

# PROJECT UPDATE

August 2005

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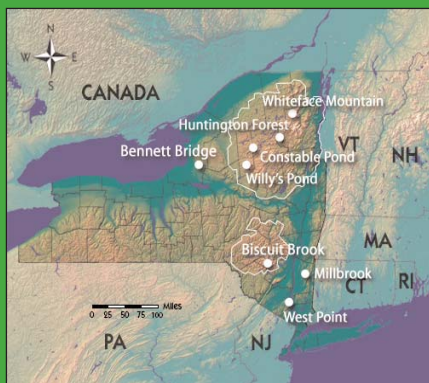
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## Project Location



Adirondack and Catskill Mountain regions outlined.

## Contact Information

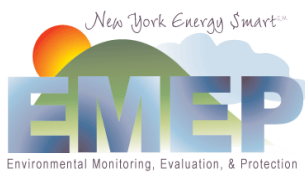
For more information on this project see:

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## Keywords

- Acidification
- Nitrogen cycling
- PnET-BGC Model
- Sugar maple
- Surface water chemistry



New York State Energy Research  
and Development Authority  
Environmental Monitoring, Evaluation,  
and Protection Program



## An Assessment of Recovery and Key Processes Affecting the Response of Surface Waters to Reduced Levels of Acid Precipitation in the Adirondack and Catskill Mountains

### PROJECT FOCUS

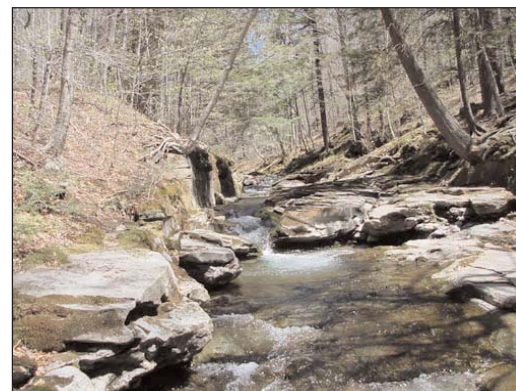
While previous studies have documented local effects of acidic deposition in New York, thus far there has been no comprehensive effort to synthesize data and compare results across broader geographical regions in the state. This project provides the first in-depth assessment of the extent to which recovery from acidification is occurring in the Catskills and Adirondacks, two regions of New York State that are especially sensitive to the effects of acidic deposition. The goals of this study were to:

- Assess trends in key indicators of acidification in precipitation and surface-water chemistry at several intensively monitored sites in the Adirondack and Catskill regions;
- Examine the role of tree species in nitrogen cycling; and
- Model the effects on regional water chemistry of several possible future acid deposition scenarios.

### CONTEXT

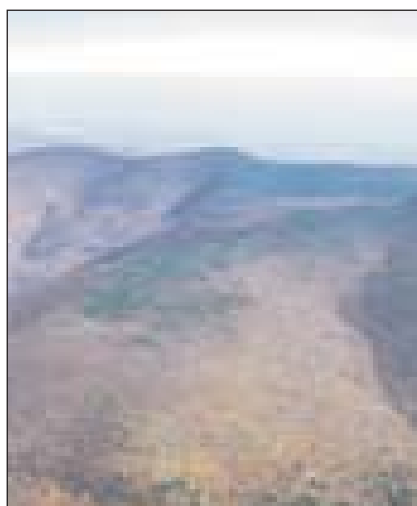
Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>), which, through complex reactions in the atmosphere, form nitric and sulfuric acids. As a result, sulfate (SO<sub>4</sub><sup>2-</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) are deposited on land and in water, contributing to the acidification of lakes and streams.

In both the Adirondack and Catskill regions of New York, surface-water acidification has had deleterious effects on aquatic and terrestrial biota; a decline in habitat has resulted in a decline in acid-sensitive species. To address this problem, several chemical criteria were used to identify the degree to which surface water is acidified and poses a danger to aquatic biota. Biota are at risk when water pH is less than 5.5, acid-neutralizing capacity (ANC) is less than 50 microequivalents per liter (µeq/L), and/or concentrations of toxic inorganic aluminum (Al) are greater than 2 micromoles per liter (µmol/L).



Credit: USGS  
Biscuit Brook, looking upstream.

### METHODOLOGY



Credit: USGS  
The Winisook watershed in the Catskill Mountains where recovery from acidification is being studied.

Trends in precipitation chemistry were evaluated for 1984-2001 using data from six sites that are part of the National Acid Deposition Program (NADP) and are located close to the Adirondack and Catskill regions. Dry deposition, the other main component of acidic deposition, was not evaluated in this study. Trends in surface water chemistry were analyzed for five Catskill streams and 12 Adirondack lakes using data from 1992-2001, the minimum length of record that includes all study sites. In addition, soil chemistry and vegetation data were compiled from stands of differing tree species composition in the Catskills and Adirondacks to determine how the dynamics of tree species modify the effects of nitric acid from precipitation and the nitrogen cycle in forested ecosystems. Finally, the PnET-BGC model was used to simulate the important processes that affect the acid-base chemistry of four Adirondack lakes and one Catskill stream. The model was also used to predict surface water chemistry under three different future acid deposition scenarios.

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Credit: USGS  
The Arbutus watershed in the Adirondacks is an intensive research site at which nitrogen cycling and retention will be estimated.

## Project Status

- Initiated 2001
- Completed 2005



Since 1975, the New York State Energy Research and Development Authority (NYSERDA) has developed and implemented innovative products and processes to enhance the State's energy efficiency, economic growth, and environmental protection. One of NYSEDA's key efforts, the Environmental Monitoring, Evaluation Protection (EMEP) Program, supports energy-related environmental research. The EMEP Program is funded by a System Benefits Charge (SBC) collected by the State's investor-owned utilities. NYSEDA administers the SBC program under an agreement with the Public Service Commission.

## PROJECT FINDINGS

### Trends in Precipitation Chemistry

Precipitation pH has increased an average of about 0.02 units in the Adirondacks and Catskills from 1984 to 2001; three-fourths of this increase has resulted from decreases in  $\text{SO}_4^{2-}$  concentrations and about one-fourth from decreases in  $\text{NO}_3^-$  concentrations. These changes are paralleled by, and are assumed to result from, similar decreases in sulfur (S) and nitrogen oxide ( $\text{NO}_x$ ) emissions largely from power plants in the predominant source region of acidic precipitation to the State.

### Trends in Surface Water Chemistry

During 1992 to 2001, sulfate ( $\text{SO}_4^{2-}$ ) concentrations decreased significantly at every surface water site by an average of  $3.3 \mu\text{eq L}^{-1} \text{yr}^{-1}$  in Adirondack lakes and  $2.5 \text{ eq L}^{-1} \text{yr}^{-1}$  in Catskill streams. These decreases in  $\text{SO}_4^{2-}$  concentrations in surface waters were highly synchronous among surface waters and in surface water-precipitation comparisons, which demonstrates the tight link between atmospheric deposition and the sulfur cycle in these watersheds. Nitrate ( $\text{NO}_3^-$ ) showed significant decreasing trends at most surface-water sites, however, the decreases were generally three- to ten-fold less than those of  $\text{SO}_4^{2-}$ . The trends in  $\text{NO}_3^-$  were generally not synchronous across the two regions or within the Adirondacks, a result of the numerous factors other than atmospheric N deposition including sugar maple that affect the N cycle and surface water  $\text{NO}_3^-$  concentrations. Other factors that affect the N cycle include land-use history, long-term climate variability, and short-term climate disturbances such as soil freezing, wind storms, ice storms, and floods, insects and pathogens, and aquatic processes.

Overall,  $\text{H}^+$  concentrations decreased significantly at about 60% of surface water sites. ANC increased significantly at about 50% of surface-water sites, and these increases averaged  $14 \mu\text{eq L}^{-1}$  in 7 of the 12 Adirondack lakes with significant trends, and  $5 \mu\text{eq L}^{-1}$  in 1 of the 5 Catskill streams with significant trends during 1992-2001. Inorganic monomeric aluminum, a metal that is toxic to many acid-sensitive species, also decreased at most surface-water sites during 1992-2001. The trends in base cation concentrations ( $\text{C}_B$ ), ANC, and  $\text{H}^+$  were not generally synchronous in surface waters within and among these regions, nor in precipitation-surface water comparisons. Thus, the myriad complexities that affect the cycles of N and  $\text{C}_B$  partially mask the otherwise strong relation between precipitation and surface-water  $\text{SO}_4^{2-}$  concentrations, an indication that trends in acid-base chemistry (ANC and  $\text{H}^+$ ) respond in part to factors such as climate variation that are independent of the acidity of precipitation.

### The Role of Sugar Maple in the Nitrogen Cycle

In sugar maple stands, rates of nitrification and nitrate leaching are higher than in those of other common hardwood and softwood species. A number of factors may account for this phenomenon, including the rate at which leaf litter decomposes in the soil and soil chemistry in the stands. Although sugar maple is the most dominant species in northern hardwood forests of New York, conditions such as beech bark disease, climate change, soil calcium depletion, and pest infestations may affect the future abundance of sugar maple and consequently nitrogen cycling and ANC trends in these regions. Thus, future trends in nitrate concentrations in surface waters may depend on changes in tree species composition, which are determined by multiple environmental factors.

### Model Simulations

The PnET-BGC model results indicate that the 1990 Clean Air Act Amendments (CAAA) will result in little additional change in surface water ANC in these two regions, but that a future scenario in which sulfur dioxide ( $\text{SO}_2$ ) emissions were reduced by 50% and  $\text{NO}_x$  emissions by 30% would increase surface-water ANC by an average of  $24 \mu\text{eq L}^{-1}$  from 2001 to 2050 in the 5 water bodies that were modeled. These changes were sufficient to increase ANC to  $> 0 \mu\text{eq L}^{-1}$ , a critical value for many surface-water biota, in the most acidic of the surface waters that were modeled.

## PROJECT IMPLICATIONS

With implementation of the Clean Air Act Amendments of 1990, it was expected that increases in precipitation pH would result in increases in pH and ANC in sensitive surface waters and decreases in sulfate ( $\text{SO}_4^{2-}$ ), nitrate ( $\text{NO}_3^-$ ), and aluminum (Al) concentrations. This would allow the recovery of species diversity in biota affected by surface-water acidification during the 20th century. Adequate data on surface-water chemistry are now available to evaluate whether these intentions are being realized. However, the accuracy of future trend analyses for flow-sensitive criteria such as  $\text{NO}_3^-$  concentrations and ANC would be strengthened by the availability of more streamflow data at the outlets of Adirondack lakes.

The results of this study indicate that surface waters are slowly recovering due to reduced levels of acid precipitation, but that additional recovery may require reductions in  $\text{SO}_2$  and  $\text{NO}_x$  emissions greater than are mandated under the 1990 CAAA. Although reduced  $\text{SO}_4^{2-}$  concentrations in precipitation are the major cause of increased ANC and pH and decreased Al concentrations in sensitive surface waters in New York, future changes in climate and ecosystem disturbance that may affect the cycling rates of N, DOC, and  $\text{C}_B$  should be closely monitored over multi-year periods because these constituents also affect pH and ANC, and have the potential to negate recovery due to decreased  $\text{SO}_4^{2-}$  concentrations in precipitation and surface waters. A quantitative understanding of the factors other than acid precipitation that may affect surface-water pH and ANC is necessary to separate the effects of clean air laws and atmospheric deposition from natural variability and disturbance.