WATER QUALITY STATUS REPORT NO. 94

PLUMMER CREEK AND CHATCOLET LAKE

Benewah and Kootenai Counties, Idaho

1990

Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau
1410 N. Hilton
Boise, Idaho 83706-1253

1990

WATER QUALITY STATUS REPORT NO. 94

PLUMMER CREEK AND CHATCOLET LAKE

Benewah and Kootenai Counties

1990

Prepared by
Stephen A. Breithaupt

Coeur d'Alene Field Office
2110 Ironwood Parkway
Coeur d'Alene, ID 83814

Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau

1990

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure	Title	Page
16	Total and particulate phosphorus concentrations (mg P/L) for station LPC1.	19
17	Nitrogen concentrations (mg N/L) for station PC3.	20
18	Nitrogen concentrations (mg N/L) for station PC2.	20
19	Nitrogen concentrations (mg N/L) for station HR2.	21
20	Nitrogen concentrations (mg N/L) for station HR1.	21
21	Nitrogen concentrations (mg N/L) for station PC1.	21
22	Nitrogen concentrations (mg N/L) for station LPC2.	22
23	Nitrogen concentrations (mg N/L) for station HR3.	22
24	Nitrogen concentrations (mg N/L) for station LPC1.	22
25	Suspended sediment concentration (mg/L) at station PC3.	23
26	Suspended sediment concentration (mg/L) at station PC2.	23
27	Suspended sediment concentration (mg/L) at station HR2.	24
28	Suspended sediment concentration (mg/L) at station HR1.	24
29	Suspended sediment concentration (mg/L) at station PC1.	24
30	Suspended sediment concentration (mg/L) at station LPC2.	25
31	Suspended sediment concentration (mg/L) at station HR3.	25
32	Suspended sediment concentration (mg/L) at station LPC1.	25

ABSTRACT

The Plummer Creek watershed drains a portion of northwestern Benewah County and southwestern Kootenai County. The 11,220 ha (27,732 acre) watershed consists of 7,075 ha (17,483 acres) of woodland, 2,559 ha (6,324 acres) of cropland, 908 ha (2,245 acres) of pasture, 502 ha (1,241 acres) of land in the conservation reserve program, and 166 ha (410 acres) of land classified as urban and industrial. A major tributary to Plummer Creek is Little Plummer Creek, which drains a surface area of 5,455 ha (13,482 acres) (included in the total watershed area). The receiving water for Plummer Creek is Chatcolet Lake, which has a surface area of 704 ha (1740 acres), a maximum depth of 11.2 m, and a volume of 28.4×10^6 m^3 (23.0×10^3 acre-ft).

The Idaho Water Quality Standards and Wastewater Treatment Requirements specify that Plummer Creek is protected for the beneficial uses of agricultural water supply and secondary contact recreation. Chatcolet Lake, as a part of Lake Coeur d'Alene, is protected for the following beneficial uses: (1) domestic water supply, (2) cold water biota, (3) salmonid spawning, (4) primary contact recreation, (5) secondary contact recreation, and (6) as a special resource water.

Suspended sediment impacts from nonpoint sources were observed at all stations, except for PC1 and HR1, both of which are located in the upper watershed above the City of Plummer. Where the impacts occurred, the peak concentrations were associated with the maximum discharge. The agricultural land uses are the primary sources of suspended sediment, but the nonpoint source stormwater runoff from the City of Plummer and the industrial areas is a significant contributor to the load at PC2. PC2 is located immediately downstream from the City of Plummer. Station PC3, at the mouth of Plummer Creek, received the greatest load of suspended sediment, both from the standpoint of total load and from load per unit watershed area. PC2 received the next largest load and load per unit watershed area.

Phosphorus impacts from nonpoint sources were observed at all stations, except PC2, HR1, and PC1. Station PC2 was effected by the point source discharge from the city's wastewater treatment plant. However, its load was small in comparison to the load observed at PC2. Of all the stations, PC3 receives the largest load of total and particulate phosphorus. From an unit area viewpoint however, PC2 had slightly greater loads of total and particulate phosphorus than did PC3.

The major form of nitrogen observed at all stations, except PC2, was nitrate+nitrite-nitrogen (NO_3+NO_2-N). Ammonia-nitrogen (NH_3-N) was a significant component of total nitrogen at station PC2. Nonpoint source contributions of NO_3+NO_2-N are not clearly defined (as determined by a relationship with discharge). NO_3+NO_2-N

concentrations were found be significantly related to a seasonal factor, which had a maximum in early January. Station PC3 received the greatest load of NO_3+NO_2-N for both the total load and area comparisons.

A significant oxygen decline occurred in the hypolimnion of Chatcolet Lake. The oxygen demanding source is unknown. The in-lake concentrations of total phosphorus and suspended sediment were at their maximum shortly after peak runoff, at both Chatcolet Lake stations. Secchi disk transparency was at a minimum at the same time. The St. Joe River does not appear to have major impact on suspended sediment and total phosphorus concentrations in Chatcolet Lake, as it exhibited concentration peaks after the peaks seen in Chatcolet Lake. Sediment accumulation near the mouth of Plummer Creek, in Chatcolet Lake, has occurred at an average rate of 2.4 cm per year since the Mt. St. Helens eruption of May 18,1980.

The Carlson trophic state indices for Chatcolet Lake exhibited a large increase in the total phosphorus and secchi disk transparency TSI values shortly after peak runoff. These were not accompanied by corresponding changes in algal biomass (chlorophyll a). Algae were shown not to cause the high suspended sediment and high trophic state values in Chatcolet Lake. Rather, they were a consequence of agricultural runoff in Plummer Creek.

PLUMMER CREEK WATER QUALITY SURVEY

The Idaho Agricultural Pollution Abatement Plan (IDL-SCC, 1979) identifies Plummer Creek as having nonpoint pollution problems from dryland farming, with sediment as the primary pollutant. The Benewah Soil Conservation District is the recipient of planning grant funds from the Agricultural Water Quality Program to study, in part, water quality of the Plummer Creek watershed. This study report provides the District with (1) information on which reaches of the creek are being impacted by agricultural runoff, (2) defines the water quality status of the creek, and (3) it evaluates the impact of sediment and nutrient loads on Chatcolet Lake.

BACKGROUND

The Plummer Creek watershed drains a portion of northwestern Benewah County and southwestern Kootenai County. The creek flows through the Coeur d'Alene Indian Reservation and Heyburn State Park, and into Chatcolet Lake, in the southwestern end of Coeur d'Alene Lake. The 11,220 ha (27,732 acre) watershed consists of 7,075 ha (17,483 acres) of woodland, 2,559 ha (6,324 acres) of cropland, 908 ha (2,245 acres) of pasture, 502 ha (1,241 acres) of land in the conservation reserve program, and 166 ha (410 acres) of land classified as urban and industrial (Burleigh, personal communication, 1989). The cropland was primarily planted in cereal crops of wheat, barley, and oats; while the pasture was planted to a grass/legume mixture. A major tributary to Plummer Creek is Little Plummer Creek, which drains a surface area of 5,455 ha (13,482 acres) (included in the total watershed area). Ownership in the watershed is comprised of an estimated 9,950 ha (24,600 acres) of private land, 890 ha (2,200 acres) of State land, and 610 ha (1,500 acres) of Tribal land. (See the section on Land Use Patterns for areas in specific sub-basins.)

The Idaho Water Quality Standards and Wastewater Treatment Requirements (IDHW-DEQ, 1985) specify that Plummer Creek is protected for agricultural water supply and secondary contact recreation. Chatcolet Lake, as a part of Lake Coeur d'Alene, is protected for the following beneficial uses: (1) domestic water supply, (2) cold water biota, (3) salmonid spawning, (4) primary contact recreation, (5) secondary contact recreation, and (6) as a special resource water.

The major water quality problem in the watershed is suspended sediment and related pollutants in Plummer Creek and Chatcolet Lake, which originate from erosion of fields used for dryland farming. These are apparently cut-over forest soils, which are subjected to snow melt, rain-on-snow events, and rainfall during a time when no crops cover the soil (winter through spring). In addition, pollutants originate from industrial and urban development in the City of Plummer and animal confinement operations. Silvicultural activities occur near the upper watershed boundary of Little Plummer Creek, but the sampling sites did not allow for a determination of their water quality impacts.

One outcome of these water quality problems is the accumulation of sediments in Chatcolet Lake at the mouth of Plummer Creek, which apparently have impaired the recreational use in that area of the lake (Bear, personal communication, 1988). Chatcolet Lake has been classified as a oligo-mesotrophic lake, subject to nutrient loading from Plummer Creek and un-sewered wastewater from float houses and recreation houses (Milligan, et al, 1983). In recent years, the float houses have been removed from Chatcolet Lake.

PREVIOUS STUDIES

The U.S. Environmental Protection Agency, as part of the National Eutrophication Survey, sampled Lake Coeur d'Alene and several of its tributaries, including Plummer Creek (EPA, 1977). The southern end of Lake Coeur d'Alene was identified as being over enriched with nutrients. The annual total phosphorus load from Plummer Creek was calculated to be 435 kg. (This is much lower than found in this study. See Annual Discharges and Loadings section below.)

The Idaho Department of Health and Welfare-Division of Environmental Quality conducted a study in 1975 to obtain water quality data for establishing effluent limits for the City of Plummer's wastewater treatment facility (IDHW-DEQ, 1975). Results of this sampling effort demonstrated significant nutrient increases from upstream to downstream monitoring sites. No conclusions were drawn on sources, other than the wastewater discharge, although runoff from dryland farming activities was discussed. In the spring of 1983, the Benewah Soil Conservation District began a monitoring effort on Little Plummer Creek to establish baseline water quality conditions during runoff periods (BSCD, 1983). Both of these studies identified sediment, nutrients, and bacteria as pollutants to be controlled to adequately protect the beneficial uses of Plummer Creek and Chatcolet Lake.

OBJECTIVES

The main intent of this study is to determine the stream reaches, which as a result of agricultural activities, receive significant contributions of sediment and nutrients. By implication, the sub-basins which these reaches drain will be identified as significant contributors. Additionally, the impact on water quality of urban and industrial areas in and around the City of Plummer is to be determined to differentiate these from agricultural impacts.

The objectives of this study are (1) determine the concentrations and loads of water quality constituents in each stream reach, and the watershed as a whole, which could be affected by pollutant addition from point and nonpoint sources, (2) identify which stream reaches are receiving significant quantities of nonpoint source pollutants from agricultural runoff, and (3) evaluate the impact of pollutant concentrations and loadings on Plummer Creek and Chatcolet Lake. The specific approach for each one of these is discussed below.

METHODS

SAMPLING SITES AND FREQUENCY

The sample sites and locations are listed in table 1 and shown in figure 1a. The selection of sites took into consideration the location of likely sources of pollution, characteristics of the receiving water, and site access.

The study took place from October, 1988 through September, 1989. The sampling frequency for the main stem stations (PC3, PC2, PC1, LPC2, and LPC1) was as follows: October through December, once per month; January through May, at least twice per month; and June through September, once per month. The high runoff stations were sampled January through May at least twice per month. The point source (WW) was sampled in November, February, May, and August. SLR was sampled during the runoff season in March and April. The lake stations were sampled once in October, twice a month from March through May, and once a month during June through September.

WATER QUALITY VARIABLES

The water quality variables which where measured and analyzed included the following:

<u>Field Measurements</u>
- flow
- stream stage
- temperature
- dissolved oxygen
- specific conductance
- turbidity
- Secchi disk transparency

<u>Biological</u>
- BOD
- chlorophyll a (Chla)
- fecal coliform
- fecal streptococci

<u>Nutrients and Sediment</u>
- ammonia nitrogen (NH_3)
- nitrate + nitrite nitrogen (NO_3+NO_2)
- total Kjeldahl nitrogen (TKN)
- total phosphorus (TP)
- total dissolved phosphorus (TDP)
- dissolved ortho phosphorus (DOP)
- suspended sediment (SS)

Table 1: Sampling site locations

ID (STORET #)	Site Description	Elevation (feet)	Distance above mouth (miles)
	PLUMMER CREEK		
PC3 (2000344)	Heyburn State Park footbridge	2130	1
SLR (2000353)	Ephemeral tributary downstream of the WW discharge; adjacent to hog operation	2645	5.8
PC2 (2000343)	Railroad crossing downstream of the WW discharge	2645	5.9
WW (2000352)	City of Plummer wastewater discharge	2645	6.1
HR2 (2000350)	Ephemeral tributary upstream of the WW discharge	2670	6.5
HR1 (2000349)	Ephemeral tributary upstream of the Crown-Pacific mill site	2722	7.3
PC1 (2000342)	Indian Agency access road crossing	2718	7.8
	LITTLE PLUMMER CREEK		
LPC2 (2000348)	Above confluence with Plummer Creek	2220	2.5
HR3 (2000351)	Road crossing 2 miles upstream of Highway 5	2640	7.6
LPC1 (2000347)	Road crossing in south half of Section 33 R4W T46N	2760	9.9
	CHATCOLET LAKE		
CL1 (2000345)	Chatcolet Lake beyond the mouth of Plummer Creek	2125	0
CL2 (2000346)	Chatcolet Lake between Rocky Point and Chatcolet boat launches	2125	na

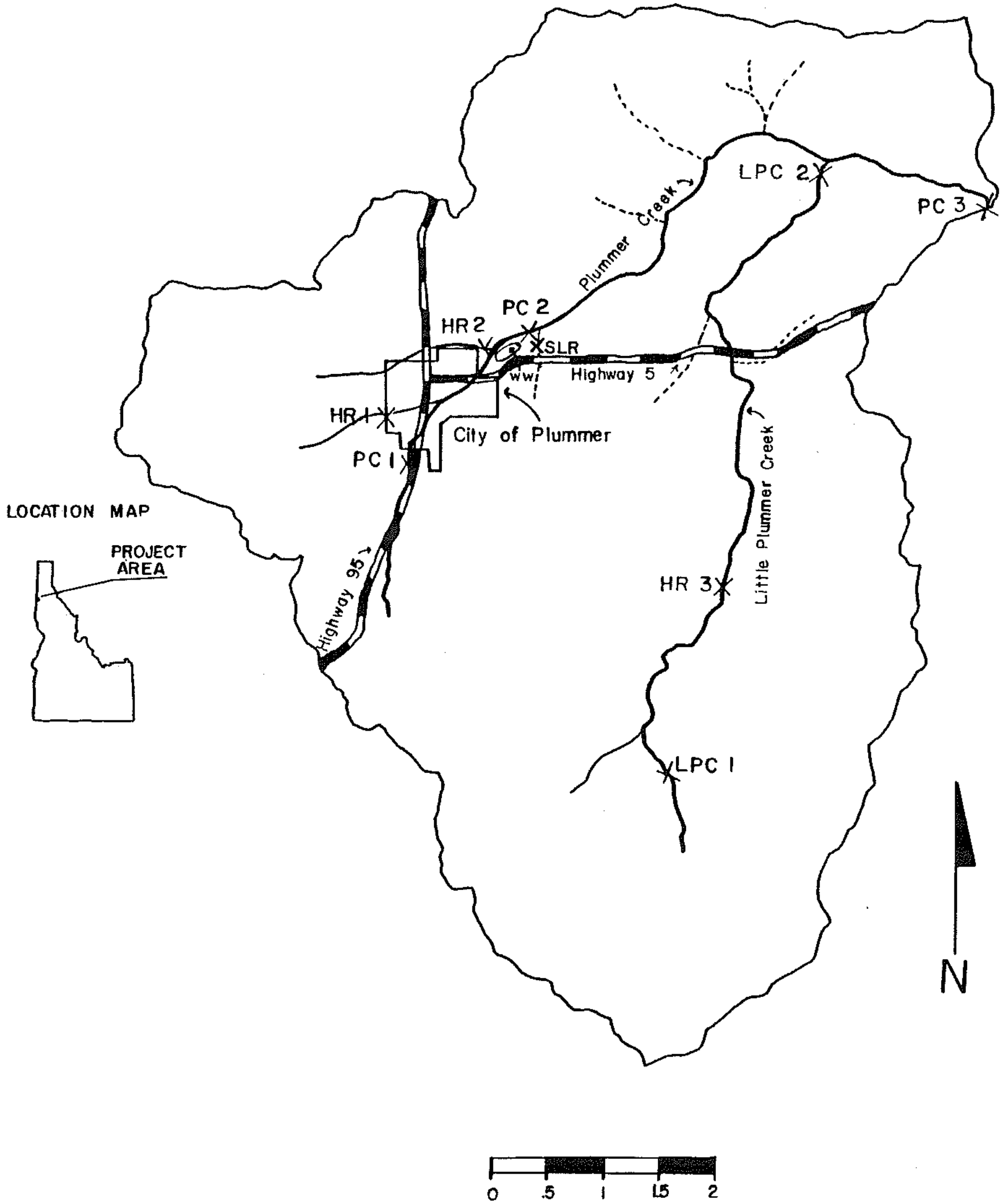

Figure 1a: Site map of the Plummer Creek study area. This depicts the watershed boundary, the main stem of the creeks and important tributaries, and the sampling sites in relation to the City of Plummer and the main roads in the watershed.

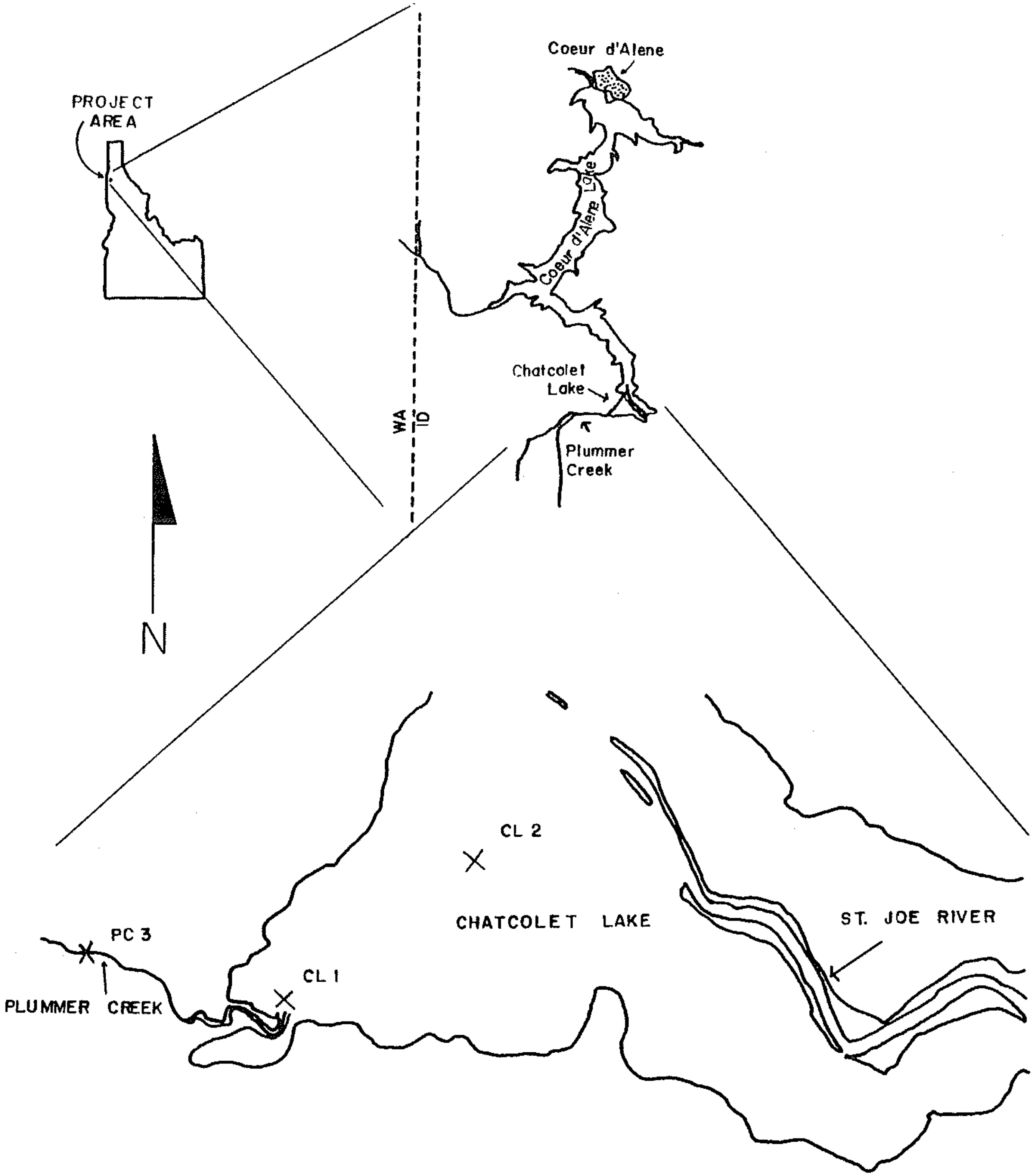

Figure 1b: Site map of the study area in Chatcolet Lake and the mouth of Plummer Creek. The sample sites in the lake and near the mouth of the creek are shown. The channel of the St. Joe River is also indicated.

Common ion and total metal concentrations were analyzed at the main stem stations to characterize the type of water and the presence of metals. It was intended to sample for bed load during peak flow at PC3, but this proved impossible because of flooding conditions at that time.

SAMPLING PROTOCOL

Maximum and minimum temperature and precipitation were measured daily by an associate of the Benewah Soil Conservation District (Wetter, personal communication, 1989). Flow and stage measurements were performed on the same day that sampling was conducted. Flow was measured using the USGS mid-section method (Rantz, 1982) with a Marsh-McBirney velocity meter and top setting wading rod. Stage was measured from a control point, typically the top of a culvert.

At PC3, a stage recorder was installed over a stilling well, and stage was measured relative to a fixed datum located above the stream bank. Due to ice/log jams at peak flow and subsequent repair of the footbridge, it was necessary to re-survey the elevation of the stilling well twice. Their were several interruptions in the record. These were caused by (1) the creek freezing, (2) the jams shifting the stilling well, and (3) the lake level rising causing slack water at PC3.

Water quality sampling at the stream stations were conducted to emulate a cross-sectional, depth-integrated composite, since the use of a DH-48 sampler proved impractical. Grab samples at depth and various points in the cross-section were composited in a polyethylene churn splitter, and sub-samples were drawn from that while mixing the composite sample.

Lake water quality sampling was accomplished by collecting samples from 0.5 meter from the surface, mid-depth, and 1.0 meter from the bottom and compositing in a polyethylene churn splitter. A necessary first step was to measure the total depth. At CL1, samples were collected at 0.5 meter from the surface only. Sub-samples were drawn from the churn splitter as stated above. Secchi disk transparency was measured using a standard 20 cm disk.

Samples for dissolved phosphorus components were filtered after all samples were collected. Plain, 0.45 um, cellulose nitrate, Micro Filtration System filters were used for all filtration, with the exception of two times when Gelman, 0.45 um filters were used. Filter blanks were run using distilled water. If detectable concentrations were found, then the blank value was subtracted from the corresponding dissolved phosphorus value. This occurred twice with the Gelman filters.

All samples were placed on ice as soon as possible after collection and kept cold until analyzed. Phosphorus and nitrogen samples were preserved using 2 ml of concentrated sulfuric acid after all samples were collected. Chlorophyll a sample bottles were immediately wrapped in aluminum foil to exclude light and stored on ice until filtered using plain, 0.45 um, cellulose nitrate, Micro Filtration System filters. These filters were wrapped in aluminum foil and frozen until analyzed.

QUALITY ASSURANCE PROTOCOLS

Samples for quality assurance evaluation were collected from stations PC3. Precision (duplicate) and accuracy (spike percent recovery) samples were obtained for total, dissolved total, and dissolved ortho phosphorus; total Kjeldahl nitrogen; ammonia nitrogen; nitrate plus nitrite nitrogen; and suspended sediment. Suspended sediment spikes were prepared in the field using 900 ml of sample and a known quantity of inert solids, which had been prepared by the Bureau of Laboratories. The other spikes were prepared by the Coeur d'Alene laboratory during analyses.

QUALITY ASSURANCE RESULTS

ACCURACY

Spike recovery results for phosphorus and nitrogen series are listed in Appendix A, along with their respective averages and 95% confidence intervals.

For suspended sediment, the average percent recovery was 100%. Individual recoveries for total and dissolved total phosphorus were very good. While dissolved ortho phosphorus' average recovery was also good, the range was greater, which resulted in a wider 95% confidence interval than seen for the other phosphorus forms. The lowest value (56%), seen on 5/22/89, occurred at a time of low flow and had little impact on the annual load, accounting for only 0.03% of that load at station PC3. The confidence intervals for each phosphorus fraction encompass the 100% recovery value, which is desirable.

All the nitrogen average spike recovery results were greater than 100%, with the greatest for total Kjeldahl nitrogen (106%). All the confidence intervals encompass the 100% value, except for total Kjeldahl nitrogen. Its lower value was only slightly greater (range of 100.1% to 112.6%). NH_3 had the widest confidence interval, followed by NO_3+NO_2 and TKN.

PRECISION

The results from duplicate sampling are summarized in table 2 and presented in full in Appendix B. Total phosphorus and dissolved ortho phosphorus both had excellent average relatives ranges, (ARR), i.e. the ARR was less than 5%. While dissolved total phosphorus was slightly higher, it was still less than 5%. Exclusion of one extreme value improved the result, as expressed by the modified ARR, to a value equivalent to that seen with the other phosphorus forms. The nitrogen series generally exhibited fair to poor precision. (Fair is considered have an ARR of 10-20%, and poor is considered to have an ARR >20%). NO_3+NO_2-N had poor precision, and it took the removal of five values before the remaining values were considered not to be extreme (Bauer, 1986), which is reflected in the modified ARR. NH_3-N had fair precision (between 10% to 20%), but it took the removal of two values to remove the extreme data. Total Kjeldahl nitrogen was similar to NH_3-N, but only one extreme value was found.

Suspended sediment exhibited poor precision, and it took the removal of four values to remove extremes from the data set. It should be noted, however, that three of those extreme cases occurred with the largest value's concentration less than or equal to 6 mg/L, and the remaining one had 14 mg/L (see Appendix B). As a result, the large range had minimal effect on loading calculations and data analyses.

For the purposes of the study, the original values were used in all calculations. These quality assurance results serve to illustrate the reliability which can be assigned to the data.

Table 2: Summary of results from duplicate analyses. Average relative range (ARR) is computed with the equation $ARR = (|x_1-x_2|/((x_1+x_2)/2))*100$. The modified ARR is computed on a data set with extreme values excluded. The procedures are from Bauer (1986). nc = not calculated.

Water Quality Constituent	Average Relative Range (%)	n	Modified Average Relative Range (%)	n
Total P	2.80	17	nc	
Dissolved Total P	4.96	17	2.75	16
Dissolved Ortho P	2.47	17	nc	
Total Kjeldahl N	18.06	17	10.51	16
Ammonia N	19.22	17	4.82	15
NO_3+NO_2 N	25.96	17	2.33	12
Suspended Sediment	20.33	15	1.84	11

OBSERVATIONS

LAND USE PATTERNS

The Soil Conservation Service, through the use of a geographical information system, determined the areas of the different types of land uses identified by the Benewah Soil Conservation District for each sub-basin (Burleigh, personal communication, 1990). These sub-basin values were summed to provide cumulative data of the land use areas upstream of each sampling station (table 3). Figure 2 illustrates the distribution of the land uses in the watershed. (Note, the results for station PC3 are inclusive of the whole Plummer and Little Plummer Creek watershed.)

Cropland was slightly less than one-fourth of the total area, and urban/industrial land use accounted for only 1.5% of the total area. Above station PC2, however, the percentage of urban/industrial land use was 5.4%, with nearly one-fourth of the area as cropland. Both of the results for PC3 and PC2 include the total area for the urban/industrial land use. The stations located on Little Plummer Creek had the smallest percentages of cumulative cropland and the highest percentages of pasture. In all the sub-basins, woodland had the largest proportion of land area, but that land was generally located in the upper parts of the watershed near the watershed boundary.

Table 3: Cumulative area (hectares) and percentage of cumulative area for each type of land use upstream of the indicated sampling station. 1 hectare = 2.47 acres. CRP is land in the conservation reserve program. Data was provided by SCC and SCS (Burleigh, personal communication, 1990).

(cumulative area-hectares)

STATION	CRP	CROPLAND	PASTURE	WOODLAND	URBAN/IND	TOTAL
PC3	502.1	2558.6	920.4	7073.5	165.7	11220.3
PC2	108.0	707.0	264.4	1823.9	165.7	3069.0
HR2	37.0	348.6	82.5	424.7	41.2	934.0
HR1	56.7	174.9	10.3	372.2	0	614.1
PC1	0	115.5	74.7	763.0	0	95.3
LPC2	270.0	805.3	584.3	3795.1	0	5454.6
HR3	0	411.0	464.2	2182.3	0	3057.5
LPC1	0	60.1	89.8	848.3	0	998.3

(percent of cumulative area)

Station	CRP	CROPLAND	PASTURE	WOODLAND	URBAN/IND	TOTAL
PC3	4.5%	22.8%	8.2%	63.0%	1.5%	100.0%
PC2	3.5%	23.0%	8.6%	59.4%	5.4%	100.0%
HR2	4.0%	37.3%	8.8%	45.5%	4.4%	100.0%
HR1	9.2%	28.5%	1.7%	60.6%	0.0%	100.0%
PC1	0.0%	12.1%	7.8%	80.0%	0.0%	100.0%
LPC2	4.9%	14.8%	10.7%	69.6%	0.0%	100.0%
HR3	0.0%	13.4%	15.2%	71.4%	0.0%	100.0%
LPC1	0.0%	6.0%	9.0%	85.0%	0.0%	100.0%

TEMPERATURE AND PRECIPITATION

Figure 3 shows the annual range in maximum and minimum temperatures at Plummer, Idaho. One significant circumstance was the large drop in temperature at the beginning of February, 1989. This caused

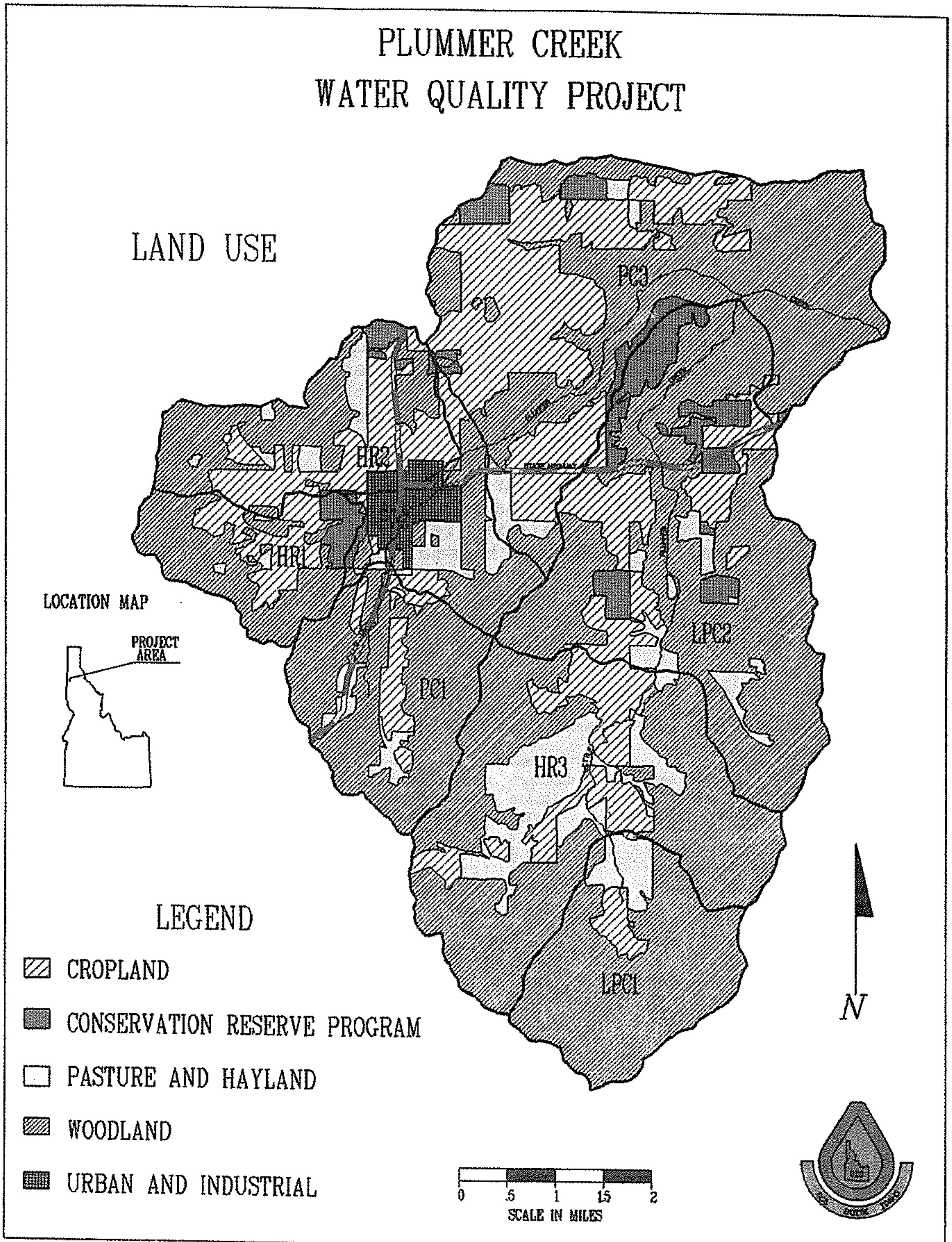

Figure 2: Land uses in the Plummer Creek watershed. The sub-basins which correspond to the sampling sites are indicated. The map was developed by the SCS from SCC data (Burleigh, 1990).

rapid declines in stream flow with substantial freezing of the stream surfaces. During the month of February, this was followed by a temperature increase and another notable decrease . Early March brought a warming trend, which resulted in the primary runoff event for the whole year. For the remainder of the runoff season, through late summer, their was an upward trend in temperature, as expected going into the summer months. August showed a drop in temperature associated with inclement weather.

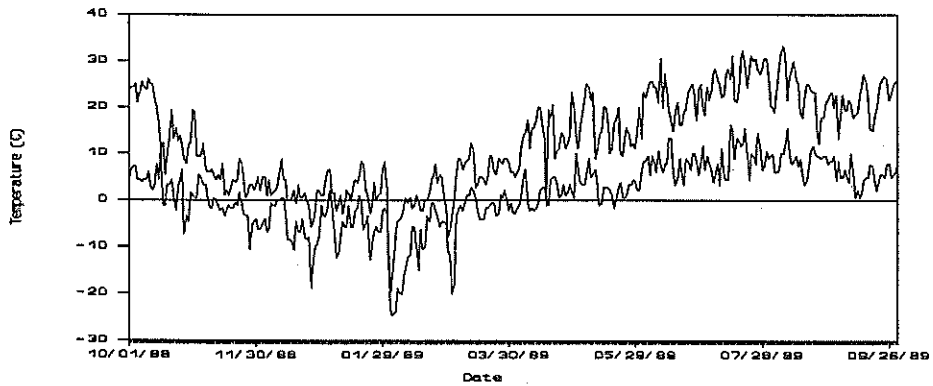

Figure 3: Daily maximum and minimum temperature (°C) for Plummer, Idaho from October, 1988 through September, 1989. Unofficial data collected by Wetter (1989).

Figure 4 illustrates the daily precipitation observed at Plummer, Idaho. This includes water equivalent snowfall. During late fall and winter, precipitation fell at regular intervals.

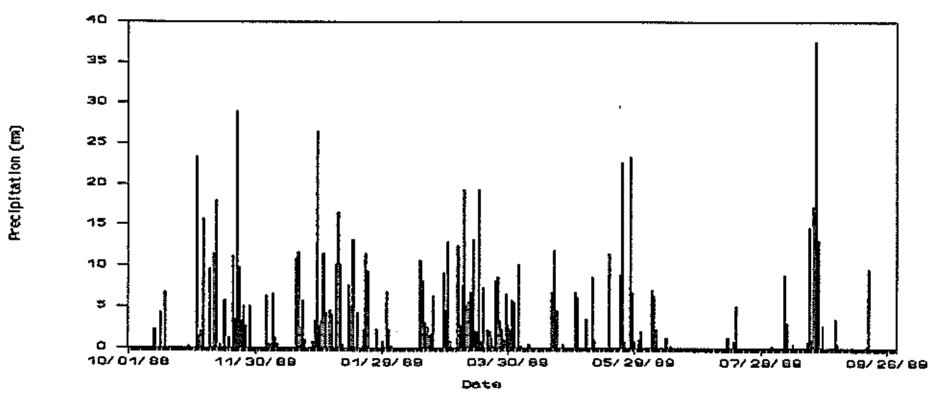

Figure 4: Daily precipitation (mm) measured at Plummer, Idaho from October, 1988 through September, 1989. Unofficial data collected by Wetter (1989).

Precipitation was primarily snowfall, as seen in figure 5, which depicts the daily snow depth at Plummer, Idaho. The drops in snowpack were primarily responsible for increases in runoff, especially the last major drop in early March.

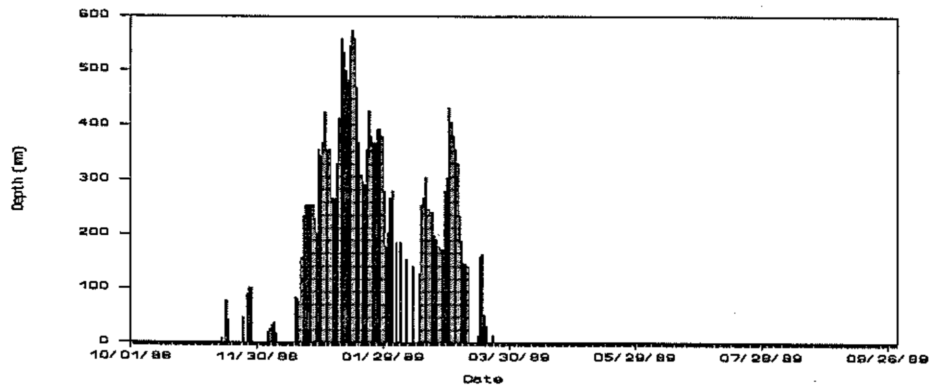

Figure 5: Daily depth of snowpack (mm) measured from October, 1988 through September, 1989 at Plummer, Idaho. Unofficial data collected by Wetter (1989).

DISCHARGE

As stated in the methods and materials section, there were problems in obtaining continuous series of stage records at PC3. Because the results are sketchy, they do not serve the purpose intended and are not discussed further. Rather, the discharges measured during the sampling runs are discussed

Besides the range of discharges measured at each station, the relative comparisons between the stations can be seen in figure 6 - 8. They are also in order from the mouth of the creek to the upper reaches of Plummer and Little Plummer Creeks. (Breaks occur in the hydrograph when the stage was measured at one station more frequently than at the others.) Peak discharges occurred in early March, with other significant discharges in late January and early April. These reflect the changes in snowpack, as stated above. Comparing station PC3 to all the others (figure 6) shows that its runoff greatly exceeded that seen at the other stations, where a discharge of 16.4 m^3/sec (580 cfs) was observed on March 13, 1989.

Stations HR2 and HR1 are ephemeral streams, drying up in late summer until the runoff season begins. Station LPC2 was also dry , but only at the August sampling run.

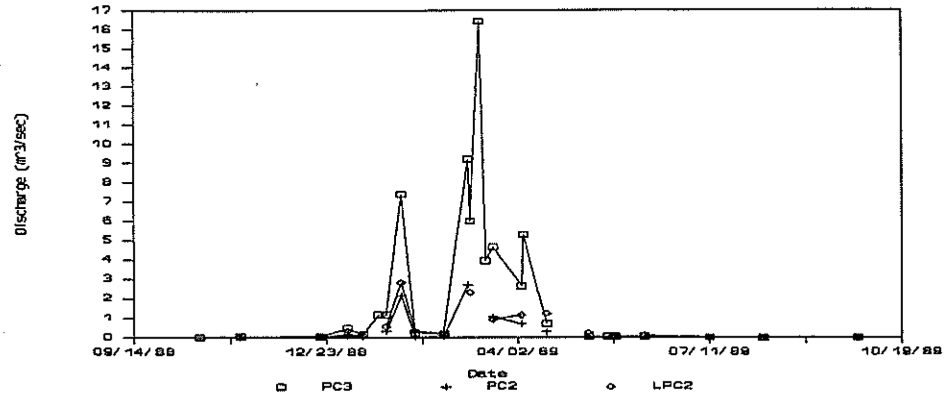

Figure 6: Discharge (m^3/sec) measured at stations PC3, PC2, and LPC2.

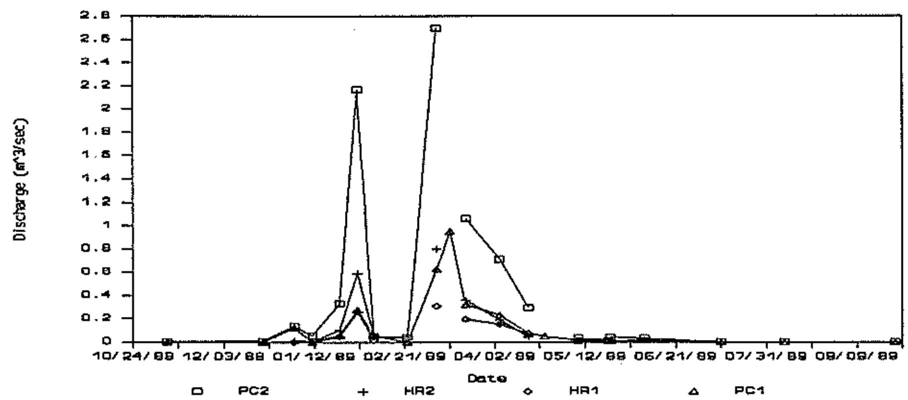

Figure 7: Discharge (m^3/sec) measured at stations PC2, HR2, HR1, and PC1.

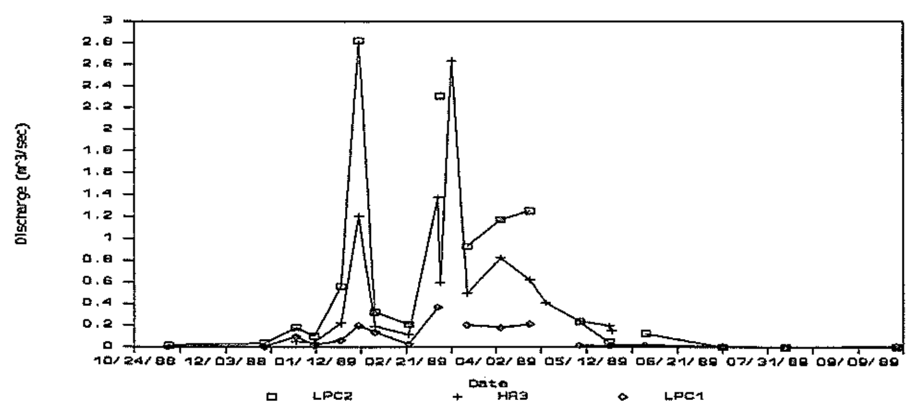

Figure 8: Discharge (m^3/sec) measured at stations LPC2, HR3, and LPC1.

PHOSPHORUS

Phosphorus concentrations over the sampling period are shown in figures 9 - 16. (Note, the range of concentrations is the same for each graph to portray the differences between stations.) The highest concentration was observed at station PC2, which is downstream of the City of Plummer and its wastewater treatment plant (figure 10).

The treatment plant has a no-discharge requirement from May 1st to November 30th, which is reflected in the high concentrations seen from December 20, 1988 to March 7, 1989. During this time, the particulate phosphorus concentration made up a minor fraction of the total, indicating soluble forms were prevalent and that the treatment plant affected the instream concentrations. However, when the peak runoff period began on March 7th, the particulate fraction became dominant and total phosphorus dropped only slightly with the increased stream flow. This suggests that nonpoint sources were making significant contributions to the levels of phosphorus at PC2 (however, see the section Relationships Between Discharge and Concentration below). Phosphorus concentrations dropped rapidly after peak runoff, and again the particulate fraction was the minor fraction. After the beginning of the no-discharge period, the particulate fraction became the dominant form.

The high concentrations at PC2 during the winter months appear to have been seen as well at station PC3 (figure 9). No corresponding increase in concentration was seen at station LPC2 (figure 14), which is at the mouth of Little Plummer Creek, the main tributary

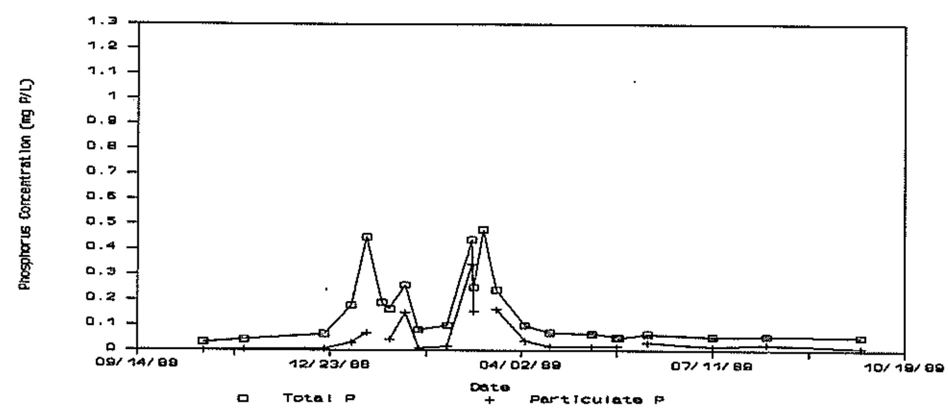

Figure 9: Total and particulate phosphorus concentrations (mg P/L) for station PC3.

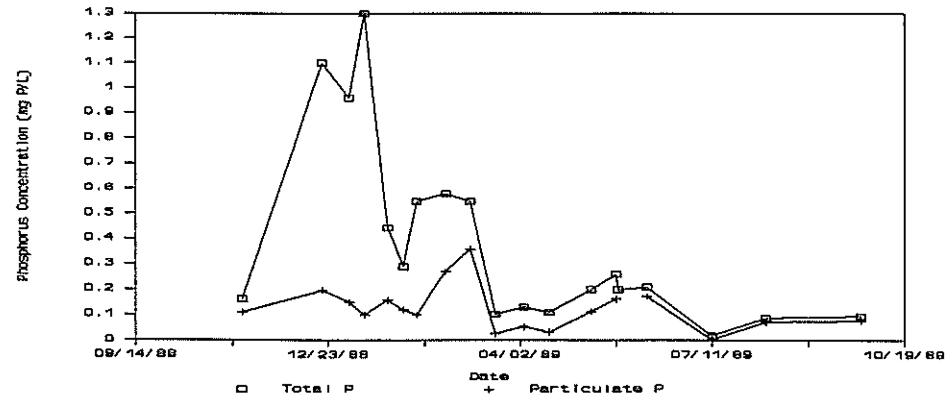

Figure 10: Total and particulate phosphorus concentrations (mg P/L) for station PC2.

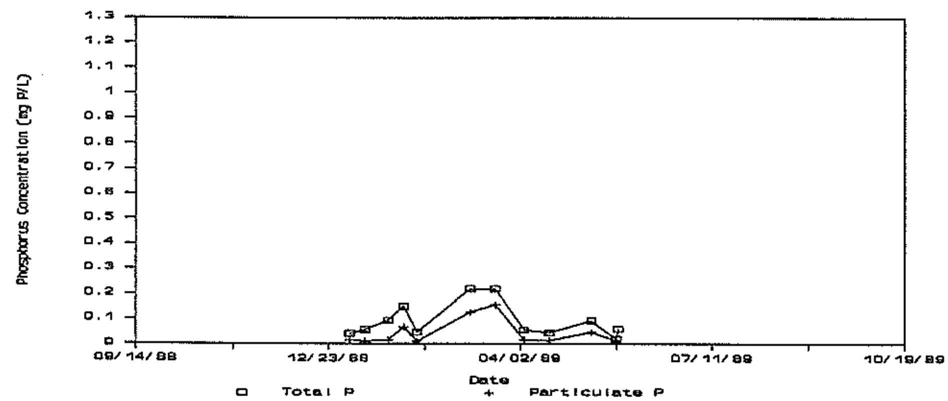

Figure 11: Total and particulate phosphorus concentrations (mg P/L) for station HR2.

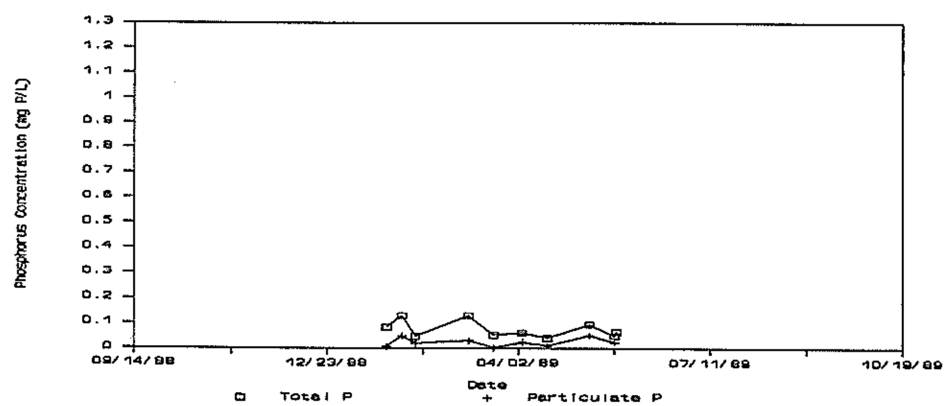

Figure 12: Total and particulate phosphorus concentrations (mg P/L) for station HR1.

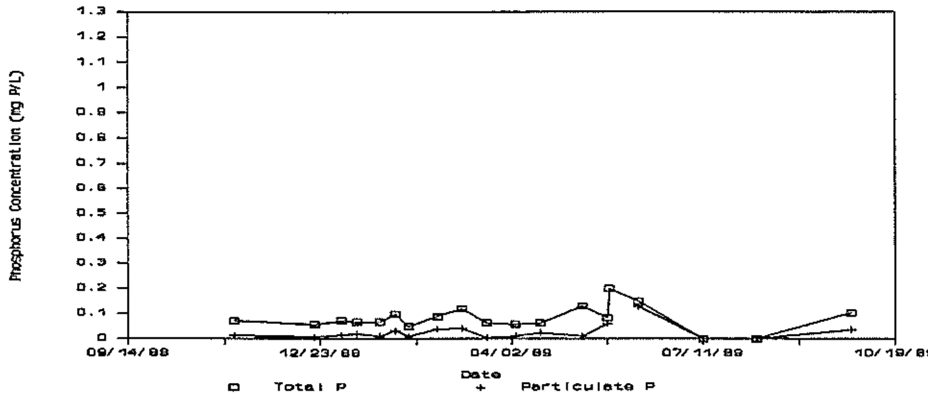

Figure 13: Total and particulate phosphorus concentrations (mg P/L) for station PC1.

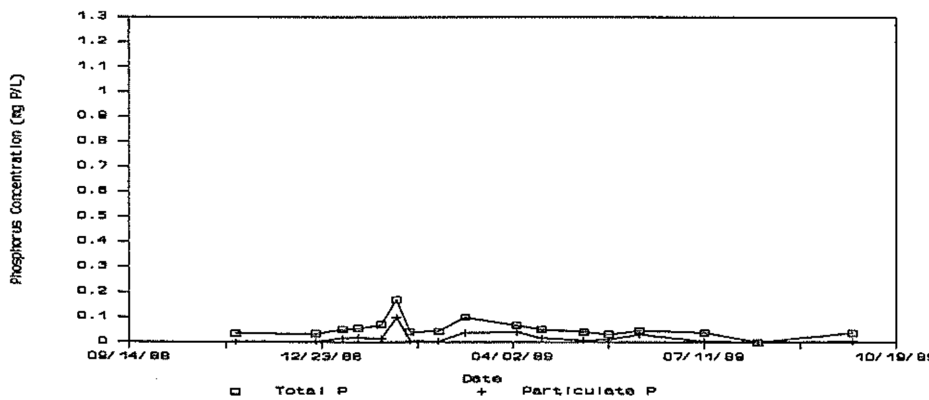

Figure 14: Total and particulate phosphorus concentrations (mg P/L) for station LPC2.

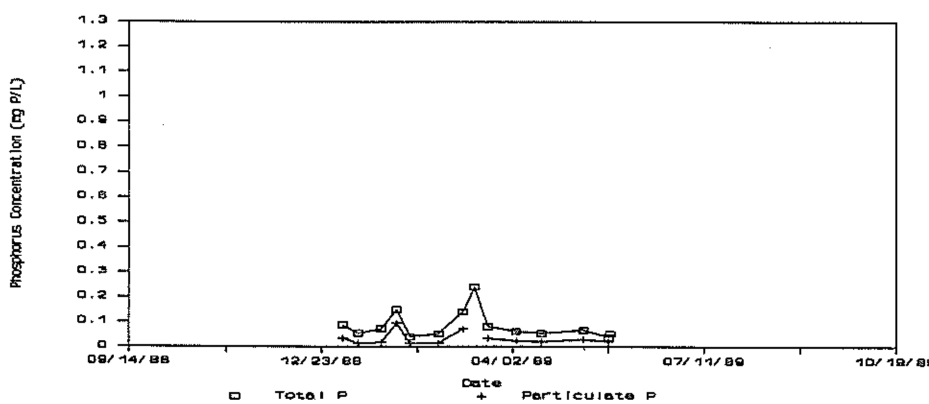

Figure 15: Total and particulate phosphorus concentrations (mg P/L) for station HR3.

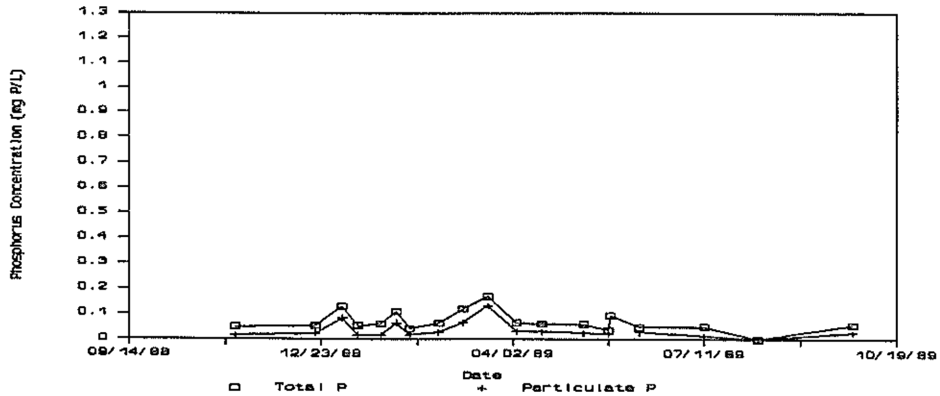

Figure 16: Total and particulate phosphorus concentrations (mg P/L) for station LPC1.

to Plummer Creek (see figure 1a). Also as seen at PC2, during the winter months, the total phosphorus concentrations at PC3 was dominated by dissolved phosphorus fractions (low particulate phosphorus levels).

At the other stations, total phosphorus increased with stream discharge and particulate phosphorus was the major component. (Compare with figures 6 - 8 and see the section Relationships Between Discharge and Concentration below.) These suggest nonpoint sources for phosphorus were prevalent at these stations.

NITROGEN

At all the stations, with the exception of PC2, the predominant form of nitrogen was nitrate + nitrite (NO_3+NO_2-N), and peak concentrations occurred at the beginning of the runoff season (early January). (Note, the range of concentrations is the same for each graph to portray the differences between stations.) Total nitrogen peaked in the early winter at station PC3 (figure 17) and exhibited a local maximum during the peak runoff period of early March. NO_3+NO_2-N was the major fraction throughout the runoff season. Ammonia (NH_3-N) exhibited a peak in early winter and again in mid-spring.

At PC2, NH_3-N was a notable fraction of the total, especially during the winter months (figure 18). NO_3+NO_2-N also contributed a large portion to the total, but it seldom contributed over 50%. It is probable that the wastewater plant caused these NH_3-N results (see Annual Loads section below). Another cause could stem from the stream channel above station PC2 being dominated by grasses. A possible mechanism for this could be the decay of the vegetation, which would release NH_3-N.

At stations HR2 and HR1, total nitrogen (which was primarily NO_3+NO_2-N) peaked shortly after runoff began and decreased throughout the remainder of the season (figures 19 and 20), until the streams were again dry.

NO_3+NO_2-N was the major fraction at stations LPC2, HR3, and LPC1 (figures 22 - 24). For each of these stations on Little Plummer Creek, the peak concentration of total nitrogen was in early winter, with a secondary peak during the high runoff period of early March. HR3's primary peak at the beginning of the runoff season occurred prior to those seen at stations LPC2 and LPC1. As with other stations exhibiting this phenomena, the peak suggests there was a seasonal component to the variation of nitrogen in addition to that caused by discharge (see the Relationships Between Discharge and Concentration section below).

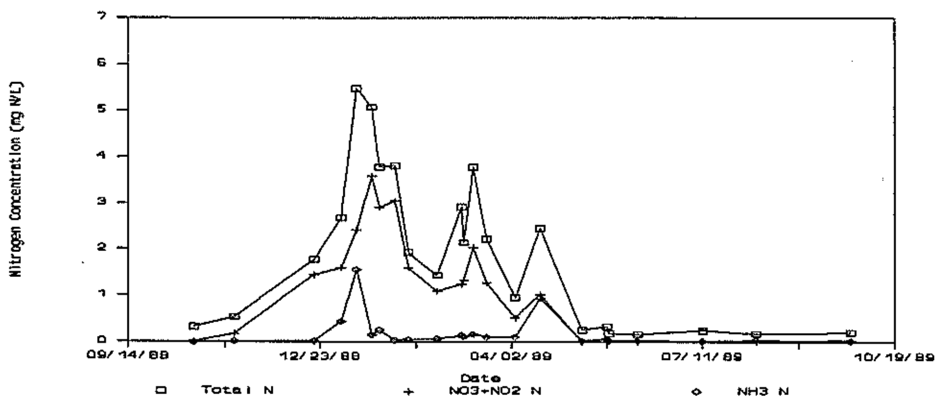

Figure 17: Nitrogen concentrations (mg N/L) for station PC3.

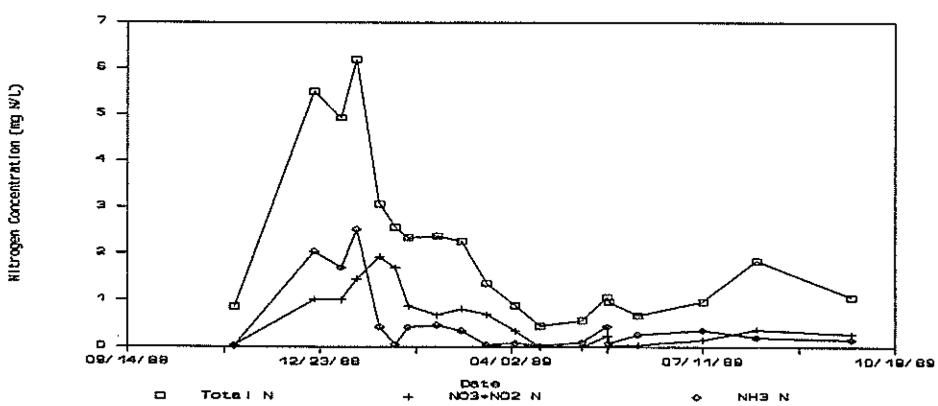

Figure 18: Nitrogen concentrations (mg N/L) for station PC2.

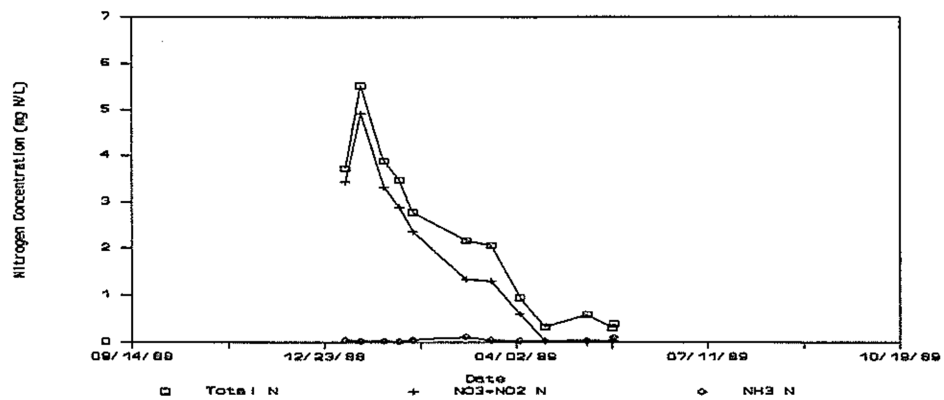

Figure 19: Nitrogen concentrations (mg N/L) for station HR2.

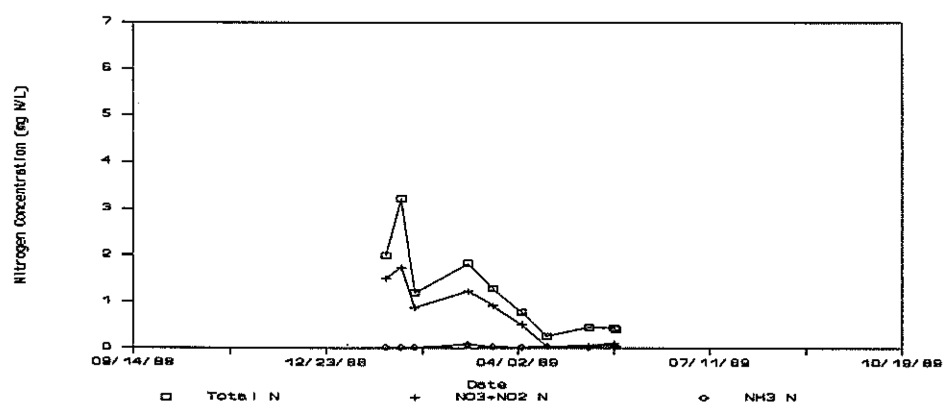

Figure 20: Nitrogen concentrations (mg N/L) for station HR1.

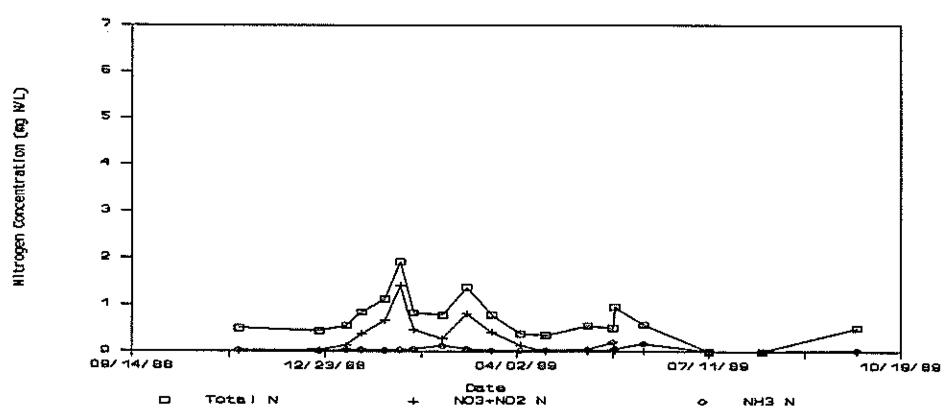

Figure 21: Nitrogen concentrations (mg N/L) for station PC1.

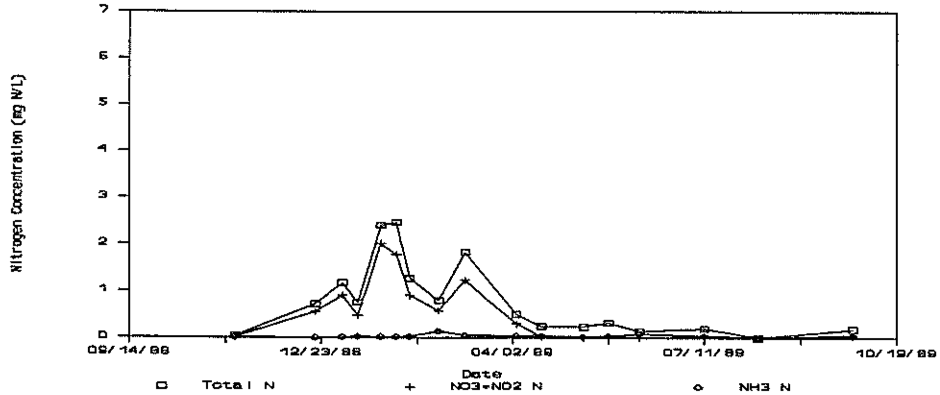

Figure 22: Nitrogen concentrations (mg N/L) for station LPC2.

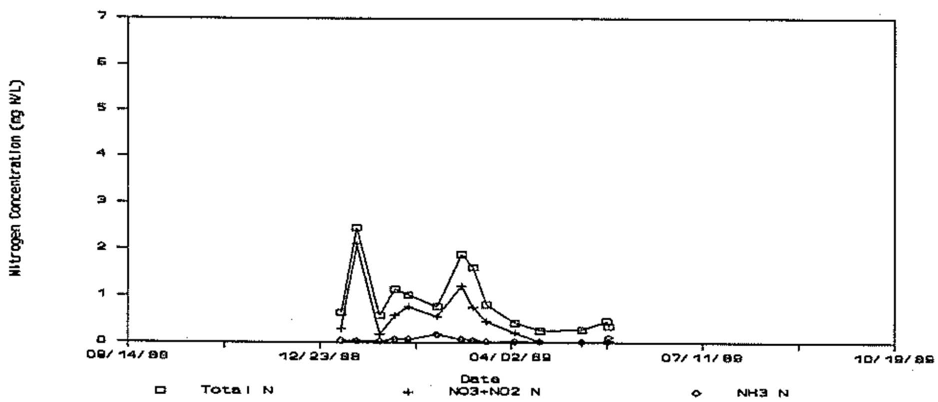

Figure 23: Nitrogen concentrations (mg N/L) for stations HR3.

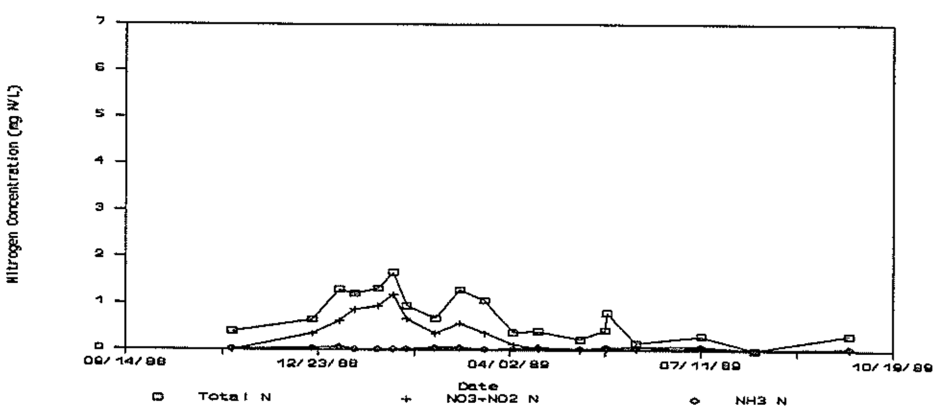

Figure 24: Nitrogen concentrations (mg N/L) for station LPC1.

SUSPENDED SEDIMENT

All stations exhibited their highest concentrations of suspended sediment during the high runoff period of early March (figures 25 - 32). (Note, the range of concentrations is the same for each graph to portray the differences between stations.) The exceptions to this were stations HR1 and PC1 (figures 28 and 29, respectively). Both of these had peak concentrations after the runoff season. It is not known why this occurred, but they could be a result of some disturbance along the creek.

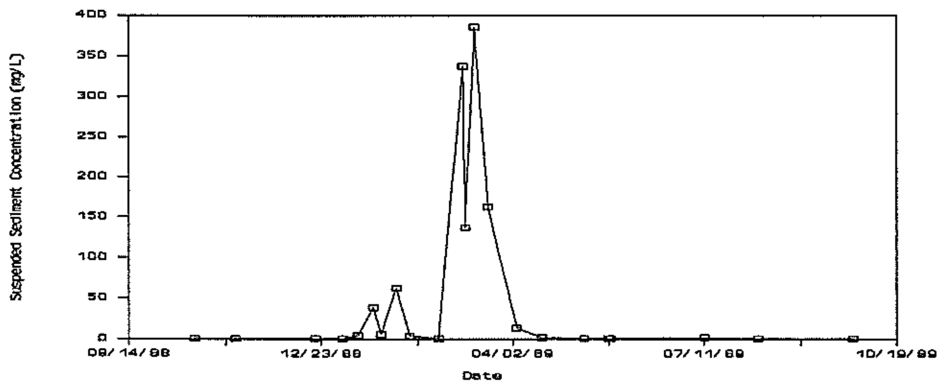

Figure 25: Suspended sediment concentration (mg/L) at station PC3.

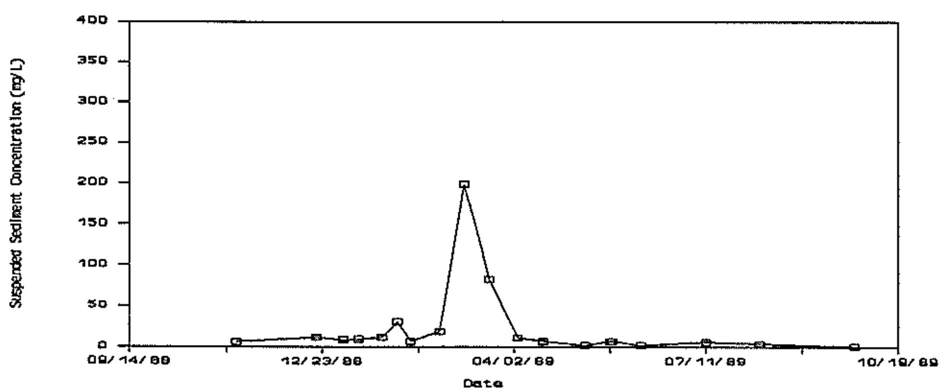

Figure 26: Suspended sediment concentration (mg/L) for station PC2.

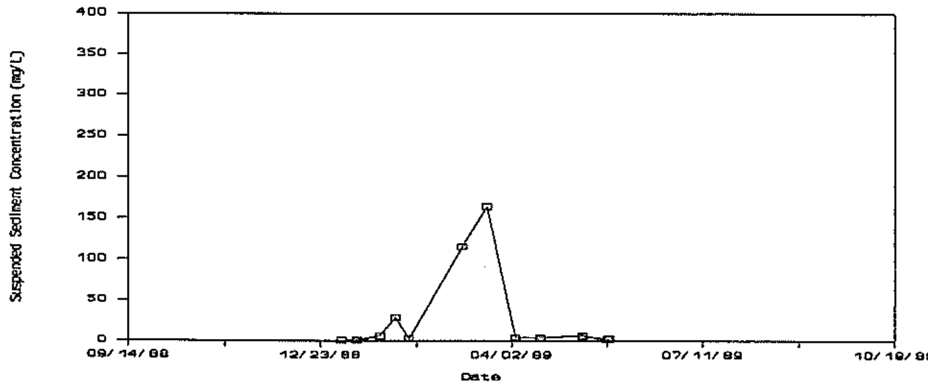

Figure 27: Suspended sediment concentration (mg/L) for station HR2.

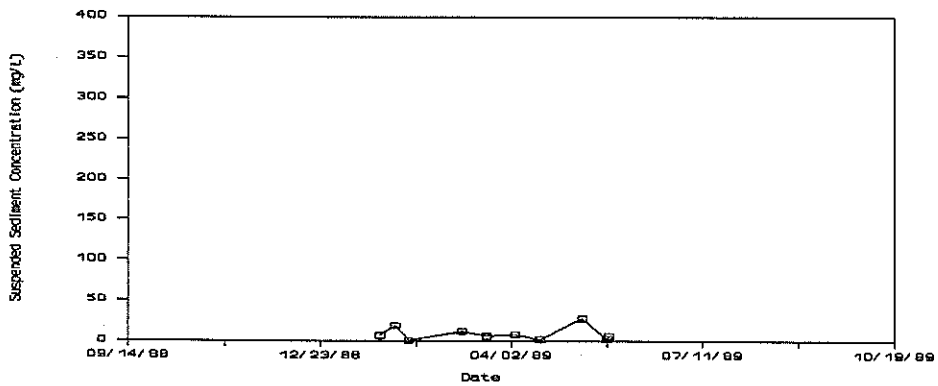

Figure 28: Suspended sediment concentration (mg/L) for station HR1.

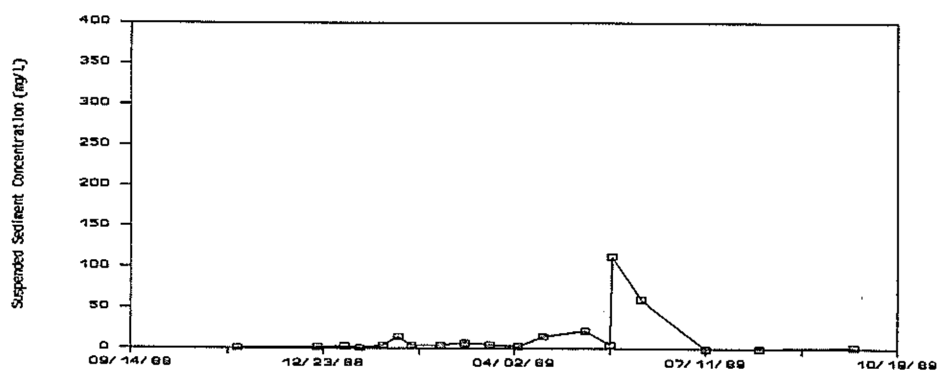

Figure 29: Suspended sediment concentration (mg/L) for station PC1.

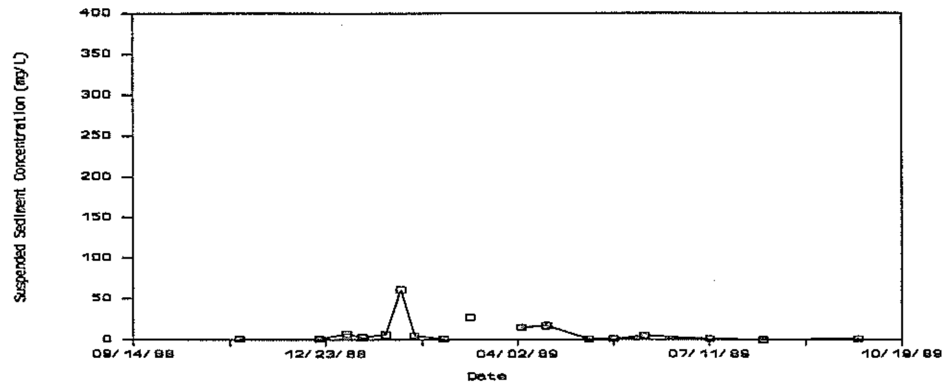

Figure 30: Suspended sediment concentration (mg/L) for station LPC2.

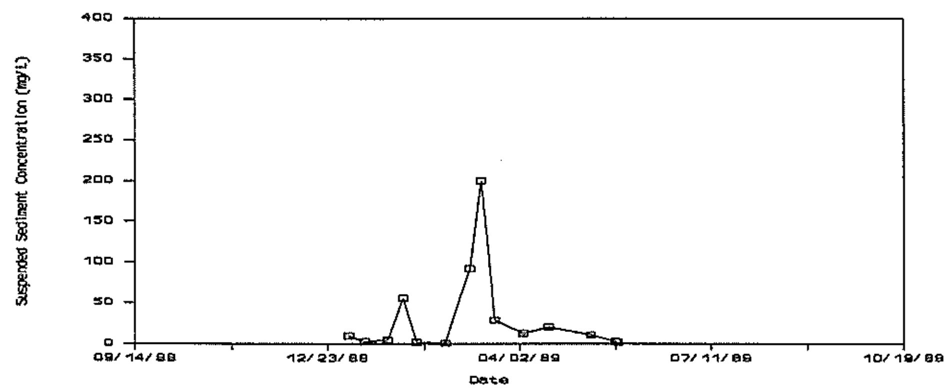

Figure 31: Suspended sediment concentration (mg/L) for station HR3.

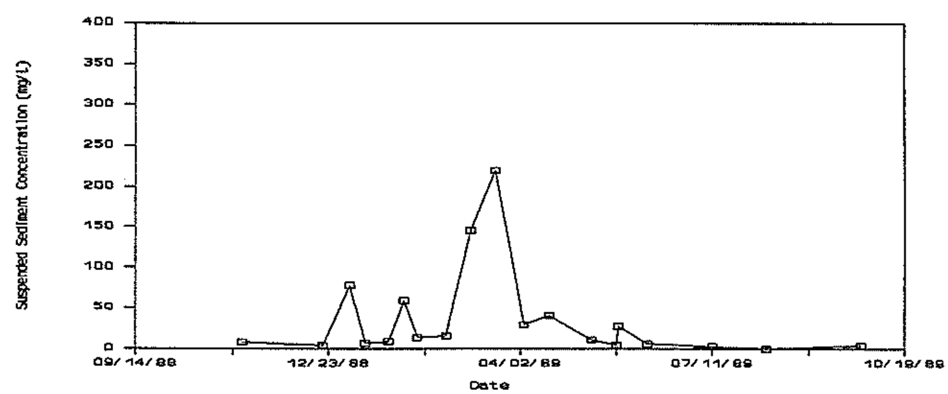

Figure 32: Suspended sediment concentration (mg/L) for station LPC1.

Because of difficulties in reaching station LPC2 during the early March runoff period, two significant gaps are shown in figure 30. It is thought that peak concentrations occurred at this time, as was seen in upstream and downstream stations. Hence, the data analyses for LPC2 will likely result in an underestimation of values calculated with this data.

BACTERIOLOGICAL RESULTS

The results from bacteriological sampling show that the maximum fecal coliform values occurred during the low flow periods in the fall of 1988 and winter of 1989. The high fecal streptococci values were obtained during times of high discharge, with the maximum occurring at peak runoff. (Fecal coliform bacteria tend to be associated with human waste, while fecal streptococci are associated with animal waste.)

It can be seen that the water quality standard for secondary contact recreation of a count of no more than 800/100ml of fecal coliform bacteria was exceeded at all the main stem stations (table 4). The maximum at LPC1 was far in excess of that. Further, 90% of the time stations PC2 and LPC1 had counts that were much higher than seen at the other stations. The counts at PC2 are not unexpected; since the station is downstream of the City of Plummer (the wastewater plant disinfects its effluent prior to discharging it to Plummer Creek). The results from LPC1 are more puzzling, as site investigation revealed no obvious source. However, they were quite consistent and are thought to reflect some unknown source.

There is no standard for fecal streptococci, but these exhibited the same trend in rank of maximum values as was seen with fecal coliform, i.e. LPC1 had the highest values of all the stations, with PC2 next in rank. However, examination of the 90%-tile values shows the results to be not greatly different, suggesting that the problem is probably wide spread.

The fecal coliform/fecal streptococci ratio (FC/FS) indicates the type of waste causing the bacteriological problems (El-Shaarawi and Pipes, 1982). Greater than 4 suggests that human wastes were involved, and less than 0.7 suggests that animal wastes were involved. These data are presented but not much reliance should be place on them; since the results appeared to be strongly influenced by discharge, as stated above.

The intermittent tributary which flows adjacent to a hog operation (represented by station SLR) had bacteriological counts of 200 FC/100 ml and 30,000 FS/100 ml during peak runoff. As the flow began to taper off, it had 3 FC/100 ml and 43 FS/100 ml. These results are comparable with those observed at the other stations and approach that seen during peak runoff at station LPC1.

Table 4: Summary of bacteriological results from the main stem stations of Plummer and Little Plummer Creeks. 90%-tile is the value below which 90% of the data were observed. FC=fecal coliform; FS=fecal streptococci. The FC/FS ratio indicates whether the bacteria are of human or animal origin: >4 suggests human wastes and <0.7 suggests animal wastes.

Fecal Coliform

	PC3 Fecal Coliform Bacteria (#/100ml)	PC2 Fecal Coliform Bacteria (#/100ml)	PC1 Fecal Coliform Bacteria (#/100ml)	LPC2 Fecal Coliform Bacteria (#/100ml)	LPC1 Fecal Coliform Bacteria (#/100ml)
Maximum	3,100	5,000	1,300	1,800	10,600
90%-tile	325	3,000	250	130	4,200
Median (50%-tile)	24	70	30	61	88
Minimum	1	7	<1	8	9

Fecal Streptococci

	PC3 Fecal Strep. Bacteria (#/100ml)	PC2 Fecal Strep. Bacteria (#/100ml)	PC1 Fecal Strep. Bacteria (#/100ml)	LPC2 Fecal Strep. Bacteria (#/100ml)	LPC1 Fecal Strep. Bacteria (#/100ml)
Maximum	13,000	15,000	2,800	6,400	50,000
90%-tile	8,750	5,500	2,200	4,700	7,300
Median (50%-tile)	275	370	100	160	485
Minimum	11	25	<1	10	1

FC/FS Ratio

	PC3 FC/FS Ratio	PC2 FC/FS Ratio	PC1 FC/FS Ratio	LPC2 FC/FS Ratio	LPC1 FC/FS Ratio
Maximum	8.86	13.51	4.39	4.50	39.26
90%-tile	0.76	8.11	2.22	2.33	20
Median (50%-tile)	0.12	0.15	0.10	0.31	1.02
Minimum	<0.01	0.01	<0.01	0.01	<0.01

DATA ANALYSIS

ANNUAL DISCHARGES AND LOADINGS

Total annual discharge and loads for each of the measured water quality constituents were calculated using a weighting procedure described in Gilbert (1987). The weights used were based on the time between sampling runs. As stated in the methods section, the sampling frequency was designed to collect the most number of samples during the period of high runoff. Hence, the weights applied during the runoff season (mid-winter through mid-spring) were smaller than for other periods; since the time periods were shorter.

Discharge

The annual discharge for PC3 was, as would be anticipated at the mouth of the watershed, greater than that seen at the other stations, with an annual volume of 31.3 x 10^6 m^3 (figure 33). The next highest discharge was at LPC2, the mouth of Little Plummer Creek, with an annual volume of 10.5 x 10^6 m^3. The discharges tended to taper off the further upstream the station was located. The exception was PC1, but it was a Plummer Creek station and HR2 and HR1 were on intermittent tributaries to Plummer Creek. WW had the smallest annual discharge of all the stations with 0.064 x 10^6 m^3. As will be seen below, a similar ranking of stations for discharges was also seen with suspended sediment, phosphorus, and nitrogen loads.

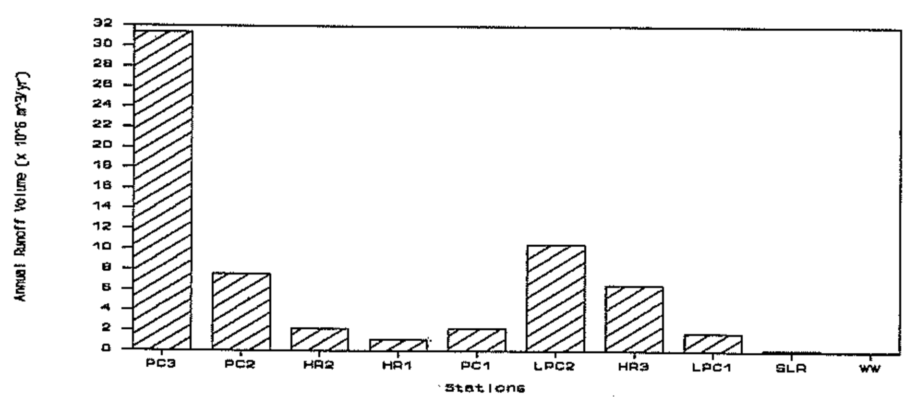

Figure 33: Total annual discharge (x 10^6 m^3) measured for each of the stations on Plummer Creek.

Suspended Sediment

The annual suspended sediment load measured at PC3 greatly exceeded that seen at the other stations (figure 34), with a dry weight mass of 5.61 x 10^6 kg. The next in rank, PC2, exhibited a load of 0.73 x 10^6 kg. The result for LPC2 was smaller than that seen at the station upstream, HR3; however, because of problems of access to the site during peak sediment transport, samples could not be taken at those times. Hence, it is thought that the actual sediment load is greater than that calculated, as stated above.

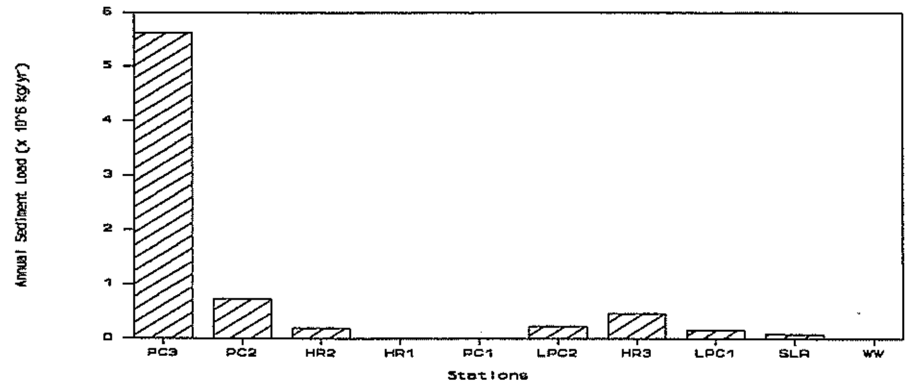

Figure 34: Total annual suspended sediment load (x10^6 kg) measured at all stations on Plummer Creek.

Phosphorus

Phosphorus load displayed a tendency similar to suspended sediment and discharge, as described above, with 9,095 kg of total phosphorus observed at PC3. An exception was that LPC2 load was slightly greater than that seen at HR3, the station immediately upstream (figure 35). In addition to the annual total phosphorus load, the particulate phosphorus load is shown.

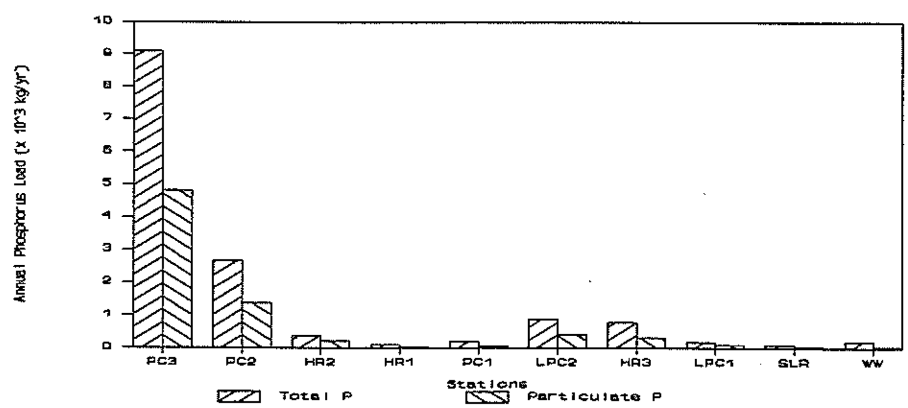

Figure 35: Total annual phosphorus load (x10^3 kg) measured at each of the stations on Plummer Creek.

Figure 36 shows the relative proportions of the dissolved and particulate phosphorus fractions to the total load. (Note that the proportions for HR3 and PC3 do not add to 1.00, because a small number of samples had total phosphorus analysis only.) For most of the stations the dissolved and particulate fractions were between 40% to 60% of the total,respectively. The exceptions were with stations HR1, PC1, and WW, where the dissolved fraction greatly exceeded the particulate fraction. Since WW is the effluent from the Plummer wastewater treatment facility, it was expected that most of its load would be in the dissolved fraction because of the breakdown of raw sewage by the treatment process. The high dissolved proportions seen at PC1 and HR1 are thought to reflect lower degree of erosion than seen in the other sub-basins. PC2, while receiving effluent from WW, did not have the majority of its load contributed by the treatment plant discharge. Rather, the peak runoff period and the phosphorus load it contributed were the most important contributor, with 58% of the total annual load observed in that one event.

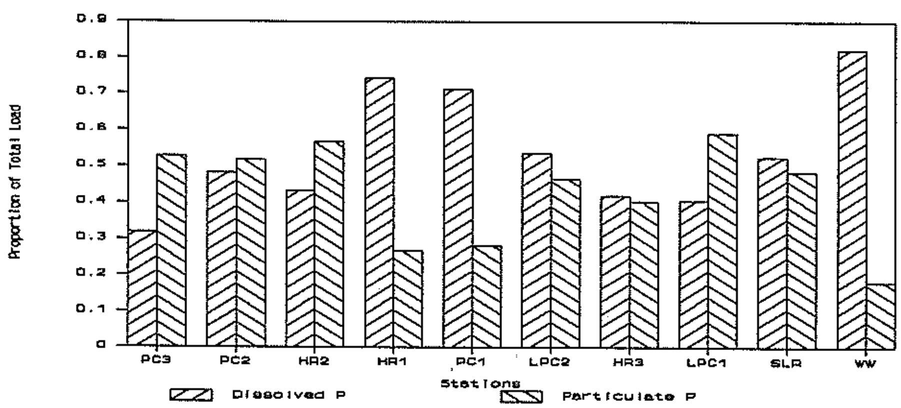

Figure 36: Proportion of annual load of the phosphorus fractions to the annual total phosphorus load for each of the stations on Plummer Creek.

Nitrogen

Figure 37 shows the annual loads for various fractions of nitrogen. Similarly to discharge, suspended sediment load, and phosphorus load, PC3 had the largest annual total nitrogen load, with 89.6 x 10^3 kg/year. PC2 and LPC2 were the next in rank, with 15.0 x 10^3 kg/year and 12.2 x 10^3 kg/year, respectively. The largest nitrogen fraction for the majority of stations was NO_3+NO_2-N (figure 38), with all but SLR and WW having at least 0.4 of the total. HR2, HR1, and LPC2 all had proportions greater than 0.6 of the total load. NH_3-N had a proportion less than 0.1 of the total, except at stations PC2, SLR, and WW. This is expected for WW; since the oxidation of sewage produces ammonia. PC2 was located below the discharge, but the total load from WW is small in comparison to that seen at PC2. SLR is an intermittent drainage to which a swine operation lagoon occasionally overflows. It is probable that the elevated NH_3-N proportion is a result of that impact.

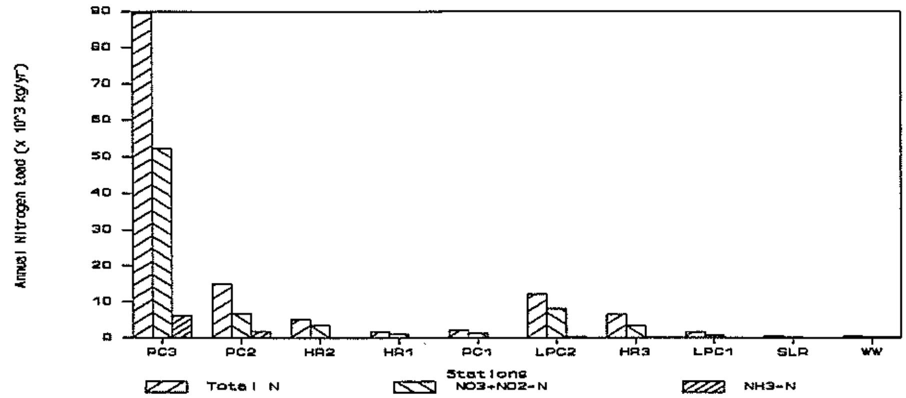

Figure 37: Total annual nitrogen load ($x10^3$ kg) measured at each station on Plummer Creek.

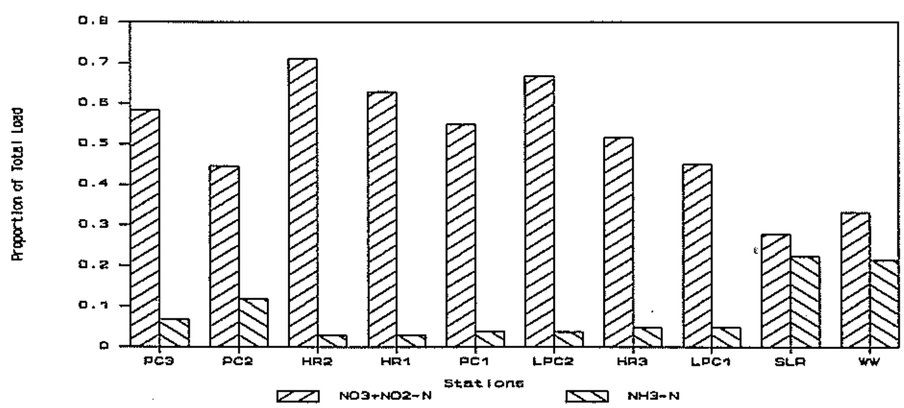

Figure 38: Proportion of annual load of the nitrogen fractions to the annual total nitrogen load for each of the stations on Plummer Creek.

RELATIONSHIPS BETWEEN DISCHARGE AND CONCENTRATION

Preston, et al (1989) discuss three different types of relationships between discharge and constituent concentration. These are dependent on whether there is an association of the constituent with particulate matter or whether it is a dissolved constituent. Further, both of these may come into play under certain circumstances, such as when a wastewater plant discharges to a stream also receiving nonpoint source impacts. A point they raise which is of particular interest here is if the constituent is associated with nonpoint sources, there may be "a direct linear relationship with flow." This relationship can be obscured, however, by the fact that the hydrograph for a particular storm exhibits the same flow (less than the peak) at least twice during the event (on the rising and falling limbs) but with greatly differing concentrations of particulate associated constituents (Baker, 1988). Bearing these points in mind, it was thought useful to analyze the relationships of discharge to the concentrations of suspended sediment, total phosphorus, particulate phosphorus, and NO_3+NO_2-N. The rationale for this is if there is a significant, positive, linear relation between them, then nonpoint sources are implicated as causing the increases in concentration. If not, there could be factors which obscure the relationship which leave the conclusion in doubt that nonpoint sources are important at that station.

To accomplish this, linear regression analyses were performed using the Number Cruncher Statistical Software (Hintze, 1987). Raw data and natural logarithm transforms of concentration and flow were examined in various combinations: concentration versus flow; log concentration versus flow; and log concentration versus log flow. The significance of the regressions was determined using the F test at level of a=0.05 (this determines if the slope is statistically different from zero). Further, the residuals (the difference between predicted and observed values) of the regression equation were subjected to a normal distribution test to determine if a significant regression had the properties of normality. (The determination of significance is dependent on the data being normally distributed). The results of individual regression slope analyses are presented in Tables 5 to 9.

Suspended Sediment

There were significant regression slopes between discharge and suspended sediment concentration at all stations, except HR1 and PC1 (Table 5). This indicates that nonpoint source impacts from suspended sediment are occurring at the remaining stations. It should be noted that the degree of impact of a nonpoint source is related to its proximity to a water channel. Based on this and figure 2, the agricultural lands are the probable source. The land adjacent to Little Plummer Creek is largely cropland or land in the CRP, at least in the upper half of its watershed. Little Plummer Creek enters a deep, wooded canyon upstream of where it crosses under Highway 5. This adjacent canyon land would not be expected to contribute to suspended sediment in the creek. The same situation applies to Plummer Creek, where it enters a deep, wooded canyon approximately 2 miles downstream of the City of Plummer. The cropland and CRP land in both these watersheds are drained by several intermittent water channels (see figure 1a), which improve the delivery of nonpoint source produced pollutants.

Station PC2 is unique in that its sub-basin includes most of the urban and industrial land use in the watershed both in absolute acreage (308 acres in the sub-basin versus a total of 410 acres in the whole watershed) and in percent of sub-basin area (5.4% in the sub-basin versus 1.5% in the whole watershed) (table 3). It is probable that nonpoint sources in the City of Plummer (street and industrial yard runoff) were significant sources of suspended sediment to this sub-basin; since two of three stations upstream of PC2 did not have a significant slope and these two stations were upstream of the City.

Table 5: Discharge and suspended sediment concentration regression results for stream stations. The transformation(s) resulting in a significant slope and normally distributed residuals are indicated with the slope. r^2 gives the proportion of association between the variables. The F test determines if the slope is significant. The probability is the chance of error in stating the slope is significant.

Station	Slope (conc/flow)	r^2	F test value/ Probability (Type I error)
PC3	0.713(lnC/lnQ)	0.720	51.53/<0.001
PC2	0.0352(lnC/Q)	0.604	25.91/<0.001
HR2	0.768(lnC/lnQ)	0.688	22.08/0.001
HR1	**	0.094	0.83/0.388
PC1	**	0.084	1.37/0.260
LPC2	0.494(lnC/lnQ)	0.642	25.13/<0.001
HR3	1.07(lnC/lnQ)	0.374	24.75/<0.001
LPC1	0.681(lnC/lnQ)	0.646	29.27/<0.001

** slope is not significantly different from zero.on figure 2 and table 3,

Total Phosphorus

In comparing total phosphorus concentration and discharge, it was found that all stations had significant relationships, except for PC2 and PC1 (table 6). HR1 was found to be only marginally significant. This indicates that nonpoint source impacts from phosphorus are occurring at the remaining stations. The reasons for this are the same as described above for suspended sediment, i.e. agricultural land runoff. As described above in the Observations section, concentrations at PC2 were influenced by the wastewater discharge, with the only clear, nonpoint source contribution occurring at peak runoff during one event. The point source discharge was possibly masking any effect that nonpoint source additions may have had on the relationship of total phosphorus to discharge (however, see the particulate phosphorus subsection below).

Table 6: Discharge and total phosphorus concentration regression results for stream stations. The transformation(s) resulting in a significant slope and normally distributed residuals are indicated with the slope. r^2 gives the proportion of association between the variables. The F test determines if the slope is significant. The probability is the chance of error in stating the slope is significant.

Station	Slope($x10^{-3}$) (conc/flow)	r^2	F test value/ Probability (Type I error)
PC3	0.744(C/Q)	0.593	30.56/<0.001
PC2	**	0.001	0.02/0.883
HR2	59.8(lnC/Q)	0.607	15.46/0.003
HR1	*5.34(C/Q)	0.416	5.57/0.046
PC1	**	0.013	0.23/0.637
LPC2	1.08(C/Q)	0.803	61.00/<0.001
HR3	2.03(C/Q)	0.853	69.58/<0.001
LPC1	6.42(C/Q)	0.371	10.01/0.006

** slope is not significantly different from zero.
* marginally significant; 0.05>a>0.01.

Particulate Phosphorus

Comparisons of the relationships between particulate phosphorus concentrations and discharge revealed significant slopes for all stations expect PC2, HR1, and PC1 (table 7). This is similar to what was seen above for total phosphorus, with HR1 clearly being non-significant. This shows that nonpoint source impacts from particulate phosphorus were occurring at the remaining stations. Since particulate phosphorus is the sediment associated fraction, it shows more clearly which stations were impacted by nonpoint source additions than total phosphorus, which includes a dissolved fraction. This suggests that nonpoint source impacts to station PC2 were not significant, and were not being masked by the wastewater discharge, as suggested above.

Table 7: Discharge and particulate phosphorus concentration regression results for stream stations. The transformation(s) resulting in a significant slope and normally distributed residuals are indicated with the slope. r^2 gives the proportion of association between the variables. The F test determines if the slope is significant. The probability is the chance of error in stating the slope is significant.

Station	Slope (conc/flow)	r^2	F test value/ Probability (Type I error)
PC3	0.356(lnC/lnQ)	0.538	19.80/<0.001
PC2	**	0.143	2.66/0.122
HR2	0.0815(lnC/Q)	0.642	16.14/0.003
HR1	**	0.025	0.18/0.685
PC1	**	0.0	0.0/0.999
LPC2	0.331(lnC/lnQ)	0.539	16.37/0.001
HR3	0.0307(lnC/Q)	0.624	16.63/0.002
LPC1	0.113(lnC/Q)	0.429	11.29/0.004

** slope is not significantly different from zero.

Nitrate+nitrite Nitrogen

NO_3+NO_2-N was examined, rather than total nitrogen, since it was the major fraction of total nitrogen. Significant relationships between NO_3+NO_2-N concentrations and discharge were found only for stations PC3 and PC1, with marginally significant relationships indicated for stations HR1, LPC2, and LPC1 (table 8). Since NO_3+NO_2-N is a soluble constituent, it is not expected to show the same relation to discharge that a sediment associated constituent (like phosphorus) would. That there was a clear relationship at station PC3 is somewhat surprising, but seems to indicate there was a nonpoint source component causing the water quality impacts. The result is more puzzling for station PC1; since the analyses for the other water quality constituents all indicated no significant relationship to discharge.

As figures 17 through 24 illustrate, peak concentrations of NO_3+NO_2-N occurred early in the runoff season but did not increase after peak runoff, as would be expected if dilution of a point source were the sole factor involved. This indicates that a seasonal factor was inmportant. Further, this suggests that a "first flush" may be occurring on a seasonal basis, and not just on an individual storm basis. This is supported by regression results shown in table 9. Step-wise, multiple linear regression analysis reveals that a seasonal factor was significantly related to NO_3+NO_2-N concentration at all stations (marginally at station PC2). Discharge was also significantly related to concentration at all stations, except PC2 and HR2, when the seasonal factor was added. However, the simple r^2 values with the seasonal factor are much greater than those determined with discharge.

Table 8: Discharge and NO_3+NO_2-N concentration regression results for stream stations. The transformation(s) resulting in a significant slope and normally distributed residuals are indicated with the slope. r^2 gives the proportion of association between the variables. The F test determines if the slope is significant. The probability is the chance of error in stating the slope is significant.

Station	Slope (conc/flow)	r^2	F test value/ Probability (Type I error)
PC3	0.740(lnC/lnQ)	0.563	27.00/<0.001
PC2	**	0.138	2.71/0.118
HR2	**	0.002	0.02/0.883
HR1	*0.103(C/Q)	0.408	5.51/0.047
PC1	0.0404(C/Q)	0.383	10.54/0.005
LPC2	*0.0125(C/Q)	0.336	7.58/0.015
HR3	**	0.023	0.28/0.606
LPC1	*0.711(lnC/lnQ)	0.270	5.90/0.027

** slope is not significantly different from zero.
* marginally significant; 0.05>a>0.01.

Table 9: Step-wise, multiple linear regression results for discharge versus seasonality and NO_3+NO_2-N concentration for the main stem and high runoff stations. The seasonality factor used was season = cos[(PROJECT DAY - 102)/365], and the concentrations were transformed using the natural logarithm. The simple r^2 values are if the variable was only one being regressed. r^2 gives the proportion of association between the variables. The F test determines if the slope is significant. The probability is the chance of error in stating the slope is significant.

Station	Flow: Slope/simple r^2 (ln conc/flow)	Season: Slope/simple r^2 (ln conc/season)	F test value/ Probability (Type I error)
PC3	0.003/0.172	2.96/0.755	36.97/<0.001
PC2	**	*1.70/0.313	7.74/0.013
HR2	**	3.96/0.824	46.69/<0.001
HR1	0.091/0.408	1.87/0.831	23.99/0.001
PC1	0.156/0.277	2.43/0.516	12.60/0.001
LPC2	0.014/0.157	2.78/0.721	19.57/<0.001
HR3	0.021/0.087	3.24/0.693	15.73/0.001
LPC1	0.119/0.190	2.11/0.617	14.46/<0.001

** slope is not significantly different from zero.
* marginally significant; 0.05>a>0.01.

UNIT AREA COMPARISONS OF LOADS

As was noted in the section on land use, the water quality sampling stations encompassed decreasing amounts of land area as one progresses upstream from the mouth of Plummer Creek. Another useful way of comparing the pollutant loading at each of the stations is to take these land areas into account by calculating the ratio of mass load to watershed area (table 10).

Examining the load per unit of total watershed area shows that station PC3 received the greatest amount of sediment, more than twice as much as the next largest (PC2) (table 10). The next greatest change in sediment load was between stations HR3 and LPC2. However, as stated above, LPC2 was not adequately sampled during the high runoff period and is likely underestimating the load. The total and particulate phosphorus loads per unit area were greatest for stations PC2 and PC3, with HR2 having an intermediate value. NO_3+NO_2-N loading per unit area was greatest at station PC3, with HR2 having the next largest value.

Table 10: Annual loads per unit total area of land use above the sampling station. The land use area used in these calculations was the cumulative area above each station (from table 3). The stations are listed in order of descending rank for each of the water quality constituents.

RANKED
Annual Load(kg)/total area(ha)

SEDIMENT	Load (kg/ha)	TP	Load (kg/ha)	PART.P	Load (kg/ha)	NO3+NO2	Load (kg/ha)
PC3	500.688	PC2	0.871	PC2	0.451	PC3	4.668
PC2	239.069	PC3	0.811	PC3	0.429	HR2	3.878
HR2	197.992	HR2	0.400	HR2	0.227	PC2	2.185
LPC1	154.428	HR3	0.257	HR3	0.104	HR1	1.843
HR3	150.020	PC1	0.208	LPC1	0.102	LPC2	1.492
LPC2	42.269	LPC1	0.173	LPC2	0.076	PC1	1.294
PC1	19.601	HR1	0.164	PC1	0.059	HR3	1.108
HR1	18.306	LPC2	0.164	HR1	0.044	LPC1	0.739

CONCLUSIONS - PLUMMER CREEK

As a result of the particular climatic and hydrologic events for the water year 1988-1989, peak runoff occurred in early March. Another, smaller peak occurred late January and was followed by a rapid decline in flow with the onset of severely cold weather. The primary cause for changes in runoff was the changes in snowpack, which in turn were a response to the precipitation and temperature patterns. But overall, as the snowpack depth dropped, stream flows increased.

Suspended sediment impacts from nonpoint sources were observed at all stations, except for PC1 and HR1. Where the impacts occurred, the peak concentrations were associated with the maximum discharge. The agricultural land uses are the primary sources of suspended sediment, but the nonpoint source stormwater runoff from the City of Plummer and the industrial areas is a significant contributor to the annual load at PC2. Station PC3 received the greatest load of suspended sediment, both from the standpoint of total load and from load per unit area. PC2 received the next largest load and load per unit area.

Phosphorus impacts from nonpoint sources were observed at all stations, except PC2, HR1, and PC1. This is particularly evident when examining the particulate phosphorus fraction. PC2 exhibited nonpoint source impacts of phosphorus only at peak flow, and most of the load was oberserved during this peak flow event. PC2 also received the point source discharge from the city's wastewater treatment plant. The plant influenced the concentrations during its discharge period, but its load was small in comparison to the load observed at PC2. Of all the stations, PC3 receives the largest load of total and particulate phosphorus. From an unit area viewpoint however, PC2 had slightly greater loads of total and particulate phosphorus than did PC3.

The major form of nitrogen observed at all stations, except PC2, was NO_3+NO_2-N. NH_3 was a significant component of total nitrogen at station PC2. Nonpoint source contributions of NO_3+NO_2-N are not clearly defined (as determined by a relationship with discharge). This is a result of its soluble nature. NO_3+NO_2-N concentrations were found be significantly related to a seasonal factor, which had a maximum in early January. This indicates a different mechanism for transport of NO_3+NO_2-N from the sub-basins, other than particle transport. Station PC3 received the greatest load of NO_3+NO_2-N for both the total load and area comparisons.

EFFECTS OF PLUMMER CREEK ON CHATCOLET LAKE

As stated in the Methods section, samples were taken from Chatcolet Lake at two stations: CL1 and CL2 (figure 1b). Station PC3 was located approximately one mile above the mouth. Also indicated in the figure is the St. Joe River, which flows adjacent to Chatcolet Lake.

Chatcolet Lake has a surface area of 704 ha (1740 acres), a maximum depth of 11.2 m, and a volume of 28.4×10^6 m^3 (Milligan, et al, 1983). The maximum depth observed at station CL2 was approximately 11 m deep and represents the deep water station.

OBSERVATIONS AND ANALYSIS

The first set of samples from Chatcolet Lake were collected in mid-October, 1988, which provides a background for comparing runoff impacts. The next sample set was collected in late March, 1989, after the lake was ice free. The peak runoff from Plummer Creek occurred in early March.

As can be seen in figure 39, Chatcolet Lake at station CL2 was isothermal until July 12, when it began it exhibit signs of stratification. By August 16, the thermal gradient was even more pronounced. The dissolved oxygen profiles also reflect

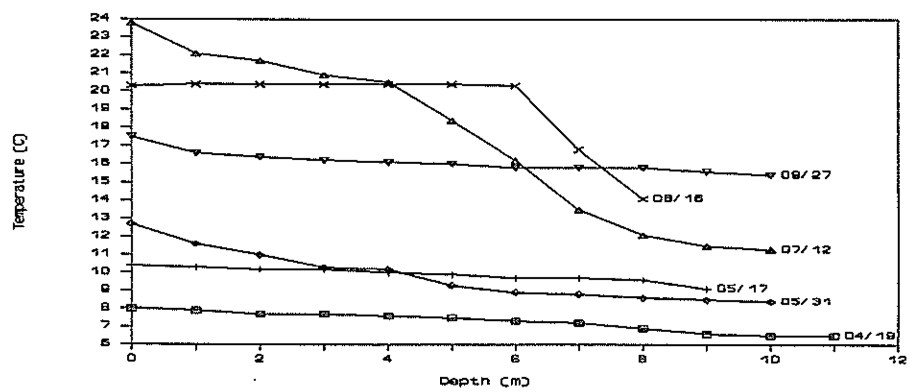

Figure 39: Temperature profiles in Chatcolet Lake during the spring and summer of 1989 at station CL2. Sampling dates are indicated.

this thermal stratification (figure 40). With the onset of stratification, the lower depths of the lake began to deoxygenate and reached a low of 0.5 mg O_2/L 0.5 m off the lake bottom.

A peak in suspended sediment and total phosphorus concentrations and a minimum in secchi disc transparency were observed in late March (figures 41 - 43), indicating an effect on lake water quality from Plummer Creek runoff. Chlorophyll a showed a relative maximum in this same set of samples (figure 44).

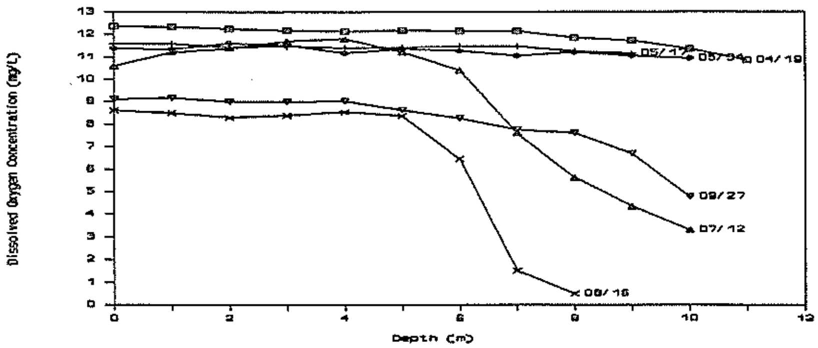

Figure 40: Dissolved oxygen profiles in Chatcolet Lake during the spring and summer of 1989 at station CL2. Sampling dates are indicated.

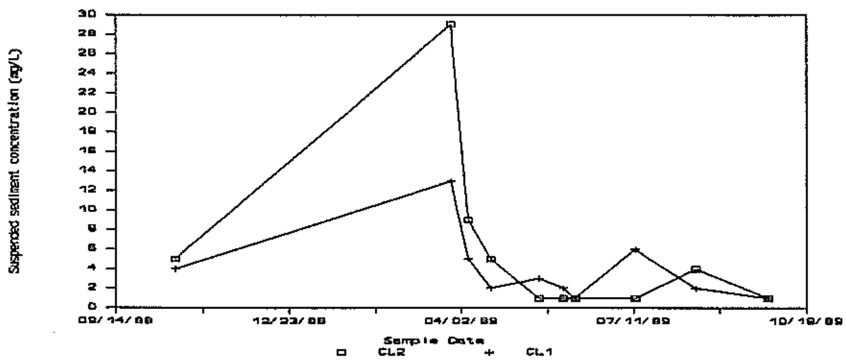

Figure 41: Suspended sediment concentrations (mg/L) in Chatcolet Lake at both stations CL1 and CL2. Results are from depth integrated composites.

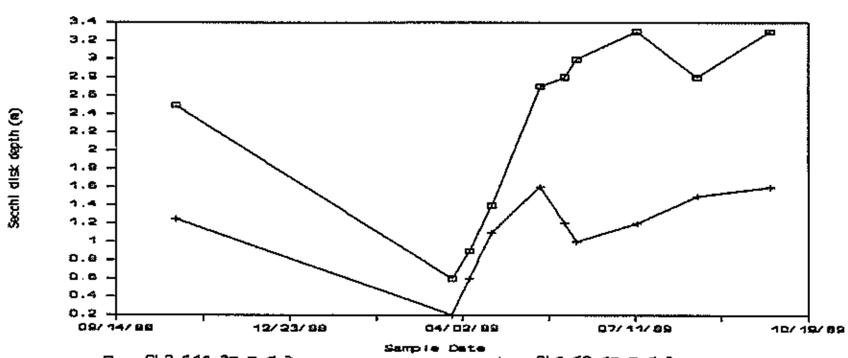

Figure 42: Secchi disk transparency (m) in Chatcolet Lake at stations CL1 and CL2. The maximu m depths (m.d.) for each station are indicated in the legend.

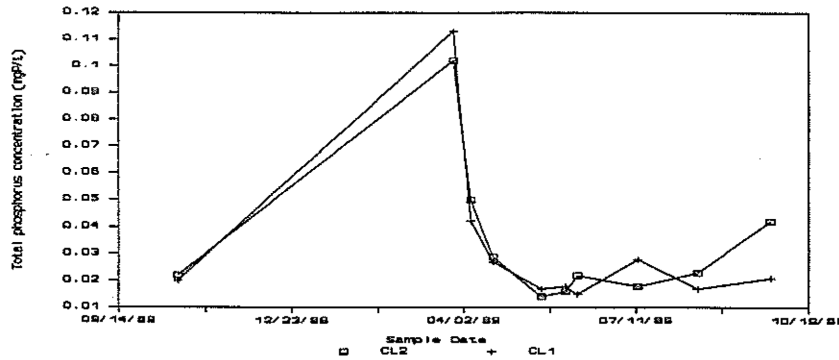

Figure 43: Total phosphorus concentrations (mg P/L) in Chatcolet Lake at stations CL1 and CL2. Results are from depth integrated composites.

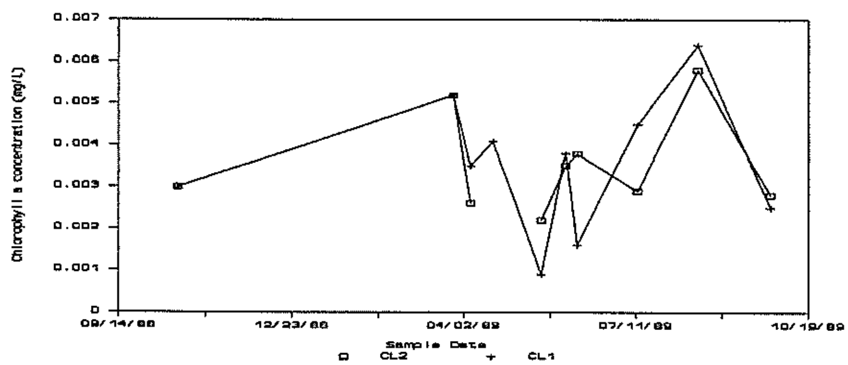

Figure 44: Chlorophyll a concentration (mg/L) in Chatcolet Lake at stations CL1 and CL2. Results ar e from depth integrated composite samples.

A concern about the Chatcolet Lake results was the effect of the St. Joe River on its water quality. Plotting the total phosphorus and suspended sediment concentrations for the lake station CL2 and the DEQ trend monitoring station (IDHW-DEQ, 1989) for the St. Joe River at St. Maries shows that the peaks were disconnected (figures 45 and 46); i.e., Chatcolet Lake exhibited a peak earlier than the St. Joe River. This indicates that the St. Joe did not have an effect on concentrations of total phosphorus and suspended sediment in the Chatcolet Lake.

Sediment cores were collected August 10, 1989 to determine the amount of sediment which had accumulated over the Mt. St. Helens ash layer. It was hoped that the sediment thickness could be mapped out and the total quantity of deposited could be determined. However, limitations with the coring apparatus prevented extensive coring. Withstanding that, one core was collected off the mouth of Plummer Creek, in its channel, that had a well defined ash layer 22 cm below the sediment surface. This would give an annual average accumulation rate of 2.4 cm/year (1 inch/year). This is probably a lower bound on that rate; since some scour would be expected to occur in the channel, even below the lake surface. Another site away from stream depostional influences had only 0.9 cm of sediment over the ash layer. This is an average accumulation rate of 0.1 cm/year. The significance of these results is to illustrate the rapid rate of deposition at the mouth of Plummer Creek. This will ultimately result in loss of the existing wetlands and further encroachment of the mouth of Plummer Creek into Chatcolet Lake, if erosion in the watershed is not significantly reduced.

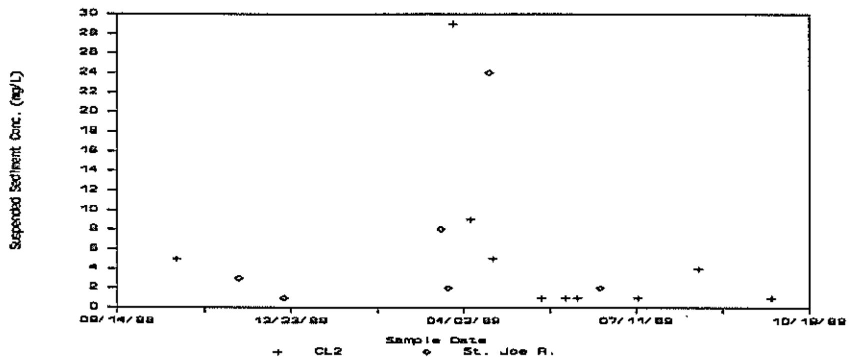

Figure 45: Suspended sediment concentrations at th e Chatcolet Lake station CL2 and the trend monitoring station on the St. Joe River at St. Maries.

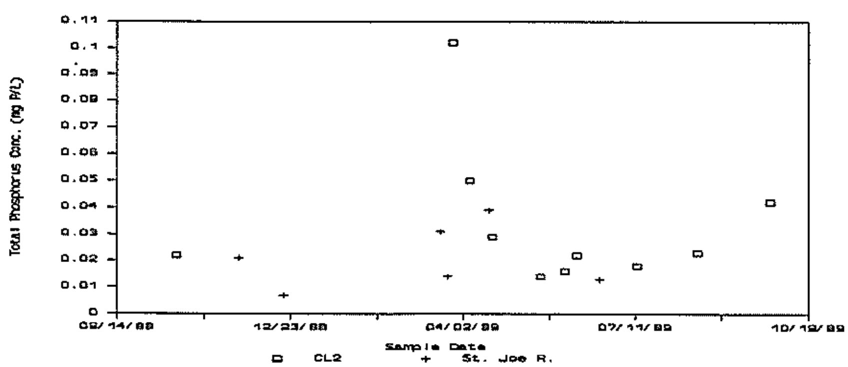

Figure 46: Total phosphorus concentrations at Chatcolet Lake station CL2 and the trend monitoring station on the St. Joe River at St. Maries.

TROPHIC STATE INDICES

Another way of examining the data from the deep water station (CL2) is to use an index. This allows for a comparison between the different water quality constituents to better describe what is occurring within the lake. Carlson's trophic state indices are used here and are plotted to illustrate how the values changed over the water year (Carlson, 1977)[1] (figure 47). Three different indices are calculated: secchi disc transparency, chlorophyll a concentration, and total phosphorus. (The indices are calculated from the observed values, and the equations are such that they will give an equivalent value for each of the three indices for a similar condition.)

It is typically expected that all three of these indices would track together. In situations where they do not, this gives an additional insight into the lake response. It should be noted that TSI values of 40 and below indicate the lake is oligotrophic (poor in nutrients and biological production). Above 50, the lake tends to eutrophic (high in nutrients and biological production). As can be seen in figure 47, chlorophyll a index does not track along with the total phosphorus and the secchi disc transparency indices during the spring runoff period, indicating that algae are not a large factor in determining the behavior of the other two indices. Also, the TSI values for secchi disk and total phosphorus are above 50 during the spring runoff period, but drop below that during most of the summer. The chlorophyll a value was below 50 throughout the study period. These indicate the lake is largely mesotrophic, with some tendency towards eutrophic conditions.

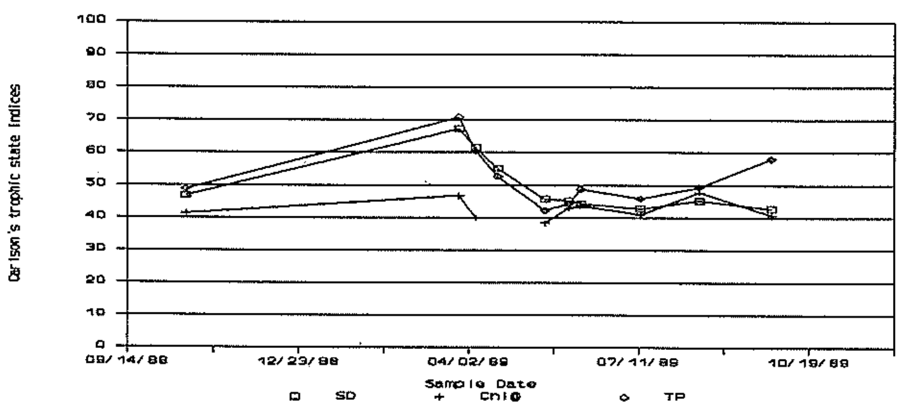

Figure 47: Carlson's trophic state indices for Chatcolet Lake at station CL2. The indices are for total phosphorus and chlorophyll a concentrations, and secchi disk transparency.

---

[1] The equations for calculating the TSIs are as follows:

TSI(SD) = 10{6-[ln(SD)/ln2]},

TSI(CHLa) = 10[6-{[2.04-0.68*ln(CHLa)]/ln2}], and

TSI(TP) = 10{6-[ln(48/TP)/ln2]}.

RELATIONSHIPS BETWEEN LIMNOLOGICAL CONSTITUENTS

As seen above, there is a question about the effect of algae on the various limnological constituents, i.e. whether the variations in algal biomass are causing those observed in the suspended sediment and total phosphorus concentrations, and the secchi disk transparency. This was done using regression analysis between chlorophyll a, suspended sediment, and total phosphorus concentration, and secchi disk transparency. The selection of the most appropriate transformations was done in a manner similar to that done in the section on Relationships Between Discharge and Concentration above. As can be seen in table 11, there was no relationship between chlorophyll a and any of the other constituents. This indicates that algal biomass was not responsible the changes in their concentration, and that it was not responsible for the changes in Chatcolet Lake's trophic status, as indicated by the Carlson's trophic state indices.

However, looking at the relationships between suspended sediment versus total phosphorus and secchi disk transparency, it can be seen that they both had significant relationships (table 11). This demonstrates that the suspended sediment concentrations caused the variations in total phosphorus and secchi disk transparency, and influenced the trophic state indices.

Table 11: Regression results between limnological constituents at the Chatcolet Lake station CL2. The transformation(s) resulting in a significant slope and normally distributed residuals are indicated with the slope.

Constituents (X vs Y)	Slope (conc Y/conc X)	r^2	F test value/ Probability (Type I error)
Chla vs TP	**	0.156	1.29/0.293
Chla vs SS	**	0.208	1.83/0.218
Chla vs SD	**	0.053	0.39/0.550
SS vs TP	0.0594(lnC/C)	0.712	19.73/0.002
SS vs SD	-0.0610(lnC/C)	0.768	26.45/0.001

** slope is not significantly different from zero.

CONCLUSIONS - CHATCOLET LAKE

From these observations and analyses several points can be made about the behavior and causes of water quality problems in Chatcolet Lake. A significant oxygen decline occurred in the hypolimnion of the lake. The oxygen demanding source is unknown, but the possibility of allochthonous organic matter should not be ruled out. Also, Milligan, et al (1983) states that the lake bottom is mostly covered by aquatic weeds. While this is unlikely in the deeper parts of the lake, there were weed beds at the mouth of Plummer Creek and along the St. Joe River. These could contribute oxygen demanding material to the lake.

The in-lake concentrations of total phosphorus, suspended sediment were at their maximum shortly after peak runoff at both stations in Chatcolet Lake. Secchi disk transparency was at a minimum at the same time. The St. Joe River does not appear to have major impact on suspended sediment and total phosphorus concentrations in Chatcolet Lake, as it exhibited concentration peaks after the peaks seen in Chatcolet Lake. Sediment accumulation off the mouth of Plummer in Chatcolet Lake has occurred at an average rate of 2.4 cm per year since the Mt. St. Helens eruption. This illustrates the rapid rate of deposition at the mouth of Plummer Creek, which will ultimately result in loss of the existing wetlands and further encroachment of the mouth of Plummer Creek into Chatcolet Lake.

The Carlson trophic state indices for Chatcolet Lake exhibited a large increase in the total phosphorus and secchi disk transparency TSI values after spring runoff. These were not accompanied by corresponding changes in algal biomass (chlorophyll a). Comparing the relationships between the various limnological constituents, it was found that secchi disk transparency and total phosphorus concentration are significantly related to suspended sediment concentration, but not to chlorophyll a concentration. Nor are suspended sediment and chlorophyll a concentrations related. This shows algae is not the cause of the high suspended sediment and high trophic state values in Chatcolet Lake. Rather, they are a consequence of agricultural runoff in Plummer Creek.

RECOMMENDATIONS

(1)(a) In addition to the critical erosion areas identified by the Benewah Soil Conservation District and the Idaho Soil Conservation Commission, the drainage areas affecting the stations PC3, PC2, and HR2 should receive a high level of attention from the agricultural planning and implementation projects. These three sites receive a high proportion of suspended sediment from nonpoint sources.

(b) The sub-basins represented by LPC2, HR3, and LPC1 should receive the next level of attention. These receive suspended sediment from nonpoint sources but have smaller loads than those identified in item (1)(a).

(c) The remaining stations HR1 and PC1 do not at present need attention. They were not identified as receiving nonpoint source impacts and had low sediment loads.

(2)(a) Concerning phosphorus, the sub-basins affecting stations PC3 and HR2 should receive a high priority for agricultural planning and implementation projects. These have high loads and were identified as being impacted by nonpoint sources.

(b) Station PC2 exhibited high loads of phosphorus, but it was not shown to be impacted by nonpoint sources of phosphorus. Attention should be paid to possible sources in the City of Plummer, besides the wastewater plant, to identify where the loads may have originated.

(c) Other sub-basins (LPC2, HR3, and LPC1), while being affected by nonpoint sources, did not have high loads of phosphorus and should receive a lower level of attention than those sub-basins identified in item (2)(a).

(3) The application of nitrogen fertilizers in all sub-basins should be examined to determine if an excess is being used beyond the needs for crop production.

(4) Additional sediment coring off the mouth of Plummer Creek should be done to better determine the load of sediment deposited in Chatcolet Lake since the eruption of Mt. St. Helens. The ash layer from that eruption provides a well defined marker from which to measure accumulation. The primary requirement for conducting such work is an apparatus which will allow coring in water deeper than 5 meters and shallower than 2 meters, and will collect a core at least 1 meter in length.

(5) The higher counts of fecal coliform bacteria are cause for concern, especially at station LPC1. The source of this should be identified and corrected. The sources of fecal streptococci appear to be spread throughout the watershed. The obvious sources of animal waste, such as the hog operation near station SLR, should be addressed.

ACKNOWLEDGEMENTS

I wish to thank John Sutherland, Jim Bellaty, and Jack Skille, all with the Idaho Division of Environmental Quality, for their assistance in installation of the stage recording equipment and in surveying the control points for stage measurement. I also wish to thank Fred Wetter, with the Benewah Soil Conservation District, who provided the meteorological data, which had obviously been collected consistently and thoroughly. The insights given by Fred Bear, with the Idaho Department of Parks and Recreation, were valuable in focusing sampling efforts in Chatcolet Lake. His and his staff's assistance in accessing key sampling sites was critical in helping the study come to fruition. Finally, the watershed data (included in figure 3) provided by "Biff" Burleigh, with the Idaho Soil Conservation Commission, and Larry Cooke , the U.S. Soil Conservation Service, were very helpful in determining the stream impacts.

LITERATURE CITED

Baker, D.B. 1988. Sediment, Nutrient and Pesticide Transport in Selected Lower Great Lakes Tributaries. EPA-905/4-88-001.

Bauer, S.A. 1986. Pilot Study of Quality Assurance Sample Procedures. IDHW-DOE.

Bear, F. 1988. Idaho Department of Parks and Recreation.

Benewah Soil and Water Conservation District. 1983. Unpublished data.

Burleigh, M. 1990. Idaho Department of Lands-Soil Conservation Commission.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. & Ocean. 22(2):361-369.

El-Shaarawi, A.H. and W.O. Pipes. 1982. Bacterial Indicators of Pollution. W.O. Pipes, ed. CRC Press. Boca Raton, Fl.

Environmental Protection Agency, U.S. 1977. Report on Coeur d'Alene Lake. Benewah and Kootenai Counties, Idaho. National Eutrophication Survey. Working Paper No. 778. EPA Region X.

Hintze, J.L. 1987. Number Cruncher Statistical Software, version 5.01. Logan, Utah.

Idaho Department of Health and Welfare - Division of Environmental Quality. 1985. Idaho Water Quality Standards and Wastewater Treatment Requirements.

Idaho Department of Health and Welfare - Division of Environmental Quality. 1989. Unpublished trend monitoring data. St. Joe River at St. Maries, Idaho.

Idaho Department of Lands - Soil Conservation Commission. 1979. Idaho Agricultural Pollution Abatement Plan.

Milligan, J.H., R.A. Lyman, C.M. Falter, E.E. Krumpe, and J.E. Carlson. 1983. Classification of Idaho's Freshwater Lakes. Id. Water & Energy Res. Res. Inst. U. of Idaho.

Preston, S.D., V.J. Bierman, and S.E. Silliman. 1989. An evaluation of methods for the estimation of tributary mass loads. Water Resources Research 43:1397.

Rantz, S.E. 1982. Measurement and Computation of Streamflow: Vol. 1. Measurement of Stage and Discharge. Geol. Surv. Water-Supply Paper 2175. U.S. Gov. Print. Of. Wash. D.C.

Rantz, S.E. 1982 Measurement and Computation of Streamflow: Vol. 2. Computation of Discharge. Geol. Surv. Water-Supply Paper 2175. U.S. Gov. Print. Of. Wash. D.C.

Wetter, F. 1989. Benewah Soil and Water Conservation District.

APPENDIX A
Quality Assurance Accuracy (Spike Recovery) Results

Phosphorus Spike Recovery

Date	Total P Conc.	Dissolved Total P Conc.	Diss. O.P. Conc.
12/20/88	101	100	100
01/03/89	101	101	100
02/22/89	103	100	102
03/07/89	95	98	102
03/20/89	92	98	102
04/17/89	96	94	99
05/09/89	100	94	102
05/22/89	99	94	56
06/07/89	99	101	80
07/11/89	97	101	95
08/08/89	101	99	102
09/26/89	99	101	90
Average=	98.58	98.42	94.17
Lower 95% confidence level=	96.70	96.67	85.81
Upper 95% confidence level=	100.46	100.17	102.52
n=	12	12	12
Std. Dev.=	2.96	2.75	13.15

Nitrogen Spike Recovery

Date	Total K.-N Conc.	Total NH3-N Conc.	NO3+NO2-N Conc.
12/20/88	107	106	103
01/03/89	105	93	119
02/22/89	104	106	95
03/07/89	107	92	104
03/20/89	125	88	87
04/17/89	103	88	98
05/09/89	90	120	104
05/22/89	*	125	103
06/07/89	101	101	98
07/11/89	105	102	97
08/08/89	120	130	100
09/26/89	101	104	106
Average=	97.25	104.58	101.17
Lower 95% confidence level=	77.83	96.05	96.52
Upper 95% confidence level=	116.67	113.12	105.81
n=	12	12	12
Std. Dev.=	30.56	13.44	7.31

Suspended Sediment (non-filtrable residue concentration) Spike Recovery

Date	Non-Filtr. Resid. Conc.
12/20/88	101
01/03/89	99
07/11/89	102
08/08/89	98
Average=	100.00
Lower 95% confidence level=	97.48
Upper 95% confidence level=	102.52
n=	4
Std. Dev.=	1.58

APPENDIX B
Quality Assurance Precision (Duplicate) Sampling Results

Total Phosphorus

Date	Total P Conc. (mg/L)	Duplicate Total P Conc. (mg/L)	Total P Conc. Range (mg/L)	Total P Relative Range (%)
12/20/88	0.065	0.067	0.002	3.03
01/03/89	0.180	0.18	0	0.00
01/11/89	0.450	0.46	0.01	2.20
01/23/89	0.165	0.169	0.004	2.40
01/31/89	0.260	0.25	0.01	3.92
02/07/89	0.082	0.08	0.002	2.47
02/22/89	0.100	0.11	0.01	9.52
03/07/89	0.440	0.45	0.01	2.25
03/20/89	0.240	0.23	0.01	4.26
04/04/89	0.100	0.1	0	0.00
04/17/89	0.070	0.069	0.001	1.44
05/09/89	0.066	0.065	0.001	1.53
05/22/89	0.053	0.051	0.002	3.85
06/07/89	0.065	0.066	0.001	1.53
07/11/89	0.059	0.057	0.002	3.57
08/08/89	0.056	0.057	0.001	1.77
09/26/89	0.025	0.026	0.001	3.92

Average % = 2.80

n= 17

Dissolved Total Phosphorus

Date	Diss. Total P Conc. (mg/L)	Duplicate Diss. Total P Conc. (mg/L)	Diss. Total P. Conc. Range (mg/L)	Diss. Total P Relative Range (%)
12/20/88	0.058	0.056	0.002	3.51
01/03/89	0.15	0.15	0	0.00
01/11/89	0.38	0.37	0.012.67	
01/23/89	0.121	0.127	0.006	4.84
01/31/89	0.11	0.1	0.01	9.52
02/07/89	0.071	0.07	0.001	1.42
02/22/89	0.085	0.089	0.004	4.60
03/07/89	0.1	0.11	0.01	9.52
03/20/89	0.078	0.079	0.001	1.27
04/04/89	0.062	0.064	0.002	3.17
04/17/89	0.053	0.049	0.004	7.84
05/09/89	0.05	0.052	0.002	3.92
05/22/89	0.037	0.038	0.001	2.67
06/07/89	0.039	0.048	0.009	20.69
07/11/89	0.039	0.039	0	0.00
08/08/89	0.032	0.03	0.002	6.45
09/26/89	0.044	0.043	0.001	2.30

Average % = 4.96 n= 17

Mod. Ave. % = 2.75 n= 16

Dissolved Ortho Phosphorus

Date	Diss. Ortho P Conc. (mg/L)	Duplicate Diss. Ortho P Conc. (mg/L)	Diss. Ortho P Conc. Range (mg/L)	Diss. Ortho P Relative Range (%)
12/20/88	0.044	0.044	0	0.00
01/03/89	0.135	0.132	0.003	2.25
01/11/89	0.33	0.34	0.01	2.99
01/23/89	0.11	0.11	0	0.00
01/31/89	0.08	0.079	0.001	1.26
02/07/89	0.059	0.062	0.003	4.96
02/22/89	0.059	0.061	0.002	3.33
03/07/89	0.071	0.068	0.003	4.32
03/20/89	0.05	0.051	0.001	1.98
04/04/89	0.047	0.047	0	0.00
04/17/89	0.033	0.032	0.001	3.08
05/09/89	0.037	0.038	0.001	2.67
05/22/89	0.016	0.016	0	0.00
06/07/89	0.02	0.022	0.002	9.52
07/11/89	0.027	0.027	0	0.00
08/08/89	0.022	0.022	0	0.00
09/26/89	0.017	0.018	0.001	5.71
Average %=	2.47	n=	17	

Total Kjeldahl Nitrogen

Date	Kjeldahl N Conc. (mg/L)	Duplicate Kjeldahl N Conc. (mg/L)	Kjeldahl N Conc. Range (mg/L)	Kjeldahl N Relative Range (%)
12/20/88	0.34	0.25	0.09	30.51
01/03/89	1.08	0.98	0.1	9.71
01/11/89	3.06	3.12	0.06	1.94
01/23/89	0.87	0.92	0.05	5.59
01/31/89	0.77	0.73	0.04	5.33
02/07/89	0.33	0.32	0.01	3.08
02/22/89	0.34	0.38	0.04	11.11
03/07/89	1.68	1.37	0.31	20.33
03/20/89	0.96	0.84	0.12	13.33
04/04/89	0.43	0.42	0.01	2.35
04/17/89	1.44	0.41	1.03	111.35
05/09/89	0.26	0.3	0.04	14.29
05/22/89	0.27	0.36	0.09	28.57
06/07/89	0.16	0.21	0.05	27.03
07/11/89	0.23	0.24	0.01	4.26
08/08/89	0.17	0.18	0.01	5.71
09/26/89	0.17	0.15	0.02	12.50
Average %=	18.06	n=	17	
Mod. Ave. % =	10.51	n=	16	

Ammonia Nitrogen

Date	Ammonia N Conc. (mg/L)	Duplicate Ammonia N Conc. (mg/L)	Ammonia N Conc. Range (mg/L)	Ammonia N Relative Range (%)
12/20/88	0.026	0.031	0.005	17.54
01/03/89	0.44	0.429	0.011	2.53
01/11/89	1.56	1.62	0.06	3.77
01/23/89	0.259	0.264	0.005	1.91
01/31/89	0.04	0.043	0.003	7.23
02/07/89	0.06	0.041	0.019	37.62
02/22/89	0.074	0.073	0.001	1.36
03/07/89	0.144	0.163	0.019	12.38
03/20/89	0.111	0.114	0.003	2.67
04/04/89	0.105	0.106	0.001	0.95
04/17/89	0.945	0.068	0.877	173.15
05/09/89	0.027	0.023	0.004	16.00
05/22/89	0.071	0.061	0.01	15.15
06/07/89	0.03	0.027	0.003	10.53
07/11/89	0.02	0.023	0.003	13.95
08/08/89	0.051	0.048	0.003	6.06
09/26/89	0.025	0.026	0.001	3.92
Average %=	19.22	n=	17	
Mod. Ave. % =	4.82	n=	15	

Nitrate+nitrite Nitrogen

Date	NO3+NO2 N Conc. (mg/L)	Duplicate NO3+NO2 N Conc. (mg/L)	NO3+NO2 N Conc. Range (mg/L)	NO3+NO2 N Relative Range (%)
12/20/88	1.45	1.45	0	0.00
01/03/89	1.61	1.68	0.07	4.26
01/11/89	2.43	2.53	0.1	4.03
01/23/89	2.92	2.96	0.04	1.36
01/31/89	3.05	2.97	0.08	2.66
02/07/89	1.61	1.59	0.02	1.25
02/22/89	1.1	1.1	0	0.00
03/07/89	1.25	1.28	0.03	2.37
03/20/89	1.27	1.3	0.03	2.33
04/04/89	0.52	0.525	0.005	0.96
04/17/89	1.021	0.042	0.979	184.20
05/09/89	0.001	0.001	0	0.00
05/22/89	0.066	0.007	0.059	161.64
06/07/89	0.011	0.009	0.002	20.00
07/11/89	0.014	0.01	0.004	33.33
08/08/89	0.012	0.011	0.001	8.70
09/26/89	0.039	0.045	0.006	14.29
Average %=	25.96	n=	17	
Mod. Ave. % =	2.33	n=	12	

Suspended Sediment

Date	Suspended Sediment Conc. (mg/L)	Duplicate Suspended Sediment Conc. (mg/L)	Suspended Sediment Conc. Range (mg/L)	Suspended Sediment Relative Range (%)
12/20/88	2	2	0	0.00
01/03/89	2	2	0	0.00
01/11/89	5	3	2	50.00
01/23/89	6	4	2	40.00
01/31/89	63	66	3	4.65
02/07/89	4	4	0	0.00
02/22/89	2	2	0	0.00
03/07/89	338	306	32	9.94
03/20/89	163	154	9	5.68
04/04/89	14	5	9	94.74
04/17/89	2	6	4	100.00
05/09/89	2	2	0	0.00
05/22/89	2	2	0	0.00
07/11/89	2	2	0	0.00
09/26/89	2	2	0	0.00
Average %=	20.33	n=	15	
Mod. Ave. % =	1.84	n=	11	