REPORT ON THE LAKE GEORGE INSHORE CHEMICAL MONITORING PROGRAM
JUNE 1988 - OCTOBER 1988

Submitted to

The Lake George Association Fund

by

Lawrence W. Eichler, Laboratory Supervisor

Elizabeth A. Lawrence, Laboratory Assistant

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Dr. Charles W. Boylen, Director

Rensselaer Fresh Water Institute
Rensselaer Polytechnic Institute
Troy, New York 12180-3590

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EXECUTIVE SUMMARY

The Inshore Chemical Monitoring Program was instituted in 1986 and designed to evaluate near-shore water quality and quantify the effects of various land uses on near-shore water chemistry. Sampling locations were selected to be representative of predominant land uses in the basin; including areas with high human population density, high density commercial usage, marina operations, and little or no human impact.

Results from this program have shown that inshore waters have higher levels of orthophosphorus and total phosphorus than mid-lake sites. Soluble silica concentrations were less at inshore sites while other nutrient levels (nitrogeneous compounds) were generally comparable to offshore levels. Sites with human activity were significantly higher in specific conductance, total phosphorus and nitrate concentration than sites in undeveloped areas. Marinas produced the highest concentrations of total phosphorus, however results were not significantly different from other sites with moderate human activity. Differences in nutrient levels were attributed to resuspension from the sediments in the shallow water areas where the sampling sites were located and increased impact from terrestrial runoff.

INTRODUCTION

The sources of the elevated levels of nutrients in the southern basin of Lake George have been the subject of a number of studies (Gibble, 1974; Ferris and Clesceri, 1975; Aulenbach, 1979; Wood and Fuhs, 1979; Sutherland _et al_., 1983; and Dillon, 1983). Although estimates vary on the precise amounts of nutrient loading from various sources, all investigators agree that atmospheric deposition (rain, snow, and dryfall) and surface runoff are the major sources of nitrogen and phosphorus to the lake. The Lake George Chemical Monitoring Program was instituted in 1980 to document any long term changes in nutrient dynamics. The nine years of data collection indicate stable levels of the principle plant nutrients (nitrogen and phosphorus) in the open waters of the lake. Low levels of dissolved oxygen in the deeper water of the South Basin over the last few years however, may be a signal of impending change. This observation, coupled with results from the Coliform Monitoring Program, strongly suggests the need for more intensive study of the inshore waters to detect changes in nutrient levels at an earlier stage.

During the winter of 1985 - 1986, data generated by the Lake George Chemical and Coliform Monitoring Programs over the previous six years were reviewed to assess the ability of these programs to monitor and protect the "health" of Lake George. Although long-term goals were being met by the scope of present programs, there was a desire to document short-term chemical effects of human activities (e.g., nutrient additions such as nitrogen, silica and phosphorus) along the lake shore as well as to compliment coliform data collected by the Fresh Water Institute (Eichler and Boylen, 1985a, 1986a). These discussions resulted in the formulation of a near-shore chemical monitoring effort.

The Inshore Chemical Monitoring Program was instituted in 1986 and designed to evaluate near-shore water quality and quantify the effects of various land uses on near-shore water chemistry. Sampling locations were selected to be representative of predominant land uses in the basin; including areas with high human population density, high density commercial usage, marina operations, and little or no human impact. Samples were collected in water depths of one meter or less to maximize the ability to detect shoreline inputs and reduce the effects of dilution. A fixed time interval sampling schedule, which provided an assessment of "ambient" chemical water quality, was selected for use in the initial years of this program.

Although precipitation event-based sampling is generally considered a more effective method for observing rapid changes in nutrient concentrations associated with surface runoff, a much larger committment of staff and equipment was required than was available. Event-based sampling, at least on a small scale, may be used in future years if deemed appropriate.

During 1986, inshore sites in the North Basin were found to be different chemically from sites with comparable land uses in the South Basin (Eichler and Boylen, 1988a). Differences in the concentrations of various chemical constituents, notably phosphorus and nitrogen compounds, in the surface waters of the two basins of Lake George have been reported in depth (Long *et al.*, 1981; 1982; Eichler *et al.*, 1984; Eichler and Boylen, 1985b; 1986b; 1987; 1988a). These between-basin differences were found to make interpretation of results from various shoreline land uses difficult. In order to reduce between-basin effects, the sampling program was moved to a geographically restricted area (Bolton Bay) in 1987.

SAMPLING SITES AND METHODS

Eight sampling sites were selected to be representative of predominant land uses in the South Basin. Those included areas with: high human population density, high density commercial usage, marina operations, little or no human impact. The sites are characterized by adjacent land use and are described in Table 1. Figure 1 is a map of Huddle Bay pinpointing the sampling sites (see Appendix 2). Where possible, sampling sites were located in areas adjacent to the open water sites used in the Lake George Chemical Monitoring Program (Eichler and Boylen, 1988a).

At each site, two stations were established; one where water depth was 0.5 meters and a second where the depth was 1.0 meter. Sites were sampled biweekly from June 14 through October 11, 1988. This time interval coincides with the period of summer stratification of Lake George. At each site, surface grab samples were collected for analysis of pH, conductivity, chloride, silica, chlorophyll a, calcium, nitrate, ammonia, total phosphorus, total filterable phosphorus, and orthophosphorus. Sample preparation and analytical techniques have been discussed at length in previous reports (Eichler and Boylen, 1986b). A list of analytical techniques employed in this study is included as Appendix 1.

Table 1. Sampling Site Names and Locations. All sites are located in the Town of Bolton.

Site Name	Type	Location
Bolton Landing	C,HD MARINA	West shore of Bolton Bay, 250 meters south of the Green Island Bridge. Adjacendt to a marina operation with high density commercial uses.
Sweetbriar Bay	C, HD MARINA	West shore of the bay on the property line of a marina and a restaurant. Moderate sized paved areas drain into the lake in this area.
East Huddle Bay	R, HD	East shore of Huddle Bay, 200 meters north of the southeast corner of the bay. A vegetated zone (lawn and trees) is maintained along the shoreline.
Stewart Brook	R, HD	West shore of Bolton Bay, 150 meters south of the Town of Bolton Pier. An area of moderate to high residential development.
West Huddle Bay	C, MD	West shore of Huddle Bay, 50 meters north of the mouth of Huddle Bay Brook. Moderate commercial (motels) and residential use.
Hiawatha Bay[1]	C, MD	West shore of Bolton Bay, in a small bay with moderate commercial use (motels). A shallow slope and large lawn areas.
Green Island	U	West shore of Green Island approximately 100 meters north of the DEC facility. This section of the island a maintained trail system but no habitation.
Clay Island	R, LD	Northwest tip of the island. Relatively undisturbed land with a flat slope and no vehicular traffic.

R = Residential; C = Commercial; HD = High Density; U = Undeveloped
MD = Moderate Density; LD = Low Density

[1] This site corresponds to the West Bolton Bay site reported in Eichler and Boylen, 1988b.

RESULTS

The past year was marked by below average amounts of precipitation in the spring of the year (Figure 2)*. Above average precipitation was recorded in both July and August with single storm events contributing a substantial portion of each month's rainfall (NOAA, 1988). A single storm, occurring between July 19 and 21, generated 3.29 inches of rain or 56% of the total monthly precipitation. A similar occurrence on August 28 and 29 produced 3.66 inches of rain or 54% of the total monthly precipitation. Precipitation in September and October was substantially below normal with a 63% deficit in September and a 35% deficit in October.

The pH results for all inshore samples were near neutral (pH = 7). Values ranged from a low of 7.16 at the Bolton Landing 0.5 meter site to a high of 7.81 found at the Clay Island 1.0 meter site (Appendix 3). The mean pH for each of the 0.5 meter sites was comparable to the mean pH for their associated 1.0 meter sites. The samples from marina sites (Bolton Landing and Sweetbriar Bay) and the West Huddle Bay commercial site (means of 7.44 and 7.45, respectively) were somewhat lower in pH than other inshore sites (mean of 7.55). Results for pH were found to differ significantly ($P < 0.001$) between sampling sites and sampling dates. Seasonal trends however, were not apparent. The pH values for inshore sampling sites were not substantially different from those reported for adjacent offshore sites (Eichler and Boylen, 1989).

* All Figures are included as Appendix 2. Tables are included as Appendix 3.

Conductivity results ranged from 92 to 126 umhos (Appendix 3 and Figure 3). The marina sites, Bolton Landing and Sweetbriar Bay, generally had higher conductivity results (mean = 102 umhos) than other sites with the exception of the Clay Island 0.5 meters site (mean = 100.2 umhos). A single conductivity of 126.0 umhos at the Clay Island 0.5 meter site on July 12th however, may have unduly biased this result, since neglecting this one value reduced the mean for this site to a level comparable to other non-marina sites (96.5 umhos). Marina sites however, were found to differ significantly ($P < 0.001$) from other sites. The Sweetbriar Bay 1.0 meter site in routinely displayed the highest conductivity values. The specific conductance of samples from inshore sites was slightly higher than for comparable offshore sites.

Chloride concentrations were highest at the Sweetbriar Bay 0.5 and 1.0 meter sites (range 7.4 - 9.5 ppm Cl). High chloride concentrations were generally observed in samples collected on July 12th. Marina sites produced the greatest mean chloride concentration, 8.2 ppm, while commercial and undeveloped sites shared a comparably low mean chloride concentrations, 7.8 ppm. Residential sites were intermediate with a mean of 8.0 ppm.

Nitrate and ammonia concentrations (Appendix 3 and Figures 5 and 6) were routinely below the limit of detection for our laboratory (0.01 mg N/l). Early in the sampling season (June 14th) detectable levels of nitrate were present at most sites adjacent to developed areas (range 0.01 to 0.14 mg N/l).

Measureable concentrations of nitrate were not observed at sites without development. Ammonia concentrations at inshore sites were only rarely above the detection limit of our laboratory with a maximum level of 0.02 mg N/1 found in six samples. The commercial site at West Huddle Bay was the only site to routinely have measureable concentrations of both nitrate (mean 0.03 mg N/1) and ammonia (mean 0.01 mg N/1).

Concentrations of Total Phosphorus (TP) were highest at the sites in developed areas (Appendix 3 and Figure 7). TP concentrations in samples from inshore waters ranged from 3 to 50 ug P/1. The marina site at Bolton Landing, 1.0 meter, produced the highest single (50 ug P/1) and mean (11.3 ug P/1) TP concentrations. Removal of the single excessively high value yielded a mean of 5.7 ug P/1 which is within the range of other developed sites. With the exception of Bolton Landing and West Huddle Bay, the 1.0 meter sites had TP concentrations which were comparable to results from the adjacent deeper water (0-2 m and 0-10 m) sites in the Offshore Chemical Monitoring Program (Eichler and Boylen, 1989).

A wide range of TP concentrations were observed in inshore samples when compared to offshore results for similar areas. However, most 0.5 meter sites had higher TP concentrations than either the associated 1.0 meter sites or nearby deeper water sites. The 0.5 meter site at Clay Island (mean = 4.3 ug P/1) had the lowest average TP concentration. The 0.5 and 1.0 m sites at Green Island also had low mean concentrations of TP (4.8 and 4.5 ug P/l, respectively). Both Green Island and Clay Island sites are relatively undeveloped areas.

Total Filterable Phosphorus (TFP) concentrations were highest at the West Huddle Bay 0.5 and 1.0 meter sites followed by Sweetbriar Bay and Bolton Landing (Appendix 3 and Figure 8). TFP concentrations at all sites ranged from 2 to 10 ug P/l with a median value of 2 ug P/l. Highest TFP values were recorded on June 14th. Sample results for all other dates were substantially lower in TFP concentration. Differences in TFP concentrations between shoreline uses were not found to be statistically significant. With the exception of West Huddle Bay, TFP concentrations at inshore sites were comparable to offshore sites.

Orthophosphorus (OP) concentrations (Appendix 3 and Figure 9) at all sites were near the detection limit of our laboratory (1.0 ug P/l). Unlike open water areas of Lake George, mean concentrations of OP were above 1.0 ug P/l at all sites. Maximum OP concentrations were observed at the West Huddle Bay 0.5 meter site, with a range from less than 1 to 4 ug P/l. The 0.5 meter sites generally exhibited greater concentrations of OP than their associated 1.0 m sites, although differences were not large. Differences in OP concentrations between shoreline uses were not found to be statistically significant.

Concentrations of soluble reactive silica ranged from 0.76 to 1.99 mg Si/l through the period of sampling, and were similar at the 0.5 and 1.0 m sites at all locations (Appendix 3). Highest average silica concentrations were observed at the West Huddle Bay site, 1.17 mg Si/1 (Figure 10). Samples from the East Huddle Bay site also contained soluble reactive silica concentrations slightly higher than other sites, with mean concentrations of 0.88 and 0.86 mg Si/1 for the 0.5 and 1.0 meter stations, respectively. Mean silica concentrations for all other sites ranged between 0.82 and 0.84 mg Si/1. Silica concentrations in inshore samples were generally less than in adjacent offshore sampling sites with the exception of West Huddle Bay.

Calcium concentrations were variable between sites (Appendix 3). The greatest mean calcium concentrations were found at the 0.5 meter station at Bolton Landing (10.6 mg Ca/1). The 0.5 meter stations generally had higher calcium concentrations than their related 1.0 m stations (Figure 11). Calcium concentrations generally increased over the sampling season.

Concentrations of chlorophyll _a_ were highly variable and differences were not statistically significant between dates or between sites (Appendix 3). The low levels of chlorophyll _a_ present in the samples (range 0.5 to 3.1 ug chl_a_/1) coupled with the variability of the data, makes any discussion of trends highly speculative.

DISCUSSION

Sampling strategy and frequency appears to be adequate for the original program goals, however, a comparison of event based versus fixed interval sampling may be considered in future studies. Runoff event based sampling is timed to precipitation or rapid snow melt episodes when large amounts of runoff occur. Precipitation and runoff are major sources of nutrients to Lake George. Rapid changes in water chemistry (Singer *et al*., 1981; Sutherland *et al*., 1983) and bacterial abundance (Eichler *et al*., 1987; 1988) of tributaries to Lake George following precipitation events have been observed. These changes were generally of short duration (24 to 48 hours), indicating that they may not be detected by a fixed interval sampling program. High intensity recreational use such as that occuring on holiday weekends, may also cause substantial short term perturbations of near shore water chemistry. The impact of this type of activity should also be considered in event based sampling.

A comparison of major precipitation events and sampling dates indicates that sampling during this study generally occurred shortly before a major rainfall with a lapse of 4 to 13 days before a subsequent sampling. The lack of any consistent trends in nearshore nutrient chemistry relative to major rainfall events and subsequent runoff may dictate the need for event based sampling. Significant differences in nutrient concentrations in inshore waters between sampling dates were seen, but these differences were not correlated to precipitation events. The inability of this study to correlate changes in nutrient concentrations in nearshore waters to major precipitation events (Figures 11 and 12) is in all probability due to the sampling regime rather than the lack of occurrence of this phenomena.

Inshore sampling sites were found to have higher levels of orthophosphorus and total phosphorus than found at offshore sites. Soluble silica concentrations were lower at inshore sites while levels of nitrate exceeded offshore concentrations during the spring of the year, but declined to comparable levels as the summer progressed.

With the exception of nitrate, no seasonal trends in the measured parameters were observed. Early summer (June) concentrations of nitrate at inshore sites were higher than at adjacent offshore sites. Measureable nitrate concentrations have been characteristic of spring (pre-summer stratification) conditions in offshore waters, and has been generally attributed to runoff from snowmelt (Eichler and Boylen, 1986b; 1987; 1988). Johannes _et al_. (1982) reported seasonal differences in nitrate concentrations of precipitation, with snow exhibiting greater concentrations of nitrate. Meltwaters derived from snowpack also contained substantial amounts of nitrate (Singer _et al_., 1981). During major snowmelt episodes, frozen soils allow the bulk of meltwaters to run off directly into streams or lakes without the benefit of nutrient removal generally associated with percolation through soil layers.

Runoff from the terrestrial portion of the lake's basin has been shown to account for a major fraction of the entire phosphorous budget of the lake (Sutherland _et_ _al_., 1983; Dillon, 1983). The nearshore areas receive the most concentrated runoff of phosphorous via both diffuse overland flow and concentrated flow from streams and stormwater drains. Dilution of this runoff by the inshore waters, sedimentation of particulate materials, and uptake of nutrients by the plant and animal communities of the lake, substantially reduce or alter the concentrations of nutrients in the water column. This process appears to occur rapidly with changes in nutrient concentrations of nearshore waters returning to "ambient" levels within several days of a major precipitation and runoff episode.

Silica is derived principally from erosion in the terrestial portion of the basin or from resuspension of lake sediments. Thus, higher levels would be expected near shore. Soluble reactive silica concentrations at the inshore sampling sites were generally less than nearby deeper water (0-2 m) locations. The commercial site at West Huddle Bay was an exception, in that the impact of a nearby stream on this site may account for the increased loading. The principle mechanism for soluble silica removal from the water column is through incorporation into the frustules (siliceous coating) of diatoms. Whether the diatom populations and/or growth in inshore waters are substantially greater than those of adjacent deeper waters was not a part of this study, but this question should be pursued as a basic part of understanding nutrient flux in the lake.

Significant differences were observed between sites with some form of development and those characterized as undeveloped. The principle differences were in pH, specific conductance and the concentrations of nitrate (Figure 13) and TP (Figure 14). Marina sites displayed lower pH and higher specific conductance than other sites. Concentrations of nitrate and TP were also higher at the marina sites than other inshore sites with the exception of the commercial site at West Huddle Bay. Elevated nutrients levels at marina sites could be caused in two ways; through resuspension from bottom sediments due to intensive recreational activities in these areas and/or enhanced stormwater runoff effects from reduced percolation of these waters into the ground. Resuspension of nutrients from bottom sediments due to recreational boat traffic has been reported (Yousef _et al_., 1980). The intensity of boat traffic within the environs of a marina would maximize the input of nutrients from this source. At marinas, limited percolation of runoff waters into the ground is caused by a predominance of impermeable surfaces, such as roofs and pavement, extending to the water's edge. Impermeable surfaces accelerate runoff and restrict infiltration, thus bypassing natural filtration by soils and vegetation.

Other developed areas characterized as commercial or residential produced nearshore TP concentrations substantially higher than undeveloped areas (Figure 14), however concentrations of TFP and OP were not significantly different between land uses. Thus, differences observed in total phosphorous concentrations in nearshore waters are attributable to phosphorus present in a particulate form. If these particulates are terrestrially derived, vegetative cover can be used as a "green belt" along the shore of the lake, acting as a fairly effective filter to remove particulates by slowing the flow of runoff waters.

The commercial site at West Huddle Bay had high levels of nutrients, particularly silica. This site, sheltered by a number of docks which limited water circulation, had an abundant growth of aquatic plants. Lack of circulation coupled with aquatic plant nutrient uptake from the sediments may have accounted for elevated nutrient levels observed at this site. The presence of Huddle Bay Brook's outlet close by may have also affected nutrient levels, though the flow appeared to be diverted by the docks. The impact of this brook on nearshore water chemistry may be substantial given the history of bacterial and chemical contamination attributed to failing septic systems along its course (Eichler _et al_., 1987; 1988). The elevated levels of nutrients and silica found are characteristic of streams draining into Lake George (Wood and Fuhs, 1973; Sutherland _et al_., 1983; Eichler and Boylen, 1988; 1989). Therefore, this site's major controlling factor may be the proximity to Huddle Bay Brook and not adjacent land uses.

Ion concentrations at inshore sampling sites ranged more widely than at the adjacent deeper water locations. This phenomena was expected since previous investigators (Singer _et al_., 1981; Sutherland _et al_., 1983) have reported large shifts in concentration of a number of ions in streams and other shoreline drainage systems related to precipitation, surface runoff, and land use activities. Dilution of these inputs by the large volume of the lake tends to mediate long term changes in nutrient concentrations in the open waters.

The results of this program indicate that elevated levels of nutrients coupled with lower pH are characteristic of the sampling sites with some form of development when compared to undeveloped areas. Since both marina sites are near a main highway (Route 9N), highway runoff may also be contributing to nutrient and salt levels at these sites. One of the two moderate density commercial sites, West Huddle Bay, also displayed elevated concentrations of nutrients. This site may be influenced by the outflow from Huddle Bay Brook, but the apparently stagnant conditions and density of submersed aquatic plants at this site may indicate other nutrient sources.

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REFERENCES

Aulenbach, D.B. 1979. Nutrient budgets and the effects of development on trophic conditions in lakes. Fresh Water Institute Report No. 79-2, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Dillon, P.J. 1983. Nutrient budgets for Lake George, New York. In: C.D. Collins (ed.) The Lake George Ecosystem, Volume III. The Lake George Association, Lake George, NY pp 157-167.

Eichler, L.W. and C.W. Boylen. 1985a. Report on the Lake George coliform monitoring program (1984). Fresh Water Institute Technical Report No. 85-7, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1985b. Report on the Lake George monitoring program. (April 1984 - November 1984). Fresh Water Institute Technical Report No. 85-6, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1986a. Report on the Lake George coliform monitoring program (1985). Fresh Water Institute Technical Report No. 86-1, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1986b. Final report on the Lake George chemical monitoring program. (April 1985 - December 1985). Fresh Water Institute Technical Report No. 86-4, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1987. Report on the Lake George chemical monitoring program, March 1986 - November 1986. Fresh Water Institute Technical Report No. 87-2, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1988a. Report on the Lake George chemical monitoring program. January 1987 - November 1987. Fresh Water Institute Technical Report No. 88-2, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1988b. The Lake George inshore chemical monitoring program. Fresh Water Institute Technical Report No. 88-3, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W. and C.W. Boylen. 1989. Report on the Lake George chemical monitoring program. January 1988 - December 1988. Fresh Water Institute Technical Report No. 89-3, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W., C.W. Boylen, and K.A. Regan. 1988. Final report on the Lake George coliform program (1988). Fresh Water Institute Technical Report No. 88-10, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W., D.R. Long, and C.W. Boylen. 1984. Report on the Lake George monitoring program (April 1983 - November 1983). Fresh Water Institute Technical Report No. 84-1, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Eichler, L.W., K.A. Regan, and C.W. Boylen. 1987. Final report on the Lake George coliform program (1987). Fresh Water Institute Technical Report No. 87-5, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Ferris, J.J. and N.L. Clesceri. 1975. A description of the trophic status and nutrient loading for Lake George, New York. In: North American Project - A Study of U.S. Water Bodies. EPA-600/3-77-086, USEPA, Corvallis, OR.

Gibble, E.B. 1974. Phosphorus and nitrogen loading and nutrient budget on Lake George, New York. Masters Thesis, Rensselaer Polytechnic Institute, Troy, NY.

Johannes, A.H., R.A. Goldstein, and C.W. Chen. 1982. A watershed approach - the EPRI - integrated lake watershed acidification study (ILWAS). In: Acid Precipitation: Effects on Ecological Systems, Ann Arbor Science Publishers, Inc.

Long, D.R., L. Eichler, D.A. Roberts, T.C. Ryan, D.B. Shafer, J. Schaninger, K.L. Smith, and D.H. Pope. 1981. The Lake George Monitoring Program for the year April 1980 - April 1981. Fresh Water Institute Technical Report No. 81-3, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Long, D.R., L.W. Eichler, R.F. Clifford, and D.H. Pope. 1982. The Lake George Monitoring Program. Fresh Water Institute Technical Report No. 82-4, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

National Oceanic and Atmosheric Administration (NOAA). 1988. Climatological data, New York. Vol.100.

Singer. R., K. Smith, D.A. Roberts, and D.R. Long. 1981. Effects of heavy mid-winter rainstorm on water quality of Smith Bay, Lake George, New York. Fresh Water Institute Technical Report No. 81-4, Rensselaer Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY.

Sutherland, J.W., J.A. Bloomfield and J.M. Swart. 1983. Final report for the Lake George urban runoff study, nationwide urban runoff program. Bureau of Water Research, New York State Department of Environmental Conservation, Albany, NY.

Wood, L.W. and G.W. Fuhs. 1979. An evaluation of the eutrophication process in Lake George based on historical and 1978 limnological data. Environmental Health Report No. 5, Environmental Health Center, Division of Laboratories and Research, New York State Department of Health, Albany, NY. 73 pp.

Yousef, Y.A., W.M. McLellon and H.H. Zebuth. 1980. Changes in phosphorus concentrations due to mixing by motorboats in shallow lakes. Water Res. 14, p. 841-852.

APPENDIX 1

Analysis	Method	Instrument
pH	Electrometric (EPA Method 150.1)	Orion, Model 811
Specific Conductance	Wheatstone Bridge type meter (EPA Method 120.1)	YSI, Model 31
Dissolved Oxygen	Membrane Electrode (EPA Method 360.1)	YSI, Model 54
Chloride	Automated Ferricyanide (EPA Method 325.2)[1]	Technicon Autoanalyzer II
Nitrate	Automated Cadmium Reduction (EPA Method 353.2)[1]	Technicon Autoanalyzer II
Ammonia	Automated Phenate (EPA Method 350.1)	Technicon Autoanalyzer II
Total Phosphorus	Colorimetric (EPA Method 365.2)	Bausch & Lomb Spec 710
Total Filterable Phosphorus	Colorimetric (EPA Method 365.2)	Bausch & Lomb Spec 710
Ortho Phosphorus	Colorimetric (EPA Method 365.2)	Bausch & Lomb Spec 710
Calcium	Direct Aspiration (EPA Method 215.1)	Perkin-Elmer Model 403
Soluble Reactive Silica	Automated Molybdate (Technicon Method)	Technicon Autoanalyser II
Chlorophyll _a_	Methanol Extraction	Bausch & Lomb Spec 710

EPA Methods listed in this table are derived from: USEPA, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Cincinnati, OH.

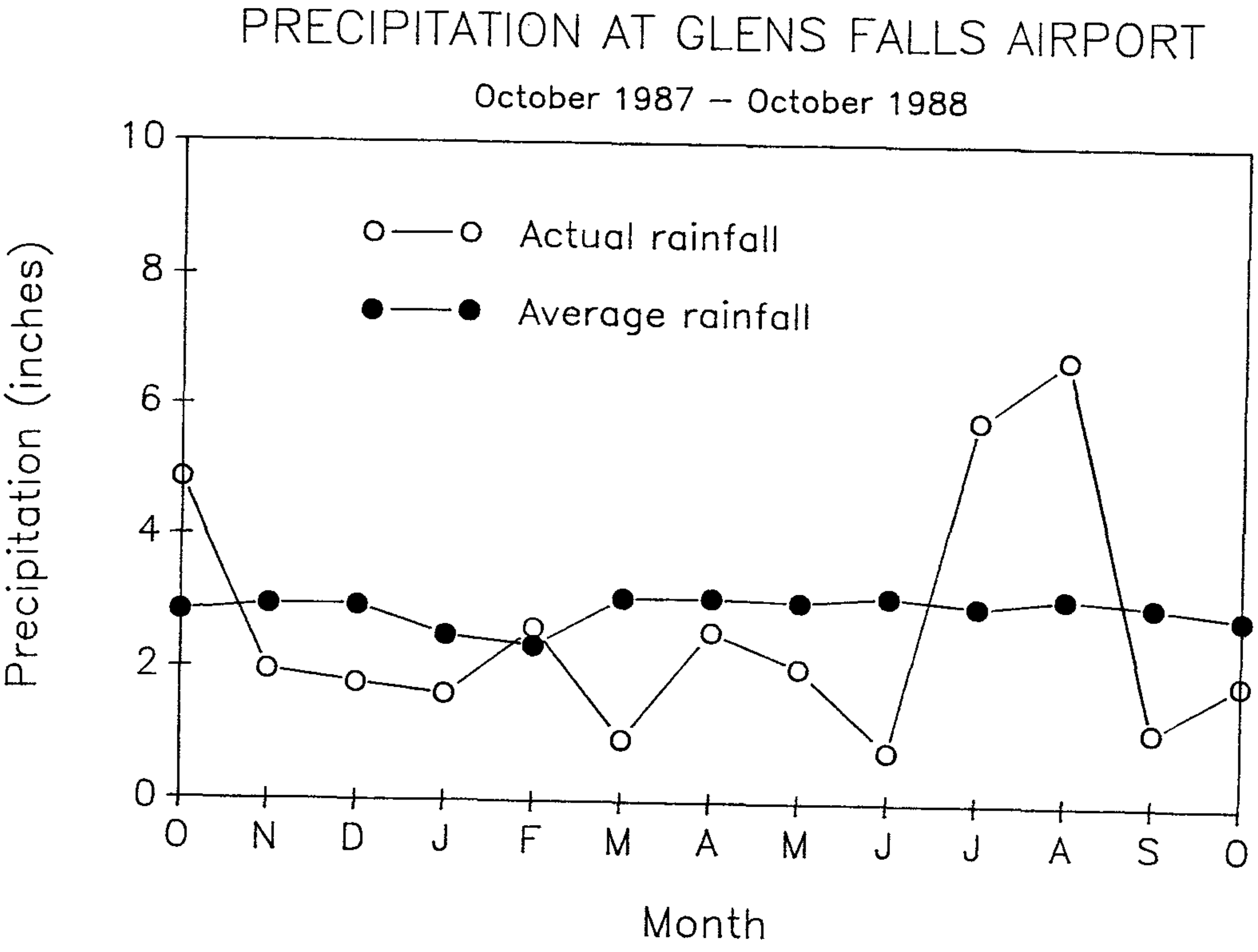

Figure 2. Precipitation at Glens Falls Airport.

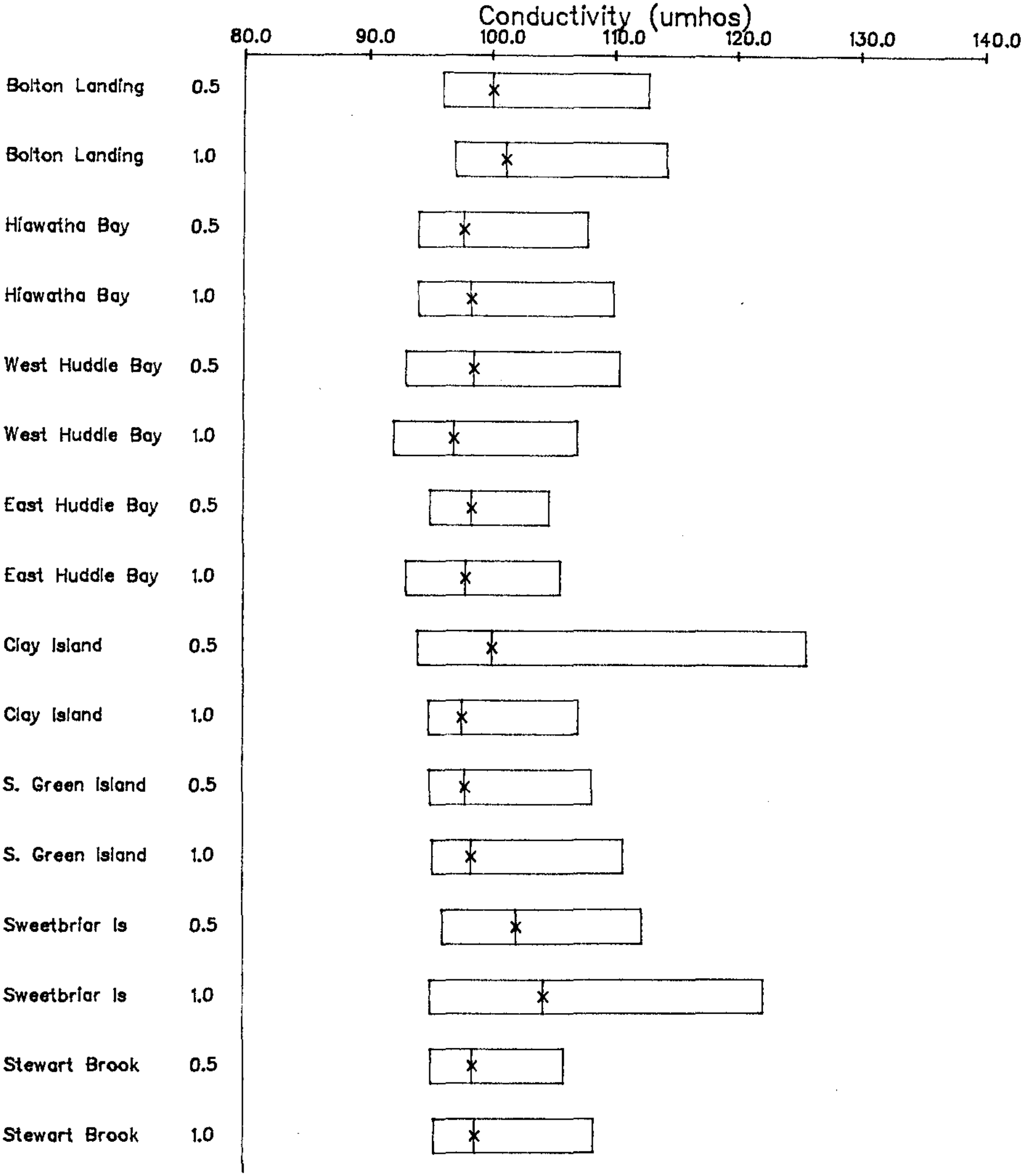

Figure 3. Minimum, maximum and average conductivity at each inshore site.

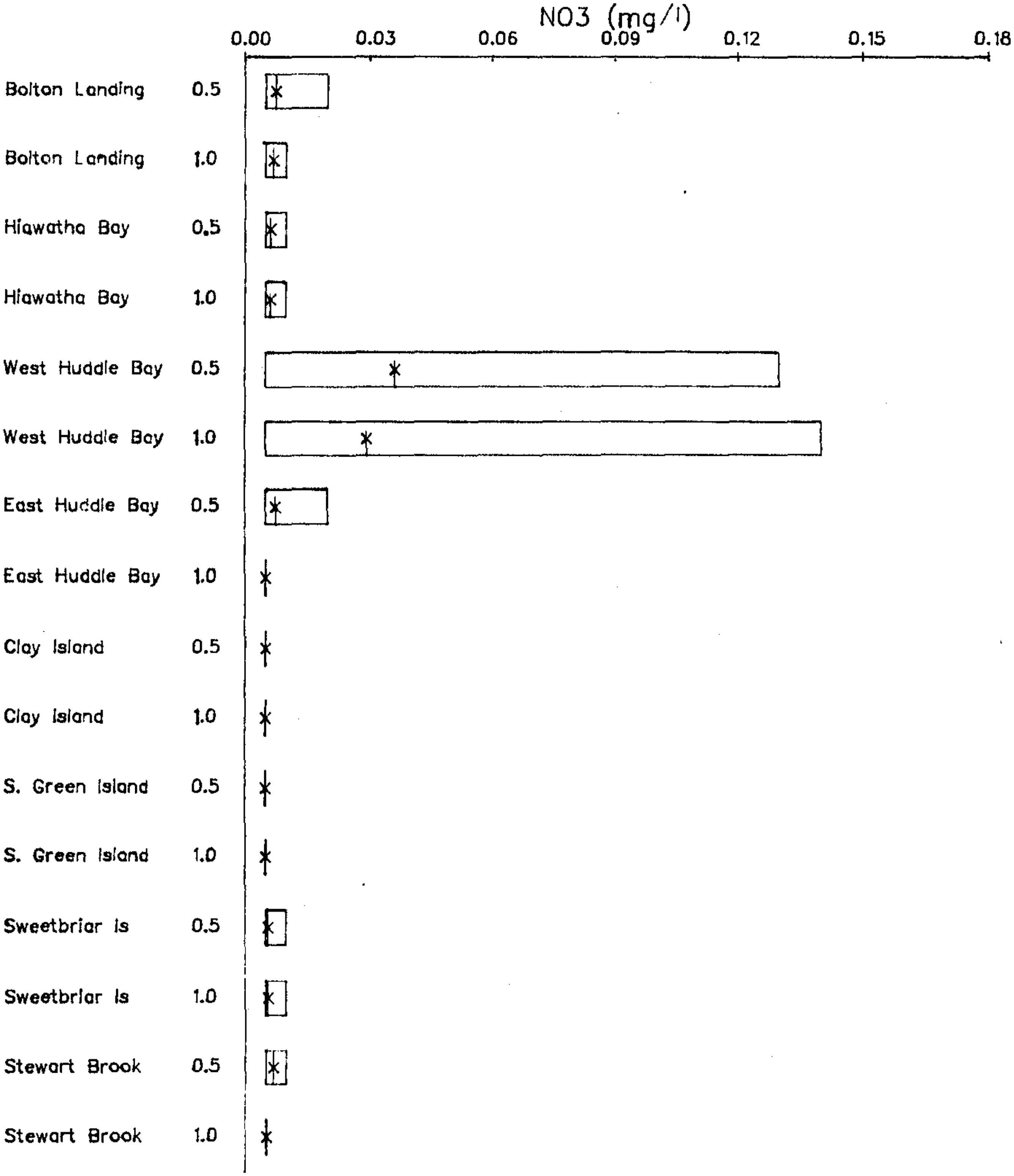

Figure 4. Minimum, maximum and average nitrate concentrations at each inshore site.

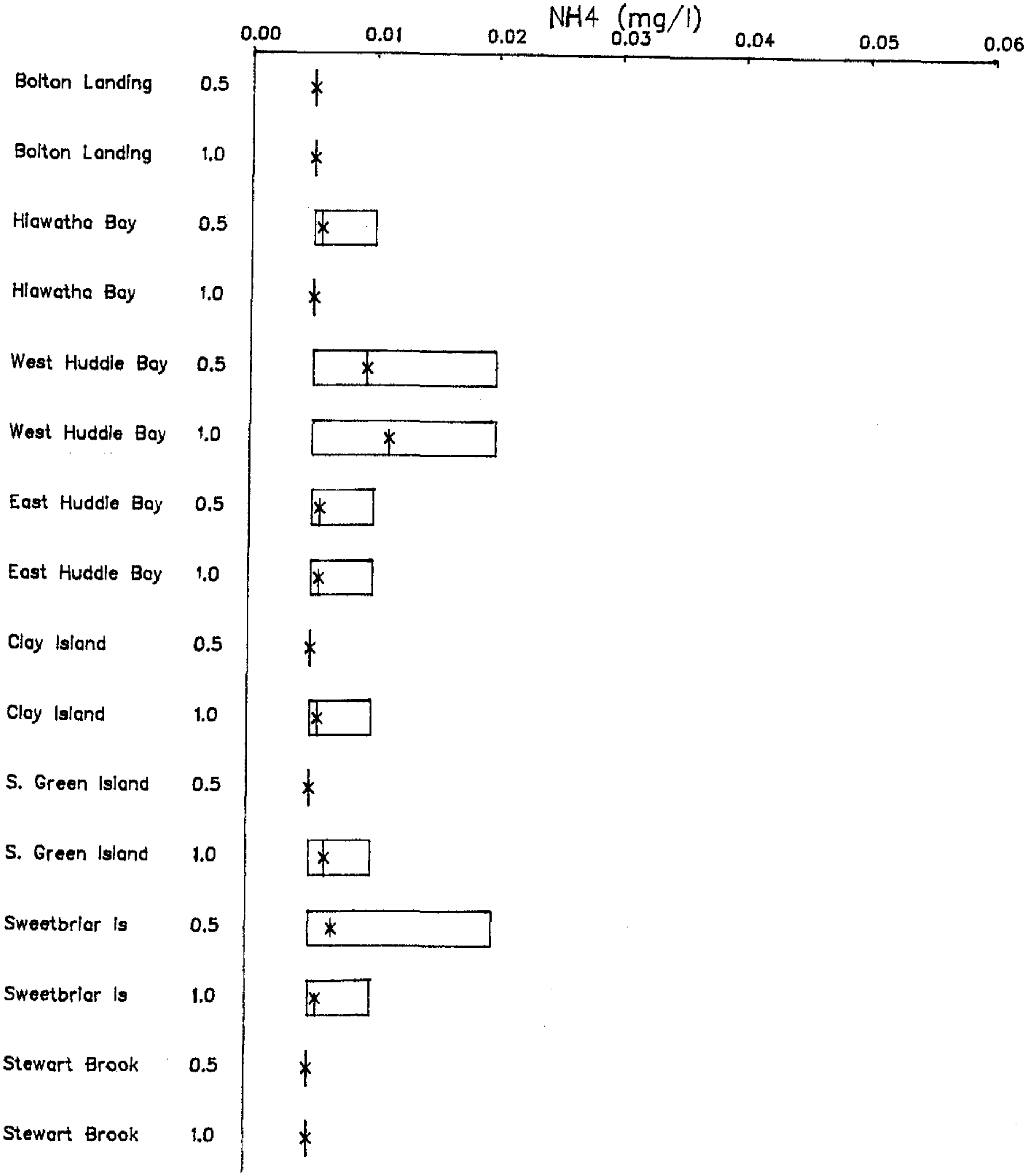

Figure 5. Minimum, maximum and average ammonia concentrations at each inshore site.

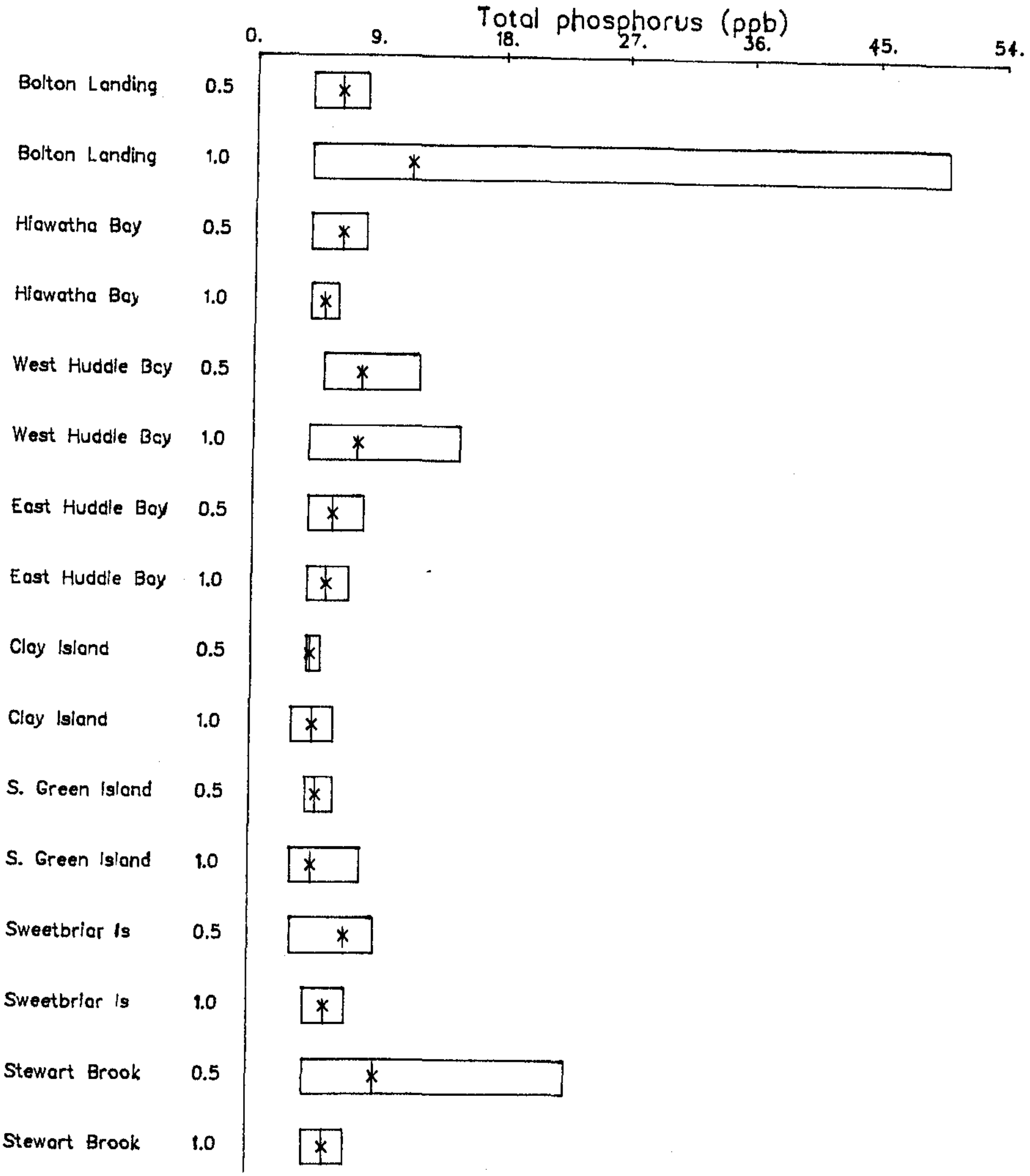

Figure 6. Minimum, maximum and average total phosphorus concentrations at each inshore site.

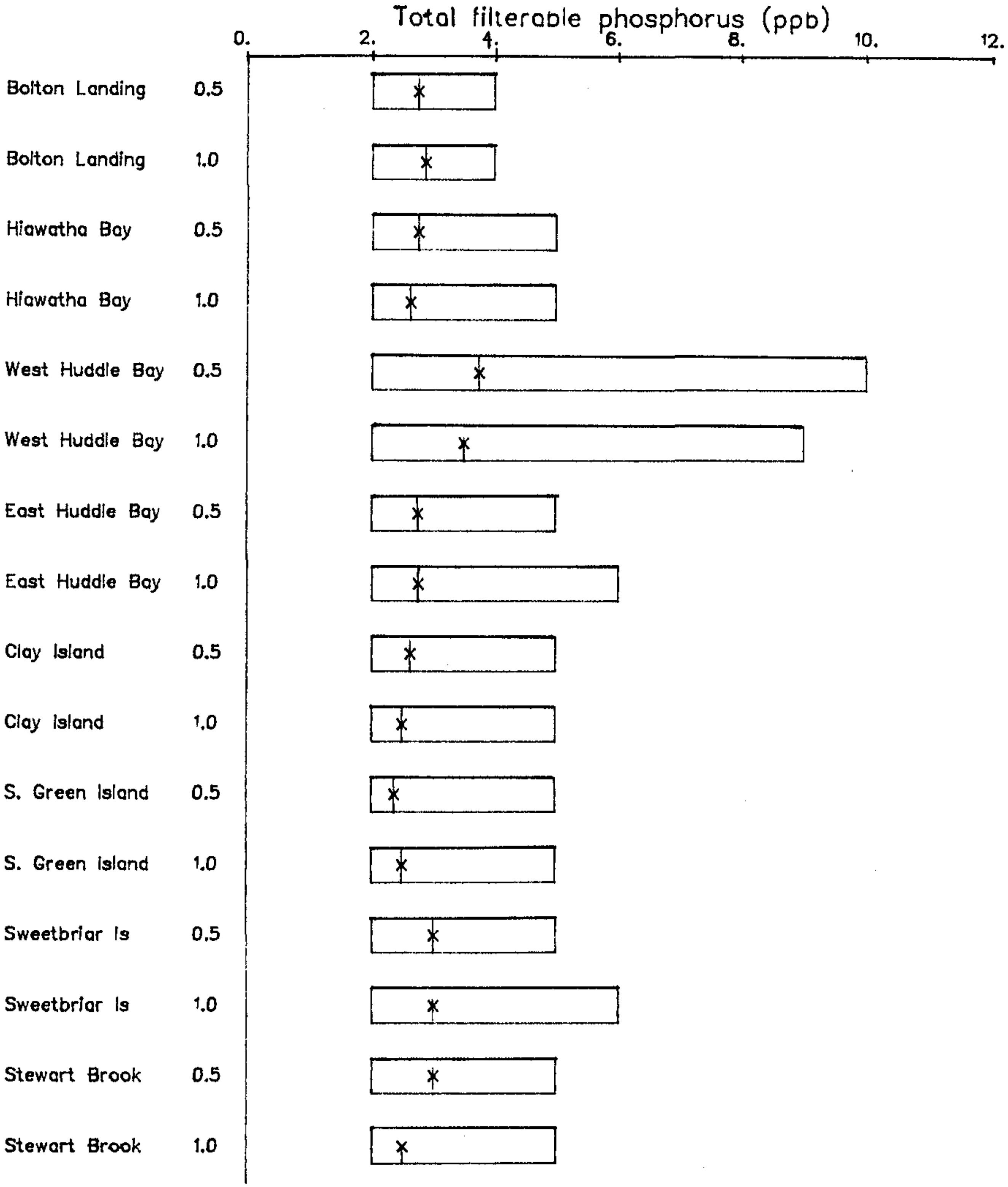

Figure 7. Minimum, maximum, and average total filterable phosphorus concentrations at each inshore site.

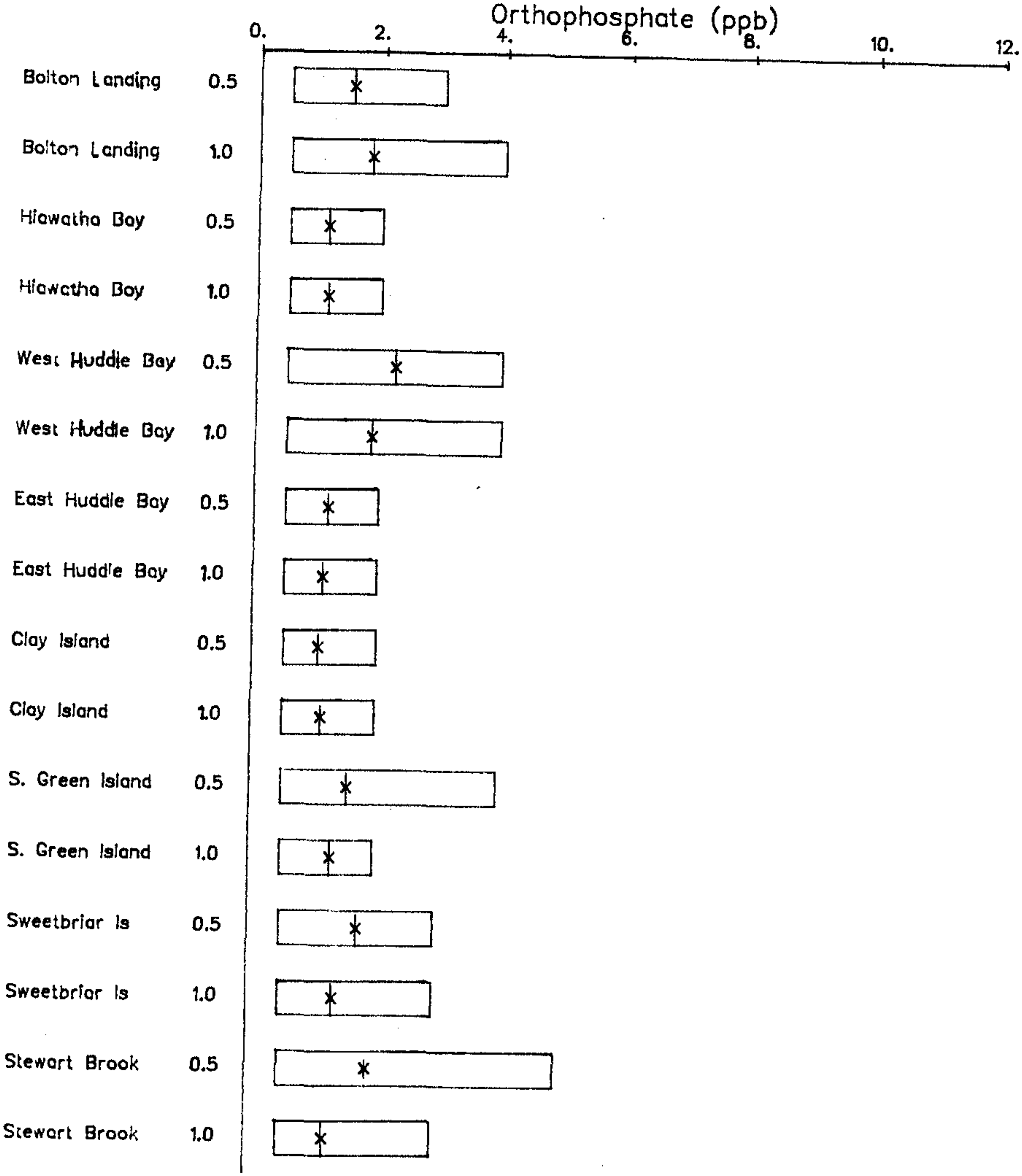

Figure 8. Minimum, maximum and average orthophosphorus concentrations at each inshore site.

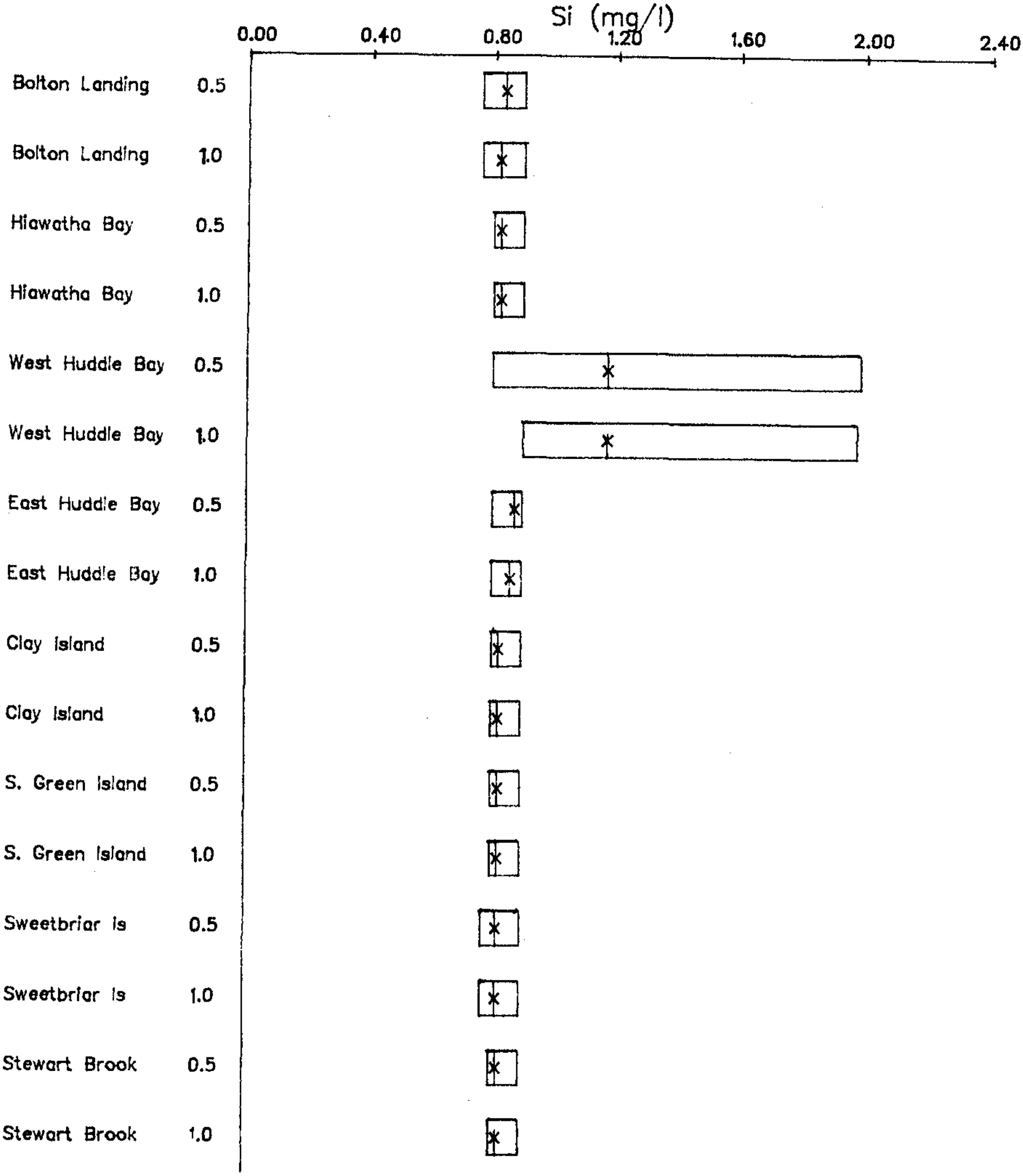

Figure 9. Minimum, maximum and average silica concentrations at each inshore site.

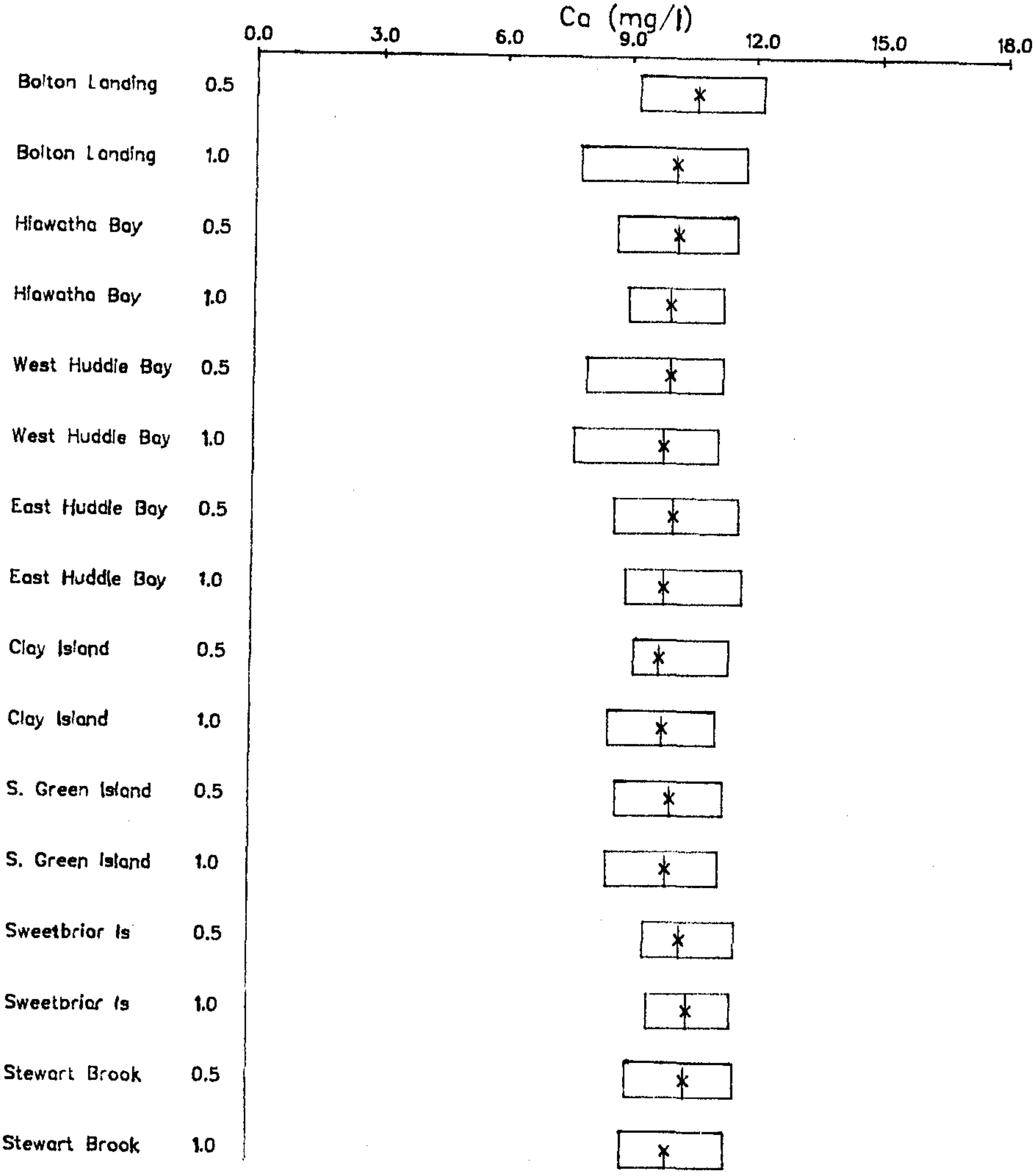

Figure 10. Minimum, maximum and average calcium concentrations at each inshore site.

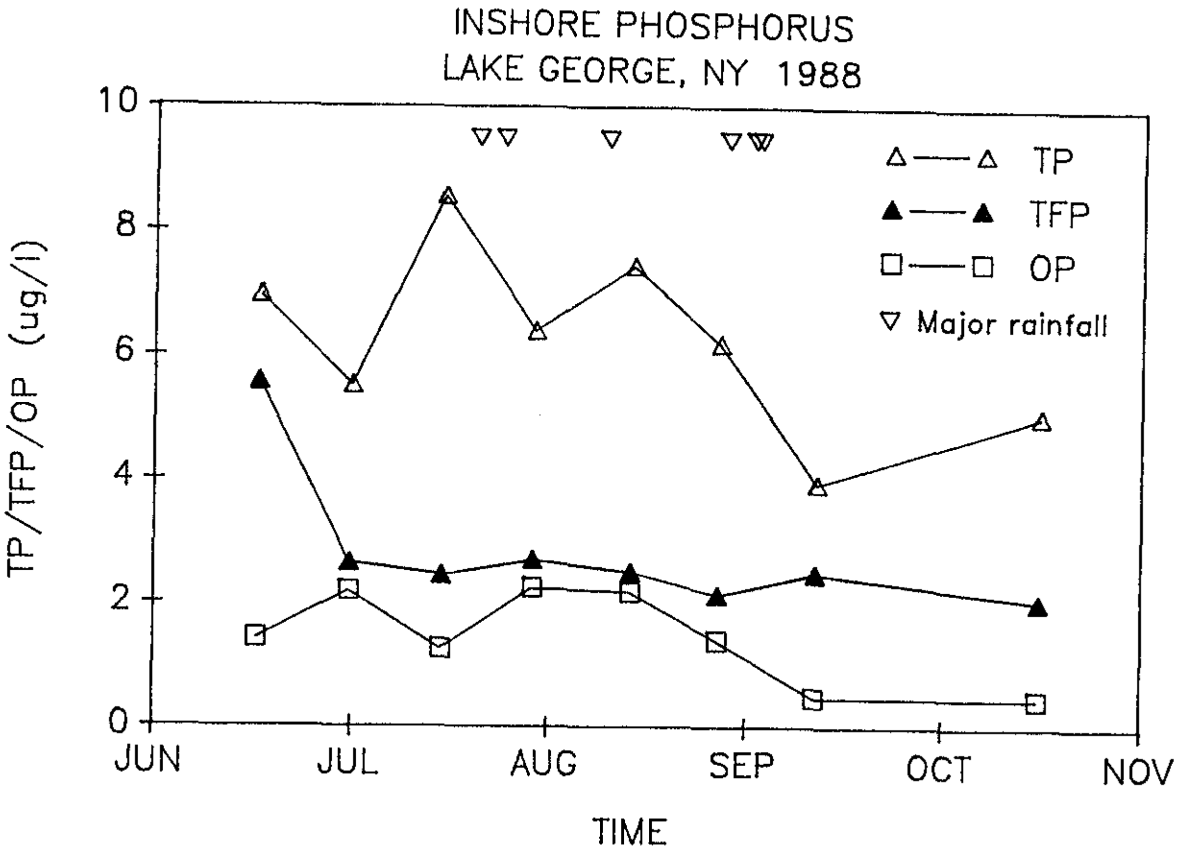

Figure 11. Inshore phosphorus data in relation to major precipitation events (rainfall greater than one inch).

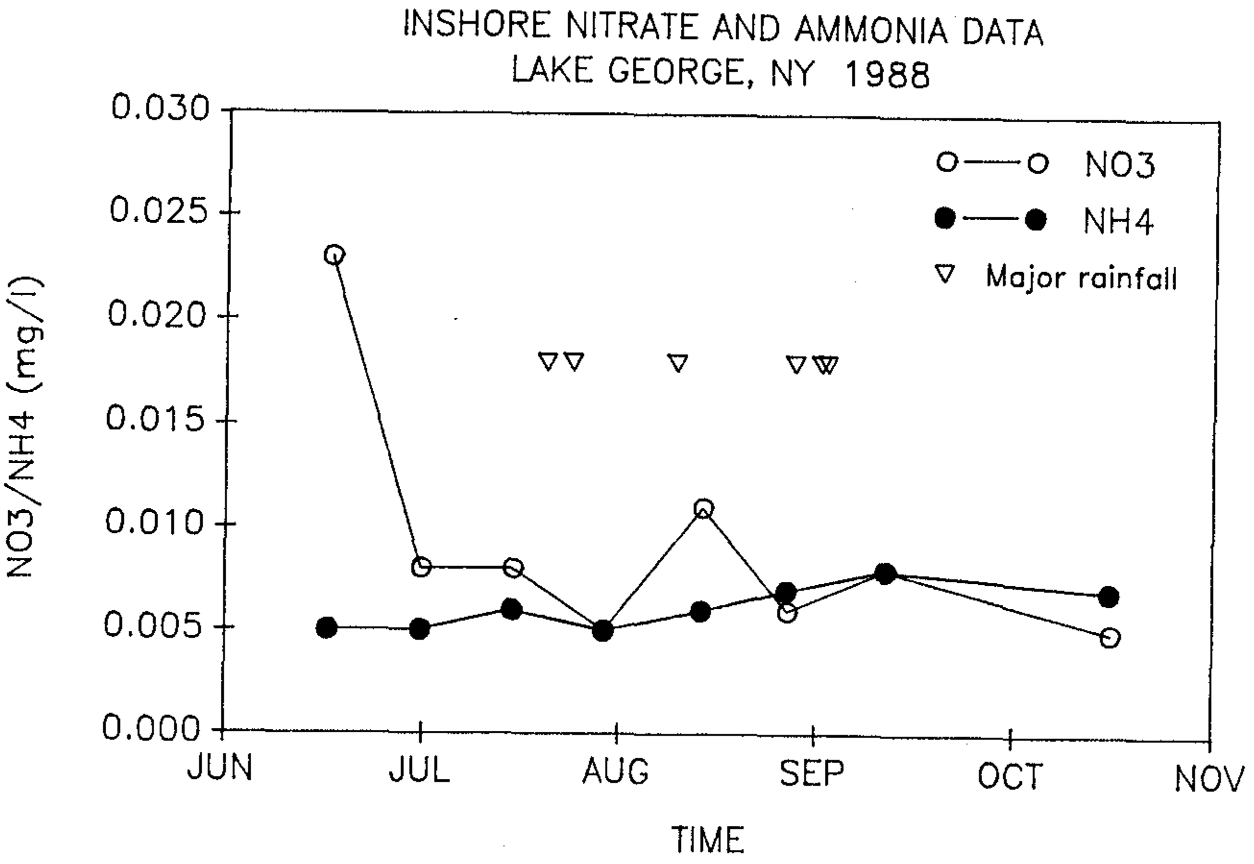

Figure 12. Inshore nitrate and ammonia data in relation to major precipitation events (rainfall greater than one inch).

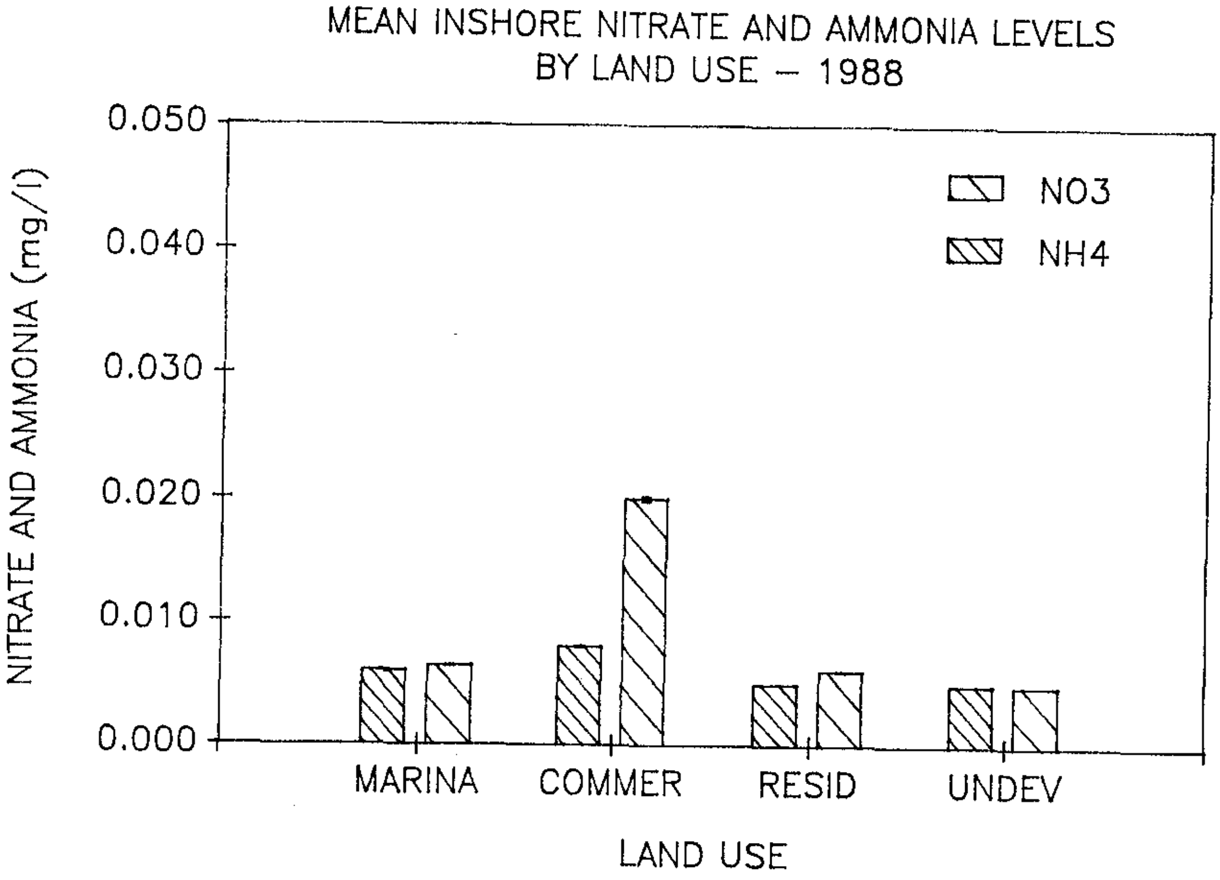

Figure 13. Mean inshore nitrate and ammonia levels related to adjacent land uses.

APPENDIX 2

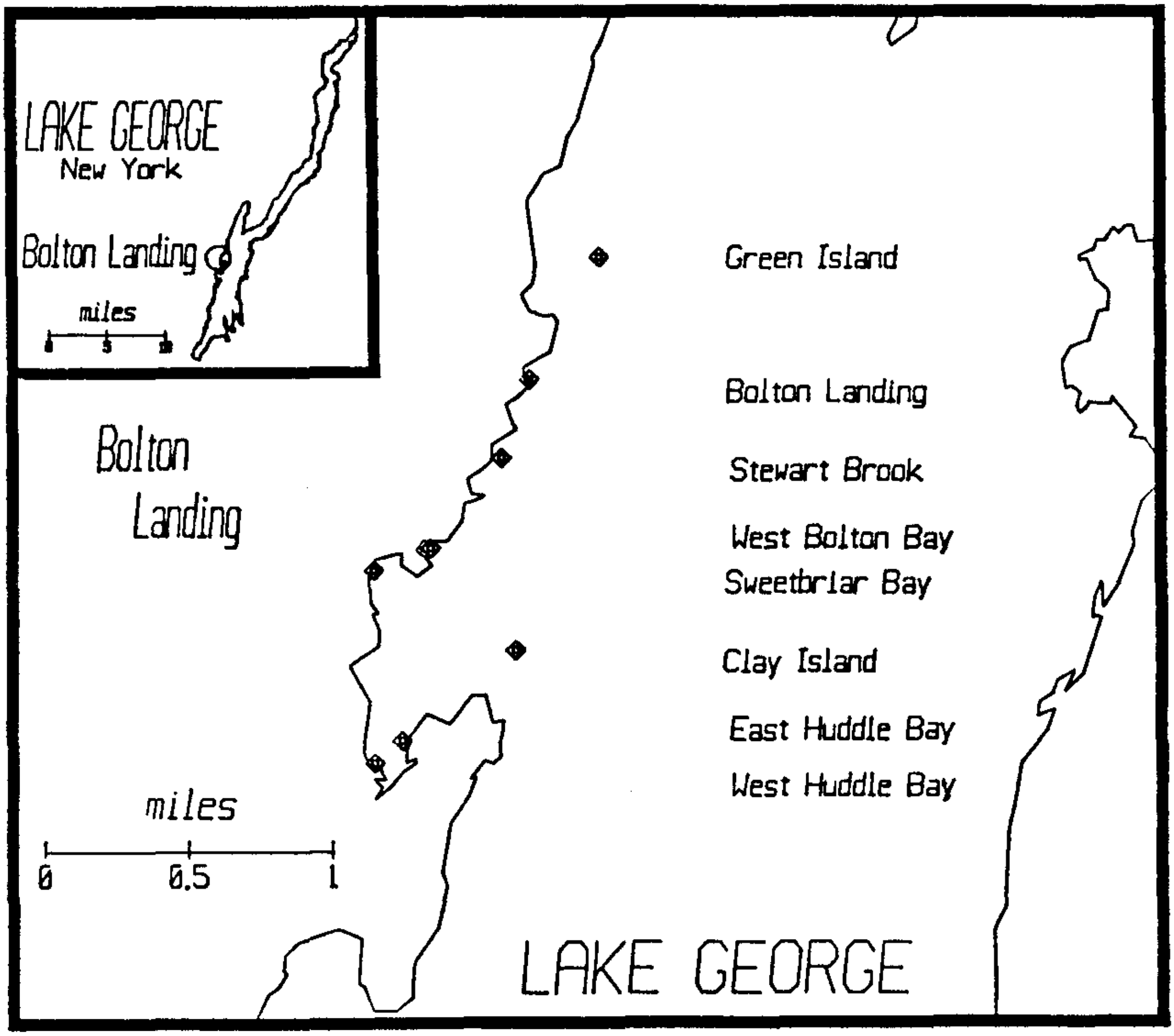

Figure 1. Map of Inshore Sampling sites. Sites are listed from north to south.

APPENDIX 3

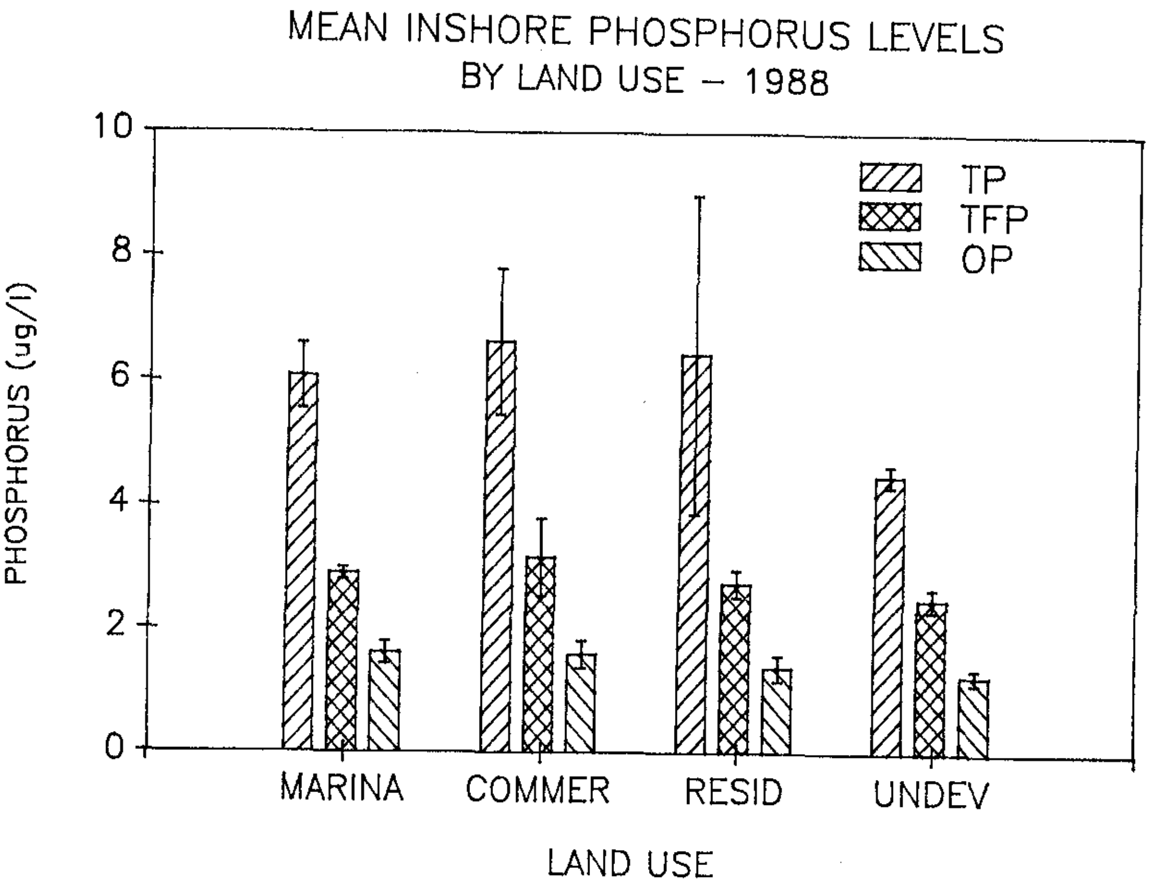

Figure 14. Mean inshore phosphorus levels related to adjacent land uses.

1988 pH

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	7.52	7.57	7.16	7.20	7.58	7.44	7.24	7.31
	1.0	7.51	7.49	7.37	7.40	7.64	7.58	7.49	7.36
Hiawatha Bay	0.5	7.61	7.74	7.69	7.73	7.71	7.79	7.68	7.64
	1.0	7.65	7.70	7.54	7.68	7.69	7.80	7.64	7.48
West Huddle Bay	0.5	7.46	7.42	7.22	7.38	7.61	7.68	7.46	7.27
	1.0	7.50	7.52	7.31	7.37	7.46	7.64	7.49	7.29
East Huddle Bay	0.5	7.70	7.62	7.45	7.60	7.45	7.57	7.51	7.35
	1.0	7.79	7.60	7.49	7.51	7.41	7.64	7.60	7.36
Clay Island	0.5	7.77	7.62	7.47	7.62	7.62	7.64	7.59	7.48
	1.0	7.81	7.53	7.47	7.52	7.60	7.70	7.68	7.32
S. Green Island	0.5	7.68	7.33	7.53	7.49	7.65	7.63	7.51	7.39
	1.0	7.70	7.53	7.55	7.61	7.65	7.64	7.51	7.33
Sweetbriar Is	0.5	7.71	7.56	7.24	7.26	7.42	7.48	7.44	7.44
	1.0	7.37	7.55	7.30	7.31	7.51	7.66	7.44	7.41
Stewart Brook	0.5	7.64	7.56	7.42	7.53	7.65	7.70	7.48	7.53
	1.0	7.83	7.62	7.47	7.56	7.62	7.68	7.50	7.43

***** : indicates no data available

1988 Conductivity (umhos)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	96.0	97.9	112.8	103.4	97.0	99.4	97.0	97.6
	1.0	98.0	99.5	114.3	106.0	97.0	97.1	101.0	97.1
Hiawatha Bay	0.5	94.0	96.1	107.9	97.3	96.0	96.2	99.0	95.5
	1.0	95.0	97.2	110.0	98.2	94.0	97.7	100.0	94.9
West Huddle Bay	0.5	93.0	98.6	110.5	96.0	97.0	98.2	100.0	95.5
	1.0	93.0	96.3	107.1	93.3	92.0	97.3	99.0	97.4
East Huddle Bay	0.5	95.0	95.8	104.9	104.1	95.0	96.8	99.0	97.0
	1.0	97.0	96.4	105.7	100.7	93.0	96.6	99.0	94.8
Clay Island	0.5	96.0	98.2	125.7	95.7	94.0	96.4	99.0	96.2
	1.0	95.0	97.0	107.2	96.1	95.0	97.0	98.0	94.9
S. Green Island	0.5	96.0	97.1	108.3	96.3	95.0	96.3	99.0	95.3
	1.0	96.0	97.1	110.8	95.6	96.0	97.6	98.0	95.2
Sweetbriar Is	0.5	96.0	102.9	112.3	108.9	102.0	99.2	100.0	97.7
	1.0	95.0	103.7	112.4	122.2	104.0	98.9	101.0	97.7
Stewart Brook	0.5	95.0	97.5	106.0	97.9	97.0	99.3	99.0	96.1
	1.0	96.0	97.2	108.4	97.9	97.0	96.7	101.0	95.3

***** : indicates no data available

1988

Cl (mg/l)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	7.6	7.1	8.5	8.2	8.1	7.8	7.8	8.1
	1.0	7.0	7.1	8.8	8.4	8.1	7.9	7.8	8.1
Hiawatha Bay	0.5	7.4	7.6	8.3	7.2	8.0	7.7	7.7	8.0
	1.0	6.9	7.8	8.3	7.2	7.9	7.8	7.9	8.1
West Huddle Bay	0.5	7.7	7.5	8.1	7.4	7.9	8.0	7.9	8.0
	1.0	7.4	7.7	8.2	7.3	7.8	7.8	7.9	8.0
East Huddle Bay	0.5	7.7	7.7	10.2	7.2	8.1	7.9	7.9	8.1
	1.0	7.6	7.7	8.0	7.5	7.8	8.0	8.0	8.0
Clay Island	0.5	7.9	7.7	8.1	7.4	7.8	7.6	7.8	7.9
	1.0	7.7	7.5	8.2	7.4	7.9	7.9	7.9	8.1
S. Green Island	0.5	8.0	7.9	8.1	7.6	7.9	8.1	8.0	8.1
	1.0	7.2	7.5	8.1	7.2	7.9	7.8	8.0	8.1
Sweetbriar Is	0.5	7.7	8.8	8.9	9.2	9.5	8.1	8.2	8.3
	1.0	8.1	9.0	8.9	8.6	9.1	7.4	7.8	8.3
Stewart Brook	0.5	7.7	8.0	8.4	7.3	8.0	7.6	7.9	8.0
	1.0	7.6	7.7	8.3	7.4	7.9	7.9	8.1	8.0

****** : indicates no data available

1988

NO3 (mg/l)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	-0.01	-0.01	-0.01	0.01	0.02	-0.01	-0.01	-0.01
	1.0	0.01	-0.01	-0.01	-0.01	0.01	-0.01	0.01	-0.01
Hiawatha Bay	0.5	0.01	-0.01	-0.01	-0.01	0.01	-0.01	-0.01	-0.01
	1.0	0.01	-0.01	-0.01	-0.01	-0.01	0.01	-0.01	-0.01
West Huddle Bay	0.5	0.13	0.04	0.03	-0.01	0.05	0.01	0.02	-0.01
	1.0	0.14	0.02	0.02	-0.01	0.02	-0.01	0.02	-0.01
East Huddle Bay	0.5	0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Clay Island	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
S. Green Island	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Sweetbriar Is	0.5	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	0.01	-0.01	-0.01	-0.01
Stewart Brook	0.5	-0.01	0.01	-0.01	-0.01	0.01	0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01

****** : indicates no data available

1988

NH4 (mg/1)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	******	-0.01	-0.01	-0.01	-0.01	-0.01
Hiawatha Bay	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
West Huddle Bay	0.5	-0.01	-0.01	0.01	-0.01	0.02	-0.01	0.02	-0.01
	1.0	-0.01	-0.01	0.02	-0.01	-0.01	0.02	0.02	0.01
East Huddle Bay	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	-0.01
Clay Island	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
S. Green Island	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	0.01	-0.01	-0.01	-0.01	0.01
Sweetbriar Is	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	0.02	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
Stewart Brook	0.5	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	1.0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01

****** : indicates no data available

1988

Total phosphorus (ppb)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	8.	5.	7.	6.	7.	6.	4.	4.
	1.0	6.	5.	50.	5.	10.	6.	4.	4.
Hiawatha Bay	0.5	6.	8.	8.	6.	7.	6.	4.	5.
	1.0	8.	6.	4.	5.	5.	5.	4.	6.
West Huddle Bay	0.5	11.	8.	9.	12.	7.	5.	5.	5.
	1.0	11.	8.	7.	15.	7.	5.	4.	5.
East Huddle Bay	0.5	6.	5.	5.	7.	8.	6.	4.	5.
	1.0	5.	5.	6.	7.	7.	8.	4.	5.
Clay Island	0.5	5.	4.	4.	4.	5.	4.	4.	4.
	1.0	6.	4.	4.	4.	6.	4.	3.	5.
S. Green Island	0.5	6.	5.	4.	5.	6.	4.	4.	5.
	1.0	8.	4.	3.	4.	4.	5.	4.	4.
Sweetbriar Is	0.5	8.	7.	9.	6.	6.	9.	3.	7.
	1.0	7.	6.	7.	5.	5.	5.	4.	6.
Stewart Brook	0.5	6.	5.	6.	5.	23.	17.	4.	8.
	1.0	6.	5.	8.	4.	7.	7.	4.	5.

****** : indicates no data available

1988

Total filterable phosphorus (ppb)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	4.	3.	4.	2.	3.	2.	2.	2.
	1.0	4.	2.	3.	3.	4.	2.	3.	2.
Hiawatha Bay	0.5	6.	2.	2.	3.	2.	2.	4.	2.
	1.0	5.	3.	2.	3.	2.	2.	2.	2.
West Huddle Bay	0.5	10.	4.	3.	3.	3.	2.	3.	2.
	1.0	8.	3.	3.	4.	3.	2.	2.	2.
East Huddle Bay	0.5	5.	3.	2.	3.	3.	2.	2.	2.
	1.0	6.	2.	2.	3.	2.	2.	3.	2.
Clay Island	0.5	5.	2.	2.	3.	2.	2.	3.	2.
	1.0	5.	2.	2.	2.	2.	2.	3.	2.
S. Green Island	0.5	5.	2.	2.	2.	2.	2.	2.	2.
	1.0	5.	2.	2.	2.	2.	2.	3.	2.
Sweetbrier Is	0.5	5.	3.	3.	3.	3.	******	2.	2.
	1.0	6.	3.	3.	3.	2.	******	2.	2.
Stewart Brook	0.5	5.	3.	2.	2.	3.	4.	2.	3.
	1.0	5.	3.	2.	2.	2.	2.	2.	2.

****** : indicates no data available

1988

Orthophosphate (ppb)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	1.	2.	2.	3.	2.	1.	-1.	-1.
	1.0	-1.	2.	4.	3.	3.	1.	-1.	-1.
Hiawatha Bay	0.5	-1.	2.	-1.	2.	2.	1.	-1.	-1.
	1.0	1.	2.	-1.	2.	2.	-1.	-1.	-1.
West Huddle Bay	0.5	4.	3.	2.	4.	2.	2.	-1.	-1.
	1.0	3.	2.	2.	4.	2.	1.	-1.	-1.
East Huddle Bay	0.5	1.	2.	-1.	2.	2.	1.	-1.	-1.
	1.0	1.	2.	1.	2.	1.	1.	-1.	-1.
Clay Island	0.5	1.	2.	-1.	1.	2.	1.	-1.	-1.
	1.0	1.	2.	1.	1.	2.	1.	-1.	-1.
S. Green Island	0.5	1.	2.	-1.	2.	4.	2.	-1.	-1.
	1.0	2.	2.	-1.	2.	1.	2.	-1.	-1.
Sweetbrier Is	0.5	2.	3.	2.	3.	1.	2.	-1.	-1.
	1.0	2.	3.	2.	1.	1.	1.	-1.	-1.
Stewart Brook	0.5	1.	2.	-1.	2.	5.	4.	-1.	-1.
	1.0	-1.	2.	-1.	2.	3.	1.	-1.	-1.

****** : indicates no data available

Rensselaer Polytechnic Institute

1988

Si (mg/1)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	0.80	0.80	0.90	0.76	0.80	0.80	*****	0.90
	1.0	0.90	0.80	0.80	0.76	0.80	0.80	0.80	0.90
Hiawatha Bay	0.5	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
	1.0	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
West Huddle Bay	0.5	1.70	1.00	1.00	1.99	1.10	0.80	0.90	0.90
	1.0	1.70	0.90	1.00	1.88	1.10	0.80	0.90	0.90
East Huddle Bay	0.5	0.90	0.90	0.80	0.90	0.90	0.80	0.90	0.90
	1.0	0.90	0.80	0.90	0.80	0.90	0.90	0.90	0.80
Clay Island	0.5	0.80	0.80	0.80	0.80	0.80	0.80	0.90	0.90
	1.0	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
S. Green Island	0.5	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
	1.0	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
Sweetbriar Is	0.5	0.80	0.80	0.80	0.77	0.80	0.80	0.80	0.90
	1.0	0.80	0.80	0.80	0.77	0.80	0.80	0.80	0.90
Stewart Brook	0.5	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90
	1.0	0.90	0.80	0.80	0.80	0.80	0.80	0.80	0.90

***** : indicates no data available

1988

Ca (mg/1)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	10.1	9.7	10.2	9.2	10.0	11.7	11.6	12.2
	1.0	8.9	9.2	7.8	8.6	9.7	11.6	11.3	11.8
Hiawatha Bay	0.5	9.7	10.2	10.6	9.7	9.0	10.7	10.9	11.6
	1.0	9.1	10.2	10.1	9.0	9.3	10.6	10.5	11.3
West Huddle Bay	0.5	9.2	9.5	10.4	8.0	9.4	11.2	11.3	11.2
	1.0	9.2	9.9	10.1	7.7	9.1	10.8	11.0	11.2
East Huddle Bay	0.5	9.7	10.1	9.7	8.7	9.7	10.9	10.5	11.7
	1.0	9.4	9.7	9.8	9.0	9.1	10.4	10.2	11.8
Clay Island	0.5	9.2	9.3	9.5	9.3	9.2	10.4	10.2	11.5
	1.0	9.1	9.3	9.6	8.8	9.6	11.1	10.8	11.2
S. Green Island	0.5	9.1	*****	10.1	8.8	9.0	11.1	11.4	11.4
	1.0	9.5	9.8	10.3	8.6	9.1	10.8	10.9	11.3
Sweetbriar Is	0.5	9.7	9.7	9.5	10.1	10.1	11.3	11.0	11.7
	1.0	*****	9.6	10.5	9.7	9.8	11.3	11.6	11.5
Stewart Brook	0.5	9.1	9.8	10.7	10.0	10.6	11.7	10.5	11.6
	1.0	9.0	9.7	9.9	9.4	10.1	11.5	10.2	11.0

***** : indicates no data available

1988

Chl-a (ppb)

Site	Depth	6/14	6/28	7/12	7/26	8/10	8/23	9/7	10/11
Bolton Landing	0.5	1.30	1.90	0.60	1.00	0.90	1.00	0.80	0.90
	1.0	1.30	1.10	2.20	1.20	1.30	0.90	1.30	0.90
Hiawatha Bay	0.5	1.10	2.00	1.40	******	1.50	1.20	1.90	1.40
	1.0	1.80	1.80	0.80	1.50	1.50	1.10	1.40	1.10
West Huddle Bay	0.5	1.40	1.00	1.00	2.00	1.00	0.70	1.20	1.30
	1.0	1.20	1.00	1.00	3.10	0.90	1.00	1.00	0.90
East Huddle Bay	0.5	0.90	1.40	1.00	2.80	1.80	0.50	0.90	1.20
	1.0	1.10	1.30	1.20	1.60	2.20	0.80	1.10	1.30
Clay Island	0.5	0.80	1.10	0.80	1.40	1.70	0.60	1.60	1.20
	1.0	0.90	0.80	0.80	1.40	0.90	1.00	1.40	1.50
S. Green Island	0.5	0.70	1.60	0.70	1.30	0.90	1.20	1.30	1.30
	1.0	******	1.30	0.60	******	0.70	1.00	1.20	1.40
Sweetbriar Is	0.5	0.80	1.30	1.40	1.50	1.20	1.40	1.10	0.80
	1.0	0.90	1.50	1.40	1.60	1.10	1.10	0.80	1.30
Stewart Brook	0.5	******	1.40	0.70	1.10	1.30	1.40	1.30	1.10
	1.0	1.30	1.30	0.90	2.40	1.20	1.20	1.40	1.10

****** : indicates no data available