

## University of New Hampshire University of New Hampshire Scholars' Repository

---

NH Water Resources Research Center Scholarship

NH Water Resources Research Center

---

6-1-2012

# Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

William H. McDowell

*University of New Hampshire*, [bill.mcdowell@unh.edu](mailto:bill.mcdowell@unh.edu)

Steve Kahl

*University of New Hampshire*

Follow this and additional works at: [https://scholars.unh.edu/nh\\_wrrc\\_scholarship](https://scholars.unh.edu/nh_wrrc_scholarship)

---

### Recommended Citation

McDowell, William H. and Kahl, Steve, "Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S." (2012). *NH Water Resources Research Center Scholarship*. 41.  
[https://scholars.unh.edu/nh\\_wrrc\\_scholarship/41](https://scholars.unh.edu/nh_wrrc_scholarship/41)

This Report is brought to you for free and open access by the NH Water Resources Research Center at University of New Hampshire Scholars' Repository. It has been accepted for inclusion in NH Water Resources Research Center Scholarship by an authorized administrator of University of New Hampshire Scholars' Repository. For more information, please contact [nicole.hentz@unh.edu](mailto:nicole.hentz@unh.edu).

# USGS Award No. G11AP20128 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

## Basic Information

<b>Title:</b>	USGS Award No. G11AP20128 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.
<b>Project Number:</b>	2011NH164S
<b>Start Date:</b>	3/28/2011
<b>End Date:</b>	3/27/2012
<b>Funding Source:</b>	Supplemental
<b>Congressional District:</b>	
<b>Research Category:</b>	Climate and Hydrologic Processes
<b>Focus Category:</b>	Acid Deposition, Surface Water, Law, Institutions, and Policy
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	William H H. McDowell, Steve Kahl

## Publications

1. Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012, New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes, Environmental Science and Technology, in press.
2. Nelson, S.J., P. Vaux, M.J. James-Pirri, and G. Giese, 2011, Assessment of natural resource conditions in and adjacent to Cape Cod National Seashore, Massachusetts, Natural Resource [Technical] Report NPS/XXXX/ NRXX—20XX/XXX, National Park Service, Fort Collins, Colorado, In press.
3. Kerr, J.G., M.C. Eimers, I.F. Creed, M.B. Adams, F. Beall, D. Burns, J.L. Campbell, S.F. Christopher, T.A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D.S. Jeffries, G.E. Likens, M.J. Mitchell, J. Shanley, H. Yao, 2011, The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA, Biogeochemistry DOI 10.1007/s10533-011-9664-1.

**Annual Report to**

USGS WRD WRRI, Reston, VA  
 US EPA, CAMD, Washington DC  
 and US EPA, ORD, Corvallis OR

June, 2012

***Determining the effectiveness of the Clean Air Act and Amendments on the recovery of surface waters in the northeastern US***

IAG 06HQGR0143

Principal Investigators: *William H. McDowell<sup>1</sup>, Sarah J. Nelson<sup>2</sup>, J. Steve Kahl<sup>1</sup>, J. Saros<sup>2</sup>*  
<sup>1</sup>Univ. of New Hampshire, <sup>2</sup>Univ. of Maine

**Overview of activities during 2011.** A schematic summary of progress on the project plan is provided below (Table 1) and discussed on the following pages. We have concluded the first year of five for the most current project agreement, which supports the continuing needs of EPA to assess the effectiveness of the Clean Air Act Amendments of 1990 (CAAA). Field work and data assessment continue on schedule. Project coordination as well as most analytical chemistry, and some field sampling are conducted by the University of New Hampshire. Additional field sampling, data quality assurance, and data reporting are conducted by the University of Maine. This year, the project is partially funding a Ph.D. candidate who is evaluating recent trends in the LTM and TIME lakes' responses to changes in atmospheric deposition.

**Table 1.** 2011-2015 Project plan progress to date.

Project Activity	2011				2012				2013				2014				2015				2016	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Project Period																						
Funding received																						
RLTM drainage																						
RLTM seepage																						
original LTM																						
HELM subset																						
BBWM-EB																						
TIME (New England)																						
TIME (Adirondacks)																						
Sample analyses																						
Data submission																						
Annual report																						

□ = project plan      ■ = completed      ▨ = in progress

## Project background

*Objectives.* This research is part of EPA CAMD programs that are verifying the effectiveness of emission controls at reducing acidification of surface waters. Our approach is to collect long-term high-quality data that characterize the trends and patterns of response in low ionic-strength surface waters. We have specifically targeted waters that have been classified as being sensitive to acidic deposition and will represent lakes across the Northeast in varying landscape settings. The goals and methods are hierarchical, ranging from intensive site-specific investigations to regional assessment of sites that have been chosen to provide a statistically rigorous sample of regional surface waters. The objectives are to:

- 1) document the changes and patterns in aquatic chemistry for defined sub-populations and sites that are known to be susceptible to acidification or recovery;
- 2) evaluate the extent to which changes in surface waters, if any, can be linked to changes in deposition that are driven by regulatory actions;
- 3) characterize the effectiveness of the CAAA in meeting goals of reducing acidification of surface waters and improving biologically-relevant chemistry in the northeastern US;
- 4) provide information for assessment of the need for future reductions in atmospheric deposition based on the long-term trajectories of the systems under study; and
- 5) assess the extent to which increased variability in precipitation events will play a role in the long-term sustainability of CAAA success in these sensitive surface waters.

*Approach.* The schedule of tasks ranges from weekly to annual, continuing data records that now range from 17 to 30 years. We evaluate chemistry on a weekly basis year-round at the small watershed-scale at BBWM, quarterly in LTM, and annually during the historical index period for the TIME and HELM lakes. These project components provide a *statistical framework* for inferring regional patterns in chemistry using TIME and LTM (and ELS-II under separate funding). The *long-term records* of LTM, HELM and BBWM provide information on seasonal and annual variability, and thus provide a seasonal context for the annual surveys.

*Expected Results.* This information is needed for EPA to meet its Congressional mandate to assess the effectiveness of the CAAA. The combination of site-specific data within the regional context provides a rigorous assessment of the effects of declining pollutant emissions on SO<sub>4</sub> concentrations, base cation depletion, and changes in N-saturation or DOC contributions to acid-base status. The results are also central to assessing whether additional emission reductions may be needed to produce recovery.

## Project Status: Water Chemistry

**Field sampling.** All project field objectives in 2011 were accomplished as planned. A summary of the annual field schedule for this project is provided below (Table 2).

**Table 2.** Annual project field schedule for lake sampling

Project	sub-project	n	Times		May	June	July	Aug.	Sept.	Oct.
			Sampled	Field work						
RLTM-Maine										
	seepage	3	3	UMaine	X		X			X
	drainage	9	3	UMaine/UNH	X		X			X
	LTM lakes	3	1	UMaine						X
TIME										
	New England	31	1	UNH			X	X	X	
	Adirondacks	42	1	ALSC			X	X	X	
HELM		25-30	1	UNH						X

**Analytical.** Analyses are complete for all samples collected through 2011. All laboratory analyses for TIME, RLTM, and HELM are conducted at the University of New Hampshire Water Quality Analysis Laboratory (WQAL) except for aluminum. Total and organic aluminum samples are processed on an ICP at the USDA Forest Service Region 1 laboratory in Durham, NH. All analyses for TIME, RLTM, and HELM continue to be conducted by, or under the supervision of, Adam Baumann as has been the case since 2006.

Samples from East Bear Brook at BBWM, which are collected on a regular basis year-round, continue to be analyzed at the University of Maine Sawyer Environmental Chemistry Research Lab.

**Data reporting.** All data collected through 2010 have been delivered to EPA. The next delivery of data to EPA is expected before August 2012, after evaluation of inter-laboratory comparisons and regular QA analyses by UNH and UMaine. Additionally, PI Nelson has been working with EPA-CAMD to improve the legacy database through improved formatting, metadata, and reporting of an expanded and re-checked legacy database.

**Presentation of findings.** Several publications and presentations continue to result from this project and are listed at the end of this report. The recent completion of a Master’s Thesis (Baumann) further highlights the significance of this research award.

**New developments:** During the past year we were able to make routine two new sets of analyses to continue to extract new and innovative information from these study sites. A subset of lakes were analyzed for DOC quality using SUVA and fluorescence (EEMS) analysis, as well as concentrations of the dissolved greenhouse gases (CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub>O) in surface waters. Moving forward this data will provide valuable insight into changes in organic sources to acid-base status as well as the influence of precipitation event variability on long-term changes in surface water chemistry. Analyses of archived samples from the LTM lakes led to a publication now in press in Environmental Science and Technology (Sancléments et al.), based on carbon quality measured as fluorescence index. This paper reports that (1) five of the nine lake samples analyzed had increasing DOC trends during 1993-2009, and (2) in these five lakes with increasing DOC, fluorescence indices suggest the source of DOC has become increasingly terrestrially-derived.

Conversations with the Adirondack Lake Survey Corporation (ALSC) at our periodic TIME/LTM cooperators meeting opened conversations about streamlining the collection and analysis of TIME-Adirondack samples. Many years of duplicate analyses provide ample opportunity for interlaboratory comparisons between ALSC and UMaine and UNH that we are hopeful will allow for analytical responsibility to shift mainly to the ALSC lab in the near future.

Data are being provided to a team including former EPA-LTM PI Katherine Webster (with P.A. Soranno, K.S. Cheruvilil, E.H. Stanley, J.A. Downing, N. Lottig, and P-N Tan), who are working on the NSF Macrosystems Biology Project “studying large-scale and long-term dynamics of lakes.”

*Publications using related project information (recent publications in bold):*

**Sanclements, M., G. Oelsner, D. McKnight, S.J. Nelson, J. Stoddard, 2012. New insights into the source of decadal increases of dissolved organic matter (DOM) in acid-sensitive lakes. Environmental Science and Technology, in press.**

**Nelson, S.J., Vaux, P., M.J. James-Pirri, and G. Giese. 2011. Assessment of natural resource conditions in and adjacent to Cape Cod National Seashore, Massachusetts. Natural Resource [Technical] Report NPS/XXXX/ NRXX—20XX/XXX. National Park Service, Fort Collins, Colorado. In press.**

**James-Pirri, M.J., S.J. Nelson, and P.D. Vaux. July 2010. Natural Resource Assessment for Saugus Iron Works National Historic Site. Natural Resources Report NPS/NER/NRR—2010/XXX. National Park Service. Boston, MA, in press.**

**Vaux, P.D., S.J. Nelson, N. Rajakaruna, G. Mittelhauser, K. Bell, B. Kopp, J. Peckenham, G. Longworth, 2008. Assessment of natural resource conditions in and adjacent to Acadia National Park, Maine. Natural Resource Report NPS/NRPC/WRD/NRR—2008/069. National Park Service, Fort Collins, Colorado.**

**Kerr, J.G., M. C. Eimers, I. F. Creed, M. B. Adams, F. Beall, D. Burns, J. L. Campbell, S. F. Christopher, T. A. Clair, F. Courchesne, L. Duchesne, I. Fernandez, D. Houle, D. S. Jeffries, G. E. Likens, M. J. Mitchell, J. Shanley, H. Yao. 2011. The effects of seasonal drying on sulphate dynamics in streams across southeastern Canada and the northeastern USA. Biogeochemistry DOI 10.1007/s10533-011-9664-1.**

Norton, S.; Fernandez, I.; Kahl, J.; Rustad, L.; Navratil, Tomas; Almquist, H., 2010. The evolution of the science of Bear Brook Watershed in Maine, USA. Environmental Monitoring and Assessment, 171(1-4): 3-21.

Navrátil, T., S.A. Norton, I.J. Fernandez, S.J. Nelson, 2010. Twenty-year inter-annual trends and seasonal variations in precipitation and stream water chemistry at the Bear Brook Watershed in Maine, USA. Environ. Monit. Assess. 171:3-21.

Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. LakeLine 27:30-34.

- Campbell, J., J. Hornbeck, M. Mitchell, M. Adams, M. Castro, C. Driscoll, J.S. Kahl, and others, 2004. Input-output budgets for inorganic nitrogen for 24 watersheds in the northeastern United States. *Water Air Soil Pollut.*, 151:373-396.
- Dupont, J., T. Clair, C. Gagnon, D. Jeffries, J.S. Kahl, S. Nelson, and J. Peckenham, 2005. Estimation of critical loads of acidity in the northeastern US and eastern Canada. *Environ. Monit. Assess.* 109:275-291.
- Hunt, K., J.S. Kahl, J. Rubin, and D. Mageean, 2007. Assessing the science-based needs of stakeholders; a case study on acid rain research and policy. *Journal of Contemporary Water Research and Education*, 136: 68-79.
- Kahl, J.S., J. Stoddard, R. Haeuber, S. Paulsen, R. Birnbaum, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. Murdoch, K. Roy, W. Sharpe, S. Urquhart, R. Webb, and K. Webster, 2004. Response of surface water chemistry to changes in acidic deposition: implications for future amendments to Clean Air Act. *Environmental Science and Technology*, Feature Article 38:484A-490A.
- Lawler, J., J. Rubin, B.J. Cosby, I. Fernandez, J.S. Kahl, S. Norton, 2005. Predicting recovery from acidic deposition: Applying a modified TAF (Tracking Analysis Framework) Model to Maine High Elevation Lakes, *Water Air Soil Pollut.* 164:383-389.
- Norton, S., I. Fernandez, J.S. Kahl, and R. Reinhardt, 2004. Acidification trends and the evolution of neutralization mechanisms through time at the Bear Brook Watershed, Maine, USA. *Water, Air, Soil, Pollution Focus* 4:289-310.
- Rosfjord, C., K. Webster, J.S. Kahl, S.A. Norton, I. Fernandez, and A. Herlihy, 2007. Anthropogenically-driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acidic deposition. *Environ Sci Technol*, 41:7688 -7693.
- Rosfjord, C., J.S. Kahl, K. Webster, S. Nelson, I. Fernandez, L. Rustad, and R. Stemberger, 2006. Acidic deposition-relevant changes in lake chemistry in the EPA Eastern Lake Survey, 1984-2004. Final report to USDA NSRC, Durham, NH. 69 p.

*Presentations using related project information (recent presentations in bold) :*

- Saros, J.E., K.E.D. Strock, S. Birkel & S.J. Nelson. 2012. Deciphering the effects of extreme hydrologic events on the response of northeastern lakes to reduced sulfur deposition. 20th annual Harold W. Borns Symposium, University of Maine.**
- Nelson, S.J., P. Vaux, M.J. James-Pirri. Data-driven assessments of National Park resources. (Invited). Acadian Internship in Regional Conservation and Stewardship, July 15, 2011.**
- Nelson, S.J., J.S. Kahl, A.J. Baumann, K.B. Johnson, 2012. “Rugged shores and clear waters”: Interpreting biogeochemical response to environmental stressors using the lakes and ponds of Maine’s Baxter State Park. Maine Water Conference, Augusta, ME, March 14, 2012.**
- Strock, K.E., J.E. Saros, S. Nelson. Why climate matters in recovery from acidification in northeastern US surface waters. Maine Water Conference, Augusta, ME, March 14, 2012.**

- Baumann, A.J., J.S. Kahl, T.R. Boucher, S.J. Nelson, and K.J. McGuire, 2012. "Changes in surface water chemistry in Maine high elevation lakes in response to the 1990 Clean Air Act Amendments. Maine Water Conference, Augusta, ME, March 14, 2012.**
- Mineau, M. M., K. S. Simon, D. T. Ely; R. L. Rancatti, I. J. Fernandez, S. A. Norton, and H. M. Valett. 2011. Effects of chronic nitrogen enrichment and acidification on coupled nitrogen and phosphorus cycling in streams: Insights from multiple spiraling techniques. Annual meeting, North American Benthological Society, Providence, RI.**
- Schneider, S.B., I.J. Fernandez, S.A. Norton, K.S. Simon. 2011. Soil base cation response to two decades of change at the Bear Brook Watershed in Maine. Gordon Conference on Catchment Science: Interactions of Hydrology, Biology and Chemistry. Bates College, Lewiston, Maine. July 10-15.**
- Nelson, S.J., C. Chen, H. Roebuck, B. Zoellick. Sensible sentinels: Preliminary mercury data for dragonfly nymphs (*Odonata: anisoptera*) across northern New England corroborate expected spatial pattern. The 10th International Conference on Mercury as a Global Pollutant (ICMGP), Halifax, NS, July 24-29, 2011; and presented at the Acadia Science Symposium, October 26, 2011.**
- Baumann, A.J., and J.S. Kahl, 2009. Assessing the effectiveness of federal acid rain policy using remote and high elevation lakes in northern New England. North American Lake Management Society International Symposium, Hartford, CT, October 29, 2009.
- Kahl, J.S., 2009. Changes in base cations related to long-term changes in Cl distribution in northeastern lakes. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.
- Kahl, J.S., 2008 (invited). Twenty year changes in spatial patterns of Cl distribution in the northeastern US. NH Water Conference, April, 2008.
- Kahl, J.S., 2007 (invited). Using societal-based incentives to address new threats to New England Lakes. Day-long short course in New England Lake Science Academy, Camp Kieve, Maine. July, 2007.
- Kahl, S., K. Webster, D. Sassan, C. Rosfjord, S. Nelson, M. Greenawalt-Yelle, 2007. Increasing Cl in northeastern surface waters: an indicator of increasing development pressure. Maine Water Conference, Augusta, ME, March 21, 2007.
- Kahl, J.S. 2006 (invited). Acid rain in New England: using high elevation lakes as sentinels of change. Maine Mountain Conference, October 21, 2006. Rangeley, Maine
- Kahl, J.S., *et al.*, 2006 (invited). The design of a national mercury monitoring network: Learning from the EPA acid rain experience. The Eighth International Mercury Conference, Madison WI, August 8, 2006.
- Kahl, J.S. *et al.*, 2006. Obfuscation of trends in base cations by regional salt contamination. Hubbard Brook Committee of Scientists annual meeting, July 12, 2006.
- Kahl, J.S., 2006 (invited). 'Natural and human-derived sources of acidity in Maine Atlantic Salmon Rivers'. Atlantic Salmon Commission workshop on acidity, Bangor ME. April 10, 2006.



- Kahl, J.S., 2005 (invited). The intersection of environmental science and environmental policy. NH Charitable Foundation Lakes Region annual meeting, Meredith, NH, September, 2005.
- Kahl, J.S., 2005 (invited). Tracking response and recovery in surface waters in the northeastern US. Annual meeting of the Ecological Society of America, Montreal, August, 2005.
- Kahl, J.S., and Catherine Rosfjord, 2005 (invited). Acid rain and the Clean Air Act in the northeastern US. Annual meeting of the NH-ME Androscoggin River Watershed Council, Bethel, June, 2005
- Kahl, J.S., 2005 (invited). Developing a lake research agenda for NH. NSF workshop on lake research infrastructure in the northeast, Colby Sawyer College, April 2005.
- Kahl, J.S., S. Nelson, and A. Grygo, 2004. Surface water chemistry data for the northeastern US for interpreting climate and acid rain trends. Northeast Ecosystems Research Consortium meeting, Durham, NH, October, 2004.
- Kahl, J.S., K. Webster, M. Diehl, and C. Rosfjord, 2004. Successes of the Clean Air Act Amendments of 1990. Maine Water Conference invited plenary talk, Augusta, ME, 2004.
- Kahl, J.S. and K. Johnson, 2004. Acid-Base Chemistry and Historical Trends in Downeast Salmon Rivers. Maine Water Conference, Augusta ME, April 2004.
- Kahl, J.S., 2004 (invited). The Clean Air Act Amendments of 1990; testing a program designed to evaluate environmental policy. Lecture, Colby College. April, 2004
- S.J. Nelson, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, W.H. Halteman, 2009. (Poster) Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting and chemical co-variates. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.
- Nelson, S.J., I. Fernandez, S. Norton, B. Wiersma, L. Rustad , J.S. Kahl, 2008. The Bear Brook Watershed in Maine: Long-term research supporting climate change inquiry. Hydroclimatic effects on ecosystem response: participant workshop, Syracuse, NY, September 19, 2008.
- Nelson, S.J., N. Kamman, D. Krabbenhoft, J.S. Kahl, K. Webster, 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: Landscape setting, chemical climate, and human influences. Northeastern Ecosystem Research Cooperative Conference, Durham, NH, November 12-13, 2008.
- Nelson, S.J. 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: landscape setting, chemical climate, and human influences. Maine Water Conference, Augusta, ME, March 19, 2008.