The Hydrology and Biogeochemistry of Bog Watersheds in Northern Minnesota: Findings from Long-Term Studies and Experiments at the Marcell Experimental Forest.

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Marcell Experimental Forest

North of Grand Rapids in Itasca County
Chippewa National Forest

Instrumented research watersheds interspersed among uplands, bogs, fens, lakes, and streams in the Marcell hills moraine.
Isolated Peatlands in Ice-block Depressions

- No dominant aspect.
- Little topographic relief.
- Deep glacial drift aquifers.
- Upland soils drain to central peatlands with one or more outlets.

*modified from Boelter & Verry, 1977*
Research Watersheds At the Marcell Experimental Forest

The Marcell Experimental Forest was established during the 1960s when hydrology of undrained peatlands was poorly understood.
Long-Term Monitoring

- Precipitation
- **Air and soil temperature**
- Streamflow
- Groundwater levels
- **Hillslope runoff**
- Soil moisture
- Water chemistry
- Atmospheric deposition
- Mineral soil properties
- Peat physical properties
- Trace gas fluxes
- Aboveground biomass
Small-Watershed Study Design

• Quantify hydrology by measuring precipitation inputs and stream outflows.

• Monitor baseline reference conditions for change.
Insight on Ecosystem Processes

- Peatland hydrology – flowpaths from uplands to peatlands that affect water yield and chemical transport.
- Responses to natural disturbances and climate variability.
- Atmospheric pollutant effects on forests and stream chemistry.
- Trace gas (carbon dioxide and methane) emissions from peatlands.
- Peatland acidity and effects of acid rain.
- Processes that affect mercury outflow to streams.
S2 Control Watershed

1968
Patterns of Precipitation & Streamflow

Although most rainfall occurs during the summer, most of the annual stream-water yield occurs in response to spring snowmelt.
Streamflow Patterns

PERCENT OF MONTHS DURING WHICH NO STREAMFLOW OCCURRED
Air Temperature Change

- Average annual air temperature has increased.
- Summer and winter air temperature has increased.

**ANNUAL MEAN AIR TEMPERATURE**

**SEASONAL MEANS OF DAILY MEAN AIR TEMPERATURE**
Precipitation and Streamflow

- No patterns in precipitation or streamflow amount.
- Snowmelt now occurs about 3 weeks earlier.

![Graphs showing annual precipitation and stream-water yield at S2 and S5 since 1961, and the timing of snowmelt.](image)
Atmospheric Deposition

Deposition with rain and snow fall has decreased:

- Sulfate
- Nitrate
- Base cations
- Chloride
- Hydrogen ion
Upland Flow is Linked to Peatlands and Streams

- Flowpaths from uplands soils to peatlands develop as snow melts and during large rainfall events.
- Intermittent flow transports solutes derived from precipitation and soils from upland soils to peatlands.
Chemical Changes within Watersheds

The forms and concentrations of solutes change as waters flows from uplands via to streams.

Urban et al., 2011, in press
Runoff of Mercury

Mercury flows from different areas at different times.

- The largest exports occur during wet summer months when mercury originates from the peatland.

Pioneering Research on Methane Emissions

Methane emissions are highest during hot summer months

Dise et al., 2011, in press
Paired-Watershed Study Design

- Quantify hydrology by measuring streamflow, precipitation inputs, and groundwater levels.
- Monitor baseline reference conditions for change.
- Compare hydrological, hydrochemical, and ecological responses of manipulated watersheds to similar but unmodified watersheds.
What are the effects of stripcutting black spruce on:

- Streamflow from the peatland.
- Regeneration of black spruce.
No Changes to Water Yield

(a) S1 vs. S5 ANNUAL STREAM-WATER YIELD

(b) S1 vs. S5 TRENDS IN ANNUAL STREAM-WATER YIELD

- 1962 to 1968
- 1969 to 1973
- 1974 to 1978

R² = 0.81
R² = 0.64
R² = 0.85

95% confidence interval
Effects of Forest Management on Black Spruce Regeneration

- The first stripcuts are adequately stocked with black spruce.
- The areas cut in 1974 have black spruce cover that is less dense.
Effects of Aspen Clearcutting

Before 1970-72 clearcut

50% uplands cut, summer 1971,

100% uplands cut, winter 1972
S4 Uplands Fertilization Study

1978
Water Yield and Chemistry Effects

CHANGE IN WATER YIELD AT S4

ANNUAL VOLUME-WEIGHTED CONCENTRATIONS OF NITRATE+NITRITE IN STREAM WATERS


upland clearcut  upland fertilization

[ N O₃⁻ + N O₂⁻ ] (μmol L⁻¹)
Aspen Clearcutting and Conversion to Conifers

1968

1980
Cattle Grazing and Conifer Conversion

1980-82 cattle grazing

summer 1981 or 1982

Autumn 2009, forest converted to conifer cover
Atmospheric Deposition Study
Water Yield and Chemistry Effects

CHANGE IN WATER YIELD AT S6

ANNUAL VOLUME-WEIGHTED CONCENTRATIONS OF NITRATE+NITRITE IN STREAM WATERS

Water Yield and Chemistry Effects
Effects on Runoff from Uplands

Rauneker, 2010, diploma thesis
Summary

• Long-term data provide valuable insight on watershed responses to environmental change and forest management.

• Because uplands route water through central peatlands that drain to streams, management strategies that affect forest cover and composition on uplands are coupled with the physical and biogeochemical processes that affect water movement and solute availability in peatlands.

• Effects of harvesting on water yield and chemistry vary among management schemes.

• After upland harvest, changes in nitrate concentrations lasted no more than one year, whereas the water-yield increases lasted about a decade.
Book summarizing 50 years of research will be published in February 2011.

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Questions

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