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Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds 2009

New Hampshire Water Resources Research Center (NH WRRC)

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 (2000 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. This could occur through the development, testing and refinement of predictive models, accurately assessing the impacts of watershed management practices, and potentially early warning of dramatic changes to surface water quality in the region resulting from rapid development.

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.

Water samples are collected from the following sub-projects.

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. Samples from 3 sites are collected monthly throughout the year. 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 Lab at UNH.

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 10+ sampling sites. Three stream sites (the Lamprey River, the North River and Wednesday Hill Brook) remained at a weekly and major storm event sampling frequency.

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 stream water and precipitation samples are collected by UNH staff and/or students and analyzed by the Water Quality Analysis Lab at UNH.

Groundwater Chemistry and nutrient dynamics.

Monthly ground water well samples have been collected from the James Farm and L1 well fields in Lee, New Hampshire within the Lamprey River watershed. 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 Water Quality Analysis Lab 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 selected samples by the NH WRRC and WQAL. WRRC staff will assist in data interpretation.

Methods, Procedures and Facilities

Samples 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 Water Quality Analysis Lab of the WRRC on the campus of UNH, Durham, NH.

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, Jeffrey Merriam was the Laboratory Manager until January 2010 and now Jody Potter manages the WQAL. 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.

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

Previous work on College Brook in the early 1990's (McDowell unpublished) shows that the UNH campus had a severe impact on water quality and was negatively affecting stream biota and the integrity of downstream ecosystems. By any yardstick, campus operations could not be considered sustainable. There was clear evidence that the UNH incinerator was causing excessive organic matter loading, resulting in high biochemical oxygen demand (BOD) and low dissolved oxygen (DO) in stream water. Since the incinerator has been closed, BOD and DO are no longer at levels detrimental to in-stream biota. Our monthly sampling regime was scaled back beginning October 2006 to the 3 stations that have historically shown the greatest changes, and we eliminated the BOD and TSS measurements (both which change little over the reach since the incinerator was closed). The most downstream sampling location is now closer to where the stream empties into the Oyster River in an effort to better quantify inputs to the Great Bay estuary. We also added a 4th site on Pettee Brook in Durham, NH in May 2008 that was previously sampled. Analyses of samples collected through 2008 have been completed and we are in the process of analyzing 2009 samples and updating our website: http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

Dissolved Oxygen (DO) in the brook is lower at the upstream stations. This difference is presumably due to hydrologic properties of the upstream sampling location which resembles a wetland (i.e. slow flow, higher organic matter and dissolved organic carbon). DO increases downstream as flow becomes faster and re-aeration higher.

Data from 2000-2008 indicate that the steam is strongly impacted by road salt at its origin, which is essentially a road-side ditch leading to a wetland area. 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.

Since Great Bay and Little Bay are "impaired" by elevated nitrogen, nitrogen (especially in the form of nitrate) exported from College Brook and into Little Bay is cause for concern. College Brook becomes more aerated as it moves downstream and ammonium decreases as nitrate increases indicating that nitrification is occurring in the stream channel, however the mass of each and an increase in total nitrogen indicates that there are additional sources of nitrate to the stream. 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 algal blooms and loss of Eelgrass have become a concern in Great Bay and Little Bay.

Lamprey River Watershed

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. We have continued to sample 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) on a weekly basis and 13 other stations throughout the watershed on a monthly basis. Analyses of samples collected through 2009 have been completed and we have updated 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. We continue to collect precipitation at Thompson Farm (UNH property located in Durham, NH) to document nitrogen inputs to the basin and this data is posted on the AIRMAP website (http://airmap.unh.edu/).

Results of stream chemistry to date show a significant increase in nitrate concentrations over time (Water Years (WY) 2000-2009) 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 (2004-2009). 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.

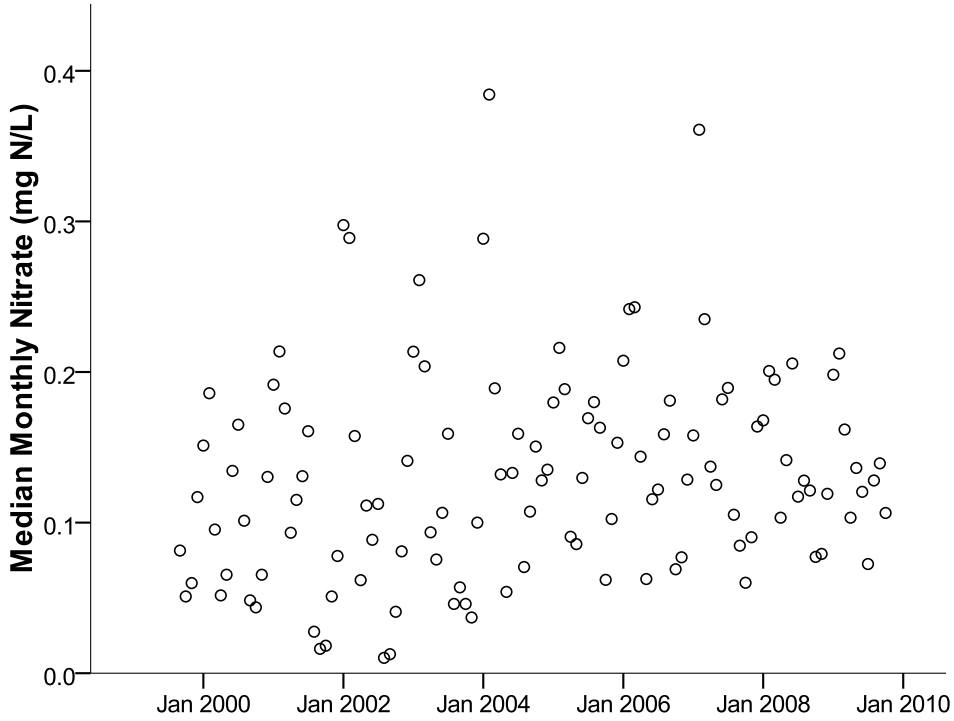

Figure 1. Median monthly nitrate concentrations over time in the Lamprey River at the USGS gauging station in Durham, NH.

When we combine our specific conductance data (2002 – 2009) 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.

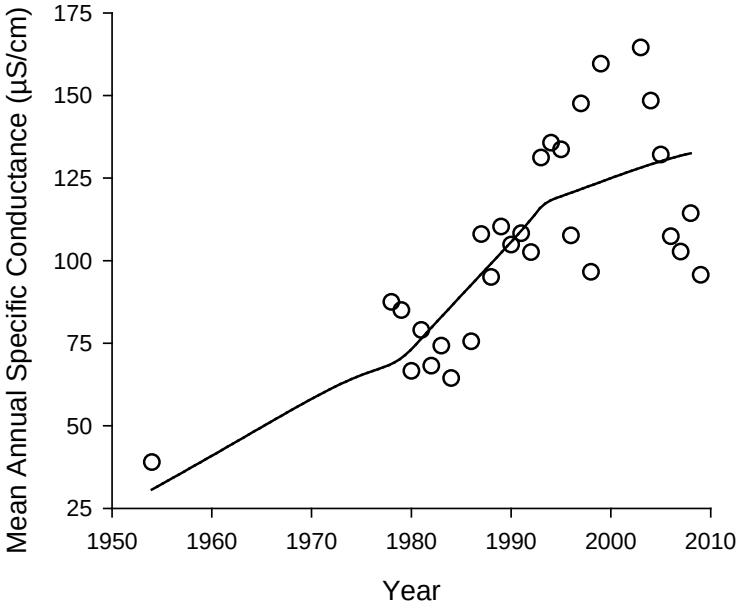

Figure 2. Mean annual specific conductance in the Lamprey River at the USGS gauging station in Durham, NH. (Daley et al. 2009).

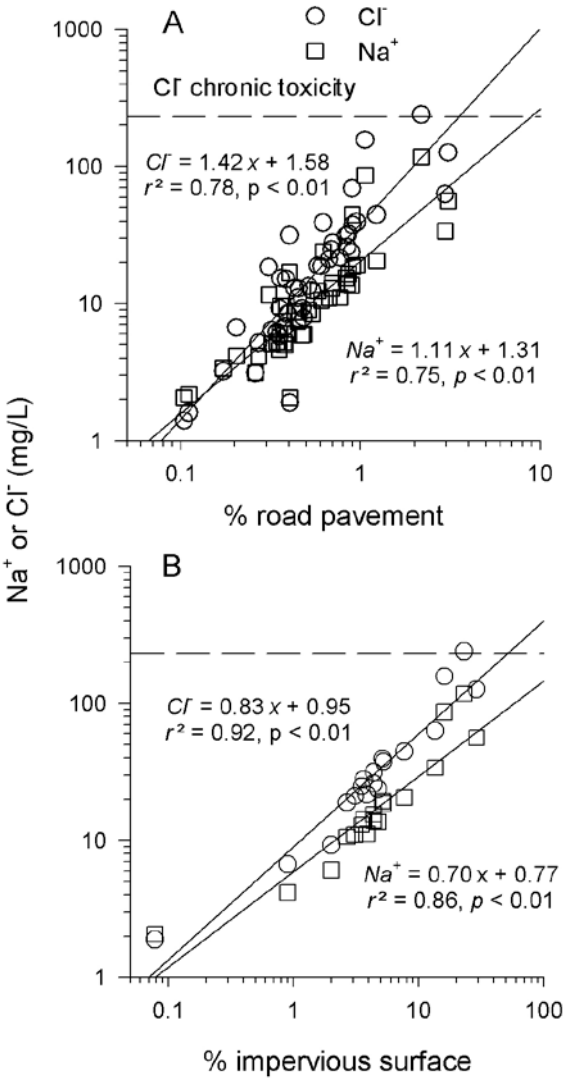

Figure 3. Relationship between both average concentrations of Na^+ (squares) and Cl^- (circles) and a.) % road pavement (College Brook, Lamprey and Ossipee sub-basins) and b.) % impervious surfaces (College Brook and Lamprey sub-basins only) (Daley et al. 2009).

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.

Groundwater Chemistry and Nutrient Dynamics.

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 from 2004-2008 with

the exception of one well (L1A-21) where nitrate increased 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.

Ossipee Watershed

Collaboration with the Green Mountain Conservation Group and their sampling of the Ossipee River watershed has continued to be beneficial. Volunteers sampled streams within the watershed every 2 weeks from April through October, and monthly winter sampling occurs at 7 sites, with approximately 340 samples collected from 30 sampling locations. 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.

Publications:

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

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.

McDowell, W.H., M.L. Daley, B. Sive and R. Talbot. *In Preparation*. Factors controlling atmospheric deposition at a coastal suburban site. Journal of Geophysical Research (Atmospheres). 2010.

Conference Proceedings & Abstracts:

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.

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.

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.

Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.

McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Georgia. Athens, GA. October, 2009.

McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Reading, United Kingdom. November, 2009.

Information Transfer:

Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Southern New Hampshire Planning Commission Meeting. Manchester, NH. April 2009.

Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Rockingham Planning Commission and Strafford Regional Planning Commission special joint meeting. Exeter, NH. May 2009.

Daley, M.L. 2009. Water Quality Research in the Lamprey River Watershed: Road Salt and Nitrogen. Lamprey River Outreach Conference: “Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes $ense For Protecting Our Water". Nottingham, NH. June 2009.

Daley, M.L. 2009. Current water quality research in the Lamprey River watershed. Lamprey River Advisory Committee. Durham, NH. October 2009.

Daley, M.L. 2009. Salt Research, Impacts to Surface & Ground Water. Road Salt BMPs for the Ossipee Watershed. Chocorua, NH. November 2009.

Daley, M.L. 2010. Nitrogen Saturation in the Highly Retentive Lamprey River Watershed? Annual Lamprey River Science Symposium. Durham, NH. January 2010.

Dunlap, K. 2010. Seasonal Nitrate Dynamics in a New Hampshire Agricultural Stream. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

McDowell, W.H. 2010. Overview of the Lamprey River Hydrologic Observatory Objectives. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

Presentations made by the Green Mountain Conservation Group staff March 2009 - February 2010.

March 7th Smart About Water Workshop with RCAP @ Tin Mountain
March 22nd Wild & Scenic Environmental Film Festival – WQM booth & info
March 27th Ossipee Aquifer Steering Committee Meeting
April 2nd Drinking Water Tool Kit & NH Water Primer w/ NH DES in Ossipee
April 11th WQM Volunteer Training
April 13th Tamworth Conservation Commission & Planning Board WQM Presentation
April 17th Ossipee Aquifer Steering Committee Meeting
April 22nd WQM Presentation for Calumet Saving the Planet Retreat
May 7th Regional Presentation for WQM with LRPC, Dr. Newton, NH DES & RCAP in Madison
May 8th WQM & Soils Workshop with UNH CE
June 3rd Camp Director Meeting & Presentation
June 26th Ossipee Aquifer Steering Committee Meeting
July 1, 2, 15, 16 Volunteer Lake Assessment Program & WQ Programs with Camps Cody, Huckins, Robin Hood, Marist & Danforth Bay
June 30, July 14, 28, Aug. 11 WQ Programs/Ossipee Lake & Tributary testing with Camp Calumet
July 24 Ossipee Aquifer Steering Committee Meeting
August 1 Household Hazardous Waste Day WQ Table in Ossipee
August 12 VLAP & WQM Presentation with NH DES in Ossipee
August 13 WQ & Shoreline Protection BMPs Workshop in Tamworth
August 24 VBAP & WQM Volunteer Training
Sept. 11 Ossipee Aquifer Steering Committee Meeting
Sept 1-18 VBAP Programs & WQM daily with Ossipee Central School, Tamworth Learning Circles, Sandwich Elementary School & Brett School in Tamworth
Oct. 22nd Ossipee Aquifer Steering Committee Meeting
Oct 18th Lakeview Celebration w/ WQM GIS presentation
November 5th Regional Road Salt Workshop in Chocorua
November 18th Community School Presentation in Tamworth of VBAP & WQ
January 8th Ossipee Aquifer Steering Committee Meeting
January 24th Annual Meeting with WQ presentation in Freedom
February 5th Ossipee Aquifer Steering Committee Meeting

Number of students supported:

Four Master's students (Kate Dunlap, Michelle Galvin, Amanda Hope and Emily DiFranco) and four undergraduate hourly employees (Daniella Williams, Valerie Schoepfer, Taylor Langkau and Liz Holden)