Streamflow and water quality monitoring on Mt. Mansfield

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Introduction: The USGS proposes to install and operate two stream gaging and water quality stations at Mt. Mansfield. At least 30 samples annually will be collected at each site, including monthly and selected high-flow samples. Samples will be analyzed for nutrients, major inorganic solutes, silica, aluminum, and dissolved organic carbon.

The objectives of the stations are to 1) calculate a water budget, and estimate evapotranspiration, 2) quantify solute fluxes from the ecosystem, 3) assess the degree of "nitrogen saturation" in the forest, and 4) evaluate the susceptibility of the streams to acidification from atmospheric deposition and the threat of aluminum toxicity to fish.

Solute budgets for the gaged watersheds will be determined using data from the NADP (wet deposition) and NDDN (dry deposition) stations at Proctor Forest (inputs) and streamflow and stream chemistry data (outputs). Hydrologic and chemical data from the monitoring stations will establish a baseline for assessing the effects of global change, and will complement VMC ecosystem research projects on Mt. Mansfield.

Reconnaissance: A reconnaissance sampling trip was made on November 6, 1992 to collect preliminary data for the siting of the monitoring stations. Measurements of temperature, pH, and specific conductance were made at 27 sites in Browns River watershed (6.1 sq. km) and 9 sites in Stevensville Brook watershed (5.2 sq. km) (Fig. 1). As a follow-up, 3 low-elevation sites (Browns River and two branches of Stevensville Brook) were sampled for full major ion analysis on November 13, 1992.

Temperature, specific conductance, and pH are easily obtained field measurements that are useful as broad hydrochemical indicators. Specific conductance is a general indicator of the total dissolved solids, which in turn reflects the amount of rock weathering that has occurred. The Underhill State Park has a single bedrock type -- quartz-mica-albite schist. Thus, variations in conductance are likely a function of 1) variations in thickness of glacial deposits, which will affect water residence time, 2) variation in the composition of those deposits (which may be derived from outside the local area), or 3) presence or absence of fracture flow through bedrock (fracture flow promotes greater weathering). In acidic headwater streams, strong acids may be present in sufficient quantities to dominate the specific conductance. A pH less than 5.0 in clear-water streams indicates acidification by atmospheric deposition.

Stream temperature is a useful indicator of the source of water to the stream - surficial or near-surface sources vs. groundwater. In November, groundwater temperatures are much warmer than near-surface temperatures, thus a warmer stream temperature suggests that a relatively greater amount of flow is contributed by groundwater.

Results and interpretations: In general, waters draining the west slope of Mt. Mansfield are poorly buffered. Headwater streams at high elevation, in particular, are quite acidic (pH<5.0). This is attributed to relatively unreactive bedrock, limited thickness of overburden (glacial till), and limited soil development. Buffering, as indicated by pH increase to 6.0 or greater, increases as stream size increases. Buffering is greater at Browns River than at Stevensville Brook. No high elevation sites were sampled at Stevensville. However, the low elevation areas are at pH 5.5 to 6.5, compared to near 7.0 at Browns River. Of the two branches of Stevensville Brook, the North branch is the least buffered. The low pH and conductivity of these streams at a time of average flow conditions suggests that these streams are susceptible to acidification episodes, uncommon for streams of this size. Browns River has three main branches which converge above the lowest sampling point. Below this confluence, the stream is circumneutral. Water from the southernmost branch (point A, Fig. 1) was also near pH 7.0, but had lower conductance, suggesting somewhat lower alkalinity. A sampling site higher on the middle branch (point B, Fig. 1) had a strikingly low pH (5.15) and conductance (18.2). It appears that significant neutralization in the Browns River watershed occurs in the lowest 20% of the basin.

Temperatures of headwater streams in Browns River ranged from 0.9 to 4.7 °C. The warmer streams reflect groundwater inputs. Colder streams reflect more surficial hydrologic pathways and/or a long in-channel residence time that allowed cooling from the cool atmosphere. Larger stream temperatures ranged between 2 and 3 °C (Fig. 2), reflecting a balance between increased groundwater inputs and increased residence time in the larger streams. The variation in temperature of the small headwater streams suggest heterogeneity in streamflow generation mechanisms.

In the headwater streams, conductance is clearly controlled by pH (Fig. 3). Conductance is nominally higher than the minimum conductance possible for a given pH. At pH>5.5, this inverse relation shifts to a positive relation; hydrogen ion contribution becomes negligible and conductance is controlled by alkalinity and major inorganic ions. Interestingly, the conductance at Stevensville sites remains constant near 20 across a broad range of pH.

In keeping with the conceptual model, pH generally increases as flow increases (Fig. 4). The two small streams sampled at Stevensville watershed are anomalies; however, these are the lowest-gradient small streams sampled, and thus are more likely than the other small streams to be dominated by groundwater inputs. The generally greater neutralization at downstream sites at Browns River is again evident, though the upstream site on the middle branch (point B, Fig. 1) is again a notable exception (more acidic than the trend).

The major ion analysis (Table 1) confirms that Stevensville Brook is poorly buffered. The north branch was acidified (negative alkalinity) whereas the south branch had a low but positive alkalinity. As expected, the greater acidity in the north branch is reflected in greater aluminum concentrations (380 µg/L vs. 225 µg/L in the south branch). Sulfate concentrations at all sites are near 5 mg/L, similar to those in precipitation, suggesting that these basins do not retain sulfate. Sulfate is the dominant anion; nitrate concentrations are quite low at all sites. The lower alkalinities at Stevensville result from slightly higher sulfate and lower base cation concentrations relative to Browns River. The difference in the two branches of Stevensville is explained primarily by a much lower calcium concentration in the north branch.

The low dissolved load of these streams implies a tight nutrient economy in the forested watersheds that they drain. Weathering rates are slow, and forest productivity may be limited by nutrient availability. The acidic character and elevated aluminum concentrations of these streams indicates that aluminum should be monitored given its possible negative impact on aquatic fauna and forest health.

Monitoring options: In view of the objective of coordinating watershed hydrology and solute flux monitoring with research on elemental cycling in forest ecosystems, the choice of monitoring sites is dependent on the degree of specificity desired. Determining solute fluxes at 1300 ft on Browns River would provide an integrated measure of biogeochemical processing of the western slope of Mt. Mansfield. But to refine the view to chemical budgets of high-elevation spruce-fir communities, for example, a smaller headwater stream is more appropriate. An upstream/downstream approach, with a station at each of the two scales, is a pragmatic solution in that it provides the specificity to evaluate a single ecosystem as well as the role of that system within the "big picture." In Browns River, particularly, investigations at these two scales has an added research interest because of the significant buffering capacity that streamwater acquires in the lower part of that basin. The upstream/downstream approach could address the mechanisms controlling this change in chemistry.

Other monitoring options include a down-basin site in each watershed (maximum integration), 2 upbasin sites in Browns River (maximum specificity, easy access), a headwater site in each basin, and the north and south branches of Stevensville Brook (possible paired watershed / watershed management studies).

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Table 1. Mt. Mansfield stream chemistry

All units except pH mg/L unless otherwise indicated.

	Elevation (ft)	pH	Alk (as $CaCO_3$)	Ca	Mg	Na	K	Al (µg/L)		NO_3 (as N)	Cl
Browns River	1280	7.05	2.07	1.86	0.47	0.34	0.21	215	4.87	0.10	0.28
Stevensville north branch	1430	4.96	-0.25	1.21	0.21	0.29	0.24	380	5.40	0.06	0.30
Stevensville south branch	1430	5.78	0.48	1.70	0.26	0.29	0.22	225	5.36	0.11	0.30

Figure 1

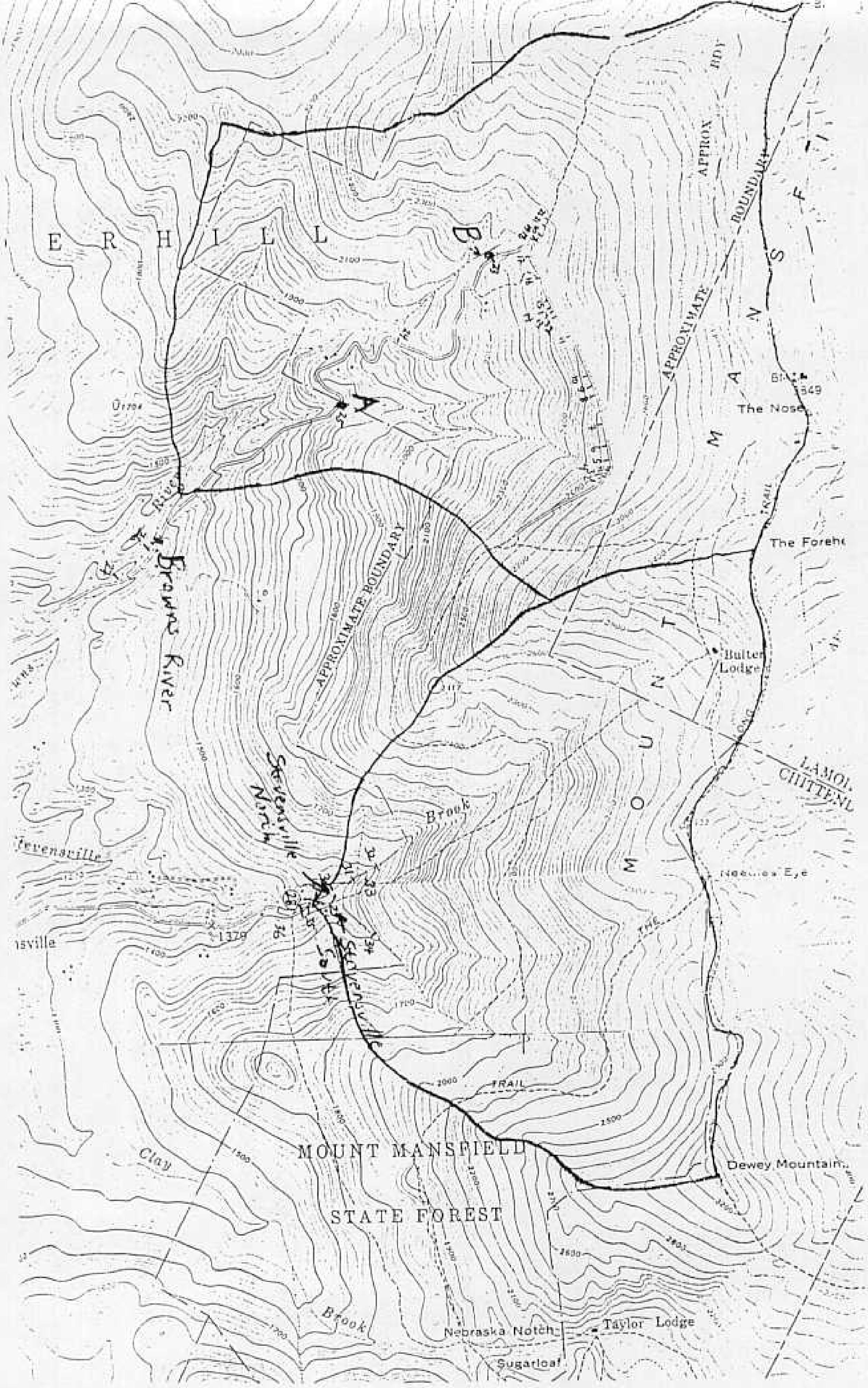

E R H I L L
APPROX BDY
APPROXIMATE BOUNDARY
The Nose
The Forehead
Butler Lodge
LAMOILLE
CHITTENDEN
Needles Eye
Dewey Mountain
MOUNT MANSFIELD
STATE FOREST
Brook
TRAIL
Clay
Nebraska Notch
Taylor Lodge
Sugarloaf
Stevensville
1379
Browns River
Stevensville North
Stevensville South
A
B
-7 sampling site

Figure 2

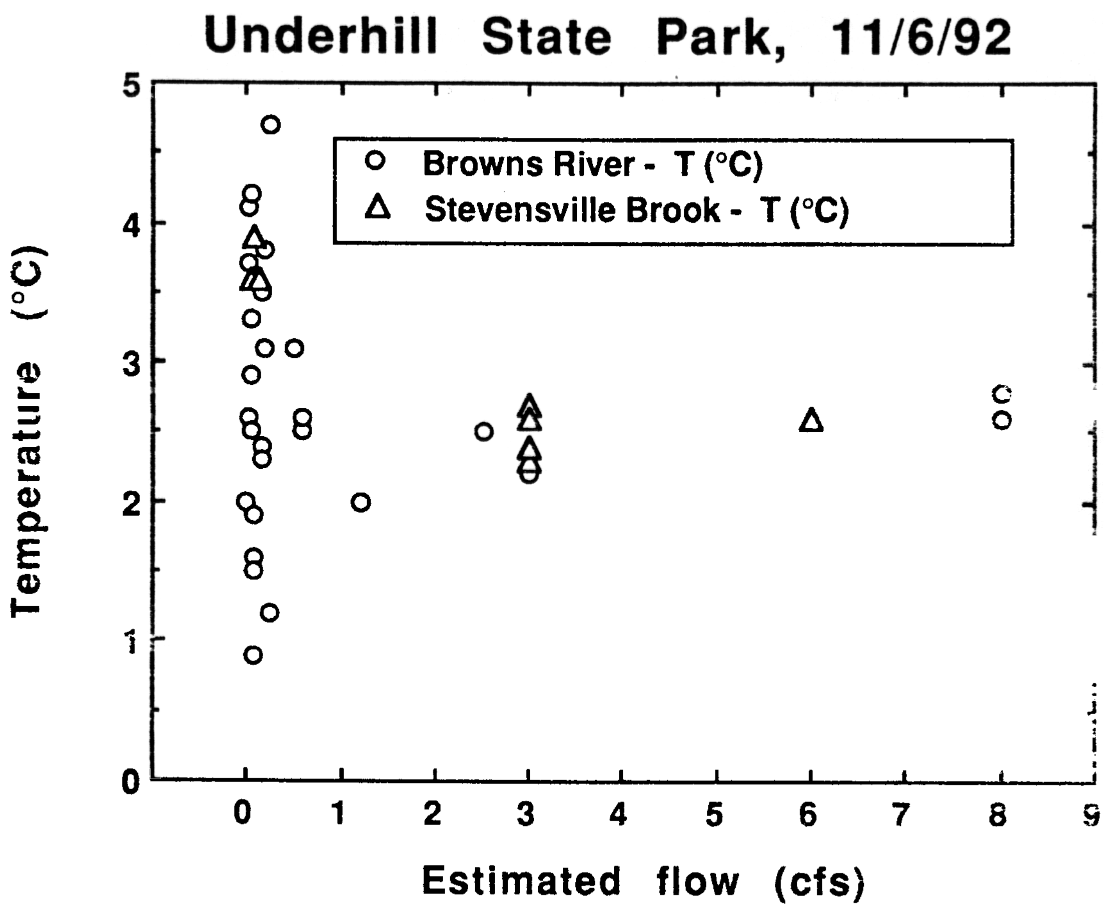
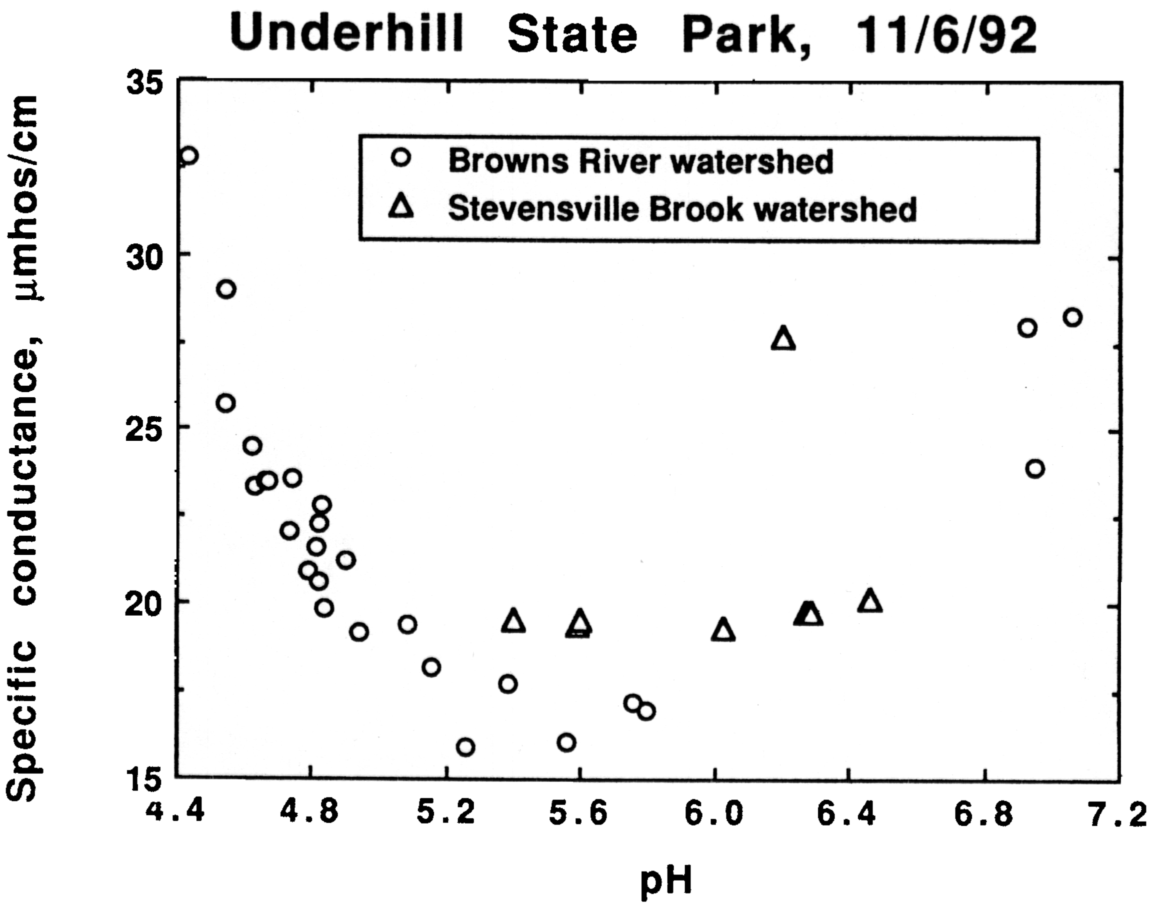
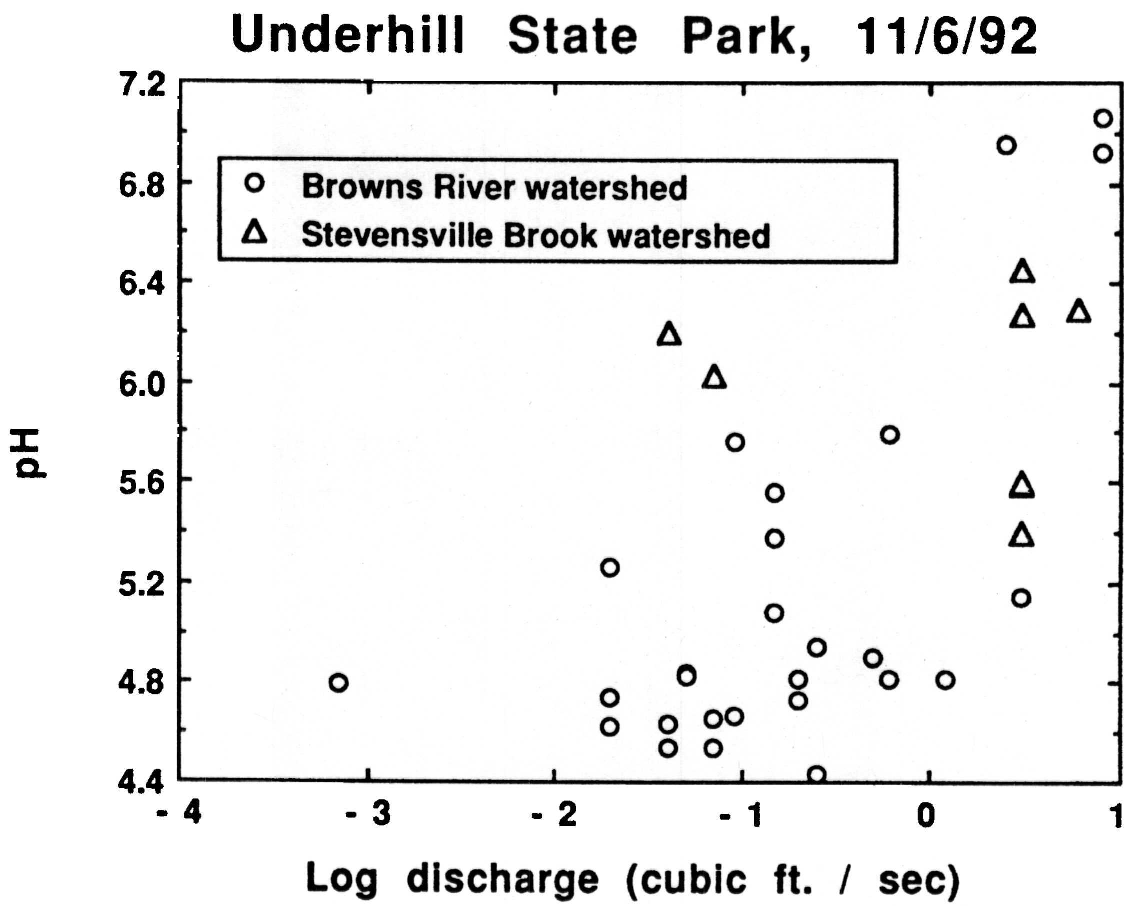

Underhill State Park, 11/6/92
Browns River - T (°C)
Stevensville Brook - T (°C)
Temperature (°C)
Estimated flow (cfs)
0
1
2
3
4
5
0
1
2
3
4
5
6
7
8
9

Figure 3



Underhill State Park, 11/6/92
Browns River watershed
Stevensville Brook watershed
Specific conductance, μmhos/cm
pH
35
30
25
20
15
4.4
4.8
5.2
5.6
6.0
6.4
6.8
7.2

Figure 4



Underhill State Park, 11/6/92
Browns River watershed
Stevensville Brook watershed
7.2
6.8
6.4
6.0
5.6
5.2
4.8
4.4
pH
- 4
- 3
- 2
- 1
0
1
Log discharge (cubic ft. / sec)