A Water Chemistry Study of Limed Ponds

Alys Holden
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Introduction

Many experts claim that acidic precipitation, "acid rain", is causing some lakes in the Northeastern U.S. (and Canada) to die. A local case study can be found in North, South, and Burnette Ponds in Savoy Mountain State Forest. Though the ponds are very close to each other, they exhibit some striking differences in water chemistry composition. North and South Ponds have been limed in order to retard the effects of acid rain, while Burnette Pond does not seem to be suffering from the acid precipitation as badly.

In Part I of this report, the general history of the ponds and the implications of pH differences are explored. In Part II, chemical trends in North Pond are cited, explained, and compared to Burnette Pond. In Part III, the data on South Pond is analyzed also using Burnette Pond as a standard. The conclusion will include opinions on how this situation has been handled and recommendations for future studies.

good intro. - - you may as well use active voice, first person in future work - - you did it!

Part I -- History

North Pond is a natural spring-fed kettle pond with a maximum depth of about 27 feet (IS&F #1). There is probably a lot of limestone in the rock composition around the pond (Nowak). South Pond is a shallow, man-made pond with a maximum depth of about 10 feet (Nowak). South Pond has been officially dead since 1983, though it has been unable to support an active fishery for 15 to 20 years (Phillips, "Savoy's . . ."). While North Pond is not "dead" (it's a state-stocked fishery), it is considered borderline. It's fish population shows some signs of acid rain impact, and it suffers from spring acid shocks when the annual thaw introduces a large volume of acidic precipitation into the pond (Phillips, "Copter..."). Fisherman were scared that if preventive measures weren't taken, the lake would eventually die.

If the pH of a water body is too low, many negative impacts occur. Heavy metals, such as aluminum, lead, and mercury, are more soluable at low pH's. Consequently, when the pH goes down, the concentration of heavy metals, many of which are toxic to animals, increases (Halliwell). The Science Resource Office of Massachusetts described the effects of acid rain in the following manner:

> "When the pH falls below 5.6, the reproduction capacity of adult fish and the survival ability of eggs and young fish decline and eventually fail. Low pH similarly affects other aquatic organisms. Bacteria eventually become unable to decompose litter, reducing the nutrient cycling critical to the ecosystem."

Obviously, acidification can be very harmful to the life of water bodies.

One way of treating acidified waters is by "liming" them. Limestone (calcium carbonate) contributes to the alkalinity (acid-reducing capacity) of a pond by the following reactions:

Keq =

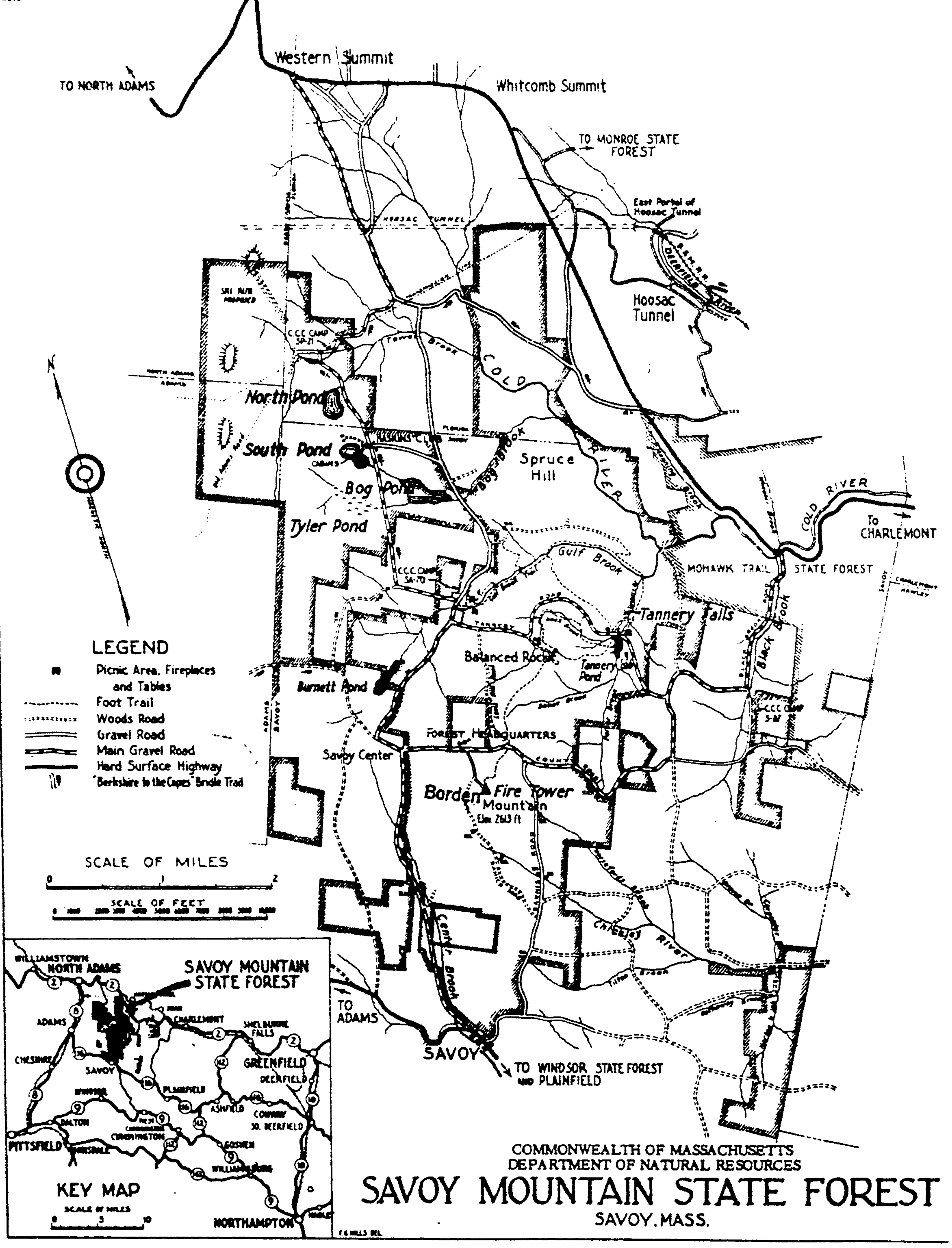
(1) $CaCO_3(c) + H_2O(l) \longrightarrow Ca^{2+} + HCO_3^- + OH^-$

(2) $OH^- + H^+ \longrightarrow H_2O(l)$

If a limestone slurry is added to a pond, it will take up some of the hydrogen ions (an excess of which causes low pH) and bring the pH closer to neutral (7). Or, if the hydroxide ions concentration is high compared to the hydrogen ion concentration, its pH may become alkaline, higher than 7 (Hem, pg. 62). The alkalinity of a pond can be measured and, in this study, corresponds to the concentration of bicarbonate (HCO_3^-).

Therefore, the sensitivity of a pond to acid rain can be measured by its alkalinity (a acid-neutralizing capacity). If a pond has high concentrations of bicarbonate, it is naturally buffered and will be able to alleviate the effect of acid rain; it should not suffer from extreme seasonal fluctuations of pH. If, on the other hand, a pond has low levels of bicarbonate, it cannot protect itself from acidification. Consequently, large fluctuations in pH can occur whenever the unbuffered pond is subjected to high volumes of acid precipitation, and the life of the pond will probably suffer.

well - stated!



COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF NATURAL RESOURCES

SAVOY MOUNTAIN STATE FOREST

SAVOY, MASS.

Part II -- North Pond

North Pond was limed on September 15, 1986. The project was carried out under the auspices of Living Lakes (a non-profit organization funded largely by utility companies) and International Science and Technology, IS&T (Phillips, "Copter...").

When liming a pond, depth, stratification, and turnover time must all be considered. North Pond is deep and stratified in the summer, so Living Lakes used a mixture of fine and coarse-grained limestone. The fine limestone will be dissolved in the upper layers while coarse limestone will sink deeper into the water and dissolve in the deeper waters (IS&T #1). The turnover, or flushing, rate of North Pond is four years, so IS&T estimates that the limestone should buffer the pond for 8 to 12 years (Phillips, "Copter...").

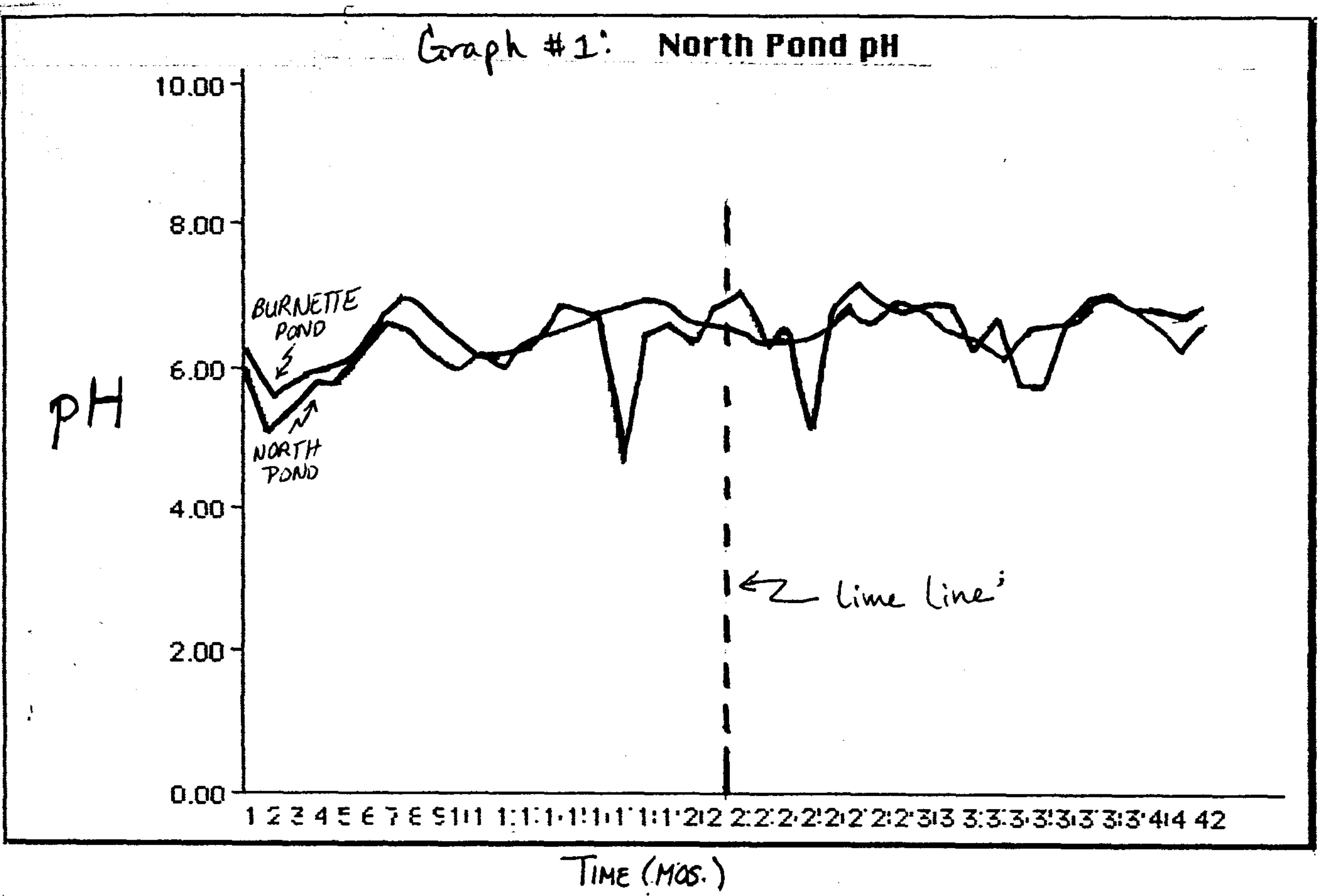
how estimated? what is lake volume?

then what will stop the buffering?

In order to give some meaning to North Pond's chemical characteristics, I compared it to Burnette Pond. Burnette Pond is a good standard by which to measure North and South Ponds because it is in the same general area yet has more healthy pH and alkalinity levels. I choose Burnette Pond instead of Bog Pond (another nearby pond) because the level of biological activity in Bog Pond is much higher than North or South Ponds. Consequently, the nutrient output of Bog Pond is probably much lower than that of North and South Ponds (all samples are taken at outlets). Burnette Pond's chemistry seems to match North and South Ponds better than Bog Pond.

larger drainage basin?

Interesting results can be obtained by comparing the pH trends of North and Burnette Ponds, as shown on the next page.



The overall pH of North and Burnette Ponds is very similiar. However, North Pond exhibits periodic drops in its pH. This indicates that while North Pond may normally have a healthy pH it doesn't have a high enough buffering capacity to protect itself in times of stress. This graph also shows that the liming has not made a significant difference in the pond's pH. There are very significant pH crashes before and after the "lime line" which marks the first sampling done after the liming. Admittedly, the pH dips are slightly less severe than before, but they are much sharper than the pH dips in Burnette pond. However, the good news is that there was no significant pH drop this spring (months 41 and 42); the liming may be becoming more effective after a few years of stabilization.

what are average values ± σ?

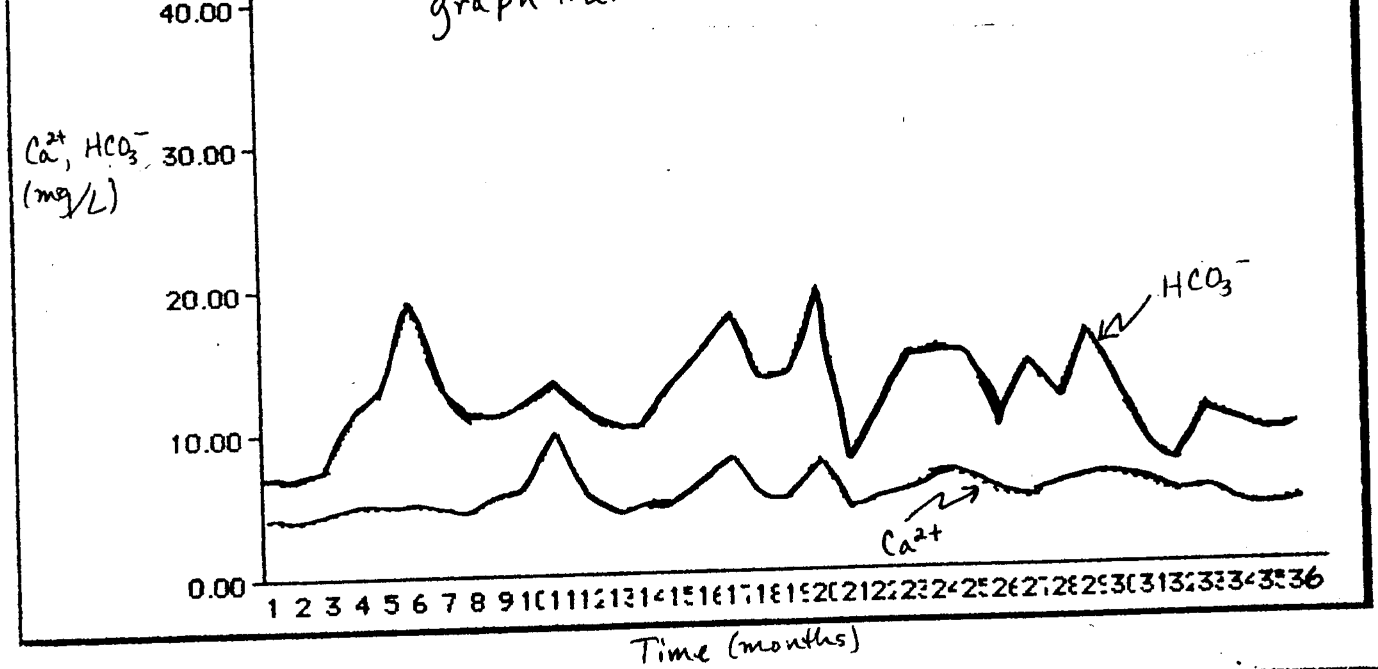
can you prove this? ALK and Ca both appear to be higher!

could you have missed it -- snowmelt was early!

possibly, but suggest a mechanism!

The calcium and bicarbonate levels correlate nicely to themselves and dramtically show why North Pond was considered borderline (see graph #2 and #3 next page).

graph #2: Burnette Ca and HCO3⁻

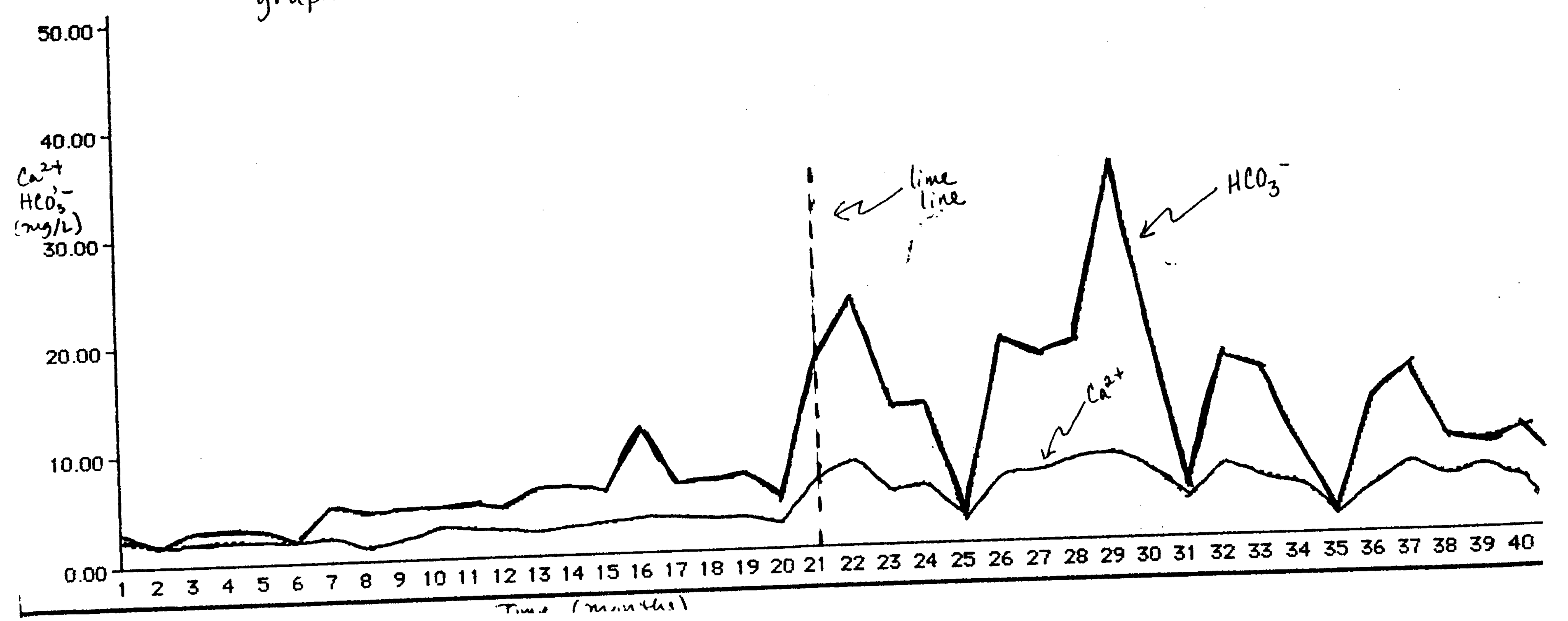


Note:
For Burnette,
date 1 = 05/15/84
date 20 = 03/11/87
date 36 = 09/02/88

For North Pond,
date 1 = 05/15/84
20 = 10/02/86
40 = 09/02/88

(see index for complete listing)

graph #3: N.P. -- Ca^{2+} and HCO_3^-



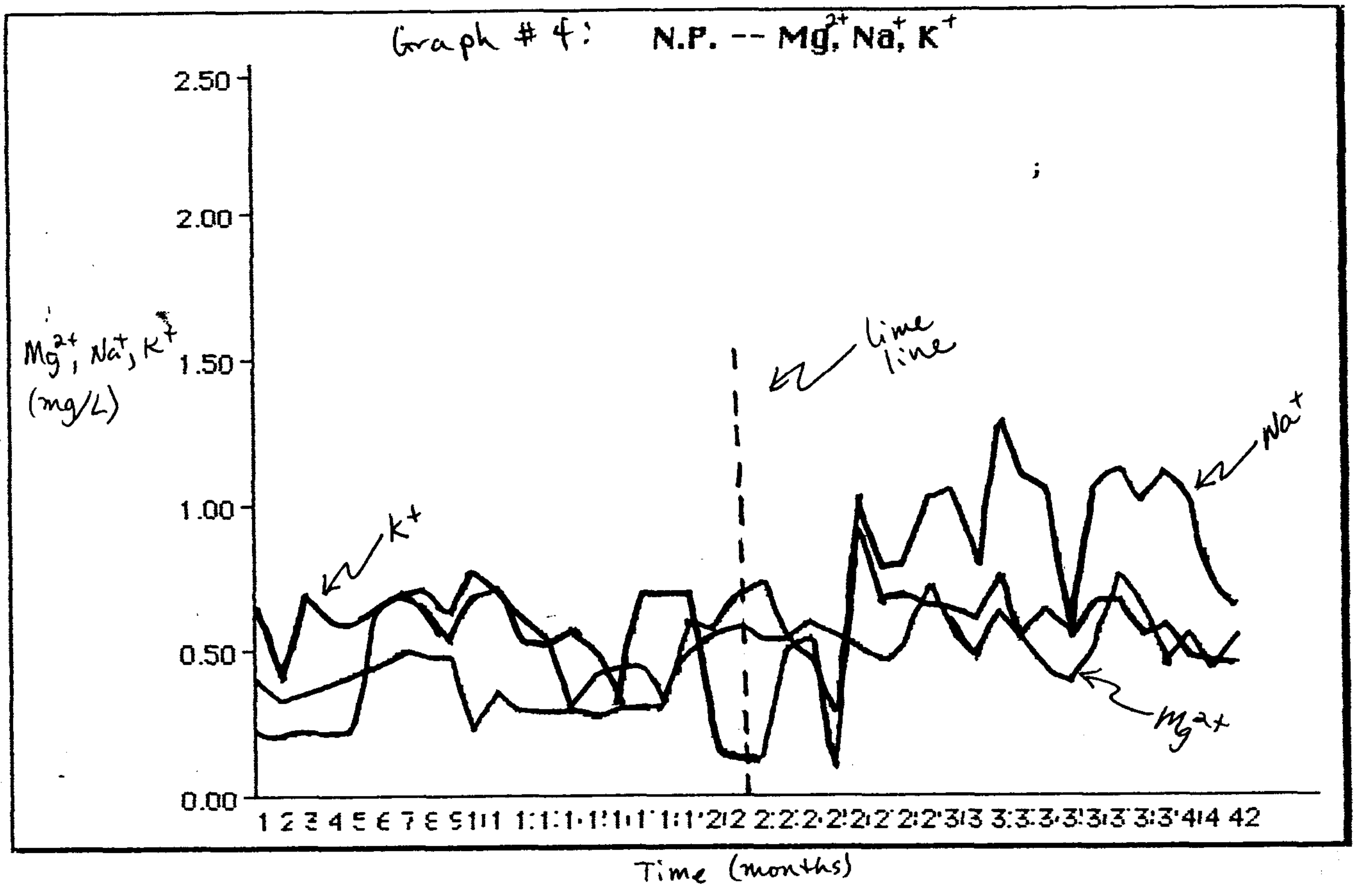
did you try $\frac{ALK}{Ca}$ or $\frac{pH}{ALK}$

As anticipated, graph #2, shows a pattern between low bicarbonate levels and low pH's. Before the liming, the bicarbonate levels of North Pond were very low compared to Burnette Pond. After the liming, the bicarbonate levels increased to levels greater than those of Burnette Pond. though North Pond still suffers from unexplained periodic dips in bicarbonate levels which Burnette doesn't.

stratification may play an important role!

Another interesting trend is that the bicarbonate and calcium ion graphs for North Pond don't peak at the same time until after the liming. (highest equate! #17 pH looks wrong & like a typo.) If, before the liming, most of the bicarbonate in North Pond was contributed from carbon dioxide in the atmosphere, (or 50%) but after the liming most of the bicarbonate was contributed from the limestone, then this pattern may be explained. If the this assumption about the sources of bicarbonate it true, then before the liming, the bicarbonate concentration was independent of calcium (and dependent on biological activity), but, after the liming, the bicarbonate concentration became directly related to calcium ion concentration. It is noteworthy that the bicarbonate and calcium ion concentration peaks mirror each other (That's good, since they're the dominant anion & cation!) throughout the testing period of Burnette Pond. This may indicate that Burnette Pond is being naturally buffered by limestone (I doubt it) in its sediments or nearby soils. (↑ exchange with soil Ca)

North Pond was also tested for magnesium, sodium, and potassium cations and chloride, sulfate, and nitrate anions. The anion data showed no trends other than a pretty constant concentration of all of the ions. This is to be expected, since there are no nearby roads or other potential sources of pollution which would contribute undue levels of these ions. All concentrations are well within any federal standards of concentration (Jorgenson, pg. 136). The cation concentrations tended to gradually increase after the liming:

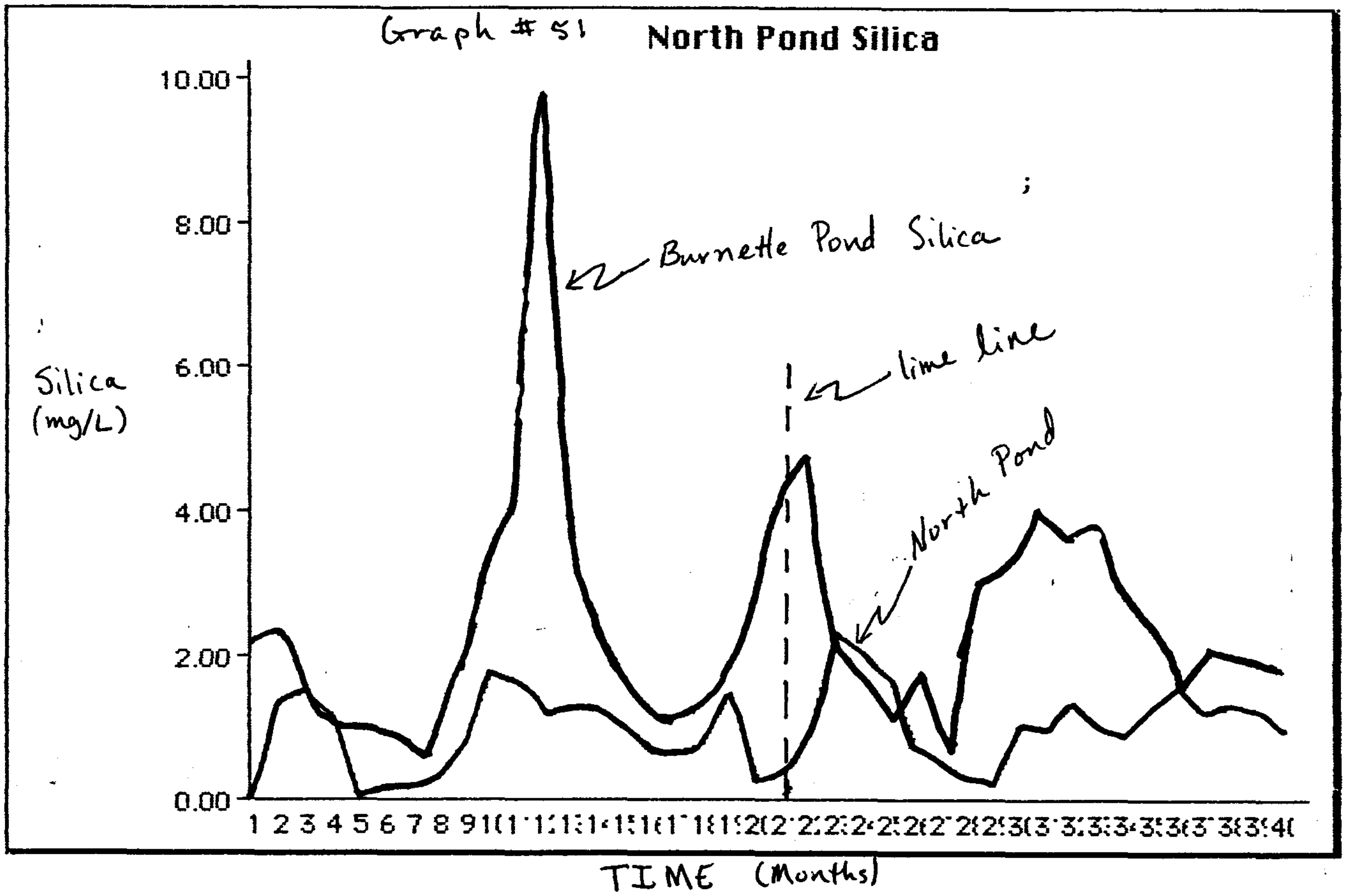


This slight increase may be due to the high nutrient content of the added limestone slurry. The slurry is listed as 95% calcium carbonate and 1.5% magnesium carbonate, with no description of the other 3.5% (IS&T #1).

it is curious that Na goes up - I don't have a ready explanation besides ion exchange -- nice, interesting graph!

The remaining test performed on the water samples was silica content. In general, silica levels correspond to high levels of biological activity because the silicon is contained in diatoms, a small microorganism which is essential at the roots of the food web (Dethier). The silica levels in the ponds ~~increase~~ decrease when the

diatoms pull SiO_2 out of solution and incorporate it in their little shells, called tests diatom bloom. In general, North Pond has lower levels of silica than Burnette Pond:

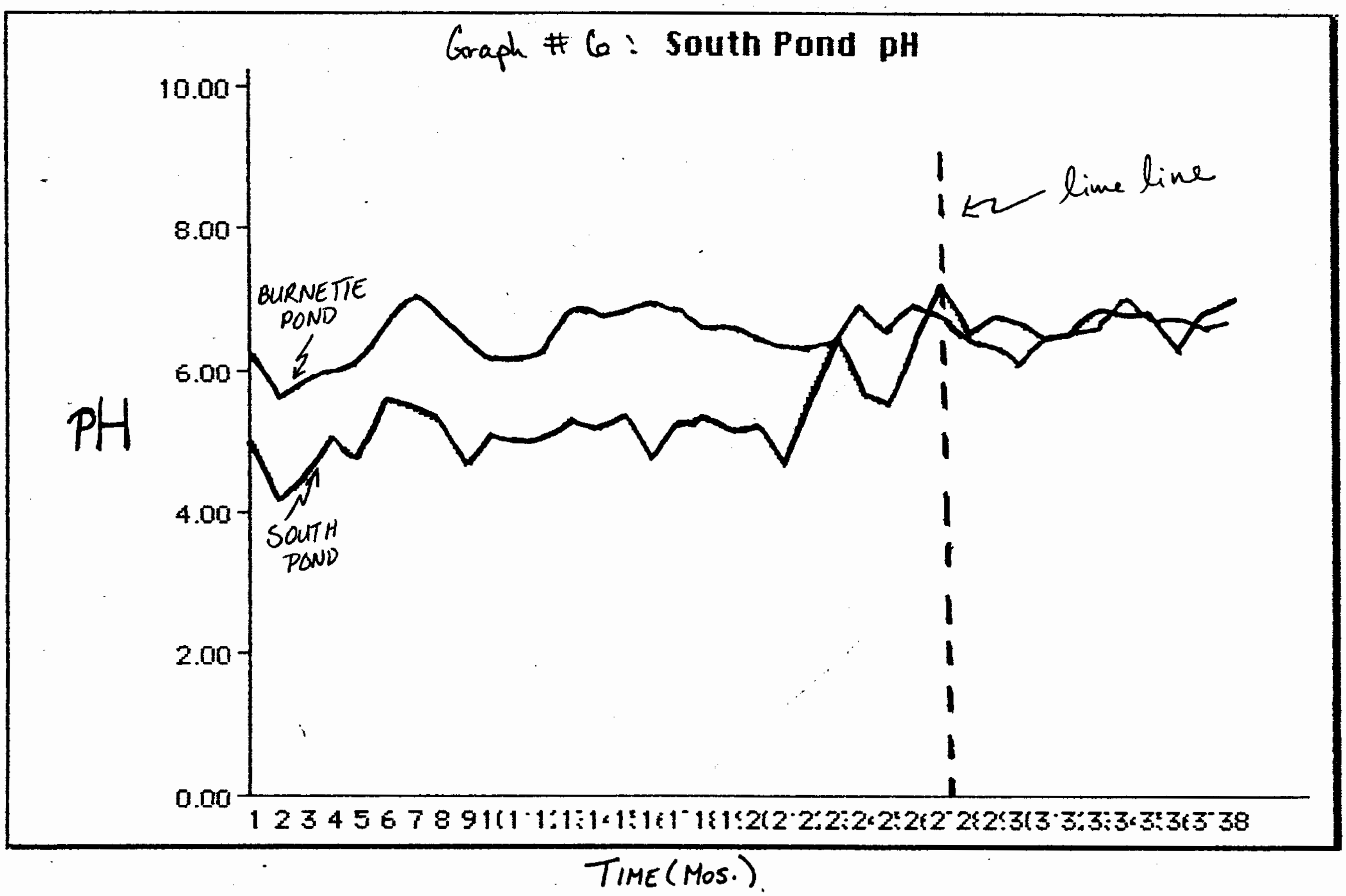


This difference in silica levels, in biological activity, may be explained by North Pond's borderline status. If North Pond was being affected by lowered pH, than it stands to reason that it would have been less healthy than Burnette and that the diatoms wouldn't have flourished. Yet, since even after the liming the North Pond silica levels continue to be lower than Burnette's, the liming may not have significantly improved the biological activity of the pond. Of course, there may be another limiting factor which is not shown by this data which affects the diatoms. good point!

Part III -- South Pond

South Pond was limed on October 26, 1987 again by Living Lakes, etc. The liming method was very different because, in contrast to North Pond, South Pond is acidic and shallow, and its flushing rate is about six months (IS&T #2). In order to counteract these factors, South Pond received a very high does of limestone. IS&T hopes that much of the limestone (0.50 tons/hectare) will sink to the sediment layer of the pond and, thus, give the pond a constant dose of calcium carbonate, providing "prolonged buffering capacity to the lake water" (IS&T, #2).

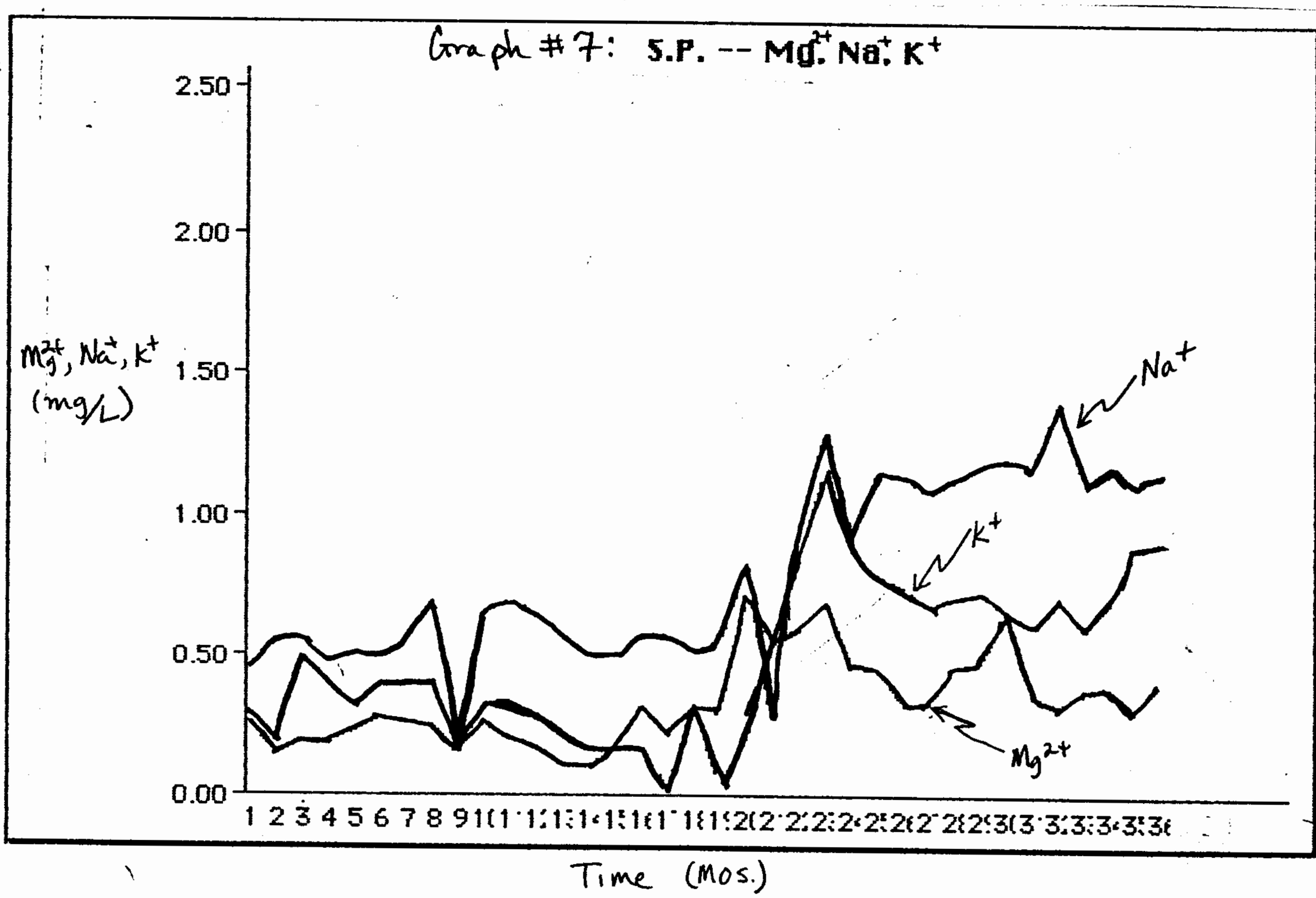
Comparing the pH's of South and Burnette Ponds yields a very definite trend:



nice graph!

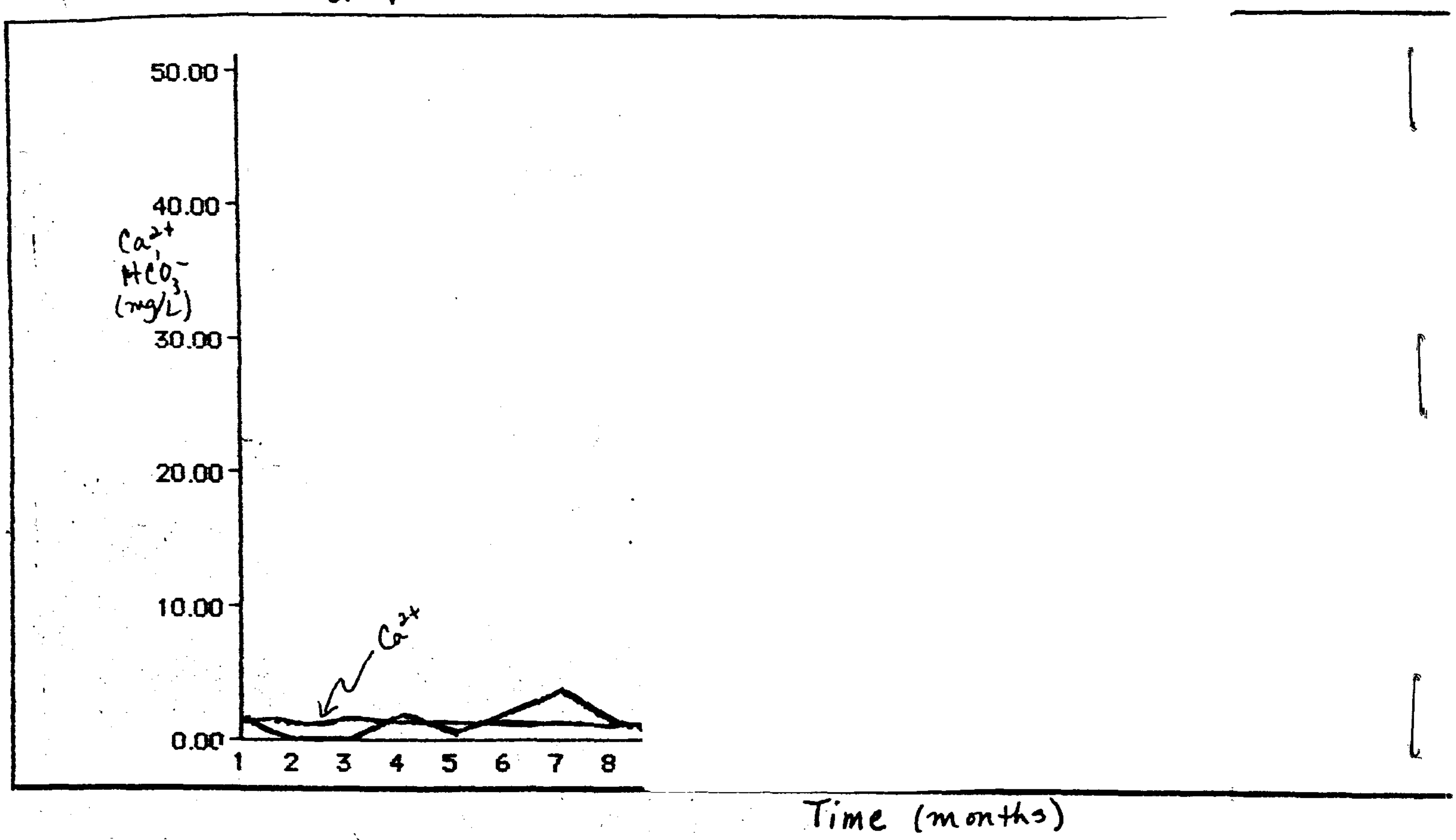
South Pond exhibited a very low average pH with fairly regular dips before the liming. Yet, after the liming, the pond went from a pH of 6.44 to 7.21 and seems to be maintaining a much higher "normal" pH (as compared to Burnette Pond). It has been about a year and half -- three turnovers -- since the liming. Since liming usually only works for two or three times the flushing rate (Phillips, "Copter..."), at least another year of sampling will be necessary to determine if the long-term liming techniques have worked.

As in North Pond, South Pond does not exhibit significant trends of the chloride, nitrate, or sulfate anions. South Pond also has a greater general increase in the sodium, potassium, and magnesium cations (the higher concentration of limestone may account for the greater and more obvious increases): curious and interesting!

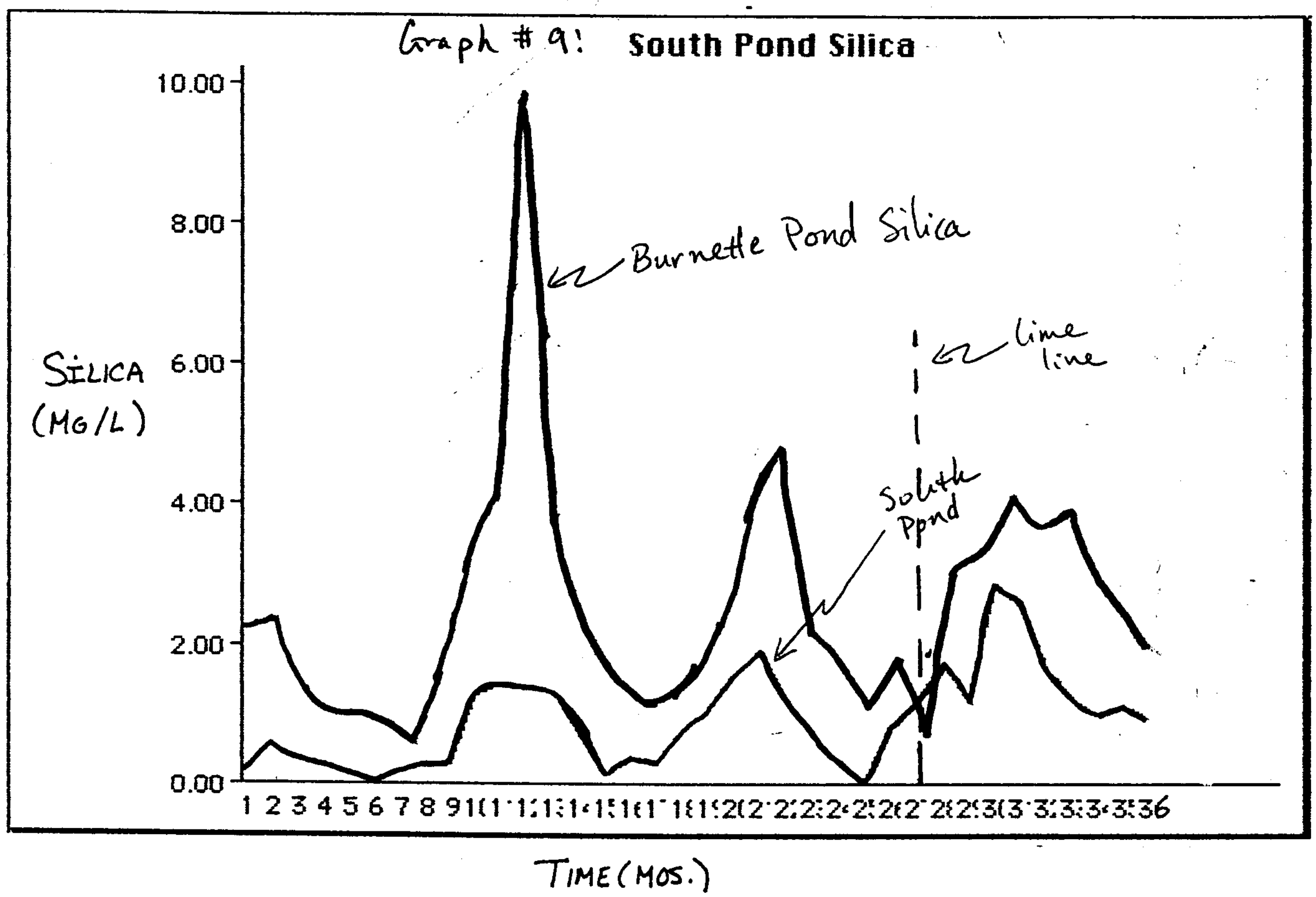


South Pond shows calcium and bicarbonate ion patterns very similiar to North Pond. The levels of the two ions are very low (0.0 in some instances) until the liming, when they increase dramatically (see graph #7, following page). The bicarbonate and calcium ion concentration peaks do not mirror each other until after the liming, indicating that South Pond is <u>not</u> being naturally buffered by calcium carbonate. In addition, the extremely low levels of bicarbonate indicate a very low level of biological activity (by plants). The bicarbonate levels reflect the "deadness" of South Pond. buffering by organic acids?

Graph #8



Since South Pond was dead before the liming, it would be nice if it were now showing signs of life. Graph #9 illustrating the silica levels of South and Burnette Ponds, may offer hope:



The silica levels of South Pond are very low until after the liming. Then the silica levels peaked at higher numbers than it had in four years. This would seem to indicate that the basic biological health of the pond is improving. No higher life forms have reappeared, however. The only sign of life is the red spotted newt (<u>Notophtalmus viridescens</u>) which can survive at a pH as low as 3.3 in th adult form (Dale). Still, the liming has made definite impacts on South Pond which may eventually lead to its revival. Besides expense, I wonder what other ecological "down" sides there may be from this practice?

Conclusion

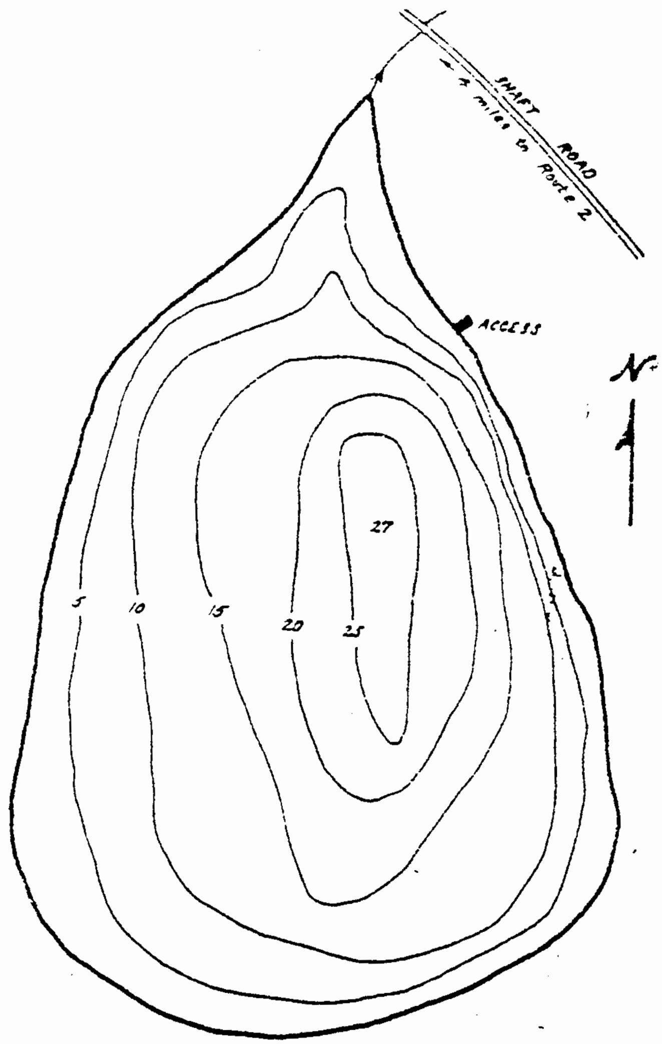
After comparing the water chemistry of North, South, and Burnette Ponds, I have come to the conclusion that liming North was a mistake. [or a waste?] The pH data did not show regular dangerously low pH levels. And, by all indications, liming the pond has not improved its health. The liming of North Pond was probably a result of fisherman overreacting to the threat of acidification (and dying fish). The jury is still out on South Pond, however. If the limestone in the sediment concept is effective, it was the correct decision. (ends justify the means?) If it doesn't work, it was an expensive lesson.

But to reach a really informed decision about the liming, more ~~stud~~ ~~ies must be~~ studies must be done. Water samples should be taken from the middle of the ponds as well as at their outlets. A vegetation and wildlife study of South Pond is necessary to determine if it is really recovering. The pH, silica, and bicarbonate data needs to be compared to weather data to see if any of the mysterious high and low peaks can be explained. Burnette Pond needs to be studied much more extensively to find out why it is so different from North and South Ponds. This would involve studies of the geology of the pond and its watershed. And finally, soil samples from the watersheds and sediment samples of all the ponds should be analyzed in order to determine how much natural buffering they have and where it is coming from.

Anlys. – What about the samples you took – – how were they run (what methods) and how do they fit in with previous values? You've done an exceptional job of pulling together a lot of data that no one has ever examined before. I like most of your observations about the data and wish that you'd tried some x–y plots using various combinations of variables. One of the most interesting (or different) things you show is the increase in cations after liming perhaps "knocked off" exchange sites by excess ~~cations~~ Ca. Good work!

North Pond Raw Data

Num	Date	pH	HCO3	SiO2	Ca	Mg	Na	K	Cl	NO3	SO4
1	05/15/84	6	3.1	0	2.33	0.4	0.23	0.65	0.8	0.15	5.8
2	05/31/84	5.1	1.7	1.4	2	0.34	0.21	0.4	0.3	0.04	5.5
3	06/17/84	5.5	3	1.5	2.1	0.37	0.23	0.7	0.8	0.1	5.8
4	07/25/84	5.3	3	1.2	2.29	0.39	0.22	0.6	0.8	0.03	5.4
5	08/19/84	5.8	3	0.1	2.22	0.43	0.23	0.6	0.6	0.24	5.7
6	09/16/84	6.2	2	0.2	2.1	0.46	0.65	0.65	0.6	0.05	5.5
7	10/21/84	6.6	5	0.2	2.3	0.5	0.7	0.71	0.7	0.16	5.5
8	11/18/84	6.5	4.3	0.3	1.43	0.49	0.72	0.65	0.7	0.01	6
9	12/16/84	6.2	4.8	0.8	1.75	0.49	0.61	0.53	0.6	0.05	6.8
10	01/29/85	6	4.7	1.78	2.95	0.24	0.77	0.68	0.5	0.09	7.4
11	02/25/85	6.2	5	1.65	2.9	0.36	0.71	0.72	0.7	0.04	7
12	03/25/85	6	4.6	1.25	2.52	0.3	0.61	0.53	0.6	9.9	5.1
13	04/24/85	6.4	6.2	1.33	2.25	0.3	0.56	0.53	0.7	9.9	5.5
14	05/21/85	6.5	6.2	1.29	2.65	0.3	0.3	0.53	0.53	9.9	5.7
15	06/21/85	6.6	5.8	1	2.9	0.27	0.42	0.5	0.6	9.9	4.87
16	07/29/85	6.73	11.52	0.63	3.3	0.3	0.45	0.33	0.33	9.9	6.92
17	08/23/85	4.69	6.24	0.68	3.2	0.3	0.45	0.7	0.32	9.9	9.86
18	09/23/85	6.45	6.48	0.3	3	0.33	0.35	0.7	0.19	9.9	7.17
19	10/23/85	6.66	6.96	1.5	3	0.6	0.5	0.7	1.13	9.9	6.41
20	09/15/86	6.35	4.56	0.29	2.56	0.57	0.55	0.17	0.91	0.07	4.31
21	10/02/86	6.87	17.52	0.39	6.33	0.69	0.59	0.14	0.97	0.05	5.05
22	11/12/86	7.08	22.8	0.91	8.1	0.74	0.54	0.14	0.38	0.08	5.19
23	02/08/87	6.38	12.72	2.37	5.1	0.54	0.54	0.51	0.84	0.38	5.25
24	03/11/87	6.54	12.96	2.08	5.65	0.6	0.49	0.55	0.94	0.54	5.31
25	04/09/87	5.15	2.64	1.73	2.2	0.56	0.26	0.11	1.16	1.3	3.39
26	05/17/87	6.92	18.48	0.71	6.22	0.52	1.03	0.92	1.26	0.29	4.39
27	07/07/87	7.19	17.28	0.53	6.54	0.47	0.78	0.67	1.29	0.12	5.34
28	08/23/87	6.94	18.48	0.31	7.65	0.52	0.81	0.7	1.31	0.09	5.28
29	09/21/87	6.79	34.56	0.24	8.07	0.73	1.03	0.65	0.61	0.13	2.65
30	10/21/87	6.92	19.44	1.01	6.57	0.58	1.06	0.64	0.72	0.13	3.34
31	11/30/87	6.87	4.56	1.01	3.55	0.47	0.8	0.61	1.03	0.36	4.99
32	12/29/87	6.28	16.56	1.36	6.75	0.65	1.3	0.76	1.22	0.27	5.16
33	01/27/88	6.72	15.6	1.01	5.63	0.53	1.12	0.54	1.1	0.38	5.66
34	02/29/88	5.79	7.92	0.89	4.86	0.43	1.07	0.64	1.06	3.9	7.54
35	03/31/88	5.75	2.16	1.32	1.95	0.39	0.59	0.55	0.63	1.52	3.54
36	04/15/88	6.61	12.48	1.59	4.71	0.5	1.07	0.67	1.02	2.02	4.47
37	05/15/88	6.99	15.36	1.24	6.39	0.76	1.14	0.68	1.91	3.01	5.58
38	07/06/88	7.06	8.80	1.31	5.32	0.65	1.01	0.56	0.39	0.55	4.20
39	08/01/88	6.85	8.20	1.29	6.02	0.45	1.12	0.59	0.39	0.07	4.19
40	09/02/88	6.60	9.40	1.01	4.95	0.56	1.02	0.49	0.41	0.11	4.24
41	04/08/90	6.29	5.08			0.44	0.74	0.47	0.69	1.12	5.05
42	04/25/90	6.64	3.15		2.45	0.55	0.66	0.46	0.51	1.11	5.66



Dose by Zone

Zone	S.A. (acres)	Dry Dose (tons) EC14	EC40	Total
one zone	18	6.0	4.0	10.0

FIGURE 2-2. NORTH POND TREATMENT INFORMATION. Source: Mass. Division of Fisheries & Wildlife

from ISeT #1

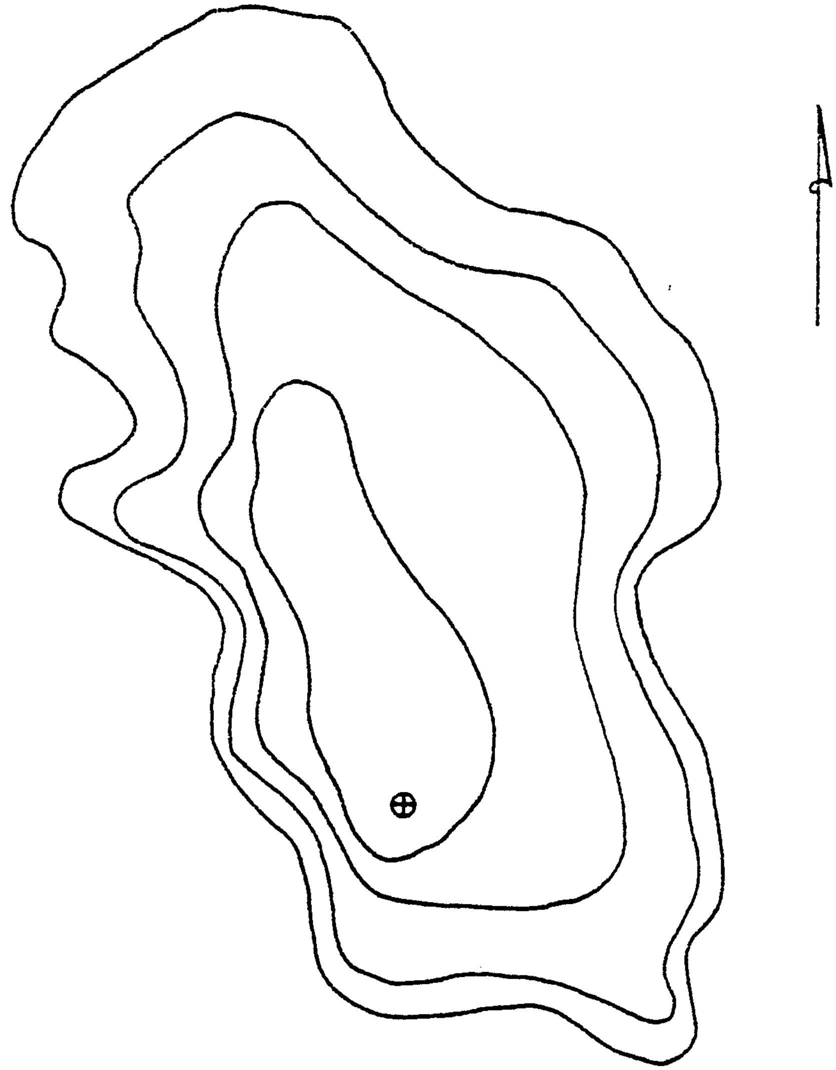


Figure 1. South Pond in Savoy State Forest, Massachusetts. Contour interval equals 1 meter. Source: Depth soundings from Massachusetts Division of Fisheries and Wildlife, base map developed by IS&T.

from IS&T #2

Burnette Pond Raw Data

Num	Year	Date	pH	HCO3	SiO2	Ca	Mg	Na	K	Cl	NO3	SO4
1	84	05/15	6.3	7	2.2	4.21	0.3	9.9	0.8	1.2	0.06	6.5
2	84	05/31	5.7	6.7	2.4	4.03	0.19	0.27	0.2	0.7	0.04	5.7
3	84	06/17	5.9	7.5	1.5	4.33	0.23	0.28	0.9	0.6	0.16	6.2
4	84	07/25	6	11.2	1	4.98	0.26	0.29	1	0.7	0.09	5.2
5	84	08/19	6.2	13.4	1	4.98	0.29	0.29	0.9	0.9	0.01	4.6
6	84	09/16	6.7	19.1	0.9	5.09	0.72	1.07	1.25	1.2	0.06	4.2
7	84	10/21	7.1	13.2	0.6	4.65	0.38	1.08	1.37	1.3	0.02	4
8	84	11/18	6.8	11.3	1.6	4.5	0.35	1.18	1.57	1.3	0.04	5.6
9	84	12/16	6.4	11.2	3.2	5.72	0.56	1.29	1.21	3.6	0.08	8.1
10	85	01/29	6.2	12	4.15	5.95	0.37	1.38	1.24	1.7	0.06	7.05
11	85	02/25	6.2	13.2	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
12	85	03/25	6.3	11.6	3.7	5.72	0.27	1.14	1.14	2.7	0.19	6.3
13	85	04/24	6.9	10.3	2.27	4.43	0.21	0.94	0.82	1.1	0.09	6.2
14	85	05/21	6.8	10.3	1.6	4.65	0.24	0.83	0.96	1.3	0.05	6.35
15	85	06/21	6.9	13.4	1.15	4.9	0.33	0.95	0.7	1.5	0.1	5
16	85	07/29	7	15.4	1.25	6.4	0.27	1.02	1.04	1.21	0.07	4
17	85	08/23	6.9	18	1.6	8	0.3	1.05	0.85	0.76	0.09	4.3
18	85	09/23	6.66	13.68	2.4	5.1	0.24	0.95	0.5	0.77	0.05	4.7
19	85	10/23	6.65	13.92	4.05	5	0.24	1.02	1.04	0.76	0.07	5.5
20	87	03/11	6.49	19.68	4.79	7.77	0.58	1.25	2.26	1.86	0.48	6.34
21	87	04/09	6.35	7.68	2.21	4.32	0.29	0.52	0.01	1.1	1.09	4.87
22	87	05/17	6.39	11.04	1.71	4.83	0.46	0.87	0.88	1.42	0.1	6.31
23	87	07/07	6.47	14.88	1.12	5.63	0.65	1.15	1.03	1.68	0.09	6.68
24	87	08/23	6.92	15.6	1.89	6.51	0.51	1.17	1.04	1.6	0.08	5.75
25	87	09/21	6.58	14.88	0.7	6.34	0.38	1.43	0.96	1.13	0.1	4.47
26	87	10/21	6.97	10.08	3.07	5.13	0.36	1.22	0.91	0.96	0.12	5.73
27	87	11/30	6.81	14.4	3.31	4.72	0.57	1.54	1.04	1.01	0.11	6.39
28	87	12/29	6.48	11.76	4.04	5.75	0.49	1.54	0.91	1.47	0.62	7.69
29	88	01/27	6.41	16.32	3.67	6.21	0.57	1.14	0.87	1.22	0.42	7.93
30	88	02/29	6.14	12.48	3.89	6.16	0.65	1.37	0.78	1.52	4.24	7.92
31	88	04/01	6.55	8.88	2.92	5.56	0.45	1.21	0.77	2.19	3.59	6.54
32	88	04/15	6.6	7.2	2.41	4.98	0.31	1.49	0.86	2.12	1.49	6.54
33	88	05/15	6.66	11.04	1.63	5.54	0.38	1.17	0.79	2.23	0.19	6.21
34	88	07/06	7.10	10.00	2.12	4.32	0.34	1.21	0.77	0.74	0.21	5.73
35	88	08/01	6.8	9.4	2.01	3.98	0.31	1.21	0.89	0.68	0.19	5.63
36	88	09/02	6.79	9.6	1.89	4.56	0.32	1.02	0.99	0.61	0.13	4.49
37	90	04/08	6.64	9.20			0.34	1.06	0.63	1.43	0.90	5.41
38	90	04/25	6.78	9.20		3.82	0.41	1.02	0.70	1.26	0.62	6.54

South Pond Raw Data

Num	Date	pH	HCO3	SiO2	Ca	Mg	Na	K	Cl	NO3	SO4
1	05/15/84	5	1.6	0.2	1.7	0.26	0.45	0.3	0.3	0.02	5.2
2	05/31/84	4.2	0	0.6	1.2	0.15	0.56	0.2	0.6	0.01	5.3
3	06/17/84	4.5	0	0.4	1.53	0.2	0.57	0.5	0.4	0.04	5.4
4	07/25/84	5.1	1.9	0.3	1.42	0.2	0.49	0.4	0.4	0.13	5
5	08/19/84	4.8	0.7	0.2	1.38	0.24	0.51	0.33	0.3	0.01	4.6
6	09/16/84	5.6	2.1	0.1	1.31	0.28	0.5	0.4	0.3	0.42	4.8
7	10/21/84	5.5	3.8	0.2	1.4	0.26	0.55	0.4	0.4	0.01	5.3
8	11/18/84	5.3	1.3	0.3	1.23	0.25	0.7	0.4	0.4	0.01	6.1
9	12/16/84	4.7	1	0.3	0.63	0.17	0.24	0.16	0.3	0.1	3.1
10	01/29/85	5.1	1.4	1.33	1.57	0.26	0.66	0.33	0.6	0.02	6.6
11	02/25/85	5	1.3	1.48	2.22	0.21	0.71	0.33	0.35	0.06	7.1
12	03/25/85	5.1	1.6	1.42	1.69	0.18	0.65	0.29	0.5	9.99	7.1
13	04/24/85	5.3	3.6	1.37	1.62	0.12	0.58	0.22	0.5	9.99	6.2
14	05/21/85	5.2	2.9	0.71	1.35	0.12	0.5	0.17	1.1	9.99	5.9
15	06/21/85	5.4	2.6	0.15	1.7	0.18	0.5	0.17	0.5	9.99	11.53
16	07/29/85	4.8	2.2	0.38	2.2	0.32	0.58	0.17	0.1	9.99	11.02
17	08/23/85	5.33	1.68	0.33	2	0.23	0.58	0.02	0.1	9.99	14.09
18	09/23/85	5.35	2.64	0.8	1.6	0.32	0.52	0.33	0.12	9.99	14.35
19	10/23/85	5.2	1.92	1.1	1.6	0.32	0.56	0.03	0.17	9.99	10.12
20	03/11/87	5.28	3.84	1.6	2.38	0.72	0.84	0.21	1.06	0.88	6.22
21	04/09/87	4.7	2.16	1.95	1.29	0.55	0.24	0.55	0.87	1.68	3.75
22	05/17/87	5.68	4.32	1.21	1.66	0.6	0.96	0.86	1.35	0.34	4.73
23	07/07/87	6.45	4.08	0.72	1.9	0.7	1.31	1.17	1.94	0.05	6.61
24	08/23/87	5.69	2.64	0.38	1.72	0.47	0.93	0.88	1.43	0.13	5.1
25	09/21/87	5.53	4.08	0.04	1.46	0.46	1.15	0.8	0.89	0.1	4.97
26	10/21/87	6.44	3.84	0.86	2.08	0.33	1.14	0.75	0.91	0.09	4.38
27	11/30/87	7.21	20.16	1.21	7.79	0.34	1.09	0.69	0.82	0.1	4.65
28	12/29/87	6.51	10.08	1.75	7.07	0.47	1.13	0.72	1.87	0.84	6.39
29	01/27/88	6.76	22.08	1.21	7.83	0.49	1.19	0.74	1.17	0.56	6.75
30	02/29/88	6.67	21.84	2.88	6.78	0.65	1.21	0.67	1.10	0.96	4.21
31	04/01/88	6.48	7.44	2.61	3.83	0.37	1.18	0.62	0.75	1.59	5.44
32	04/15/88	6.57	12.72	1.67	4.43	0.33	1.4	0.71	1.04	1.13	4.23
33	05/15/88	6.86	12	1.24	5.18	0.38	1.12	0.62	1.31	2.42	4.97
34	07/06/88	6.79	9.60	1.02	4.21	0.39	1.16	0.70	0.42	0.09	4.23
35	08/01/88	6.78	7.8	1.12	4.28	0.32	1.12	0.89	0.38	0.09	4.31
36	09/02/88	6.30	5.60	0.99	3.03	0.41	1.15	0.91	0.40	0.11	3.78
37	04/08/90	6.82	13.07			0.31	0.73	0.56	0.68	0.89	5.04
38	04/25/90	7.00	9.43		2.45	0.55	0.69	0.44	0.63	0.56	3.05

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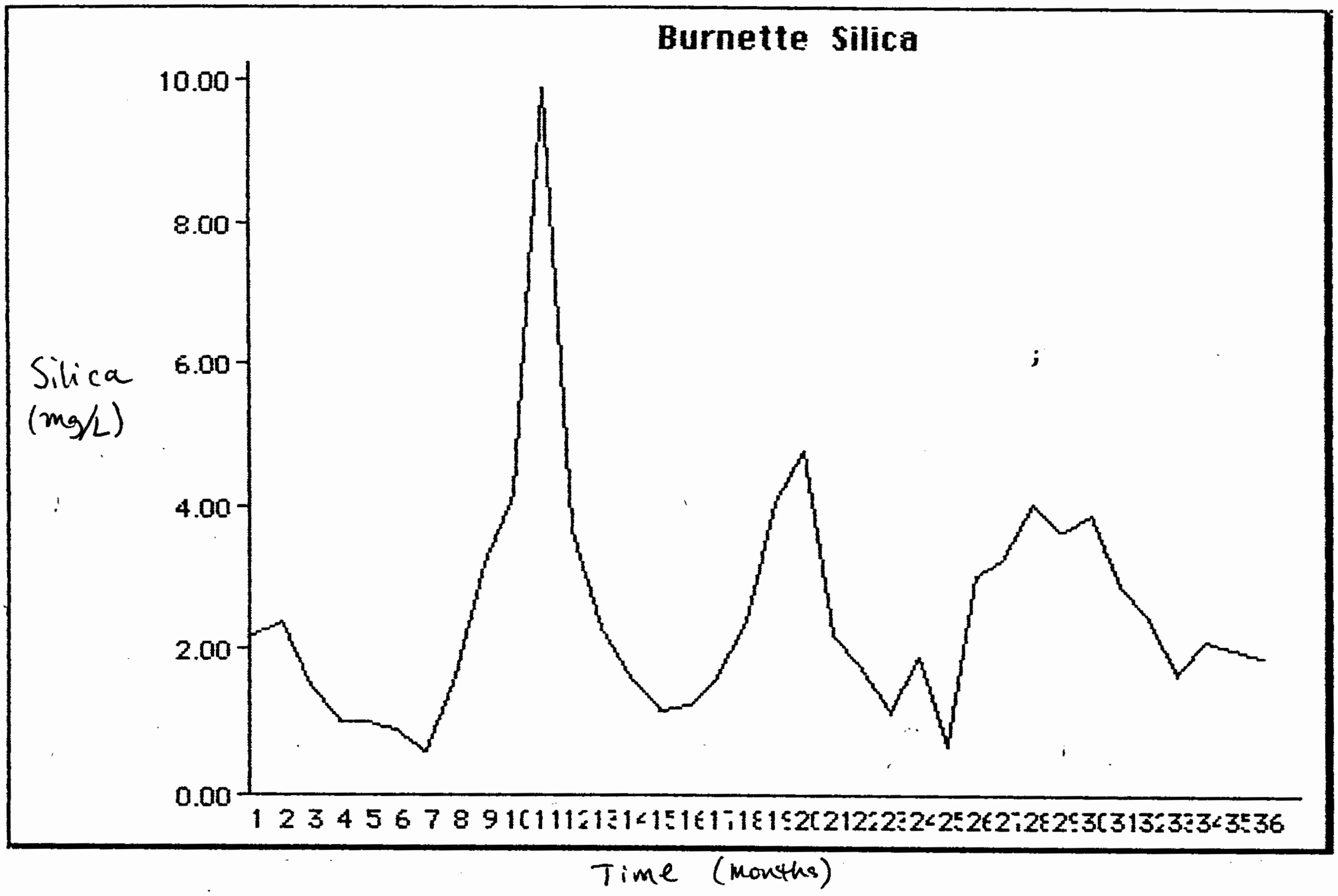

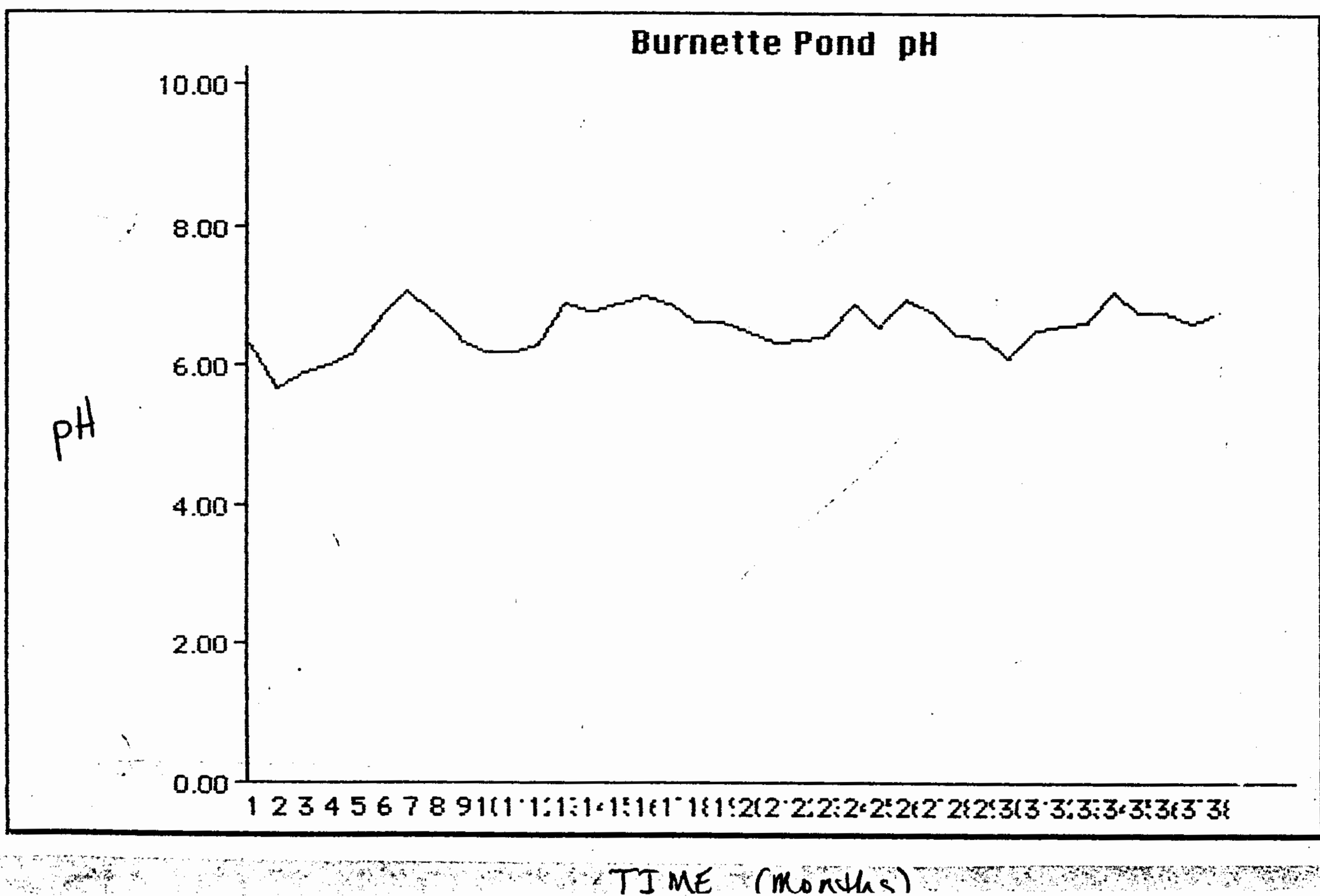

Tophet Brook, upper

Date	Ca	Mg	Na	K mgL^{-1}	HCO_3	SO_4	Cl	NO_3	SiO_2	pH	Specific conductance $\mu mho\ cm^{-1}$	Estimated discharge
3/5/83	2.80	0.31	1.48	0.64	3.4	7.5	1.6		4.6	5.7	31	
4/3/83	2.22	0.25	0.98	1.50	3.9	5.3	0.7		3.1	6.0	28	
5/15/83	2.25	0.26	0.98	0.56	3.3	6.8	0.5		2.5	5.6	24	
6/19/83	2.0	0.23	1.14	0.90	3.9	5.4	0.4		3.2	5.8	21.5	
7/17/83	2.55	0.42	1.14	0.60	5.4	3,6	0.9		5.0	5.9	24	
8/21/83												
9/18/83	3.35	0.73	1.68	1.50	10.5	6.7	1.9		5.8	6.3	39	
0/16/83	4.25	0.63	1.4	1.00	3.9	12.3	2.2		6.1	5.8	42	
1/20/83	3.10	0.37	1.3	0.70	3.4	10.5	1.6		5.1	5.5	34	
2/18/83	2.20	0.23	0.98	1.00	2.4	8.3	0.9		3.7	5.3	27	
1/28/84	2.55	0.32	1.21	0.85	1.7	8.3	1.6		5.6	5.5		
2/19/84		0.17		0.60	2.2	6.5	1.0		3.5	5.1		
3/18/84	2.45	0.38	0.98	0.64	2.6	7.3	1.2		4.4	5.3		

Tophet Brook, upper

I.2

Burnette Pond, Savoy 33 33004

Date	pH	Alkalinity, EPA	mg/L as $CaCO_3$ Standard methods
4/8/83	6.3	3.4	5.2
5/15/83	6.5	5.4	7.4
6/19/83	6.8	7.2	9.3
7/17/83	6.95	10.0	11.8
8/21/83	7.1	12.2	14.1
9/18/83	6.90	14.3	16.2
10/14/83	6.97	12.5	15.1
11/20/83	6.94	12.4	14.5
12/18/83	---	---	---
1/15/84	6.4	8.0	10.0
2/19/84	6.6	6.0	7.9
3/18/84	6.3	7.7	9.7
4/15/84	6.0	2.3	4.1

Burnette Pond

Date	HCO_3	SO_4	Cl	SiO_2	pH	S.C.
	[------------mg L^{-1}			------------]		
4/8/83	6.3	6.4	0.7	3.1	6.3	-
5/15/83	9.0	7.0	0.8	1.9	6.6	36
6/19/83	11.3	6.8	0.6	1.5	6.8	-
7/17/83	14.4	5.6	0.7	1.5	7.0	47
8/21/83	17.2	4.2	0.6	1.2	7.1	44
9/18/83	19.8	4.0	0.6	1.2	6.9	47

Bog Pond at dam, Savoy   33 33002

Date	pH	Alkalinity, EPA	mg/L as $CaCO_3$ Standard methods
4/8/83	5.5	0.4	2.3
5/15/83	5.5	0	2.0
6/19/83	5.7	0.7	2.9
7/17/83	5.65	0.8	2.5
8/21/83	6.0	0.8	2.7
9/18/83	5.75	1.2	3.1
10/14/83	5.90	1.1	3.2
11/20/83	5.71	0.8	2.9
12/18/83	---	---	---
1/15/84	5.6	1.2	3.2
2/19/84	5.2	0	1.9
3/18/84	5.7	1.4	3.3
4/15/84	5.3	0.5	2.2

Bog Pond

Date	HCO_3	SO_4	Cl	SiO_2	pH	S.C.
	[-------------mg	L^{-1}	-------------	]		
4/8/83	2.8	4.5	0.7	2.1	5.5	20
5/15/83	2.4	6.3	0.5	0.9	5.5	25
6/19/83	3.5	6.5	0.2	<0.1	5.7	23
7/17/83	3.1	4.6	<0.1	<0.1	5.7	22
8/21/83	3.3	3.8	0.3	<0.1	6.0	19
9/18/83	3.8	4.7	0.3	<0.1	5.7	21

Tophet Brook, upper

Date	Ca	Mg	Na	K mgL^{-1}	HCO_3	SO_4	Cl	NO_3	SiO_2	pH	Specific conductance µmho cm^{-1}	Estimated discharge
3/5/83	2.80	0.31	1.48	0.64	3.4	7.5	1.6		4.6	5.7	31	
4/3/83	2.22	0.25	0.98	1.50	3.9	5.3	0.7		3.1	6.0	28	
5/15/83	2.25	0.26	0.98	0.56	3.3	6.8	0.5		2.5	5.6	24	
6/19/83	2.0	0.23	1.14	0.90	3.9	5.4	0.4		3.2	5.8	21.5	
7/17/83	2.55	0.42	1.14	0.60	5.4	3,6	0.9		5.0	5.9	24	
8/21/83												
9/18/83	3.35	0.73	1.68	1.50	10.5	6.7	1.9		5.8	6.3	39	
0/16/83	4.25	0.63	1.4	1.00	3.9	12.3	2.2		6.1	5.8	42	
1/20/83	3.10	0.37	1.3	0.70	3.4	10.5	1.6		5.1	5.5	34	
2/18/83	2.20	0.23	0.98	1.00	2.4	8.3	0.9		3.7	5.3	27	
1/28/84	2.55	0.32	1.21	0.85	1.7	8.3	1.6		5.6	5.5		
2/19/84		0.17		0.60	2.2	6.5	1.0		3.5	5.1		
3/18/84	2.45	0.38	0.98	0.64	2.6	7.3	1.2		4.4	5.3		

Tophet Brook, Upper

I.2

Burnette Pond, Savoy 33 33004

Date	pH	Alkalinity, EPA	mg/L as $CaCO_3$ Standard methods
4/8/83	6.3	3.4	5.2
5/15/83	6.5	5.4	7.4
6/19/83	6.8	7.2	9.3
7/17/83	6.95	10.0	11.8
8/21/83	7.1	12.2	14.1
9/18/83	6.90	14.3	16.2
10/14/83	6.97	12.5	15.1
11/20/83	6.94	12.4	14.5
12/18/83	---	---	---
1/15/84	6.4	8.0	10.0
2/19/84	6.6	6.0	7.9
3/18/84	6.3	7.7	9.7
4/15/84	6.0	2.3	4.1

Burnette Pond

Date	HCO_3	SO_4	Cl	SiO_2	pH	S.C.
	[------------mg L^{-1}			------------]		
4/8/83	6.3	6.4	0.7	3.1	6.3	-
5/15/83	9.0	7.0	0.8	1.9	6.6	36
6/19/83	11.3	6.8	0.6	1.5	6.8	-
7/17/83	14.4	5.6	0.7	1.5	7.0	47
8/21/83	17.2	4.2	0.6	1.2	7.1	44
9/18/83	19.8	4.0	0.6	1.2	6.9	47

Bog Pond at dam, Savoy 33 33002

Date	pH	Alkalinity, EPA	mg/L as $CaCO_3$ Standard methods
4/8/83	5.5	0.4	2.3
5/15/83	5.5	0	2.0
6/19/83	5.7	0.7	2.9
7/17/83	5.65	0.8	2.5
8/21/83	6.0	0.8	2.7
9/18/83	5.75	1.2	3.1
10/14/83	5.90	1.1	3.2
11/20/83	5.71	0.8	2.9
12/18/83	---	---	---
1/15/84	5.6	1.2	3.2
2/19/84	5.2	0	1.9
3/18/84	5.7	1.4	3.3
4/15/84	5.3	0.5	2.2

Bog Pond

Date	HCO_3	SO_4	Cl	SiO_2	pH	S.C.
	[-------------	mg L^{-1}	-------------	]		
4/8/83	2.8	4.5	0.7	2.1	5.5	20
5/15/83	2.4	6.3	0.5	0.9	5.5	25
6/19/83	3.5	6.5	0.2	<0.1	5.7	23
7/17/83	3.1	4.6	<0.1	<0.1	5.7	22
8/21/83	3.3	3.8	0.3	<0.1	6.0	19
9/18/83	3.8	4.7	0.3	<0.1	5.7	21