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NUTRIENT LOADING OF STREAMS ENTERING LAKE NEATAHWANTA, OSWEGO COUNTY, N.Y. :

A Summary of Lake Neatahwanta Tributary Monitoring

9 May 1993 - 14 May 1994

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Prepared for the

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EXECUTIVE SUMMARY

This study suggests that the highly eutrophic condition of Lake Neatahwanta is in large part due to the very high loadings of nutrients from the surrounding watershed. Specifically, Sheldon Creek was identified as a major contributor of phosphorus and total suspended solids to the lake. The amount of nutients entering the lake from Sheldon Creek were in excess of those observed in creeks of New York receiving point source loadings from small sewage treatment plants. Improvement of the water quality of Lake Neatahwanta will depend upon the identification and remediation of the major sources of nutrients in the watershed and in the Sheldon Creek watershed in particular.

INTRODUCTION

Freshwater resources have historically played an instrumental role in community development and economic sustainability. Lake Neatahwanta plays a role in the economy of the entire county, has aesthetic value and provides diverse opportunities for those who enjoy the resource directly. Management of this resource depends largely on the identification of both the cause and effect of elements likely to reduce the economic and social value of the lake. Non-point source pollution resulting mainly from various land uses, as well as point sources within the 10,811 acre watershed have the potential to significantly alter the water quality of Lake Neatahwanta and reduce its value as a resource.

To determine the magnitude of nutrient loading to the lake from its tributaries, the Oswego County Soil and Water Conservation District (referred to as Oswego County) has contracted with the Center for Applied Aquatic Science and Aquaculture (CAASA) in the Department of Biological Sciences at SUNY Brockport to do a comprehensive water quality monitoring and assessment program in 1993 and 1984. Both in-lake and watershed monitoring of Lake

Neatahwanta has enabled researchers to compile data on priority nutrients degrading water quality, as well as priority subbasins in which to focus remedial efforts. The use of automated, event-responsive gaging stations, allows for accurate nutrient loading estimates. These stations also increase our ability to determine conditions which generate significant nutrient and sediment losses from the surrounding watersheds. Previous water quality monitoring efforts on Lake Neatahwanta suggested that the lake was under significant stress due to high nutrient levels (Browne 1991) but the study did not carefully address the sources of the nutrients. Determination of sources and magnitude of nutrient loading from watersheds is prerequisite to remedial action and essential to making cost-effective land management decisions as it reduces the likelihood of costly miscalculations based on the assumption of nutrient sources and modeling rather than their actual identification.

What sub-watersheds of Lake Neatahwanta provide the greatest amount of nutrients to the Lake? Are the loading from these watersheds high or low as compared to other known areas of significant nutrient loading? What nutrients and materials are being lost from the watershed? Are the losses related to meteorlogic events and to what seasons of the year? This report reflects an in-depth study of water quality and nutrient loading of three tributaries of the Lake Neatahwanta watershed and attempts to answer these questions in the context of the objectives of Oswego County's monitoring program.

The objectives of Oswego County's monitoring program include:

1. To determine the status of Oswego County's primary surface waters and observe changes over time;
2. To document what types and amounts of nutrients may be adversely impacting water quality and the conditions which generate them;
3. To determine what industrial and agricultural practices within a watershed may be impacting water quality in Lake Neatahwanta;
4. To develop a technical database for informed water quality management decisions; and

5. To assess the feasibility and effectiveness of potential control measures likely to be used to reduce non-point and point sources of pollution to the lake.

SUMMARY of RESULTS

An automated, continuous gaging station was installed on Sheldon Creek in May of 1993 allowing event monitoring. In addition, two other streams (Ley and Summerville Creeks) were monitored weekly from May 1993 to May 1994. Based on the total stream phosphorus loading and chlorophyll data collected for Lake Neatahwanta and its tributaries, Lake Neatahwanta would be considered a eutrophic body of water. Sheldon Creek and its watershed above the confluence with Summerville Creek dominate the hydrologic discharge to Lake Neatahwanta contributing 77% of the runoff with 47% of the discharge occurring in the spring. This discharge pattern coincides with the high spring precipitation and the snow melt.

Major losses of sodium from the watershed occurred during the study period. The mean annual concentration of sodium in Sheldon Creek is high (26.03 mg/L). Sheldon Creek and its watershed above the confluence with Summerville Creek contributes 87% of the sodium entering the Lake, while 75% of the salt (as sodium) that enters the lake from all sources, enters in the winter and spring when deicing salt is applied to roads.

Sheldon Creek was by far the major contributor of suspended solids and nutrients to Lake Neatahwanta. Over 538 metric tons of suspended solids are delivered to the lake which represents 99% of the annual load. Similarly, Sheldon Creek contributed 89%, 90%, and 90% of the total phosphorus, total nitrogen and nitrate, respectively, entering Lake Neatahwanta. Areal loading of phosphorus from Sheldon Creek is very high and is comparable to loading from watersheds receiving sewage plant effluent. Highest loading of nitrate occurred in the spring and winter, while the highest loading of total phosphorus (TP) and total kjeldahl nitrogen (TKN) occurred during the spring and fall. Events accounted for 73% of TKN, 81% of TP and 25% of nitrate annual loading; that is, loading of nutrients from Sheldon Creek is event driven.

RECOMMENDATIONS:

1. The Lake Neatahwanta tributary monitoring should be continued to develop a strong baseline database of discharge and loading information. The continuous monitoring and event and non-event water chemistry sampling should be continued on Sheldon Creek as a reference or baseline site to note future improvements or degradation.
2. Similarly, the summer monitoring of one site on Lake Neatahwanta should be maintained as a reference or baseline site for future improvements.
3. The following "mini" projects are suggested to verify the relative contributions of the following areas.
   a. Some estimates of discharge should be obtained at Granby Creek at the dam. we need measurements of the notch in the dam.
   b. Similarly some consideration should be given to monitoring the storm sewers that empty in the lake described in the F.X. Browne report.
   c. An event should be monitored at Ley and Summerville Creek using a sequential sampler. SUNY Brockport would be able to provide a loaner.
   d. Some spring estimates of discharge and nutrient chemistry should be obtained for Pine Hill Creek.
4. A Stressed Stream Analysis should be considered for Sheldon Creek due to inordinately high loading of phosphorus and suspended solids. Summerville and Ley Creeks have high areal loading of total phosphorus and should also be considered for Stressed Stream Analysis. Within an entire lake basin, Stressed Stream Analysis (SSA) is an approach that identifies impacted sub-watersheds and their associated streams. Within a stream, SSA is an approach for determining how and where a stream and its ecological community are adversely affected by a pollution source or other disturbance. It is a technique that identifies the sources, extent, effects and severity of pollution in a watershed. In its fullest use, it combines elements of the sciences of hydrology,

limnology, ecology, organismal biology and genetics in an integrated approach to analyze cause and effect relationships in disturbed stream ecosystems. Within a sub-watershed, the stream is used to monitor the "health" of the watershed. Because nutrients are easily transported by water they can be traced to their source by systematic geographic monitoring of the stream. Stressed Stream Analysis is a technique that divides the impacted sub-watershed into small distinct geographical units. Samples are taken at the beginning and end of each unit to determine if a nutrient (or other contaminant) source occurs within that reach. If required, the severity of the pollution within the impacted sub-watershed, and or the entire watershed, can then be evaluated by spatial analysis of the quantity and quality of biological indicators, such as fish and invertebrates, and by biological examination of structural and functional changes in individual organisms and populations in affected communities.

5. A Best Management Program should be developed and implemented to address the sources of nutrients and soil loss **discovered in the stress stream analysis.** Since water must come in contact with the nutrient source and then be transported to the surface or (subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices that include a reduction of near-stream cropland or fertilization and control of water movement can be means of significantly reducing non-point source pollution. A review of management practices designed to reduce loss of fertilizers to the surface flow or to increase the retention of fertilizers into the soil should be undertaken. Much of this has been done in the Browne (1991) report.

METHODS

Study Site:

Lake Neatahwanta is located in Oswego County in north-central New York State. The lake is shared between the City of Fulton and the town of Granby. Lake Neatahwanta has a surface area of 276 ha and a mean depth of 2.5 m (Browne 1991). The Lake is fed by three major tributaries, Ley Creek, Pine Hill Creek and Sheldon Creek and drains to the Oswego River via Tannery Creek (Fig 1). Sheldon Creek has a major branch that we call Summerville Creek. A continuous gaging and sampling station was set up on Sheldon Creek where it flows under

Lakeshore Road in the Town of Granby. For this study, "Sheldon Creek" refers to the stream and associated watershed above (upstream) the confluence of Summerville Creek. Summerville Creek was sampled at Minetto - Lysander Road, also in the Town of Granby. Ley Creek was sampled on Ley Creek Road near the City of Fulton. Granby Creek was sampled near the fire station in Granby Center. Pine Hill Creek was not sampled during this reporting period.

General:

Stream water samples were collected and stream height was measured weekly at stream sites from 9 May 1993 to 14 May 1994 by the Oswego County Soil and Water Conservation District. Sites were chosen, above the influence of Lake Neatahwanta, for ease of access (i.e. closeness to a bridge or culvert for gaging purposes)(Fig. 1). Precipitation events were monitored hourly at Sheldon Creek with an Isco sequential sampler. Grab samples were taken four times from Granby Creek and three times at a farm bridge on Sheldon Creek below the confluence of Sheldon and Summerville Creeks near Lake Neatahwanta. Lake Neatahwanta water samples were taken monthly from June - August 1993 (Fig. 1).

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All filtration units and other processing apparatus were cleaned routinely with phosphate-free RBS. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (EPA 1979) or Standard Methods for the Analysis of Water and Wastewater (APHA 1989). Sample water for dissolved nutrient analyses (nitrate + nitrite) was filtered immediately with 0.45 µm MCI Magma Nylon 66 membrane filters and held at 4°C until analysis.

Water Chemistry

Chlorophyll a: Chlorophyll a was measured with a fluorometer following the method of Wetzel and Likens (1991).

Nitrate + Nitrite: Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (EPA 1979).

Sodium: Sodium was determined by atomic absorption spectrophotometry (Perkin Elmer 3030) APHA 1989).

Total Phosphorus: The persulfate digestion procedure was used prior to analysis by the automated (Technicon Autoanalyser) colorimetric ascorbic acid method (APHA 1989).

Total Kjeldahl Nitrogen: Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were performed:

1. In the sodium salicylate-sodium nitroprusside solution, sodium nitroferri-cyanide (0.4g) replaced the concentrated nitroprusside stock solution.
2. The reservoir of the autoanalyser was filled with 0.2M H_2SO_4 instead of distilled water.
3. Other reagents were made fresh prior to each analysis.

Total Suspended Solids: APHA (1989) Method 2540D was employed for this analysis.

Physical Measurements:

Stream Velocity: Stream velocity was measured either in the culvert or within the cement channel of a bridge (Chow 1964). Measurements were at equally spaced locations at each station on all dates with a Global flow meter. A regression equation was calculated for velocity versus stream height and are presented in Figures 2 - 4.

Stream Height: Hourly readings of stream level from Sheldon Creek were measured using an Isco flow meter equipped with a bubbler sensor. On all other streams, stream height was determined weekly by measuring the distance from the surface of the stream to a standard location on the overlying bridge or culvert. Stream area for various stream heights was calculated by planimetry. A polynomial was fit to the values for stream area using Sigma Plot (Jandel Scientific), which allowed stream cross-sectional area to be estimated for all sampling dates based on stream heights (Fig. 6-8).

Discharge and Loading:

Sheldon Creek:

Hourly level readings on Sheldon Creek were converted to discharge by a second order polynomial (Fig. 5). Where hourly readings were not available, the daily average level or the weekly stream height measurement was used for calculation of discharge. In the calculation of nutrient loading, event loading was calculated by adding up hourly discharge for both the rising and falling limb and multiplying them by their respective chemistries. During non-event periods, hourly discharge was summarized into a weekly discharge and multiplied by that period's chemistry value. If a hydrologic event occurred during the week, event loading was substituted for the period of the event to obtain total loading (event plus non-event).

Other Creeks:

Rating curves for other creeks were developed based on the cross sectional area and velocity at different stream heights for each of the sampled tributaries of Lake Neatahwanta. Regression analysis allowed the estimation of discharge in other creeks based on daily discharge from Sheldon Creek (Table 1). After daily discharges for all creeks were calculated, the loading calculations were handled similar to Sheldon Creek with the exception of events. Event discharge for the other creeks was not separated into rising and falling limbs. The total event discharge was multiplied by the weekly chemistries to obtain event loading. Since chemistry from non-event periods underestimate chemistry from event periods, loading from all creeks, except Sheldon Creek, are conservative (i.e. they are underestimates).

Watershed Area: Areas used in the loading calculations were obtained by planimetry from USGS topography maps. Watershed areas were not the whole area of the watershed but were the area of the watershed upstream from the sampling point.

Quality Control

Quality Assurance Internal Quality Control: Multiple sample control charts (APHA 1989) were constructed for each parameter analyzed, except total suspended solids. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run. Frequency of instrument calibration is indicated in Table 2. Table 3 provides a summary of the quality assurance data.

External Quality Control: The New York State Department of Health's Environmental Laboratory Approval Program (ELAP) proficiency test results are presented in Table 4. Biannually, reference solutions were obtained from the Water Resources Division of the US Geologic Survey. Results from the blind external quality exercises are presented in Tables 5.

RESULTS and DISCUSSION

STREAM CHEMISTRY AND LOADING TO LAKE NEATAHWANTA:

Discharge

The mean daily stream discharge values (m^3/day) for the 9 May 1993 to 14 May 1994 period were in descending order: Sheldon Creek (96,831); Summerville Creek (20,562) and Ley Creek (8,051) (Table 6). 77.2% of the water discharged into Lake Neatahwanta was from Sheldon Creek (not including the Summerville Branch) (Fig. 9). Discharge from Sheldon Creek, as with other creeks, was highest during the spring (47%) and winter (28%) (Fig. 10). This coincides with the precipitation and snow melt patterns for the seasons.

Water Chemistry

Annual means for stream water chemistry data are presented in Table 6. Concentrations of total phosphorus and total kjeldahl nitrogen in stream water are highest in Ley Creek, while nitrate and sodium concentrations are highest in Sheldon Creek. In general, total phosphorus concentrations were relatively high in the Lake Neatahwanta tributaries sampled. The water chemistry of the streams draining sub-watersheds of Lake Neatahwanta generally reflect land usage and/or point sources within that watershed. To evaluate the sources of these materials in the watershed a procedure called stressed stream analysis or stream segment analysis could be used to evaluate sources of pollution in future work.

Because of its low discharge, the assumption was made that Granby Creek was not a major contributor of nutrients to the lake. This was checked by sampling on four different dates. Results from grab samples from Granby Creek indicate that concentrations of total phosphorus, total suspended solids, and total kjeldahl nitrogen are generally as low or lower than the other creeks routinely sampled (Table 7). Considering the low discharge expected from the creek and the low nutrient concentrations, Granby Creek is not a major source of nutrients to the lake.

A large field in agriculture lies between the continuously gaged site at Sheldon Creek. This non-point source could be influencing loadings the lake. The continuous gaging site could not be placed closer to the lake because of the spring high water influence from the lake that would compromise stream height measurements. A concern over the nutrient loading from this unmonitored field near the mouth of Sheldon Creek was addressed in the following manner. Several samples were taken at the farm bridge (Fig. 1) near the mouth of the stream to evaluate the contribution of nutrients from the field. Concentrations of nutrients and suspended solids were not significantly different between the two sites on Sheldon Creek (Table 6 and 7). If the field was making a large contribution, concentrations of various materials should have increased. This did not happen. Although this is not proof positive that nutrients are not being lost from the one field in question, it is unlikely that significant amounts are being added to the stream and the lake from this area.

Loading

Table 8 presents loading of total phosphorus, total kjeldahl nitrogen, nitrate, total suspended solids and sodium for the period 9 May 1993 to 14 May 1994. The loading data presented here is based on continuous discharge measured at Sheldon Creek and thus reflects high discharge caused by precipitation events and snow melt. The event data presented is a result of only those events that were triggered by the continuous discharge recorder located on Sheldon Creek. Due to various problems associated with the initial setup of this instrumentation some early events were not sampled. Therefore, event discharge and loading are probably underestimated. The loading calculated does not include event water chemistry, except in the case of Sheldon Creek where all events were analyzed. Annual loading can be derived by multiplying values from Table 8 by 365.

Loading - Sodium:

Sodium, a major constituent of deicing salt, was lost from the watershed during the study period (Table 8). Sheldon Creek contributes 87% of the sodium entering the Lake, while 75% of the salt (as sodium) that enters the lake, enters in the winter and spring when deicing salt is applied to roads (Fig. 11). The seasonal contribution of sodium from each creek is presented in Figure 11. The grab samples taken at Granby Creek also have a high sodium concentration (mean = 28.57 mg/L), which probably reflects salt usage within this watershed. Loading from this watershed is probably low because of low discharges .

Loading - Total Suspended Solids:

Concentrations of total suspended solids in stream water generally reflect the amount of materials (e.g. soils) being lost from a watershed. Seasonal suspended solid loss for each creek is presented in Figure 12. Sheldon Creek was by far the major contributor of suspended solids to Lake Neatahwanta at 538 metric tons for the year and represents 99% of the annual load of suspended solids into the Lake. This number is biased by the fact that events were monitored only in Sheldon Creek. This would lead to an underestimation of TSS in creeks not monitored during events since most TSS lost occurs during events.

Loading - Total Phosphorus, Nitrate and Total Kjeldahl Nitrogen (TKN)

Phosphorus is an element required for plant growth whether on land or in the water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction of lakes. For example, phosphorus may enter from the watershed as a result of sewage effluent disposal and because of heavy fertilizer use for lawns or in agriculture. Watersheds that contribute high loading of nutrients are potentially the cause of increased phytoplankton and macrophyte (weed) production.

Annually, Sheldon Creek was the major contributor of nutrients to Lake Neatahwanta accounting for 89%, 90%, and 90% of the total phosphorus (Fig. 13), total nitrogen (Fig. 14) and nitrate (Fig. 15), respectively, entering the Lake. Highest loading of nitrate occurred in the spring and winter (Fig. 16), while the highest loading of total phosphorus and TKN occurred during the spring and fall (Figs. 17 and 18). Events accounted for 73% of TKN, 81% of TP and 25% of nitrate annual loading (Fig. 19). These results strongly suggest that Sheldon Creek is the major source of nutrients to Lake Neatahwanta,

Comparison to Other Watersheds:

The various creeks of the Irondequoit Bay watershed (Monroe County, NY.) have been identified as grossly polluted prior to remedial action (O'Brien and Gere 1983). Similarly, Northrup Creek (central Monroe County), which receives effluent from a sewage treatment plant, is known to be polluted and to possess a higher loading of phosphorus than creeks in the Irondequoit Bay watershed (Makarewicz 1988). A comparison of Lake Neatahwanta tributaries to Monroe County creeks is instructive in identifying the relative condition of creeks entering Lake Neatahwanta (Table 9). Compared to the suburban and urban watersheds of Monroe County, Sheldon Creek has a phosphorus loading that is exceedingly high, and due to its relatively small watershed, the phosphorus loading on an areal basis is much greater than creeks receiving treated sewage (Lower Northrup Creek, Irondequoit Creek prior to diversion of sewage). Areal based phosphorus loading of Summerville and Ley Creeks are comparable to the Monroe County creeks receiving treated sewage. This suggests a major point source or non-point source of nutrients in the Sheldon Creek watershed.

A comparison of the discharge and loading for 1989-1990 estimated by F.X. Browne (1991) and the discharge and loading calculated for this report (1993-1994) indicates that the F. X. Browne estimates are significantly lower than the 1993-1994 values (Table 10). A comparison of baseline chemistry data between both studies indicate reasonable agreement suggesting a problem with the watershed discharge estimates. The methods section of the F.X. Browne report is sketchy at best and does not allow for the full reconstruction of their methods or the data for estimating discharge. We do know that in 1989 - 90 study, automated stream gauges were not set up on the tributaries. Instead, gaging was manual and occurred as little as three times during the reporting period. This method would underestimate discharge because precipitation and snow melt events were not being included. In the current study, discharge was monitored throughout the reporting period and would obviously include all precipitation events which did represent a major portion of the discharge from the watershed. Also, the use of literature nutrient export coefficients by F.X. Browne provided an estimate of loading based on an

average watershed. In essence, the current report uses actual measurements of export coefficients based on discharge and nutrient concentrations from the given watershed. In general, a much greater effort was put forth to actually 'measure' the discharge and loading to Lake Neatahwanta for this report compared to the F.X. Browne Study. We are confident with the discharge and loading values reported in this study.

Best Management Practices:

To achieve the goal of controlling macrophytes and improving the water quality of Lake Neatahwanta, management of the watersheds becomes desirable. Whether or not management practices include a reduction of fertilization, control of water movement can be a means of significantly reducing non-point source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices which reduce surface runoff have been shown to dramatically decrease the magnitudes of sediment and chemical losses from land areas (Haith 1975).

Haith (1975) and the NYSDEC (1986) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other management practices include diversion terraces and ditches, stormwater detention ponds and infiltration pits. The relatively few days of high runoff required to export much of the annual water and nutrients from the Lake Neatahwanta watershed implies the necessity of management practices designed to deal with the large volumes of water involved during intense runoff events. Changes in cropping and soil conservation practices, decreases in impervious services and provision of buffer areas along surface waterways will result in predictable changes in runoff quantities and qualities and hence non-point source pollution (Haith 1975).

TROPHIC STATUS OF LAKE NEATAHWANTA:

It is now well accepted that eutrophication of lakes depends on excessive discharge of phosphorus and nitrogen to inland waters. This concept, sometimes called the nutrient loading concept, implies that a quantifiable relationship exists between the amount of nutrients reaching a lake and its trophic status, which can be measured by chlorophyll *a* levels. The results of the Lake Neatahwanta grab samples are presented in Table 11. Figure 20 presents the relationship of chlorophyll level to potential available phosphorus for some common upstate New York lakes and bays. Based on the phosphorus loading and chlorophyll data that we have collected for Lake Neatahwanta and its tributaries, Lake Neatahwanta falls into the eutrophic category of bodies of water. Lake Neatahwanta is a productive body of water.

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Table 1. Regression equations predicting discharge for Lake Neatahwanta tributaries on continuous discharge at Sheldon Creek. SHEL = Sheldon Creek discharge (m^3/s).

Creek	Regression Equation	Coefficent
Summerville Creek	$m^3/s = SHEL \times 0.17297 + 0.04413$	$r^2 = 0.86$
Ley Creek	$m^3/s = SHEL \times 0.07557 + 0.00849$	$r^2 = 0.84$

Table 2. Frequency of calibration of instruments or reagents.

Instrument	**Recalibration**
Technicon - Nitrate/Nitrite	Weekly
Technicon - Total phosphorus	Weekly
Technicon - Total kjeldahl nitrogen	Weekly
Atomic absorption spectrophotometer - Sodium	Weekly

Table 3. Summary of internal quality assurance data from the water qualty laboratory at SUNY Brockport for 1993 - 1994. SRP = soluble reactive phosphorus, TP = total phosphorus and TKN = total kjeldahl nitrogen. Values are in mg/L unless otherwise noted.

	Count	True value	Mean	Standard Deviation	Coefficient of Variation	Confidence level (95%)	Relative error
Alkalinity	43	79.79	77.03	3.749	0.047	1.1	3.6
Calcium	40	30.00	30.01	0.474	0.016	0.1	0.0
Chloride	35	26.49	26.19	2.232	0.084	0.7	1.2
Conductivity (µmhos/cm)	35	717.00	716.25	6.371	0.009	2.1	0.1
Potassium	38	1.00	0.94	0.069	0.069	0.0	6.0
Magnesium	35	10.00	10.28	0.285	0.029	0.1	2.8
Sodium	44	10.00	9.86	0.451	0.045	0.1	1.4
Nitrate	36	0.40	0.39	0.020	0.051	0.0	3.7
Turbidity	40	0.50	0.52	0.044	0.087	0.0	4.2
pH	32	4.01	3.97	0.028	0.007	0.0	0.9
Sulfate	42	20.00	19.18	1.327	0.066	0.4	4.3
SRP (µg P/L)	32	24.80	23.83	1.120	0.045	0.4	4.1
TP (µg P/L)	36	37.20	35.00	3.108	0.084	1.0	6.3
TKN (µg N/L)	40	0.49	0.52	0.086	0.176	0.0	5.6

Table 4. Results of the semi-annual ELAP Non-Potable Water Chemistry Proficiency Test, January 1994. Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal.

Analyte	Mean/Target	Result	Score
Residue			
Solids, Total Suspended	58.2 mg/L	59.4 mg/L	4
Solids, Total Suspended	30.4 mg/L	31.3 mg/L	4
Hydrogen Ion (pH)			
Hydrogen Ion (pH)	6.00	5.97	4
Hydrogen Ion (pH)	3.02	3.01	4
Organic Nutrients			
Kjeldahl Nitrogen, Total	7.28 mg/L	7.91 mg/L	4
Kjeldahl Nitrogen, Total	4.61 mg/L	5.60 mg/L	3
Phosphorus, Total	0.8 mg/L	0.8 mg/L	4
Phosphorus, Total	4.3 mg/L	4.3 mg/L	4
Total Alkalinity			
Alkalinity	59.3 mg/L $CaCO_3$	61.1 mg/L $CaCO_3$	4
Alkalinity	482.0 mg/L $CaCO_3$	486.0 mg/L $CaCO_3$	4
Inorganic Nutrients			
Nitrate (as N)	3.45 mg/L as N	3.67 mg/L as N	4
Nitrate (as N)	6.36 mg/L as N	6.24 mg/L as N	4
Orthophosphate (as P)	3.4 mg/L as P	3.4 mg/L as P	4
Orthophosphate (as P)	4.7 mg/L as P	4.7 mg/L as P	4
Minerals			
Chloride	60.0 mg/L	59.3 mg/L	4
Chloride	140.0 mg/L	139.0 mg/L	4
Wastewater Metals I and II			
Calcium, Total	29.30 mg/L	30.20 mg/L	4
Calcium, Total	69.50 mg/L	70.30 mg/L	4
Magnesium, Total	4.67 mg/L	4.62 mg/L	4
Magnesium, Total	23.40 mg/L	22.00 mg/L	4
Potassium, Total	9.97 mg/L	10.70 mg/L	4
Potassium, Total	24.90 mg/L	25.00 mg/L	4
Sodium, Total	50.10 mg/L	50.00 mg/L	4
Sodium, Total	20.70 mg/L	21.70 mg/L	4

Table 5. Results of the semi-annual interlaboratory testing program (October 1993) of the U.S. Geological Survey performed by SUNY Brockport. The USGS rating is as follows: 0 (poor), 1 (questionable), 2 (satisfactory), 3 (good), 4 (excellent). The reference samples analysed were titled "Nutrients" and "Major Constituents".

Parameter	Reported	Most probable value	USGS rating
Total phosphorus	0.06	0.06	4
Specific conductance	1,064	1,076	4
Soluble reactive phosphorus	0.05	0.05	4
pH	8.22	8.29	2
Sulfate	201	206	3
Alkalinity	160	168	0
Chloride	91.7	98.2	0
Total kjeldahl nitrogen	0.37	0.27	4
Nitrate	0.10	0.11	3
Calcium	75.1	78.9	3
Potassium	11.24	9.44	0
Magnesium	16.3	17.4	2
Sodium	123	126	3
Overall			2.5

Table 6. Summary of physical and chemical parameters for the period 9 May 1993 to 14 May 1994 for Sheldon, Summerville and Ley Creeks. Values represent the annual mean ± standard error followed by the range.

	Sheldon	Summerville	Ley
Total phosphorus (µg P/L)	102.4 ± 7.0 19.6 - 245.4	115.3 ± 15.2 15.2 - 657.5	278.8 ± 27.0 39.6 - 1167.5
Nitrate + nitrite (mg N/L)	1.41 ± 0.06 0.03 - 2.68	0.40 ± 0.08 0.00 - 2.78	0.76 ± 0.16 0.00 - 8.62
Total suspended solids (mg/L)	8.9 ± 1.3 0.0 - 54.0	8.5 ± 1.6 0.4 - 57.8	10.1 ± 1.7 0.0 - 62.8
Total kjeldahl nitrogen (µg N/L)	658 ± 39 250 - 1985	675 ± 44 70 - 1710	825 ± 47 148 - 1930
Sodium (mg/L)	26.03 ± 1.89 8.50 - 59.16	6.48 ± 0.21 1.22 - 9.88	9.48 ± 0.76 2.78 - 27.29
Discharge (m^3/d)	96,831	20,562	8,051
Watershed area (ha)	1,357	409	632

Table 7. Water chemistry parameters for grab samples taken at the Sheldon Creek Bridge Site and from Granby Creek. TP = total phosphorus, TSS = total suspended solids, TKN = total kjeldahl nitrogen and Na = sodium.

Sheldon Bridge Site

DATE	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Na (mg/L)
06-08-93	120.3	0.84	9.0	170	18.59
10-26-93	92.4	1.12	5.6	590	14.98
11-02-93	72.9	0.79	3.2	500	14.33
Mean	95.1	0.92	5.9	420	15.97

Granby Creek

DATE	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Na (mg/L)
05-10-93	37.8	0.42	2.8	330	23.03
06-08-93	56.5	0.36	6.0	310	27.65
10-26-93	102.6	0.42	7.8	770	29.39
11-02-93	59.9	0.18	5.8	380	34.22
Mean	64.2	0.35	5.6	448	28.57

Table 8. Average daily loading of selected parameters from Sheldon, Summerville and Ley creeks. Annual loading can be derived by multiplying values by 365. TP = total phosphorus, TSS = total suspended solids and TKN = total kjeldahl nitrogen.

	Discharge (m3/d)	TP (kg/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
Sheldon	96,831	37.20	128.40	26,232	159.99	1,475
Summerville	20,562	2.24	8.73	197	11.66	135
Ley	8,051	2.37	5.95	57	6.54	91

	Discharge (m3/ha/d)	TP (g/ha/d)	Nitrate (g/ha/d)	TSS (g/ha/d)	TKN (g/ha/d)	Sodium (g/ha/d)
Sheldon	71.4	27.4	94.6	19331	117.9	1,087
Summerville	50.3	5.5	21.3	482	28.5	330
Ley	12.7	3.7	9.4	90	10.4	144

Table 9. Comparison of phosphorus loading in subbasins of the Irondequoit Bay watershed, other Monroe County creeks, tributaries of Sodus and Port Bays and Lake Neatawanta tributaries. Irondequoit basin data are from 1980-81 (O'Brien and Gere 1983). Data from other Monroe County creeks are from 1987-88 (Makarewicz 1988). Wayne County creek data from 1990-91 are from Makarewicz *et al.* 1991, Makarewicz *et al.* 1992 and Makarewicz *et al.* 1993.

Subbasin or Creek	Total Phosphorus Loading (kg P/d)			Total Phosphorus Loading (g P/ha/d)		
Irondequoit Watershed						
Irondequoit Creek at Browncroft Blvd. 1975-77 (pre-diversion)		220			5.6	
1978-79 (post-diversion)		78.00			2.00	
Irondequoit Creek at Blossom Road (remedial action)						
1979		85			2.30	
1982		34			0.92	
1985		28			0.76	
Monroe County Creeks						
Larkin		2.20			0.70	
Buttonwood		3.60			1.58	
Lower Northrup		12.40			6.64	
Upper Northrup		3.40			3.23	
Wayne County Creeks	1990-91	1991-92	1992-93	1990-91	1991-92	1992-93
First	0.13	0.09		0.17	0.11	
Second	0.49	0.38		0.19	0.15	
Third	0.60	0.47		0.50	0.39	
Clark	0.04	0.03		0.03	0.22	
Sodus West	0.49	0.35		0.60	0.43	
Sodus East	21.47	26.27	34.58	7.01	8.57	11.28
Port Bay Watershed	1990-91	1991-92	1992-93	1990-91	1991-92	1992-93
Wolcott	17.24	12.73	22.13	3.90	2.88	5.01
Bobolink			0.01			0.02
Clapper			0.39			1.97
Sanford			0.25			1.11
Williams			0.24			0.27
Lake Neatahwanta Watershed	1993-94			1993-94		
Sheldon	37.20			27.41		
Summerville	2.24			5.47		
Ley	2.37			3.75		

Table 10. Comparison of discharge and baseline chemistry for Sheldon and Ley Creeks between 1989 to 1990 and 1993 to 1994. Data for 1989 - 90 is from Browne (1991). NS = no sample taken in that season.

SHELDON CREEK

	Discharge (m³/d)		Total phosphorus (µg P/L)		Nitrate (mg N/L)		Total suspended solids (mg/L)		Total kjeldahl nitrogen (µg N/L)	
	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94
SPRING	36,847	172, 236	85.3	102.1	1.10	1.21	10.9	11.3	530	603
SUMMER	7,480	10,545	141.5	119.7	0.52	1.55	23.1	11.1	3050	643
FALL	25,765	86,576	NS	121.9	1.75	1.37	20.0	4.7	1200	722
WINTER	34,110	112,166	102.5	65.9	1.93	1.54	8.1	8.3	745	666
ANNUAL	25,977	96,831	106.3	102.4	1.24	1.41	14.9	8.9	1298	658

LEY CREEK

	Discharge (m³/d)		Total phosphorus (µg P/L)		Nitrate (mg N/L)		Total suspended solids (mg/L)		Total kjeldahl nitrogen (µg N/L)	
	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94	1989-90	1993-94
SPRING	10,986	13,789	247.3	344.0	0.85	0.38	26.7	16.9	790	846
SUMMER	2,278	1,530	198.5	213.4	0.56	0.89	13.3	11.2	455	741
FALL	7,757	7,253	91.0	332.9	0.86	1.06	8.2	9.0	680	899
WINTER	10,321	9,190	301.3	219.7	1.97	0.74	6.2	2.6	790	814
ANNUAL	7,813	8,051	237.1	278.8	1.13	0.76	12.8	10.1	701	825

Table 11. Water chemistry parameters for grab samples taken on Lake Neatahwanta. TP = total phosphorus, TSS = total suspended solids, TKN = total kjeldahl nitrogen Chl *a* = chlorophyll *a*, Pheo = pheophytin and ND = non-detectable.

DATE	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Chl *a* (µg/L)	Pheo (µg/L)
06-15-93	128.2	ND	25.2	1,850	85.2	54.0
07-20-93	268.6	0.1	30.9	3,500	56.0	0.0
08-24-93	171.4	ND	31.0	3,950	37.1	19.5

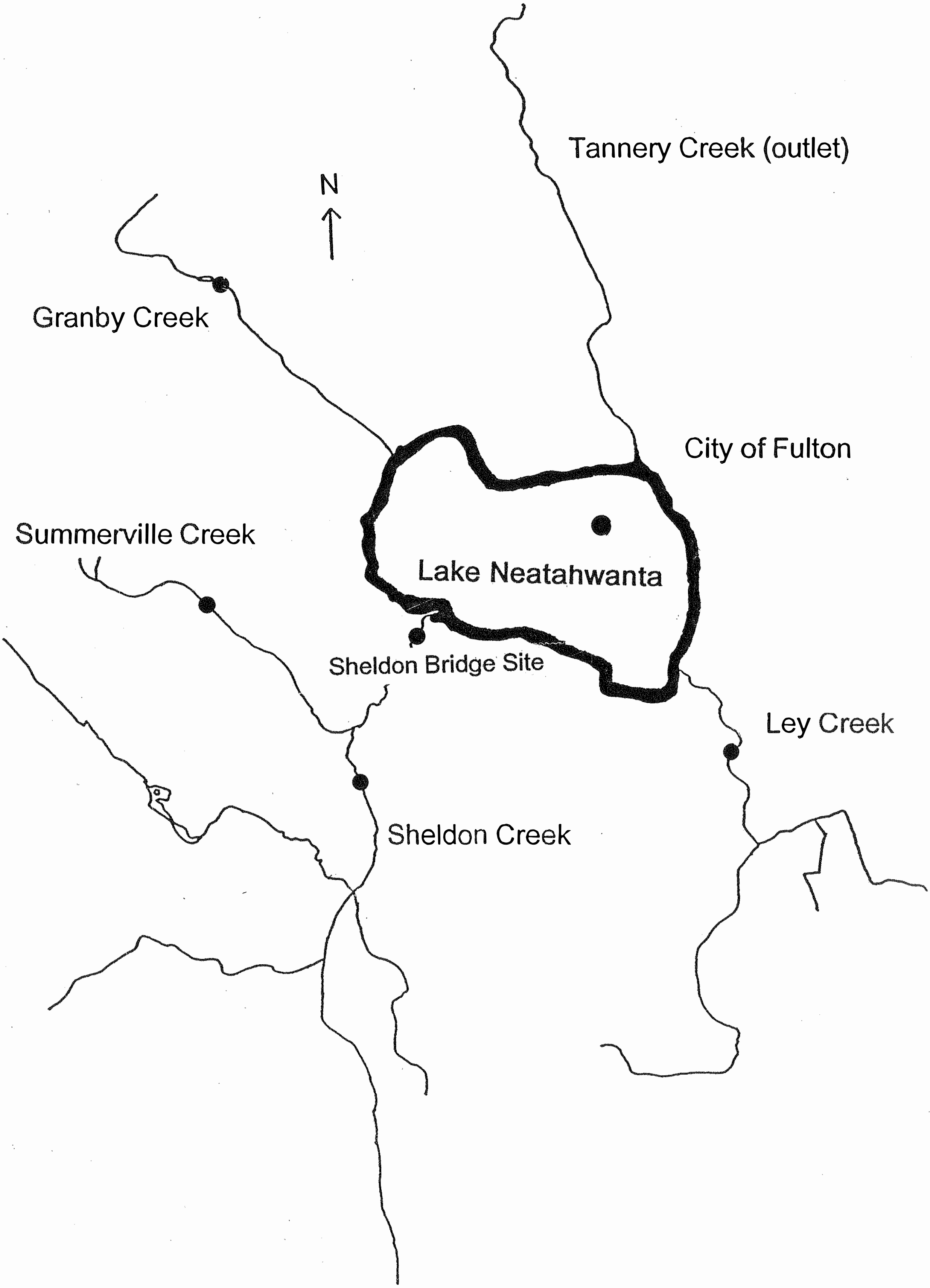


Figure 1. Lake Neatahwanta and its tributaries showing Lake sampling stations and tributary sampling sites, Oswego County, N.Y.

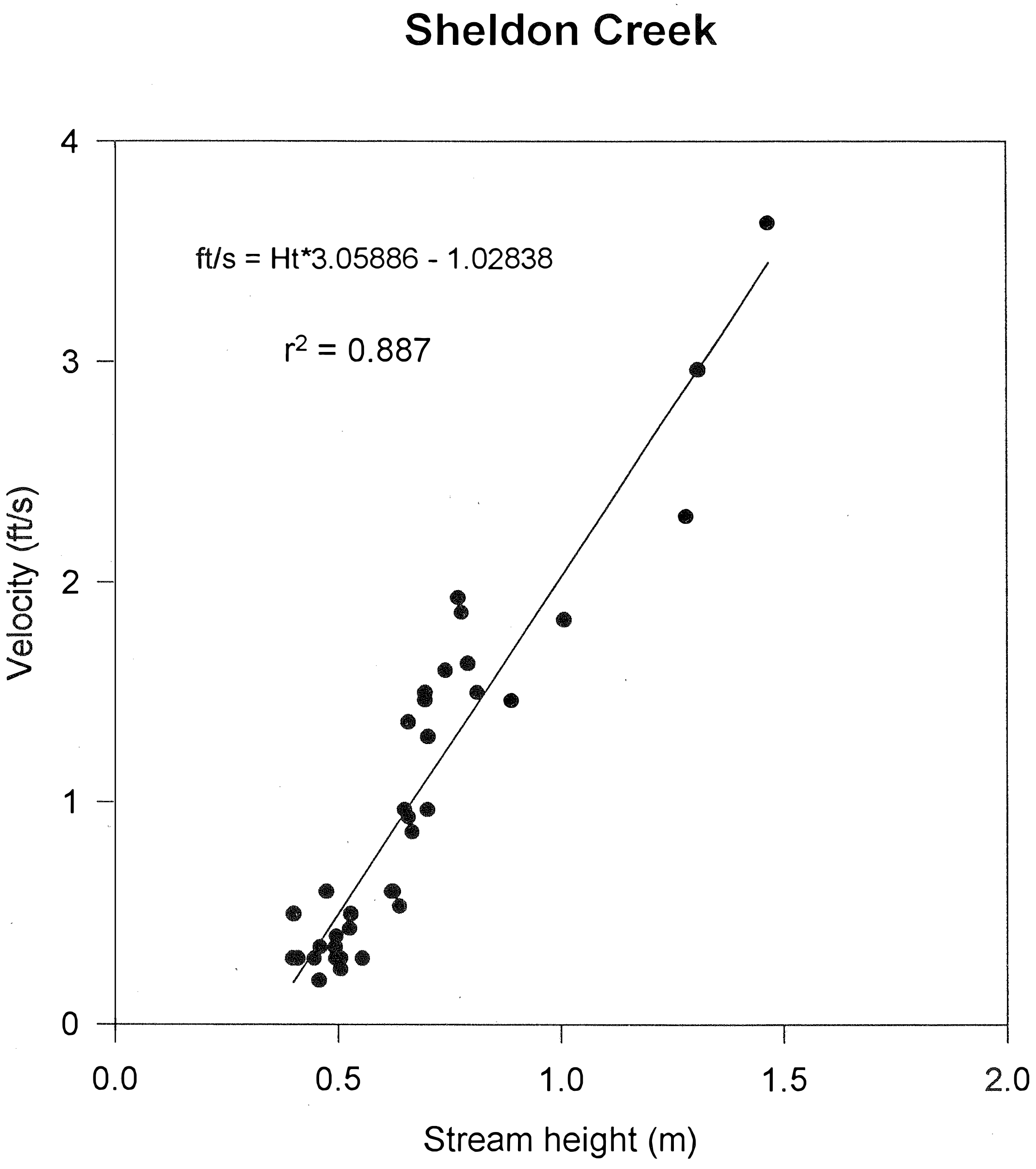


Figure 2. Velocity versus stream height for Sheldon Creek.

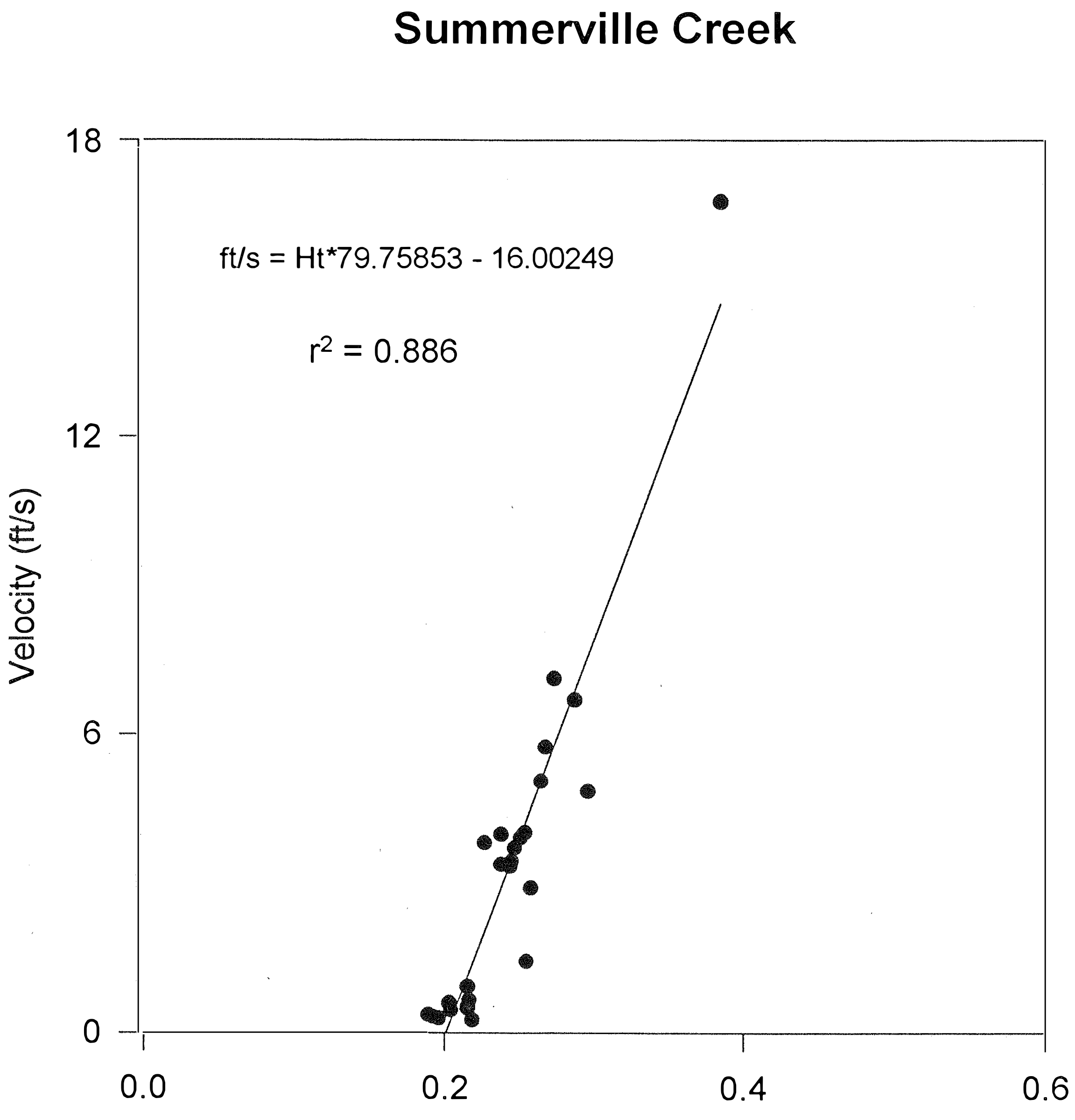


Figure 3. Velocity versus stream height for Summerville Creek.

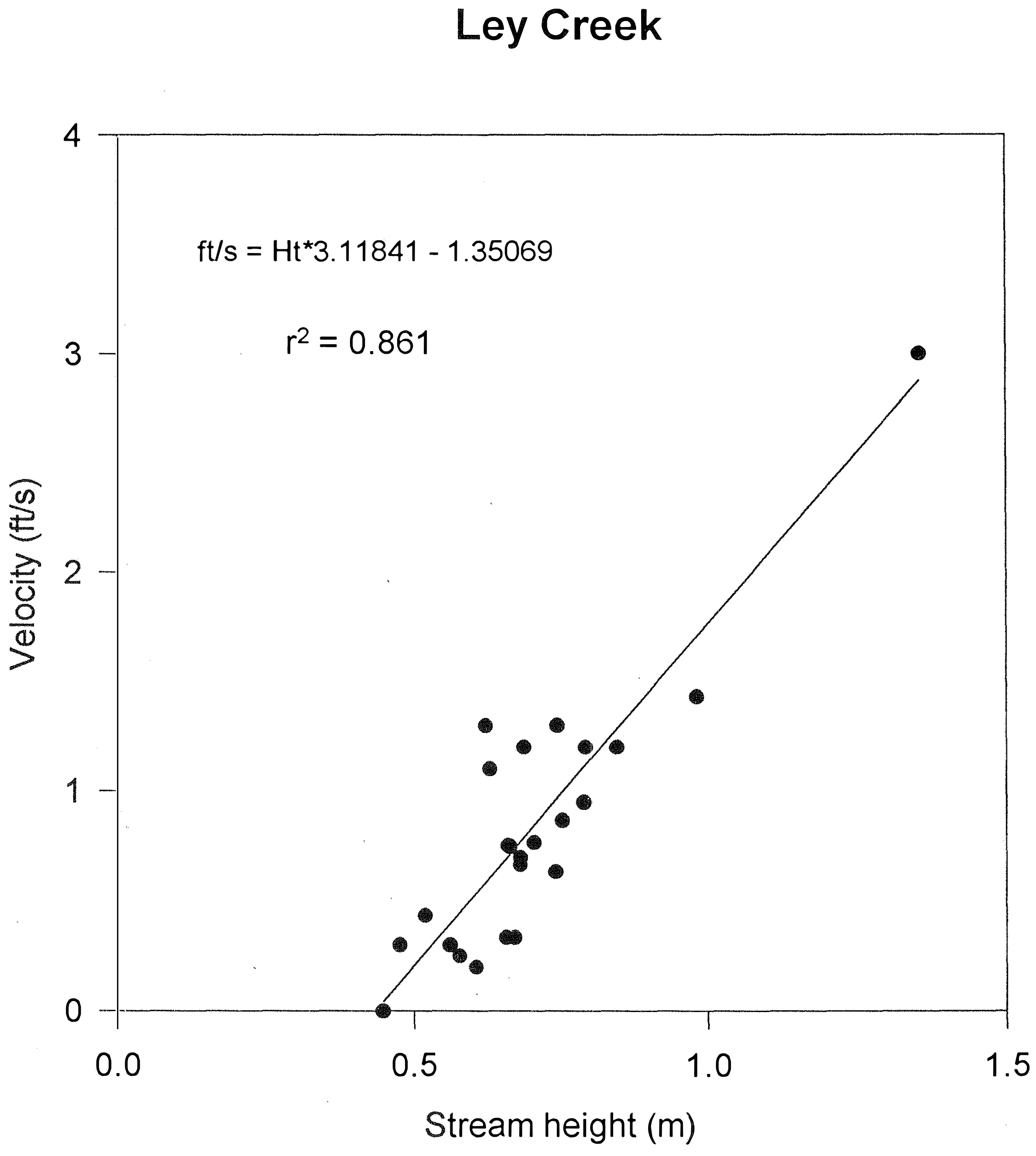


Figure 4. Velocity versus stream height for Ley Creek.

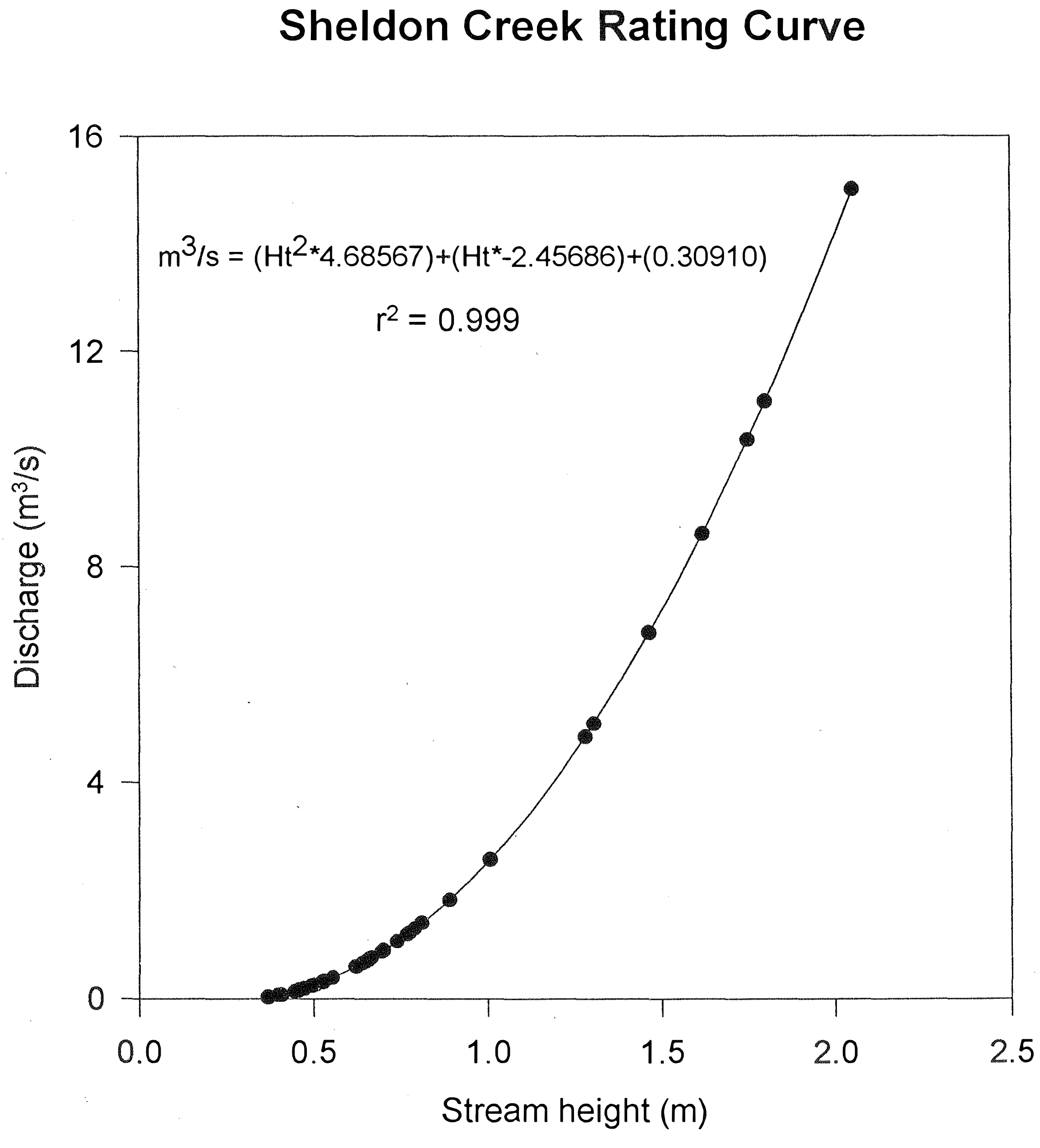


Figure 5. Discharge versus stream height (Rating Curve) for Sheldon Creek.

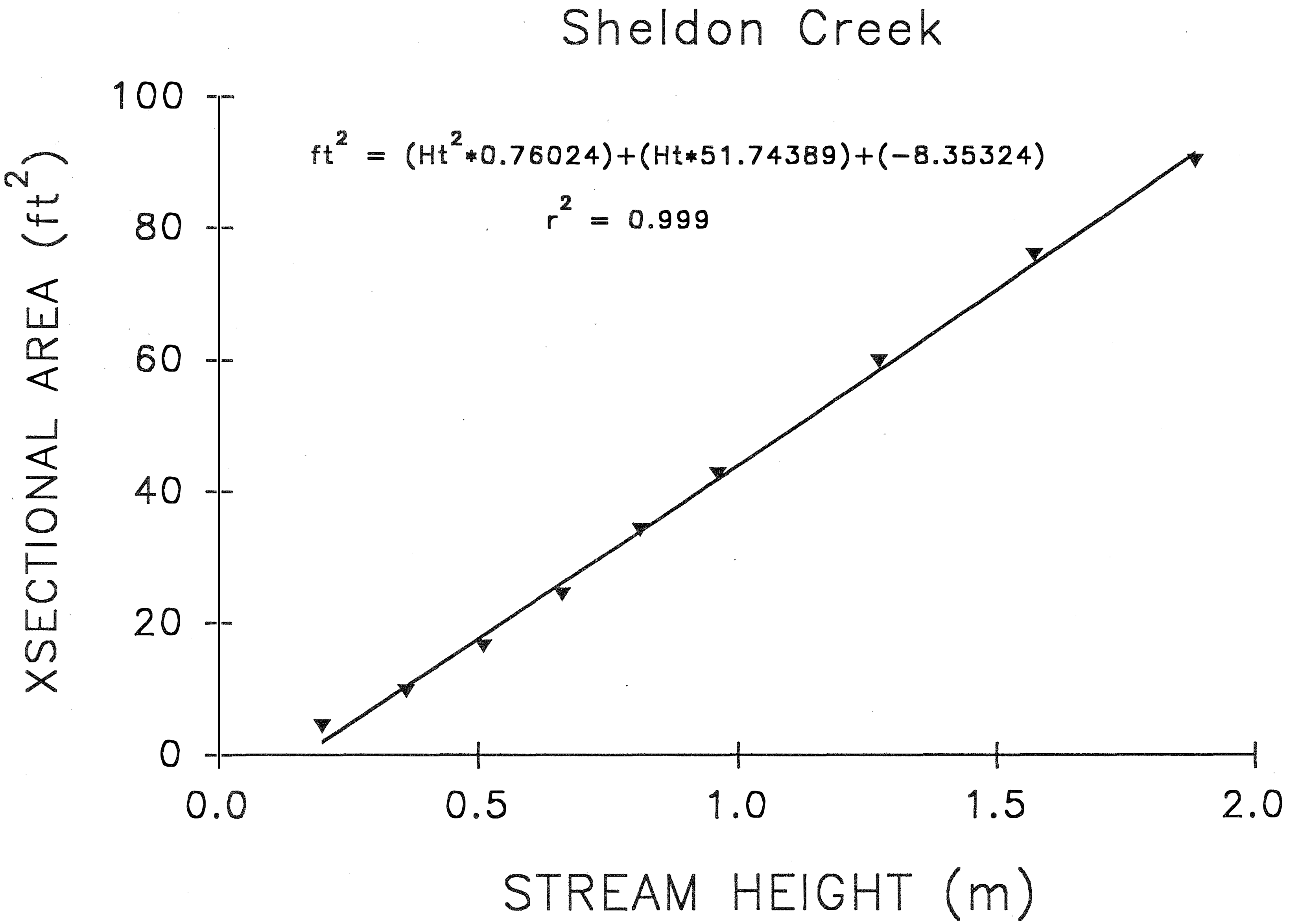


Figure 6. Cross-sectional area versus stream height for Sheldon Creek.

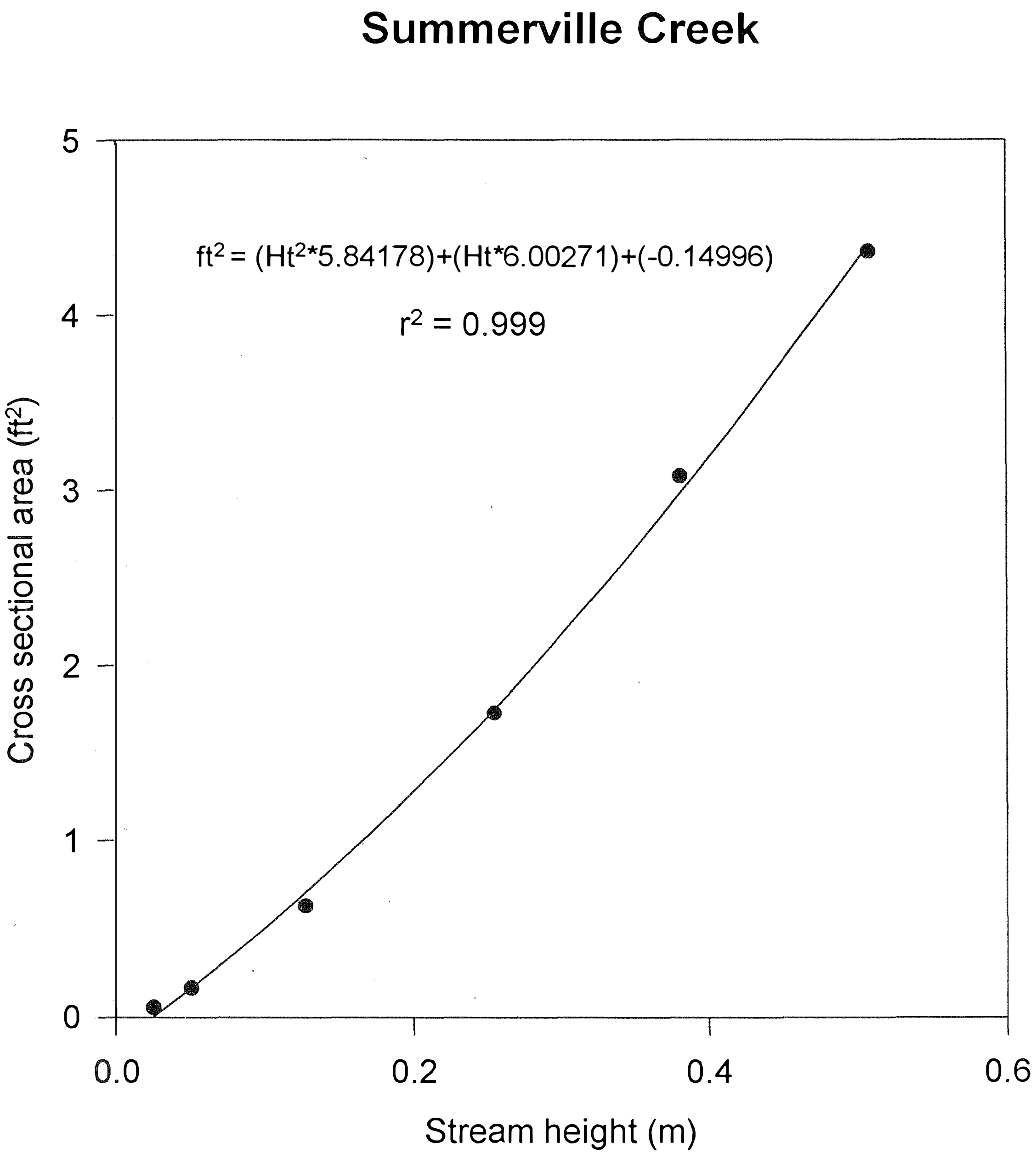


Figure 7. Cross-sectional area versus stream height for Summerville Creek.

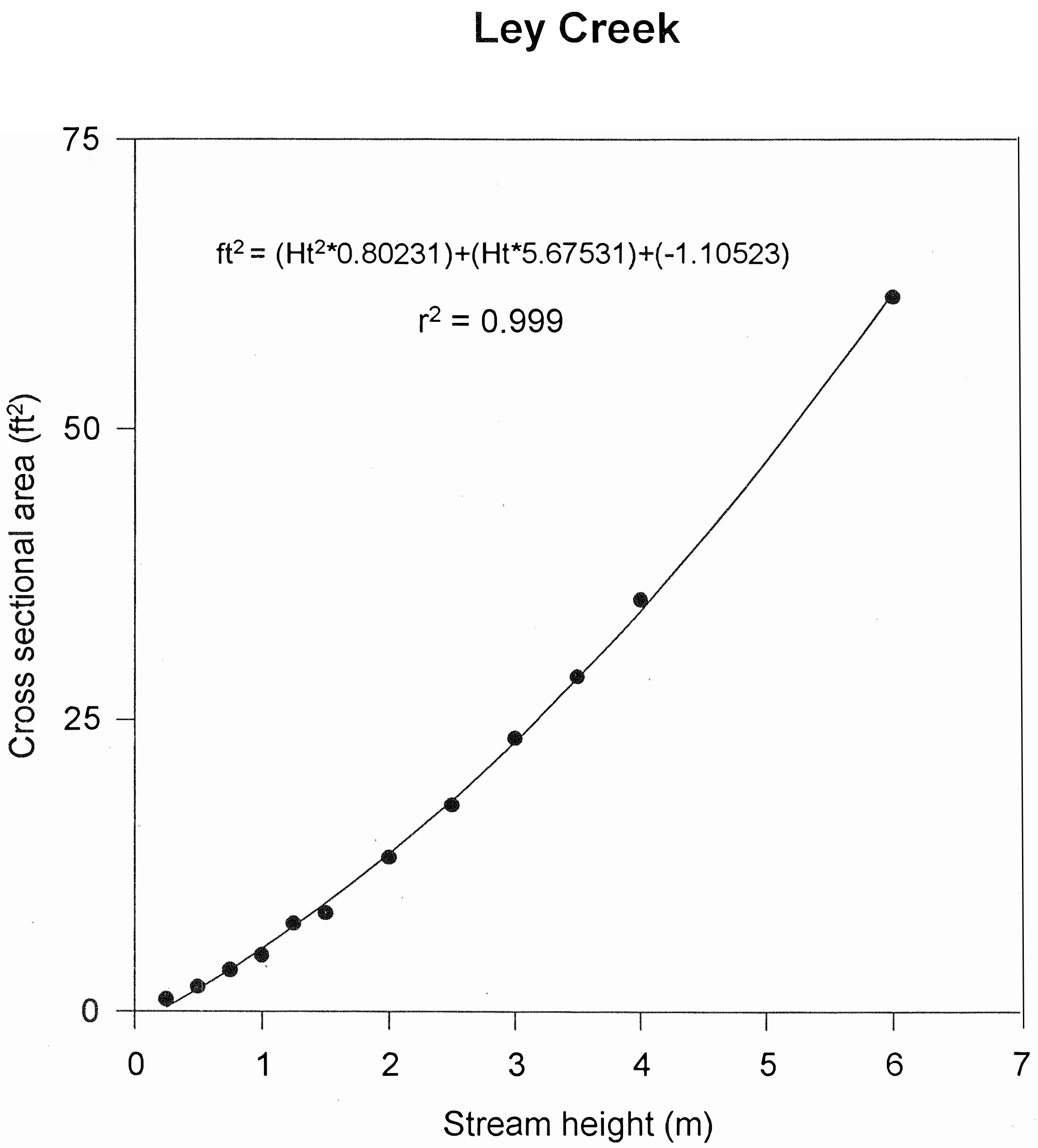
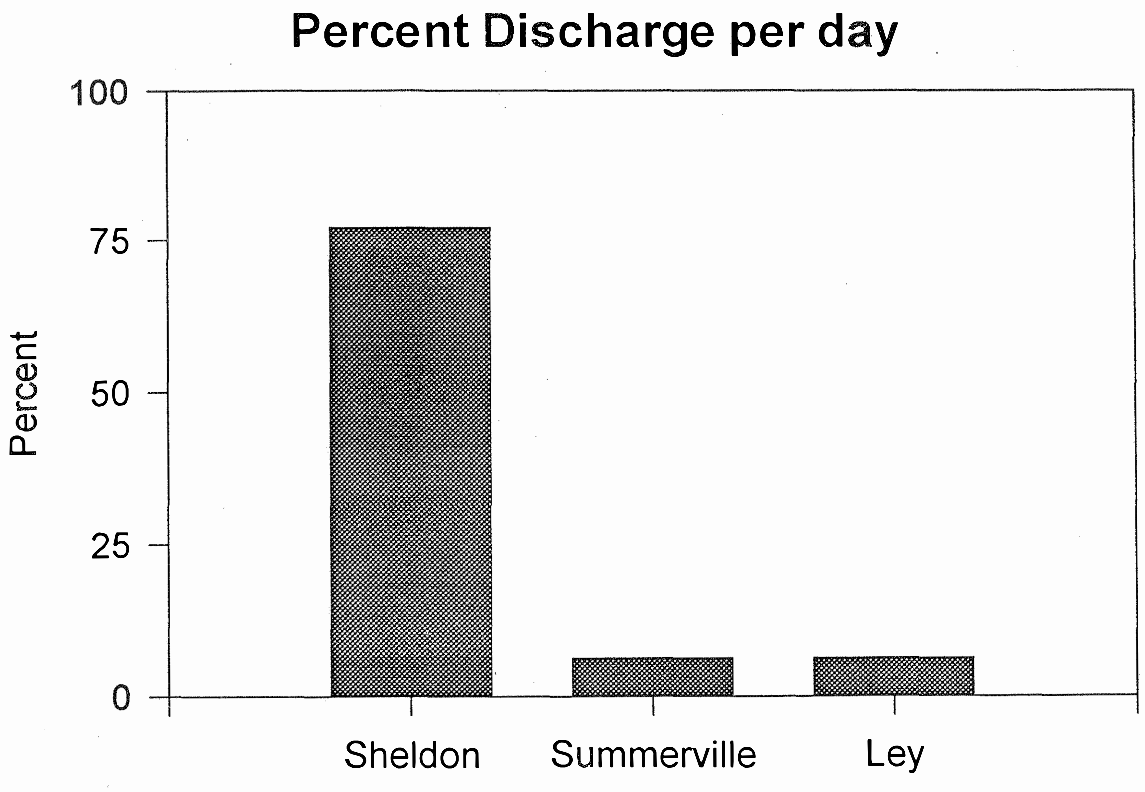


Figure 8. Cross-sectional area versus stream height for Ley Creek.



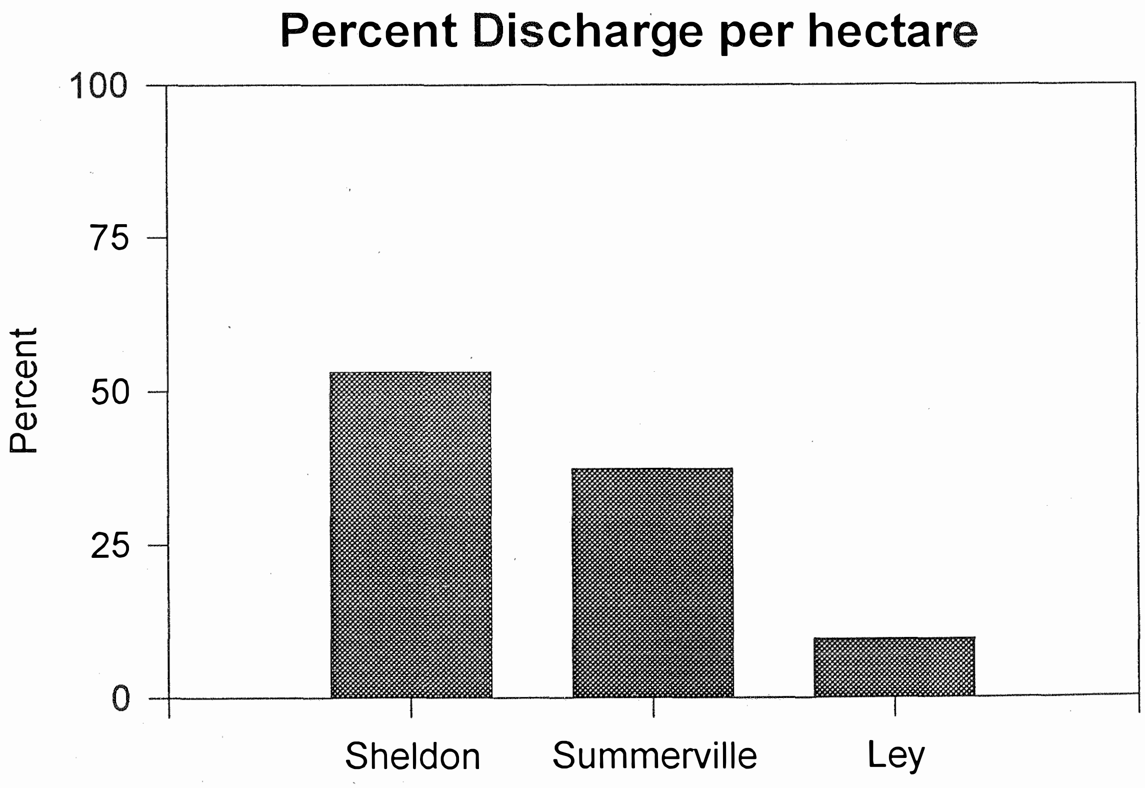


Figure 9. Comparative areal and total discharge from streams into Lake Neatahwanta.

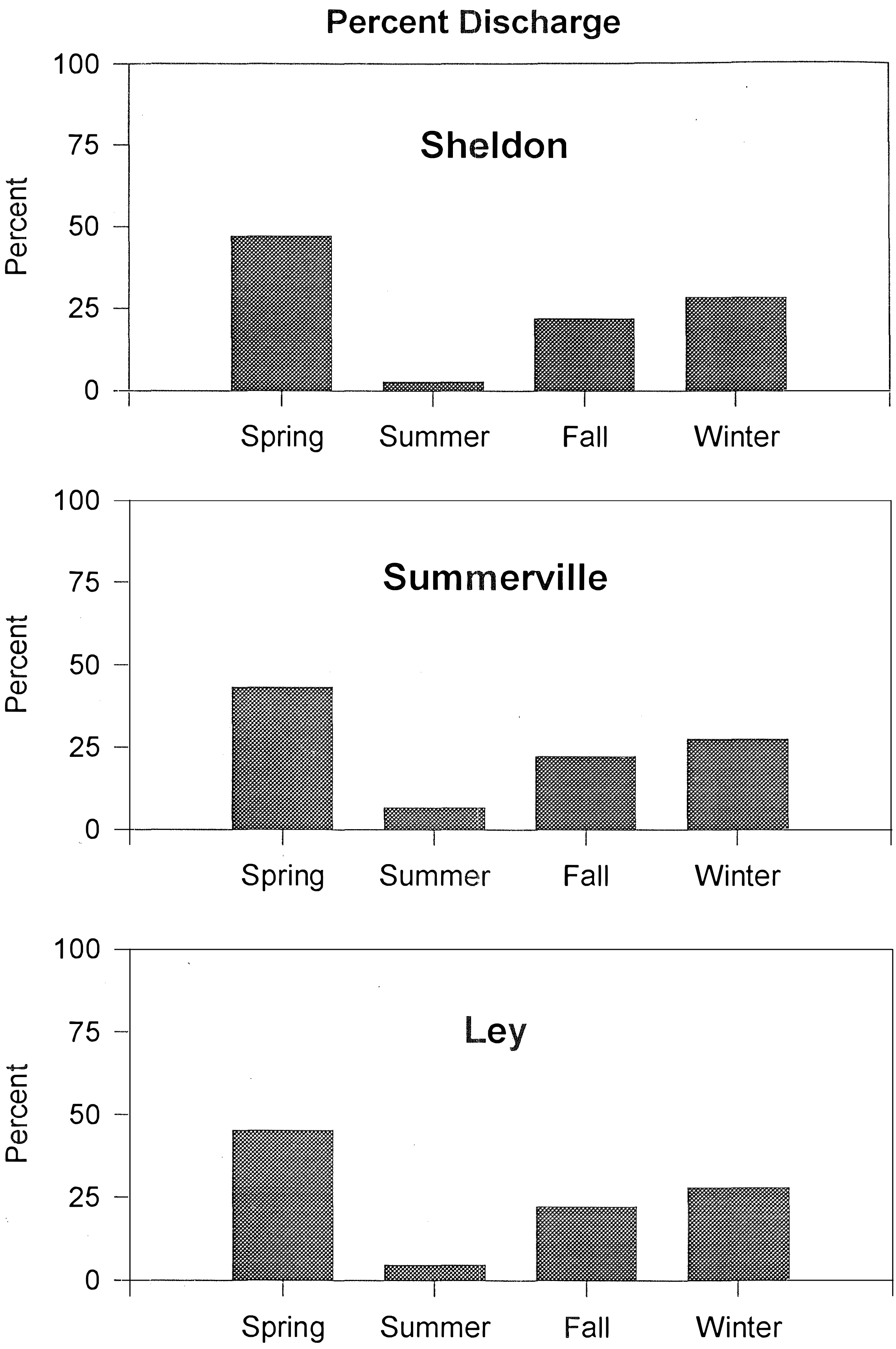


Figure 10. Seasonal discharge from creeks into Lake Neatahwanta.

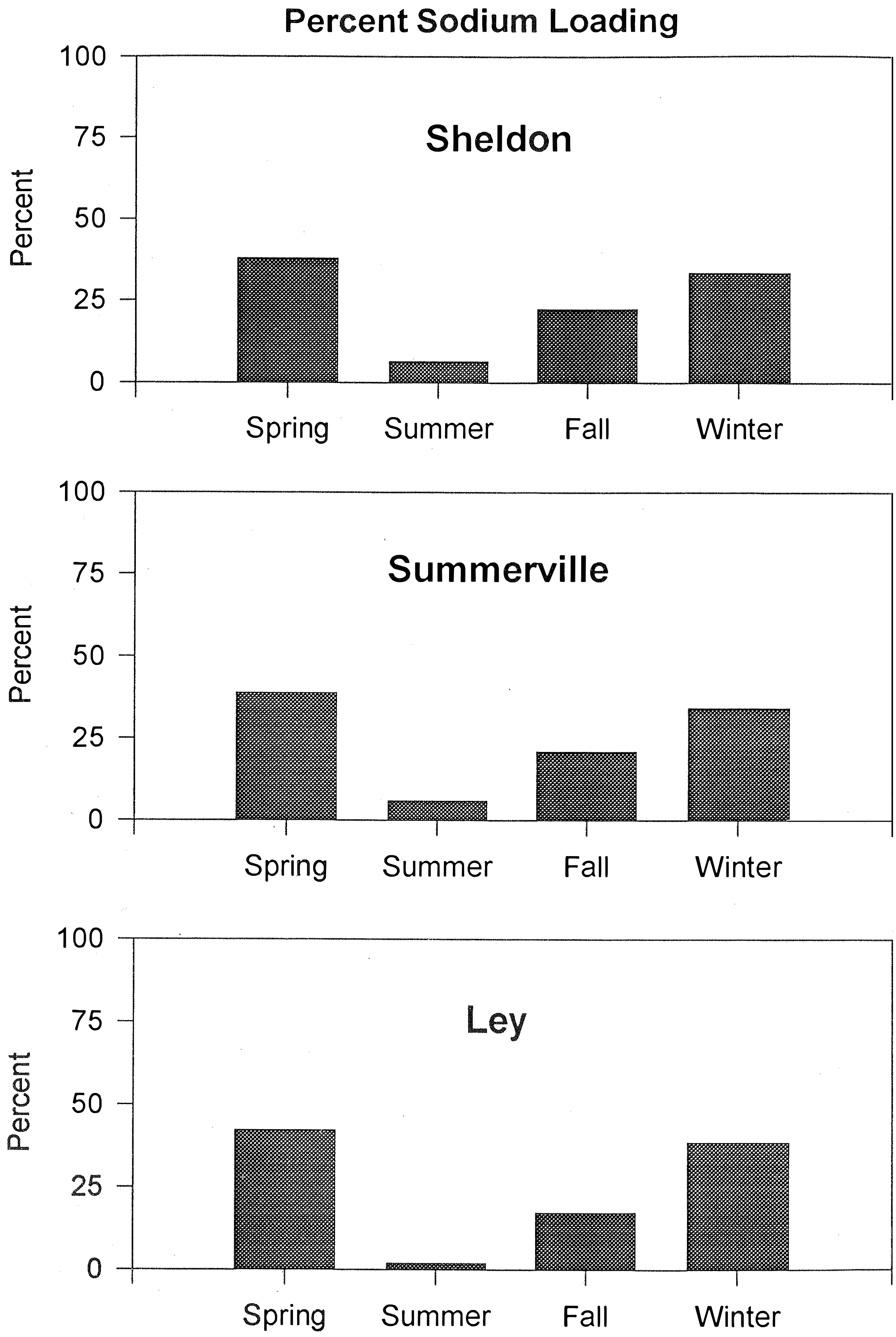


Figure 11. Seasonal loading of sodium from creeks into Lake Neatahwanta.

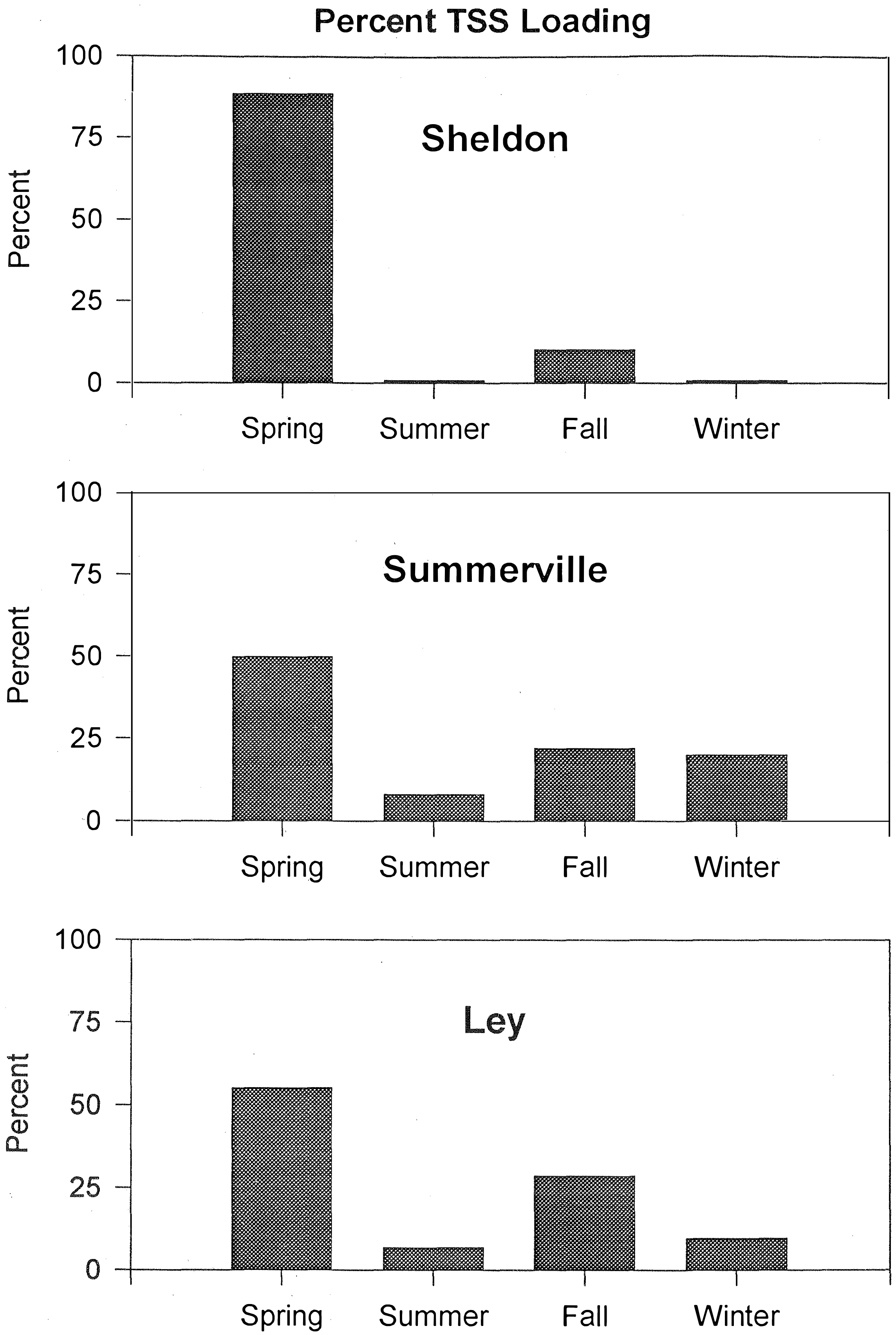


Figure 12. Seasonal loading of total suspended solids from creeks into Lake Neatahwanta.

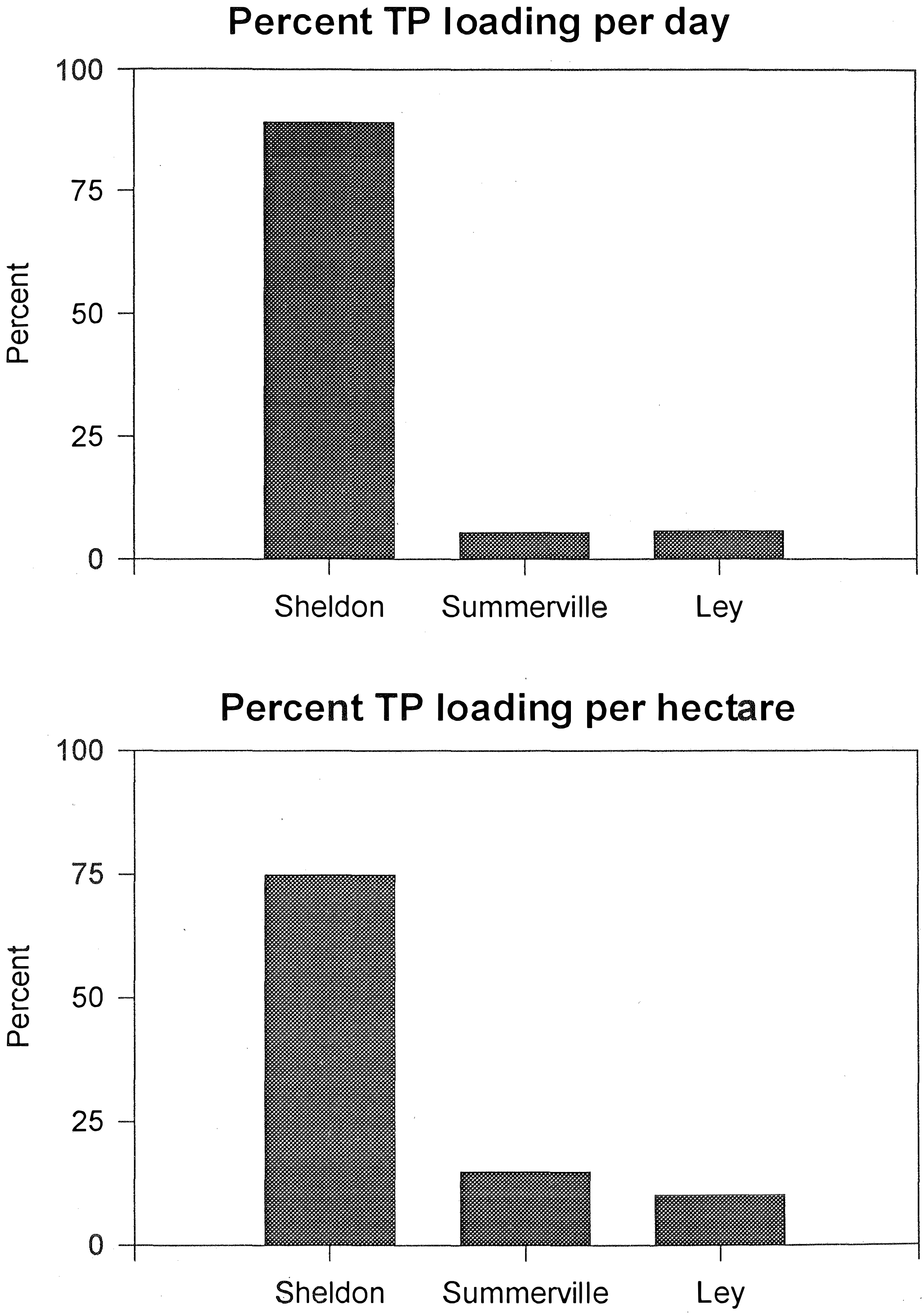
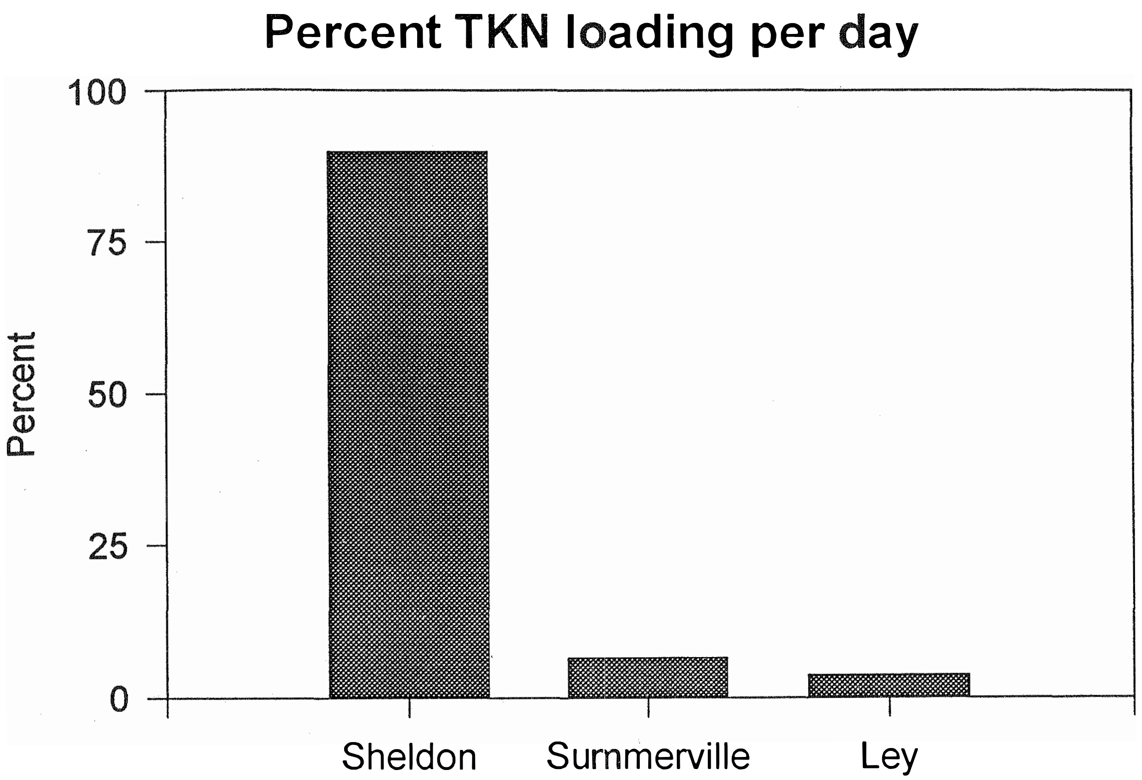


Figure 13. Comparative areal and total loadings from streams into Lake Neatahwanta - total phosphorus.



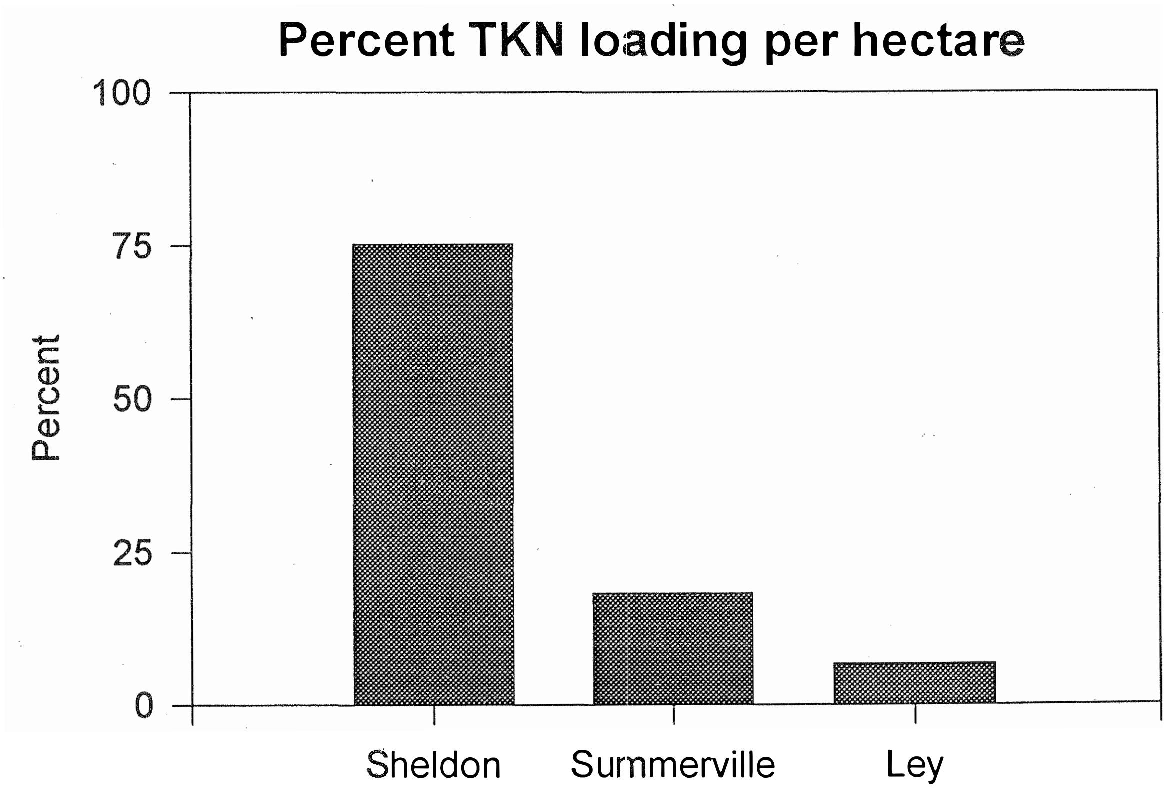
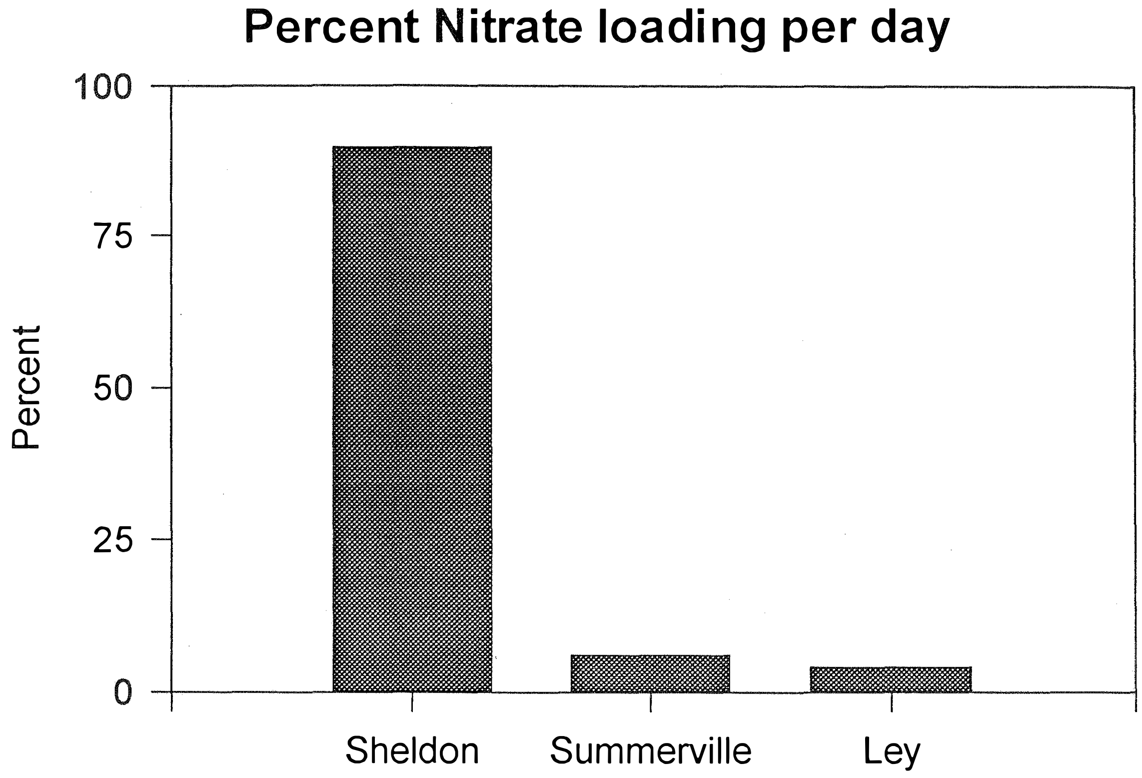


Figure 14. Comparative areal and total loadings from streams into Lake Neatahwanta - total kjeldahl nitrogen.



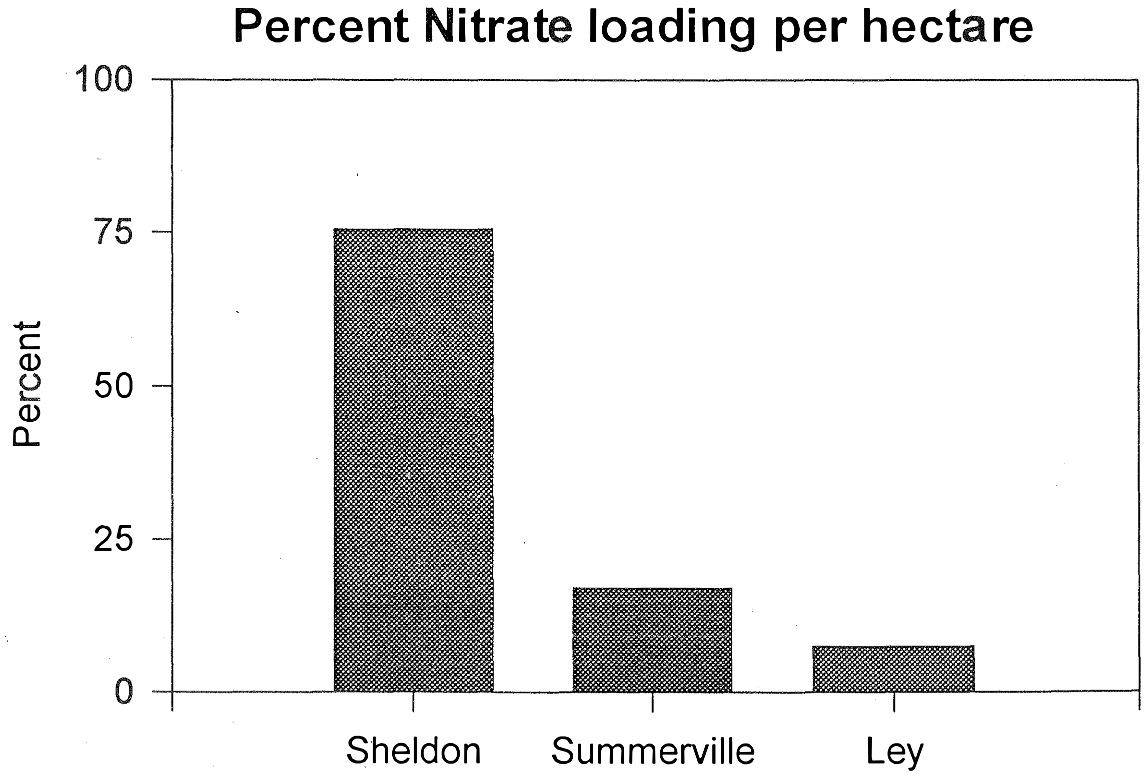


Figure 15. Comparative areal and total loadings from streams into Lake Neatahwanta - nitrate.

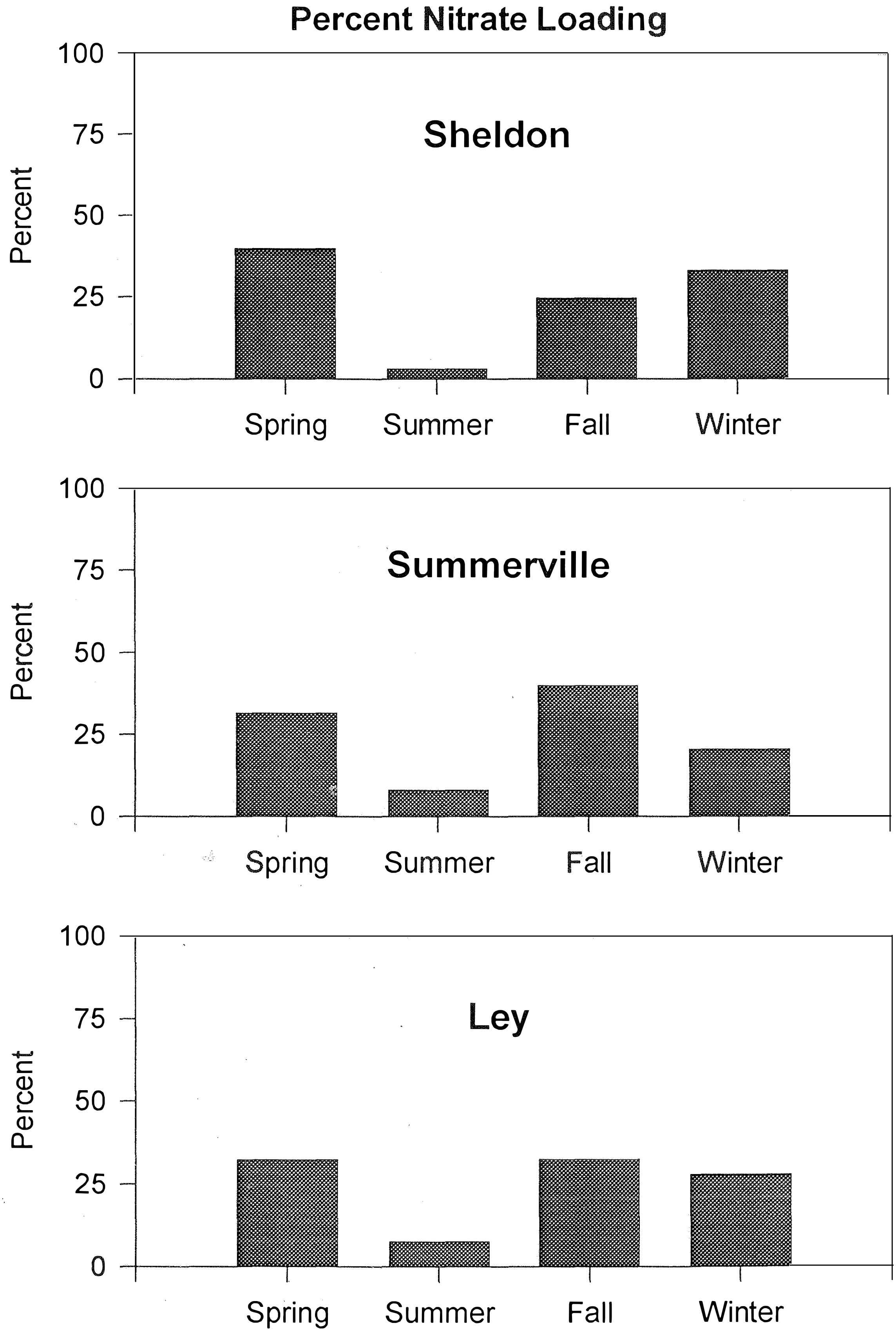


Figure 16. Seasonal loading of nitrate from creeks into Lake Neatahwanta.

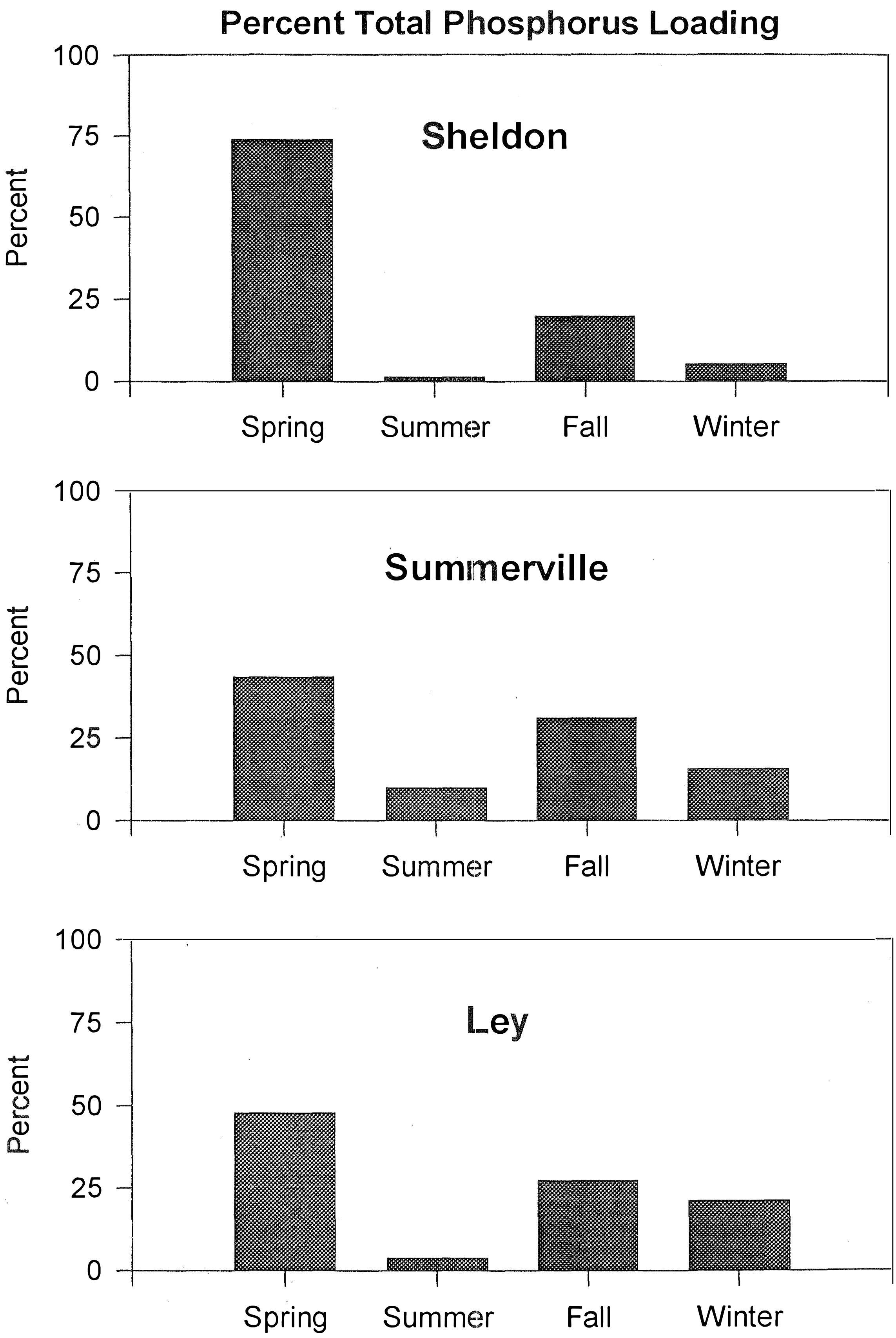


Figure 17. Seasonal loading of total phosphorus from creeks into Lake Neatahwanta.

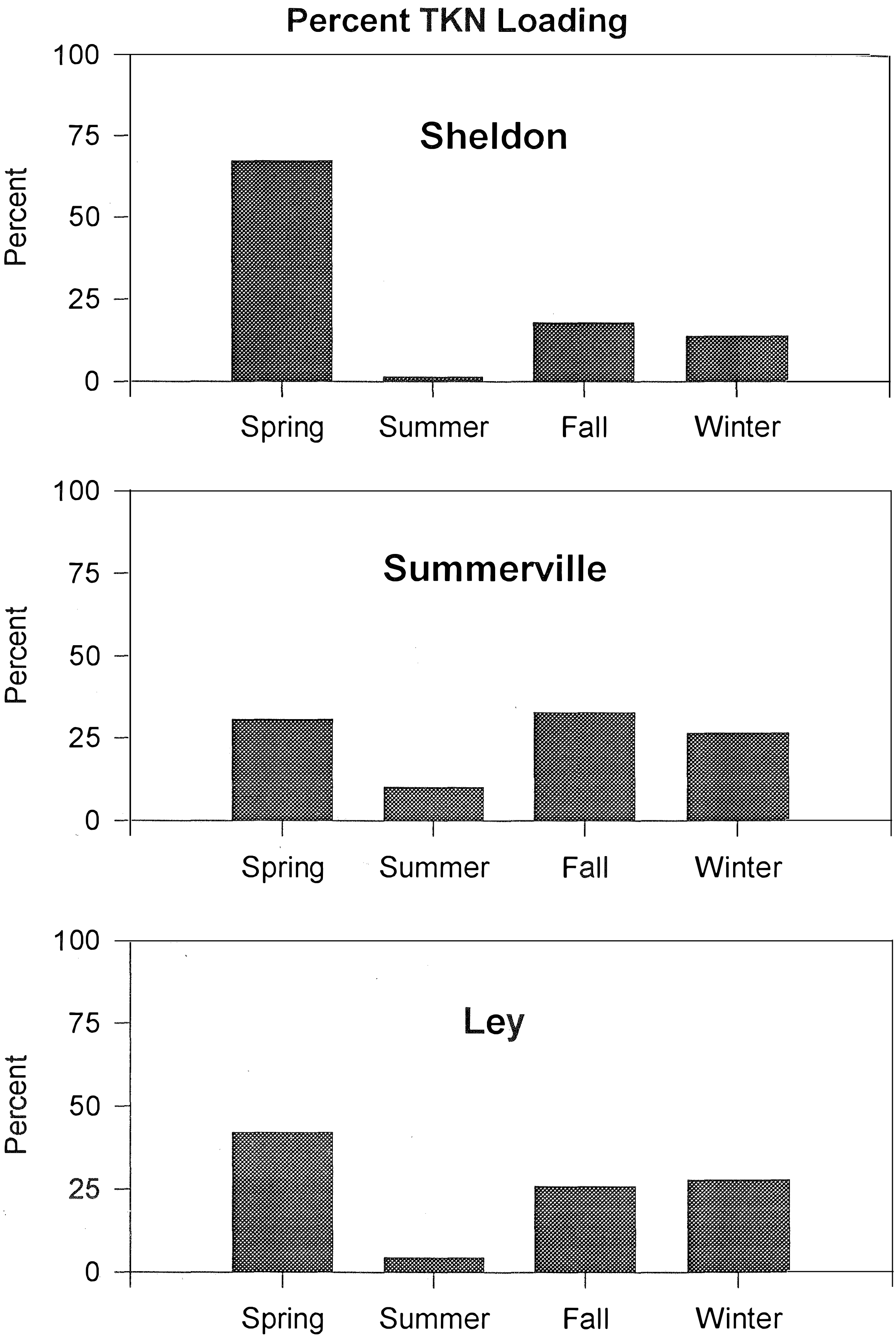


Figure 18. Seasonal loading of total kjeldahl nitrogen from creeks into Lake Neatahwanta.

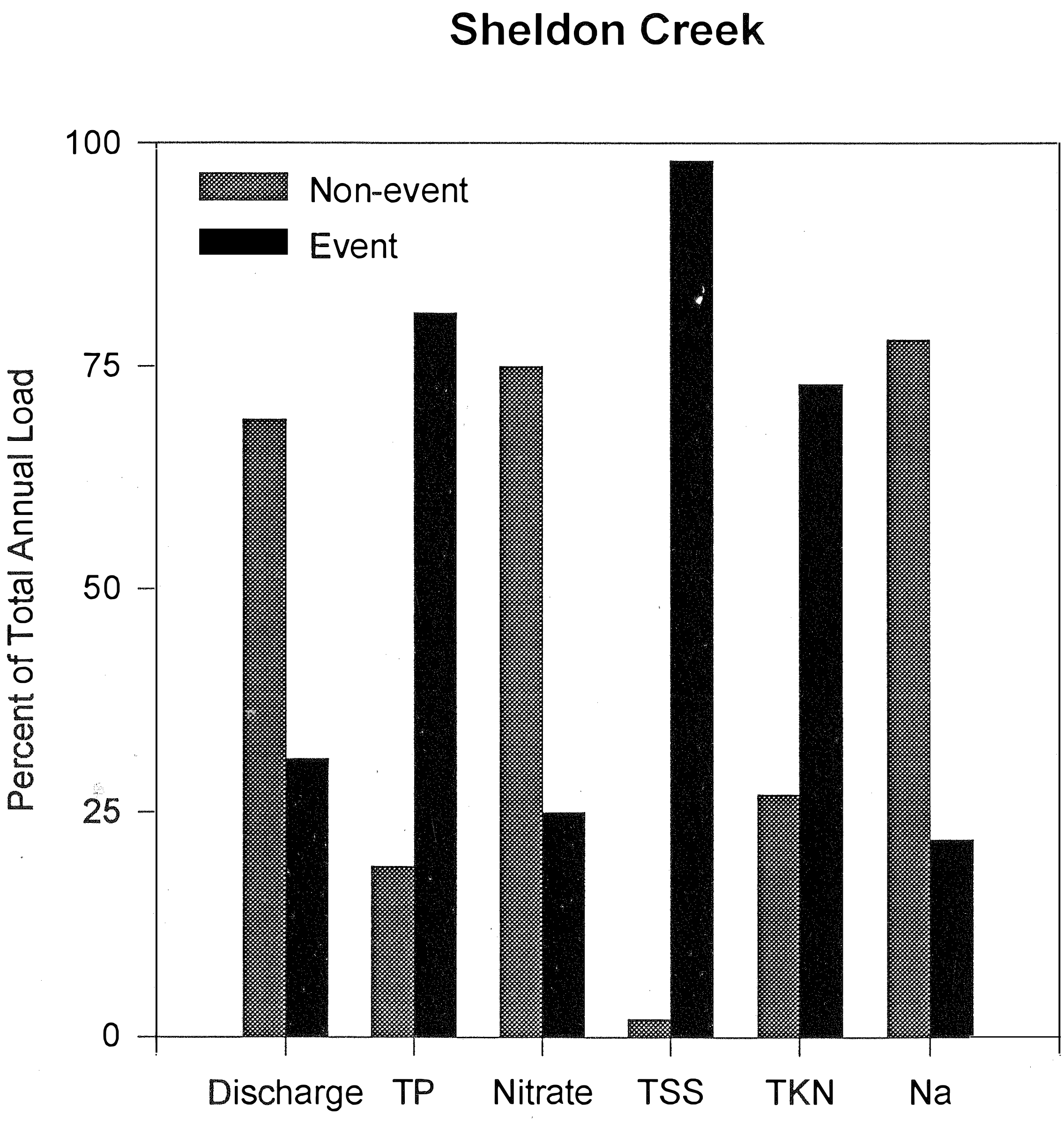


Figure 19. Comparison of event and non-event loading in Sheldon Creek.

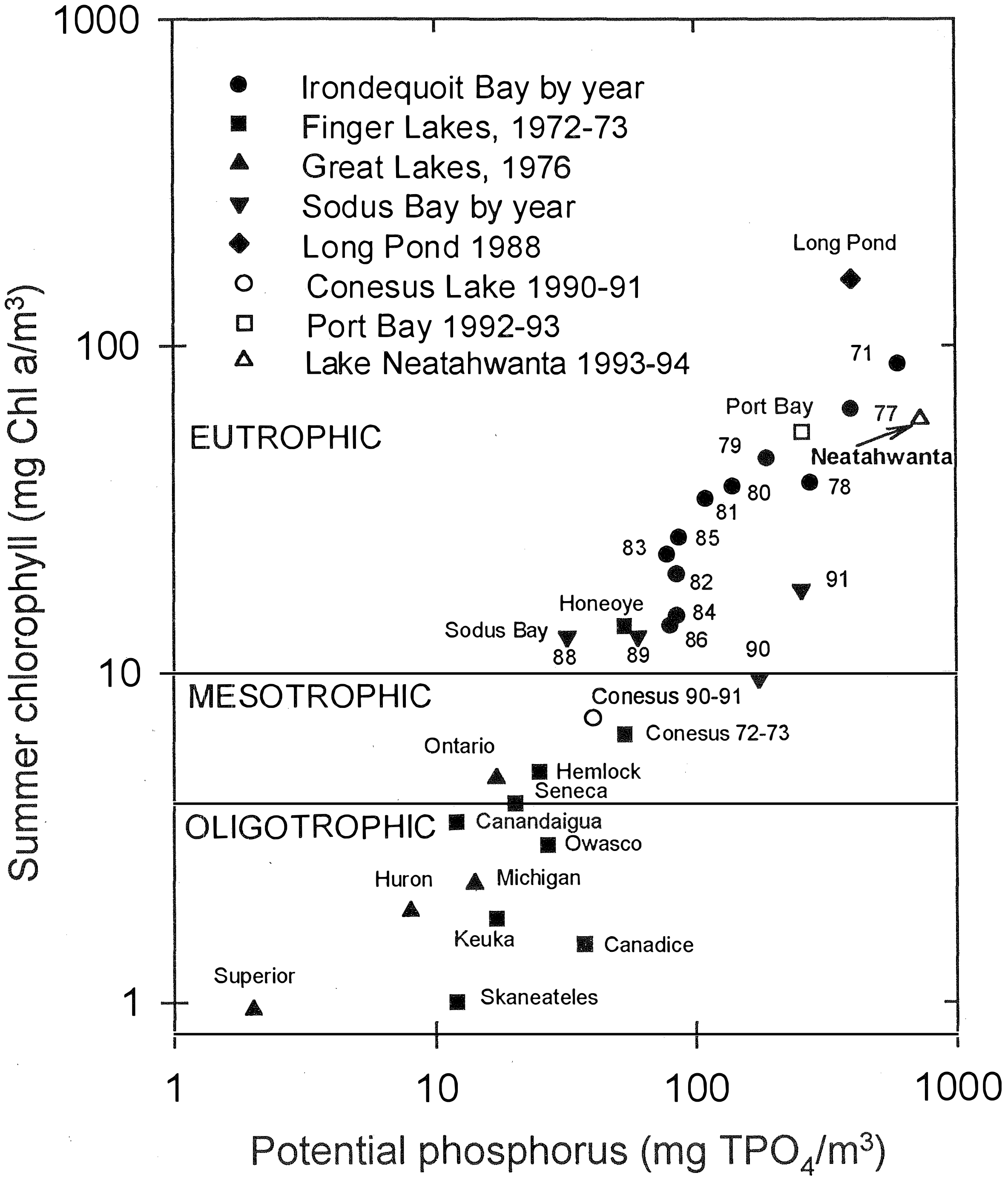


Figure 20. Relationship between mean summer chlorophyll concentration (mg Chl $\underline{a}$/m^3) and potential phosphorus (mg TPO$_4$/m^3), a function of retention time and total phosphorus loading. Modified from Burton (1988) and Vollenweider (1976).