of 653 ug/l on June 13/84 (Table 8). There did not appear to be a discernable pattern to the results. Total dissolved phosphorus varied from 11 to 28 ug/l with the higher values recorded during lower flows. In contrast to the high total phosphorus result of June/84, total dissolved phosphorus on that date remained low (12 ug/l).

2. Nitrogen

A lack of data during freshet makes a proper appraisal of total nitrogen tenuous during that period. The existing data showed very little change over the three sampling dates with a mean of 426.7 and a range of 410 to 450 (Table 8). There was a general decline in total nitrogen over the winter period. A maximum reading of 910 ug/l was obtained on August 22.

Ammonia was not detected on any sampling date during the course of the study. Only one detectable nitrite-nitrate reading was obtained during the study (Jan. 30). Organic nitrogen comprised 100% of the total nitrogen except for the January sample.

3. General Ions

Non-filterable residues were very small at the outlet of the lake ranging from 3 - 9 mg/l (Table 8). The small variation did not follow any observable pattern. Specific conductance also showed a very small variance with a range of 197 to 207 umhos/cm. There was, however, a much larger variation in pH values with ranges from 7.9 to 9.0 and a mean of 8.1.

4. Coliforms

Of the five coliform samples taken, only one tested positive, and that was barely detectable at 2 MPN for total only. Faecal was not detected in any of the samples.

Table 8. Selected parameters at Nicola River at Outlet of Nicola Lake (NL-1) at all sampling dates in 1983 and 1984.

DATES	**PARAMETERS**				
	Tot. P	Diss. P	Tot. N	NFR	Conductance
July 19	33	11	450	6	201
Aug. 22	47	15	910	5	198
Sept. 27	40	18	440	5	205
Nov. 16	43	17	540	8	207
Dec. 06	45	17	430	4	222
Jan. 30	42	28	370	3	197
Feb. 28	42	20	400	3	205
Mar. 19	51	16	460	9	205
May 16	42	17	420	6	204
May 30	45	15	410	9	204
June 13	653	12	-	3	200

DISCUSSION

In a previous study (Holmes, 1979), total phosphorus concentrations varied from 27 - 110 ug/l. These values, except for the maximums, were very comparable to the present study. Except for the one anomalous result of 653 ug/l obtained on June 13/84, the total phosphorus concentrations were amazingly uniform at the lake outlet. Nicola Lake obviously acts as a "sink" retaining phosphorus in the sediments as evidenced by the low concentration exiting the lake compared to that entering from the tributaries. The one large anomalous reading which occurred during very high water was also noted at other sites on that date. Since a corresponding increase was not noted in the dissolved phosphorus, this may indicate a short circuiting of sediment P through the lake with the source probably being Quilchena Creek (755 ug/l on that date).

Total dissolved phosphorus varied from 8 - 89 ug/l in 1979 and again, except for two high values were also comparable to the present study. The pattern in 1979 had high values during the colder, low growth period and lower concentrations during the warmer, high growth months. Dissolved phosphorus was obviously incorporated into phytoplankton during the warmer months and released when blooms collapsed. The dissolved P exiting the lake was much less than that entering the lake through the tributaries (Table 8).

Total nitrogen exiting the lake was always in the form of organic indicating the source was probably algal cells. The date of maximum nitrogen discharge was characterized by a large algal bloom in the lake and a corresponding discharge of large quantities of algal cells present in the river water. Except for the one sampling date, nitrogen concentrations were fairly uniform in the discharge waters.

The non-filterable residue concentrations were quite small and uniform showing that the lake retained the particles. Although no analyses were done, this residue was probably organic in nature indicating the presence of algal cells.