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May 10, 1990
Report on Nitrates in Taconic Streams

Nitrogen plays a vital role in all ecosystems, but can wreak havoc when it plays too much of one. Nitrogen is used by plants, animals, and fungi in the creation of proteins and amino acids. Without it, life would be impossible for most species. With too much, though, the same holds true.

A look at figure 1 shows that something strange is afoot in Birch Brook. In 1988 nitrate levels jumped to 3 times their normal levels. In the following paper I will try to account for this jump in concentration. I will also argue that there is cause for concern, because all the other streams along the Taconic Crest are subject to the same forces. These nitrates can cause algal blooms, as in the Williamstown Reservoir, higher concentrations in drinking water pose a health threat, particularly to small children, but most importantly, they signify that something might be going wrong. In this day and age, it's a safe bet that when something goes wrong with the environment, homo sapiens is at least partially to blame.

I sampled 11 streams that drain about 1/2 to 1 square mile of east-facing forest dominated by hardwoods (see figure 2). Whenever possible, I sampled them above areas of direct human influence. That is, above houses, septic systems, and cultivated fields. I sampled Halifax Hollow, Lincoln Hollow, and Frost Hollow in Pownal, Vermont. I took water from off Northwest Hill Road, from Birch Brook, Flora Glen, Hemlock Brook, and Sweet Brook here in Williamstown. Finally I sampled Bentley Hollow, the drainage from the Wildlife Sanctuary, and Gardner Hollow in

Hancock. I collected the water on April 7, 1991, an unseasonably hot day with low flow conditions. There was about 0.11 inches of rain in Williamstown the previous night.

I measured the pH and alkalinity of each sample that night. The anions were measured on the IC within three weeks. The results showed incredible consistency (table 1, figure 3). All had temperature between 10 and 15 degrees Celsius. The average pH was 7.25 with a standard deviation of 0.24. Alkalinity was the one area in which the samples really diverged; the average was 12.2 mg calcium carbonate, with a standard deviation of 6.5. Chloride levels averaged 0.40 mg per liter, with a standard deviation of 0.04 mg/L. There were two exceptions, Flora Glen and the lower section of Hemlock Brook. Each had chloride in excess of 10 mg/L. This unfortunately makes sense; each is below a road which receives considerable salt during the winter. Sulfate levels were also quite consistent, showing an average of 7.02 mg/L with a standard deviation of 0.62 mg/L.

I believe that these 11 streams will all react similarly to changes in the environment. That is to say that the spikes seen on the Birch Brook readings are probably to be seen elsewhere as well. A look at the nitrate readings shows Birch Brook to be at the low end of the sample. I postulate that the other streams will experience the same peaks, meaning the problem of increasing nitrate flows is widespread.

I think this theory is tenable not only because the samples I collected were consistent, but more importantly the factors affecting each stream in the long run are very similar. Each drains the same soil type, for example. A look at figure 4 reveals that the Taconic Crest has fairly consistent soil types. Taconic-Macomber association, Farmington Rock outcrop complex, Lanesboro-Dummerston association, Hoosic gravelly loam, and Fullham-Lanesboro association are all to be found. These are all moderately permeable soil types with strong acid to moderate alkaline tendencies.

Even further, each of the drainage basins is populated primarily by sugar maple, beech, red oak, and birch (figure 5). The geology is most likely the same throughout the sample, in that they are all on the same ridge. There might be slight variations, but probably no radical shifts in the fifteen or so miles between Halifax Hollow and Gardner Hollow. The differences are likely dependant upon elevation. Lower sampling sites might more likely have dolomite bedrock, which would affect ANC.

The differences in alkalinity result most likely from different dolomite concentrations in the soils drained. The lower sections of the range have more dolomite, so more calcium carbonate would be in solution downstream. Flora Glen and Sweet Brook, the two sites with the highest alkalinity, were probably sampled below sections where dolomite was present in the bedrock. The chloride comes probably from ocean storms. The sulfate comes from the weathering of minerals, as well as from acid precipitation. Where then does the nitrate come from?

I will spend the remainder of this paper suggesting answers to this seemingly simple question. There are many factors surrounding the nitrate levels which must be considered before any conclusions can be drawn. First, the increase started in winter or spring of 1988. It did not coincide with any radical increase in sulfate levels, so the answer could not be as simple as increased acid precipitation. Second, the trends in temperature have been increasing (figures 6, 7). The two years before the increased ~~flows~~ NO_3, the springs were hotter than normal. Third, there was one major event, a storm in October 1987, which contributed large amounts of organic litter in the form of downed trees. Fourth, nitrate concentrations are higher at higher elevations. Figures 8 and 9 show graphs from both Sherman Springs Stream and Birch Brook. There are many more pieces to this puzzle. I will attempt to fill in as many as possible, but have little hope of definite conclusions.

Nitrogen exists naturally in many states. It cycles through ecosystems in the form of ammonia, ammonium, nitrite, nitrate, nitrogen gas, and organic nitrogen. The transitions between various forms takes place through both biological and chemical processes. The difficulty in environmental science is determining the balance between the transformations.

Nitrogen enter a system in the atmosphere, mostly in the form of nitrous oxides from fossil fuel combustion. There is also a large amount of nitrogen in a system initially, in the form of organic nitrogen, as well as nitrate and ammonia in the soil. As we set this picture in motion, nitrogen moves quickly from form to form, leaving a twisted path that is hard to quantify. Growing plants and microbes, through a process called assimilation, break down both ammonia and nitrates, fixing them in plant tissues. It is then known as organic nitrogen, usually in proteins and amino acids. Plants also fix nitrogen ~~straight~~ directly from the atmosphere, again creating organic nitrogen. At the same time, consumers and predators eat organic nitrogen in the form of plants and animals, changing it through a process called heterotrophic conversion. Dead organic nitrogen, either litter on the forest floor, dead plants, or excrement, ~~are~~ is broken down by microbes in a process known as ammonification. This ammonia either vaporizes or is further broken down into nitrite, then nitrate. This nitrification is a matter of oxidation.

Bacteria also play a role in denitrification, the reduction of nitrate to N_2O and other nitrogen gasses. These gasses then dissipate into the atmosphere. The other manner in which nitrate leaves a system is by leaching into water and flowing away.

The balance of each of these reactions is not known entirely, but research has found factors which can influence them all. In essence, though, nitrogen enters a system in the air and in water. It arrives as a gas and as nitrate in acid precipitation. It gets used and reused by the system, then it leaves, again in the form of gas and nitrate in water. Humans have good reason to worry about both of these products; nitrogen gasses contribute catalytically to the destruction of ozone, while nitrate can lead to problems in drinking water.

Here in the purple valley, there are more nitrates higher up. Andrew deGarmo first noted this in Hopper Brook two years ago. Rebecca Edwards and Mike Yarne and Mitchell Young found similar results (figures 9,8). This brings a certain urgency to the question of nitrate flow, since the higher areas recharge the deep aquifer which will supply all of Williamstown's water in years to come.

Normally, you would expect nitrate levels to increase as you descended a stream, as more and more sources of nitrates flowed into a system. The high concentrations do not flow right from the ground, but rather result from contact with the soil (Chris Brookfield). It seems then that there are just large amounts of nitrates in the soil, too much to be used by plants, too much to be denitrified by microbes. (particularly at this time of year)

It seems to me that these high levels can be traced to 1) the disturbance in October 1987 which deposited large amounts of organic litter on the forest floor. This could easily have been magnified on the Taconic by the thin soil layer, which would allow more trees to be uprooted. 2) the acidic soils along the Taconic which might inhibit the actions of dinitrifying bacteria. 3) warmer weather which could increase bacterial activity. 4) the moderately well drained soils, which would allow the water to leach out nitrates quite easily. 5) the lack of clays in the soil. The combination of these factors, which I will investigate individually, might bring about the results we see in Birch Brook, and which probably occur elsewhere in the region.

1) The snow storm of October 4, 1987. The trees in the region were certainly surprised by the large amounts of wet snow which fell before the leaves had fallen. The weight of the snow brought many trees to the ground. In 1987 then, there was a larger than usual amount of organic nitrogen deposited on the forest floor. As I mentioned earlier, the thin soils on the Taconic would have left the trees even more vulnerable to uprooting. The leaves would be quick to decompose, saturating the soils with nitrates. The increased levels might last for

probably no real difference after a year, since they fall anyway!

years as the litter on the ground turns to organic soil. Add to this the fact that fewer trees are around to fix nitrogen and nitrates, and there might be a real surge in nitrate levels in the soil. perhaps!

but this has "always" been true

2) The acidic soils found along the Taconic would inhibit the activities of denitrifying bacteria. Studies show that they are more effective with the pH between 7 and 8 (Stanford et al., 1975). They then would operate comparatively slowly in acidic soils, so proportionately less of the nitrate would be turned into gasses. The influx of organic nitrogen would result in a surge of nitrates, more than the denitrifiers might handle.

3) Warmer weather would give an advantage to all bacteria, so organic nitrogen and ammonia would be more quickly be converted to nitrates, which then would not be absorbed. Even if the general trend is not a factor, the openings in the canopy from the broken trees would allow more sun to reach the soil, so the soil temperatures would rise. Since the sites all face east, they would be warmed first thing in the morning and keep active through the day. (during the spring)

4) The soils, then ~~would~~ could be inundated with nitrates. The surge would flow towards the streams with the first rains. Even with snowmelt, the anions would be on the move. Of course, not all will flow ~~over~~ under the surface; some will enter the deep aquifer, to be drinking water in years to come.

5) The soils along the Taconic contain little or no clay, so they will not tend to trap nitrates. Small clay particles are somewhat charged, so anions tend to stick to them.

In Science magazine, v.204, Peter Vitousek postulates that there will be nitrate flow from a system if the nitrogen isn't immobilized by plants or clays, if it isn't denitrified, if there is enough phosphorous for nitrification, if the soil was previously nitrate rich, and if there is water flow. All of these conditions seem to be true for the Taconic Range, so it makes a certain amount of sense that flows are increasing.

What is your Ref on water data!

This analysis, of course, is far from exhaustive. I do not know all the factors which change the balance of nitrates one way or the other. They apparent surge in nitrate levels could be the result of changes in sampling and/or analysis techniques. That the algal blooms started in the reservoir about the same time might suggest otherwise, though. Acid rain may play a large role in the chemistry of soil. This surge as of late could mean that surface soils have in effect been titrated.

This hypothesis is based on a sample of one stream. That being the case, it is no cause for alarm. This stream, though, is representative of large areas of land which supply drinking water to many Berkshire towns. A more careful study of the precipitation, vegetation, soil, and streams will be necessary before my theory can be validated. It is important to note, though, that there are changes in the system that we recognize, but don't understand.

C - I like this paper, but you need to be more formal in future science papers, particularly when you present such a variety of data and hypotheses. You need to come up with an explanation for the elevated data you show for several streams. This suggests something about upland soils or vegetation and can probably be separated from the October '87 storm. Let's talk more about this. [illegible]

Sources:

I borrowed data from Mitchell Young, Mike Yarne, and Rebecca Edwards.

I used information from Chris Brookfield's conclusions.

I got information on nitrates from the following

Nitrates: An Environmental Assessment. National Research Council, Washington,DC

Ambio volume 6, "Nitrogen, an essential life factor" Bert Bolin and Eric Arrhenius, 1977

"Nitrate Losses from Disturbed Ecosystems" Peter Vitousek et al. Science volume 204 p.469

Global Freshwater Quality by Michael Maybeck, D.Chapman, and R.Helmer World Health Organization 1989

Acid Soil and Acid Rain by I.R. Kennedy Research Studies Press, 1986

Soil Survey of Berkshire County, USDA 1988

Kathryn Gilterson's thesis on Vegetation in Williamstown 1977

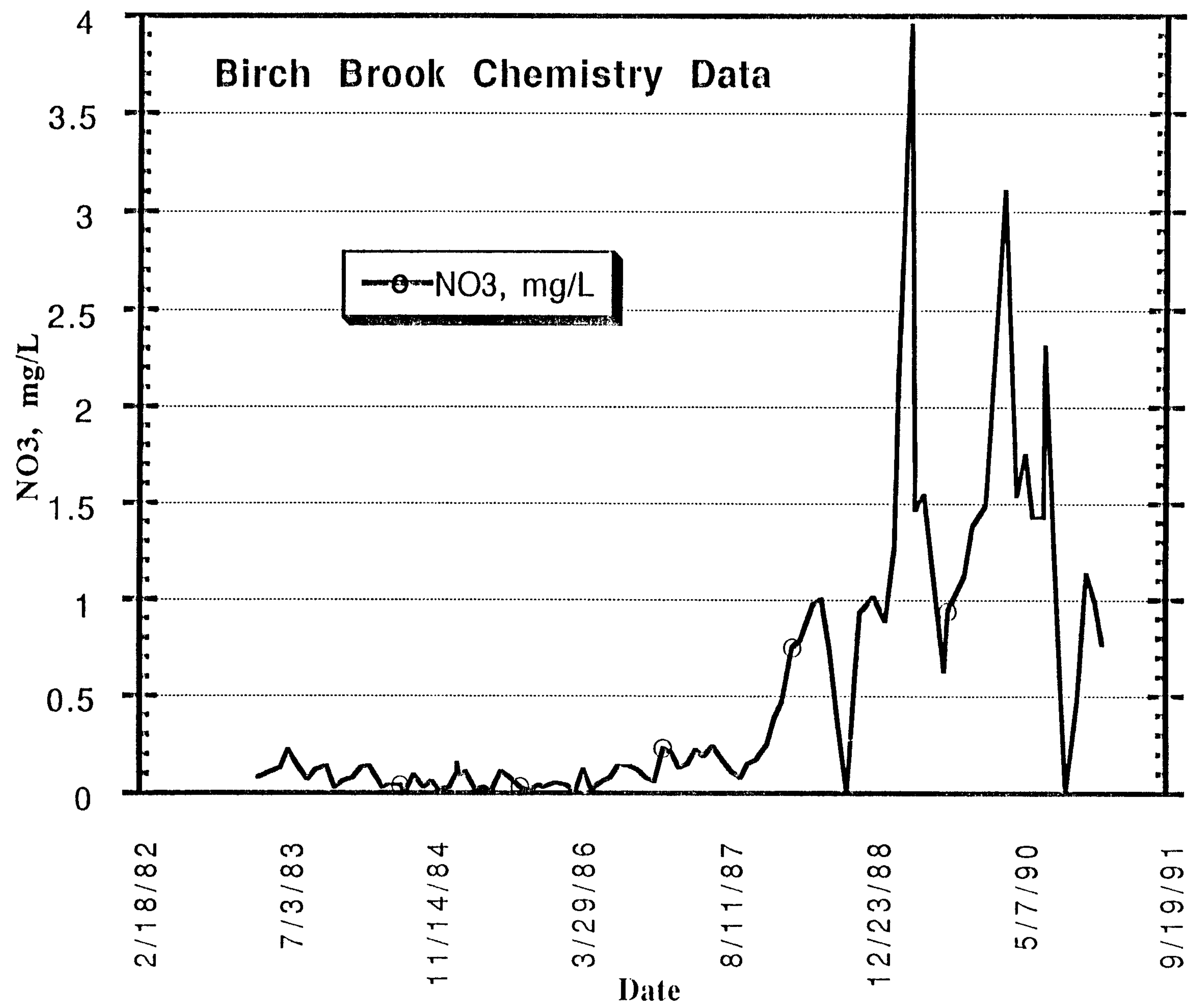
Table 1

Page #1 - "Taconic 4.9.91" Thursday, May 9 2:17 PM 1991

Sample	temp, C	pH	ANC	Cl-	NO3	SO4
Halifax	11.00	7.37	13.40	0.37	1.64	8.32
Lincoln	12.00	7.35	14.20	0.36	1.03	7.84
Frost	12.00	7.25	8.60	0.34	1.86	6.51
N.W.Hill	13.00	7.28	11.20	0.37	1.74	7.23
Birch	15.00	7.34	8.60	0.39	0.65	6.94
Flora	12.00	7.62	27.40	27.70	0.40	8.20
Hemlock1	13.00	7.05	6.00	0.40	1.88	6.14
Hemlock2	14.00	7.27	11.00	10.80	1.33	5.65
Sweet	11.00	7.55	19.60	0.38	2.34	6.66
Bentley	13.00	7.21	6.10	0.41	2.08	7.21
Wildlife	10.00	6.70	4.60	0.48	0.62	6.95
Gardner	11.00	7.03	15.80	0.44	2.27	6.56

Page #1 - "Sherman Springs Stream Data" Thursday, May 9 2:19 PM 1991

A	Dry NO3	0.5" rain	1" rain	altitude
Sherman F	4.35	4.37	4.73	964.00
Sherman G	4.52	4.39	4.73	1000.00
Sherman H	4.81	4.45	4.65	1005.00
Sherman I	5.30	4.94	5.37	1060.00
Sherman J	5.68	5.10	5.68	1125.00



Birch Brook Chemistry Data
NO3, mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
2/18/82
7/3/83
11/14/84
3/29/86
8/11/87
12/23/88
5/7/90
9/19/91
Date

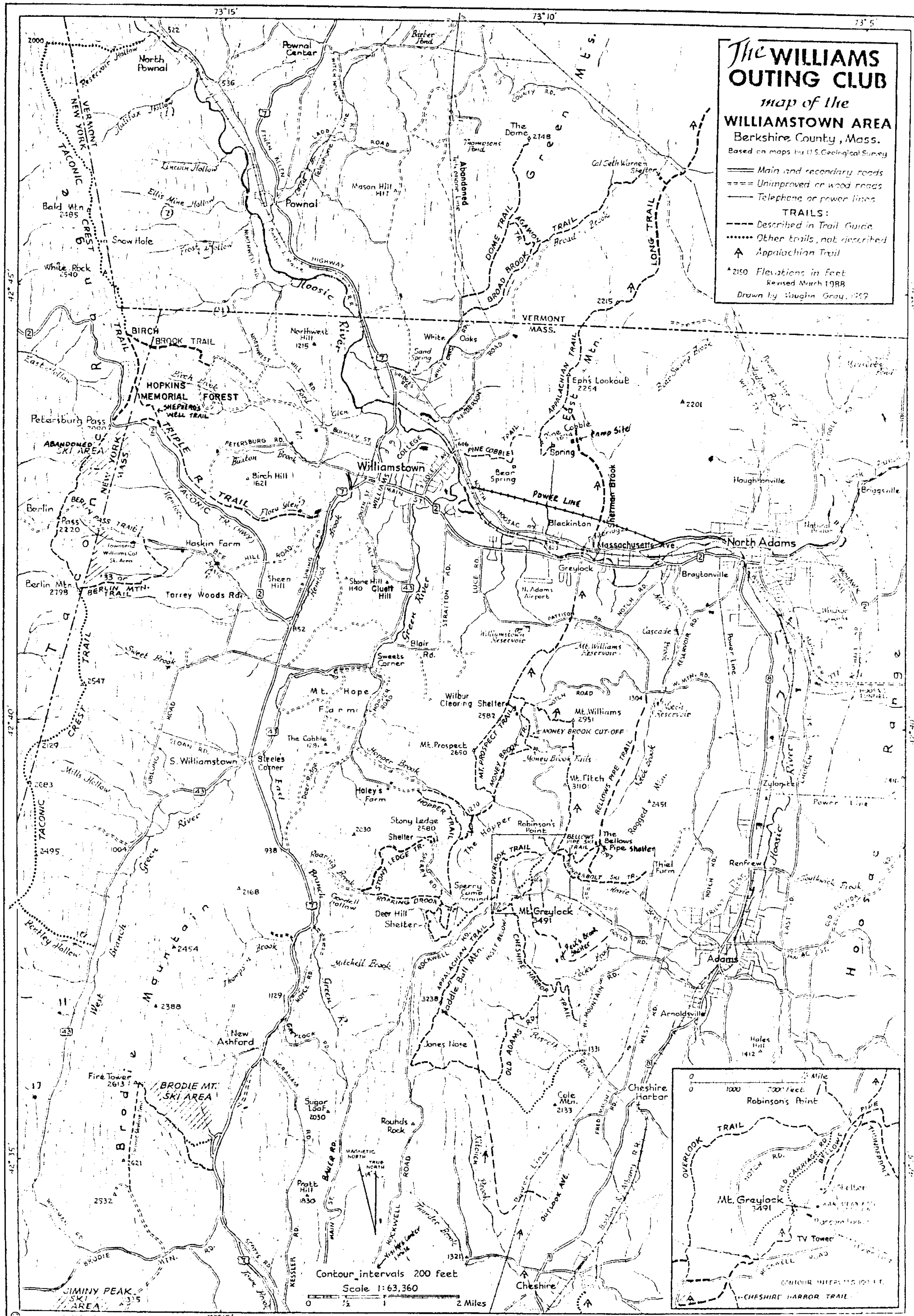
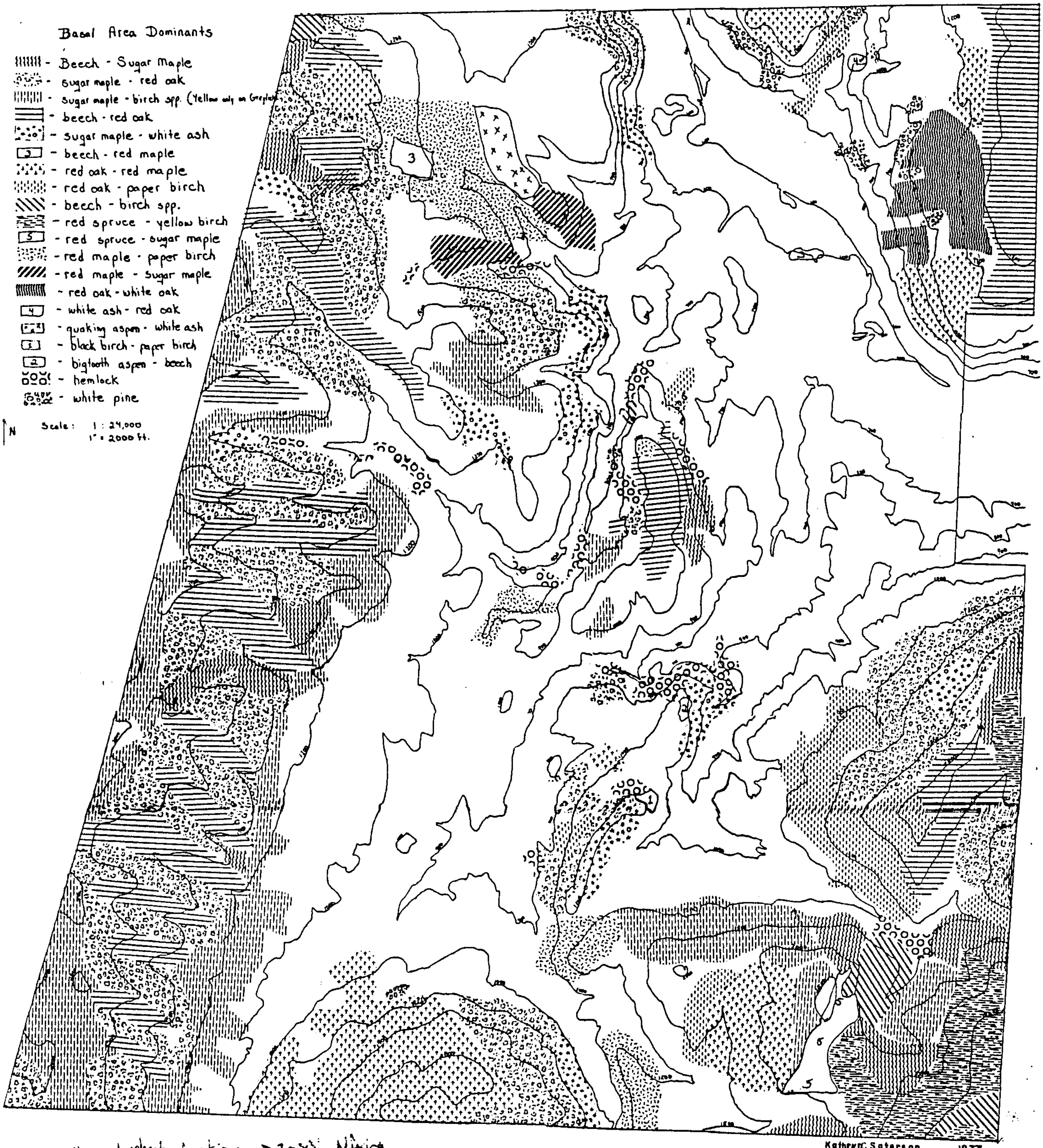

The WILLIAMS OUTING CLUB
map of the
WILLIAMSTOWN AREA
Berkshire County, Mass.
Based on maps by U.S. Geological Survey
Main and secondary roads
Unimproved or wood roads
Telephone or power lines
TRAILS:
Described in Trail Guide
Other trails, not described
Appalachian Trail
2150 Elevations in Feet
Revised March 1988
Drawn by Vaughn Gray, 1959
73°15'
73°10'
73°5'
42°45'
42°40'
42°35'
North Pownal
Pownal Center
Pownal
Mason Hill
The Dome 2748
Bald Mtn. 2485
Snow Hole
White Rock 2540
Hoosic River
VERMONT
MASS.
BIRCH BROOK TRAIL
HOPKINS MEMORIAL FOREST
Petersburg Pass
Northwest Hill 1215
White Oaks
Sand Spring
Eph's Lookout 2254
Pine Cobble
Spring
Williamstown
Birch Hill 1621
Bear Spring
POWER LINE
Blackinton
North Adams
Massachusetts Ave.
Berlin Pass 2220
Haskin Farm
Berlin Mtn. 2798
BERLIN MTN. TRAIL
Torrey Woods Rd.
Sheep Hill
Stone Hill 1140
Cluett Hill
Greylock
Braytonville
N. Adams Airport
Houghtonville
Briggsville
Cascade
Blair Rd.
Sweets Corner
Mt. Hope Farm
Wilbur Clearing Shelter 2582
Mt. Williams 2951
Mt. Prospect 2690
The Cobble
S. Williamstown
Steeles Corner
MONEY BROOK CUT-OFF
Money Brook Falls
Mt. Fitch 3110
Haley's Farm
Hopper Brook
HOPPER TRAIL
Stony Ledge Shelter
The Hopper
Robinson's Point
The Bellows
Pipe Shelter
BELLOWS PIPE TRAIL
Ragged Mtn.
Thiel Farm
OVERLOOK TRAIL
STONY LEDGE TR.
Roaring Brook
Sperry Camp Ground
Deer Hill Shelter
Mt. Greylock 3491
Renfrew
Zylonite
Adams
Arnoldsville
Saddle Ball Mtn.
CHESHIRE HARBOR TRAIL
Mitchell Brook
New Ashford
Jones Nose
Hales Hill 1412
Fire Tower 2613
BRODIE MT. SKI AREA
Brodie Mountain
Sugar Loaf 2030
Rounds Rock
Cole Mtn. 2133
Cheshire Harbor
Pratt Hill 1830
Cheshire
JIMINY PEAK SKI AREA
TACONIC CREST TRAIL
TAconic Range
Hoosac Range
Green Mts.
Contour intervals 200 feet
Scale 1:63,360
0 1/2 1 2 Miles
Robinsons Point
Mt. Greylock 3491
TV Tower
CHESHIRE HARBOR TRAIL

Figure 5

A VEGETATION MAP OF WILLIAMSTOWN



spruce – highest elevations >2000' N facing

beech – med high elevations E facing W – clumpy

sugar maple

hemlock – ravines – [illegible]

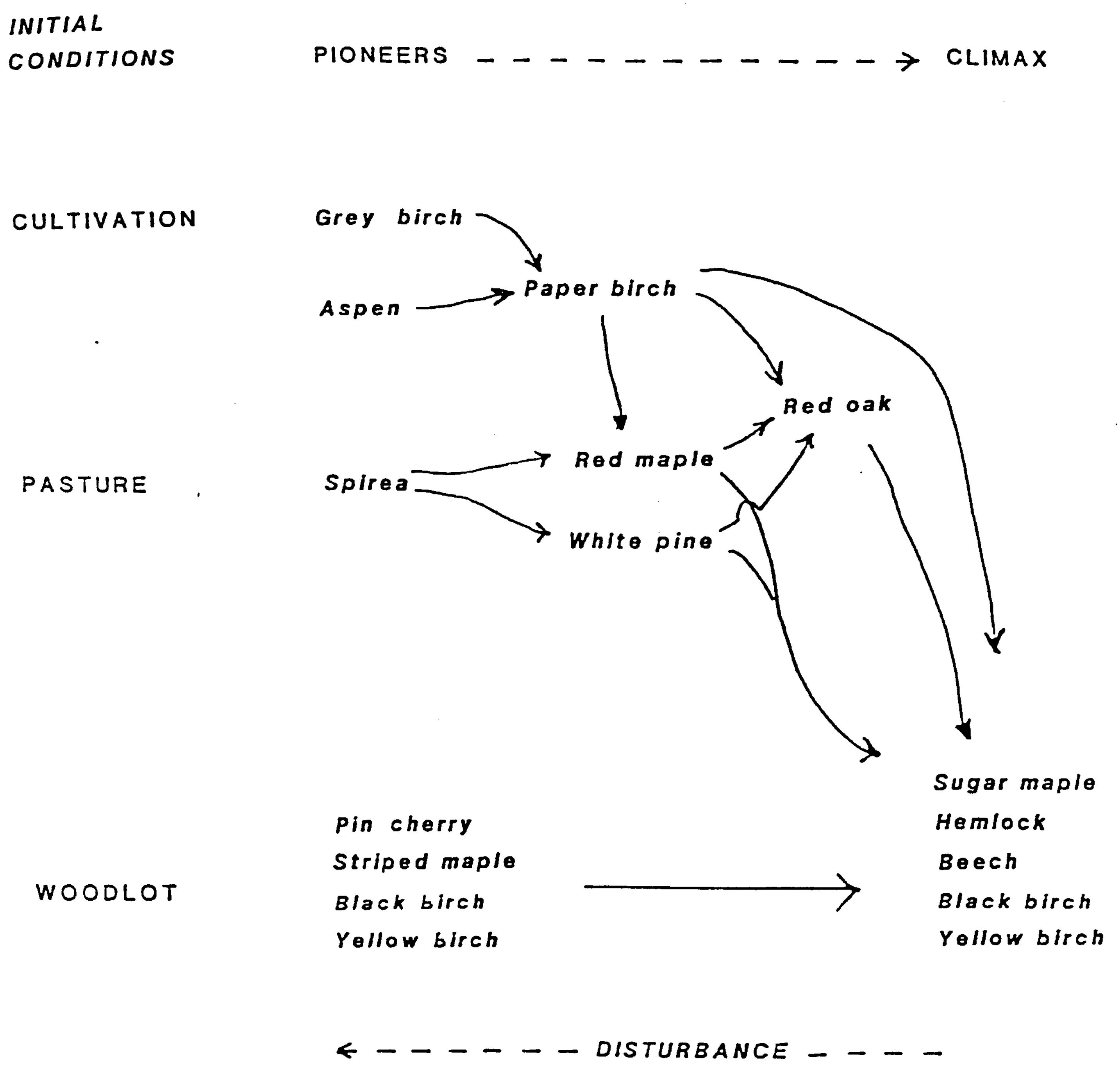


Figure 15. Successional Trends in the Hopkins Forest.

Figure 6

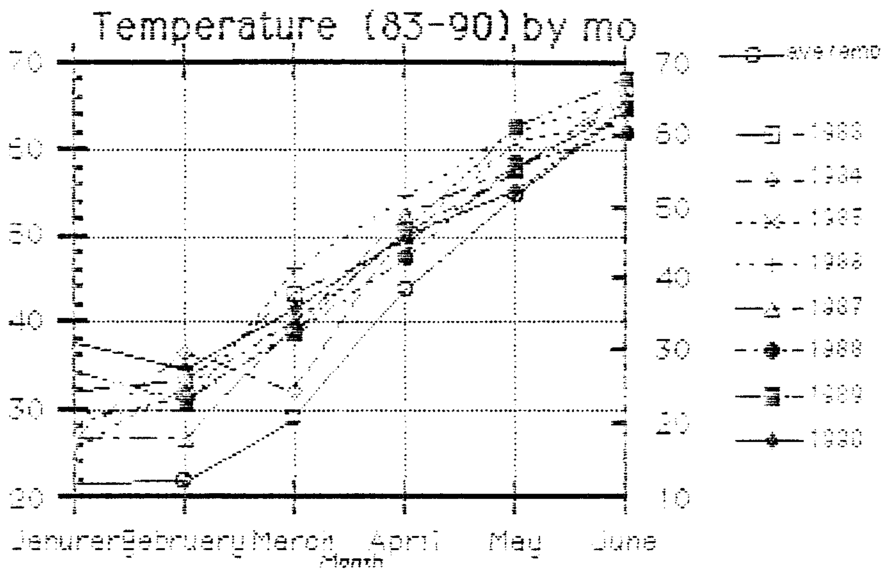
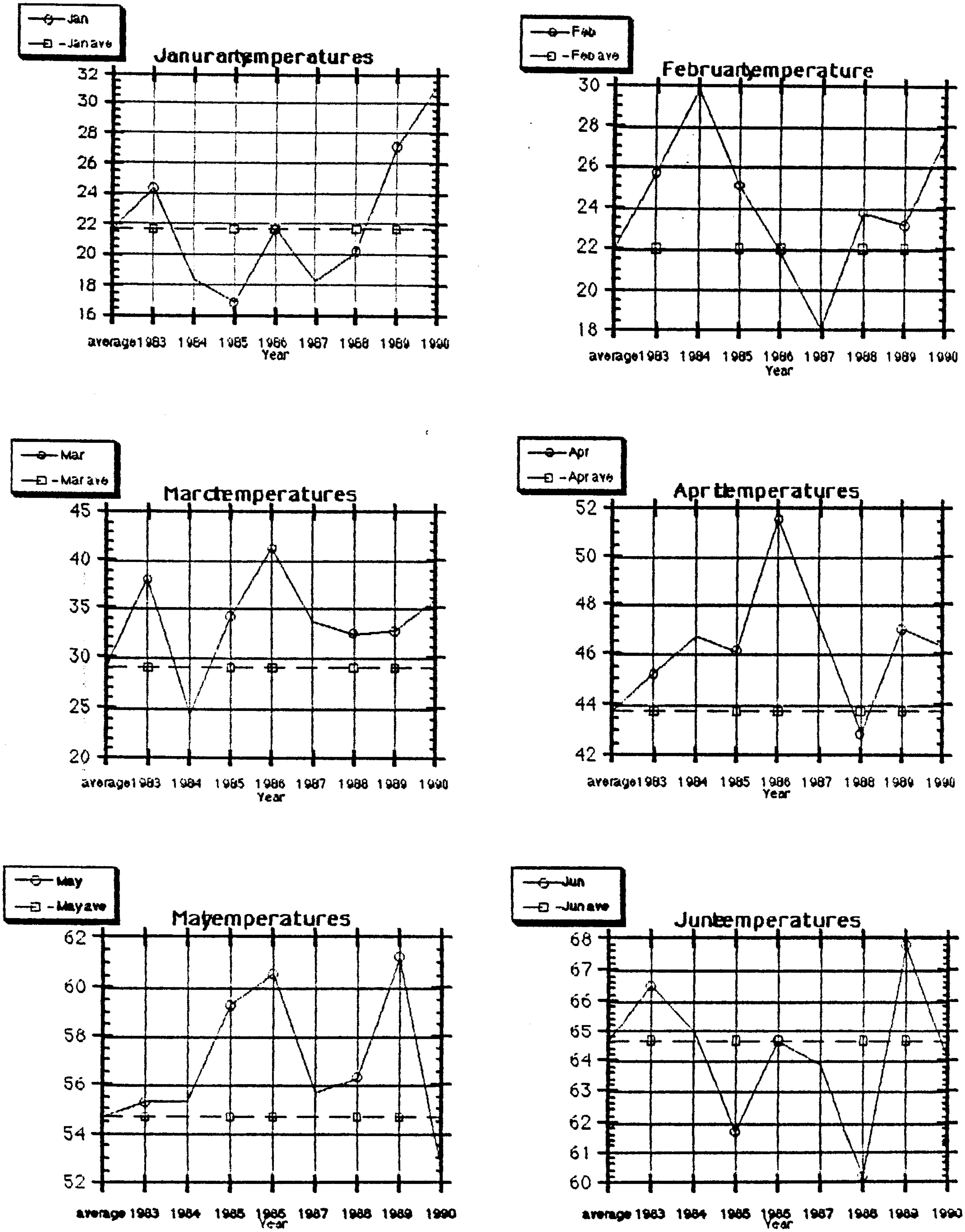
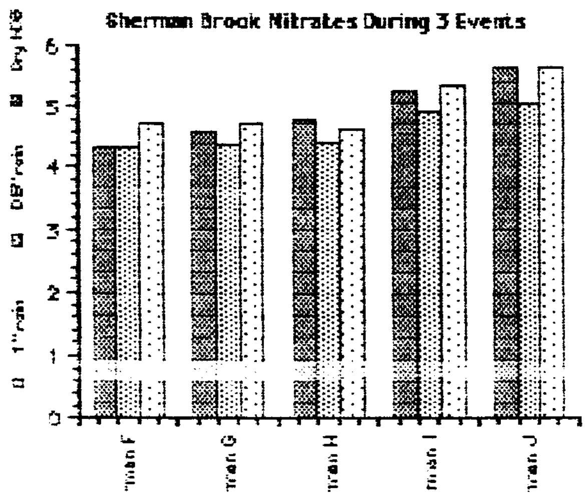
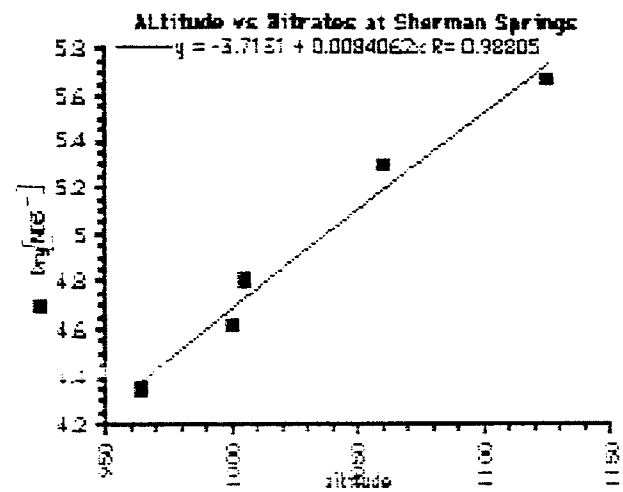

Temperature (83-90) by mo
ave temp
1983
1984
1985
1986
1987
1988
1989
1990
January
February
March
April
May
June
Month

Figure 7

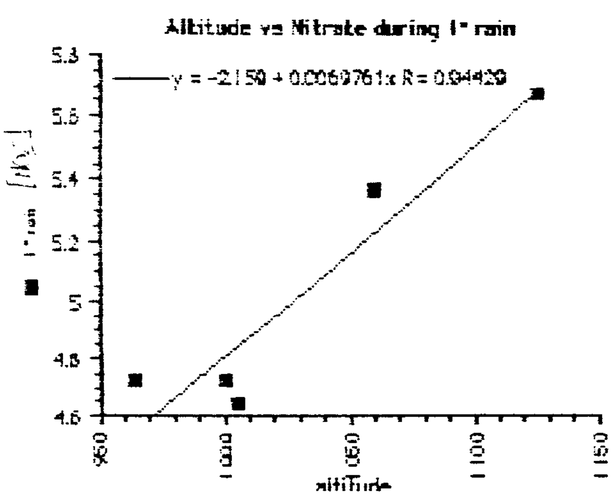

Jan
Jan ave
Janurarytemperatures
32
30
28
26
24
22
20
18
16
average 1983 1984 1985 1986 1987 1988 1989 1990
Year
Feb
Feb ave
Februarytemperature
30
28
26
24
22
20
18
average 1983 1984 1985 1986 1987 1988 1989 1990
Year
Mar
Mar ave
Marchtemperatures
45
40
35
30
25
20
average 1983 1984 1985 1986 1987 1988 1989 1990
Year
Apr
Apr ave
Apriltemperatures
52
50
48
46
44
42
average 1983 1984 1985 1986 1987 1988 1989 1990
Year
May
May ave
Maytemperatures
62
60
58
56
54
52
average 1983 1984 1985 1986 1987 1988 1989 1990
Year
Jun
Jun ave
Junetemperatures
68
67
66
65
64
63
62
61
60
average 1983 1984 1985 1986 1987 1988 1989 1990
Year



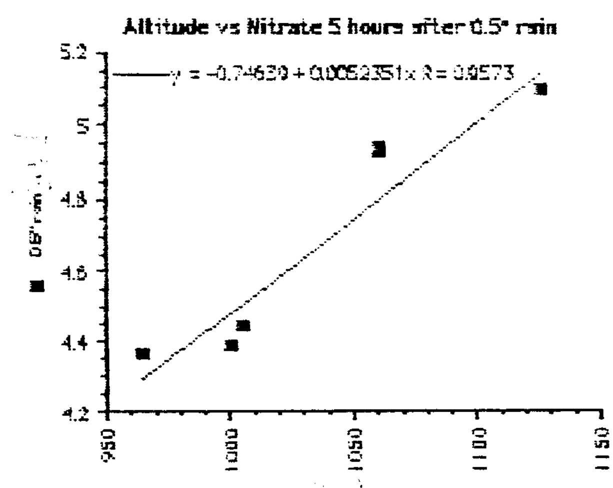
Sherman Brook Nitrates During 3 Events
1" rain
0.5" rain
Dry
tran F
tran G
tran H
tran I
tran J



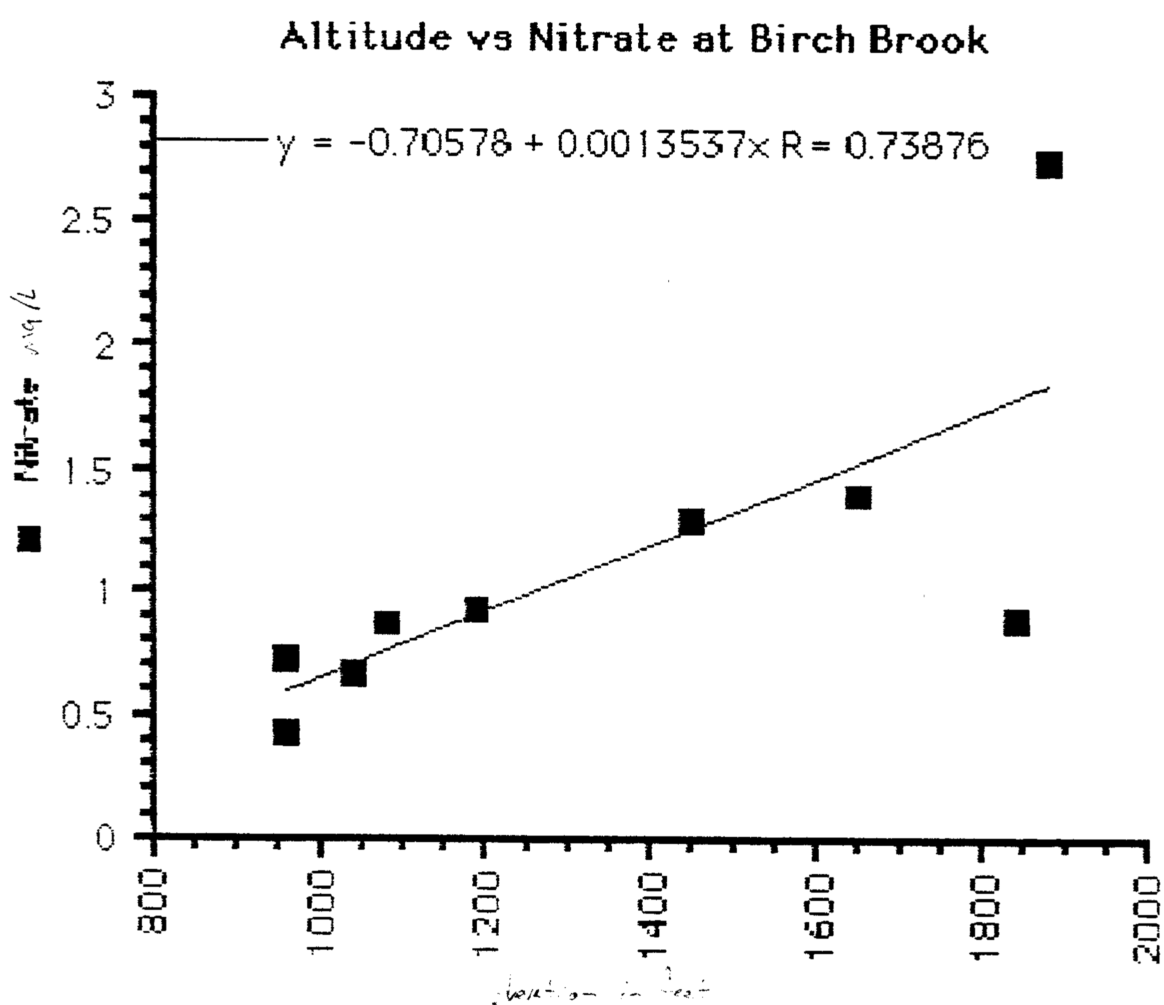
Altitude vs Nitrates at Sherman Springs
y = -3.7151 + 0.0084062x R= 0.98205
altitude



Altitude vs Nitrate during 1" rain
y = -2.150 + 0.0069761x R= 0.94429
1" rain
altitude



Altitude vs Nitrate 5 hours after 0.5" rain
y = -0.74639 + 0.0052351x R= 0.9573



Altitude vs Nitrate at Birch Brook
y = -0.70578 + 0.0013537x R = 0.73876
Nitrate
3
2.5
2
1.5
1
0.5
0
800
1000
1200
1400
1600
1800
2000