**Spring Shocks in Birch Brook**

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ENVI 102: Introduction to Environmental Science

Independent Project Report

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**Abstract**

This experiment was performed to determine whether or not acidic snowmelt was a significant factor in nitrate leaching from soil during "spring shocks." We took streamwater and snowmelt samples, and analyzed these samples for pH and ion content. We then compared this data to stream discharge and temperature for Birch Brook. While there were no statistically significant correlations, our data suggested both that spring shocks do occur. It also suggested that these acidic spring shocks cause shocks in the brook pH and ion content. It is likely that snowmelt flows into the brook both above and below ground; it is also likely that acidic snowmelt flowing through the soil leaches out ions and nutrients. It is uncertain whether or not this phenomenon is detrimental to aquatic or forest health.

**Introduction**

Acid precipitation was one of the first environmental problems to draw the attention both of scientists and the public. This is no surprise—acid rain has immediate and dramatic effects, dissolving marble statues, turning vegetation brown and brittle, and killing aquatic life. Recent efforts to cut down on industrial release of sulfur and nitrogen oxides, which contribute to acid rain, have had some effect. However, acid precipitation is still a large threat to the environment.

This experiment was performed to examine another, less obvious detrimental effect of acid precipitation: the leaching of nitrate from soil due to acidic snowmelt. Trees and other vegetation need nitrate and other nutrients to grow; however, they do not need these nutrients during the winter and early spring, when they lie dormant. However, bacteria nitrify the soil year-round. Consequently, a build-up of nitrate is created in the colder months of the year. This nitrate will be used by trees during their spring and summer growth spurts. However, acidic snowmelt, as it passes through groundwater on its way to streams, may leach this nitrate from the soil. We hoped to see whether "spring shocks," or increases in stream flow levels due to snowmelt, were correlated to abnormal levels of nitrate or pH in the streams. If so, we wanted to determine whether or not these abnormal levels are detrimental to either vegetation or aquatic life.

**Methods**

*Fieldwork:* Our main sampling site was Birch Brook, a tributary of the Hoosic River System. We took samples from the brook in Williamstown, Massachusetts, at a location off of Petersburg Road. Sampling began on 7 March 2007, during the first significant snowmelt of the spring, and lasted until 12 April 2007, when the snowpack had completely melted. Water samples were taken by dipping a collection bottle into the stream; temperature was also taken onsite by dipping a probe into the river. Snow collections were taken by pressing a collection bottle into the snow on the riverbank to obtain a snow core; one snow collection was taken in the same manner from the fields behind the Clark Art Museum, also in Williamstown, Massachusetts.

*Labwork:* We waited to perform our analyses until we had collected all of our samples; in the meanwhile, we stored samples in the refrigerator to inhibit bacteria growth. When we had finished the fieldwork portion of the experiment, we measured the $Na^+$, $Ca^{2+}$, $Mg^{2+}$, and $K^+$ content of the samples using the Atomic Absorption Spectrophotometer and $NO_3^-$, $PO_4^{-3}$, $SO_4^{-2}$, $Cl^-$, and $F^-$ content using the Ion

Chromatograph. We measured pH and Acid Neutralizing Capacity (ANC) at intervals over a longer period of time; we generally measured the ANC of a sample some days after measuring its pH. For all four of these techniques, we followed the methods outlined in the ENVI 102 Lab Manual.

**Results**

*Discharge and Temperature Data*: Thanks to the Birch Brook Watershed Database, we were able to compare our data to daily weather and stream parameters for the months of March and April, as well as historical data. Stream flow and outside temperature, the two main indicators of spring shocks, seemed to indicate three major shocks of water entering the brook (Fig. 1). These shocks were clearest in discharge data, but were somewhat reflected in temperature as well. Unfortunately, our data collection stopped before the third shock, but we could use weather and stream data to examine our measurements in light of the first two spring shocks.

*pH Data:* Our pH data for Birch Brook is reasonably erratic. While the data could be interpreted to show two shocks of lower pH levels and higher acidity, the scarcity of data points makes this interpretation uncertain (Fig. 2). Furthermore, we had significant difficulties in collecting our pH data. We initially used one set of machines, then realized that they were extremely inaccurate. Consequently, there was a large lag between our collection of samples and our analysis of their pH levels. During much of this lagtime, the samples were kept at room temperature, albeit covered. It is possible that a combination of these factors could have caused our data to be less than accurate.

However, our measurements of pH of the Brook are much lower than those of the snowfall. While the two measurements are not directly correlated, this does not necessarily mean anything—after all, snowmelt traveling through groundwater would not immediately flow into the brook. Once again, though, our paucity of data prevents us from making any definite conclusions about correlations between snow pH and brook pH. It is interesting, though, that the levels of snow pH vary greatly; unless certain snowfalls were more influenced by industrial processes than others, this phenomena points to inaccuracy in our data. It also makes it even more difficult to correlate shocks in brook pH to acidic snowmelt.

*ANC Data:* Our Acid Neutralizing Capacity data turned out to be very similar to our pH data—while the two have peaks of very different magnitudes, these peaks generally occur at similar intervals and dates (Fig. 3). This, unlike the varying pH levels, is a positive sign for the accuracy of our analysis—as we took ANC measurements even later than we took pH measurements, it seems unlikely that lagtime was a significant source of error in our data. This correlation also seems to suggest that any buffering capacity of the brook was quickly overwhelmed when faced with acid snowmelt—when the stream's pH is lowered, the ANC decreases proportionally. If the brook had a significant buffer, the ANC would decrease even when the pH did not.

*Ion Chromatograph Data*: Our nitrate data similarly suggests two major peaks in stream nitrate content (Fig. 4). Furthermore, nitrate levels for streamwater are higher across the board than those for snowmelt. Interestingly, the nitrate levels do not drop back down after these shocks—there is a decided upward trend throughout the data. However, our average nitrate level is higher than that of all but one month in the entire

20+ year chemical database for Birch Brook; this sheds some doubt on the accuracy of our data (Fig. 5). These shockingly high values might be due to problems with our standards during our IC run—indeed, our sulfate data is nonexistent and our phosphate data is unreliable due to problems with standards.. While it is indeed possible that we simply caught the height of the spring shocks in our collection, it seems more likely that specific values are not necessarily to be trusted.

However, regardless of specific values, the data should still be proportionally accurate within the set. This makes our upward trend in nitrate very interesting. It is possible that the second spring shock was more potent than the first—this is plausible, as the snowpack that melted during the first shock had been existent for a few months, while the second snowpack was not on the ground long before melting. As snowpacks tend to degrade over time, letting ions and nutrients collect at their bases, the first snowpack could have produced a more dilute snowmelt.

*Atomic Absorption and Emission Spectrophotometry Data:* Our hope in running our samples on the AAS/AES was that there would be strong correlations between cation levels in the snow and in the streamwater. However, this did not appear to be the case—our AAS/AES values were generally much higher for streamwater than for snowmelt. The scarcity of our snowmelt data made it difficult to conclusively judge the existence of a correlation between the two data sets, but no immediate correlation is apparent. It is indeed possible that cation concentrations increased due to leaching during the acidic snowmelt's passage through groundwater.

**Discussion**

Our data did not show the strong correlations that we expected. While parameters such as stream pH or nitrate would be expected to correlate with stream discharge, these correlations were both fairly weak (Figs. 7, 9). Other correlations, such as pH and nitrate level, were inversely related, making it difficult to empirically determine the level of correlation (Fig. 8). The same difficulties existed for data that were offset by time due to melting and passage through groundwater—for example, snow pH and stream pH. Our small data set, coupled with its relative inaccuracy, also made it difficult to make concrete conclusions.

However, qualititative conclusions are possible. Our data shows definite drops in pH and jumps in nitrate level that seem to indicate shocks (Fig. 10). While these data sets do not match up perfectly with discharge data, this is likely due to timelag (Fig. 11). The jumps in nitrate, coupled with the higher cation and anion concentrations in the streamwater than in the snowmelt, suggest that acidic snowmelt does indeed pass through the soil and leach out ions. This result is corroborated by Campbell, Mitchell, and Mayer; however, Strand, Abrahamsen and Stuanes have performed two experiments that suggest that acid rain causes nitrate leaching only in very small quantities.

However, our data does not suggest that spring shocks were accompanied by shocks in ion levels. Instead, it appears that these levels gradually increased over the entire period of snowmelt. While pH and ANC seem to indicate more of a shock, they also gradually increase over the period, making it seem likely that the shocks in these parameters were caused by snowmelt flowing aboveground. It seems that any snowmelt that seeped into the groundwater had a much more gradual effect on the parameters we measured. This makes perfect sense—groundwater does not move very fast, so it would follow that effects in stream parameters linked to groundwater would be more gradual. Consequently, it may not even be that helpful to look at specific data points to determine whether nutrient leaching is occurring. Monthly averages are more helpful; these averages indicate that while peaks in stream nitrate content do occur in the spring and summer, they drop drastically during the fall, allowing more nitrate to be stored in the soil.

It is very possible that some of the confusion in our data is due to different sources of the nitrate in the river. While some of this nitrate is undoubtedly leached from the soil and carried in groundwater to the river, it is also likely that some is due to atmospheric deposition through snowfall. Nitrate from this source would either be deposited directly into the brook during snowfall, or would run aboveground into the brook—as Campbell, Mitchell, and Mayer suggest in their report, at heavy melting periods the soil can reach its saturation point, forcing the snowmelt to run aboveground into bodies of water.

**Conclusion**

Our experiment indicated that spring shocks do happen—in periods of heavy snowmelt, brook discharge increases, and pH and nitrate levels are affected. However, it is not so clear that these effects are detrimental to river or soil health. Acidic pulses in the brook are brief; it seems unlikely that they could hurt aquatic life. The same seems likely for nutrient pulses, although the upward trend of our nitrate data makes this less certain.

It does not appear that nutrient loss due to spring shocks is very detrimental to tree health, either. As biomass data from the trees of five Hopkins Forest plots shows, the rate of increase in biomass is remaining relatively steady—in the last decade, biomass has increased roughly half as much as it increased in the previous 20 years (Fig. 12). As the trees are still growing at a steady rate, they do not appear to be suffering that much from loss of nutrients. Spring shocks occur when the trees are dormant; it appears that nutrients are renewed by the time they begin growing again, both through nitrification and atmospheric deposition.

However, acid precipitation is still a large problem for other parts of the country—one must keep in mind that Birch Brook is not surrounded by industrial emitters. Furthermore, Hopkins Forest is reasonably healthy; it is possible that if acid precipitation was combined with other environmental problems, the trees would become overwhelmed. Unfortunately, acid precipitation is caused by industrial emissions; as industry is such a large part of the American economy, it will be difficult to end emissions. However, measures such as the Clean Air Act have caused significant decreases in the amount and toxicity of emissions. Continued emissions cuts, coupled with new technology like emissions scrubbers, can continue to effect a change. Whether or not acid precipitation has directly harmed Birch Brook or the surrounding area, it is a serious threat to the environment that demands immediate and continued attention.

**Recommendations for Future Projects**

One of the largest problems with our research was that we simply did not have enough data, especially of snowmelt. While stream data did tell us that shocks of some sort occurred, it would have been very helpful to be able to correlate specific parameters such as pH and ion concentration of the stream with snowmelt. It would have also been helpful to know exactly when the snow fell—as the ion content of snowpacks decrease over time, it was difficult to tell whether a specific sample of melted snow was dilute or concentrated.

It would have also been helpful to have more baseline data. While the database was very helpful, our data seemed to differ quite a bit. Furthermore, the database was somewhat incomplete—it did not include information on phosphate, for example. It would have been useful to extend our data collection for a month in either direction to create a baseline that we were positive was directly comparable to our spring shock data.

Finally, our pH and ANC results would likely have been more accurate if we had analyzed the samples all at the same time, and sooner after collecting them. This was not entirely our fault, though, as we had a great deal of difficulty with the pH meters. Even once we began to use a higher-quality pH meter, replicates performed on different days varied by up to 0.66, suggesting that the unreliability of our data was not entirely due to human error (Appendix II).

**Acknowledgments**

I would like to thank Professor Bingemann and Jay Racela very, very much for collecting samples for us during spring break. I'd also like to thank Professor Stoll for advice and help on the project. I would like to thank the creators and maintainers of the Birch Brook Watershed Database, as well as the Hopkins Forest Weather Database. Finally, I'd like to thank Stuart Jones '08, my partner in crime.

## References

Campell, John L., Myron J. Mitchell, and Bernhard Mayer. "Isotopic assessment of NO3- and SO42- mobility during winter in the Adirondack Mountains, New York." *Journal of Geophysical Research* (111). 15 November 2006.

Driscoll, C.T., et. al. *Acid Rain Revisited: Advances in scientific understanding since the passage of the 1970 and 1990 Clean Air Act Amendments.* Hubbard Brooks Research Foundation. Science Links Publication. 2001 Vol. 1, no. 1.

ENVI 102 Lab Manual. "Water Analysis Procedures." 2007.

Federal Research Centre for Forestry and Forest Products. "Forest Condition in Europe: 2000 Executive Report." United Nations Economic Commission for Europe: Germany, 2000.

Kopáček, Jiří, Evžen Stuchlík and Richard F. Wright. "Long-term trends and spatial variability in nitrate leaching from alpine catchment–lake ecosystems in the Tatra Mountains." *Environmental Pollution.* Volume 136, Issue 1, July 2005, Pages 89-101.

Strand, L.T., G. Abrahamsen and A. O. Stuanes. "Leaching from Organic Matter–Rich Soils by Rain of Different Qualities." *Journal of Environmental Quality.* 31:547-556 (2002).

Strand, L.T., G. Abrahamsen and A. O. Stuanes. "Lysimeter Study on the Effects of Different Rain Qualities on Element Fluxes from Shallow Mountain Soils in Southern Norway." *Water, Air, and Soil Pollution.* Volume 165, Numbers 1-4 / July, 2005.

Williams College. *Birch Brook Watershed Data.* <http://oit.williams.edu/weather/watershed/>.

Williams College. *Williamstown Weather Archive.* <http://oit.williams.edu/weather/archives.cfm>.

## Appendix I. Figures.

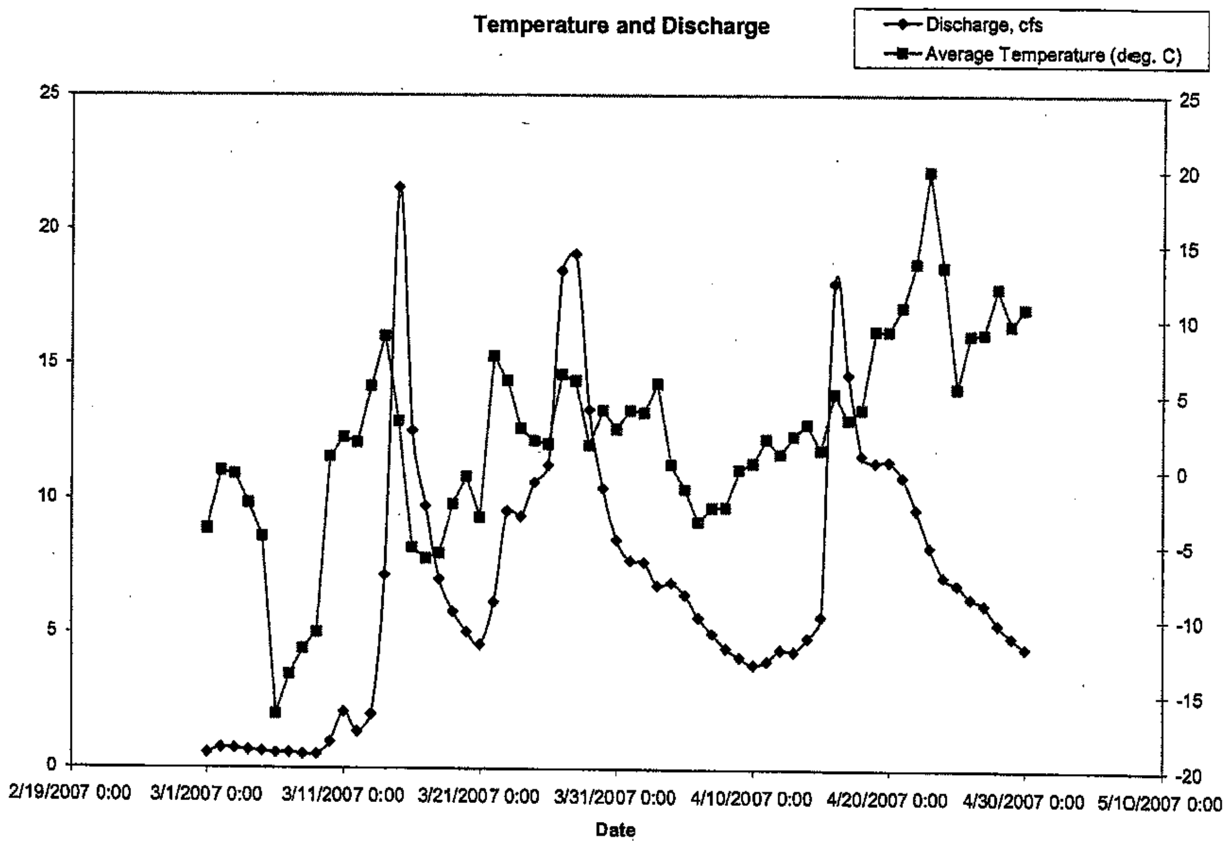


Figure 1. Temperature and Discharge of Hopkins Forest and Birch Brook, resp.

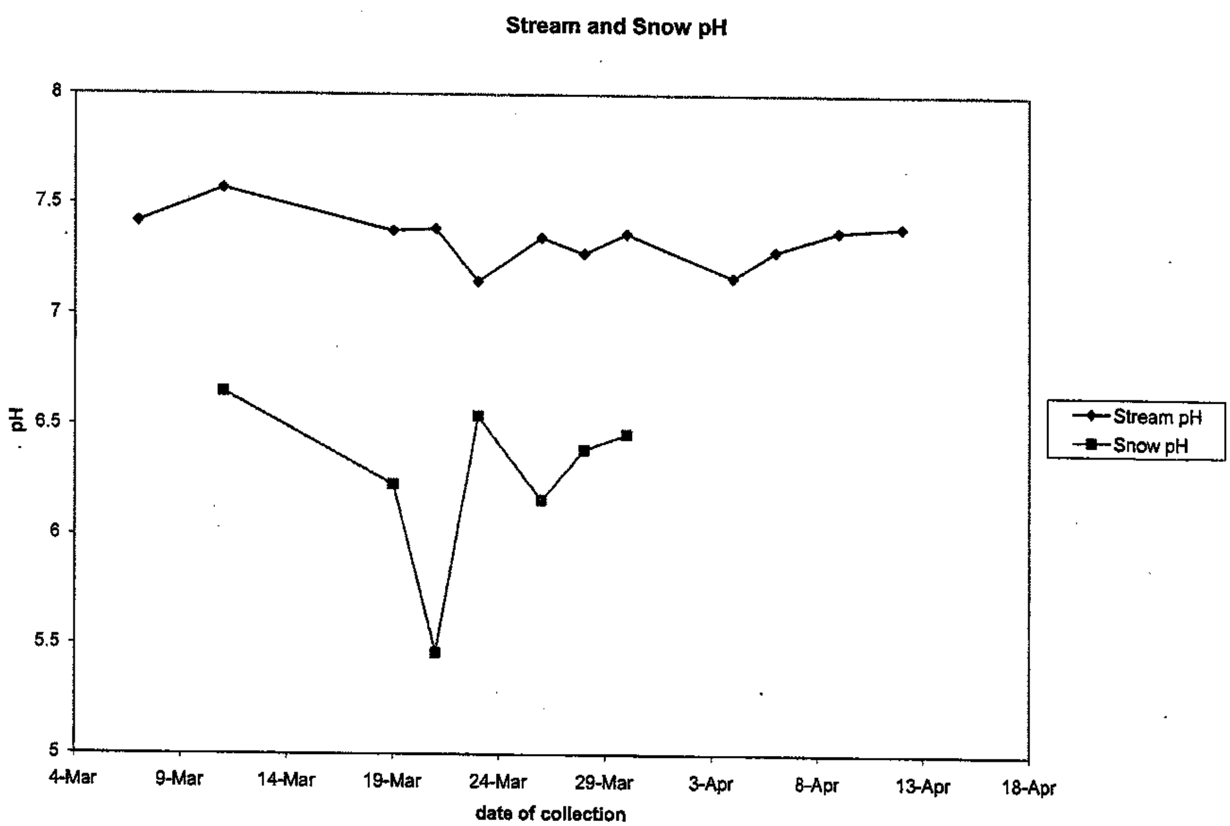


Figure 2. Stream and snow pH levels of Birch Brook.

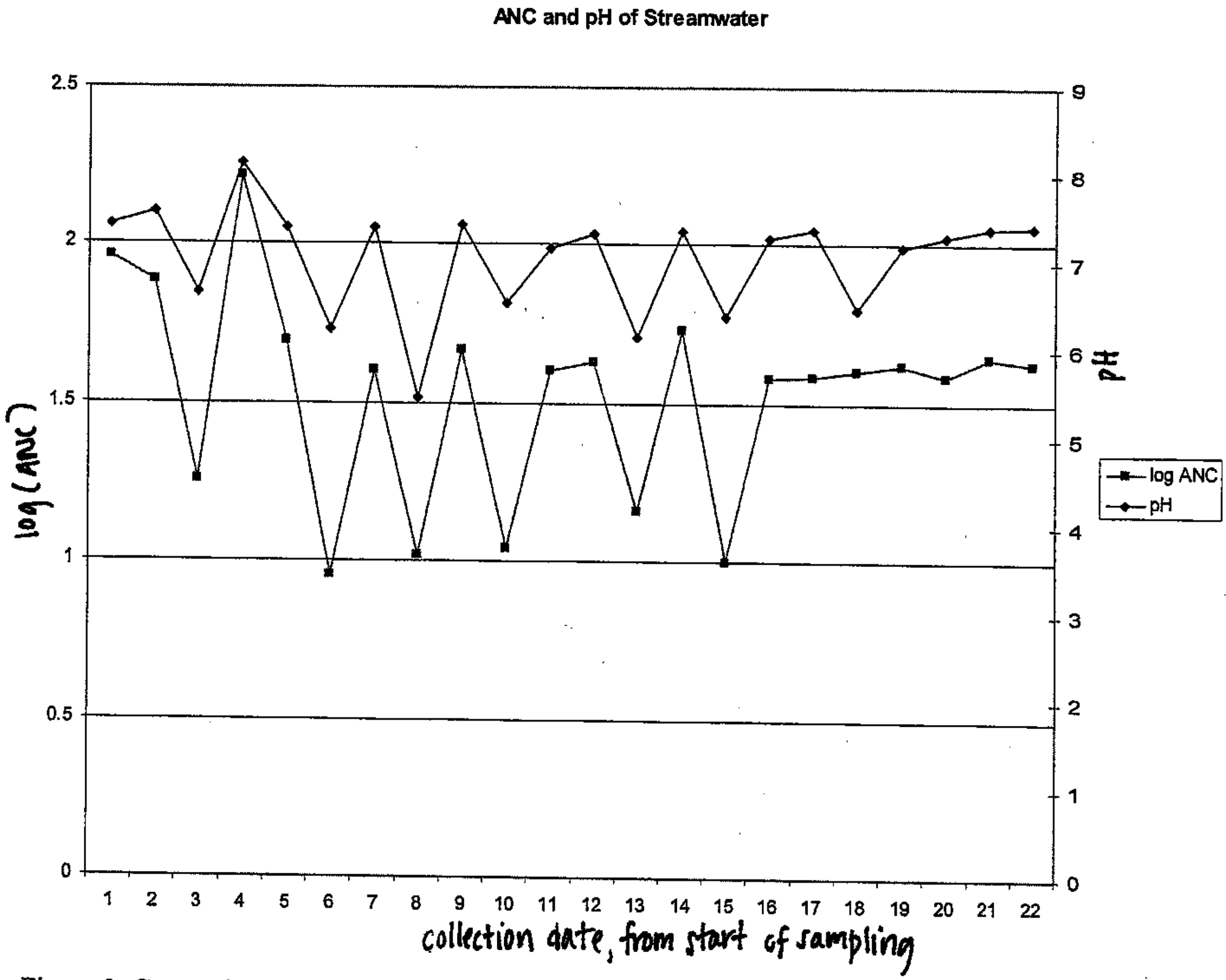


Figure 3. Comparison of ANC values and pH levels of Birch Brook streamwater.

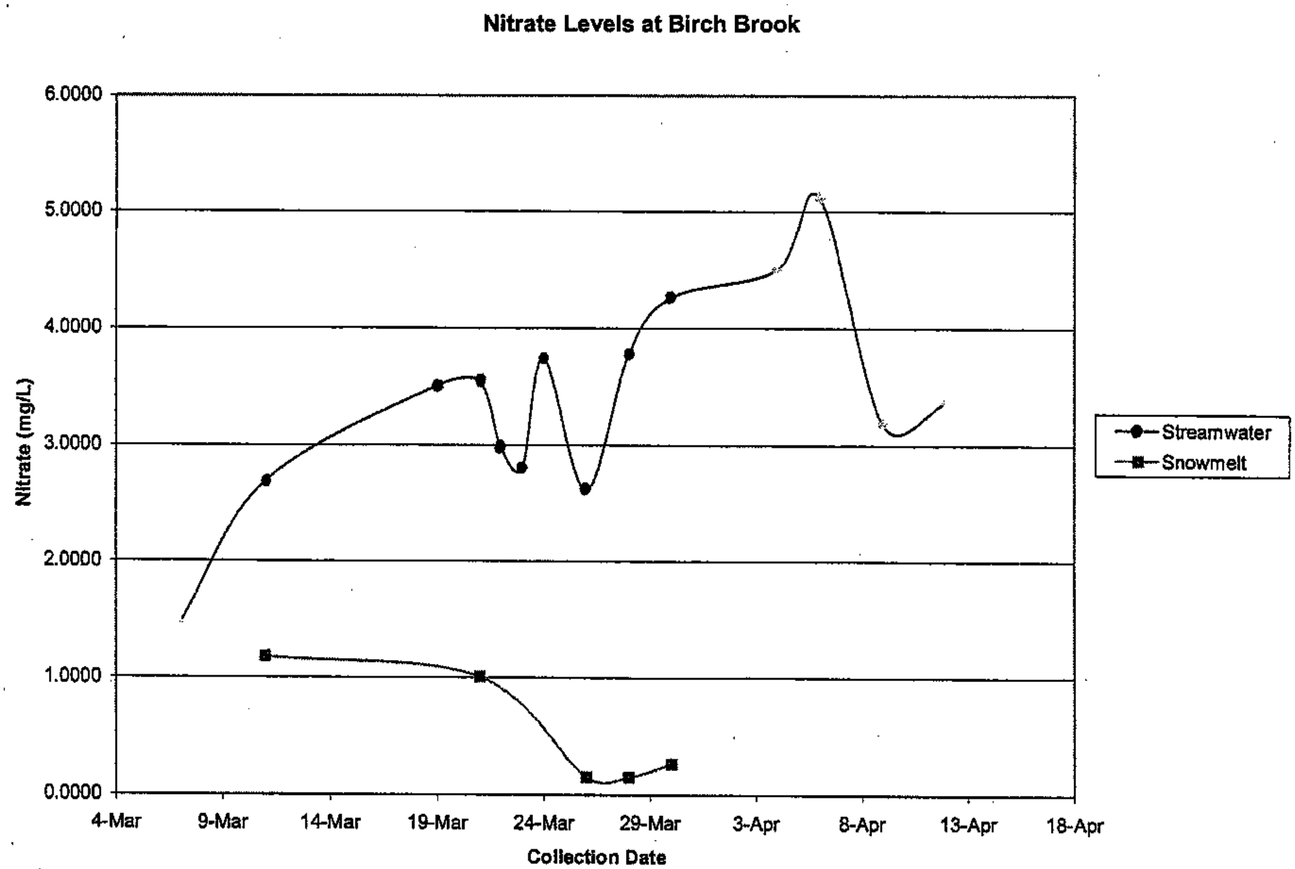


Figure 4. Comparison of nitrate levels of Birch Brook streamwater and nearby snowmelt.

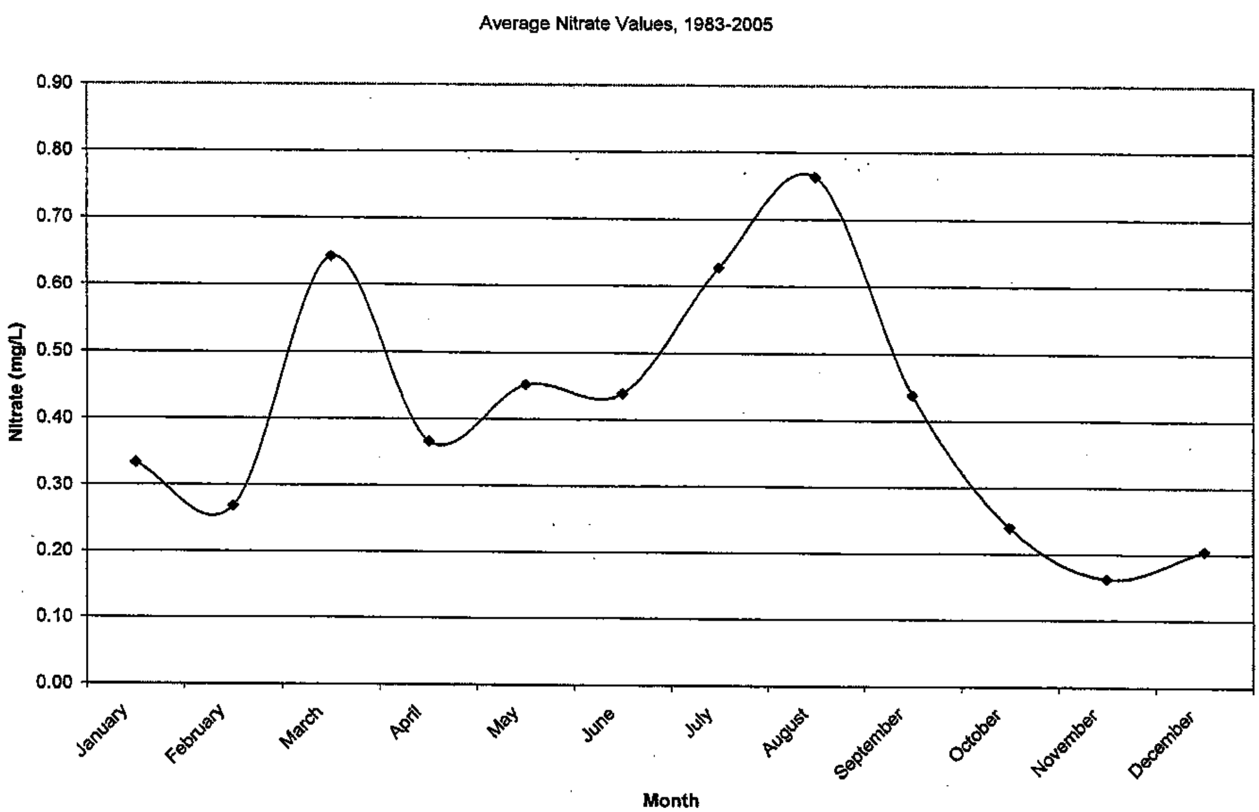


Figure 5. Twenty-two year monthly averages of nitrate values for Birch Brook streamwater.

Atomic Absorption Spectrophotometry: Calcium

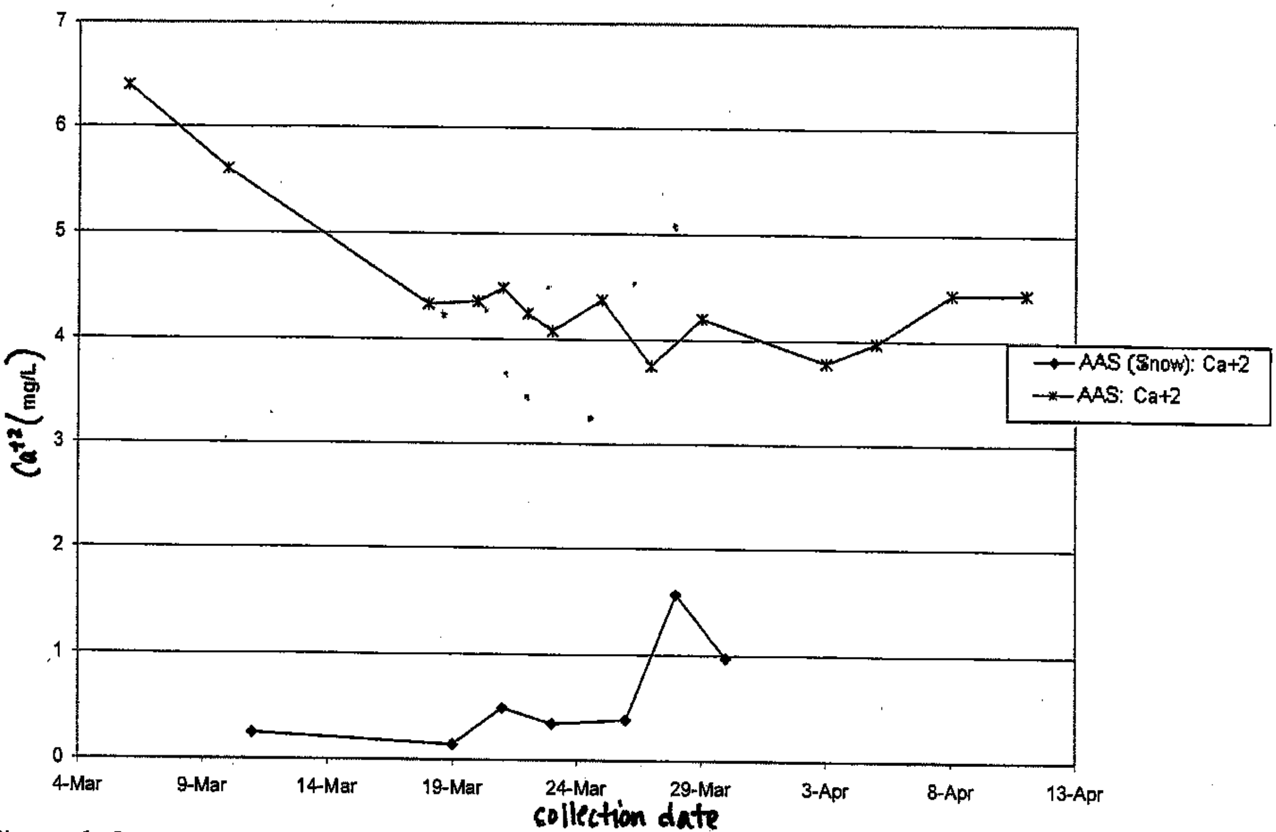


Figure 6. Comparison of calcium ion content of Birch Brook streamwater and nearby snowmelt.

pH vs. discharge

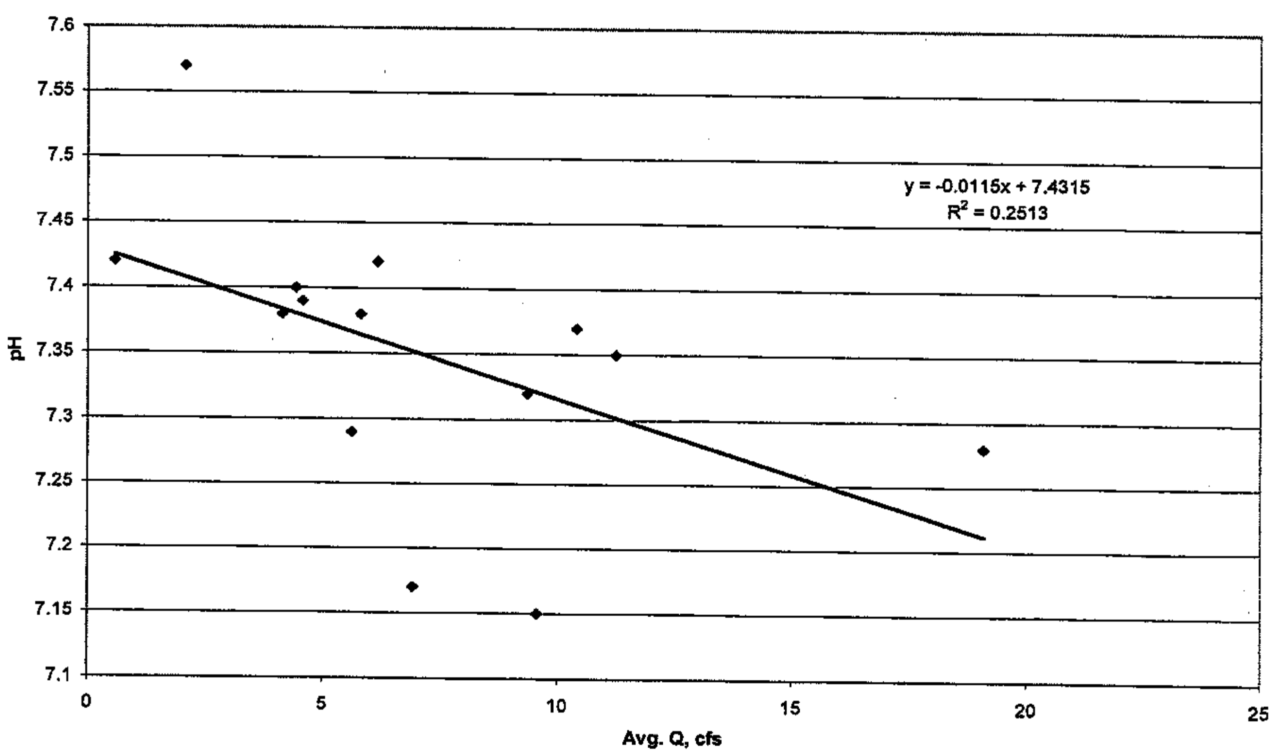


Figure 7. Correlation of pH level of streamwater and flow speed.

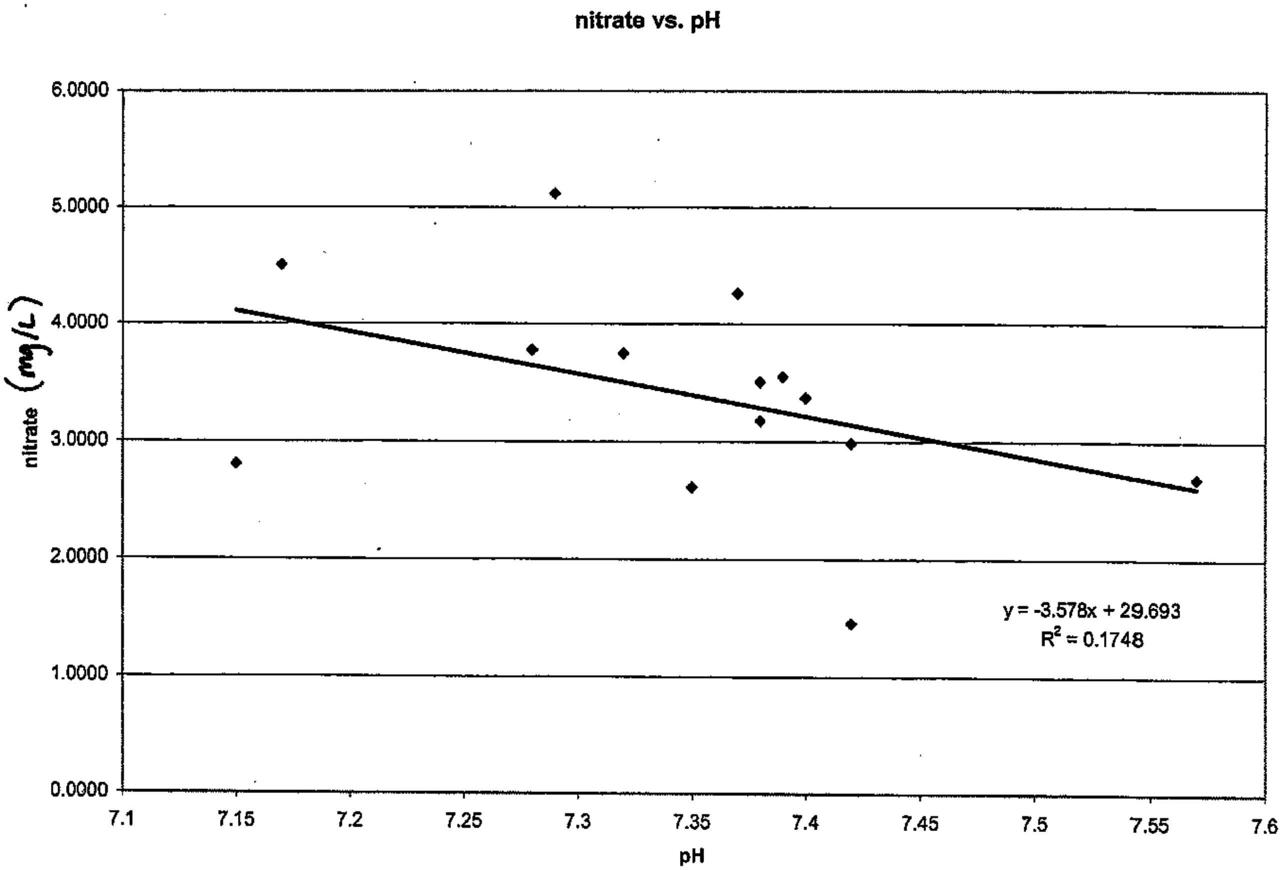


Figure 8. Correlation between nitrate levels in stream water and pH.

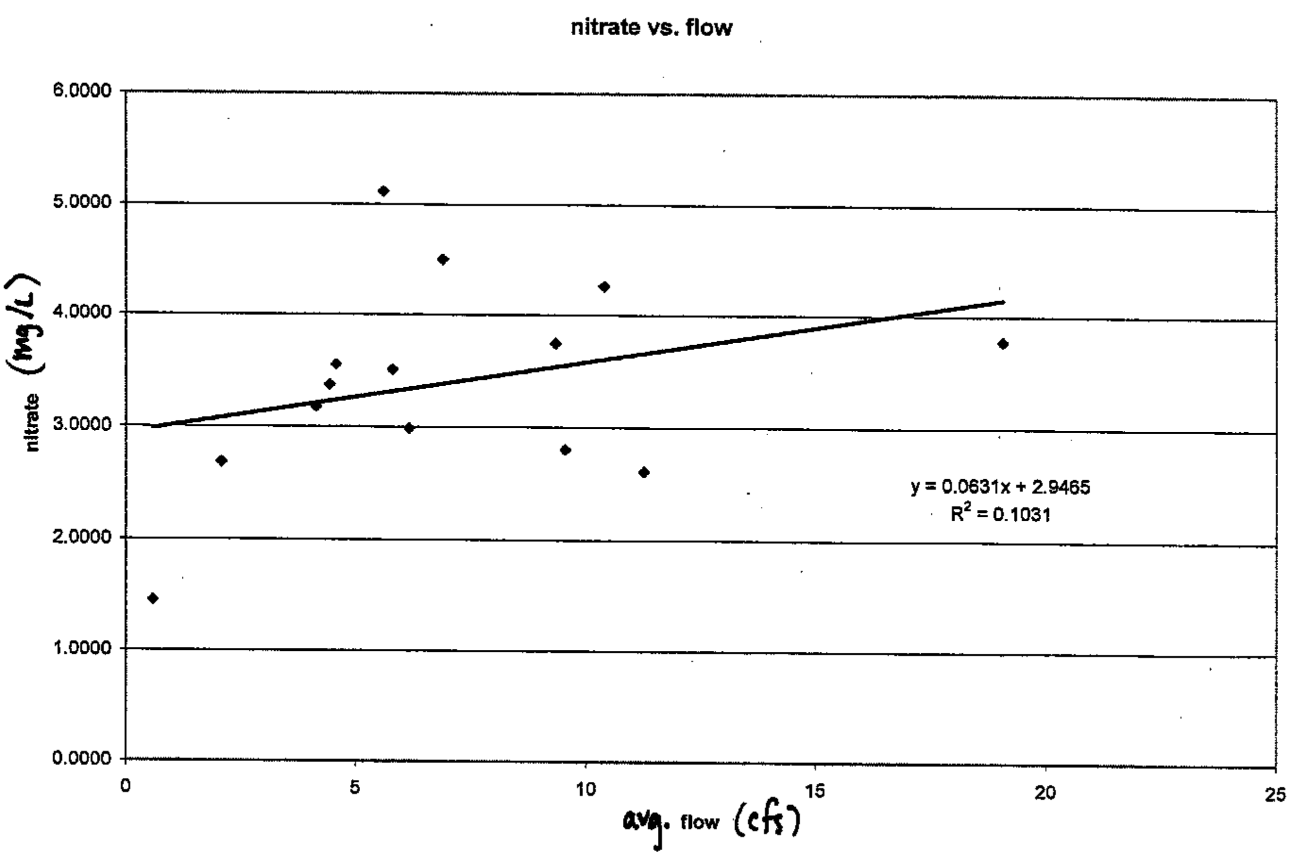


Figure 9. Correlation between streamwater nitrate levels and discharge.

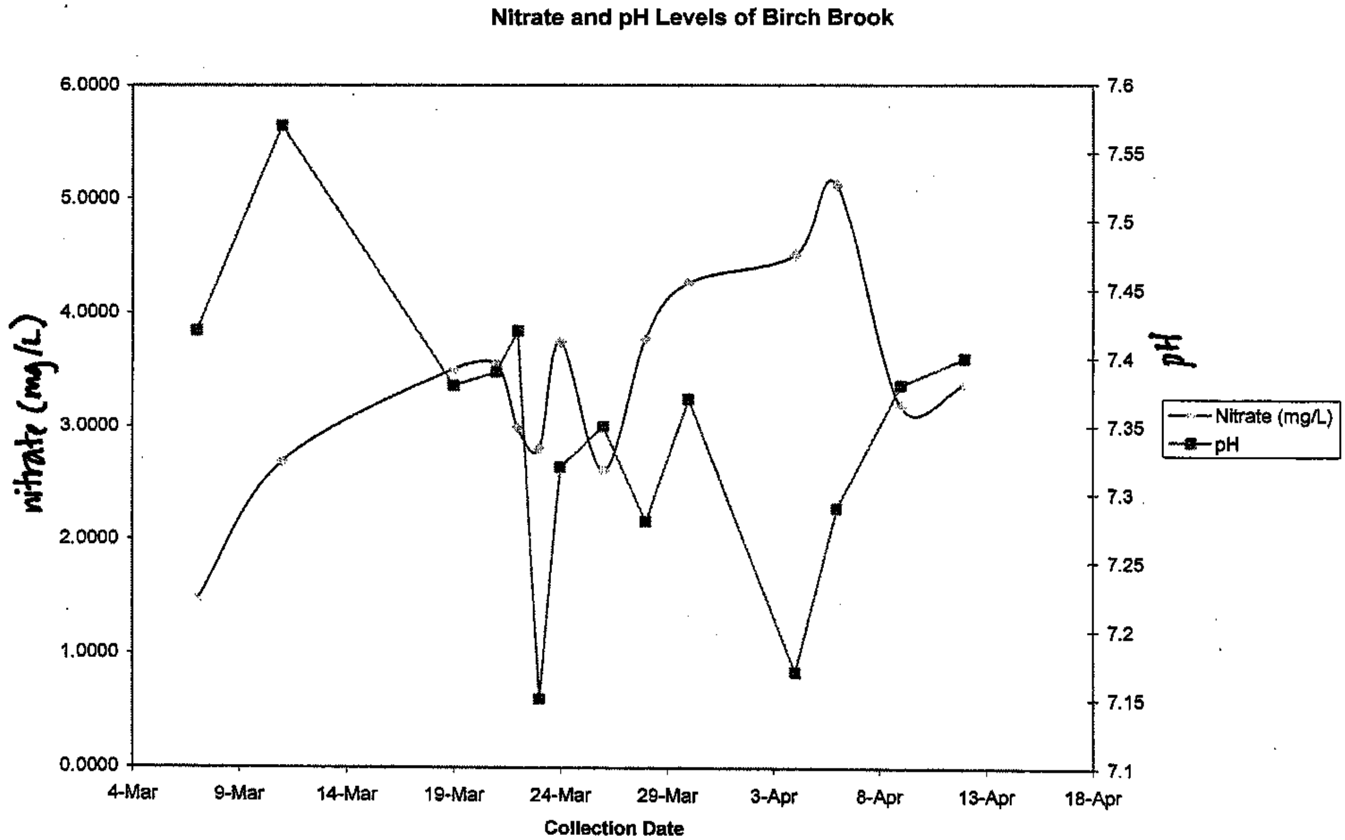


Figure 10. Comparison of nitrate and pH levels of Birch Brook.

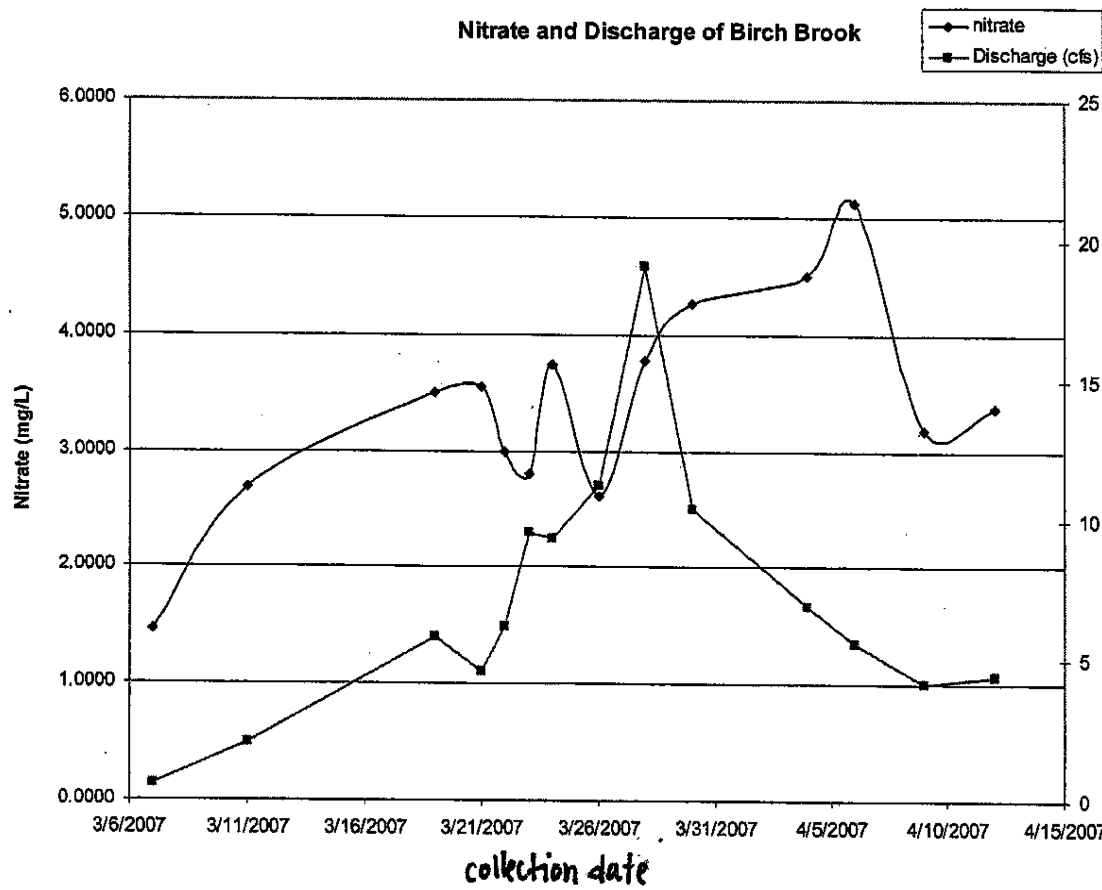


Figure 11. Comparison of nitrate levels and discharge rate of Birch Brook.

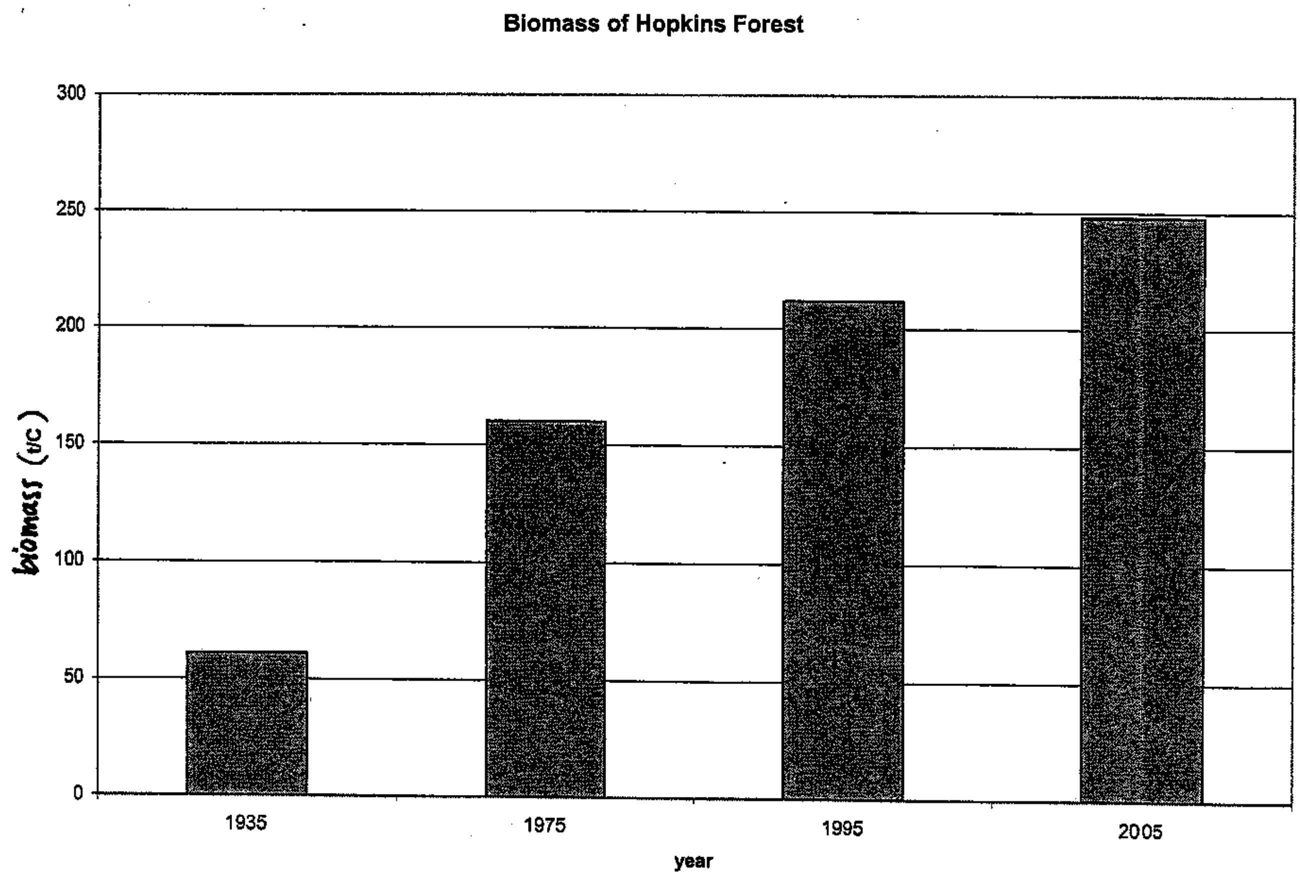


Figure 12. Biomass of Hopkins Forest over the past 73 years.

## Appendix II. Raw Data.

| Birch Brook Sample Date | pH | pH reruns | ANC | AAS: Ca+2 | AAS Mg+2 | AAS: K+ | AAS: Na+ | IC: NO3 | Discharge |
|---|---|---|---|---|---|---|---|---|---|
| BB 3/7 | 7.42 | 7.69 | 91 | 6.393 | 1.5 | 0.113 | 0.641 | 1.4532 | 0.58 |
| BB3/11 | 7.57 | 7.77 | 76 | 5.602 | 1.292 | 0.129 | 0.578 | 2.6865 | 2.08 |
| clark snow 3/11 | 6.65 | 6.68 | 18 | 0.249 | 0.07 | 1.048 | 1.031 | 1.1776 | |
| hemlock 3/13 | 8.12 | | 165.5 | 17.09 | 3.982 | 0.767 | 1.565 | 3.5301 | |
| BB 3/19 | 7.38 | 7.6 | 49.5 | 4.333 | 1.055 | 0.1 | 0.549 | 3.5064 | 5.81 |
| BB Snow 3/19 | 6.23 | | 9 | 0.144 | 0.025 | 0.024 | 0.108 | n.a. | |
| BB 3/21 | 7.39 | 7.1 | 40 | 4.359 | 1.031 | 0.083 | 0.486 | 1.0068 | 4.58 |
| BB Snow 3/21 | 5.46 | 5.52 | 10.5 | 0.494 | 0.08 | 0.008 | 0.137 | 3.5503 | |
| BB 3/22 | 7.42 | | 46.5 | 4.486 | 1.045 | 0.156 | 1.025 | 2.9876 | 6.17 |
| BB Snow 3/23 | 6.54 | | 11 | 0.345 | 0.1 | 0.064 | 0.088 | n.a. | |
| BB 3/23 | 7.15 | | 40 | 4.244 | 0.972 | 0.132 | 0.73 | 2.8038 | 9.56 |
| bb 3/24 | 7.32 | 7.35 | 43 | 4.079 | 0.952 | 0.116 | 0.645 | 3.7469 | 9.36 |
| BB Snow 3/26 | 6.16 | 6.3 | 14.5 | 0.384 | 0.081 | 0.071 | 0.102 | 0.1482 | |
| BB 3/26 | 7.35 | 7.4 | 54 | 4.378 | 0.985 | 0.113 | 0.71 | 2.6118 | |
| BB Snow 3/28 | 6.39 | | 10 | 1.569 | 0.078 | 0.007 | 0.086 | 0.1483 | 11.27 |
| BB 3/28 | 7.28 | 7.3 | 38 | 3.751 | 0.909 | 0.128 | 0.619 | 3.7766 | 19.09 |
| BB 3/30 | 7.37 | | 38.5 | 4.203 | 0.959 | 0.117 | 0.465 | 4.2615 | 10.42 |
| BB snow 3/30 | 6.46 | 7.12 | 40 | 0.972 | 0.513 | 0.115 | 0.189 | 0.2634 | |
| BB 4/4 | 7.17 | 6.94 | 42 | 3.786 | 0.95 | 0.136 | 0.471 | 4.5055 | 6.91 |
| BB 4/6 | 7.29 | | 38.5 | 3.974 | 0.99 | 0.094 | 0.491 | 5.1196 | 5.62 |
| BB 4/9 | 7.38 | 7.4 | 44 | 4.439 | 1.075 | 0.107 | 0.529 | 3.1776 | 4.15 |
| BB 4/12 | 7.4 | | 42.5 | 4.443 | 1.058 | 0.107 | 0.552 | 3.3726 | 4.44 |