MA Water Resources Research Center

Annual Report

2017-2018

March 1, 2017 – June 30, 2018

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Cover photo: Eagleville Pond, Orange MA
by MF Hatte

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Introduction

This report covers the period March 1, 2017 to June 30, 2018, the 53rd year of the Massachusetts Water Resources Research Center (WRRC). The Center was under the direction of Dr. Paula Rees, who held joint appointments as Director of the WRRC and Director of Diversity Programs for the College of Engineering at the University of Massachusetts Amherst (UMass) until September 1, 2017, when she resigned her position and was replaced by Marie-Françoise Hatte as Interim Director.

The goals of the Massachusetts Water Resources Research Center are to address water resource needs of the Commonwealth and New England through research, creative partnerships, and information transfer. Through the USGS 104B program, WRRC aims to encourage new faculty as well as students to study water resources issues.

In fiscal year 2017, three new research projects were supported through the USGS 104B Program:

- "**The Massachusetts Isoscape Project: A tool for understanding hydrologic processes and water resource sustainability**" was led by Dr. David Boutt of UMass Amherst. ***Boutt'****s* research project built on a regional-scale monthly record of the stable isotopic composition of surface and ground water in Massachusetts with the goal of assessing constraints on the seasonality of recharge, ground water residence times, sources of water to streams, and understanding the sensitivity of stream baseflow to seasonal hydrologic variability.
- "**Addressing water supply issues through the modeling, analysis and optimization of renewable hybrid systems for water and electricity production**" was headed by Dr. Jon McGowan at UMass Amherst. ***McGowans'****s* project developed a conceptual model for a solar hybrid energy-desalination system capable of producing fresh water and electricity.
- Dr. Baoshan Xing at UMass Amherst worked on the "**Development of an in-field method for detecting engineered nanoparticles and their transformations in aquatic environments using surface-enhanced Raman spectroscopy**." ***Xing***'s project received a no-cost extension to develop a new field method to detect low levels of nanoparticles and track their transformations in the aquatic environment.

The **Acid Rain Monitoring Project**, led by WRRC Associate Director Marie-Françoise Hatte, was continued for another year in order to document trends in surface water acidification. The **Blackstone River Water Quality Modeling** project also continued, as did the projects entitled **Development of Pilot Extreme Flood Vulnerability Assessment Protocols under Present and Future Climatic Conditions for Roadway Stream Crossing Structures within the Deerfield River Watershed, Massachusetts***,* and **Advancing agricultural water security and resilience under nonstationarity and uncertainty: A conversation among researchers, extension, and stakeholders on the evolving roles of blue, green and grey water***.*

A new project, **MassDEP-UMass Data Sharing Collaborative**, started in early 2018 to assist the Massachusetts Department of Environmental Protection make use of water quality monitoring data collected by external groups.

The **North East Graduate Student Water Symposium 2017** was held in September 2017 to offer students an opportunity to present their water related research and meet other researchers.

Progress results for each project are summarized for the reporting year in the following sections.

Research Program

1. The Massachusetts Isoscape Project: A tool for understanding hydrologic processes and water resource sustainability

Principal Investigators: David Boutt
Start Date: March 1, 2017
End Date: February 28, 2018
Funding Source: 104B (2017MA465B)
Reporting Period: 3/1/2017 – 2/28/2018
Research Category: Ground-water Flow and Transport

Problem and Research Objectives:
Surface and ground water in the Northeast US are heavily impacted by intense land-use changes, urbanization (Weiskel et al., 2007), and climatic changes (Hodgkins et al., 2002; Hodgkins et al., 2003, Hunntington et al., 2004; Hayhoe et al., 2007). More emphasis is being placed on water suppliers, stakeholders, and environmental managers to assess water quantity and water quality with increasing confidence intervals for sustainable management (e.g. minimum streamflow regulations). However, an over-reliance on physical measures of hydrologic behavior (such as streamflow and water table elevation) that do not uniquely assess the connectedness, residence time, and age distribution of surface and ground waters (McDonnell et al., 2010) cloud decision-making and introduce significant uncertainty. Recently, advances in theory and instrumentation have allowed the use of geochemical tracers (such as H_2O, D and ^{18}O) in combination with physical data to resolve discrepancies in measurements and reduce uncertainty in system conceptualization (IAEA, 2000). These tools and techniques are not yet been widely available to water suppliers.

The interpretation of stable isotope data in isotope hydrology relies on accurate, high-precision measurements of H and O isotopes of water samples (Brand et al 2009; Wassenaar et al 2012). With the advent of low-cost and high-throughput liquid water isotope analyzers based on cavity ring-down spectroscopy (CRDS, Berden et al 2000), hydrologic scientists can fully utilize these tools for assessment and management decisions with greater certainty. The applicability of stable isotopic tracers rely on robust understanding of the seasonal behavior of precipitation and the characterization of the isotopic behavior of surface and ground water isotopes.

Methodology, Principal Findings, and Significance:
Database and sample Collection:

With support through the 104B program we have continued to populate our isotope database. The current database consists of 3000 precipitation measurements across 14 stations, 4500 surface water measurements across 300 sites, and 3000 groundwater samples from 300 wells screened in overburden and bedrock wells. During the summer of 2017 alone we collected 1000 new samples of surface water and groundwater. A map of new sample locations is presented in Figure 2. Significant effort was put into developing a network of collaborators at local watershed organizations.

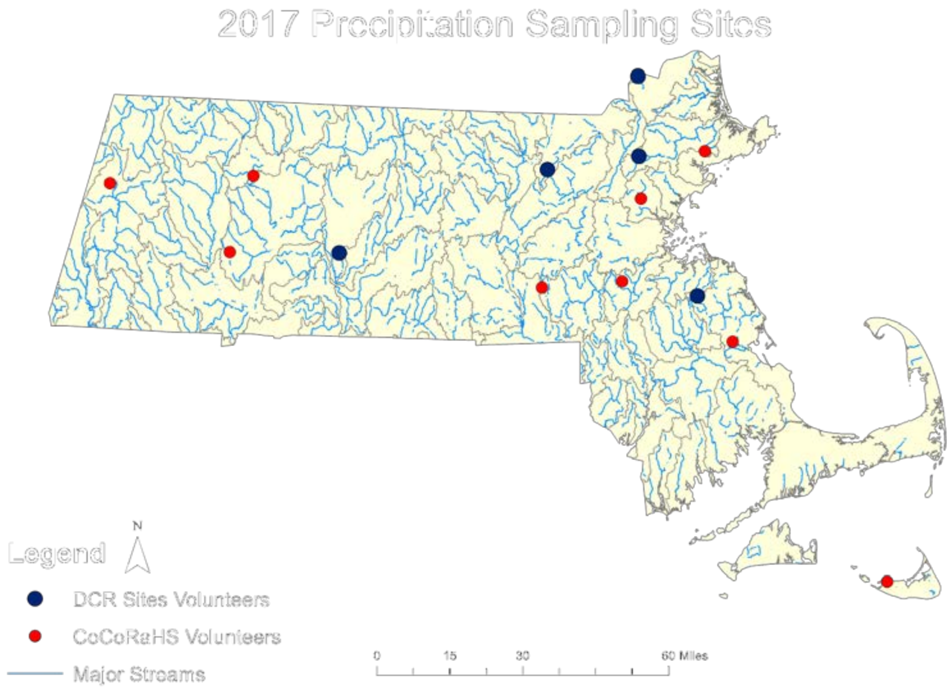


Figure 1: Precipitation sampling localities across the state of Massachusetts. Precipitation samples are composited bi-weekly at 14 proposed locations

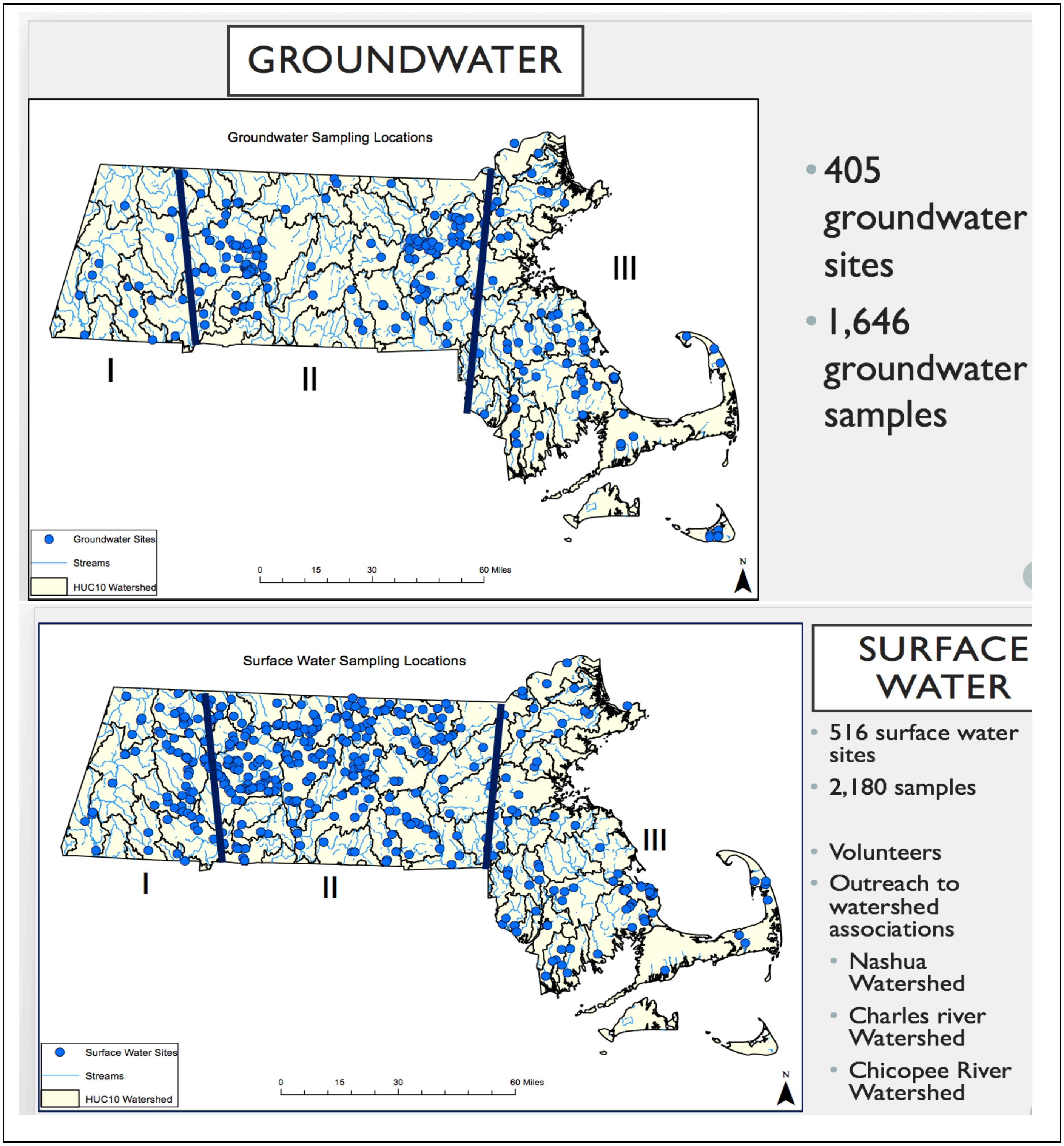
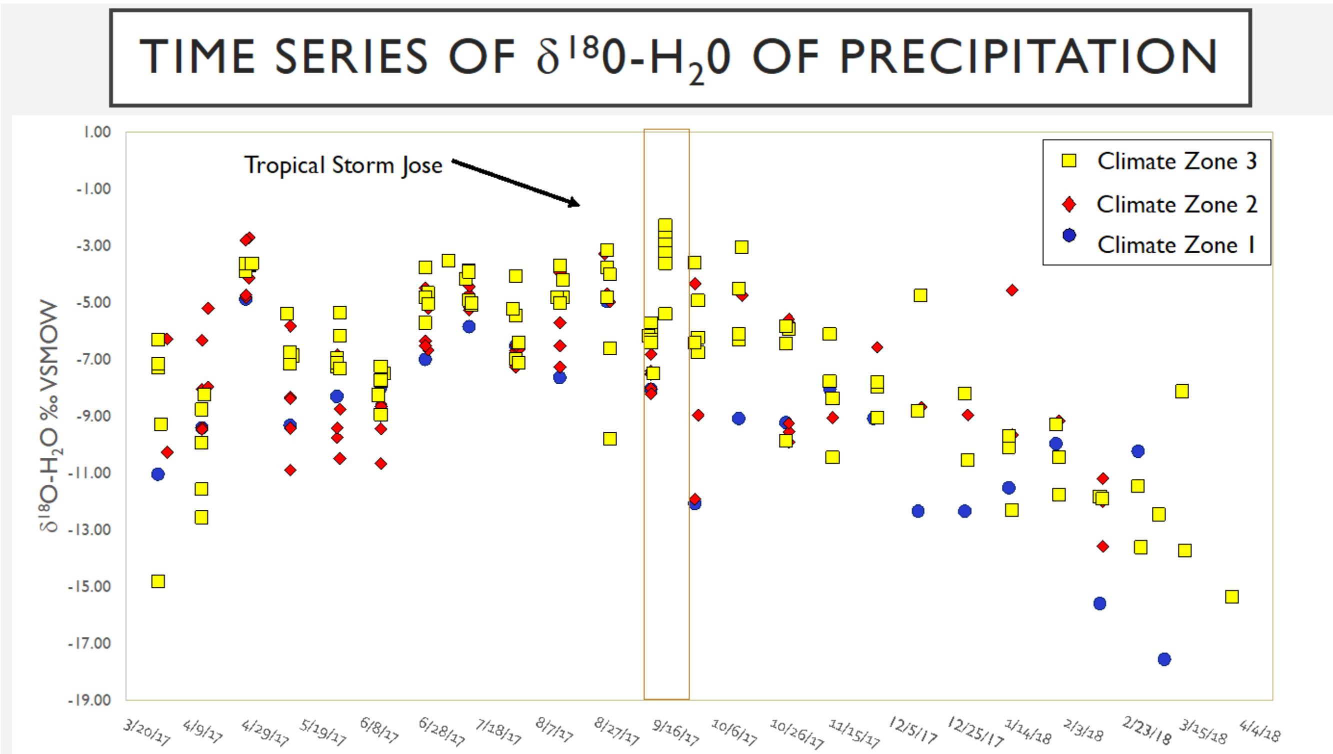


Figure 2: New sample locations in 2017

Results:


TIME SERIES OF δ18O-H2O OF PRECIPITATION
Tropical Storm Jose
Climate Zone 3
Climate Zone 2
Climate Zone 1
δ18O-H2O ‰ VSMOW
1.00
-1.00
-3.00
-5.00
-7.00
-9.00
-11.00
-13.00
-15.00
-17.00
-19.00
3/20/17
4/9/17
4/29/17
5/19/17
6/8/17
6/28/17
7/18/17
8/7/17
8/27/17
9/16/17
10/6/17
10/26/17
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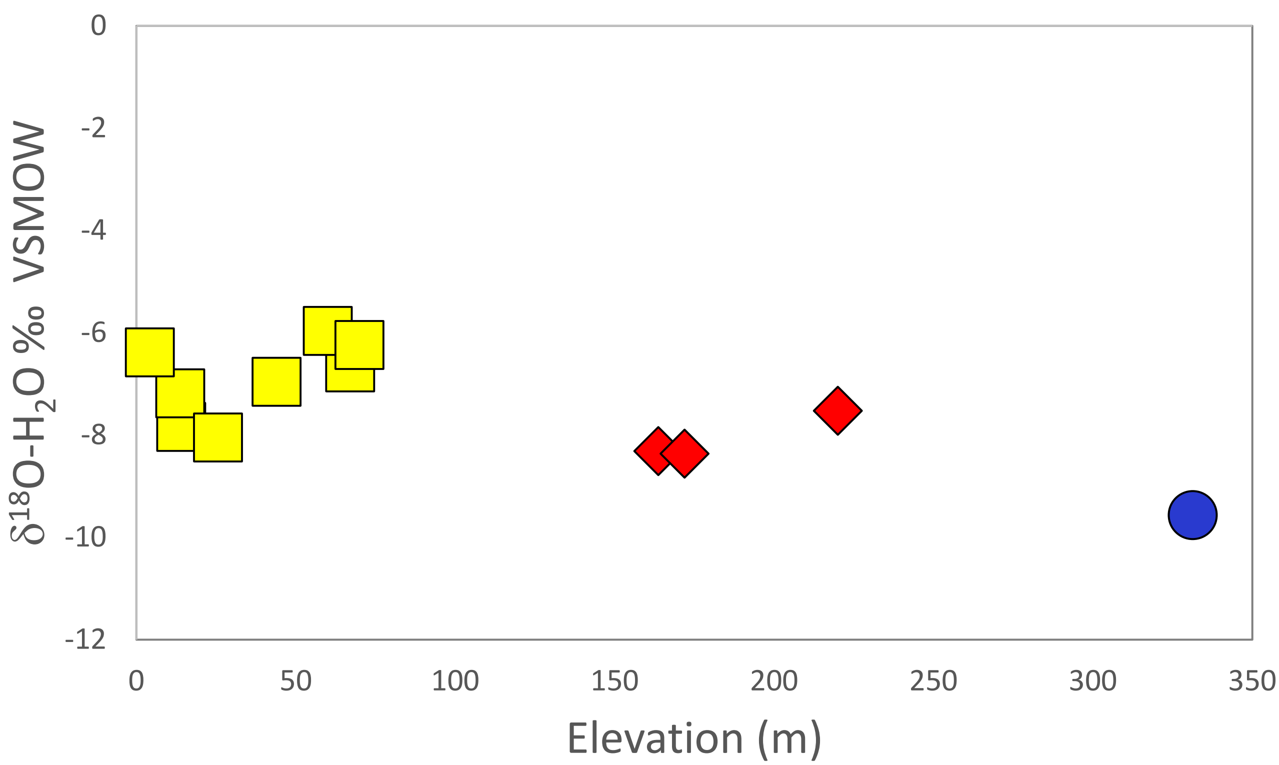
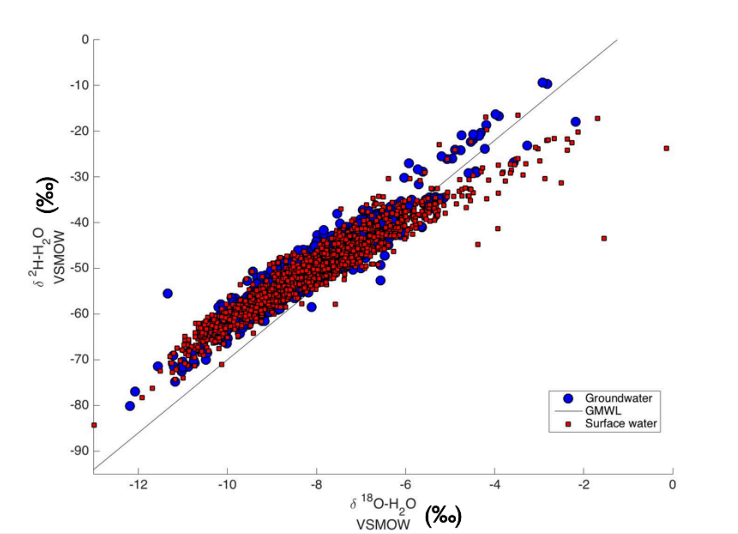
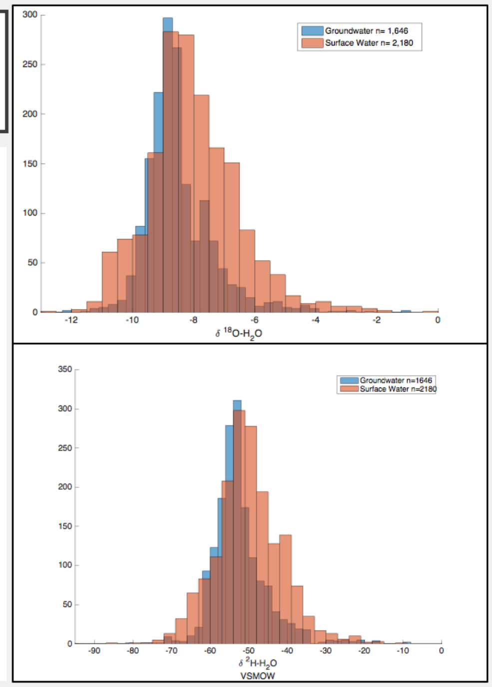
3/15/18
4/4/18


δ18O-H2O ‰ VSMOW
0
-2
-4
-6
-8
-10
-12
0
50
100
150
200
250
300
350
Elevation (m)

GROUNDWATER VS. SURFACE WATER





Summary:

1. Elevation and latitude plays a role in isotopic variability, waters at a high elevation will be isotopically depleted compared to waters located at lower elevations.
2. Topographic location in terms of climate zone affects the isotopic composition of surface water, groundwater and meteoric waters.
3. When categorized by aquifer type, each aquifer has varying isotopic compositions.
4. Type of surface water carries its own isotopic signature.

CURRENT FINDINGS

- Groundwater
  - $\delta^{18}O$-H_2O ranges from -12‰ to -1‰
  - $\delta^{2}H$-H_2O ranges from -80 ‰ to 11‰
  - Aquifers have unique isotopic compositions
  - Decreasing trend in elevation and latitude
- Surface Water
  - $\delta^{18}O$-H_2O ranges from -13‰ to1‰
  - $\delta^{2}H$-H_2O ranges from -92 ‰ to -11‰
  - Correlation between elevation, catchment size
- Precipitation
  - Precipitation type has unique isotopic compositions
  - Current results indicate a difference in rain fall location
  - Continued analyses will present more findings

Student Support:
Shawna LaPlante, BS Environmental Science 2018 UMass-Amherst.
Kaleb Jones, BS Geology 2019 UMass-Amherst
Mary Lagunowich, BS Earth Systems 2018 UMass-Amherst

Publications and Conference Presentations:

Belaval, Marcel; Boutt, David; Schroeder, Timothy; Ryan, Peter; J. Kim, Jonathan, 2018, Characterizing the groundwater-surface water system in a PFOA-contaminated fractured rock aquifer using radon and stable isotopes, 53rd Annual GSA Northeastern Section Meeting - 2018, DOI: 10.1130/abs/2018NE-310939.

Cole, A.; Boutt, D., 2017, Spatial and Temporal Mapping of Distributed Surface and Groundwater Stable Isotopes Enables New insights into Hydrologic Processes Operating at the Catchment Scale, American Geophysical Union, Fall Meeting 2017, abstract #H13G-1483

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2. Addressing water supply issues through the modeling, analysis, and optimization of renewable hybrid systems for water and electricity production

Principal Investigators: Jon McGowan
Start Date: March 1. 2017
End Date: February 28, 2018
Funding Source: 104B (2017MA463B)
Reporting Period: 3/1/2017 – 2/28/2018
Research Category: Engineering

Problem and Research Objectives:
In recent decades, growth in the world population, economic and living standards have been responsible for substantial increases in global energy consumption. Moreover, exploitation of fossil fuels to supply energy demands has led to global climate change, which is expected to have far-reaching and long-lasting consequences on the planet. These factors have motivated the importance and necessity of developing more efficient ways for energy conservation and generation that avoid the production of greenhouse gases that contribute to climate change. One method to address these issues is to develop combined production such as cogeneration, trigeneration, and multigeneration for simultaneous production of electricity, cooling, heating, fresh water, etc. using renewable energy sources such as solar. By using hybrid systems with multiple output products, the overall efficiency of the system can be increased over a single output system, and by using renewable sources, carbon and other harmful emissions are avoided.

The overall objective of this project is to propose, model, simulate, and optimize several integrated systems that can efficiently, renewably, sustainably, and economically address different demands including power, fresh water, cooling, and heating for both residential and industrial applications. Concentrated solar tower is used as a prime or supplementary mover for all proposed configurations and cycles, enabling a high temperature thermal heat source to generate electricity and provide thermal requirements of other systems.

Concentrated solar tower technology has attracted more interests in recent years due to its capability to provide high temperature thermal energy leading to a higher thermodynamic efficiency. Several solar tower technologies have been proposed that employ different design receivers and utilize different heat transfer fluids including molten salt, air, water/steam, CO_2, liquid metals and solid particles. In this project, however, the main focus is on utilizing air and CO_2 as working fluid in the solar receiver.

A main common aspect of all solar tower technologies is the utilization of several mirrors (heliostats) to reflect and concentrate direct normal irradiation (DNI) to a receiver mounted on the top of a tower. The heliostat field performance is described based on the optical efficiency, which is the ratio of the net energy reflected by heliostat field and absorbed by the receiver to the incident energy on the heliostat field.

A significant part of the required investment cost for developing solar tower technologies is attributed to heliostat field. Therefore, optimal design of heliostat field is of high significance to improve the optical efficiency of the field and overall performance of the system and reduce the investment cost.

This project differs from previous investigations and brings new contributions to the research community in several different key aspects. The novelty of this research mainly lies in the development of several novel utility scales cogeneration, trigeneration and multigeneration configurations using the above sub-systems that satisfy the most important demands in both the residential sector as well as industrial sector such as food, textile, chemical, oil, etc. Also, an efficient multi-objective optimization approach will be employed to introduce the most suitable configurations for each sector to reach higher profitability of the plant, higher efficiency, reliability and sustainability of the system as well as lower environmental impacts. Furthermore, another novel aspect of the project is the development of control schemes and strategies that can meet all the operational, reliability and safety requirements of the hybrid system operating autonomously throughout the year. This makes the developed hybrid system and mathematical model realistic and applicable for both sectors for year-round utilization. Finally, a number of case studies in the United States and worldwide will be developed and the optimization process and control scheme will be developed based on the possible electricity, fresh water, cooling and heating demands of each case study.

One of the important aspects to integrate power cycles with other cycles such as cooling, heating, and desalination for trigeneration and multigeneration purposes, is that integration should be accomplished in such a way that it minimizes the impact on the power production. This consideration is relevant for all configurations and systems in this project.

The objectives of this project include:

Specific objective 1: Create several computational codes that can simulate different integrated system based on the concentrated solar tower as a prime mover for the purpose of multigeneration of electricity, fresh water, cooling and heating. The integration of concentrated solar tower to the high-temperature, high-efficiency power cycles such as a Rankine or Brayton combined cycle is modeled. By using a combined cycle, a system is modeled that can reach higher operating temperatures and produce more electricity than the case of the Rankine cycle.

Specific objective 2: Propose and evaluate different thermodynamic configurations using the above mentioned sub-systems that can be applied to the residential and industrial sectors. For this aim, the developed computational codes simulate utility scale multigeneration systems at different scales. Then the plant economic performance is assessed by performing a detailed economic evaluation in terms of cost analysis, payback period and other important economic factors. In economic evaluation, the variation of cost is investigated due to modifications in the plant configuration, especially high temperature cycles, desalination units and refrigeration systems.

Specific objective 3: Via sensitivity analyses, determine and introduce the most important design parameters that influence the performance and economic of each proposed integrated configuration.

Specific objective 4: Apply an efficient multi-objective optimization approach to optimize each proposed configuration and introduce the most suitable configurations. The optimization approach enables a trade-off between higher performance, lower capital investment as well as the cost of generation of electricity, fresh water, cooling and heating, environmental concerns and sustainability.

Specific objective 5: Compare the performance of optimized hybrid systems with separate plants that do not implement a hybrid approach, cogeneration plants (producing two useful outputs) and trigeneration plants (producing three useful outputs).

Specific objective 6: Consider several case studies in the United States, as well as other parts of the world, with different energy, fresh water, cooling and heating demands in both residential and industrial sectors as well as different climate conditions and solar energy features. Site-specific direct normal irradiation (DNI) data and other required climate data are collected and used in simulations.

The results generated from this project will provide substantial insight regarding the technical, economic and environmental aspects of utility scale hybrid multigeneration systems using concentrated solar tower as a primary or supplementary energy source. The proposed configurations have the potential to make a significant impact on supplying all products. This project will provide guidelines for constructors, investors, decision makers and plant operators with a large number of decisions including choosing the optimal configurations based on existing demands of a location as well as operating and controlling the sub-systems.

Methodology:

To fulfill the objectives, several computational codes are developed using engineering equation solver (EES) software. EES is an equation-solving program that enables the solution of thousands of non-linear equations numerically. One of the main features of EES that significantly assists this research is its high accuracy thermodynamic and transport property databases for hundreds of substances, enabling it to simulate thermodynamic cycles that use different fluids [24]. The computational codes to simulate hybrid systems in this project include any of the following advanced systems:

- Concentrated solar tower systems as a primary or supplementary mover
- Back-up energy using natural gas
- High efficiency steam and transcritical CO_2 Rankine power cycles
- High efficiency Brayton and combined power cycles
- High efficiency supercritical CO_2 Brayton power cycles
- Organic Rankine cycle (ORC) power cycles
- A thermally driven MED or TVC-MED water desalination system
- Thermally driven LiBr-H2O absorption cooling cycles
- Thermally driven NH3-H2O absorption refrigeration cycles
- An electrically driven vapor compression or cascade refrigeration cycle

For all above-mentioned advanced cycles, proper thermodynamic models were developed and implemented in EES. The thermodynamic mathematical modeling of all cycles was carried out under steady state and steady flow (SSSF) conditions by assuming negligible kinetic, potential and chemical energies.

For an economic evaluation of the proposed integrated systems, economic models were developed to calculate different economic indicators such as total annual cost (TAC), annual capital cost (ACC), annual operating cost (AOC), levelized cost of energy (LCOE), levelized cost of cooling (LCOC), levelized cost of water (LCOW), net present value (NPV) and payback period (PBP).
As noted, due to the significant capital cost of heliostat field (mirrors), optimal design of heliostat field is of high significance to improve the optical efficiency of the field and overall performance of the system and reduce the investment cost. For this purpose, a detailed mathematical modeling is developed using Matlab to simulate the performance of different sizes heliostat field and provide an optimal filed configuration to achieve a higher flied efficiency and a lower capital cost.

Principal Findings and Significance:
The developed computational tools can simulate the operation of proposed integrated systems at various operating conditions and at different geographical locations. They enable parametric studies to identify the influence of several design parameters on the overall performance of systems. The developed computational codes for all considered cycles allow evaluation of several feasible configurations for different residential and industrial applications. Using the developed computational codes, it is also possible to conduct component and system configuration optimization to achieve optimal production of electricity, fresh water, heating and cooling.

The important contribution of this research is the proposal of different new integrated systems. The proposed systems can be developed and implemented for practical applications to supply the demands efficiently and economically in both residential and industrial sectors. Techno-economic analysis of the proposed hybrid systems for efficient energy utilization is a creative contribution to the body of knowledge.

The results of this research demonstrate that proposed multigeneration systems can supply multiple demands including electricity, fresh water and cooling at a higher thermodynamic efficiency and lower capital and operating costs than single production of these multiple useful products.

Student Support:
The provided funding was used to support a part of Ph.D. dissertation conducted by Kasra Mohammadi.
Student Email Address: kmohammadi@umass.edu

Publications and Conference Presentations:

Mohammadi, Kasra, Jon G. McGowan. Thermodynamic analysis of hybrid cycles based on a regenerative steam Rankine cycle for cogeneration and trigeneration. Energy Conversion and Management 158 (2018) 460-475.

Mohammadi, Kasra, Jon G. McGowan. A thermo-economic analysis of a combined cooling system for air conditioning and low to medium temperature refrigeration. Under review in Journal of Cleaner Production, Elsevier.

Mohammadi, Kasra, Jon G. McGowan. An efficient integrated trigeneration system for productions of dual temperature cooling and fresh water: thermoeconomic analysis and optimization. Under review in Applied Thermal Engineering, Elsevier.

Mohammadi, Kasra, 2018, Thermo-economic and optimization of several hybrid multigeneration systems driven by concentrated solar power plants, PhD Dissertation, Mechanical Engineering Department, University of Massachusetts Amherst, Amherst, Massachusetts, pp. TBA

3. Development of an in-field method for detecting engineered nanoparticles and their transformations in aquatic environments using surface-enhanced Raman spectroscopy

Principal Investigators: Baoshan Xing
Start Date: March 1. 2017
End Date: December 31, 2019
Funding Source: 104G (2017MA462B)
Reporting Period: 3/1/2017 – 2/28/2018
Research Category: Water Quality

Problem and Research Objectives:
Silver nanoparticles (AgNPs) are released to and/or naturally formed in the environment due to their widespread use. Thus, it is urgent to develop reliable and rapid analytical methods which can be used in the field to detect AgNPs. We are developing a procedure which couples a rapid filtration with a portable Raman spectrometer to achieve on-site detection of AgNPs for aqueous samples. This method will enable simple volume adjustment and consistent AgNP distribution on the membrane. It will be the first field-deployable SERS method for sensitive measurements of trace levels of AgNPs in environmental waters.

Principal Findings and Significance:
As the award arrived in late summer 2017 and the majority of the budget is for the graduate student summer salary, we could not use the funding this funding cycle. We were granted a no-cost extension and will use the fund for the student summer salary of 2018 to do the proposed research.

4. Acid Rain Monitoring Project

Principal Investigators: Marie-Françoise Hatte
Start Date: January 1, 2018
End Date: June 30, 2018
Funding Source: Massachusetts Department of Environmental Protection and Bureau of Waste Prevention
Reporting Period: 1/1/2018 – 6/30/2018
Research Category: Water quality

Introduction:
This report covers the period January 1, 2018 to June 30, 2018, the seventeenth year of Phase IV of the Acid Rain Monitoring Project. Phase I began in 1983 when about one thousand citizen volunteers were recruited to collect and help analyze samples from nearly half the state's surface waters. In 1985, Phase

II aimed to do the same for the rest of the streams and ponds[1] in Massachusetts. The third phase spanned the years 1986-1993 and concentrated on a subsample of streams and ponds to document the effects of acid deposition to surface waters in the state. Over 800 sites were monitored in Phase III, with 300 citizen volunteers collecting samples and doing pH and ANC analyses. In 2001, the project was resumed on a smaller scale: about 60 volunteers are now involved to collect samples from approximately 150 sites, 26 of which are long-term sites with ion and color data dating back to Phase I. In the first years of Phase IV (2001-2003), 161 ponds were monitored for 3 years. Between Fall 2003 and Spring 2010, the project monitored 151 sites twice a year, mostly streams, except for the 26 long-terms sites that are predominantly ponds. Since 2011, reduced funding eliminated our October sampling and monitoring now occurs in April only. In 2011, we also stopped monitoring some of the streams in order to add and revisit ponds that were monitored in 2001-2003. This year is the seventh year of monitoring for those added ponds.

Goals:
The goals of this project are to determine the overall trend of sensitivity to acidification in Massachusetts surface waters and whether the 1990 Clean Air Act Amendment has resulted in improved water quality.

Methodology:
The sampling design was changed in 2011 to monitor both streams and ponds, and that design continues to date. In 2001-2003 mostly ponds were monitored. In Fall 2003 the sampling scheme switched to streams to evaluate their response to air pollution reductions. In 2011 the site list was modified to include both ponds and streams. Half of the streams monitored since 2003 were kept, and half of the ponds monitored in 2001-2003 were added back. The streams that were removed were chosen randomly within each county. Ponds that were reinstated on the sampling list were chosen at random within those counties and by ease of accessibility to replace the removed streams. Because those sites were chosen without a preconceived plan, they can be considered picked at random.

One collection took place this year, on **April 8, 2018**.

Methods were unchanged from previous years: Volunteer collectors were contacted six weeks before the collection to confirm participation. Clean sample bottles were sent to them in the mail, along with sampling directions, a field sheet/chain of custody form, and directions including latitude and longitude coordinates along with maps to the sampling sites. Volunteers collected a surface water sample at their sampling sites either from the bank or wading a short distance into the water body. They collected water one foot below the surface, upstream of their body, after rinsing their sample bottle three times with pond or stream water. If collecting by a bridge, they collected upstream of the bridge unless safety and access did not allow it. They filled in their field data sheet with date, time, and site code information, placed their samples on ice in a cooler and delivered the samples to their local laboratory right away. They were instructed to collect their samples as close to the lab analysis time as possible. In a few cases, samples were collected the day prior to analysis because the lab is not open on traditional

[1] Note: The term stream in this report refers to lotic waters (from creeks to rivers) and the term ponds refers to lentic waters (lakes and ponds, but not marshes)

"ARM Sunday." Previous studies by our research team have established that pH does not change significantly in 24 hours when the samples are refrigerated and stored in the dark.

Volunteer labs were sent any needed supplies (sulfuric acid titrating cartridge, electrode, buffers), two quality control (QC) samples, aliquot containers for long-term site samples, and a lab sheet one week to ten days before the collection. They analyzed the first QC sample (an unknown) in the week prior to the collection and called in their results to the Statewide Coordinator. If QC results were not acceptable, the volunteer analyst discussed possible reasons with the Statewide Coordinator and made modifications until the QC sample analysis gave acceptable results. On collection day or the day after, volunteer labs analyzed the second QC sample before and after the regular samples, and reported the results on their lab sheet along with the regular samples. Analyses were done on their pH-meters with KCl-filled combination pH electrodes. Acid neutralizing capacity (ANC) was measured with a double end-point titration to pH 4.5 and 4.2. Most labs used a Hach digital titrator for the ANC determination, but some used traditional pipette titration equipment. Aliquots were taken from 24 long-term sites to fill two 50mL bottles and one 50mL tube per site for later analysis of ions and color. These aliquots were kept refrigerated until retrieved by UMass staff.

Note that two of our 26 long-term sites were not sampled (Lake Lorraine in Springfield and Great Pond in Wellfleet) this year. Also note that it was discovered this year that Great Pond was accidentally dropped from the long-term list and replaced with Hatches Creek in Eastham in 2014. We will not include results for Hatches Creek with the long term sites analyses, as it was not selected to be a long term site in 2001 and does not satisfy the criteria to be put on that list. We plan to re-instate Great Pond to the long-term sites list in 2019.

Aliquots, empty bottles, and results were collected by the ARM Statewide Coordinator between one and three days after the collection.

The Statewide Coordinator reviewed the QC results for all labs and flagged data for any lab results that did not pass Data Quality Objectives (within 0.3 units for pH and within 3mg/L for ANC). pH and ANC data were entered by one ARM staff and proofread by another. Data were entered in a MS excel spreadsheet and uploaded into the web-based database at http://63.135.115.71/acidrainmonitoring/.

Data were also posted on the ARM web page at http://wrrc.umass.edu/research/acid-rain-monitoring-project.

Water Resources Research Center's Travis Drury, with the help of sophomore student Haena Jung, managed the Environmental Analysis Lab (EAL) and provided the QC samples for pH and ANC to all of the volunteer labs. EAL also provided analysis for color analysis for the long-term site samples. The UMass Extension Soils Laboratory analyzed the samples from the long-term sites for cations, and University of New Hampshire's Water Quality Analysis Laboratory, under the direction of Jody Potter, analyzed the samples from the long-term sites for anions.

Aliquots for 24 long-term sites were analyzed for color on a spectrophotometer within one day; anions within two months on an Ion Chromatograph; and cations within one month on an ICP at the UMass

Extension Soils Laboratory on the UMass Amherst campus. The available data was sent via MS Excel spreadsheet to the Statewide Coordinator who uploaded it into the web-based database.

The Project Principal Investigator plotted the data to check for data inconsistencies and gaps. She then analyzed the available April data from 1983 through 2018, using the statistical software JMP (http://www.jmp.com/software/) to run bivariate analyses of pH, ANC, and ions against date. This yielded trends analyses with a fitted X Y line, using a 95% confidence interval.

Results:

1. There were 149 sites to be monitored, 76 ponds and 73 streams. Of those, 19 ponds and 7 streams are "long-term" sites that are sampled every year and analyzed for color and a suite of ions in addition to pH and ANC.

2. Sampling was completed for 138 sites (72 ponds and 66 streams) including 24 of our long-term sites.

3. There were no quality control problem this year, so that all sites sampled yielded results for pH and ANC.

4. For the ion analyses, both UNH and UMass analyzed the 24 long term site samples for Mg, Ca, Na, and K. Because the UMass lab had a positive blank for K, we decided to use the UNH data for these 4 ions. The other ions (Mn, Fe, Al, Cu) were analyzed by UMass only and UMass results were uploaded to the database. We noticed that one known 2017 outlier for K was included in the dataset, so we corrected that and included the corrected value in our analysis. Note that neither lab provides analyses for Si, so that parameter is no longer included in the analysis.

5. The network of volunteers was maintained and kept well informed on the condition of Massachusetts surface waters so that they would be able to participate effectively in the public debate. This was accomplished by e-mail and telephone communications, as well as through updates via an internet listserv. Over 60 volunteers participated in this year's collection. Several new volunteer collectors were recruited to replace ill or retiring volunteers via Volunteermatch.org, a press release which was picked up by at least two Massachusetts newspapers, several internet listservs, and by word of mouth. There were 10 volunteer labs across the state, in addition to the EAL at UMass Amherst, in charge of pH and ANC analyses (Table 1). As the Cape Cod National Seashore lab was not available this year, their samples were analyzed by the Bristol County Community College lab.

Table 1: Volunteer Laboratories

Analyst Name	Affiliation	Town
Joseph Ciccotelli	Ipswich Water Treatment Department	Ipswich
Amy Johnston	UMass Boston	Boston
Mark Putnam	MDC Quabbin Lab	Belchertown
Dave Bennett	Cushing Academy	Ashburnham
Kimberly Newton and Mary Rapien	Bristol Community College	Fall River
Bob Bentley	Analytical Balance Corp	Middleborough
Dave Christensen	Westfield State University	Westfield
Denise Prouty	Upper Blackstone Water Pollution Abatement District	Millbury
Carmen DeFillippo	Pepperell Waste Water Treatment Plant	Pepperell
Cathy Wilkins	Greenfield High School	Greenfield
Travis Drury	UMass Amherst Environmental Analysis Lab	Amherst

6. The ARM web site and searchable database were maintained and updated. 2018 pH, ANC, color, and ion data that met data quality objectives were added to the web database via the uploading tool created in previous years. The database was evaluated for quality control and uploading errors were corrected. We discussed needed improvements to the data upload utility and database for future improvement of data downloads, and plan to hire our database consultant next year to add these improvements.

7. The data collected was analyzed for trends in pH and ANC in April months (138 sites) and for color and ions (24 sites), using the JMP® Statistical Discovery Software (http://www.jmp.com/software/). Trend analyses (scatter plots, regression, and correlation) were run on pH, ANC, color, and each ion separately for each site, predicting concentration vs. time.

Data Analysis Results:

pH and ANC

Trend analysis for pH and ANC

Table 2 displays the number of sites that show a significant change over time for pH or ANC. If the difference was not statistically significant ($p>0.05$), the sites are tabulated in the 'No Change' category.

Table 2: Trend analysis results for pH and ANC, April 1983 – April 2018 (Number of sites)

	All Sites		Ponds		Streams	
	pH	**ANC**	**pH**	**ANC**	**pH**	**ANC**
Increased	42	45	21	29	21	16
Decreased	6	0	1	0	5	0
No Change	90	93	50	43	40	50
Total	138	138	72	72	66	66

Those results are graphed as percentages of all sites in Figure 1.

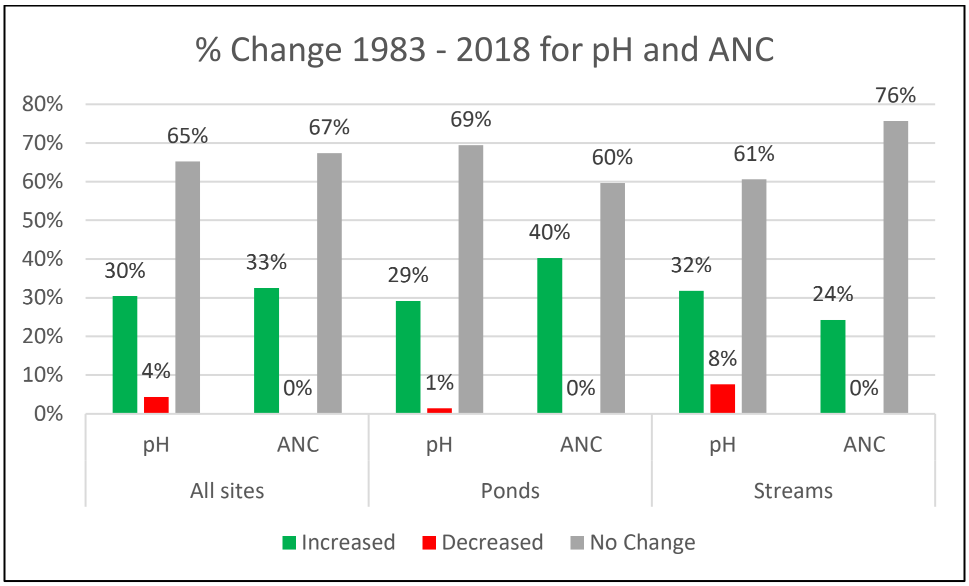

Figure 1. Percent change in number of sites for pH and ANC, from trend analysis, April 1983-2018

This trend analysis indicates that for most sites, neither pH nor ANC changed significantly over time. However, for those sites that show a significant change, many more show an increase than a decrease in value: 30% of the sites saw an increase in pH and 33% had an increase in ANC.

While in general the picture does not vary much from year to year, this year a much higher percentage of ponds exhibited an increase in ANC compared to streams (40% vs. 24%), while more streams had a higher pH than in the past than ponds (32% vs. 29%). More streams saw a drop in pH (8%) than ponds (1%), while neither ponds nor streams saw any decrease in ANC.

Last year, when there was snow on the ground in early April, we observed a small change to more acidic conditions. This year the picture looks similar overall, though fewer ponds showed a decrease in pH and alkalinity, and more streams showed such a decrease. This year there was no snow on the ground on sampling day, though it snowed 2 days prior. Over the whole winter, 2018 had similar total snow amounts as 2017, but March was much snowier this year than last. We purposely sample in early

April to catch any large snowmelt events, but this year the snow melted early and we evidently missed the big snowmelt event.

Ions and color

Trend analyses were run for 24 long-term sites that were analyzed for eleven ions and for color. Results are shown in Table 3 and Figure 2. Note that the trends period is 1985-2018 rather than 1983-2018 because we do not have ion analyses for 1983 and 1984 for the long-term sites.

Table 3: Trends for number of sites with increases or decreases in ion concentration and color April 1985 – April 2018

	Increased	Decreased	No Change
Color	19	0	5
Cl	17	0	7
NO3_N	11	1	12
SO4	0	22	2
Mg	5	0	19
Mn	0	5	19
Fe	0	6	18
Cu	2	0	22
Al	2	3	19
Ca	5	0	19
Na	13	0	11
K	8	0	16

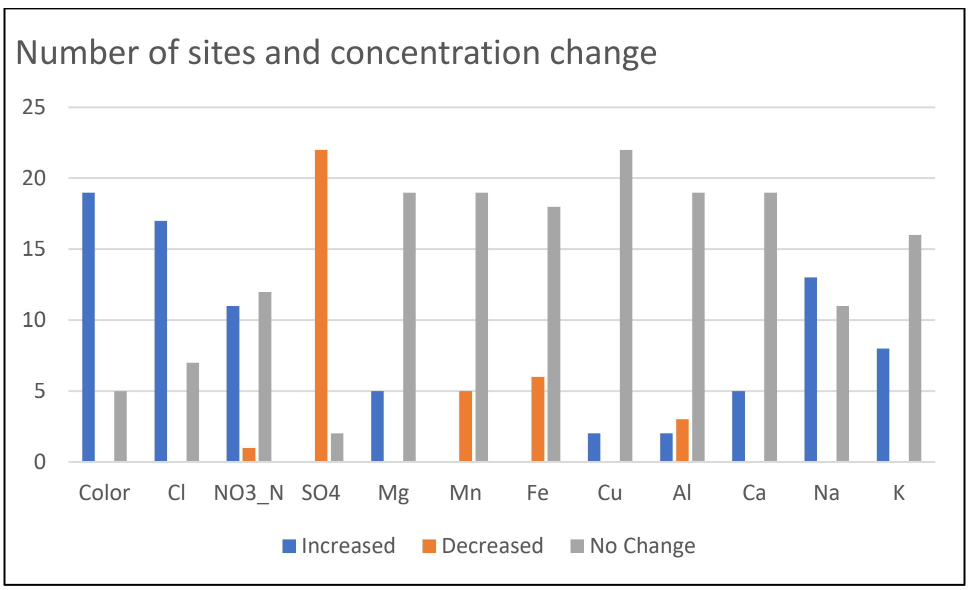

Figure 2: Results of trend analysis for ions and color at 24 long-term sites, April 1985-2018 Shown is how many sites showed an increase (blue), decrease (orange), or no significant change (yellow) over the period 1985 – 2018

Results are similar to last year. While there are still more sites that show no significant change either up or down, more cations display an increase than a decrease over the years. Sodium is now again the ion with the most increases, with iron showing the most decreases. This year we had another opportunity to compare analytical results for four cations (Mg, Ca, Na, and K) between the UNH and the UMass lab, and because of a positive blank at UMass, we used the UNH results for those 4 cations. As we noted last year, the UMass lab results are often higher than the UNH lab, and indeed this year we are seeing fewer statistically significant increases, particularly for Potassium.

For anions, we continue to see a very significant downward trend in Sulfate (again 22 sites). Nitrates, on the other hand, continue to show more increases than decreases, and it is unknown at this time whether it is due to increasing vehicular emissions, or a result of climate change – smaller and less persistent snowpacks result in fine root damage and reduced microbial activity. This can result in losses of nutrient elements, most notably Nitrogen in the form of NO_3^-.

Color is still increasing in most of our sites, which is consistent with a recovery of natural alkalinity.

Discussion:
The continued trend in decreasing sulfate confirms that the Clean Air Amendment of 1990 is having a positive effect in the quality of the Commonwealth's surface water quality. Road salting in the winter continues to affect the concentration of sodium and calcium in the water bodies. Continued monitoring will help tease out whether nitrate pollution is countering the beneficial effect of decreased sulfates.

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5. Blackstone River Water Quality Monitoring Study

Principal Investigators: Paula Rees
Start Date: 2/26/2004
End Date: Ongoing
Funding Source: Upper Blackstone Water Pollution Abatement District
Reporting Period: 7/1/2017 – 6/30/2018
Research Category: Water quality

Problem and Research Objectives:
Since plant upgrades were completed in 2009, the Upper Blackstone Water Pollution Abatement District (Upper Blackstone) has conducted water quality monitoring of the Blackstone River to assess the river's response to reduced nutrient concentrations in the wastewater treatment facility (WWTF) effluent. The river monitoring program was initiated in 2010 and expanded in 2012, with consistent year to year monitoring at the same river sites to build a multi-year data record. In 2017, the river monitoring program included monthly water quality sampling for nutrients and chlorophyll-a, as well as periphyton surveys.

The Upper Blackstone's monitoring program is conducted under a Quality Assurance Plan (QAP) approved by the Massachusetts Department of Environmental Protection (MassDEP).

The Blackstone River water quality data collected as part of the Upper Blackstone's monitoring program are publicly available for download through the CUAHSI Hydrologic Information System (HIS) databases and servers (his.cuahsi.org).

Methodology:
River sampling for nutrients and chlorophyll-a was conducted from April through November at 9 Blackstone River main stem sites located in Massachusetts and Rhode Island, including three Rhode Island sites which were co-sampled with the Narragansett Bay Commission's (NBC) ongoing monitoring program. Additionally, periphyton sampling was conducted at four sites in Massachusetts once in June, July, and August.

Principal Findings and Significance:

- Upper Blackstone continues to refine their treatment process to minimize nutrient loads and daily variability, particularly in the summer months. The facility performed well against its seasonal nutrient limits in 2017. TN concentrations and loads from the plant were higher than average from November to April, when there are no numeric TN limits, which contributed to the highest annual TN effluent load observed during the period 2012 – 2017.
  - The percent reduction in yearly TN and TP effluent load in 2017 compared to plant performance 2006 – 2008 was 34% and 85%, respectively.
  - Effluent average summertime (June - September) TP daily loads in 2017 were the lowest observed since plant upgrades went online in 2010, and TN daily loads were the second lowest.
  - Overall, summertime daily average TN effluent concentrations were slightly elevated in 2017 compared to 2016, but lower than earlier years, while summertime daily average TP effluent concentrations were the lowest observed since the plant upgrade in 2009.
    - Upper Blackstone facility average April – October permit season TP effluent concentration was similar in 2017, 2016, 2015 and 2013. The average winter (November – March) permit season TP effluent concentration in 2017 was double that of 2013 – 2015 but lower than in 2016.
    - Upper Blackstone facility average April – October permit season TN effluent concentration was also similar to prior years, but higher than in 2016. However, the average winter permit season TN effluent concentration was the highest observed since 2012.
    - The interquartile range of summertime effluent concentrations remained tight for both TN and TP, indicating strong control of the treatment process.
- Air temperatures in 2016 – 2017 were quite variable in comparison to historic data, following no systematic trend. The impact of temperature on in-stream productivity is not clear; water temperature data are likely more important but inconsistent availability of data since 2012 makes this difficult to assess.
  - Spring air temperatures were variable, with periods both below and above normal monthly temperatures.

  - Air temperatures in June were at the upper quartile of observed data.
  - Air temperatures in July and August were cooler than average
  - Warmer than normal air temperatures were observed in September and October.
  - Periphyton levels in exceedance of the 200 mg/m^2 CALM guidance were associated with stream water temperatures above 23^o C.
- High rainfall in April – June in 2017 may have helped moderate productivity in the river during the month of July; however, 7-day and 30-day average Q values were notably lower throughout much of August and September compared to 2012 - 2015, likely contributing to elevated periphyton levels during these months in 2017.
  - The winter of 2016 - 2017 was about average in terms of snowfall.
  - In terms of precipitation, the total accumulation of 45.6 inches in 2017 at Worcester was just slightly below the long-term average from 1949 to 2017 of 47.6 inches; however, monthly accumulations were quite variable. Rainfall in April through June was above normal, followed by low monthly totals in July – September. October was comparatively wet.
  - Calculations based on the average of daily contributions suggest that in 2017, effluent comprised approximately 50% of the river flow at Millbury from June through September 2017. Effluent contributions to summertime (June – September) flows have varied from 33% to 65% since 2003.
  - In 2017, only July, August, and September were characterized as low flow sampling days.
  - Low mid-to-late summer precipitation was reflected in lower than average flows in July – September at Millbury and in August – September at Woonsocket.
    - While flows were not as low as during the 2016 sampling season, which was the driest summer season sampled to date by Upper Blackstone's routine monitoring program (2012 – 2016), the minimum 7-day average flow at Millbury in 2017 was 40 cfs, the second lowest since 2012 (lowest 7-day average was 37 cfs in 2016), and occurred in early October.
    - In terms of biological activity, low flows provide conditions amenable for plant growth with high penetration of light through the water column and reduced dilution of the available nutrients.
- In-stream TP and TN levels in the river in 2017 show continued improvement. In-stream TP concentrations were below the Massachusetts CALM guidance of 100 µg/L 65% of the time.
  - Average water column TP and TN concentrations in 2017 fell within the interquartile range of values observed since 2012 at all sampling sites. For TN, the values fell below 2012 – 2017 median levels at all sites.
  - TP and TN loads observed in the river that were associated with "low" flow sampling events were amongst the lowest observed at all sites since sampling began in 2012.

  - Trends in water quality were evaluated using a seasonal Mann-Kendall test computed on flow-weighted TP and TN data collected since 2012.
    - Decreasing TP trends were noted when accounting for either season or month at 2 sites (RMSL and RMSD) and when accounting for sampling month (but not season) at W1242.
    - Decreasing TN trends were noted at all sites *except for* W0767 and W0680 when accounting for month and at all sites *except for* W0767, UBWPAD2, and W0680 when accounting for season.
- Chlorophyll-a concentrations were below the CALM guidance of 16 µg/L 96% of the time in 2017. However, trend analysis of the data collected since 2012 suggests that overall chlorophyll-a levels are increasing slightly. This trend is not consistent across sites. Chlorophyll-a levels in 2017 at the two most downstream sites were the lowest observed since routine sampling began in 2012, and a statistically significant decreasing trend is evident at the most downstream site when data are blocked by season.
  - In general, summertime chlorophyll-a levels in 2017 exhibited an interquartile range comparable to those observed in 2013 and 2015 and were characterized by a smaller spread and lower values than in 2012, 2014, and 2016.
  - Average summer chlorophyll-a levels were elevated compared to other years at W0767, just below Rice City Pond (W1779) and the state line (RMSL). Maximum sampling season chlorophyll-a concentrations in 2017 at W1779 and RMSL were only lower than previously observed during the 2014 sampling season.
  - Average and maximum summer chlorophyll-a levels were the lowest observed since 2012 at the two sampling sites in RI (R116 and RSMD).
  - Trends in water quality were evaluated using a seasonal Mann-Kendall test computed on flow-weighted chlorophyll-a concentration data collected since 2012.
    - An increasing trend at the 99% significance level was observed when the data are blocked by month and all sites are lumped together.
    - Decreasing trends in chlorophyll-a were noted when accounting for season at the most downstream site, Slater Mill Dam (RMSD).
    - Increasing trends in chlorophyll-a were observed at W1258 and W0680 when accounting for season.
- Periphyton levels were below the CALM guidance of 200 mg/m^2 83% of the time in 2017.
  - MassDEP utilizes 200 mg/m^2 as guidance for "nuisance levels" of periphyton based on the literature (MassDEP, 2009; NEIWPCC, 2001). Data collected in 2012 through 2015 fall below this target level, but the August and September 2017 samples collected at the site downstream from the confluence exceeded this target level. Concentrations above 200 mg/m^2 were also observed in 2016.

  - o Water column TP concentrations when periphyton levels greater than 200 mg/m^2 have been observed have typically been above 130 ppb, however environmental conditions such as river flow conditions, air and water temperatures, and light penetration also influence growth.
  - o The years 2014, 2015, 2016, and 2017 were all fairly dry years, however only sampling dates when the mean 7-day prior flow fell below ~55 cfs and water column TP concentrations were above 130 ppb resulted in periphyton exceedances at the UBWPAD sampling site UBWPAD, which is the confluence of the Blackstone River and the effluent channel. At W1258 and Depot Street, exceedances only occurred when the mean 7-day prior flow fell below 50 cfs.

- Data from continuous DO meters installed in the river in 2017 show compliance with the Massachusetts standards nearly all, if not all, of the time.
  - o In 2017, MassDEP installed continuous T/DO probes at the four periphyton sampling locations in the Blackstone River from June 2 to November 2. The continuous meters were not cleaned or recalibrated during the five-month monitoring period. Calibration measurements were collected approximately monthly using a calibrated hand-held T/DO probe.
  - o Observed DO data was in compliance with the MA DO standard of 5 mg/l (MA Class B Standard) nearly all of the time, with occasional non-compliance at UBWPAD2.
  - o The data was in compliance with DO percent saturation guideline of < 125% saturation (CALM) at all sites and all days of valid data.
  - o There were a handful of days at three of the four meters (W0680, UBWPAD2, and W1258) where the maximum diel (diurnal) variation in DO was greater than 3 mg/l (CALM).

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6. Development of Pilot Extreme Flood Vulnerability Assessment Protocols under Present and Future Climatic Conditions for Roadway Stream Crossing Structures within the Deerfield River Watershed, Massachusetts

Principal Investigators: Paula Rees, Scott Jackson, Stephen Mabee, UMass Amherst; Benjamin Letcher, USGS Conte Lab; Michael Rawlins, Northeast Climate Science Center.
Start Date: 1/1/2014
End Date: 12/30/2018
Funding Source: Massachusetts Department of Transportation
Reporting Period: 7/1/2017 – 6/30/2018
Research Category: Floods

UMass Amherst, on behalf of MassDOT, is developing risk-based and data driven protocols for assessing the present and future extreme flood vulnerability of roadway crossing structures within the Deerfield River Watershed. These protocols incorporate consideration of a range of potential climatic and natural system stressors and risk factors, including present and future flood hydrologic conditions, geomorphic stability, ecological system accommodation, structural flood resilience, and transportation/emergency response service disruption impact. It is UMass Amherst and MassDOT's intent that the proposed protocols will serve to augment and improve MassDOT's current inspection/maintenance, system planning and project development processes, and thereby help assure the present and future safety and resilience of the state's inventory of bridges and culverts.

Goals of study:
The goal of the project is to develop a systems-based approach to improve the assessment, prioritization, planning, protection and maintenance of roads and road-stream crossings that:

- Complements existing MassDOT project development and bridge design business processes;
- Provides a decision-making tool that can be used during project planning and development phases; and
- Familiarizes and engages other agencies, such as the Massachusetts Department of Environmental Protection (MassDEP), the Army Corps of Engineers (ACOE), and the Federal Emergency Management Agency (FEMA), with this approach.

A proactive approach for upgrading structures to account for climate change may be more cost effective than responding to road and crossing failures, which may occur due to inaction. An integrated approach - accounting for culvert condition, geomorphic and climate change impacts, future development, river stream continuity (aquatic and wildlife organism passage), and potential disruption of local services in the decision making process - will reduce uncertainties and improve prioritization schemes compared to vulnerability assessments that focus solely on climate change.

MassDOT already has an effective statewide Bridge Inspection program that provides rigorous hands-on bridge structural and site safety inspection coverage for over 11,100 bridges and culverts. The intent of this project is not to replace the existing statewide inspection program, but rather to complement this program by collecting additional data, in particular for closed bottomed structures less than 10 feet in length. If MassDOT has already inspected a culvert, their report will be reviewed and the project team will defer to DOT's overall categorization of poor, critical, or not at risk.

Objectives:
The project team is exploring a variety of methods for conducting a climate change vulnerability assessment of culverts throughout the Deerfield River watershed. Our project includes:

1. Vulnerability assessment for roads and road-stream crossings under present climate conditions affecting streamflow
2. Vulnerability assessment for roads and road-stream crossings under future climate conditions affecting streamflow
3. Integration of vulnerability factors due to future hydrologic and hydraulic conditions, geomorphic response, and aquatic stream continuity and fragmentation into a decision support tool that complements, supports, and augments present MassDOT system planning, project development, and bridge/culvert inspection processes.

In assessing climate change vulnerability of the transportation system, the Federal Highway Administration (FHWA) considers three factors (FHWA, 2012): ***exposure*** (whether the asset is in an area experiencing direct impacts of climate change), ***sensitivity*** (expected response of the asset to this impact), and ***adaptive capacity*** (ability of the transportation system to cope with the impacts). Our assessment explicitly accounts for exposure and sensitivity by considering system response to changes in precipitation predicted by various future climatic conditions. Sensitivity of both hydraulic risk and geomorphic risk to predicted climate change is being evaluated. While the project team is laying the foundation for assessing adaptive capacity, additional work will be needed to take this to a higher level.

Beyond providing a vulnerability assessment specific to the Deerfield, our aim is to identify the strengths, weaknesses and sensitivities of the various methodologies utilized to analyze each objective. Based on this information, the project team will provide recommendations for a transportation vulnerability assessment framework that could systematically and cost-effectively be applied to the rest of the Commonwealth.

Linked Considerations:
Procedurally, UMass Amherst proposes to advance this project through the progressive development of four linked components:

- Culvert condition. As a complement to the state's bridge inspection program, apply a rapid condition assessment of culverts to identify those that are most at risk of failure due to structure or stream degradation and lateral or vertical movement of stream channels

- Climate Change and Associated Geomorphic Impacts. Develop a process for identifying elements of transportation infrastructure that are vulnerable to failure during storm events due to changes in precipitation patterns as the result of climate change. This will include direct vulnerability due to resulting extreme flows as well as indirect vulnerability due to geomorphic responses to changes in climate such as erosion and landslides, or system-wide adjustments in river morphology

- Potential disruption of local services or emergency response routes. Incorporate vulnerability assessment with an assessment of the associated potential of a failure to disrupt local services or infrastructure (fire and police protection, access to hospitals, water supply, utilities, etc.)

- River and stream continuity. Implement a process for assessing transportation related barriers to aquatic and wildlife continuity and identify those sites where mitigation of those barriers would do the most good for fish, other aquatic organism, and wildlife population persistence.

While not a major focus of the proposed work, local future development is another factor impacting vulnerability being considered.

The work builds upon field-based and landscape-scale assessments of roads, road-stream crossings, streams and watersheds that have been developed at UMass Amherst over that past ten years. The significant and unique aspect of this work is that it will insert climate change uncertainty, stream continuity issues and geomorphic condition into the decision-making process for road and stream crossing planning and vulnerability assessment.

Activity this fiscal year:

- Analyses were completed and final report writing was begun and almost finished
- A Stream Crossings Explorer tool was created and posted online for public use at http://sce.ecosheds.org/
- Outreach was initiated with several meetings with agencies and Deerfield River watershed town officials to present project results and the Stream Crossings Explorer.

7. MassDEP-WRRC Data Sharing Collaborative

Principal Investigator: Marie-Françoise Hatte
Start Date: January 1, 2018
End Date: June 30, 2018
Funding Source: Massachusetts Department of Environmental Protection
Reporting Period: 1/1/2018 -6/30/2018

Background:
The Massachusetts Department of Environmental Protection (MassDEP)'s Watershed Planning Program (WPP) is responsible for protecting, enhancing, and restoring the quality of the waters of the Commonwealth, and is required by the Federal Clean Water Act (CWA) to report to the US Environmental Protection Agency (EPA) every two years on the health of both fresh and marine waters with respect to the level of attainment or impairment of designated uses such as recreation (e.g., swimming, boating), shellfishing, fish consumption, drinking water, and the integrity of aquatic ecosystems. The cornerstone of WPP's decision-making related to designated use assessments is reliable scientific data and technical information from its monitoring program, as well as that from other parties. To meet specific data needs, the WPP collects physical, chemical and biological data for surface waters throughout the Commonwealth. This monitoring activity requires a comprehensive array of plans, procedures and activities that culminate in producing sufficient data of known and documented quality. In addition to these data, WPP also solicits data from outside groups and reviews them for potential use in decision-making.

In light of declining Federal and state CWA program resources, MassDEP is looking to include in its assessment data collected by watershed groups and municipalities. Toward this goal, MassDEP entered into a collaborative partnership with the Water Resources Research Center at the University of Massachusetts at Amherst (WRRC) to communicate with monitoring groups and assist in the technical review of Quality Assurance Project Plans (QAPP) and data submissions from those groups.

Project Outline:
Richard Chase and Jennifer Sheppard of MassDEP came to UMass on February 14, 2018 to train WRRC staff Travis Drury, Marie-Françoise Hatte and Jerry Schoen on QAPP and Data Review protocols. MassDEP gave WRRC several completed reviews of both QAPPs and data submittals from monitoring groups in order for WRRC staff to familiarize themselves with the protocol and to practice performing reviews with a model for comparison.

MassDEP also provided WRRC with a comprehensive spreadsheet dated January 2018 that listed all the groups that, to DEP’s knowledge, were monitoring in Massachusetts. Those groups ranged from USEPA to small lake citizen groups. WRRC contacted all of the groups to assess which ones were indeed monitoring, who had approved QAPPs, who already submitted data to DEP, and who needed what type of assistance with monitoring or data submittal.

MassDEP then sent WRRC recently received QAPPs and Data Submittals for technical review by WRRC. After a few reviews, WRRC and MassDEP conferred via telephone to go over reviews and answer questions about the protocol.

In the four months after the February training, MassDEP sent four QAPPs and four data sets to WRRC for review. Those were all completed by the end of the contract on June 30, 2018.

Results:

Monitoring Groups Outreach Response Summary

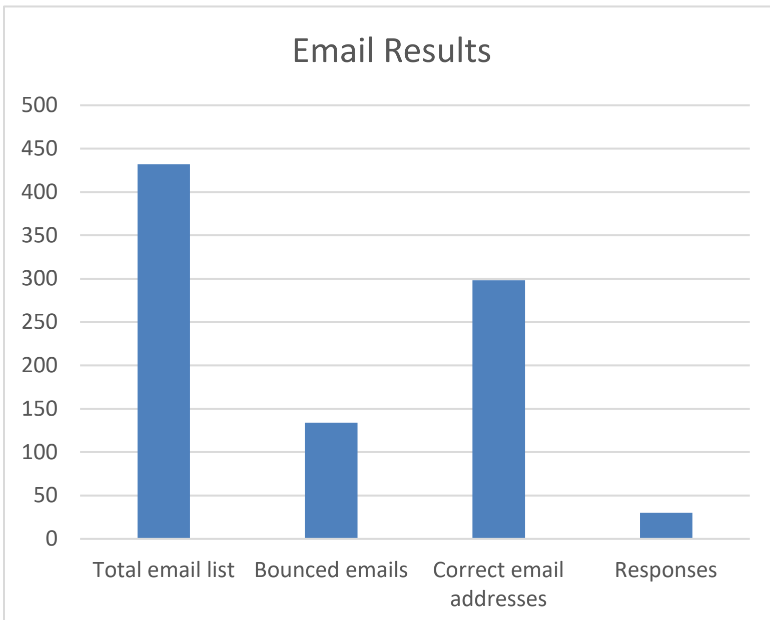
On February 16, 2018 WRRC sent the following email to 432 addresses provided by MassDEP in their "Statewide Groups 01302018.xls" file:

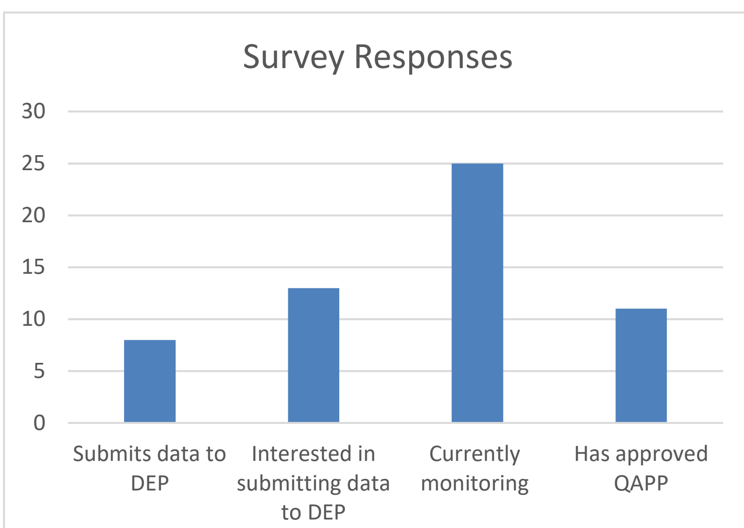
> The Water Resources Research Center is working with MassDEP to optimize and review monitoring data submittal to DEP's Watershed Planning Program (WPP). At this time we would like to confirm which groups are currently collecting data on surface waters in the state, which ones have approved QAPPs, and which ones would like their data to be used by WPP in its biennial assessment of the state's fresh and marine waters' health.
>
> We would appreciate it if you could answer the following question in your reply:
>
> (1) Do you currently submit monitoring data to DEP? (If responding yes, you may skip to question 6)
> (2) Do you currently have a monitoring program?
> (3) If not, are you interested in starting a monitoring program?
> (4) Do you have an approved QAPP for your monitoring program?
> (5) Are you interested in submitting your data to DEP?
> (6) Do you need assistance, and if so, how?
> a. QAPP preparation
> b. Starting a monitoring program
> c. Training related to water quality data collection, QA/QC and data interpretation
> d. Data management and formatting for submittal to DEP
> e. Other:
>
> Thank you for your time. Don't hesitate to contact us if you have any questions, and we will follow up with groups who participate in the survey.
>
> Marie-Françoise Hatte
> Interim Director
> Water Resources Research Center
> 201 Ag Engineering Bldg
> 250 Natural Resources Rd
> Amherst, MA 01003
> 413-545-5531
> mfhatte@umass.edu

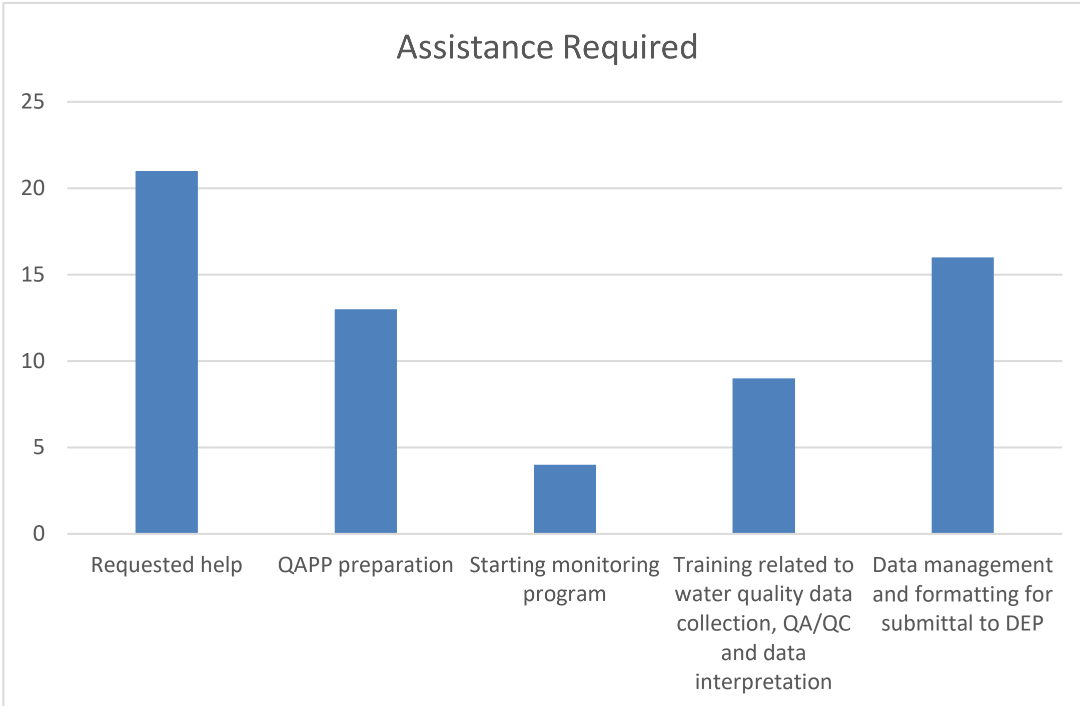
Of those 432 messages, 134 bounced as incorrect addresses, and 298 were correct addresses. Only 3 incorrect addresses were later corrected, but the email was not sent again. In the future more work could be done to obtain current addresses for those found to be incorrect or out of date.

30 groups responded, and of those:

- 8 groups already submit their data to DEP
- 13 more are interested in submitting data to DEP
- 25 are currently monitoring
- 11 or 12 have approved QAPPs
- 21 requested help:
- 13 with QAPP preparation
    - 4 with starting a monitoring program
    - 9 with training related to water quality data collection, QC, and data interpretation
- 16 with data management and formatting for submittal to DEP.






Assistance Required
25
20
15
10
5
0
Requested help
QAPP preparation
Starting monitoring program
Training related to water quality data collection, QA/QC and data interpretation
Data management and formatting for submittal to DEP

The groups who responded were:

Group Name	Monitoring Program	QAPP	Submits Data to DEP
Barnstable Land Trust	No	No	No, does not want to
Blackstone Watershed Group	Yes	has approved QAPP	Yes
Bridgewater State University	not currently	no QAPP	No, wants to
Buzzards Bay Coalition	Yes		Yes
Charles River Watershed Association	Yes	has approved QAPP	Yes
Charlton Lake and Ponds Committee	Yes		Yes
Chicopee River Watershed	Yes	no QAPP	No, wants to
Connecticut River Conservancy	Yes	no longer current	No, wants to
Deerfield River Watershed Association	Yes	has approved QAPP	No, wants to
French River Connection	Yes	has approved QAPP	No
Friends of Alewife Reservation	Yes, not consistent	no QAPP	
Friends of Fort Point Channel	No		
Friends of Pontoosuc Lake Watershed Inc.	Yes	no QAPP	No, wants to
Greater Northfield Watershed Association	Yes		
Indian Lake Watershed Association	Yes	has approved QAPP	No, wants to
Ipswich River Watershed Association	Yes	Yes	Yes
Lake Quinsigamond Watershed Association	Yes	does not collect data independently	No, does not want to
MA Congress of Lakes and Ponds Association	No		No
Manchaug Pond Foundation	Yes	not sure	Maybe by BRWANo or BRC
Massachusetts River Alliance	No		
Mystic River Watershed Association	Yes	has approved QAPP	No, wants to
Nashua River Watershed Association	Yes		Yes
Neponset River Watershed Association	Yes	has approved QAPP	Yes
Otis Reservoir Property Owners Association (ORPOA)	Yes	no QAPP	No, wants to
Parker River Clean Water Association	Yes	no QAPP	No, wants to
Plymouth Dep. of Marine and Environmental Affairs	Yes	has approved QAPP	No, wants to
Provincetown Center for Coastal Studies	Yes	has approved QAPP	No, wants to
Taunton River Watershed Alliance	Yes	no QAPP	Yes
Westport River Watershed Alliance	Yes	has approved QAPP	Yes
Woods Hole Research Center	Yes	no QAPP	No, wants to

Groups asking for assistance:

Group Name	**QAPP Preparation**	**Starting a monitoring program**	**Training on data collection, QA/QC and data interpretation**	Data mgt and formatting for submittal to DEP	**Other:**
Blackstone Watershed Group				yes	1. Developing a true relational database to replace our current web-based data entry system that would allow (a) more efficient input of data by the three Field Coordinators, (b) better synch of of the data entry and data qc processes (performed by the Program Coordinator), and (c) more effective analysis and reporting functions. 2. Guidance on appropriate descriptive and statistical analysis of wqm data - both short term and long term.
Bridgewater State University	yes				
Charles River Watershed Association	yes		yes	yes	
Charlton Lake and Ponds Committee				yes	
Chicopee River Watershed	yes	yes	yes	yes	mostly needs funding and equipment for calibration service
Connecticut River Conservancy	yes			yes	
Deerfield River Watershed Association	yes			yes	
Friends of Alewife Reservation	yes	yes	yes		use cellphone: 617-290-4864
Friends of Pontoosuc Lake Watershed Inc.	yes		yes	yes	asked if we are interested in conducting workshop at their fall symposium
Greater Northfield Watershed Association					wants info about starting a program to look over

Indian Lake Watershed Association					needs more time, just started monitoring last year
Ipswich River Watershed Association			yes		We could benefit from training on appropriate accuracy limits of QA/QC data and on methods of data interpretation, especially using statistics and how to design data collection strategies based on appropriate statistical tests.
Lake Quinsigamond Watershed Association					understaffed; has data uploaded to EPA's website but does not plan on sending to DEP
Manchaug Pond Foundation	yes	yes	yes	yes	We would benefit from your assistance as we are currently developing a monitoring program for our watershed streams and a cold water fishery.
Mystic River Watershed Association	yes				
Nashua River Watershed Association				yes	
Neponset River Watershed Association		yes	yes	yes	
Parker River Clean Water Association	yes		yes	yes	
Plymouth Dep. of Marine and Environmental Affairs				yes	
Provincetown Center for Coastal Studies				yes	
Taunton River Watershed Alliance	yes			yes	all volunteer program, limited resources, data on website
Westport River Watershed Alliance			yes	yes	
Woods Hole Research Center	yes			yes	data on website

Technical Reviews Performed by WRRC:

Organization	Document	Year(s)	Assigned on	Responsible Staff	Checked by	Date sent to DEP
Charles RWA	Data Review	2014-2016	2/14/2018	Schoen	Hatte, Drury	4/23/2018
Mystic RWA	QAPP	2018	3/27/2018	Schoen	Hatte	4/6/2018
Nashua RWA	QAPP	2018-2020	4/5/2018	Schoen	Hatte	4/12/2018
Nashua RWA	Data Review	2017	4/27/2018	Schoen	Hatte	7/3/2018
OAR	Data Review	2014-2017	4/27/2018	Schoen	Hatte	6/29/2018
Westport RWA	QAPP	2018	4/24/2018	Schoen	Hatte	5/7/2018
Orleans Ponds	QAPP	2018-2020	5/24/2018	Hatte		6/4/2018
Garfield Lake	Data Review	2017	6/13/2018	Drury	Hatte	6/29/2018

Other Tasks:
After discussions with MassDEP, WRRC consulted with a software engineer regarding future data management options to facilitate and standardize QAPP development and data submission by groups, and outlined some options. We also participated in a conversation with the Connecticut Strategic Monitoring Project participants at the Connecticut River Conservancy and the Pioneer Valley Planning Commission to explore ways WRRC could assist the program with QAPP development and data management. The recommendation that ensued was to use EPA's WQX data entry tool, though it is not easier to use than the template currently used by MassDEP. There may be ways that we could facilitate data entry via the creation of a tool, if necessary.

Conclusions/Recommendations:
FY 2018 was a pilot project to ascertain whether WRRC could provide assistance to MassDEP in its outreach to monitoring groups and in sharing the load of QAPP and Data Submittal reviews. We got a very late start in the fiscal year, which did not leave much time to accomplish of all our goals. Nonetheless, WRRC was able to process all of the requests sent by MassDEP, and could have handled more, mostly thanks to the availability of returning retired employee Jerry Schoen. In the coming fiscal year we will have more availability and if the program continues, more can be accomplished if the start date is earlier in the fiscal year.

We would recommend spending some time getting back to the groups who responded to our survey, in a more personal manner, in order to fully understand their needs and how we could meet those needs. Finding contact information for those groups we were not able to reach in FY18 would also be a beneficial task.

As most of the needed assistance described so far by monitoring groups was help in developing QAPPs and Data Submission, we would recommend concentrating on developing tools and conducting workshops to automate those tasks to the extent possible in the future.

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8. Advancing agricultural water security and resilience under nonstationarity and uncertainty: A conversation among researchers, extension, and stakeholders on the evolving roles of blue, green and grey water

Principal Investigator: Paula Rees, Water Resources Research Center, UMass Amherst
Start Date: 09/30/2013
End Date: 08/20/2017
Reporting Period: 07/01/2017 – 06/30/2018
Funding Source: USDA NIFA

Problem and Research Objectives:
Falkenmark and Rockström first introduced the green-blue water paradigm in 2004. Since then, it has gained widespread acceptance in the international and U.S. water management communities. The blue-green-grey framework has enormous implications for water-resource assessment and agricultural water management. Production of food and other forms of biomass for human uses is the largest component of the human freshwater budget. The perspective of blue, green and grey water management is likely to be a key tool in addressing world agricultural challenges.

The Massachusetts Water Resources Research Center (WRRC) organized a special track of the 2014 joint National Universities Council on Water Resources (UCOWR), National Institutes for Water Resources (NIWR), and Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI) Conference to provide a global overview of the state of our knowledge about the blue-green-grey framework for agricultural management as well as new innovations it has brought about. Funding for the track was provided from USDA-NIFA. Tufts University hosted the conference June 18 – 20, 2014, and played a key role in also helping organize the blue-green-grey conference track. Development and organization of the conference track was a collaborative effort between the WRRC, members of the grant Scientific Advisory Board, and the conference steering committee.

Through discussion and dialogue, the conference track helped identify needs, opportunities, and challenges for future research, extension programming, and education around the Blue, Green, Grey water management paradigm. Beyond the academics and agency staff that traditionally attend UCOWR conferences, Extension Educators and their stakeholders--the agriculture producers that are directly impacted by policies and regulations, were invited to participate. The registration of sixty-five participants, including invited speakers, was sponsored by the grant. Additional participants were drawn from the 250+ conference registrants. The track was also broadcast live through a webinar. In the summer of 2014, the presentations were posted on YouTube after minor editing: https://www.youtube.com/channel/UCNHEd1-hYBlEWfVL2e9BgXA. Further details about the track and speakers are available at **http://wrrc.umass.edu/events/blue-green-grey-water-agriculture**.

Over the last year, we contacted potential researchers in this field tosubmit articles on their state-of-the-art work in the field to be published in a special issue of the Journal of Contemporary Water Research & Education (JCWRE). We confirmed 9 articles (see Table below) and coordinated their submissions and reviews with UCOWR staff.

Author Name	Article Title
Courage Bangira	Food security as a water grand challenge
Bonnie Colby	Water trading: Innovations, modeling prices, data concerns
Brian Haggard	Subwatershed prioritization using baseflow water quality monitoring data
Clever Mafuta	The role of green water management in sub Saharan Africa
Marty Matlock	Measuring water resource sustainability
Stanly Mubako	Blue, green and grey water quantification approaches: A bibliometric and literature review
Lawrence Parsons	Agricultural use of reclaimed water in Florida: Food for thought
Bahman Sheikh	Grey water – Agricultural use of reclaimed water in California

Information Transfer

One of the Massachusetts Water Resources Research Center's goals is the transfer of information on water resources. In FY2017 we proposed to hold two educational symposia: a water conference symposium focused on **water supply challenges** and the **water-energy nexus**, and the **New England Graduate Student Water Symposium.**

9. Water Symposium

Our plans to organize a symposium on the UMass Amherst Campus in January 2018 to follow up on previous workshops and investigate new topics was postponed to 2019 due to a Principal Investigator's major health issue. A no-cost extension was requested and granted and the symposium will take place in the next fiscal year.

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10. North East Graduate Student Water Symposium 2017

Principal Investigators: Paula Rees
Start Date: March 1, 2017
End Date: February 28, 2018
Funding Source: 104B (2017MA466B)
Reporting Period: 3/1/2017 – 2/28/2018

National conferences provide valuable presentation experience and networking opportunities. Unfortunately, the cost of travel, lodging, and registration presents substantial obstacles for most graduate students. To address this problem, the New England Graduate Student Water Symposium (NEGSWS) was created in 2014 and ran for its fourth consecutive year in 2017. Also in 2017, the conference maintained the NEGSWS acronym, but the full name was changed to "North East Graduate Student Water Symposium" to more accurately reflect the expanding geographic representation of the attendees.

The conference was organized by a team of University of Massachusetts graduate students with help from the Massachusetts Water Resources Research Center and University of Massachusetts College of Engineering Professor Dr. David Reckhow. Thanks to the support of conference sponsors, registration was free for students and two nights of hotel accommodations were provided to presenters and student coauthors for a small $45 fee. Due to the unique draw of a student-only conference and low costs, approximately 157 people attended the conference from 34 institutions and organization from the North East region of North America (Table 1). Attendees came to the NEGSWS conference from nine U.S. states—Connecticut, Maine, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island—and two Canadian provinces—Nova Scotia and Quebec.

Table 1: Institutions and organizations represented at the symposium

CDM Smith	Salem State University
Clarkson University	Smith College
Columbia University	Syracuse University
Cornell University	The State University of New York at Buffalo
Dalhousie University	Thermo Fisher Scientific
ENSA Agadir	Tighe & Bond
Harvard University	Tufts University
Lafayette College	University at Buffalo SUNY
Lehigh University	University of Connecticut
LuminUltra Technologies Ltd.	University of Maine
Manhattan College	University of Massachusetts Amherst
Massachusetts Institute of Technology	University of Massachusetts Boston
McGill University	University of Massachusetts Lowell
Montclair State University	University of Minnesota
Northeastern University	University of New Hampshire
Rensselaer Polytechnic Institute	University of Rhode Island
Roger Williams University	Wright-Pierce

The conference opened Friday, September 8, 2017 with an informal dinner which allowed attendees to check in at registration and network with faculty, sponsors, and other students (Figure 1). Technical presentations began the next morning and continued through Sunday. All presentations were given by undergraduate and graduate students, but post docs, alumni, faculty, and industry representatives were invited to attend. Presentations were grouped into the following topics: flood risk, hydrology, and water resources management; environmental monitoring: technologies and techniques; wastewater treatment; drinking water treatment; surface water modelling and monitoring; groundwater: assessment and remediation; and environmental systems management.

Figure 1: Friday evening NEGSWS dinner

Saturday's events also included a poster session (Figure 2), a career fair with presentations from industry sponsors, and an entrepreneurship panel which informed students on the basics of turning their research into entrepreneurship opportunities.

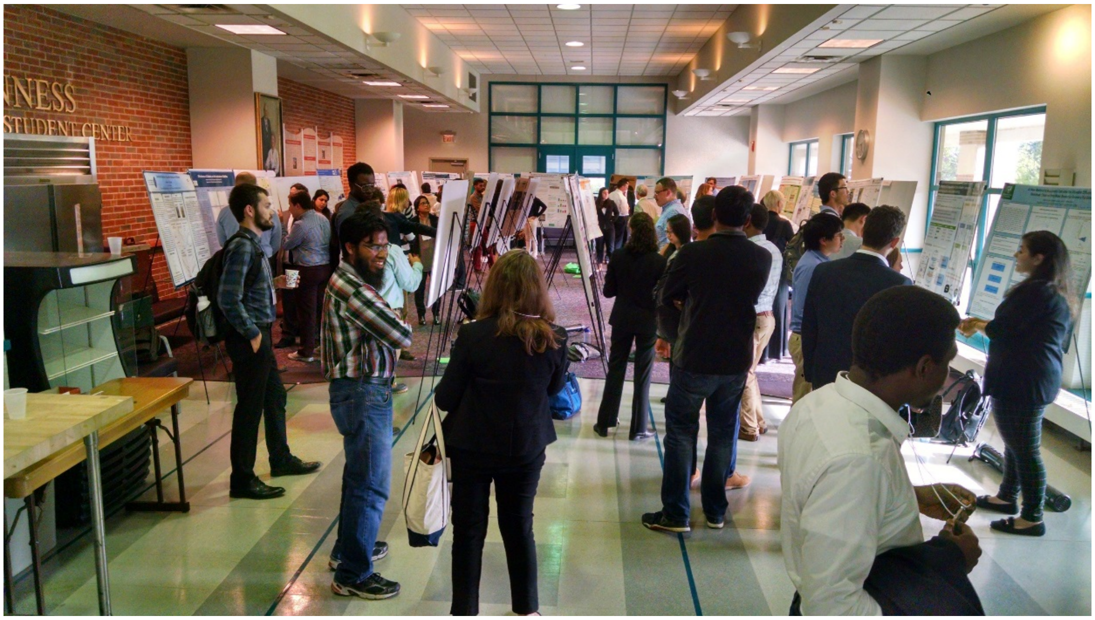


Figure 2: Poster presentations

On Sunday, one more session of technical presentations was held before the keynote speaker, former U.S. EPA Administrator Gina McCarthy, wrapped up the conference. Overall, there were 55 technical presentations and 37 posters presented by undergraduate and graduate students.

Figure 3: Students interacting with industry sponsors

Figure 4: Group Photo of NEGSWS 2017 Attendees

NEGSWS

North East Graduate Student Water Symposium

Friday, September 8th

5:30pm – 6:00pm	**Registration** –*Engineering Quad*
6:00pm – 9:00pm	**Dinner** – *Engineering Quad*

Saturday, September 9th

8:00am – 9:00am	**Registration** – *Marcus Lobby*
9:00am – 10:30am	**Technical Session 1**
10:30am – 10:45am	**Break** – *Marcus Lobby*
10:45am – 12:15 pm	**Technical Session 2**
12:15pm – 1:30pm	**Lunch** – *UMass Dining Commons*
1:30pm – 3:00pm	**Technical Session 3**
3:00pm – 3:30pm	**Break** – *Marcus Lobby*
3:30pm – 4:15pm	**Career Fair and Industry presentations-** *Marcus Auditorium Room 131*
4:15pm – 5:00pm	**Entrepreneurship Panel-** *Marcus Auditorium Room 131*
5:00pm – 6:30pm	**Poster Session**- *Student Gunness Center*
7:00pm – 9:30pm	**Dinner** –*Holiday Inn Express, Hadley*

Sunday, September 10th

8:30am – 9:00am	**Registration** – *Marcus Lobby*
9:00am – 10:30am	**Technical Session 4**
10:30am – 10:45am	**Break** – *Marcus Lobby*
11:00am – 12:15pm	**Keynote Lecture- Gina McCarthy-** *Elab 2 Auditorium*
12:15pm – 1:00pm	**Small Reception, Group photo and Closing**

Figure 4: NEGSWS 2017 schedule

Financial Overview:

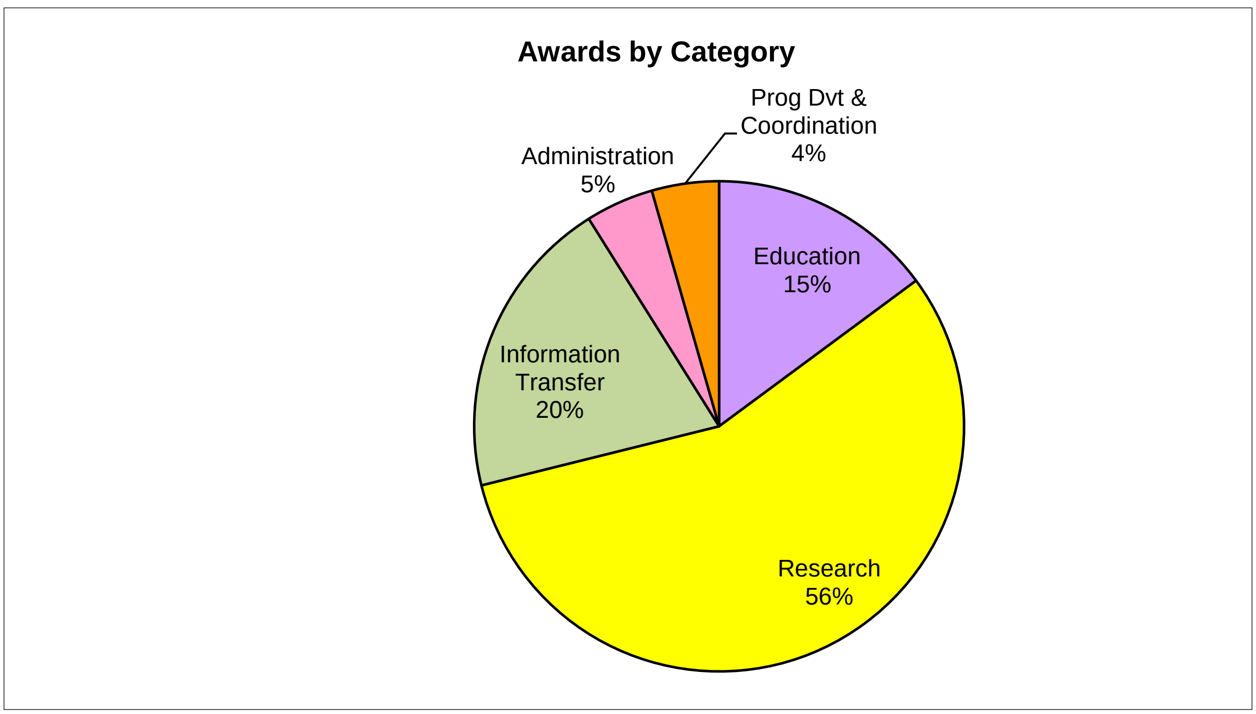
Center revenues come strictly from grants and contracts. The University of Massachusetts contributes 20% of the salary for a half-time Director and also provides physical facilities for the WRRC.

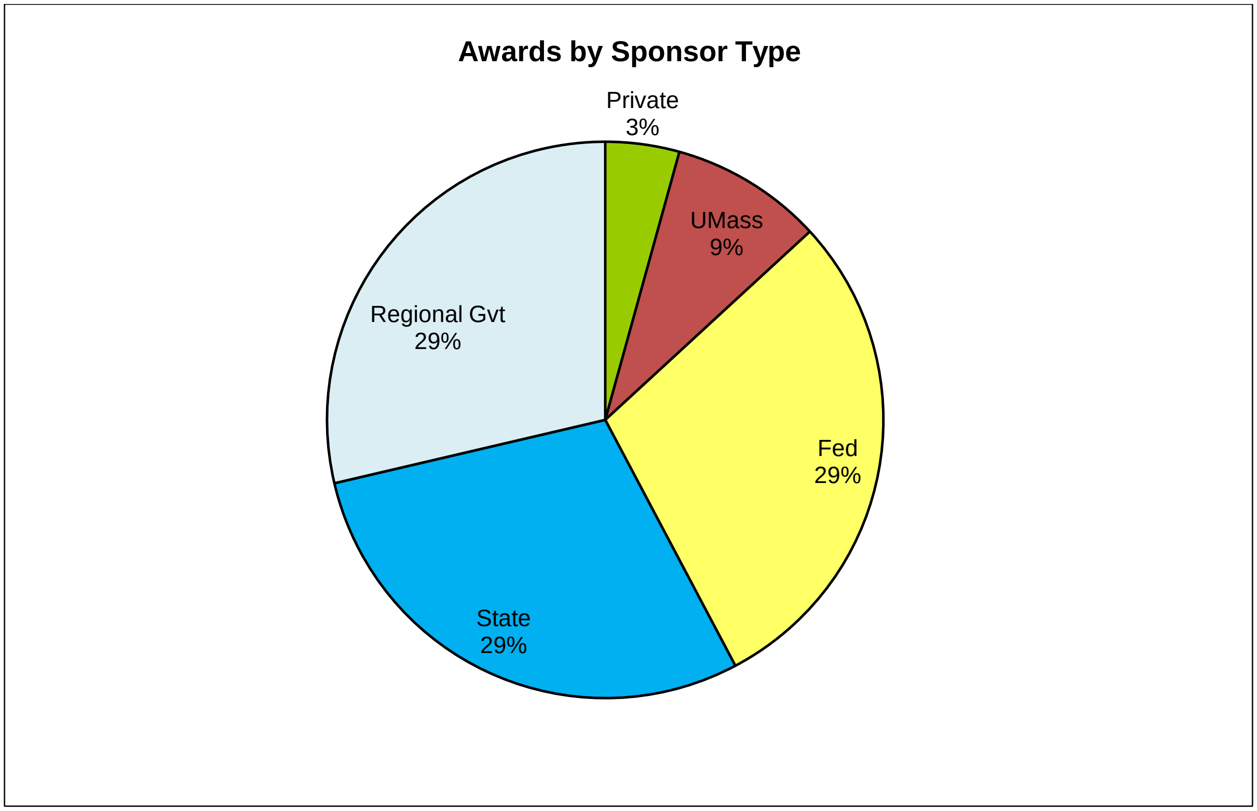
Total revenues amounted to $ 374,738

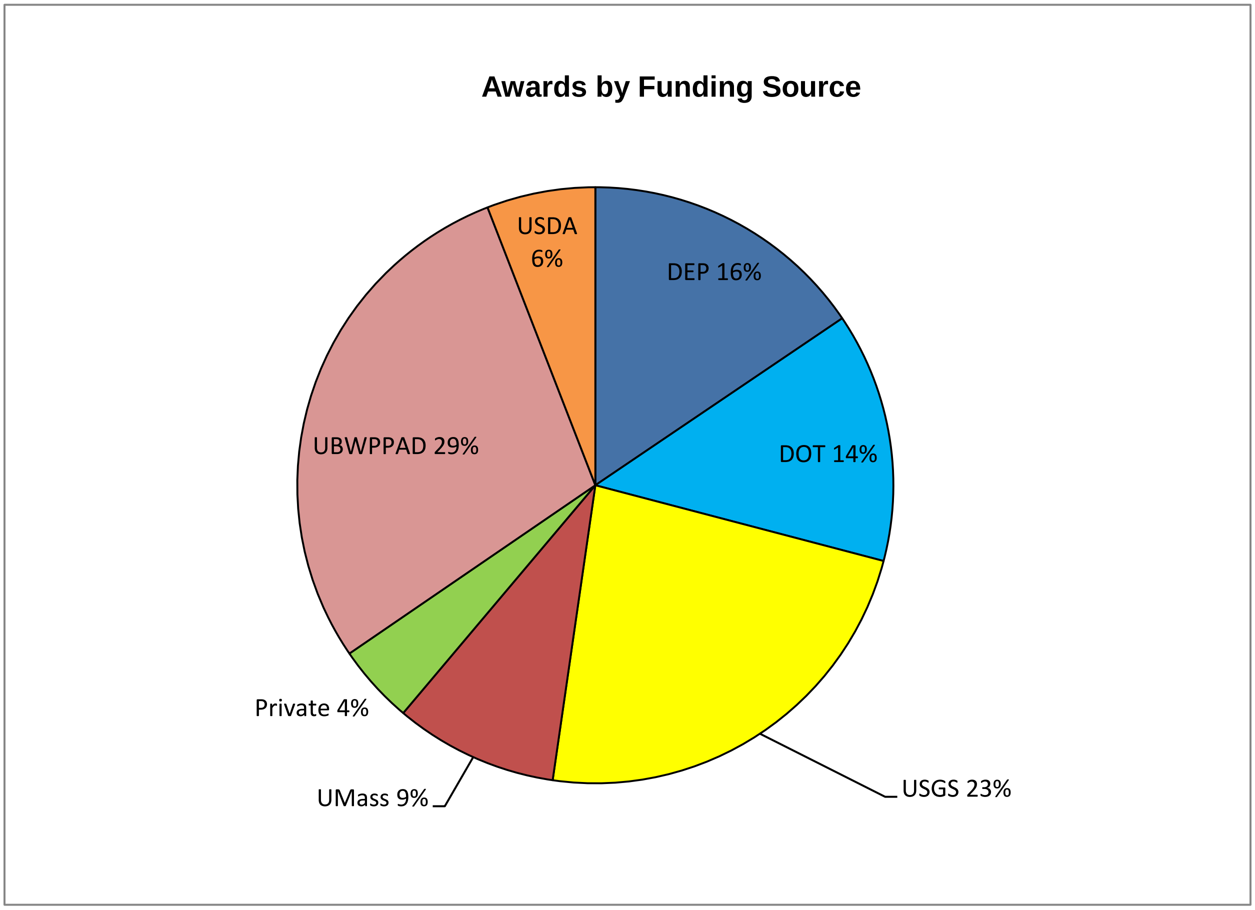
USGS 104B: $ 92,335 broken down as follows:

$ 16,860	Administration
$ 20,433	Workshops
$ 24,000	McGowan research project
$ 5,000	Xing research project
$ 25,642	Boutt research project

MA DOT	$ 50,792
Blackstone River	$ 107,393
USDA	$ 22,083
UMass (Director)	$ 33,214
ARM Project	$ 31,074
DEP Data Sharing Project	$ 27,144
EAL	$ 16,105




Awards by Sponsor Type
Private
3%
UMass
9%
Fed
29%
State
29%
Regional Gvt
29%


Awards by Funding Source
USDA
6%
DEP 16%
DOT 14%
USGS 23%
UMass 9%
Private 4%
UBWPPAD 29%