6-1-2011

# Water Resources Research Center Annual Technical Report FY 2010

New Hampshire Water Resources Research Center (NH WRRC)

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# Annual Technical Report
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# Introduction

The New Hampshire Water Resources Research Center (NH WRRC), located on the campus of the University of New Hampshire (UNH), is an institute that serves as a focal point for research and information on water issues in the state. The NH WRRC actually predates the Federal program. In the late 1950s Professor Gordon Byers (now retired) began a Water Center at UNH. This Center was incorporated into the Federal program in 1965 as one of the original 14 state institutes established under the Water Resource Research Act of 1964. The NH WRRC is currently directed by Dr. William McDowell with administrative and technical assistance from Associate Director Ms. Michelle Daley and Mr. Jody Potter. The NH WRRC is a standalone organization, in that it is not directly affiliated with any other administrative unit at UNH, and it reports to the Dean of the College of Life Sciences and Agriculture (COLSA). The NH WRRC has no dedicated laboratory or research space, and instead relies on space allocated for the research activities of the WRRC director by COLSA. The NH WRRC does have administrative space on campus, which houses the Associate Director, WRRC files, and short-term visiting staff and graduate students. The WRRC website (www.wrrc.unh.edu) serves as a focal point for information dissemination and includes all NH WRRC publications and results from past research, as well as links to other sites of interest to NH citizens and researchers.

# Research Program Introduction

The NH WRRC supported four research projects with its 2010 104b funding:

1. Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

2. Water Quality Change-Effects of Development in Selected Watersheds

3. Hydrologic and Isotopic Investigation of Base Flow Generation in the Headwaters Lamprey River Watershed

The Water Quality Analysis Lab (WQAL) is affiliated with the NH WRRC and facilitates water resources research through technical assistance and sample analysis. The WQAL was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH WRRC and housed in James Hall. The mission of the Water Quality Analysis Laboratory is to provide high-quality, reasonably priced analyses in support of research projects conducted by scientists and students from throughout the University, state, and nation. Past clients have included numerous research groups on the UNH campus, Federal agencies, scientists from other universities, and private firms. Many thousands of analyses are conducted each year.

# Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

## Basic Information

| | |
|---|---|
| **Title:** | Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds |
| **Project Number:** | 2003NH21B |
| **Start Date:** | 3/1/2010 |
| **End Date:** | 2/28/2011 |
| **Funding Source:** | 104B |
| **Congressional District:** | NH01 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Non Point Pollution, Surface Water, Nutrients |
| **Descriptors:** | |
| **Principal Investigators:** | William H H. McDowell |

## Publications


1. Buyofsky, L.A. 2006. Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed. M.S. Dissertation, Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH
2. Proto, Paul J. 2005, The Significance of High Flow Events in the Lamprey River Basin, New Hampshire, for Annual Elemental Export and Understanding Hydrologic Pathways. M.S. Dissertation, Department of Earth Sciences, College of Engineering and Physical Sciences, University of New Hampshire, Durham, NH, 176 pages.
3. Buyofsky, Lauren A. May 2006. Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, MS Dissertation, Department of Natural Resources, College of Life Sciences and Agriculture , University of New Hampshire, Durham, NH, .
4. Legere, K.A. September 2007. Nitrogen loading in coastal watersheds of New Hampshire: an application of the SPARROW model. Masters Thesis, University of New Hampshire, Durham, NH. 75 pages.
5. Traer, K. December 2007. Controls on denitrification in a northeastern coastal suburban riparian zone. Masters Thesis, University of New Hampshire, Durham, NH. 97 pages.
6. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
7. Daley, M.L., J.D. Potter, W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: Impacts of road salt and hydrologic variability. Journal of the North American Benthological Society, submitted.
8. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
9. Daley, M.L., J.D. Potter and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: impacts of road salt and hydrologic variability. Journal of the North American Benthological Society 28(4):929-940.

10. DiFranco, E. 2009. Spatial and temporal trends of dissolved nitrous oxide in the Lamprey River watershed and controls on the end-products of denitrification. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 108 pages.
11. Daley, M.L. and W.H. McDowell. In Preparation. Nitrogen saturation in highly retentive coastal urbanizing watersheds. Ecosystems.
12. Daley, M.L. 2009. Nitrogen Sources and Retention within the Lamprey River Watershed and Implications for Management. State of the Estuaries Conference. Somersworth, NH. October 2009.
13. Daley, M.L. 2009. Water Quality of Private Wells in Suburban NH and Impacts of Land Use. Northeast Private Well Symposium. Portland, ME. November, 2009.
14. Daley, M.L. 2009. Spatial and Temporal variability in nitrogen concentrations, export and retention in the Lamprey River watershed. Joint NH Water and Watershed Conference. Concord, NH. November, 2009.
15. Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.
16. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
17. Daley, M.L., J.D. Potter and W.H. McDowell, 2010, Nitrogen Assessment for the Lamprey River Watershed, Report prepared for the New Hampshire Department of Environmental Services. http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/unh_nitrogenassessment.pdf
18. Dunlap, K, 2010, Seasonal Nitrate Dynamics in an Agriculturally Influenced NH Headwater Stream, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 102 pages.
19. Galvin, M, 2010, Hydrologic and nutrient dynamics in an agriculturally influenced New England floodplain, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.
20. Daley, M.L., W.H. McDowell, B. Sive, and R. Talbot, In Preparation, Factors controlling atmospheric deposition at a coastal suburban site, Journal of Geophysical Research (Atmospheres).
21. Daley, M.L. and W.H. McDowell, 2010, Landscape controls on dissolved nutrients, organic matter and major ions in a suburbanizing watershed, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.
22. Davis, J.M., W.H. McDowell, J.E. Campbell and A.N. Hristov, 2010, Hydrological and biogeochemical investigation of an agricultural watershed, southeast New Hampshire, USA, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.
23. Hope, A.J. 2010. Ecosystem Processes in a Piped Stream. Plum Island Ecosystems Long Term Ecological Research All Scientists Meeting, Woods Hole, MA. April 8, 2010.
24. Hope, A.J. and W.H. McDowell, 2010, Ecosystem Processes in a Piped Stream, Aquatic Sciences: Global Changes from Center to Edge, ASLO & NABS Joint Summer Meeting, Santa Fe, NM, June 2010.

# Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

## Statement of Critical Regional or State Water Problem

New Hampshire's surface waters are a very valuable resource, contributing to the state's economic base through recreation (fishing, boating, and swimming), tourism and real estate values. Many rivers and lakes also serve as local water supplies. New Hampshire currently leads all New England states in the rate of development and redevelopment (2010 Census). The long-term impacts of population growth and the associated changes in land use to New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point source pollution to the state's surface waters (e.g. septic systems, urban runoff, stormwater, road salt application, deforestation and wetland conversion). Long-term datasets that include year-to-year variability in precipitation, weather patterns and other factors will allow adequate documentation of the cumulative effects of land use change and quantification of the effectiveness of watershed management programs.

## Statement of Results or Benefits

The proposed project will provide detailed, high-quality, long-term datasets which will allow for a better understanding of the impacts of land use change and development on surface water quality. These datasets could be used to develop, test and refine predictive models, accurately assess the impacts of watershed management practices and serve as potential early warning signs of dramatic changes to surface water quality in the region resulting from rapid development. Long-term datasets from this project will also be essential to adaptive management strategies that strive to reduce non-point sources of pollution in New Hampshire.

## Objectives of the Project

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use UNH staff, students and volunteers from local communities to collect samples from the College Brook watershed (Durham, NH), the Lamprey River watershed, and the Ossipee River watershed. Details of long-term datasets collected in each watershed are below.

### *College Brook watershed*

The College Brook watershed, which is dominated by the University of New Hampshire, receives a variety of non-point pollution from several different land uses. Dissolved organic carbon (DOC), total dissolved nitrogen (TDN), nitrate ($NO_3$-N), ammonium ($NH_4$-N), dissolved organic nitrogen (DON), orthophosphate ($PO_4$-P), chloride ($Cl^-$), sulfate ($SO_4$-S), sodium ($Na^+$), potassium ($K^+$), magnesium ($Mg^{+2}$), calcium ($Ca^{+2}$), and silica ($SiO_2$), pH and conductivity are measured to assess water quality. Currently, samples from 3 sites are collected monthly throughout the year and sampling of College Brook began in 1991. Sample collection is done by UNH staff and/or students and samples are analyzed in the Water Quality Analysis (WQAL) Lab at UNH.

***Lamprey River Hydrologic Observatory***

The Lamprey River watershed is a rural watershed located in southeastern NH and is under large development pressure as the greater area experiences the highest population growth in the state. The Lamprey River Hydrologic Observatory (LRHO) is a name given to the entire Lamprey River basin as it serves as a platform to study the hydrology and biogeochemistry of a suburban basin and is therefore used by the UNH community as a focal point for student and faculty research, teaching and outreach. Our goal for the long-term Lamprey water quality monitoring program is to document changes in water quality as the Lamprey watershed becomes increasingly more developed and to understand the controls on N transformations and losses.

The Lamprey River has been sampled weekly and during major runoff events since October 1999. Samples are analyzed for DOC, TDN, $NO_3$-N, $NH_4$-N, DON, and $PO_4$-P. Additionally, samples collected since October 2002 are also analyzed for total suspended sediment (TSS), particulate carbon (PC), particulate nitrogen (PN), dissolved inorganic carbon (DIC), $Cl^-$, $SO_4$-S, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $SiO_2$, pH, conductivity, dissolved oxygen (DO) and temperature. In January of 2004, we began routine sampling of additional Lamprey stream sites for dissolved organic matter (DOM) nitrogen, phosphorus and other parameters. During 2004 all stream sites were sampled on a weekly basis, in January 2005, the frequency of stream sampling was curtailed to monthly (instead of weekly) for most sites and three stream sites (the Lamprey River, the North River and Wednesday Hill Brook) remained at a weekly and major storm event sampling frequency. In the past year, 14 sites were included in the monthly sampling regime. All stream water samples are collected by UNH staff and/or students and analyzed by the WQAL at UNH.

From November 2003 to January 2005, bulk precipitation samples were collected on a weekly basis at numerous locations throughout the basin for analysis of nitrogen, phosphorus, DOM, major cations and anions and silica. Precipitation data from this time period indicated that rain chemistry within the Lamprey watershed does not vary spatially. Therefore since January 2005, we have collected wet-only precipitation samples from one collector in the watershed on an event to weekly basis. Several volunteers have been monitoring precipitation volume throughout the basin since October 2003 and will continue to do so as precipitation amount is spatially variable. All precipitation samples are collected by UNH staff and/or students and analyzed by the WQAL at UNH.

Quarterly ground water well samples have been collected from the James Farm and L1 well fields in Lee, New Hampshire. James Farm monthly samples were collected from January to September of 1995 and from July 2004 through December 2006. L1 monthly samples were collected from July 2004 through December 2006. Quarterly groundwater samples have been collected since January 2007 at both locations. All groundwater samples are collected by UNH staff and/or students and analyzed by the WQAL at UNH.

***Ossipee Watershed***

Volunteers of the Green Mountain Conservation Group sample streams within the Ossipee watershed of New Hampshire. Samples are collected every 2 weeks from May to November, and monthly during the winter months. Water chemistry (DOC, TDN, $NO_3$-N, $NH_4$-N, DON, $PO_4$-P, $Cl^-$, $SO_4$-S, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $SiO_2$) is measured on a sub-set of the samples by the NH WRRC and WQAL. WRRC staff will assist in data interpretation.

**Methods, Procedures and Facilities**

The Water Quality Analysis Laboratory (WQAL) was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH Water Resources Research Center and housed in James Hall. Dr. William McDowell is the Laboratory Director and Jody Potter is the Laboratory Manager. Together, they have over 40 years of experience in water quality analysis, and have numerous publications in the fields of water quality, biogeochemistry, and aquatic ecology.

Samples for this project are collected at intervals described above. Samples are filtered in the field using pre-combusted glass fiber filters (0.7 µm pore size), and frozen until analysis. All samples are analyzed in the WQAL of the WRRC on the campus of UNH, Durham, NH. Methods for analyses include ion chromatography ($Cl^-$, $NO_3^-$, $SO_4^{-2}$ and $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$), discrete colorimetric analysis ($NH_4$, $PO_4$, $NO_3/NO_2$), and High Temperature Oxidation (DOC, TDN). All methods are widely accepted techniques for analysis of each analyte.

**Principal Findings and Significance**

***College Brook watershed***

Monthly samples collected at 3 stations on College Brook and 1 station on Pettee Brook which also drains the UNH campus have been analyzed through 2010. We are now in the process of collecting and analyzing 2011 samples and updating our website: http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

Recent data show that DO is lowest at the upstream stations where it does drop below 5 mg/L (level that is necessary to support in-stream biota) during the summer months. The downstream stations do not drop below 5 mg/L and this difference is due to the hydrologic and biogeochemical properties of the upstream sampling location which has slow stream flow, high dissolved organic matter content and resembles a wetland. DO increases downstream as flow becomes faster and the stream is re-aerated. It is highly unlikely that historical incinerator operations are impacting present day DO levels in this brook as they have in the past.

Data from 2000 until now indicate that the steam is strongly impacted by road salt application at its origin, which is essentially a road-side ditch along the state highway leading to a wetland area, and by road salt applied by UNH and the town of Durham which drains to the middle and lower reaches of the brook. Average sodium and chloride concentrations, as well as specific conductance, appear to have remained reasonably constant since 2001, but are much higher than in 1991 (Daley et al. 2009). Concentrations are highest at the upstream stations and tend to decline downstream as the stream flows through the campus athletic fields and then increase as the stream passes through the heart of campus and downtown Durham. Concentrations are also highest during years of low flow.

College Brook has noticeably higher nitrogen concentrations than many other local streams draining less developed or undeveloped watersheds. As College Brook flows from upstream to downstream where it becomes more aerated, ammonium decreases and nitrate increases indicating that nitrification is occurring in the stream channel. However, an increase in dissolved inorganic nitrogen (DIN; the sum of ammonium and nitrate) and total nitrogen indicates that there are additional sources of nitrogen to the stream as it flows though UNH and Durham. This is possibly from fertilization of the athletic fields and/or storm water runoff. There also appears to be a slight, but insignificant, increase in nitrate over time. This will need to be closely monitored as managers strive to reduce the nitrogen loading to Great Bay and Little Bay. Great Bay and Little Bay are "impaired" by elevated nitrogen and nitrogen (especially in the form of nitrate) exported from College Brook and into Little Bay is cause for concern.

***Lamprey River Hydrologic Observatory***

Analysis of weekly samples collected from the Lamprey River at the USGS gauging station in Durham, NH (referred to as "L73"), the North River at the former USGS gauging station in Epping, NH (N27) and a small tributary to the Lamprey River in Lee, NH (W01) and monthly samples collected at 13 other stations throughout the watershed through 2010 has been completed and we are in the process of updating the LRHO website (http://www.wrrc.unh.edu/lrho/index.htm). The USGS discontinued the operation of the North River gauging station in October 2006 and since then we have been recording weekly stage height and calculating flow based on the USGS rating curve. We are able to record stream flow at W01 using an electronic distance meter in combination with a rating curve that we have developed for this site. We have also developed a stream flow model for W01 where daily discharge can be estimated from meteorological measurements (such as precipitation and temperature) and this model is useful for estimating historic flows. Weekly precipitation samples at Thompson Farm (UNH property located in Durham, NH) were collected to document nitrogen inputs to the basin.

Results of stream chemistry to date show a significant increase in nitrate concentrations over time (Water Years (WY) 2000-2010) in the Lamprey River (Figure 1) and no change in nitrate concentrations in the North River or Wednesday Hill Brook over a shorter time period (2004-2010). We have shown previously that stream water nitrate is related to watershed population density (Daley 2002) and since suburbanization continues to occur throughout the greater Lamprey River watershed, population growth is likely responsible for the increase in stream water nitrate. Wednesday Hill Brook watershed is near its development capacity, unless the Town of Lee, NH changes its zoning regulations, and the lack of increase in W01 nitrate may be due to the limited population growth in this watershed, that this watershed has reached nitrogen saturation or that the relatively short period of data collection is not reflective of long-term trends. The long-term increase in nitrate in the Lamprey River has significant impacts for the downstream receiving water body, the Great Bay estuarine system. Great Bay is currently impaired by elevated nitrogen and is experiencing dangerously low dissolved oxygen levels and a significant loss of eelgrass which provides important habitat for aquatic life. The Lamprey River is the largest tributary to Great Bay, and thus the long-term data provided by the NH WRRC from the LRHO are of considerable interest for watershed management.

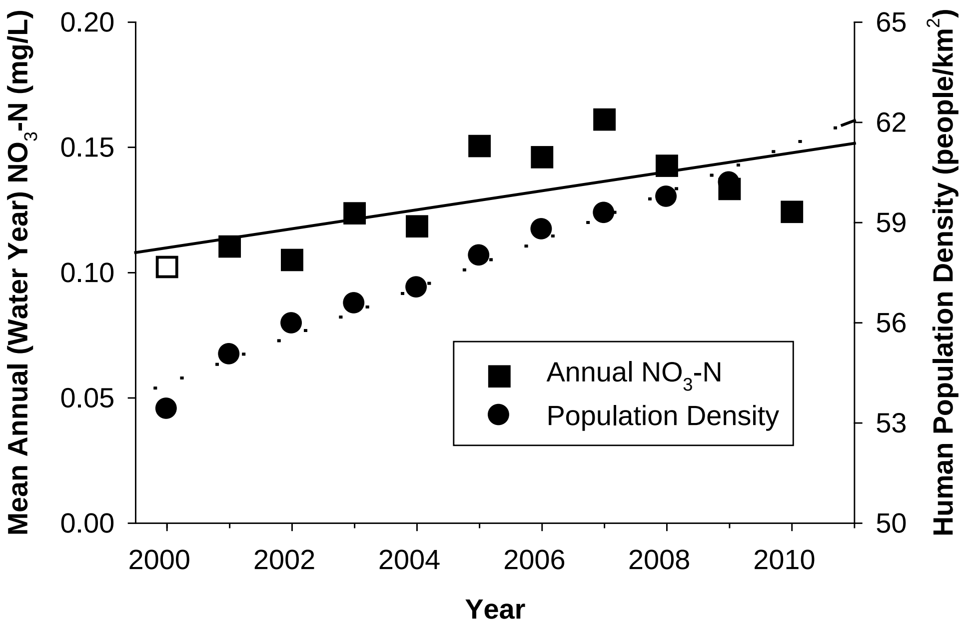


Figure 1. Annual (water year) nitrate concentration and estimated annual human population density over time in the Lamprey River basin. We have applied the Seasonal–Kendall Test (SKT; seasons set to 52) to weekly data from September 1999 through September 2009 and flow-adjusted nitrate concentrations have increased significantly over this time period (SKT t = 0.28, $p < 0.01$). The trend through mean annual concentrations and human population density is shown.

When we combine our specific conductance data (2002 – 2010) with data collected by the USGS (1978 - 1999), we see a long-term increase in specific conductance in the Lamprey River (Figure 2). Sodium and chloride concentrations are directly related to specific conductance ($r^2 = 0.95$, $p<0.01$ for $Na^+$; $r^2 = 0.93$, $p < 0.01$ for $Cl^-$) and we conclude that this increase in specific conductance indicates a corresponding increase in NaCl. Sine $Na^+$ and $Cl^-$ are strongly correlated with impervious surfaces in southeast NH (Figure 3) and road pavement among southeastern and central NH basins. We conclude that the associated road salt application to these surfaces is responsible for these spatial and temporal changes in streamwater NaCl.

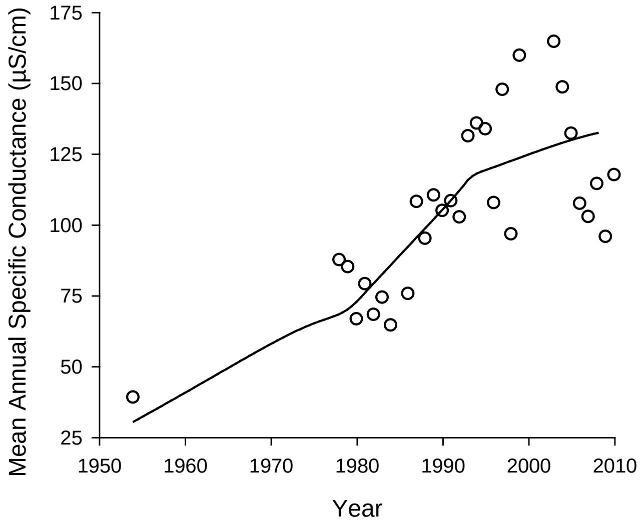


Figure 2. Mean annual specific conductance in the Lamprey River at the USGS gauging station in Durham, NH. (modified from Daley et al. 2009).

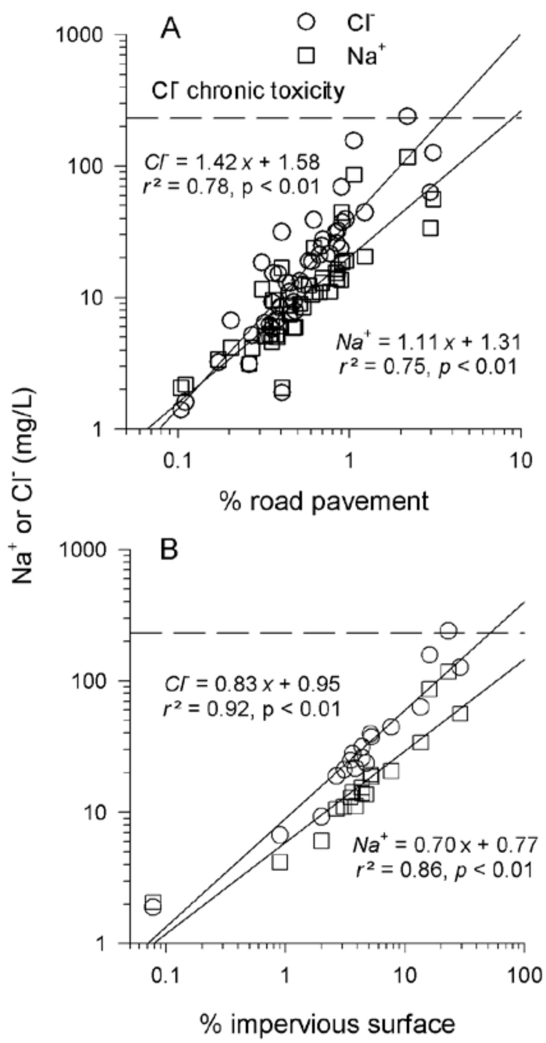


Figure 3. Relationship between both average concentrations of $Na^+$ (squares) and $Cl^-$ (circles) and a.) % road pavement (College Brook, Lamprey and Ossipee sub-basins) and b.) % impervious surfaces (College Brook and Lamprey sub-basins only) (Daley et al. 2009).

Results of precipitation monitoring show that wet deposition and estimated dry deposition together account for more than half of the N input to the Lamprey watershed and that wet deposition chemistry can be linked to airmass chemistry. DOC and TDN in precipitation are related to biogenic airmass sources, $NH_4$-N, $NO_3$-N and $SO_4$-S are related to urban/industrial airmasses and Na and Cl are weakly related to ocean aerosols.

James Farm ground water nitrate concentrations have shown conflicting patterns over the past ten years. There has been no change in nitrate concentrations among 4 wells, nitrate has increased in two wells and decreased in one well. L1 ground water nitrate concentrations have remained constant or decreased slightly with the exception of one well (L1A-21) where nitrate has ranged from <0.2 to 3.0 mg N/L. Decreased concentrations in recent years may reflect dilution by two 100 flood events in 2006 and 2007. James Farm and L1 ground water data demonstrates higher $NO_3^-$ concentrations with low dissolved organic carbon (DOC) concentrations as well as low $NO_3^-$ concentrations with high DOC concentrations, which suggests possible denitrification influencing ground water $NO_3^-$ concentrations.

Results from long-term water quality monitoring in the LHRO have helped leverage funding for additional research on nitrogen cycling in NH's suburbanizing watersheds. Because of the significant interest in nitrogen loading to Great Bay, existing information on the spatial and temporal variability of nitrogen concentrations in the LRHO that are driven by population growth and land use change and the relationships that the NH WRRC has formed with various stakeholders in NH, the NH WRRC faculty and staff received a grant from NOAA and the National Estuarine Research Reserve System (NERRS). The grant is a collaborative science project to study nitrogen sources and transport pathways in watersheds of the Great Bay estuarine system. The project involves a significant amount of integration and collaboration with local stakeholders throughout the entire research process to ensure that the scientific results will be useful to local managers and decision makers.

***Ossipee Watershed***

Collaboration with the Green Mountain Conservation Group (GMCG) and their sampling of the Ossipee River watershed provides much benefit to the NH WRRC and the long-term monitoring of rapidly developing suburban watersheds. Volunteers sampled streams within the watershed every 2 weeks from April through October, and monthly winter sampling was conducted by GMCG staff at 7 sites. Over 100 samples were collected for analysis in the WQAL and additional field data was collected at a total of 45 sites throughout 6 towns using the help of many volunteers. Many presentations were made to planning boards, conservation commissions and other local government groups (see Information Transfer section below). Data have been used to heighten awareness of the impacts of excessive road salting and snow dumping in local streams. The impact of road salting in this central NH watershed is similar to what we see in coastal NH (Figure 3a). Communication with local road agents has led to the remediation in one development where road salting was an issue. Samples collected and data generated from this funding have shown an improvement in water chemistry following reduced salting and snow dumping. Data have also been useful in promoting low impact development techniques and best management practices where new development has been proposed in proximity to rivers and streams within the watershed.

**Number of students supported:**

Five Master's students (Kate Dunlap, Michelle Galvin, Amanda Hope, Lucy Parham and Jason Bailio) and 3 undergraduate hourly employees (Althea Marks, Daniella Williams, Sarah Brown and Taylor Langkau) and one post-undergraduate/pre-graduate school volunteer (Jess Stevenson).

**Publications:**

Daley, M.L. and W.H. McDowell, *In Preparation*, Nitrogen saturation in highly retentive coastal urbanizing watersheds, Ecosystems.

Daley, M.L., J.D. Potter and W.H. McDowell, 2009, Salinization of urbanizing New Hampshire streams and groundwater: impacts of road salt and hydrologic variability, Journal of the North American Benthological Society, 28(4), 929–940.

Daley, M.L., J.D. Potter and W.H. McDowell, 2010, Nitrogen Assessment for the Lamprey River Watershed, Report prepared for the New Hampshire Department of Environmental Services. http://des.nh.gov/organization/divisions/water/wmb/coastal/documents/unh_nitrogenassessment.pdf

Dunlap, K, 2010, Seasonal Nitrate Dynamics in an Agriculturally Influenced NH Headwater Stream, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 102 pages.

Galvin, M, 2010, Hydrologic and nutrient dynamics in an agriculturally influenced New England floodplain, M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 94 pages.

Daley, M.L., W.H. McDowell, B. Sive, and R. Talbot, *In Preparation*, Factors controlling atmospheric deposition at a coastal suburban site, Journal of Geophysical Research (Atmospheres).

**Conference Proceedings & Abstracts:**

Daley, M.L. and W.H. McDowell, 2010, Landscape controls on dissolved nutrients, organic matter and major ions in a suburbanizing watershed, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.

Davis, J.M., W.H. McDowell, J.E. Campbell and A.N. Hristov, 2010, Hydrological and biogeochemical investigation of an agricultural watershed, southeast New Hampshire, USA, American Geophysical Union Fall Conference, San Francisco, CA, December, 2010.

Hope, A.J. 2010. Ecosystem Processes in a Piped Stream. Plum Island Ecosystems Long Term Ecological Research All Scientists Meeting, Woods Hole, MA. April 8, 2010.

Hope, A.J. and W.H. McDowell, 2010, Ecosystem Processes in a Piped Stream, Aquatic Sciences: Global Changes from Center to Edge, ASLO & NABS Joint Summer Meeting, Santa Fe, NM, June 2010.

**Information Transfer:**

Bucci, J., McDowell, W.H., Daley, M.L., Potter, J.D., Hobbie, E., French, C. and Miller, C. 2011. Detecting nitrogen sources and flow paths in the Great Bay watershed and engaging decision makers in the Science. Annual Lamprey River Science Symposium. Durham, NH. January 2011.

Daley, M.L. 2010. Current Water Quality Research in the Lamprey River Watershed: Nitrogen and Chloride. Lamprey River Advisory Committee. Durham, NH. January 2010.

Daley, M.L. 2010. Current Water Quality Research in the Lamprey River Watershed: Nitrogen and Chloride. Town of Newmarket, NH. January 2010.

Daley, M.L. 2010. Road Salt Impacts to New Hampshire Streams and Groundwater. “The Road Less Salted” Water Quality & Salt Reduction Seminar. Greenland, NH. May 2010.

Daley, M.L. 2010 Shared slides on nitrogen cycling from the Lamprey River watershed with Ted Diers for a presentation on nitrogen in the Great Bay watershed given by NH DES. May 2010.

Daley, M.L. 2010. Water Quality in the Suburbanizing Lamprey River Basin. University of New Hampshire Inventory and Monitoring of Ecological Communities class. Durham, NH. September 2010.

Daley, M.L. 2010. Suburbanizing NH watersheds and N Saturation. University of New Hampshire Watershed Water Quality Management class. Durham, NH. November 2010.

Daley, M.L. 2011. Testified in support of nominating the remaining segments of the Lamprey River and its major tributaries into the State Rivers Management Protection Program. NH House of Representatives Resources, Recreation & Development Committee Public Hearing. Concord, NH. January 2011.

Daley, M.L. and McDowell, W.H. 2011. Declining nitrogen retention with increasing nitrogen inputs in the Lamprey and Oyster River watersheds. Annual Lamprey River Science Symposium. Durham, NH. January 2011.

Hope, A.J. 2009. Proposed Research on Pettee Brook (a Piped Stream). ORWA Water Testing Committee. US Forest Service, Durham NH, September 2009.

Hope, A.J. 2010. Ecosystem Processes in Pettee Brook (a Piped Stream). Oyster River Watershed Association (ORWA) Water Testing Committee. US Forest Service, Durham NH, October 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Plymouth State University, April 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Duke University, April 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Yale University, April 2010.

McDowell, W.H. 2010. Nitrogen Impairment in a Suburban Basin: Can We Engineer a Solution? University of New Hampshire, September 2010.

McDowell, W.H. 2010. Nitrogen Impairment in a suburban Basin: Can we engineer a solution? University of Connecticut, January 2011.

McDowell, W.H. and Daley, M.L. 2011. Long-term water quality trends in the Lamprey River. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

**Press Releases**

Daley, M.L. 2010. "Scientists say time to cut nitrogen in estuary is now" by Aaron Sanborn asanborn@seacoastonline.com in http://www.seacoastonline.com/ May 12, 2011.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen research at the NH Water Resources Research Center as it relates to the nitrogen impairment of Great Bay. Lee, NH Town Crier. January 2011.

McDowell, W.H. 2010. "$600K grant helps study nitrogen in estuary, bay" By Dave Choate dchoate@seacoastonline.com in http://www.seacoastonline.com/ December 04, 2010.

McDowell, W.H. 2010. "Grant will seek pollution source in NH's Great Bay" by Associated Press in http://www.bostonherald.com December 6, 2010.

McDowell, W.H. 2010. "UNH's grant money may be a 'saving grace' for Great Bay" by Kristen Phelps in The New Hampshire (UNH newspaper) December 6, 2010.

McDowell, W.H. 2010. "New grant to address Great Bay's pollution 'hot spots'" on http://www.fosters.com/ December 6, 2010.

**Presentations made by the Green Mountain Conservation Group staff March 2010 - February 2011.**

March 12th Ossipee Aquifer Steering Committee Meeting
April 9th Ossipee Aquifer Steering Committee Meeting
April 10th WQM Volunteer Training
May 11th Ossipee Central School water testing program
May 12th Tamworth Brett School water testing program
May 13th Road Salt & Water Quality Regional Workshop
May 13th Pequawket Foundation WQM presentation
May 14th Ossipee Aquifer Steering Committee Meeting
May 14th Effingham Planning Board Presentation
May 15th VLAP Training
June 1st Ossipee Central School GET WET! & water quality presentation
June 1st, 2nd & 3rd Duncan Lake BMP Project
June 4th WQM Intern Lake Hosting Training
June 8th Mustang Academy Madison WQM RIVERS program
June 9th Camp Director Meeting & Presentation
June 11th Ossipee Aquifer Steering Committee Meeting – Work Session
June 16th Drive Time Radio Program WQM
June 18th MWV Chamber After Hours Program
June 25th NH Lakes Congress Conference
July 7, 8, 21, 22 Volunteer Lake Assessment Program & WQ Programs with Camps Cody, Huckins, Robin Hood, Marist & Danforth Bay
July 6, 20, Aug. 3 WQ Programs/Ossipee Lake & Tributary testing with Camp Calumet
July ?? Madison Library Kids Program on Macroinvertebrates
July 9th Ossipee Aquifer Steering Committee Meeting
August 7 Household Hazardous Waste Day WQ Table in Ossipee
August 10 VLAP & WQM Presentation with NH DES in Ossipee
August 13th Ossipee Aquifer Steering Committee Meeting
August 25 VBAP, Trout in the Classroom & WQM Volunteer Training
Sept. 16th Ossipee Aquifer Steering Committee Meeting
Sept 7-17 VBAP Programs & WQM daily with Ossipee Central School, Effingham Elementary, The Community School, Tamworth Learning Circles, Sandwich Elementary School & Tamworth Brett School
Oct. 22nd Ossipee Aquifer Steering Committee Meeting
October 29th Regional Road Salt Reduction Workshop with UNH T2 in Chocorua
November 12th Ossipee Aquifer Steering Committee Meeting
November 18th Student WQM Presentation in Tamworth of VBAP & WQ
December 7th Regional Groundwater Protection Workshop
January 14, 2011 Ossipee Aquifer Steering Committee Meeting
February 11, 2011 Ossipee Aquifer Steering Committee Meeting

January 8th 2010 Ossipee Aquifer Steering Committee Meeting
January 23rd 2011 Annual Meeting with WQ presentation in Freedom
February 8th 2011 Kingswood Fair for Youth Coalition for Clean Water
February 11th 2011 Ossipee Aquifer Steering Committee Meeting
February 15th Trout Unlimited & WQM Program Tamworth
February 16th Drive Time Radio Program
February 17th GET WET! & WQM Training Madison

# Water Quality Change-Effects of Development in Selected Watersheds

## Basic Information

| | |
|---|---|
| **Title:** | Water Quality Change-Effects of Development in Selected Watersheds |
| **Project Number:** | 2006NH60B |
| **Start Date:** | 3/1/2010 |
| **End Date:** | 2/28/2011 |
| **Funding Source:** | 104B |
| **Congressional District:** | NH01 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Non Point Pollution, Nutrients, Surface Water |
| **Descriptors:** | |
| **Principal Investigators:** | Jeffrey Schloss |

## Publications


1. Baumann, A.J. and J.S. Kahl. 2007. Chemical trends in Maine High Elevation Lakes. LakeLine 27:30-34.
2. 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.
3. 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.
4. Craycraft, R. and J.A.Schloss, 2009. New Hampshire Lakes Lay Monitoring Program Yearly Report 2008. 28 individual lake reports 18 to 160 pages each. University of New Hampshire Center for Freshwater Biology. Durham, NH.
5. Craycraft, R. and J.A.Schloss, 2009. Newfound Watershed Assessment Project 2007 and 2008. Special report in fulfillment for the NH DES 319 Watershed Assistance Grant. University of New Hampshire Center for Freshwater Biology. Durham, NH. 170 pages (report 83pp, appendices 87pp).
6. Wilderman, Susan E. 2009. Contributions of Groundwater Seepage to the Water and Nutrient Budget of Mendums Pond Barrington, New Hampshire. MS Thesis. University of New Hampshire. Durham, NH. May 2009.
7. Craycraft, R. and J.A.Schloss, 2010, New Hampshire Lakes Lay Monitoring Program Yearly Report 2009, 27 individual lake reports 18 to 160 pages each, UNH Center for Freshwater Biology, University of NH, Durham, NH.
8. Harvey, Rebecca, 2010, Pharmaceuticals and Personal Care Products in the Environment, Masers Thesis, Plymouth State University, Plymouth NH, 93pp.
9. Harvey, R, 2010, Pharmaceuticals and Personal Care Products in the Environment, Fact Sheet, Squam Lakes Association, Holderness, NH, 4pp.

**Effects of Development on Nutrient Loading**
**Final Report: covering March 1, 2010 through February 28, 2011**
**Project Director: Jeffrey A. Schloss**

Statement of Regional or State Water Problem-

The waters of New Hampshire represent a valuable water resource contributing to the state's economic base through recreation, tourism, and real estate revenues. Some lakes and rivers serve as current or potential water supplies. For most residents (as indicated by boating and fishing registrations, shoreline re-development) our waters help to insure a high quality of life. As documented in the 2000 Census, New Hampshire currently leads all of the New England states in the rate of new development and redevelopment. The long-term consequences of the resulting pressure and demands on the state’s precious water resources remain unknown. Of particular concern is the response of our waters to increasing non-point source pollutant loadings due to watershed development and land use activities. While many states are struggling to address surface waters that have been classified as “impaired waters” as a result of the EPA mandated 303d listing, New Hampshire has only a few 303d listed waters and stakeholders are more concerned with developing anti-degradation laws and policies to protect existing outstanding waters. To facilitate this, the relationships between land use, nutrient loading and lake nutrient response need to be established for these important watersheds of concern to allow for informed local decision-making.

Objectives:

1. To continue collection and analysis of long-term water quality data in selected watersheds with extended emphasis for the Newfound Lake, Acton-Wakefield and Winnipesaukee watersheds where current outreach work includes encouraging local decision-making to support anti-degradation practices.
2. To assist state agencies and communities in setting Total Phosphorous concentration targets as part of their lake watershed management plans
3. To disseminate results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
4. To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
5. To further document the changing water quality in a variety of watersheds throughout the state in the face of land use changes and best management efforts.
6. To determine next steps for further analysis of long-term data sets and GIS spatial data on land cover.

Methods:

A few weeks following the ice-out in the spring of 2010, a cooperative single-day synoptic sampling for total phosphorus at the various major basins of Lake Winnipesaukee was initiated by UNH, the NH Department of Environmental Services and the Lake Winnipesaukee Association. Sampling was done at the time following mixis but at selected sites, samples were taken about 1 meter from the bottom. Results were used to provide additional data for decision-making and calibration for the STEPL water quality model being used by the Lakes Region Planning Commission for the Towns of Meredith, Laconia and Guilford.

Emphasis on Lakes Lay Monitoring Program efforts was on expanding shallow water monitoring sampling to try to detect septic leachate influences and impervious runoff . Lake and stream monitoring through the LLMP generally involved a minimum of monthly sampling starting at spring runoff through to lake stratification and weekly to bi-weekly sampling through to fall mixing. Water clarity (secchi disk), chlorophyll a, acid neutralizing capacity, dissolved organic color, dissolved oxygen and nutrients (total N, total P and nitrate) were the default suite of parameters measured for lakes while nutrients, turbidity, dissolved organic color and flow were the parameters of choice for the lake tributary work. On occasion, student field teams traveled to join the volunteer monitors to perform quality assurance checks and do more in-depth analysis and lake profiling at the deepest sites which included temperature-oxygen-ph-specific-conductivity-ORP-chlorophyll a phycocyanin and turbidity profiles with depth. Detailed methods can be found in the Quality Assurance Project Plans cited in the publications section of this report.

<u>Major Findings and Significance</u>:

**Winnipesaukee**: The spatial pattern of nutrient concentrations (as measured by total phosphorus) on Lake Winnipesaukee was influenced by the local morphometry and development/ impervious cover extent; Those areas with more embayed and lower volumes of water, with greater shore-land and concentrated development, exhibited greater nutrient concentrations. Spring TP values for most areas of the lake remained within the levels indicative of pristine, low productivity waters. While this result was expected as it has been suggested by our long-term monitoring of selected sites of the lake, this was the first time a synoptic study allowed for samples taken at the same time and at a greater number of stations within the lake. This information was instrumental in not only testing the calibration of the modified STEPL nutrient loading model and the combined lake response predictive model (the latter as used and modified for this study in previous years 2008-2010) but served to further inform the stakeholders of the Towns of Meredith, Guilford and Laconia and supported their decision to move towards protecting their local areas with anti-degradation practices and policies.

**Newfound:** Lower order stream sampling in 2010 indicated the potential for development in upper areas of the watershed could have impacts downstream. While total phosphorus concentrations in undeveloped subwatersheds were typically very low and near or at the level of our detection, time integrated monitoring of periphyton samplers fitted with temperature and light loggers were able to detect even relatively low density development increased stream productivity. These results were a proof of concept on how even pristine subwatersheds may be monitored for increasing nutrient loading.

**Additional Findings 2010 LLMP**: The work by our volunteers continued to add to our long-term database which combined with our GIS watershed database will allow for a better understanding of how patterns of development and hydrological connectedness influence nutrient loading to our surface waters which is the planned focus of future NIWR support..

**Updated Findings from previous (2009) NIWR Supported Projects (Effects of Development on Nutrient Loading: Influence of Septic Systems and Boron as a Septic Source Tracer):**
Boron has a high potential for use in NH watersheds as a tracer for septic system influence (as well as sewage treatment outflows) but both ambient and septic/sewage influenced Boron levels are at concentrations too low to produce consistent results for Boron isotope analysis. However, as the concentration differences between control samples (lakewater/riverwater) and impacted site samples were at least on a range of 1 to 2 orders of magnitude. Lake sites suspected of being influenced by old/failing septic system had Boron concentrations at least twice that of control samples and were often at least 1 order of magnitude greater. Other metals and specific ions that were elevated in the septic system and sewage plant effluent included (with order of magnitude): Li, Mg, K, Ca, TDN (1 order); Na, Sr (2 orders); Cl, $NH_4$, ortho-$P0_4$, TP (3 orders). As lake water samples tended to have lower concentrations of most constituents measured, the highest probability of the use of any of these markers would be lakes with moderate to significant septic failures. Tryclosan, a common indicator for detergents and antiseptics were also assessed through ELISA techniques. Concentrations of this marker were found to be the highest in the septic system junction box (2.5-2.7 ppb) which was two to three orders of magnitude greater than lake and river water controls. The treatment plant effluent samples were generally one to two orders of magnitude greater. All of the below sewage treatment plant water samples indicated that all concentrations were diluted sufficiently a small distance downriver so any impacts from these substances would be very local to the outflow. PCPP study (see below) indicated that although some concentrations from the wastewater effluent were found in levels in the range that chronic effects may occur, they also get diluted quickly after introduction.

As an offshoot of this study a graduate student from Plymouth State University was supported through NIWR funding to explore additional potential indicators of septic and wastewater pollution. She developed a modified solid phase extraction HPLC/MS method for the analysis of four pharmaceutical and personal care compounds and conducted a pilot survey for these compounds at locations in Squam Lake (lake sites and a septic system), and above, below and the outflow of two waste water treatment plants in the Merrimack River Watershed. The abstract of this work is reproduced below to summarize this work. Additional details can be found in the actual Master's Thesis (Harvey 2010) cited elsewhere in this report:

*Pharmaceuticals and personal care products (PPCPs) are a class of emerging contaminants that include, but are not limited to, prescription and non-prescription drugs, perfumes, detergents and soaps, body lotions and sun block. PPCPs reach the environment primarily through two routes, the release of treated waste via wastewater treatment plants' effluent stream and through agricultural run-off. Since the 1980s, PPCPs have been recognized as having the potential to cause adverse effects in the environment and are identified by the US EPA as potentially hazardous* *compounds, even at low parts-per-billion or parts-per trillion concentrations. Among other effects, studies have linked PPCPs to antibiotic resistance in bacteria and viruses and to the feminization of certain fish species. Unfortunately there is a significant limit in the peer reviewed literature on both the occurrence of these compounds and their effects in the environment.*

*One reason for this information gap is the lack of analytical equipment/protocols with sensitivities low enough to detect these compounds at their environmental concentrations. The purpose of this study was to establish a reliable method to detect four PPCPs in aquatic samples within the state of New Hampshire, and to pilot test the method on environmental samples from rivers, lakes and private septic systems in Central New Hampshire.*

*The method this study adapted was originally established by the US Geological Survey's (USGS) National Water Quality Lab in Denver, CO. It uses solid phase extraction (SPE) and high performance liquid chromatography coupled with mass spectroscopy (HPLC/MS) to identify and quantitatively measure 14 different PPCPs. Generally, SPE separates compound targets from the sample of water, while HPLC separates the target compounds from each other and MS produces a signal from each compound that is proportional to its concentration. This study adapted the USGS method to use methanol instead of acetonitrile as the HPLC mobile phase and limited the detection to four PPCPs, each from different therapeutic drug classes: acetaminophen (a common analgesic), caffeine (a stimulant), carbamazepine (an anti-epileptic, mood stabilizer) and trimethoprim (an antibiotic).*

*As a result of these adaptations, many instrumental parameters were optimized for instrument sensitivity. The adapted method has interim reporting levels ranging between 8 and 100 ng/L for the targeted compounds while the USGS reports detection limits of 25 ng/L to 40 ng/L for these compounds. The adapted method demonstrates fair accuracy; mean percent recovery of compounds in reagent-free water was within 20% of the true value, while fortified environmental samples had mean percent recoveries within 35% of the true value. A standard operating procedure for this method was written and is on-file with the NH Department of Environmental Services.*

*A pilot study used this adapted method to document the occurrence of these four compounds in water resources in Central New Hampshire, US. A total of 16 samples were collected: 6 lake samples were collected along with 7 river samples, 2 samples from wastewater treatment plants' wastewater effluent stream and 1 from the distribution box of a private septic system. None of the compounds were detected in any of the lake samples. One river sample had 79 ng/L caffeine. One wastewater treatment plant was found to have acetaminophen (720 ng/L), caffeine (1200 ng/L) and carbamazepine (280 ng/L) while the other was found to have only carbamazepine (330 ng/L). The private septic system's distribution box was found to have >2,000ng/L of both acetaminophen and caffeine. The most commonly occurring PPCP was caffeine (three occurrences: 19%), followed by carbamazepine and acetaminophen (two occurrences each: 12.5%), trimethoprim was not detected in any of the 16 samples collected.*

**Publications, Presentations, Awards:**

Reports:

Craycraft, R. and J.A.Schloss, 2010, New Hampshire Lakes Lay Monitoring Program Yearly Report 2009, 27 individual lake reports 18 to 160 pages each, UNH Center for Freshwater Biology, University of NH, Durham, NH.

Peer Reviewed Reports:

Craycraft, R. and J.A.Schloss, 2010, Newfound Lake Watershed Assessment Project Quality Assurance Project Plan Amendment Sampling Program, UNH Center for Freshwater Biology, University of NH, Durham, NH. 20pp. (approved 3/8/2010)

Craycraft, R. and J.A.Schloss, 2010, Acton/Wakefield Watershed Alliance Quality Assurance Project Plan Amendment, UNH Center for Freshwater Biology, University of NH, Durham, NH, 77pp. (approved 3/10/2010)

Craycraft, R. and J.A.Schloss, 2010, Newfound Lake Culvert Assessment and Site Specific Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 16pp. (approved 8/18/2010)

Craycraft, R. and J.A.Schloss, 2010, New Hampshire Center for Freshwater Biology and Lakes Lay Monitoring Programmatic Quality Assurance Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 80pp. (approved 10/20/2010)

Craycraft, R. and J.A.Schloss, 2010, Mirror Lake Water Quality Site Specific Project Plan, UNH Center for Freshwater Biology, University of NH, Durham, NH, 14pp. (approved 11/9/2010)

Thesis:

Harvey, Rebecca, 2010, Pharmaceuticals and Personal Care Products in the Environment, Masers Thesis, Plymouth State University, Plymouth NH, 93pp.

Outreach Materials:

Harvey, R, 2010, Pharmaceuticals and Personal Care Products in the Environment, Fact Sheet, Squam Lakes Association, Holderness, NH, 4pp.

Presentations:

April 17, 2010. Global Awareness Local Action earth day event held at the Carpenter School gymnasium in Wolfeboro. Topic: Lake Water Quality Monitoring in NH.

May 19, 2010. Angle Pond Association Annual Meeting (Sandown): A Lake is a reflection of Its Watershed (for the UNH Speakers Bureau).

June 25, 2010. New Hampshire Lakes Association NH Lakes Congress (Holderness). Craycraft: Lake sampling- provided an overview of common lake sampling measurements and rationale; Schloss- presentation on the science behind the Comprehensive Shoreland Protection Act and a presentation- Over 30 Years of Research on Squam Lake: What have we learned?

June 26, 2010. Naturally Newfound Fair (Alexandria) -- discussed Newfound Watershed water quality sampling results with interested residents, recruited potential volunteers.

July 3, 2010- Goose Pond Association Annual Meeting (Enfield): Landscaping at the Water's Edge: reigning in storm runoff.

July 10, 2010. Laural Lake Association Annual Meeting Lake friendly landscaping presentation.

July 17, 2010. Attended Lake Wentworth Foundation Business Meeting (Wolfeboro) to answer questions related to water quality assessment as part of a proposed WMP 319 Grant Application

July 19, 2010. Pond ecology presentation at Shannon Pond (sponsored by Castle in the Clouds, Moultonboro)) as part of their weekly summer "walks and talks" series.

July 2010. Pharmaceuticals and Personal Care Products in New Hampshire Waters. Pakistani Educational Leaders Institute Conference, Plymouth State University, Plymouth NH. Presented by Rebecca Harvey.

August 13, 2010. Moose Mountain Regional Greenway: Water quality talk during the Woods, Water and Wildlife Festival -- discussed potential for water quality impacts in Salmon Falls Watershed and actions local residents can take to minimize impacts.

August 14, 2010. Half Moon Pond Association (Alton)- Landscaping at the Water's Edge.

September 26, 2010. Lake Winnipesaukee talk on the Winnipesaukee Belle sponsored by the Moose Mountain Regional Greenway. Discussed water quality, threats and lake friendly practices for watershed residents.

October 10, 2010. Pharmaceuticals and Personal Care Products in the New Hampshire Environment. Northeastern Ecosystem Research Collaborative Conference. Sarasota Springs, New York. Presenter: Rebecca Harvey.

February 26, 2011. Newfound Lakes Region Association Winterfest (February 2011) - Discussed Newfound Watershed water quality and viewed potential threats (i.e. sanding of gravel roads, steep sloped terrain, etc) while outdoors.

Ongoing monthly meetings with Lake Winnipesaukee Watershed Project Steering Committee concerning P modeling for local decision-makers to set target lake P concentrations (Meredith, Guilford and Laconia).

Ongoing monthly meetings for Lake Wentworth 319 Grant project planning.

**Number of students supported:**

Directly: (partial wage/salary funding)
Graduate:

| | | |
|---|---|---|
| Jeff Schloss | PhD | Natural Resources and Earth Systems Science |
| Rebecca Harvey | MS | Environmental Science and Policy (Plymouth State) <br> Graduated: May 2010 |

Undergraduate:

| | | |
|---|---|---|
| Emma Leslie | BS | Zoology |

Indirectly (supplies and support to LLMP project)
Undergraduate:

| | | |
|---|---|---|
| Gabrielle Hodgman | BS | Biology (General)* |
| Lejla Kadic | BS | Biology (pre-med)* |
| Andrew Middleton | BS | Environmental Conservation** |
| Jessica Waller | BS | Marine Biology |
| Emma Carrol | BA | Sociology |
| Emily Ramlow | BS | Environmental Conservation |

*- Graduated May 2010
** Graduated December 2010

# Grant No. 06HQGR0143 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

## Basic Information

| | |
|---|---|
| **Title:** | Grant No. 06HQGR0143 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S. |
| **Project Number:** | 2006NH86S |
| **Start Date:** | 3/6/2006 |
| **End Date:** | 3/5/2011 |
| **Funding Source:** | Supplemental |
| **Congressional District:** | 1 |
| **Research Category:** | Not Applicable |
| **Focus Category:** | None, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | Steve Kahl, William H H. McDowell |

## Publications


1. 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, in press.
2. 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. Environmental Science and Technology, in press.
3. 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, in press.
4. 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. Environmental Science and Technology, in press.
5. 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.
6. 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.
7. Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. LakeLine 27:30-34.
8. 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.
9. 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.
10. 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.
11. Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. LakeLine 27:30-34.
12. 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.
13. Nelson, S.J., W.H. Halteman, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, 2010. Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting, and chemical co-variates. Environmental Science and Technology, in review.
14. Nelson, S.J., W.H. Halteman, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, 2011, Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting, and chemical co-variates, Intended for: Environmental Science and Technology, In final prep, May 2011.
15. 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.
16. S.J. Nelson, P. Vaux, M.J. James-Pirri, and G. Giese, 2010, 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 final prep.
17. 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.
18. Fernandez, Ivan; Stephen, Norton, 2010, The Bear Brook Watershed in Maine: The Second Decade: Preface. Environmental Monitoring and Assessment, 171(1-4): 1-2(2)
19. Norton, S.; I. Fernandez; J. Kahl; L., Rustad; Tomas, Navratil; H., Almquist, 2010, The evolution of the science of Bear Brook Watershed in Maine, USA. Environmental Monitoring and Assessment, 171(1-4): 3-21.
20. Kim, Jong-Suk; Shaleen, Jain; Stephen, Norton, 2010, Streamflow variability and hydroclimatic change at the Bear Brook Watershed in Maine (BBWM), USA, Environmental Monitoring and Assessment, 171(1-4): 47-58.
21. Laudon, Hjalmar; Stephen, Norton, 2010, Drivers and evolution of episodic acidification at the Bear Brook Watershed in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 59-69.
22. Porcal, Petr; Aria, Amirbahman; Jiri, Kopacek; Stephen, Norton, 2010. Experimental photochemical release of organically bound aluminum and iron in three streams in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 71-81.
23. Simon, Kevin; Michael, Chadwick; Alexander, Hury; H.,Valett, 2010, Stream ecosystem response to chronic deposition of N and acid at the Bear Brook Watershed, Maine, Environmental Monitoring and Assessment, 171(1-4): 83-92.
24. Amirbahman, Aria; Brett, Holmes; Ivan, Fernandez; Stephen, Norton, 2010, Mobilization of metals and phosphorus from intact forest soil cores by dissolved inorganic carbon, Environmental Monitoring and Assessment, 171(1-4): 93-110.
25. SanClements, Michael; Ivan, Fernandez; Stephen, Norton, 2010, Soil chemical and physical properties at the Bear Brook Watershed in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 111-128.
26. Elvir, Jose; G. Wiersma; Suzanne, Bethers; Peter, Kenlan, 2010, Effects of chronic ammonium sulfate treatment on the forest at the Bear Brook Watershed in Maine, Environmental Monitoring and Assessment, 171(1-4): 129-147.

27. Fernandez, Ivan; Mary, Adams; Michael, SanClements; Stephen, Norton, 2010, Comparing decadal responses of whole-watershed manipulations at the Bear Brook and Fernow experiments, Environmental Monitoring and Assessment, 171(1-4): 149-161.

**Annual Report to**

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

June, 2011

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

IAG 06HQGR0143


Principal Investigators: *Bill McDowell[1], Steve Kahl[1], Sarah Nelson[2]*
[1]Univ. of New Hampshire, [2]Univ. of Maine


**Overview of activities during 2010.** A schematic summary of progress on the project plan is provided below and discussed on the following pages. We have concluded the fifth year of this five year project that supports the continuing needs of EPA for meeting the Congressional mandate for the agency to assess the effectiveness of the Clean Air Act Amendments of 1990. Field work and data assessment are on schedule, and the supplemental zooplankton component is well underway.

Project coordination is being conducted by the University of New Hampshire, with field and laboratory assistance continuing to come from the University of Maine.

| | 2006 | | | 2007 | | | | 2008 | | | | 2009 | | | | 2010 | | | | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Project Activity* | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 |
| project period | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| funding received | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| RLTM outlets | | | | ⁘ | | | | ■ | | | | ⁘ | | | | ⁘ | | | | ⁘ |
| RLTM drainage lakes | | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | |
| RLTM seepage lakes | | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | |
| original LTM lakes | | | ■ | | | | ■ | | | | ■ | | | | ■ | | | | ■ | |
| HELM subset | | | ■ | | | | ⁘ | | | | ■ | | | | ■ | | | | ■ | |
| BBWM - EB | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| TIME New England | | ■ | | | | ■ | | | | ■ | | | | ■ | | | | ■ | | |
| TIME Adirondacks | | ■ | | | | ■ | | | | ■ | | | | ■ | | | | ■ | | |
| sample analyses | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ |
| zooplankton analyses | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| annual report | | | | ■ | | | | ■ | | | | ■ | | | | ■ | | | | ■ |
| annual data report | ■ | | | | ■ | | | | ■ | | | | ■ | | | | ■ | | | |

▢ = project plan ▨ = in progress ■ = completed ⁘ = cancelled (weather)

## Project background

*Objectives*. This proposed research is part of the EPA program to collect long-term data on the trends and patterns of response in surface waters sensitive to acidic deposition. The goals and methods are hierarchical from intensive site-specific to regional statistical populations. 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 linkages in changes in surface waters, if any, to changes in deposition that are related to regulatory goals;
3) characterize the effectiveness of the Clean Air Act Amendments in meeting goals of reducing acidification of surface waters and improving biologically-relevant chemistry in the northeastern US; and
4) provide information for assessment of the need for future reductions in atmospheric deposition based on the rate of recovery (or not) of the systems under study.

We continue to explore changes in biological condition using zooplankton collected in 2004 under separate funding from 145 ELS-II lakes in the northeast, as part of our 20$^{th}$ anniversary re-analysis of the Eastern Lake Survey (see Rosfjord *et al*., 2007). This re-sampling included total and methyl mercury analyses for lake water, GIS analyses of lake context, and creation of an integrated GIS-chemistry database for the 1986 ELS-II lakes and 2004 re-sampling data. Zooplankton size metrics are now in the electronic, coordinated database and final compatibility checks of taxa names across decades are in progress. Initial analyses are in progress by K. Webster in consultation with the project team. In addition to a peer-reviewed journal article in preparation (Nelson et al. 2011), the mercury and methylmercury database was recently included in USGS scientist D. Krabbenhoft's work to develop national Hg sensitivity maps and models. The lakes in the 2004 re-sampling were unique in their statistical sampling design, collection during the same time period, and inclusion of all major geochemical variables. The lakes from this work represent ~10% of the entire national database used by Krabbenhoft in sensitivity modeling. Krabbenhoft is using the dataset and modeling framework to assess Hg sensitivity in National Parks at the request of the National Park Service.

*Approach*. The schedule of tasks ranges from weekly to annual, continuing data records that now range from 16 to 29 years. We evaluate chemistry on a weekly basis year-round at the small watershed-scale at BBWM, weekly during the spring melt period at LTM lake outlets when seasonal conditions warrant, quarterly in LTM, and annually during the historical index period for the HELM and TIME lakes. These project components provide a *statistical framework* for inferring regional chemical patterns 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 fundamental for EPA to meet the Congressional mandate for reporting on the effectiveness of the Clean Air Act Amendments (CAAA). The combination of site-specific data within the regional context will provide for an effective assessment of the effects of declining pollutant emissions on $SO_4$ concentrations, base cation depletion, and changes in N-saturation or DOC contributions to acid-base status. The results are also central to the decisions on additional emission reductions that may be needed to produce recovery.

**LTM/TIME annual field schedule**

| LTM-Maine | Apr | | | | May | | | | Jun | | | | Jul | | | | Aug | | | | Sep | | | | Oct | | | | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Bean | | | | | X | | | | | | | | | | | | X | | | | | | | | | w/ HELM | | | |
| 2 Partridge | | | | X | | | | | | | | | | | X | | | | | | | | | | | | | X | |
| 3 Jellison Hill | | | | X | | | | | | | | | | | X | | | | | | | | | | | | | X | |
| 4 Crystal | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | | |
| 5 Duck | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | | |
| 6 Bracey | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | | |
| 7 Newbert | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | X |
| 8 Wiley | | | | | X | | | | | | | | | | | | X | | | | | | | | | | X | | |
| 9 Abol | | | | | X | | | | | | | | | | | | X | | | | | | | | | | X | | |
| 10 Mud | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | |
| 11 Salmon | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | |
| 12 Tunk outlet | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | |
| 13 Second | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | X | |
| 14 Little Long | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| 15 Tilden | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 Anderson | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TIME-Maine** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 Round Pond | | | | w/ TIME NH | | | | | | | | | | | | | | | X | | | | | | | | | | |
| 2 Mountain Pd | | | | fly with HELM | | | | | | | | | | | | | | | | | | | | | | fly w/ HELM | | | |
| 3 Bog Pd Hartland | | | | w/ Bean in spring and summer | | | | | | | | | | | | | | X | | | | | | | | | | | |
| 4 East Branch Lake | | | | [Penobscot Nation sample] | | | | | | | | | | | | | | X | | | | | | | | | | | |
| TIME NH | | | | | | | | | | | | | | | | | | | X | X | X | | | | | | | | |
| TIME New Engl | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | |
| TIME NY | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | | | | | |
| HELM | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | |

Spring weekly drainage lake samples: weather and snowcover dependent

## Project Status: Water Chemistry

**Field sampling**. All project field objectives in 2010 were accomplished as planned with the exception of the spring drainage lake samples. Maine experienced an extremely wet spring making spring sampling logistically difficult and potentially unsafe for field crews.

**Analytical**. Analyses are complete for all samples collected through 2010. 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 it has been since 2006.

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

**Data reporting**. All data collected through 2009 have been delivered to EPA. The next delivery of data to EPA is expected in June 2011, after evaluation of inter-laboratory comparisons and regular QA analyses by UNH and UMaine.

**Presentation of findings.** Several publications and presentations have resulted from this project since the final report for the previous LTM/TIME grant, listed at the end of this report. The completion of Adam Baumann's M.S. thesis work is expected in July and will yield multiple publications focusing on results from the HELM project (see appendix).

**New developments:** We requested and were awarded funding to continue our work on the previously outlined objectives through FY2011. During the next sampling year group to explore climate related research objectives such as DOC quality using SUVA and fluorescence analysis, as well as dissolved greenhouse gases ($CH_4$, $CO_2$, and $N_2O$) in surface waters.

***Recent publications** using related project information*


**Nelson, S.J., W.H. Halteman, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, 2011. Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting, and chemical co-variates. Intended for: Environmental Science and Technology. In final prep. May, 2011.**

**Fernandez, Ivan; Stephen, Norton, 2010, The Bear Brook Watershed in Maine: The Second Decade: Preface. Environmental Monitoring and Assessment, 171(1-4): 1-2(2)**

**Norton, S.; I. Fernandez; J. Kahl; L., Rustad; Tomas, Navratil; H., Almquist, 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.**

**Kim, Jong-Suk; Shaleen, Jain; Stephen, Norton, 2010, Streamflow variability and hydroclimatic change at the Bear Brook Watershed in Maine (BBWM), USA, Environmental Monitoring and Assessment, 171(1-4): 47-58.**

**Laudon, Hjalmar; Stephen, Norton, 2010, Drivers and evolution of episodic acidification at the Bear Brook Watershed in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 59-69.**

**Porcal, Petr; Aria, Amirbahman; Jiri, Kopacek; Stephen, Norton, 2010. Experimental photochemical release of organically bound aluminum and iron in three streams in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 71-81.**

**Simon, Kevin; Michael, Chadwick; Alexander, Hury; H.,Valett, 2010, Stream ecosystem response to chronic deposition of N and acid at the Bear Brook Watershed, Maine, Environmental Monitoring and Assessment, 171(1-4): 83-92.**

**Amirbahman, Aria; Brett, Holmes; Ivan, Fernandez; Stephen, Norton, 2010, Mobilization of metals and phosphorus from intact forest soil cores by dissolved inorganic carbon, Environmental Monitoring and Assessment, 171(1-4): 93-110.**

**SanClements, Michael; Ivan, Fernandez; Stephen, Norton, 2010, Soil chemical and physical properties at the Bear Brook Watershed in Maine, USA, Environmental Monitoring and Assessment, 171(1-4): 111-128.**

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**Fernandez, Ivan; Mary, Adams; Michael, SanClements; Stephen, Norton, 2010, Comparing decadal responses of whole-watershed manipulations at the Bear Brook and Fernow experiments, Environmental Monitoring and Assessment, 171(1-4): 149-161.**

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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.

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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.

**Recent presentations using project information**

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.

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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.

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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.

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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.

Appendix I. Draft abstract from MS candidate Baumann thesis (partially supported by this IAG).

## Changes in surface water chemistry in Maine high elevation lakes in response to the 1990 Clean Air Act Amendments


## ABSTRACT:

The 1990 U.S. Clean Air Act Amendments (CAAA) set target reductions for both sulfur and nitrogen emissions to reduce acidic deposition and improve the biological status of low alkalinity surface waters in the United States. The Maine High Elevation Lake Monitoring (HELM) project was designed to complement assessments from other acid rain monitoring programs in the northeast that had underestimated the number of acidic lakes. HELM lakes are more susceptible to the effects of acid deposition than lowland lakes typically included in other surveys because they receive higher amounts of precipitation, and the watersheds are less able to neutralize acidic inputs because of steep slopes, shallow soils, and resistant bedrock. Since 1986, decreases in HELM surface water SO4 concentrations of 1.6µeq/L/yr. combined with lesser decreases in base cations (0.68 µeq/L/yr.) have led to significant increases in ANC (0.58µeq/L/yr.) and significant decreases in hydrogen ion (-0.05µeq/L/yr.). These improvements have led to a 50% decrease in the number of acidic (ANC <0) HELM lakes since 1986-87, and a 10% increase in the number of lakes projected to resist spring acidification (baseflow ANC > 30). Toxic inorganic aluminum comprises 9% less of the total aluminum in HELM lakes today than in 1986-87, due to the decrease in acidity and a 0.03mg/L/yr. increase in DOC which complexes inorganic Al. At current rates of change in both surface waters and deposition, we predict a recovery scenario for 2025 in which HELM lakes reach a background 24µeq/L $SO_4$ and non-dystrophic lakes have pH ≥ 6 and ANC ≥ 30µeq/L as depositional $SO_4$ becomes undetectable.


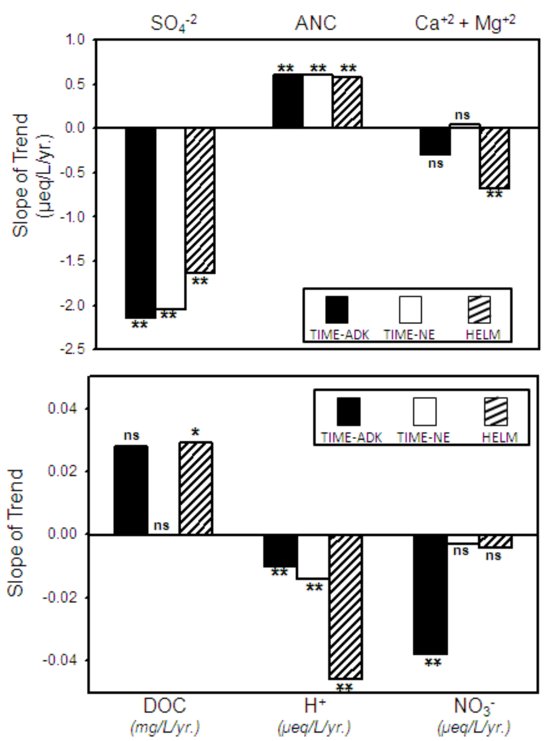


**Figure 3.** (a) Regional comparison of trends in biologically relevant chemistry in acid sensitive surface waters. Bars represent the median slope of the regression analysis for each individual lake. Units are noted in parentheses below each analyte. Significance is indicated by either ** ($p < 0.01$), * ($p < 0.05$) or ns ($p > 0.05$). (b) Note the change in scale of y-axis.

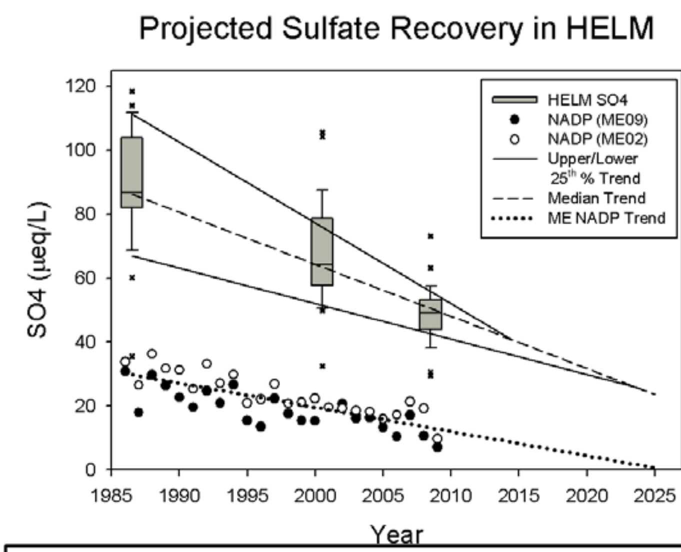


**Figure 10.** Estimated recovery scenario for HELM $SO_4$ concentration assuming continuing declines in $SO_4$ in atmospheric deposition. Boxplots represent HELM (n=28) data for 1986-87, 2000-01, and 2008-09 respectively. Boxes represent the 25th and 75th percentiles around the median, and error bars indicate the 10th and 90th percentiles. Solid lines show the regression for the upper and lower 25th percentiles and the dashed line represents the regression for the median. Dots indicate NADP data from Greenville (ME09) and Bridgton (ME02), ME while the dashed line represents the regression of both NADP stations together.

Appendix II. Draft abstract from MS candidate Baumann thesis (partially supported by this IAG).

## Increasing organic acidity as an indicator of recovery from acid rain in Maine high elevation lakes.

**ABSTRACT:**

Reduced acidity in precipitation in the northeastern U.S. has led to improvements in surface water chemistry in some of the most affected waters. Nowhere is this more apparent than in Maine high elevation lakes (HELM). An important result of decreased acid rain has been an increase in the amount of dissolved organic carbon (DOC) across the northern hemisphere. This response has led to a shift in the source of acidity from anthropogenic inorganic (acid rain), to natural organic DOC sources. This shift in acidity source has minimized the long-term increase in lake pH compared to the decrease in pH in precipitation.

We have previously established that HELM lakes have responded rapidly to changes in deposition and are thus well suited to look at the impacts of increased DOC on recovery from acid rain. Sulfate fraction (SF, the relative contribution of $SO_4$ to the total anionic charge) has decreased 5% to 40% in HELM lakes since 1986-87, yet decreased $H^+$ is not widespread. Over the same time period, DOC has increased at 0.03mg/L/yr, the equivalent of 0.13 µeq/L/yr. We estimate that organic anions ($OA^-$) now contribute 10% to 15% more to anionic charge than in 1986-87.

The influence of increased $OA^-$ is magnified because the HELM lakes are becoming increasingly dilute as acidic deposition declines and ionic leaching from watersheds decreases. Conductivity in HELM lakes has decreased from 17.6 µS/cm to 13.4 µS/cm since 1986-87. Overall, HELM lakes have experienced a shift in the $SO_4$:$OA^-$ ratio from? 3.4 to 1.3 since 1986-87. We found significant differences between lakes with a small change in $OA^-$ (low $\Delta$OA) and those with large increases in $OA^-$ (high $\Delta$OA). Declines in $H^+$ in the low $\Delta$OA group of 0.09 µeq/L/yr. were twice that of the population median and 10x that of the high $\Delta$OA group. Furthermore, only the low $\Delta$OA group exhibits a strong acidic deposition recovery pattern, with a significant decline in SF corresponding to a decrease in $H^+$. This means that HELM lakes are recovering in one of two ways. Low DOC lakes have experienced decreased $H^+$ as a direct result of decreased mineral acid inputs, while high DOC lakes have undergone a shift towards a natural organic source of acidity. While recovery in ANC may take an additional 10 to 30 years, recovery in pH is essentially complete in many lakes because their pH was not controlled by mineral acids and was relatively unaffected by acidic deposition. This conclusion is consistent with ample paleolimnological evidence from the northeastern US.

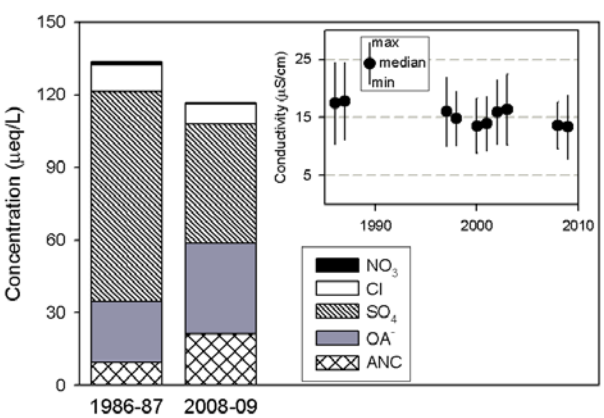


**Figure 2.** Shift in anion concentrations of the median HELM lake from 1986-87 to 2008-09. [inset: decrease in median HELM conductivity since 1986].

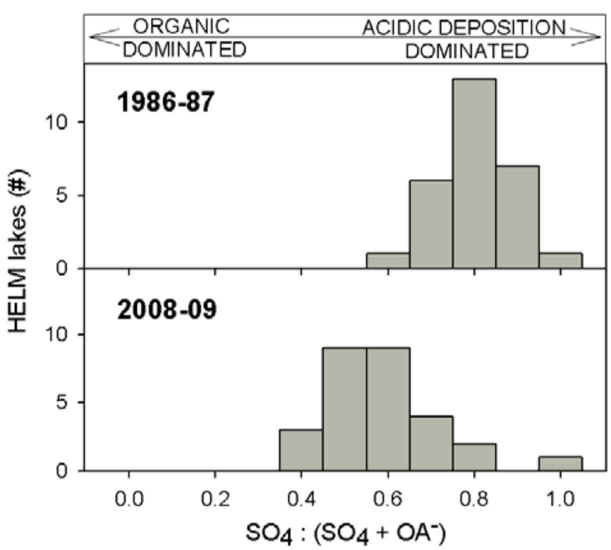


**Figure 3.** Shift in the relative influence of inorganic acid anions and organic anions in HELM lakes .

# Hydrologic and Isotopic Investigation of Base Flow Generation in the Headwaters Lamprey River Watershed

## Basic Information

| | |
|---|---|
| **Title:** | Hydrologic and Isotopic Investigation of Base Flow Generation in the Headwaters Lamprey River Watershed |
| **Project Number:** | 2010NH128B |
| **Start Date:** | 3/1/2010 |
| **End Date:** | 2/28/2011 |
| **Funding Source:** | 104B |
| **Congressional District:** | NH01 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Wetlands, Surface Water, Geochemical Processes |
| **Descriptors:** | None |
| **Principal Investigators:** | John Matthew Davis |

## Publication

1. Zuidema, S., 2011, Identifying groundwater contributions to baseflow in a temperate headwater catchment, Thesis, M.S., University of New Hampshire, Durham, NH.

## Statement of Critical Regional or State Water Problem

Many watersheds throughout New England are experiencing population growth resulting in increasing demands for water withdrawals and loading of anthropogenic by-products. The region is also expected to experience significant changes in the hydrologic cycle over the next century as a result of climate change (e.g. Hayhoe et al., 2007; Burakowski et al., 2008). Effective adaptation to both an increase in population and a changing climate will require a better understanding of the hydrology and biogeochemistry of the forested low-relief watersheds that are vital to sustaining our water resources and maintaining ecological habitats.

Streamflow during periods between precipitation or melt events is termed baseflow. Baseflow is often attributed solely to groundwater, though drainage from lakes, ponds, and unsaturated soils may also contribute to streamflow [Dingman, 2002]. In the most general terms, baseflow is considered whole catchment drainage [Stewart *et al.*, 2007]. In a changing climate, earlier snow melt [Hodgkins and Dudley, 2006], and the possibility for more pronounced seasonality of precipitation in the northeast [Hayhoe *et al.*, 2006] may result in increased reliance of summer baseflows to meet human and ecological water resource demands. The stores that generate baseflow have varied consequences on the water quality and quantity of water. For example, water draining from groundwater storage should generally maintain a lower temperature than water draining from surface reservoirs during summer months, which will benefit cold water fish species. Additionally, biogeochemical processing of solutes such as nutrients within surface and subsurface reservoirs would be expected to be different, and predicting the downstream influence of nutrient loading downstream requires an understanding of the relative contribution of reservoirs during baseflow.

## Objectives

During the summer of 2010, streamflow from the Headwaters Lamprey River Watershed (New Hampshire) and one of its headwater catchments were investigated hydrologically and isotopically to assess which stores contributed to baseflow generation. Heavy isotopes of hydrogen and oxygen occur naturally in very small abundances within the water molecule and accumulate in surface reservoirs that undergo evaporation. These stable isotopes of water enable the differentiation between water stored as groundwater from water experiencing open-water evaporative enrichment. The primary objectives were to:

- Examine correlation between geographic metrics of wetland and waterbody coverage with observed isotopic enrichment and hydrologic response.
- Assess the quantity of direct groundwater and surface water discharge in observed streamflow throughout the dry summer.
- Assess the role of groundwater in the water balance of an upstream wetland reservoir.

## Methods

The 740 ha Northwood Study Catchment (NWSC) was instrumented with four streamflow measurement sections, six riparian groundwater monitoring wells, and a stilling well set within the Lower Wet Meadow, an 11 ha beaver affected surface reservoir, and a meteorological station used to estimate evapotranspiration (Figure 1). Samples of groundwater, surface water, and precipitation were collected and analyzed for stable isotopic composition at the Northern Arizona

University Colorado Plateau Stable Isotope Laboratory, and dissolved silica and non-particulate organic carbon (NPOC) at the University of New Hampshire Water Quality Analysis Laboratory.

For both isotopes of the water molecule, abundances of stable isotopes of water are reported in the standard delta notation: the relative difference in the molar ratios of the heavy isotope to light isotope of a sample and Vienna standard mean ocean water (VSMOW) expressed in permil (‰). The contributions from evaporated surface water bodies (swb) and groundwater (gw), which are considered to be the only contributing sources to streamflow, are assessed using end-member mixing analysis of the proportional fraction of either end-member ($f_{swb}$ or $f_{gw}$) evaluated from isotopic composition. The fractional contribution from surface water sources was derived from the Lower Wet Meadow. An isotopic mass balance of the Lower Wet Meadow was developed that used measurements of volumetric discharge and isotopic composition of inputs and accounted for evaporative fractionation under prevailing meteorological conditions to predict isotopic composition of the reservoir. The mass balance was calibrated to samples of the reservoir isotopic composition for different volumetric inputs of groundwater estimated as the residual. The findings from the mass balance were corroborated with sampling results from silica and NPOC.

## Principal Findings

The isotopic enrichment was observed to increase (less negative δ-values) at subcatchments of the NWSC that had greater measures of wetland or waterbody coverage; the strongest correlation, using Kendall's $\tau$, was found comparing $\delta^{18}O$ with the length of catchment

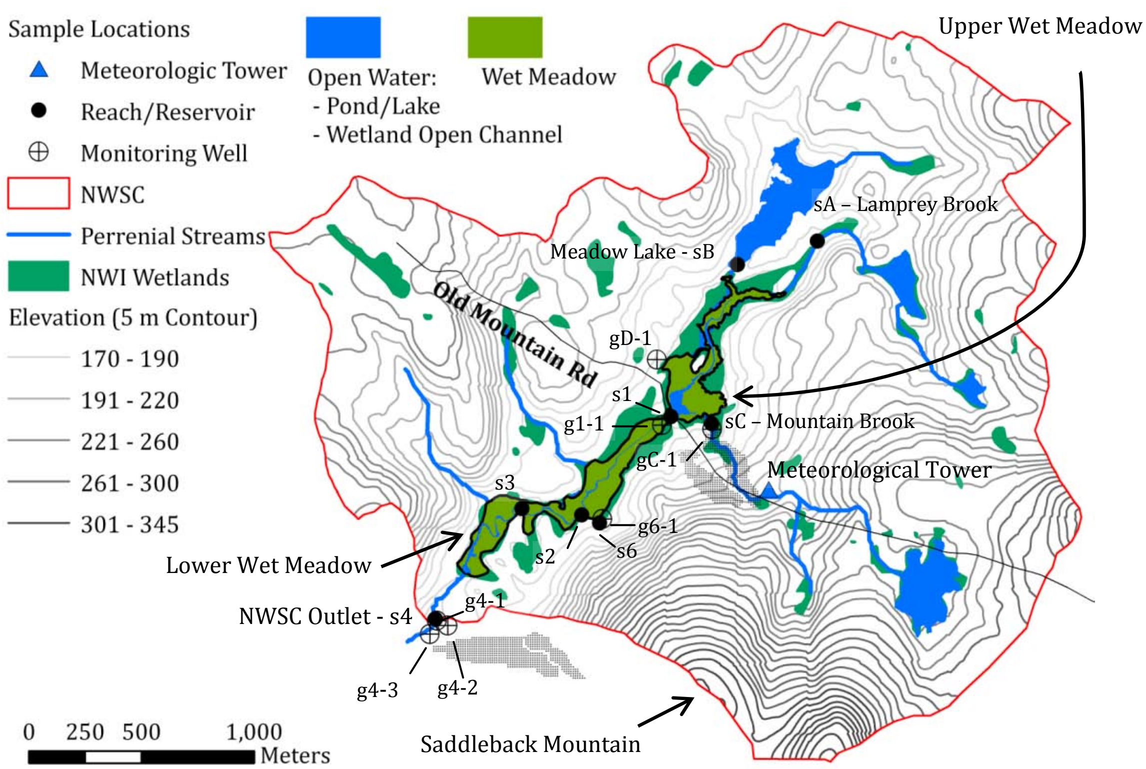


**Figure 1:** The Northwood Study Catchment in portions of the Northwood Meadows State Park and Forest Peters Wildlife Management area instrumented and investigated as part of the study. North is vertical.

stream course within wetlands (Figure 2). The relationship between stream length within wetlands and isotopic compositions suggests relative differences in groundwater contributions to baseflow, with watersheds having smaller streamlength in wetlands (e.g. SC) exhibiting more groundwater contributions (isotopically less enriched). Ranking subcatchments by the relative length of stream course within wetlands also provides insight into runoff mechanisms better than some more traditional metrics, such as wetland and waterbody areal coverage. For example, while Mountain Brook catchment (sC) has greater areal coverage of wetlands and waterbodies than the Lamprey Brook catchment (sA), it exhibits much lower runoff (Figure 3). In addition to the greater relative contribution of groundwater in sC (as indicated by isotopic characteristics), the lower runoff suggests that groundwater plays a subordinate role to stream-connected surface storage in the generation of runoff.

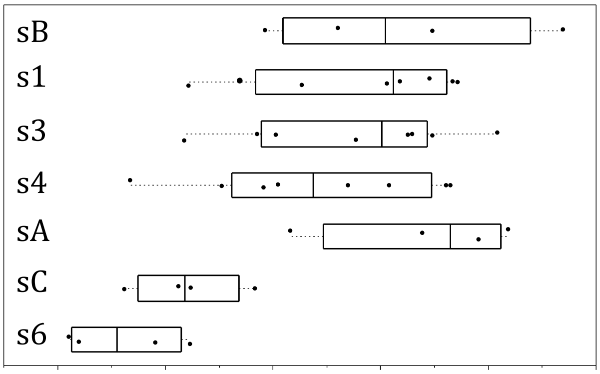


**Figure 2:** Correlation between stream length within wetlands and isotopic composition.

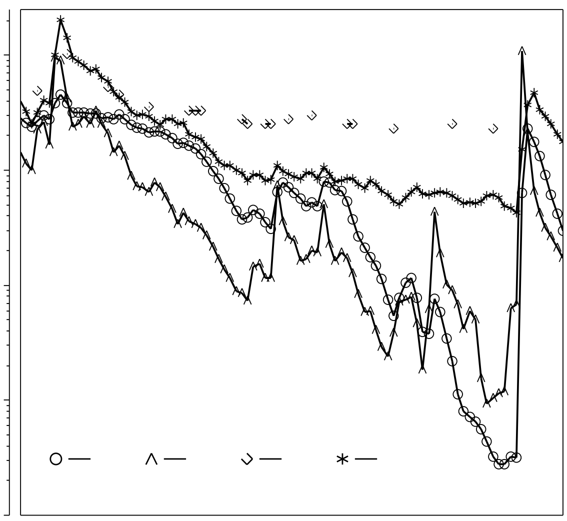

**Figure 3:** Area-average runoff for four subcatchments of the NWSC (locations on Figure 1).

End-member mixing analysis showed that groundwater provided 18-30% (<50% at 95% confidence) of the direct volumetric discharge from the catchment at s4 (Figure 4). The mixing fraction analysis results varied little if the groundwater component of streamflow was assumed to have an isotopic composition of bedrock groundwater, which was measured by Frades and others [In Prep] near the NWSC and found to maintain a consistent isotopic composition annually. A similar magnitude of streamflow generation from wetland drainage in a small catchment in central Maine (40-80%) has been reported recently [Morley *et al.*, 2011].

The remainder of streamflow leaving the catchment was derived from the Lower Wet Meadow; by mid-summer upstream streamflow into the meadow was essentially cut-off due to drying upstream. The isotopic mass balance model for the Lower Wet Meadow confirmed that groundwater inflows were <35% of total surface discharge and that most streamflow leaving the meadow was likely the result of a loss from surface storage. The groundwater influx is controlled by the specific yield of the Lower Wet Meadow – larger values for the specific yield require a greater inflow of groundwater to maintain volumetric and mass balance of the meadow. The isotopic mass balance appears to optimally predict observed isotopic composition (Nash-Sutcliffe efficiencies for both $\delta^{18}O$ and $\delta^{2}H$ >0.95) for a value of the shallow specific yield of 0.8. Groundwater inflow likely increased late in the summer (Figure 5), possibly due to drying of the meadow outpacing groundwater drainage. Increased groundwater inflows were corroborated by dissolved silica and NPOC analytical results, which showed concentrations in the Lower Wet Meadow and streamflow at the catchment outlet more similar to groundwater later in the summer.

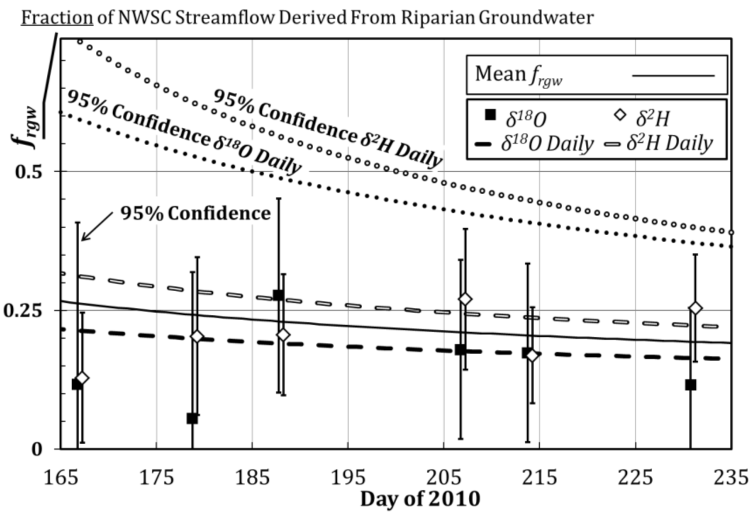


**Figure 4:** Fraction of groundwater in surface discharge from the NWSC. $f_{rgw}$ assumes only riparian groundwater. Mixing fraction is presented from both $\delta^{18}O$ and $\delta^{2}H$ sampling results. Markers with error bars and dashed lines with dotted error intervals indicate the estimate of mixing fraction and associated uncertainty on sampling dates and from daily trend regression estimates, respectively.

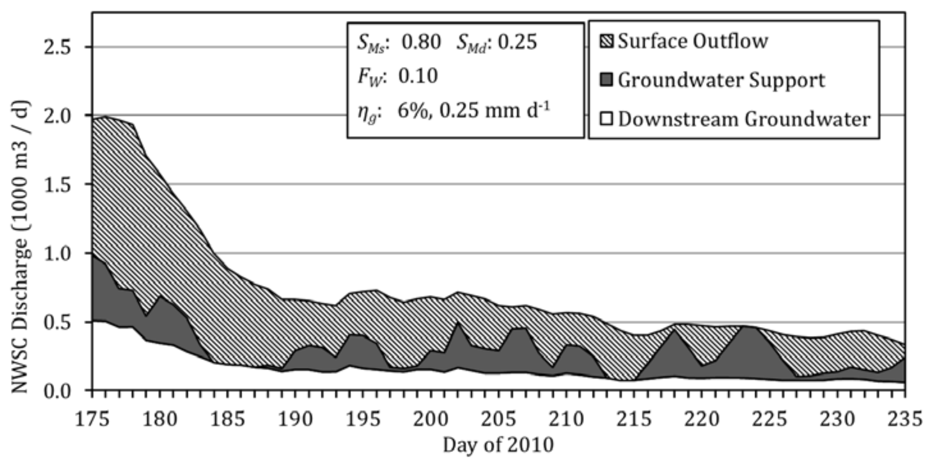


**Figure 5:** Discharge hydrograph of component outflow from the NWSC. Groundwater support is calculated from the water balance as the ratio of the net groundwater flux (residual) to surface outflow from the meadow, and is presented as the 3-day moving average assuming an optimized value of $S_{Ms}$ = 0.80. Groundwater inflows appear greater later in the summer.

## Statement of Significance or Benefits

The investigation resulted in the establishment and characterization of the dominant hydrological processes of the Northwood Study Catchment, a mesoscale study catchment in the headwaters of the Lamprey River. The study found evidence for surface drainage from wetland surface reservoirs as a possible baseflow generating mechanism in the headwaters of the Lamprey River, an often overlooked mechanism. Wetland resources may therefore be critical to meeting water resource demands in a climate of greater seasonality. An extensive inventory of stable isotopic samples was collected throughout the Northwood Study Catchment and the Headwaters Lamprey River Watershed between June and August 2010, a period that experienced about 60% of normal precipitation for the season [Zuidema, 2011]. The inventory of samples will be utilized to inform the broader effect of wetlands on baseflow generation at the catchment scale as Mr. Zuidema pursues his Ph.D. in Earth Systems Science at the University of New Hampshire. The results of this investigation advances our understanding of how temperate near-coast catchments may respond to prolonged dry conditions and how drainage from wetlands and other small surface stores relates to whole catchment drainage.

**Publications and Presentations**

Zuidema, S., 2011, Identifying groundwater contributions to baseflow in a temperate headwater catchment, Thesis, M.S., University of New Hampshire, Durham, NH.

Zuidema, S., 2011, The role of wetlands on sustaining base flow in the headwaters of the Lamprey with implications for water supply and biogeochemistry, Lamprey River Symposium, Session I, January 7, 2011, University of New Hampshire, Durham, NH.

**Students Supported**

The project has partially supported one master's student in the University of New Hampshire, Department of Earth Sciences Hydrology program, Shantar Zuidema, who has successfully defended his master thesis. Additional project participants include Charles Grant, who graduated from the University of New Hampshire with a B.S. in Environmental Science, and Cathleen Turner, who is currently enrolled in the Environmental Science program focusing in hydrology. The project and the Northwood Study Catchment have been used for introducing hydrological measurement techniques to additional undergraduate (Molly Jankolovits) and graduate (Scott Arndt) students.

## References

Dingman, S.L., 2002, Physical Hydrology, Second Edition, Waveland Press, Illinois, USA.

Frades, M.C., Davis, J.M., Bryce, J.G., McDowell, W.H, In Prep. Isotopic characterization of (baseflow in the) Headwaters Lamprey River Watershed, New Hampshire USA.

Hayhoe, K., Wake, C.P., Huntington, T.G., Luo, L., Schwartz, M.D., Sheffield, J., Wood, E., Anderson, B., Bradbury, J., DeGaetano, A., Troy, T.J., Wolfe, D., 2006. Past and future changes in climate and hydrological indicators in the US Northeast. Climate Dynamics, 28, 381-407.

Hodgkins, G.A., Dudley, R.W., 2006. Changes in the timing of winter–spring streamflows in eastern North America, 1913–2002. Geophysical Research Letters, 33, L06402.

Morley, T.R., Reeve, A.S., Calhoun, A.J.K., The Role of Headwater Wetlands in Altering Streamflow and Chemistry in a Maine, USA Catchment1. JAWRA Journal of the American Water Resources Association.

Stewart, M.K., Mehlhorn, J., Elliott, S., 2007. Hydrometric and natural tracer (oxygen-18, silica, tritium and sulphur hexafluoride) evidence for a dominant groundwater contribution to Pukemanga Stream, New Zealand. Hydrological Processes, 21, 3340-3356.

# Information Transfer Program Introduction

The NH WRRC supported to information transfer projects with its 2010 104b funding:

1. New Hampshire WRRC Information Transfer

2. Public information digests in support of the UNH Stormwater Center and the NH Stormwater Commission

# New Hampshire WRRC Information Transfer

## Basic Information

| | |
|---|---|
| **Title:** | New Hampshire WRRC Information Transfer |
| **Project Number:** | 2008NH97B |
| **Start Date:** | 3/1/2010 |
| **End Date:** | 2/28/2011 |
| **Funding Source:** | 104B |
| **Congressional District:** | |
| **Research Category:** | Water Quality |
| **Focus Category:** | Nitrate Contamination, Non Point Pollution, Water Quality |
| **Descriptors:** | None |
| **Principal Investigators:** | William H H. McDowell |

## Publications

There are no publications.

## Information Transfer

Unbridled development and population growth can have detrimental impacts to water resources and ecosystem services. Rapid population growth is occurring in New Hampshire and state regulations, planning board decisions and zoning classifications all attempt to minimize the environmental impact of this rapid population growth. Most land use planning decisions are made at the local level on a town by town basis, often by volunteers who serve on various boards, commissions and committees. Decisions by these various resource managers are often made without a full understanding of the consequences that their decisions will have on water resources or ecosystem services.

This project provided salary for the Center's Director and Associate Director to meet with state representatives, local town officials, watershed groups, the general public and scientists to discuss WRRC findings that relate to population growth and land use change. The NH WRRC website (http://www.wrrc.unh.edu/) is also used to disseminate information on water resources, and is updated and maintained by salary provided by this project. The time of the Director and Associate Director is increasingly spent discussing current and future research in the Lamprey River Hydrologic Observatory, which is partially funded by the longstanding 104B project "Water Quality and the Landscape: Long-term monitoring of a rapidly developing suburban watershed." On January 7, 2011 the NH WRRC totally funded and organized the **Fourth Annual Lamprey River Symposium** (see also below). Presentations focused on water quality, hydrology, stormwater, thermal pollution, nitrogen cycling in coastal New Hampshire and remapping of the Lamprey River 100 year floodplain. The symposium attracted over 90 attendees, including scientists (37 from UNH and 1 from elsewhere), regional leaders (27), town officials (11), members of state agencies (8), and federal agencies (6). The agenda and presentations have been posted on the NH WRRC website at: http://www.wrrc.unh.edu/lrho/symposium.htm. This annual symposium and other discussions in which the Center's Director and Associate Director participate further the research and information transfer goals of the WRRC.

### Examples of Information Transferred

The NH WRRC's long-term water quality data on the rapidly developing suburban Lamprey River watershed has been shared with local towns as they investigate new potential sources for public water supply. Several towns in the watershed are investigating new water supplies to support the increased demand for water from their growing populations. Newmarket, NH is under considerable pressure to develop new water supplies, as its surface water treatment plant was shut down several years ago due to high concentrations of dissolved organic carbon (DOC). This DOC, although of largely natural origin from wetlands in the Lamprey River basin, results in production of dangerous trihalomethanes upon chlorination. Trihalomethanes are known carcinogens and the town of Newmarket was required to shut down the water treatment plant and rely solely on the two town wells.

Newmarket has contracted with Emery & Garrett Groundwater, Inc (EGGI) to increase their town water supply. Emery & Garrett Groundwater, Inc has suggested that the town withdraw water from the Lamprey River in Lee NH during high flow periods and artificially "recharge" their town wells to generate an underground storage supply that would meet the town water needs even during dry summer conditions. The NH WRRC provided EGGI with long-term Lamprey River data to assess whether seasonality and year to year variability in water quality (especially DOC) made it appropriate for artificial recharge. The town of Newmarket has not been able to appropriate funding to further develop this artificial recharge project, but the long-term dataset provided by the NH WRRC was instrumental in this water supply decision-making process.

The town of Durham (including the University of New Hampshire) relies heavily on the Lamprey River for water supply since the town's local surface water source, the Oyster River, is often unable to meet the town's demand. Like Newmarket, Durham has also contracted with EGGI to determine if artificial recharge of their Spruce Hole Aquifer with Lamprey River water is an appropriate and viable option to meet the town's water supply needs. The NH WRRC continues to provide EGGI with long-term water quality data on the Lamprey River to inform this water supply decision-making process in Durham. As more towns in the future look to the Lamprey for water supply, the long-term dataset provided by the NH WRRC will become increasingly valuable.

In addition to providing data on surface water quality, the NH WRRC has also identified water quality impairments in private wells within southeastern NH and presented the results to homeowners, local town officials, regional watershed groups and state agencies. Private wells are not regulated, even though they supply 40% of the NH population, and therefore it is up to the individual homeowner to test and treat their water if necessary. This puts the uninformed homeowner at risk of consuming contaminated water. We sampled 188 private wells to infer linkages between land use practices and groundwater quality and to educate the general public on the importance of private well testing. One private well that we sampled exceeded the US EPA public drinking water standard for nitrate (10 mg N/L), 10 wells were greater than levels associated with increased risk of gastric cancer (4 mg N/L; Ward et al. 1996), and 28 wells were elevated above 2 mg N/L, indicating anthropogenic sources of N contamination (e.g. fertilizers or septic system effluent). Nine percent of the wells exceeded the EPA secondary drinking water standard for chloride (250 mg/L) and 46% of the wells exceeded the EPA advisory level (20 mg Na/L) for persons with hypertension. It is likely that road salt application is the dominant source of such high sodium and chloride levels in groundwater. In summary, 21% of the wells exceeded the EPA MCL for either nitrate, arsenic, lead or uranium and 38% of the wells exceeded advisory levels for nitrate (4.0 mg N/L), chloride (250 mg/L) or sodium (20 mg/L). A total of 59% of private well users are exposed to contaminants that are cause for health concern. The NH WRRC has shown that even private wells drilled deep into bedrock fractures are subject to contamination from activities on the land surface. Local resources managers should take this into consideration when making land use planning decisions and these results were included within many of the outreach presentations listed below.

Over the two years, there has been significant focus on nitrogen loading to New Hampshire's largest estuary, the Great Bay estuary, and the impairment to aquatic life it has caused. In June 2009, numeric nitrogen criteria were established for Great Bay and in August 2009, Great Bay, Little Bay and the tidal rivers were added to the New Hampshire 2008 303d list of impaired waters rendering them in violation of the federal Clean Water Act. Based on a draft version of a waste load allocation report prepared by Philip Trowbridge (NH DES 2010), only 27% of the nitrogen entering Great Bay and Little Bay is from point sources; the majority (73%) enters via non-point sources of pollution. The Lamprey River is the largest tributary to Great Bay, and thus the long-term data provided by the NH WRRC from the LRHO are of considerable value for watershed management. The NH WRRC provides the best dataset in NH for assessing the spatial and temporal variability in N concentrations and export in response to suburbanization and changes in land use. These 11+ years of data will be instrumental in assessing the success of current and future efforts to reduce non-point sources of nitrogen pollution reaching Great Bay. There is much interest in LRHO datasets from NH DES, the Piscataqua Region Estuaries Partnership (PREP), the Environmental Protection Agency (EPA) and other municipal, regional, state and federal agents. Many of the presentations and meetings listed below focused on transferring information on nitrogen cycling to stakeholders throughout NH's coastal watershed and beyond.

**Symposia, Conferences and Seminars Organized and Funded**

The NH WRRC totally funded and organized the "**Fourth Annual Lamprey River Symposium**" held January 7, 2011 in Durham, NH. The symposium is dedicated to exchanging the results of recent research on the water quality, hydrology, water resources issues, and management of the Lamprey River basin. The Symposium is a vehicle for researchers to share data and insights with other researchers, as well as those in the management and policy arena who would benefit from exposure to the latest research on the watershed. The symposium drew over 90 attendees, including researchers, legislators, water system operators, town officials, regional leaders and government officials. The symposium contained 13 presentations split up over three sessions. There was a break out session on nitrogen cycling and a poster session during lunch (5 posters and displays were exhibited). The day ended with an open discussion on research priorities in the Lamprey watershed and southeast NH. This event was totally funded and organized by the NH WRRC. Staff from UNH cooperative extension and Great Bay National Estuarine Research Reserve helped moderate the open discussions.

The NH WRRC sponsored the "**NH Water and Watershed Conference**" in Plymouth, NH on March 25-26, 2011. The conference is a unique, two-day event designed to meet the information and networking needs of lake, river, and watershed groups; environmental organizations; volunteer monitors; municipal board and staff members; elected officials; local and regional planners; policy makers; scientists; educators; consultants and students. The focus for the 2011 conference is on effective strategies at the local, regional, state, and federal levels that address the changing environmental and societal conditions and their effects on New Hampshire's aquatic environment. The NH WRRC co-Sponsored this conference along with FB Environmental Associates, GeoInsight Inc., Hach Hydromet, In-Situ Inc., New England EnviroStrategies, New Hampshire Department of Environmental Services, New Hampshire Fish and Game Department, Plymouth State University, Squam Lakes Association, United States Geological Survey Water Resources of NH and VT, Vanasse Hangen Brustlin, Inc. (VHB), Weston & Sampson Engineers Inc., Waterline Companies and the White Mountain National Forest. The conference contained 4 or 5 tracks each day including headwaters, streams and rivers; lakes wetlands and the coastal zone; wastewater and stormwater infrastructure; groundwater; land use change; local, regional, statewide and national strategies and skill building. The conference drew over 250 people, including researchers, legislators, water system operators, land use planners, and government officials.

The "**Road Less Salted**" water quality and salt reduction seminar was held on May 13, 2010 as a follow-up activity to the conference "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water" (see below). The salt reduction seminar was co-sponsored by NH Department of Environmental Services, GBNERR Coastal Training Program, LRAC, LRWA, NH WRRC, and Hodgson Brook Restoration Project. The workshop drew over 80 people including members of local boards and commissions, public works directors and road agents, municipal decision makers/planners, private contractors and landscapers who plow snow, property managers or owners, and local watershed or environmental organizations.

The NH WRRC sponsors a monthly **seminar series on water issues in New Hampshire** along with the USGS and the Department of Natural Resources at UNH. Five seminars were held during the academic year of this reporting period. Two seminars were held at the USGS office in Pembroke, NH and three were held at the University of New Hampshire in Durham, NH. Topics included biogeochemical cycles in watersheds and links to toxic algal blooms, engineering a solution to nitrogen impairments in NH's Great Bay, SPARROW modeling, climate change and geophysical methods used in water supply investigations.

**Outcomes of Information Transferred**

In June 2009, the NH WRRC together with the Great Bay National Estuarine Research Reserve (GBNERR) Coastal Training Program, Lamprey River Watershed Association (LRWA), Lamprey River Advisory Committee (LRAC) and Piscataqua Region Estuaries Partnership (PREP) formed the Lamprey River Watershed Outreach Collaborative and co-sponsored an outreach conference in June 2009 focusing on pressing water issues for the residents of the 14 towns that make up the watershed. The conference was titled "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water" and drew over 70 people including teachers, legislators, town officials, regional leaders and government officials. Topics covered were 1) issues and challenges to land use decision making in the 14 towns that share the Lamprey watershed (presented by Erika Washburn, UNH PhD candidate) 2) water quality issues with road salt use and elevated nitrogen levels (presented by NH WRRC associate director) 3) consistency of environmental planning and regulation between towns in the watershed (presented by PREP).

The Lamprey River Outreach Collaborative conference highlighted the need for watershed wide land use planning and decision making and gave momentum to an earlier idea that the entire Lamprey should be nominated into the NH Rivers Management and Protection Program (RMPP). Currently, the Lamprey has 17.5 km (in Durham and Lee) of the 78 km mainstem reach designated into the NH RMPP. Following the Lamprey River Outreach Conference, a Lamprey River Nomination Committee (LRNC) was formed and in June 2010, a nomination package was submitted by the LRNC, LRWA and the LRAC to the NH Department of Environmental Services (DES) to designate the remaining portions of the Lamprey River and all its major tributaries into the NH RMPP. This nomination represented a total of 141 river km and the major tributaries included were the North Branch, Pawtuckaway, North, Little and Piscassic Rivers. Together, these nominated rivers capture 14 towns, two counties and 3 regional planning commissions that all share the Lamprey River watershed. This nomination package was the most complex nomination that the NH State Rivers Management Committee had ever seen and the first one to push for a watershed approach (as opposed to nominating a segment of a river or the main stem of a river, but not its tributaries). The committee was extremely impressed that elected officials from all of the watershed towns wrote letters of support and by the number and variety of individual support letters. On September 28, 2010, the NH State Rivers Management Committee voted to approve the nomination and the resulting House Bill has passed in both the House and the Senate. The Governor is expected to sign this bill into law this summer. At that point, a watershed wide local advisory committee will be formed and the designation will give the Lamprey watershed preferential eligibility over non-designated rivers for state funding and technical resources.  Conversations about the structure of this watershed wide committee have begun and the NH WRRC has been part of these conversations.

The progressive movement of this nomination represents significant outreach efforts of the NH WRRC, all the partners of the Lamprey River Outreach Collaborative (http://www.wrrc.unh.edu/lrho/outreach.html) and also the social science work of Erika Washburn (PhD dissertation "To pave or not to pave: a social landscape analysis of land use decision-making in the Lamprey River watershed", December 2009).  The LRNC, LRWA and LRAC made considerable efforts to put the nomination package together, but the public support for this nomination which is necessary for state designation would not have been possible without the extensive outreach of the Lamprey River Outreach Collaborative of which the NH WRRC plays a large role (http://www.wrrc.unh.edu/lrho/outreach.html).  The concept of land use decision-making and natural resource management from a watershed perspective instead of solely by political boundaries with no regard to upstream or downstream neighbors is one that is gaining traction in southeast NH and is an outcome that the NH WRRC as well as other organizations is very proud of.  This type of approach is the only to solve some of the current water quality impairments in New Hampshire (e.g. road salt contamination and elevated nitrogen and phosphorous in several water bodies).

**Presentations:**

Bucci, J., McDowell, W.H., Daley, M.L., Potter, J.D., Hobbie, E., French, C. and Miller, C. 2011. Detecting nitrogen sources and flow paths in the Great Bay watershed and engaging decision makers in the Science. Annual Lamprey River Science Symposium. Durham, NH. January 2011.

Daley, M.L. 2010. Road Salt Impacts to New Hampshire Streams and Groundwater. "The Road Less Salted" Water Quality & Salt Reduction Seminar. Greenland, NH. May 2010.

Daley, M.L. 2010 Shared slides on nitrogen cycling from the Lamprey River watershed with Ted Diers for a presentation on nitrogen in the Great Bay watershed given by NH DES.  May 2010.

Daley, M.L. 2010. Water Quality in the Suburbanizing Lamprey River Basin. University of New Hampshire Inventory and Monitoring of Ecological Communities class.  Durham, NH. September 2010.

Daley, M.L. 2010. Suburbanizing NH watersheds and N Saturation.  University of New Hampshire Watershed Water Quality Management class.  Durham, NH. November 2010.

Daley, M.L. 2010. Testified in support of nominating the remaining segments of the Lamprey River and its major tributaries into the State Rivers Management Protection Program. NH House of Representatives Resources, Recreation & Development Committee Public Hearing.  Concord, NH. January 2011.

Daley, M.L. and McDowell, W.H. 2010. Landscape controls on dissolved nutrients, organic matter and major ions in a suburbanizing watershed. American Geophysical Union Fall Conference, San Francisco, CA. December 2010.

Daley, M.L. and McDowell, W.H. 2011. Declining nitrogen retention with increasing nitrogen inputs in the Lamprey and Oyster River watersheds. Annual Lamprey River Science Symposium. Durham, NH. January 2011.

Daley, M.L., McDowell, W.H. and Bucci, J. 2011. Nitrogen inputs, outputs, retention and concentrations in watersheds of the Great Bay Estuary system. NH Water and Watershed Conference. Plymouth, NH. March 2011. Daley, M.L. 2011. Shared slides with Matt Liebman from the US EPA. March 2011.

Davis, J.M., McDowell, W.H., Campbell, J.E., Hristov, A.N. 2010. Hydrological and biogeochemical investigation of an agricultural watershed, southeast New Hampshire, USA. American Geophysical Union Fall Conference, San Francisco, CA. December, 2010.

Hope, A.J. and McDowell, W.H. Ecosystem Processes in a Piped Stream. Aquatic Sciences: Global Changes from Center to Edge. ASLO & NABS Joint Summer Meeting. Santa Fe, NM. June 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Plymouth State University, April 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Duke University, April, 2010.

McDowell, W.H. 2010. Biogeochemistry of Suburban Basins – Putting People into the Landscape. Yale University, April 2010.

McDowell, W.H. 2010. Nitrogen Impairment in a Suburban Basin: Can We Engineer a Solution? University of New Hampshire, September 2010.

McDowell, W.H. 2010. Nitrogen Impairment in a suburban Basin: Can we engineer a solution? University of Connecticut, January 2011.

McDowell, W.H. and Daley, M.L. 2011. Long-term water quality trends in the Lamprey River. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

**Press Releases**

Daley, M.L. 2010. "Scientists say time to cut nitrogen in estuary is now" by Aaron Sanborn asanborn@seacoastonline.com in http://www.seacoastonline.com/ May 12, 2011.

Daley, M.L. and McDowell, W.H. 2011. Nitrogen research at the NH Water Resources Research Center as it relates to the nitrogen impairment of Great Bay. Lee, NH Town Crier. January 2011.

McDowell, W.H. 2010. "$600K grant helps study nitrogen in estuary, bay" By Dave Choate dchoate@seacoastonline.com in http://www.seacoastonline.com/ December 04, 2010.

McDowell, W.H. 2010. “Grant will seek pollution source in NH’s Great Bay” by Associated Press in http://www.bostonherald.com December 6, 2010.

McDowell, W.H. 2010. “UNH’s grant money may be a ‘saving grace’ for Great Bay” by Kristen Phelps in The New Hampshire (UNH newspaper) December 6, 2010.

McDowell, W.H. 2010. “New grant to address Great Bay's pollution 'hot spots'” on http://www.fosters.com/ December 6, 2010.

**Meetings Attended:**

Daley, M.L. 2010 and 2011. Attended several of the Ecosystem Task Force meetings that occur monthly during the academic year at UNH. Durham, NH.

Daley, M.L. 2010 and 2011. Attended several of the PREP Technical Advisory Committee meetings that occur approximately bi-monthly in either Durham or Portsmouth, NH.

Daley, M.L. 2010. PREP Economic Valuation Study Meeting. NH Fish and Game Department, Durham, NH. December 2010.

McDowell, W.H. 2010. Attended a boat tour of Great Bay with NH DES and ME DEP commissioner and EPA Region 1 Representatives. September 2010.

McDowell, W.H. 2010. Attended meeting with BORWPP (Bellamy and Oyster River Protection Partnership). October 2010.

McDowell, W.H. 2010. Attended several of the Ecosystem Task Force meetings that occur monthly during the academic year at UNH. Durham, NH.

McDowell, W.H. 2010. PREP Monitoring Planning Review Committee. October 7, 2010.

McDowell, W.H. and Daley, M.L. 2010. Attended a cookout and field trip to Suncook River avulsion site with USGS staff, state representatives, scientists and other stakeholders interested in the Suncook River avulsion. July 2010.

McDowell, W.H. and Daley, M.L. 2011. Meet with Phil Trowbridge and Paul Currier from NH DES to discuss the Nitrogen Loading Model (NLM) that NH DES is developing. January 2011.

# Public information digests in support of the UNH Stormwater Center and the NH Stormwater Commission

## Basic Information

| | |
|---|---|
| **Title:** | Public information digests in support of the UNH Stormwater Center and the NH Stormwater Commission |
| **Project Number:** | 2010NH131B |
| **Start Date:** | 3/1/2010 |
| **End Date:** | 2/28/2011 |
| **Funding Source:** | 104B |
| **Congressional District:** | NH01 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Non Point Pollution, Surface Water, Management and Planning |
| **Descriptors:** | None |
| **Principal Investigators:** | Robert Roseen, Thomas P. Ballestero |

## Publications


1. UNH Stormwater Center, 2011, Stormwater Commission Summary, Fact Sheet.
2. UNH Stormwater Center, 2011, Winter Maintenance, Fact Sheet
3. UNH Stormwater Center, 2011, Thermal Impacts of Stormwater BMPs, Fact Sheet.
4. UNH Stormwater Center, 2011, Greenland Meadows LID Case Study: Economics, Fact Sheet.
5. UNH Stormwater Center, 2011, Greenland Meadows LID Case Study: Water Quality, Fact Sheet.
6. UNH Stormwater Center, 2011, Boulder Hills LID Case Study: Economics, Fact Sheet.

# Final Report
## Public Information Digests in Support of the UNH Stormwater Center and the NH Stormwater Commission
## May 10, 2011

**Principal Investigators**

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### Problem

New Hampshire faces a host of water resource-related issues, including flooding, drought, non-point source pollution, lake eutrophication, erosion and sedimentation, and perhaps even climate change. Each of these issues (and more) are associated with environmental consequences and management responses (or lack thereof) related to stormwater runoff. New Hampshire is late in addressing stormwater in relation to other states as a number of northeastern states already have new stormwater laws in place, whereas New Hampshire is only now formally addressing a number of the issues in the legislature's Stormwater Commission.

There is a critical need for the public, municipal officials, and policy makers to understand the scope of this issue, and to devise broadly acceptable management solutions to reduce impacts of stormwater runoff. Finding information to educate this audience is elusive, because translation from scientific research for the lay person is sparse for this topic. Information in New Hampshire is so limited that the New Hampshire Department of Environmental Services, (NHDES) distributes copies of a stormwater Digest from Maine (Morse and Kahl, 2003) in its public information sessions on protecting water quality.

### Objectives

The objective of this project was to develop and publish two Information Digests for a lay audience on stormwater topics. Fortunately resources existed to prepare additional documents totaling 6 digests in all. The intent of this outreach product was to transform existing technical research information into a publication that is readily usable and to provide it to those parties involved in everyday decision-making, with particular emphasis on the target audience of municipal decision makers.

### Methods

Information from other outreach documents and from research (including research results and best management practice (BMP) solutions from the University of New Hampshire Stormwater Center (UNHSC)) was assessed and streamlined for the target audience. The authors used their experience with the Stormwater Commission, and from interactions with other municipalities through the UNHSC to address common issues and misunderstandings of the target audience.

The outline of each Digest generally follows the format of a) overview, b) social need, c) impacts, d) technical solutions, and e) policy or management options. Each document is approximately 2-8 pages pages long and was intentionally kept simple, short, and non-academic to reach as broad an audience as possible. Drafts of each document were prepared in text with images and concepts for review. When finalized, the files were provided to a graphic designer for final preparation.

These documents were developed for both print distribution and electronic distribution and will be made available through the Stormwater Center website which currently hosts a wide range of resources. To reach a broad audience of citizens, legislators, municipal officials, lay board members, and public works staff will require distribution of hard copies. Each document was also formatted for PDF and HTML availability via email and the internet.

**Major findings and significance**

Creative management and effective new legislation/policy for stormwater in New Hampshire is needed and public education on stormwater in New Hampshire has been minimal to date. The information transfer documents created by this project will educate the public by translating some of the technical research conducted by the UNHSC that have direct relevance to current stormwater management issues. We expect that these documents will be the first of a series of public educational Digests oriented toward environmental solutions from the Stormwater Center as the mission of the UNHSC is to advance effective stormwater management through research-based outreach education.

This project will also serve a vital information technology role for the legislature's Stormwater Commission, which is staffed by the NHDES. We expect that NHDES will post the documents on their website, as will the New Hampshire Lakes Association. The documents will be made available to other governmental and non-governmental organizations as well. This expansion will permit a broader reach of the UNHSC to inform state and local land use decision makers in the New England region and beyond.

**Publications, presentations, awards**

The following Fact Sheets were developed as part of this project:

1. Stormwater Commission Summary
2. Winter Maintenance
3. Thermal Impacts of Stormwater BMPs
4. Greenland Meadows LID Case Study: Economics
5. Greenland Meadows LID Case Study: Water Quality
6. Boulder Hills LID Case Study: Economics

The fact sheets are listed in Appendix A.

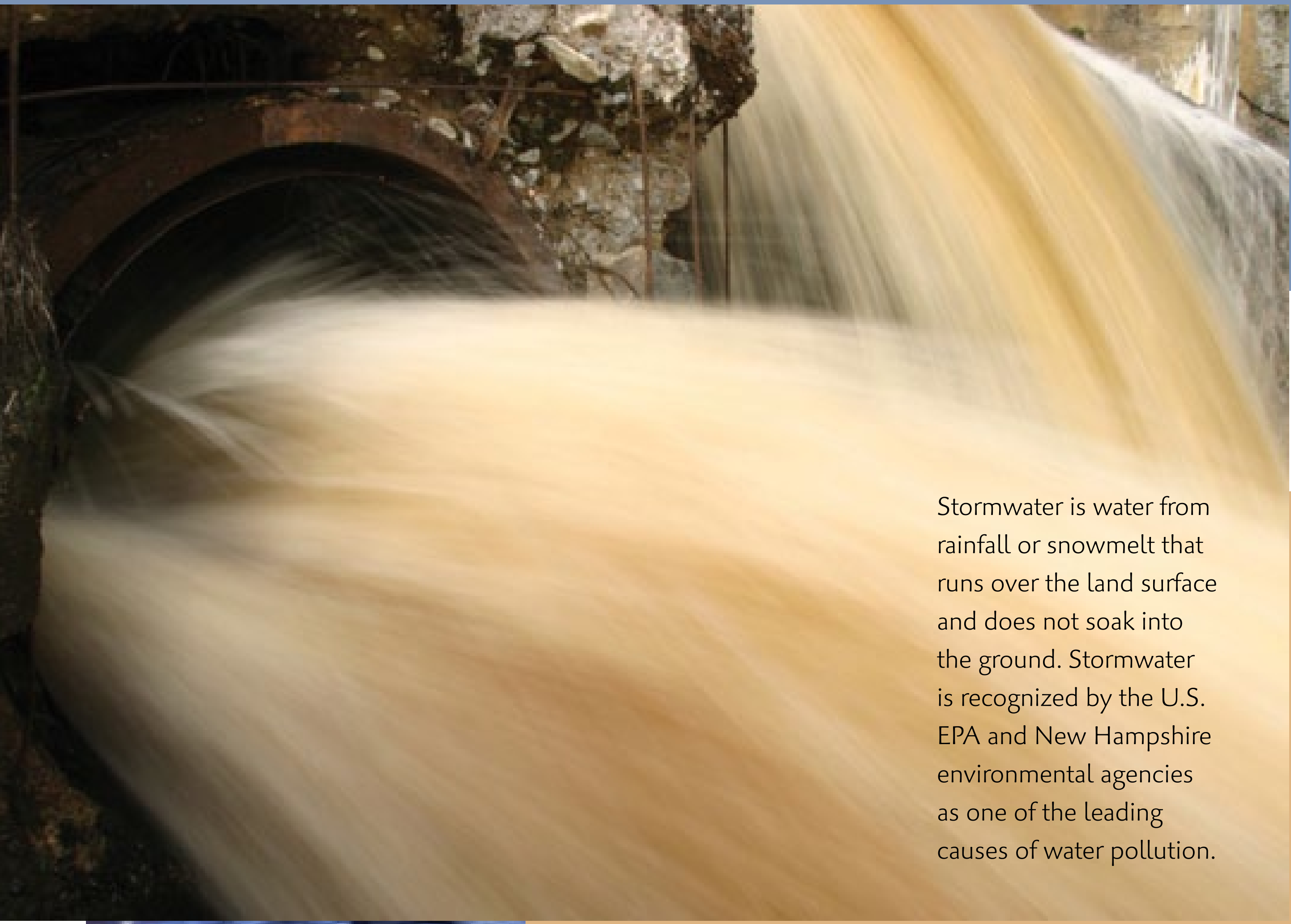
## Outreach or Information Transferred

These documents have been developed for both print distribution and electronic distribution. The documents are available through the Stormwater Center website which currently hosts a wide range of resources (http://www.unh.edu/unhsc/specs-and-fact-sheets-0). To reach a broad audience of citizens, legislators, municipal officials, lay board members, and public works staff will require distribution of hard copies. Each document was formatted for PDF and available via the internet.

## Appendix A: Fact Sheets

1. Stormwater Commission Summary
2. Winter Maintenance
3. Thermal Impacts of Stormwater BMPs
4. Greenland Meadows LID Case Study: Economics
5. Greenland Meadows LID Case Study: Water Quality
6. Boulder Hills LID Case Study: Economics

# S U M M A R Y  B R I E F
## NH Stormwater Commission Final Report



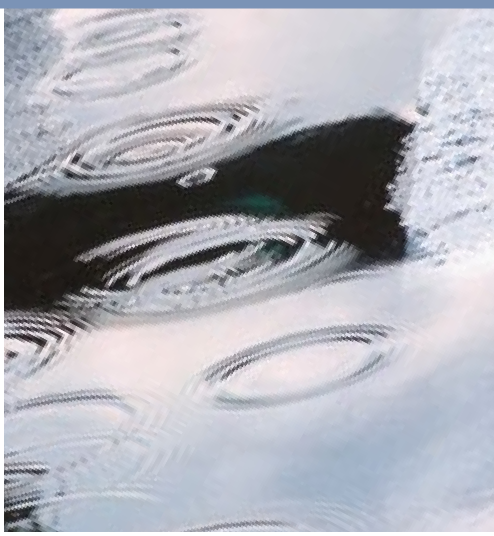
Stormwater is water from rainfall or snowmelt that runs over the land surface and does not soak into the ground. Stormwater is recognized by the U.S. EPA and New Hampshire environmental agencies as one of the leading causes of water pollution.

This document summarizes the major points from the Stormwater Study Commission November 2010 Final Report. The New Hampshire legislature established the Stormwater Commission in 2008 to identify issues and find solutions to reduce impacts from stormwater runoff. This Summary Brief is a non-technical overview intended for the legislature and other public officials.

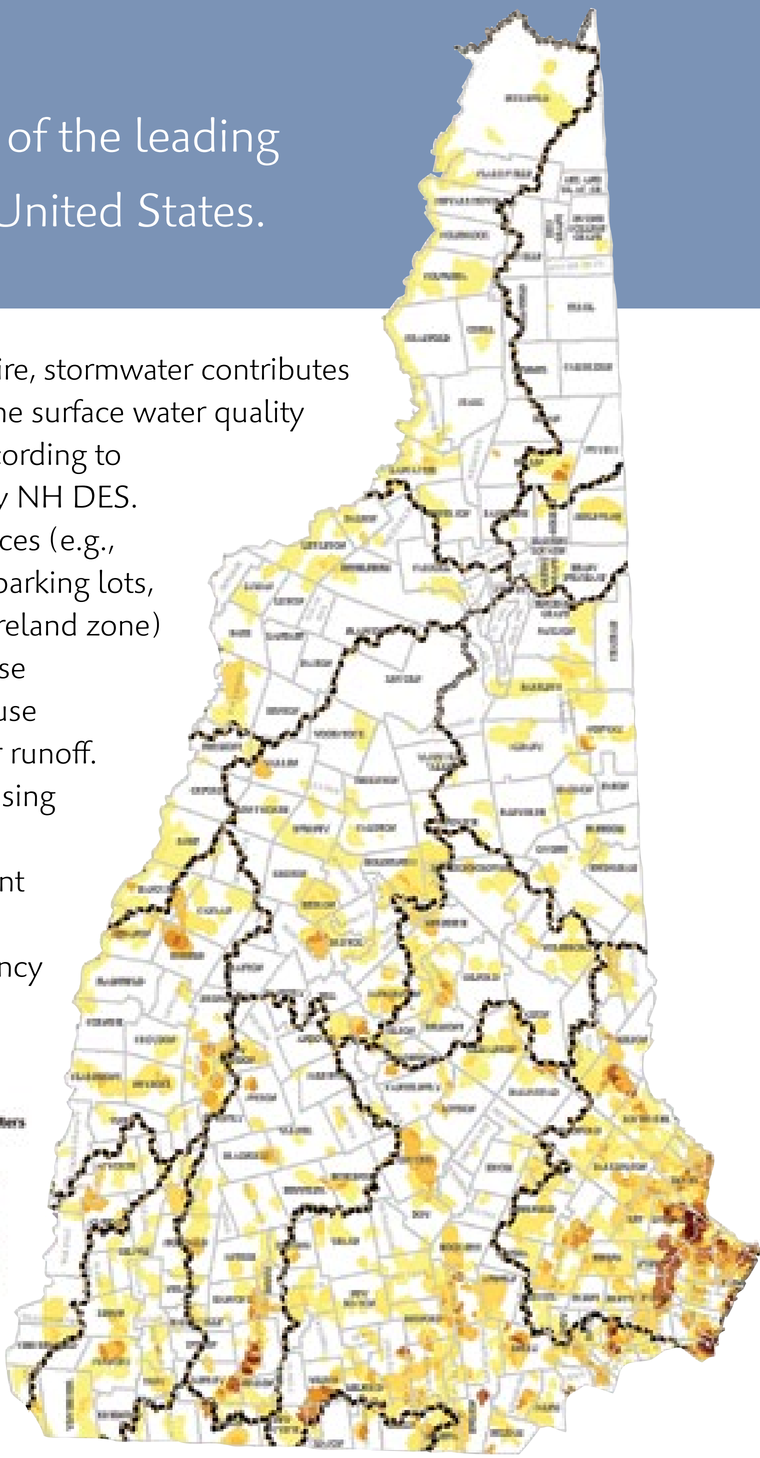
The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# O V E R V I E W

Stormwater is recognized as one of the leading causes of water pollution in the United States.



In New Hampshire, stormwater contributes to over 80% of the surface water quality impairments, according to data compiled by NH DES. Impervious surfaces (e.g., roads, rooftops, parking lots, lawns in the shoreland zone) and other land use development cause most stormwater runoff. Moreover, increasing imperviousness from development contributes to increased frequency and magnitude of flooding.




2010 surface water impairments related to stormwater with 1-mile buffer (NHDES, 2010).

Recent flooding in New Hampshire, exacerbated by imperviousness, has resulted in a tragic loss of life and millions of dollars of damage to our road and highway systems, private residences, and business properties. New regulations and action is needed on a state level in preference to and advance of new Federal regulations.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# COSTS OF STORMWATER

A preliminary estimate of the capital costs to properly manage stormwater in New Hampshire is more than $180 million. The estimate was widely acknowledged by the commission to be low. While the monetary cost of managing stormwater is high, **the potential cost of inaction is even higher.**

Without significantly changing our approach to managing stormwater, New Hampshire will likely experience even more extensive flooding and degradation of water resources that will impact drinking water quality, aquatic habitat, recreational opportunities, and tourism.

In consideration of these issues, the Stormwater Study Commission was tasked with examining the following issues related to stormwater:

- The effect of stormwater and stormwater management on water quality, water supply and quantity, terrestrial and aquatic habitat, flooding, and drought hazards
- The relationship between land use change and stormwater
- The relationships among and adequacy of federal, state, and local regulations and practices that pertain to stormwater management
- State and municipal infrastructure construction and maintenance practices
- The role of design, construction, and maintenance practices by residential, commercial, and industrial property owners
- The effects of climate change on stormwater and stormwater management

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# THE STORMWATER PROBLEM

**In contrast to a forested landscape,** which infiltrates and naturally filters most precipitation and snowmelt, impervious surfaces in a watershed prevent water from soaking into the ground.

This overland flow is stormwater, which becomes polluted when it causes erosion and picks up contaminants such as nutrients and pesticides.

Even aside from pollution issues, the volume of stormwater runoff alone causes erosion and often warms surface waters, degrading aquatic habitats and damaging fisheries. Left untreated, stormwater can severely degrade the water quality of New Hampshire's waters.

Population growth and traditional development practices typically create more impervious surfaces, and in the next 20 years New Hampshire is projected to add about 180,000 new residents. Without adequately addressing the existing statewide stormwater problems and preparing for growth through improved planning and improved stormwater management strategies, additional degradation of the State's water resources from stormwater pollution will occur.

Compounding these problems are the potential impacts of climate change, which are predicted to bring about increasing rainfall, made worse by increased development and the risk of flooding.

To adapt to these changes and to protect our water resources, the Commission recommends a number of changes to the way stormwater is managed and land is developed in New Hampshire. A watershed-based strategy that distributes the responsibility and cost of stormwater management is essential to restoring and protecting the State's water resources, drinking water supplies, aquatic habitat, and recreational opportunities. Also essential is a shift away from traditional landscape development and stormwater management practices to a low impact development (LID) approach. LID is a development and stormwater management approach that focuses on controlling stormwater through better site planning, good housekeeping, and the use of small, decentralized stormwater treatment practices such as rain gardens, vegetated swales, green roofs, and porous pavement to treat stormwater close to the source.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# ECONOMIC ADVANTAGES OF LID

## Municipalities and developers are realizing economic benefits by incorporating Low Impact Development (LID) strategies.

LID strategies, including 'green infrastructure', infiltrate stormwater back into the ground instead of allowing stormwater to run over the land surface. On a national level, substantive economic benefits for commercial development and municipal infrastructure projects are increasingly being observed when using a combination of conventional and green infrastructure for stormwater management. New York, Philadelphia, Chicago, Kansas City, and Portland, Oregon, as well as other major cities, are using green infrastructure tools as a cost-effective means of managing stormwater runoff, in addition to providing aesthetic benefits to their communities.

Green infrastructure is often viewed as more expensive. However, costs savings are frequently realized because expensive traditional infrastructural elements can be reduced or eliminated.

**rain gardens**

**porous pavement**

**bioretention systems**

Green infrastructure is often viewed as more expensive. However, cost savings are frequently realized because expensive traditional infrastructural elements, such as curbing, catch-basins, piping, ponds, and other hydraulic controls, can be reduced or eliminated. Other economic benefits include land development savings because projects require less land disturbance, a reduction in home cooling from use of natural vegetation and reduced pavement area, and higher property values. Increasing use of LID strategies will reduce the cost of development and managing stormwater as the markets develop for these products and methods.

The economic benefits of incorporating LID strategies were shown in two particular case studies in New Hampshire. These projects included a commercial and a residential development, each of which resulted in savings of 6% to 26% over the cost of permitting and construction using conventional designs, in addition to substantial environmental benefits.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# RECOMMENDATIONS

Based on research over two years of study, the Commission developed a set of recommendations, draft legislation, and findings. While the Commission recognizes the broader implications of current economic conditions, it feels that its report recommendations are necessary for improving New Hampshire's stormwater infrastructure and water quality statewide, and funding the proposed implementation process. The Commission's recommendations include the following:

## 1 Define the Term "Stormwater" in State Law

Add a definition of stormwater in state law to clarify that stormwater is not sewage or waste. Expand upon and make the stormwater definition consistent with the federal definition of 40 CFR 122.26(b)(13):

**"Stormwater means stormwater runoff, snow melt runoff, and surface runoff and drainage."**

## 2 Property Owner's Responsibility for Stormwater

Include the concept in state statute that property owners are responsible for stormwater that originates on and discharges from their property and that such stormwater discharges shall not cause or contribute to a violation of water quality standards.

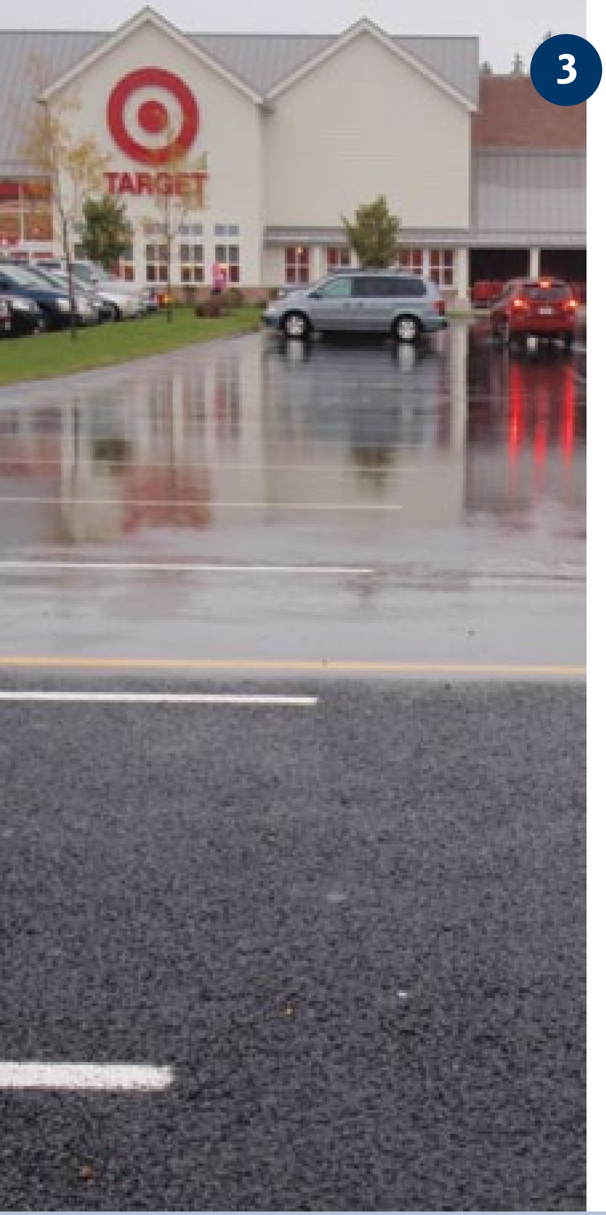
## 3 Statewide Stormwater Utility Program

Create a statewide stormwater utility program to:

1. raise revenue for stormwater best management practices ("BMPs") construction and management, and
2. create incentives, through the utility fee structure, for property owners to install and maintain stormwater BMPs. This approach eliminates the unfunded mandate problem, and charges only those responsible for stormwater runoff, rather than imposing a broad-based tax to solve the problem.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

# RECOMMENDATIONS




## 3 Statewide Stormwater Utility Program (continued)

The Commission agrees that a statewide, watershed-based stormwater utility is the best way to achieve the successful implementation of stormwater management to meet water quality standards and to provide a consistent and dedicated revenue stream for a stormwater program to be viable and self-supporting. The goal of this program would include covering the entire state of New Hampshire under a statewide stormwater utility, or groups of individual municipal or regional utilities. Individual municipalities would have three options:

**Option 1:** Create a municipal stormwater utility with incentives.

**Option 2:** Join an inter-municipal stormwater utility district.

**Option 3:** In lieu of **1** or **2**, a municipality would automatically become part of a state-administered watershed utility.

A new state-administered stormwater mitigation fund (SMF) would also be created from an impact fee on new and redevelopment projects greater than 10,000 square feet which do not meet State requirements. The SMF should include incentives for developers to promote LID land use planning and development, and would reinforce the connection between stormwater, land use, impervious coverage, and stormwater-related impacts, such as pollution and flooding. Incentives would have a fee structure based on percent impervious cover for both new and redevelopment.

## 3A Statewide Stormwater Discharge Permit

In the absence of a statewide stormwater utility, NHDES should create a fee-based statewide stormwater discharge permit for all developed properties in the state. A statewide permit program would establish statewide requirements for mitigating potential adverse impacts to water quality from stormwater and the implementation of BMPs to control stormwater from developed areas. The Commission recommends the statewide stormwater utility option over the statewide stormwater discharge permit option because it is incentives-based and has greater flexibility with respect to fee reduction and environmental protection.

The full commission report can be found at
www.nh.gov/oep/legislation/2008/hb1295/index.htm

# RECOMMENDATIONS

## 4 Municipal Authority to Regulate Stormwater

Clearly enable municipalities to regulate stormwater within their boundaries, including operation and maintenance aspects currently not authorized by enabling legislation for municipal land use planning and regulation. The Commission believes municipalities should be authorized to regulate stormwater, particularly small MS4 municipalities, so they can comply with the EPA's NPDES stormwater general permit requirements without fear of exceeding their jurisdiction under state statute.

## 5 Other Issues

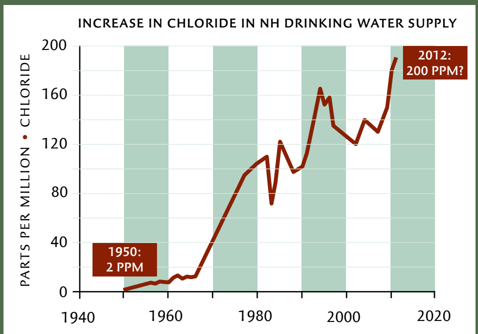
The Commission concluded some additional issues in regards to a Municipal Authority to Regulate Stormwater include:

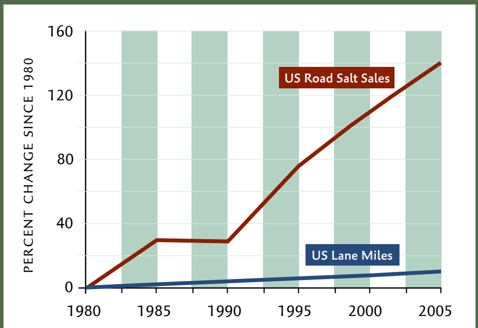
- Municipalities should be given authority to regulate stormwater originating from properties within their boundaries, even when not specifically initiated by or associated with zoning/land use approval process.
- Requirements placed upon property owners by municipal stormwater regulations should be identical, or at least very similar from one municipality to another to avoid a patchwork of different regulations and to promote watershed protection.
- Minimum performance standards for construction and maintenance of BMPs and stormwater management regulations should be developed by NHDES for adoption by municipalities.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

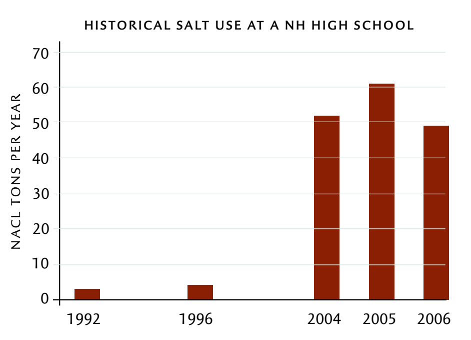
UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

# Road Salt: Problems and Solutions




*US DOT Salt Institute*




*Sassan and Kahl, 2007*

## THE PROBLEM:

### The use of road salt is having a significant negative impact on the environment, on human health, and on local economies.

**Each year, communities in colder regions use large amounts of road salt. Following its application, road salt percolates into the surrounding landscape, infiltrating soils and waters. This can cause a number of potentially harmful impacts.**

### Environmental

In addition to damaging trees and vegetation along roadways, excessive road salt use is linked to increased levels of chloride in surface and ground waters. Elevated chloride can inhibit plant growth, impair reproduction, and reduce the diversity of organisms in streams (USGS, 2009).

### Human Health

Road salt usage can contaminate our drinking water supplies with high levels of sodium and chloride. Traditionally, typical chloride background concentrations in New England high elevation lakes and unpolluted groundwater wells have been recorded between 1 to 10 parts per million (mg/L). Today it is not uncommon to find chloride concentrations in lakes, streams, and groundwater above the EPA drinking water limit of 250 mg/L.

### Economic

Water quality degradation in our lakes, rivers, and streams can negatively affect recreational and tourism revenue as well as decrease property values. Some New England cities even face federally-imposed development moratoria because of violations of water quality standards due to high salt concentrations in local streams. In addition, the escalating cost of road salt has had a financial impact on local and state budgets.

**Compounding these concerns is the fact that nationally, road salt usage has increased considerably in recent years. The use of salt at a local high school (left) is typical of increases in local salt application over the past two decades.**

This document was prepared by the NH Water Resources Research Center, 2011
by Steve Kahl, Dari Sassan, and Robert Roseen.

# THE SOLUTION:

## Use common sense methods to reduce salt pollution.

### SOLUTION #1

## Reduce the application rates of salt.

Communities can use less salt and still meet public safety requirements. For example, research in Minnesota and Canada has demonstrated that salt use can be lowered by up to 50% without a reduction in public safety.

Alternative de-icers are available, but these solutions are much more expensive and also cause a host of environmental impacts. Instead, communities should recognize that salt is a contaminant of concern while focusing on reducing the need for de-icers of any kind.

Widely-available technology such as ground-speed-controlled spreaders, underbelly plows, and GPS-equipped trucks can prevent over-use of salt, as can simple measures such as sweeping snow instead of plowing.

### SOLUTION #2

## Reduce the need for salt.

If water didn't pond and freeze on roads and sidewalks, there would be no need for salt application. Therefore, the use of landscape designs and paving materials that work to infiltrate water will greatly decrease the need for salting.

*Porous asphalt after spring rain on snow event.*

Research at UNH has shown that 75% reductions in road salt are possible using porous pavements, including porous concrete and asphalt. By using these materials, water that would otherwise freeze on the surface is instead infiltrated to the soil.

## Want to learn more?


Deacon et al, 2005. Effects of urbanization on stream quality in NH. USGS, Concord NH. **http://pubs.usgs.gov/sir/2005/5103/SIR2005-5103_report.pdf**

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Sassan, D., and J.S. Kahl, 2007. Salt loading due to private winter maintenance practices in the NH I-93 TMDL corridor study. Final report to NH DES and NH DOT.

Trowbridge, P., J.S. Kahl, D. Sassan, D. Heath, and E. Walsh, 2010. Relating road salt TMDLs to exceedances of the water quality standard for Cl in NH streams. Environ. Sci. Technol., 44:4903-4909.

UNH Stormwater Center, a research resource for innovative methods to control stormwater and its impacts. **www.unh.edu/unhsc**

US DOT Salt Institute. U.S. annual salt sales. **www.saltinstitute.org**



THIS FACTSHEET PRODUCED WITH SUPPORT FROM WRRC

April 2011

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

# Examination of Thermal Impacts from Stormwater BMPs

In a study in Durham, New Hampshire, four years of runoff temperature data were examined for a range of stormwater best management practices (BMPs) in relation to established environmental indicators.

**The stormwater BMPs examined included:**

**Conventional**

- Vegetated Swale
- Detention Pond
- Retention Pond

**Low Impact Development**

- Bioretention
- Gravel Wetland

**Manufactured Treatment Devices**

- Storm Tech Isolator Row
- ADS Infiltration System
- Hydrodynamic Separator

Surface systems that are exposed to direct sunlight have been shown to increase already elevated summer runoff temperatures, while systems that provide treatment by infiltration and filtration can moderate runoff temperatures by thermal exchange with cool subsurface materials.

The storm drain system in this study had an annual average event mean temperature (EMT) greater than the mean groundwater temperature of 47$^{o}$F that commonly feeds coldwater streams.

The examination of BMPs indicates that outflow from the larger surface systems is warmer and more variable than from parking lots. The filtration and infiltration systems cooled stormwater runoff to temperatures close to groundwater temperature.

*Top: A view of a healthy coldwater fishery. Center: Large parking areas store tremendous amounts of heat which is transferred into stormwater runoff. Bottom: Subsurface treatment systems such as gravel wetlands can buffer temperature impacts for stormwater runoff.*

The full report can be found at www.unh.edu/unhsc/thermal-impacts.

## SURFACE SYSTEMS: Thermal Extremes

The summer temperatures of the two stormwater ponds, vegetated swale, and HDS (Hydrodynamic Separators) systems, indicate that they **provide little to no reduction of high runoff temperatures.**

The Retention and Detention ponds have the largest variation in temperature. The Retention Pond is the only system to exceed both the Upper Optimum Limit (UOL) and the Lethal Limit of 80°F, however, the Detention Pond with a maximum temperature of 79.4°F comes very close.

The permanent pool of water in the Retention Pond appears to act as a heat sink during periods of extreme heat.

## FILTRATION & INFILTRATION SYSTEMS: Thermal Buffers

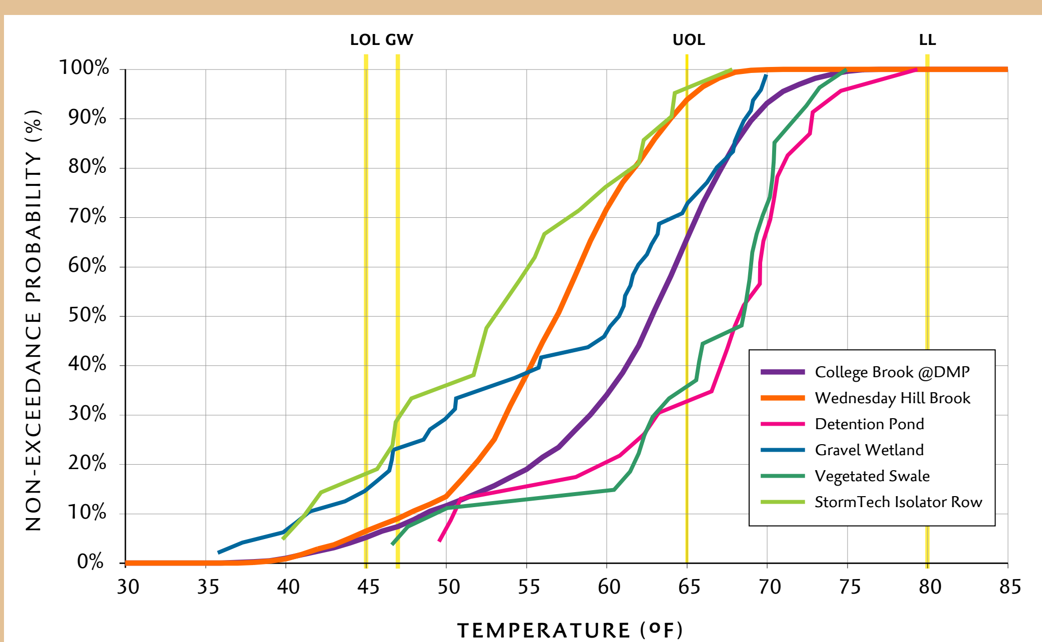
Filtration and infiltration systems **showed the strongest ability to reduce temperature variations.** The gravel wetland, the ADS (Advanced Drainage Systems™) Infiltration System, and the StormTech Isolator Row have a strong capacity to reduce temperatures of runoff.


*StormTech Isolator Row.*

The Bioretention system showed minor buffering capacity and was consistently cooler in the summer and warmer in the winter than the runoff. These filtration and infiltration systems are, on average, reducing the summer temperatures and increasing the winter temperatures of the runoff to near the average groundwater temperature of 47°F.

The two subsurface infiltration systems, ADS and STIR, are the only systems with mean July temperatures within the optimum zone of 45°F to 65°F for coldwater aquatic species. All other systems result in runoff within the stress zone for aquatic species, between 65°F and 80°F.

The Gravel Wetland, the ADS infiltration system, and the Isolator Row systems have the lowest exceedance values of the UOL at 13.0%, 5.0%, 1.5% respectively.




Comparison of summer temperatures for two streams: Wednesday Hill Brook (unimpacted) and College Brook (impacted); a wet and dry pond, a gravel wetland, and subsurface infiltration (Stormtech Isolator Row) with environmental indicators for cold water fisheries:

**Average Annual Groundwater Temperature (GW) = 47°F**

**Lower Optimum Limit (LOL) = 45°F**

**Upper Optimum Limit (UOL) = 65°F**

**Lethal Limit (LL) = 80°F**


THIS FACTSHEET PRODUCED WITH SUPPORT FROM WRRC

April 2011

# Greenland Meadows LID Case Study: Economics

## Utilizing an LID approach that featured porous asphalt and a gravel wetland, a cost-competitive drainage system was designed for a large retail development.

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H. The development is located on a 56-acre parcel and includes three, one-story retail buildings, paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, and advanced stormwater management facilities. The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres.

The development at Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

Framingham, Mass.-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, a sub-surface reservoir for rooftop runoff, and a large gravel wetland for the treatment of nitrogen. The UNH Stormwater Center provided guidance and oversight with the porous asphalt installations and supporting designs.

**This case study shows how a combination of porous asphalt and standard pavement design with a sub-surface gravel wetland was more economically feasible than a standard pavement design with a conventional sub-surface stormwater management detention system. This analysis covers some of the site-specific challenges of this development and the environmental issues that mandated the installation of its advanced LID-based stormwater management design.**

## ADDRESSING ENVIRONMENTAL ISSUES

During the initial planning stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay.

Tetra Tech Rizzo worked closely with New England Development, the UNH Stormwater Center, the New Hampshire Department of Environmental Services, and the Conservation Law Foundation (CLF) on the design of this innovative stormwater management system with LID designs.

## HYDROLOGIC CONSTRAINTS

Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, said one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. “The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration,” Potvin said. “Water did not infiltrate well during site testing and the soils were determined to not be adequate for receiving runoff.” As such, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

## ECONOMIC COMPARISONS

Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

**Conventional:** This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel sub-base and stone backfill, stormwater wetland, and supporting infrastructure.

**LID:** This option included the use of porous asphalt and standard paving, a subsurface stone reservior for rooftop runoff, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site’s stormwater prior to discharge into Pickering Brook.

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, the Conservation Law Foundation feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. “Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging,” Turner said. “We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources.”

TABLE 1: Comparison of Unit Costs for Materials for Greenland Meadows Commercial Development

| ITEM | CONVENTIONAL OPTION | LID OPTION | COST DIFFERENCE |
|---|---|---|---|
| Mobilization / Demolition | $555,500 | $555,500 | $0 |
| Site Preparation | $167,000 | $167,000 | $0 |
| Sediment / Erosion Control | $378,000 | $378,000 | $0 |
| Earthwork | $2,174,500 | $2,103,500 | –$71,000 |
| Paving | $1,843,500 | $2,727,500 | $884,000 |
| Stormwater Management | $2,751,800 | $1,008,800 | –$1,743,000 |
| Addtl Work-Related Activity (Utilities, Lighting, Water & Sanitary Sewer Service, Fencing, Landscaping, etc.) | $2,720,000 | $2,720,000 | $0 |
| **Project Total** | **$10,590,300** | **$9,660,300** | **–$930,000** |

*Costs are engineering estimates and do not represent actual contractor bids.

TABLE 2: Conventional Option Piping

| | TYPE | QUANTITY | COST |
|---|---|---|---|
| Distribution | 6 to 30-inch piping | 9,680 linear feet | $298,340 |
| Detention | 36 and 48-inch piping | 20,800 linear feet | $1,357,800 |

TABLE 3: LID Option Piping

| | TYPE | QUANTITY | COST |
|---|---|---|---|
| Distribution | 4 to 36-inch piping | 19,970 linear feet | $457,780 |
| Detention* | — | 0 | $0 |

*Costs associated with detention in the LID option were accounted for under "earthwork" in Table 1.

**Table 1** compares the total construction cost estimates for the conventional and the LID option. As shown, paving costs were estimated to be considerably more expensive (by $884,000) for the LID option because of the inclusion of the porous asphalt, subbase, and subsurface reservoir. However, the LID option was also estimated to save $71,000 in earthwork costs as well as $1,743,000 in total stormwater management costs, primarily due to piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of $930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management. **Tables 2 and 3** further break down the differences in stormwater management costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by $159,440, the LID option also completely removed the need to use large diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of $1,357,800. "The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative," Potvin said. "Utilizing void spaces in the porous asphalt subsurface reservoir to detain stormwater allowed us to design a system using significantly less large diameter pipe. This represented the most significant area of savings between each option."

## CONSERVATIVE LID DESIGN

Although the developers were familiar with the benefits of porous asphalt, Potvin said they were still concerned about the possibility of the systems clogging or failing. "The developers didn't have similar projects they could reference," he said. "For this reason, they were tentative on relying on porous asphalt alone."

To resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs: additional stormwater infrastructure including leaching catch basins. "This was a conservative 'belt and suspenders' approach to the porous asphalt design," Potvin said. "Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration."

To further alleviate concerns, a combination paving approach was utilized. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was put in near the front and more visible sections of the retail center and for the loop roads, delivery areas expected to receive truck traffic. "This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores," Potvin said.

## LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the side parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage. The subbase includes the use of a filter course of medium-grained sand, which provides an additional means of stormwater treatment. Peak flow attenuation is insured by controlling the rate at which runoff exits with an outlet control structure. Nearly the entire site is routed to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove nitrogen and other pollutants as well as mitigate the thermal impacts of stormwater.

## CURRENT CONDITIONS

As of 2011, and 3 years of operation, LID in a commercial setting is functioning well both from a durability and water quality perspective. Water quality monitoring indicates a very high level of treatment (see accompanying water quality fact sheet). The porous pavements continue to function well for both permeability and durability. They retain a high level of permeability in part due to a routine maintenance schedule. Pavement durability for passenger vehicles has been strong. Durability has been an issue for non-design loads. In parking areas designed for passenger vehicles only, on occasion, tractor trailers have used the paved areas for turning resulting in damaged pavement. Damage and repairs to porous pavements were managed similarly to standard pavements. The durability is consistent with the standard asphalt and concrete areas where damage is also observed from the demands of high use. The inadvertent use of porous pavements for non-design loads can be prevented by careful design including the use of tight turning radius, obstructions for large vehicles, and the posting of signs.

## SUMMARY

Although the use of porous asphalt and gravel wetlands in large-scale commercial development is still a relatively new application, this case study showed how LID systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits. With Greenland Meadows, an advanced LID-based stormwater design was implemented given the proximity of the development to the impaired Pickering Brook waterway. In addition to helping alleviate water quality concerns, the LID option eliminated the need to install large diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

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April 2011

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

# Greenland Meadows
# LID Case Study: Water Quality

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H.

The development is located on a 56-acre parcel and includes three one-story retail buildings (Lowe's Home Improvement, Target, and a supermarket), paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, as well as advanced stormwater management facilities.

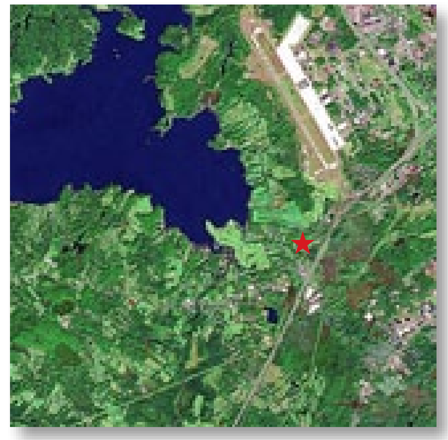
Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to this development, the project site contained an abandoned Sylvania light bulb factory with the majority of the property vegetated with grass and trees.

Framingham, Mass.-based Tetra Tech Rizzo provided site drainage engineering, which included the design of two porous asphalt installations covering a total of 4.5 acres along with a sub-surface gravel wetland. The University of New Hampshire (UNH) Stormwater Center provided design guidance, LID project review, and oversight with the LID installations.


## ADDRESSING ENVIRONMENTAL ISSUES

During the project permitting stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an impaired waterway that connects to the Great Bay. One group that was particularly interested in the project's approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.



## LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the eastern parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage for the underlying sand filter.

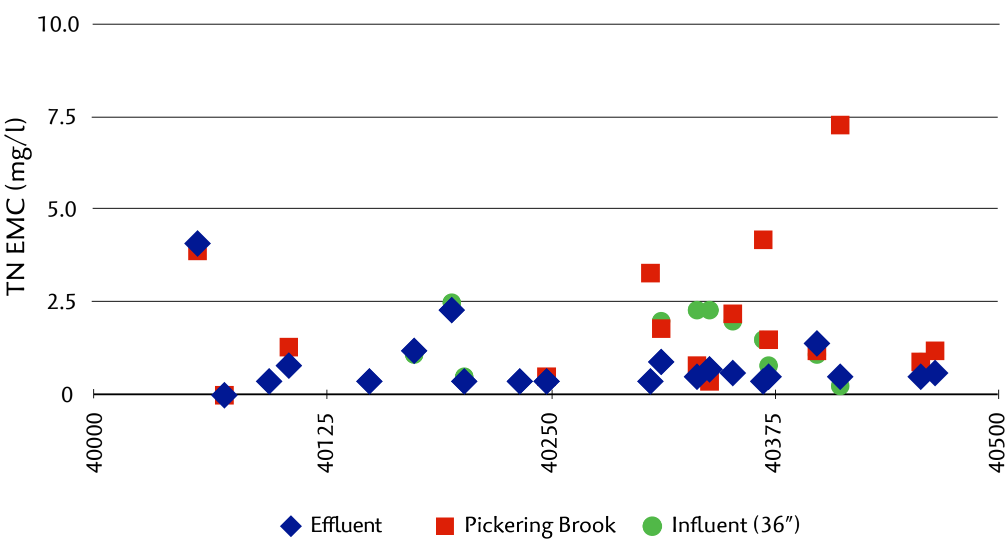
Runoff from the sand filter, which itself provides extended detention and filtration, flows through perforated underdrain pipes that converge to a large gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater.

## WATER QUALITY MONITORING

A four-phase wet weather flow monitoring program involving the use of automated samplers was implemented at the Greenland Meadows site in order to assess background conditions for Pickering Brook, evaluate stormwater quality runoff from the project site, and determine the resultant water quality of Pickering Brook downstream from Greenland Meadows. This effort is also being done to assess treatment system performance with respect to effluent concentrations (pre- and post-construction) and upstream receiving water conditions.

The first three phases of montoring were completed between July of 2007 and October 2010 and included:

- pre-construction monitoring (phase one),
- construction activity monitoring (phase two), and
- one year of post-construction monitoring (phase three).




The fourth phase is currently underway and will include four years of monitoring to determine the long-term performance of the system. Runoff constituent analyses routinely include total suspended solids (TSS), total petroleum hydrocarbons-diesel (TPH-D), total nitrogen ($NO_3$, $NO_2$, $NH_4$, TKN), and total metals (Zn). Additional analytes such as total phosphorus and ortho-phosphate have been added due to their relative importance in stormwater effluent characteristics.

| | POST-CONSTRUCTION | PRE-CONSTRUCTION | PICKERING BROOK |
|---|---|---|---|
| **Total Suspended Solids** | 3 mg/L | 5 mg/L | 53 mg/L |
| **Total Nitrogen** | 0.50 mg/L | 0.55 mg/L | 1.35 mg/L |
| **Total Phosphorus** | 0.005 mg/L | 0.05 mg/L | .145 mg/L |

## WATER QUALITY PERFORMANCE

To date, the median TSS, TN, and TP concentrations for the post-construction treated runoff are below pre-construction monitoring concentrations and significantly below concentrations found in the receiving waters of Pickering Brook. The results are depicted above.

Monitoring results indicate that the stormwater management systems are operating well and are providing a high level of treatment for runoff originating from a high contaminant load commercial site, offering significant protection to the impaired receiving waters of Pickering Brook.

Water quality results show that effluent pollutant levels leaving the site at the gravel wetland are typically at or below ambient stream concentrations across a wide range of contaminants. In addition, baseflow benefits, while not yet quantified, are observed discharging in a manner similar to shallow groundwater discharge, providing a nearly continuous source of cool, clean baseflow from the site.

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UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

# Boulder Hills, New Hampshire LID Case Study: Economics

This case study shows how utilizing an LID approach to site drainage engineering, specifically with porous asphalt installation, led to more cost-effective site and stormwater management designs.

Utilizing an LID approach that featured porous asphalt resulted in economic benefits in addition to more effective stormwater management for this residential development project.

Boulder Hills, paved in 2009, is a 24-unit active adult condominium community in Pelham, New Hampshire that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land and includes a total of 5 buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

**The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and flood zone areas. Over time, the porous asphalt placements are also anticipated to require less salt application for winter de-icing, resulting in additional economic and environmental benefits.**

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage. The University of New Hampshire (UNH) Stormwater Center advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

## DESIGN PROCESS

Initially, SFC Engineering Partnership began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., L.L.S., manager of SFC's Civil Engineering Department, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas while the upland areas were fragmented and limited," Jordan said. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations.


**Comparison of Two Designs, LID Design (top) and Conventional (bottom) for Boulder Hills, Pelham, NH (SFC, 2009).**

We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and specifically, porous asphalt, emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive. Stickville was aware of the advantages of LID and porous pavement and was interested in utilizing these measures as a possible marketing tool which could help differentiate them as green-oriented developers. SFC advised Stickville LLC to pursue this option. Jordan had attended a seminar on porous pavement presented by The UNH Stormwater Center which covered the multiple benefits of utilizing this material, including its effectiveness for being able to meet stormwater quantity and quality requirements.

"Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel," Jordan said. "In addition to controlling runoff, stormwater mitigation measures also had to be adequate in terms of treatment. Porous pavement allows us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage."

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. "The planning board was on board from the very beginning," he said. "They were very supportive of utilizing porous asphalt and recognized the many benefits of this option."

The project was paved by Pike Industries, a leader in the production of porous asphalt in the Northeast.

## ECONOMIC COMPARISONS

SFC Engineering Partnership designed two development options for the project. One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional asphalt in the roadway and driveways with porous asphalt and using subsurface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly than traditional asphalt, the engineers found that utilizing this material would result in cost savings in other areas:

- Installing porous asphalt significantly lowered the amount of drainage piping and infrastructure required.
- Using porous asphalt reduced the quantity of temporary and permanent erosion control measures needed
- Using porous asphalt cut in half the amount of rip-rap, and lowering the number of catch basins from eleven to three.
- The LID design completely eliminated the need to install curbing, outlet control structures, as well as two large stormwater detention ponds.
- There was a 1.3 acre reduction in the amount of land that would need to be disturbed, resulting in lower site preparation costs.

| ITEM | CONVENTIONAL | LOW IMPACT | DIFFERENCE |
|---|---|---|---|
| **Site Preparation** | $23,200.00 | $18,000.00 | –$5,200.00 |
| **Temp. Erosion Control** | $5,800.00 | $3,800.00 | –$2,000.00 |
| **Drainage** | $92,400.00 | $20,100.00 | –$72,300.00 |
| **Roadway** | $82,000.00 | $128,000.00 | $46,000.00 |
| **Driveways** | $19,700.00 | $30,100.00 | $10,400.00 |
| **Curbing** | $6,500.00 | $0.00 | –$6,500.00 |
| **Perm. Erosion Control** | $70,000.00 | $50,600.00 | –$19,400.00 |
| **Additional Items** | $489,700.00 | $489,700.00 | $0.00 |
| **Buildings** | $3,600,000.00 | $3,600,000.00 | $0.00 |
| **PROJECT TOTAL** | **$4,389,300.00** | **$4,340,300.00** | **–$49,000.00** |

This table shows the construction estimate cost comparisons between the conventional and the low impact development options. As shown, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most noticeably, drainage.

Overall, the LID option was calculated to save the developers $49,000 ($789,500 vs. LID cost of $740,300) or nearly 6 percent of the stormwater management costs as compared to the conventional option.

## CONCLUSIONS

Beyond its effectiveness at reducing stormwater runoff, facilitating more groundwater infiltration, and promoting water quality benefits, porous asphalt was shown in this case study to be capable of bringing positive economic results. Primarily, cost savings were achieved in the Boulder Hills site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized. Compared to a conventional development plan, an option utilizing LID featuring porous asphalt was shown in this example to be more economically feasible.

Overall, the LID option was calculated to save the developers $49,000, or nearly 6 percent of the stormwater management costs, as compared to the conventional option.

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# USGS Summer Intern Program

None.

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 NCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 14 | 0 | 0 | 1 | 15 |
| **Masters** | 8 | 0 | 0 | 1 | 9 |
| **Ph.D.** | 1 | 0 | 0 | 0 | 1 |
| **Post-Doc.** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 23 | 0 | 0 | 2 | 25 |

# Notable Awards and Achievements

In 2009, a conference focused on the Lamprey River watershed (titled "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water") was co-sponsored by the NH WRRC. The conference highlighted the need for watershed wide land use planning and decision making and gave momentum to an earlier idea that the entire Lamprey should be nominated into the NH Rivers Management and Protection Program (RMPP). Currently, the Lamprey only has 17.5 km (in Durham and Lee) of the 78 km mainstem reach designated into the NH RMPP. Following the conference, a Lamprey River Nomination Committee (LRNC) was formed and in June 2010, a nomination package was submitted by the LRNC, LRWA and the LRAC to the NH Department of Environmental Services (DES) to designate the remaining portions of the Lamprey River and all its major tributaries into the NH RMPP. This nomination represented a total of 141 river km and captured 14 towns, two counties and 3 regional planning commissions that all share the Lamprey River watershed. This nomination package was the most complex nomination that the NH State Rivers Management Committee had ever seen and the first one to push for a watershed approach (as opposed to nominating a segment of a river or the main stem of a river, but not its tributaries). The committee was extremely impressed that elected officials from all of the watershed towns wrote letters of support and by the number and variety of individual support letters. The NH State Rivers Management Committee voted to approve the nomination and the resulting House Bill has passed in both the House and the Senate in 2011. The Governor is expected to sign this bill into law this summer. At that point, a watershed wide local advisory committee will be formed and the designation will give the Lamprey watershed preferential eligibility over non-designated rivers for state funding and technical resources. Conversations about the structure of this watershed wide committee have begun and the NH WRRC has been part of these conversations. The concept of land use decision-making and natural resource management from a watershed perspective instead of solely by political boundaries with no regard to upstream or downstream neighbors is one that is gaining traction in southeast NH and is an outcome that the NH WRRC (as well as other organizations) is very proud of.

Results from long-term water quality monitoring in the LHRO supported by the project “Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds” have helped leverage funding for additional research on nitrogen cycling in NH’s coastal watersheds. Because of the significant interest in nitrogen loading to the Great Bay estuary, existing information on the spatial and temporal variability of nitrogen concentrations in the LRHO that are driven by population growth and land use change and the relationships that the NH WRRC has formed with various stakeholders in NH, the NH WRRC faculty and staff received a $600,000 grant from NOAA and the National Estuarine Research Reserve System (NERRS). The grant is a collaborative science project to study nitrogen sources and transport pathways in watersheds of the Great Bay estuarine system. The project involves a significant amount of integration and collaboration with local stakeholders throughout the entire research process to ensure that the scientific results will be useful to local managers and decision makers. This new project complements the information transfer goals of the NH WRRC.