# Water Resources Institute
# Annual Technical Report
# FY 2013

# Introduction

The University of Wisconsin WRI serves as the gateway to federal WRRI grants for all Wisconsin colleges and universities. While the WRI's federal base funding from the U.S. Geological Survey totals less than $100,000 per year, every federal dollar is matched with at least two nonfederal dollars. All WRRI grants are awarded on a competitive, peer-reviewed basis. WRI funds are leveraged with additional funding from the UW System Groundwater Research Program, part of Wisconsin's Groundwater Research and Monitoring Program. Faculty members and research staff who have achieved PI status from any UW System campus are eligible to apply for this funding. Guided by the Wisconsin Groundwater Coordinating Council, this program is the mechanism whereby the UW System and the state departments of Natural Resources, Safety & Professional Services, and Agriculture, Trade & Consumer Protection pool limited state and federal resources to support a coordinated, comprehensive and multidisciplinary response to the state's critical water resource issues. Together, these programs have helped establish the University of Wisconsin as a national leader in groundwater research. The Wisconsin WRI funds an average of 15 short-term research projects of either a fundamental or applied nature that typically involve about 50 faculty, staff and students at a half-dozen campuses around the state each year. By supporting short-term projects, the institute is able to quickly respond to issues as they emerge. WRI annually provides about 30 graduate and undergraduate students in the UW System with opportunities for training and financial support while they work toward their degrees. During the current reporting period a total of 31 students/trainees (14 undergraduates, 7 master's degree students, 8 Ph.D. students and two post-doctoral students) received WRI support from both Federal and non-Federal sources.

WRI research and other water-related information are readily accessible via a Web site (www.wri.wisc.edu) and the Water Resources Library (WRL), a nationally unique collection of documents covering every major water resource topic. The library's catalog is available online and searchable via the Internet, making the WRL a national and global resource. The WRL became the first academic library in the state to make its collection available online to the public when it launched "Wisconsin's Water Library" (www.aqua.wisc.edu/waterlibrary) in 2003. The portal permits Wisconsin residents to check out WRL books and other documents free of charge via their local libraries. WRI also helps organize and cosponsor state and regional conferences on water issues. The WRI is housed in the Aquatic Sciences Center which also houses the UW Sea Grant Institute, part of another federal-state partnership of 30 university programs that promote research, education, and outreach on Great Lakes and ocean resources. This unique administrative union of Wisconsin's federal Water Resources Research Institute and Sea Grant programs enables the UW Aquatic Sciences Center to address the full range of water-related issues in Wisconsin, from surface water to groundwater, from the Mississippi River to the shores of Lakes Michigan and Superior.

# Research Program Introduction

As established by Wisconsin's Groundwater Law of 1984, the state provides $250,000 to $300,000 annually to the UW System to support groundwater research and monitoring. In 1989, the WRI became the UW System's lead institution for coordinating the calls for proposals and peer reviews for distribution of the funds. To avoid duplication and better target groundwater research funding, several other state agencies (the departments of Safety & Professional Services, Natural Resources, and Agriculture, Trade and Consumer Protection) agreed to partner with the WRI to establish an annual Joint Solicitation for Groundwater Research and Monitoring. This annual solicitation has funded more than 400 groundwater research and monitoring projects since its inception and has helped establish Wisconsin as a leader in groundwater research. The results of the Wisconsin Groundwater Research and Monitoring Program (WGRMP) are recognized internationally, and WRI plays an important role in coordinating project reporting and making all technical reports available through our institute's library and website.

Our priorities for groundwater research are established annually by the Wisconsin Groundwater Research Advisory Council (GRAC) and are included as part of the Joint Solicitation. The GRAC is our institute's advisory council and also convenes to make project funding decisions. All proposals submitted to the Joint Solicitation receive rigorous external peer review (coordinated by the WRI) and relevancy review by the Research Subcommittee of the state's Groundwater Coordinating Council.

Beginning in 2010, the annual 104(B) allocation was used to expand the scope of the joint solicitation to include research on the effects of climate change on Wisconsin's water resources. Priorities for climate change research were established through a partnership between the WRI and the Wisconsin Initiative on Climate Change Impacts (WICCI). Established in 2007, WICCI is a university-state partnership created to: (a) assess and anticipate the effects of climate change on specific Wisconsin natural resources, ecosystems and regions; (b) evaluate potential effects on industry, agriculture, tourism and other human activities; and (c) develop and recommend adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders.

We believe these partnerships with other state agencies provides WRI with the ability to fund highly relevant research and allows our limited funds for 104(B) to be leveraged to the fullest extent.

# Award--The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds

## Basic Information

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|---|---|
| **Title:** | Award--The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds |
| **Project Number:** | 2008WI244S |
| **Start Date:** | 9/15/2008 |
| **End Date:** | 9/14/2013 |
| **Funding Source:** | Supplemental |
| **Congressional District:** | 2nd |
| **Research Category:** | Water Quality |
| **Focus Category:** | Toxic Substances, Wetlands, Water Quality |
| **Descriptors:** | mercury, catchment processes |
| **Principal Investigators:** | James Hurley, David P. Krabbenhoft |

## Publications


1. Kolker, A., Olson, M., Krabbenhoft, D.P., Tate, M.T., and Engle. M.A., 2010, Patterns of mercury dispersion from local and regional emission sources, rural Central Wisconsin, USA, Atmos. Chem. Phys., 10, 1–10, 2010.
2. Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. 2010, Comparison of Atmospheric 1 Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America, Geophysical Research (in press).
3. Engle, MA, MT Tate, DP Krabbenhoft, A Kolker, ML Olson, ES Edgerton, JF DeWild, and AK McPherson. 2008. Characterization and cycling of atmostpheric mercury along the centeral US Gulf of Mexico coast. Applied Geochemistry 23, 419-437
4. Geboy N, DP Krabbenhoft, MA Engle, and T Sabin. 2011. The Solubility of Mercury-Containing Aerosols in Fresh and Sea Water. In the Proceedings of the 10th International Conference on Mercury as a Global Pollutant, Halifax, Nova Scotia. 1 page.
5. Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. 2010, Comparison of Atmospheric Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America, J. Geophys. Res., 115, D18306, doi:10.1029/2010JD014064

# Annual Progress Report

**Selected Reporting Period:** 3/1/2010 - 2/28/2011

**Submitted By:** David Krabbenhoft
**Submitted:** 5/27/2011

## Project Title

WR08R005: The Transport, Fate and Cycling of Mercury in Watersheds and Air Sheds

## Project Investigators

James Hurley, University of Wisconsin

## Progress Statement

This project looks at two mercury related questions: (1) mercury in watersheds; and, (2) mercury cycling and transport in the atmosphere. During reporting period the project completed its second year of "recovery" (i.e., no longer loading mercury to the study watershed) on the Mercury Experiment to Assesses Atmospheric Loadings in Canada and the US (METAALICUS) project. Our portion of the project is to monitor the watershed-scale response of the artificial load of mercury that was administered from 2001 through 2007 using three different stable isotopes (198Hg, 201Hg, 202Hg) to the study wetland, uplands and lake, respectively. During this phase of the project, we will quantify the response of the watershed to a mercury "load reduction" through continuous monitoring of the isotope concentrations and water flux from the terrestrial flows into the study lake. On the atmospheric studies, the project performed one assessment study of mercury deposition spanning time and space domain near a emission stack in central Wisconsin; and significantly enhanced our field monitoring system by securing the extra instrumentation needed to make "gradient" measurements (Eddy Correlation method) of mercury concentrations in the atmosphere above our study sites.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

Our results show that in coastal settings, the intersection of terrestrially based mercury emission sources interacting with chemical oxidants formed in the marine boundary layer result in exacerbated mercury deposition in the near coastal environments. These finds have direct implications for water-resource rich ecosystems along the East Coast of the US, and people who fish in those waters. Also, the application of the mercury depositon model developed by this project to these field settings provides a scientifically based explanation for why coastal areas in the southeastern US are among the highest mercury deposition zones.

**Description**

Results from the past year of data collection revealed that despite the cessation of loading the watershed on the METAALICUS project, concentrations in runoff continued to increase. This phenomenon reveals the inherent time lags that are part of the natural response to changes in loading watersheds. On the atmospheric studies portion of the project the assessment revealed the importance of the marine boundary layer for facilitating atmospheric mercury reactions and deposition.

**Description**

The expanded ability to measure mercury concentration in the atmosphere using the Eddy Correlation method will significantly improve our ability to understand the bi-directional nature of mercury fluxes between the atmosphere and the land/water surface.

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Characterization and cycling of atmospheric mercury along the central U.S. Gulf of Mexico Coast |
| **Author(s)** | Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Kolker, A., Olson, M.L., Edgerton, E.S., DeWild, J.F., and McPherson, A.K. |
| **Publication/Publisher** | Applied Geochemistry 23 (2008), pp. 419–437. |
| **Year Published** | 2008 |
| **Volume & Number** | 23 |
| **Number of Pages** | 19 |
| **Description** | |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Patterns of mercury dispersion from local and regional emission sources, rural Central Wisconsin, USA |
| **Author(s)** | Kolker, A., Olson, M., Krabbenhoft, D.P., Tate, M.T., and Engle. M.A., |
| **Publication/Publisher** | Atmos. Chem. Phys., |
| **Year Published** | 2010 |
| **Volume & Number** | 10, 1–10 |
| **Number of Pages** | 10 |
| **Description** | Abstract. Simultaneous real-time changes in mercury (Hg) speciation- reactive gaseous Hg (RGM), elemental Hg (Hg°), and fine particulate Hg (Hg-PM2.5), were determined from June to November, 2007, in ambient air at three locations in rural Central Wisconsin. Known Hg emission sources within the airshed of the monitoring sites include: 1) a 1114 megawatt (MW) coal-fired electric utility generating station; 2) a Hg-bed chlor-alkali plant; and 3) a smaller (465 MW) coal-burning electric utility. Monitoring sites, showing sporadic elevation of Hg°, Hg-PM2.5, and RGM were positioned at distances of 25, 50 and 100 km northward of the larger electric utility. Median concentrations of Hg°, Hg-PM2.5, and RGM were 1.3–1.4 ng m−3, 2.6–5.0 pg m−3, and 0.6–0.8 pg m−3, respectively. A series of RGM events were recorded at each site. The largest, on 23 September, occurred under prevailing southerly winds, with a maximum RGM value (56.8 pg m-3) measured at the 100 km site, and corresponding elevated SO2 (10.4 ppbv; measured at 50 km site). The finding that RGM, Hg°, and Hg-PM2.5 are not always highest at the 25 km site, closest to the large generating station, contradicts the idea that RGM decreases with distance from a large point source. This may be explained if: 1) the 100 km site was influenced by emissions from the chlor-alkali facility or by RGM from regional urban sources; 2) the emission stack height of the larger power plant promoted plume transport at an elevation where the Hg is carried over the closest site; or 3) RGM was being generated in the plume through oxidation of Hg°. Operational changes at each emitter since 2007 should reduce their Hg output, potentially allowing quantification of the environmental benefit in future studies. |
| **Any Additional Citation Information** | |

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|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Comparison of Atmospheric Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America |
| **Author(s)** | Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. |
| **Publication/Publisher** | Geophysical Research |
| **Year Published** | In Press |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | |
| **Any Additional Citation Information** | |

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|---|---|
| **Publication Type** | Proceedings/Symposium (Not Peer-Reviewed) |
| **Title** | The Solubility of Mercury-Containing Aerosols in Fresh and Sea Water |
| **Author(s)** | Geboy, N., Krabbenhoft, D., Engle, M., and Sabin, T. |
| **Publication/Publisher** | Proceeding of the 10th International Conference on Mercury as a Global Pollutant |
| **Year Published** | 2010 |
| **Volume & Number** | 1 |
| **Number of Pages** | 1 |
| **Description** | Abstract presented at this international meeting |
| **Any Additional Citation Information** | |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Nicholas Ostrowski |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Kenneth Bradbury |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Masters |
| **Graduation Month** | August |
| **Graduation Year** | 2012 |
| **Department** | IES |
| **Program** | Letters and Science |
| **Thesis Title** | |
| **Thesis Abstract** | |

# Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity

## Basic Information

| | |
|---|---|
| **Title:** | Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity |
| **Project Number:** | 2010WI253G |
| **Start Date:** | 9/1/2010 |
| **End Date:** | 8/31/2013 |
| **Funding Source:** | 104G |
| **Congressional District:** | WI-002 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Models, Water Quality, Water Quantity |
| **Descriptors:** | None |
| **Principal Investigators:** | Anita Thompson, Bruno Basso, Mike Fienen, David Hyndman, Randall Jackson, K. G. Karthikeyan, Anthony Kendall, Brian J Lepore |

## Publication

1. Stenjem, Ryan S. 2013. Subsurface water and nutrient dynamics of cellulosic biofuel cropping systems. M.S. Thesis, Biological Systems Engineering, University of Wisconsin, Madison, WI. 134p.

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Anita Thompson
**Submitted:** 5/8/2014

## Project Title

WR10R008: Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity

## Project Investigators

Anita Thompson, University of Wisconsin-Madison

## Progress Statement

Objective 1 - Data Collection and Compilation

Watershed and plot scale field data collection
Subsurface drainage and nutrient loading continued to be monitored in 2013 and 2014 from continuous corn (CC), switchgrass (SG), hybrid poplar (HP) and Miscanthus (M) treatments. Samples were analyzed for volume, total nitrogen, total phosphorus, dissolved reactive phosphorus, nitrate, ammonia, and dissolved organic carbon. Hourly soil temperature and moisture data were collected and analyzed. Minor repairs to the lysimeter systems were made to maintain them.

Surface runoff was collected from small-scale (1m X 1m) runoff plots in M, CC, and SG (3 replicates in each system) between 18 April 2013 and 5 October 2013. Thirty-three natural rainfall events were monitored and runoff samples were analyzed for volume, total nitrogen, total phosphorus, total dissolved phosphorus, dissolved organic carbon, total solids, and total organic matter (OM). Remaining nutrient analyses for samples from previous seasons were completed. Leaf Area Index (LAI) was measured for the three cropping systems throughout the growing season. Antecedent soil moisture and precipitation were measured for each event.

Watershed scale stream data collection continued in 2013 and 2014 within the Middle Rock and Flambeau watersheds. These two watersheds represent prime agricultural cropland and non-managed marginal land, respectively. Each watershed has 16 stream locations that have been visited three times for nutrient and ion sampling and discharge measurement. Thirteen sites in the Middle Rock and 5 sites in the Flambeau are located at USGS gauges that collect continuous discharge readings available for download. Three of the sites within the the Middle Rock watershed have stream gauge and transducer installations that record temperature and pressure. The Middle Rock watershed contains four groundwater wells that have also been monitored for groundwater temperature and pressure.

GIS data collection
A cropland data layer and soil texture data have been obtained for the state of Wisconsin. In order to discriminate and characterize prime cropland and marginal land soils, land cover classes representative of each soil type were extracted and analyzed for their soil textures. ROSETTA was then used to determine the field capacity and saturated hydraulic conductivity for each of the soil textures. These hydrologic properties will be used to quantify important distinctions between current cropland and non-managed lands for SALUS simulations of biofuel feedstock crops and their impact on the water cycle.

Objective 2 - Model Coupling and Development
SALUS model experiments have been developed to simulate maize, switchgrass, miscanthus, and hybrid poplar cropping systems for 2011 and 2012. These crop simulations were analyzed for crop yield, recharge as drainage, and nitrate leached and validated using subsurface lysimeter and surface runoff data. Validation for the hybrid poplar simulations was not possible due to issues with the equipment and data for that cropping system. Preliminary SALUS simulations for these crops on marginal lands have been generated using the spatial analysis of soil textures and hydrologic properties on non-managed lands in Wisconsin and will continue to be developed into 2014. Coupling of the SALUS and ILHM models to bring these simulations up to watershed scale is expected to begin in the summer of 2014.

Objective 3 - Model Validation
Three sites in the Middle Rock watershed along the Yahara River had temperature and pressure transducers installed in July of 2011. These are being monitored and downloaded regularly to build a time series of stream stage that is used with discharge measurements to develop a stage-discharge relationship for each of the stream gauges. The three sites have also been sampled for nutrients as part of the watershed-scale data collection. The coupled SALUS-ILHM model will be validated using the watershed-scale stream nutrient and discharge data collected in October 2012, June 2013, and April 2014.

Objective 4 - Model Intercomparison
Comparison of the coupled SALUS-ILHM and GSFLOW models for the Flambeau and Middle Rock watersheds is anticipated to begin in Fall of 2014.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

Plot-scale Analysis:
Spring and early Summer in 2013 (March through June) were wet periods relative to the first three years of the study. Precipitation during the first half of 2013 exceeded the 30 year average by nearly 25 cm. However, cumulative precipitation during the second half of 2013 was only 30 cm, approximately 15 cm below average for that time period (refer to Figure 1 in the Supplemental Information section).

The different precipitation pattern of 2013 compared to the previous years resulted in somewhat different drainage patterns than previously observed (refer to Figure 2 in the Supplemental Information section). Drainage in Spring 2013 from CC and HP treatments was higher than any other season monitored, while SG drainage was the second highest recorded total. Also, the extremely wet start to the year reduced the differences in total drainage among the cropping systems in both spring and summer of 2013. The very dry second half of 2013 and very cold start to 2014 limited drainage; no drainage occurred from any cropping system in the fall of 2013 or winter 2014 (as of 28 March 2014).

Nitrate ($NO_3$) loading from CC was consistently greater than from the other cropping systems throughout 2013 and early 2014 (refer to Figure 3 in the Supplemental Information section). However, $NO_3$ concentrations from CC declined dramatically from the spring to summer period in 2013. Nearly 50% more drainage occurred from CC in spring of 2013 compared to the spring of 2012, however nitrate loading from CC was approximately 30% lower in 2013. Nitrate loading from SG and HP remained very low relative to CC; $NO_3$ concentrations have been below the threshold of detection in HP for the entire study period.

Differences in dissolved organic carbon, ammonia, and dissolved reactive phosphorus concentration in drainage among the cropping systems were not generally significant and seasonal loading differences were primarily driven by differences in drainage among the cropping systems.

Storm event runoff depth and runoff coefficient (ratio of runoff depth to rainfall depth) over the study period followed the order CC > M > SG (refer to Table 1 in Supplemental Information section). Differences among crops were more pronounced when antecedent moisture content exceeded field capacity. Relationships between runoff and several rainfall parameters were evaluated. The strongest linear relationship was between runoff depth and rainfall erosivity (product of maximum 30 minute rainfall intensity and total storm kinetic energy); the magnitude of the increase followed the order CC > M > SG. Similar to storm event runoff depths, storm event sediment and nutrient loads followed the order CC > M > SG (refer to Table 1 in Supplemental Information section).

Watershed-scale Data Collection:
Multi-instance stream data collection continued in 2013 and into 2014 at several established sites throughout the Middle Rock and Flambeau watersheds, in Southern and Northern Wisconsin, respectively. Stream discharge measurements and nutrient samples were collected by the MSU hydrogeology lab at 16 sites in each of the two watersheds in June 2013 and April 2014, including three sites in the Middle Rock watershed with stream gauge and transducer installations for continuous stream temperature and pressure monitoring. These sites were also periodically visited by UW-Madison project members for additional discharge measurements and data downloading.

Stream discharge and nutrient concentrations:
Stream samples were collected in October 2012 and June 2013 from both the Middle Rock and Flambeau watersheds and analyzed for total phosphorus, total nitrogen, soluble reactive phosphorus, nitrate, and ammonia (refer to Figure 4 in the Supplemental Information section). These data will be used to validate coupled SALUS-ILHM model simulations for surface water quality associated with biofuel crop production. Nutrient concentrations in the Flambeau watershed, where the primary

land cover is forest, are significantly lower than in the predominantly agricultural Middle Rock watershed, especially for total nitrogen and nitrate. Furthermore, concentrations for all five parameters tended to be lower during the June 2013 sampling period than October 2012, particularly for total phosphorus and soluble reactive phosphorus.

Stream monitoring and discharge rating curve data:
Stream temperature and pressure continued to be monitored throughout 2013 and into 2014 at three sites located along the headwaters of the Yahara River in the Middle Rock watershed (refer to Figure 5 in the Supplemental Information section). The transducers contained in the stream gauges have been able to accurately capture both base flow conditions and numerous high flow conditions for the past three years. Stream discharge and gauge height is also periodically collected at these three sites in order to develop discharge rating curves (refer to Figure 6 in the Supplemental Information section). Data collection has been carried out during both base flow and high flow condition. The continuous pressure data will be used in conjunction with the relationship determined from the discharge rating curves to establish continuous discharge, which will be used to validate coupled SALUS-ILHM model simulations for changes in streamflow associated with biofuel crop production. All three rating curves have yielded correlations between observed gauge height and discharge with coefficient of determination values of 0.88 or higher.

Groundwater well monitoring:
Similar transducers have continued to record groundwater temperature and pressure in four groundwater wells located in the headwaters region of the Middle Rock watershed (refer to Figure 7 in the Supplemental Information section). As a result of declining water tables, only one well (VX373) has captured any sustained periods of quality data. The highest water table elevations have been observed during the late summers of 2011 and 2013 while water levels were below the well screen for all of 2012 and into the summer of 2013. Data collection in VX373 will continue through 2014.

Plot-scale Model Validation:
SALUS simulations were generated for production of maize, switchgrass, and miscanthus cropping systems using conditions from 2011 and 2012. Crop yield, recharge, and nitrate leached were simulated for each crop and validated using harvest information and subsurface drainage and surface runoff concentration data (refer to Figure 8 in the Supplemental Information section). Crop yield, drainage, and runoff nitrate concentrations were averaged over multiple plots of the respective crops then totaled for 2011 and 2012 for crop yield and nitrate leached and compared as a time series for recharge. These simulations produced values very close to those observed at the cropping systems for all three crops and parameters. SALUS overpredicted recharge values for switchgrass and miscanthus during late 2012. Further development of these two models from simple cultivars to complex cultivars within SALUS is expected to address these variations. Observed runoff concentrations of nitrate in 2011 and 2012 were 1 kg/ha and 5 kg/ha respectively, while SALUS predicted no leaching.

Marginal Land Scenario Development:
Comparison of soil hydrologic properties on crop and non-managed lands:
Work has begun on characterizing marginal lands within the state of Wisconsin. This work will lead to the development of a coupled SALUS-ILHM model to simulate the impacts of biofuel crop production on surface runoff and drainage in the mostly forested and non-managed Flambeau watershed located in the northern part of the state. Two sets of soil textures, representing managed cropland and non-managed land, were extracted using a cropland data layer and a soils map. Croplands were characterized by maize and soybean production, while non-managed lands were defined by various forest and shrubland land covers. ROSETTA was then used to compliment the soil textures with hydrologic properties including field capacity and saturated hydraulic conductivity. Figure 9 in the Supplemental Information section shows the distribution of field capacity values across non-managed lands for the state of Wisconsin. The frequencies for the two hydrologic properties on the two land types were then compared to show that land currently used as cropland tends to have higher field capacity and lower hydraulic conductivity when compared to non-managed lands (refer to Figure 10 in the Supplemental Information section).

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Simulating Spatial and Temporal Variability of Regional Evapotranspiration and Groundwater Recharge: Influences of Land Use, Soils, and Lake-Effect Climate |
| **Author(s)** | Kendall and Hyndman |
| **Publication/Publisher** | Advances in Water Resources |
| **Year Published** | |
| **Volume & Number** | |

| | |
|---|---|
| **Number of Pages** | |
| **Description** | In Preparation |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Water and nutrient fluxes in an experimental multi-species biofuel crop plantation |
| **Author(s)** | Brena, A., Kendall, A. Basso, B., and Hyndman, D |
| **Publication/Publisher** | |
| **Year Published** | |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | In Preparation |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Thesis/Dissertation |
| **Title** | Subsurface water and nutrient dynamics of cellulosic biofuel cropping systems |
| **Author(s)** | Stenjem, R. |
| **Publication/Publisher** | University of Wisconsin - Madison |
| **Year Published** | |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | M.S. Thesis |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Surface runoff, sediment and nutrient loads from biofuel cropping systems |
| **Author(s)** | Polich, M., A.Thompson, and K.G. Karthikeyan |
| **Publication/Publisher** | |
| **Year Published** | |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | In preparation |
| **Any Additional Citation Information** | |

## Other Project Support

| | |
|---|---|
| **Source** | USDA-NIFA Hatch |
| **Dollar Value** | $270,983 |
| **Description** | Linking Cropping System Diversity with Nutrient Loss Dynamics in Alternative Biofuel Production Systems |
| **Start Date** | 10/1/2009 |
| **End Date** | 9/30/2013 |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Modeling Regional Groundwater Implications of Biofuel Crop Production in the Great Lakes Region |
| **Presenter(s)** | Austin Parish |
| **Presentation Type** | Poster session |
| **Event Name** | AGU Fall Meeting |
| **Event Location** | San Francisco, CA |
| **Event Date** | 12/11/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | |
| **Description** | |

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|---|---|
| **Title** | Runoff Water and Nutrient Fluxes from Biofuel Cropping Systems |
| **Presenter(s)** | Michael Polich |
| **Presentation Type** | Poster session |
| **Event Name** | American Water Resources Association Wisconsin Section |
| **Event Location** | Brookfield, Wisconsin |
| **Event Date** | 3/7/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | |
| **Description** | |

| | |
|---|---|
| **Title** | Water Quantity and quality impacts of biofuel cropping systems |
| **Presenter(s)** | Anita Thompson |
| **Presentation Type** | Seminar |
| **Event Name** | University of Wisconsin Arboretum Seminar Series |
| **Event Location** | Madison, Wisconsin |
| **Event Date** | 5/7/2013 |
| **Target Audience** | Mixed |
| **Audience Size** | |
| **Description** | |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Augustin Brena |
| **Campus** | Other |
| **Advisor Name** | David Hyndman |
| **Advisor Campus** | Other |
| **Degree** | Post Doc |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Geological Sciences |
| **Program** | Hydrogeology |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Anthony Kendall |
| **Campus** | Other |
| **Advisor Name** | David Hyndman |
| **Advisor Campus** | Other |
| **Degree** | Post Doc |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Geological Sciences |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

| | |
|---|---|
| **Student Name** | Daniel Mossing |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Anita Thompson |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Undergraduate |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Biological Systems Engineering |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Austin Parish |
| **Campus** | Other |
| **Advisor Name** | David Hyndman |
| **Advisor Campus** | Other |
| **Degree** | Expected Masters |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Geological Sciences |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Michael Polich |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Anita Thompson |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Expected Masters |
| **Graduation Month** | |

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|---|---|
| **Graduation Year** | |
| **Department** | Biological Systems Engineering |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Ryan Stenjem |
| **Campus** | University of Wisconsin-Madison |

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|---|---|
| **Advisor Name** | Anita Thompson |
| **Advisor Campus** | University of Wisconsin-Madison |

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| **Degree** | Other |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Biological Systems Engineering |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Zach Zopp |
| **Campus** | University of Wisconsin-Madison |

| | |
|---|---|
| **Advisor Name** | Anita Thompson |
| **Advisor Campus** | University of Wisconsin-Madison |

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|---|---|
| **Degree** | Other |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Biological Systems Engineering |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

## Undergraduate Students Supported

New Students: **0**
Continuing Students: **1**

# Influence of Adsorbed Antibiotics on Water Quality and Soil Microbes

## Basic Information

| | |
|---|---|
| **Title:** | Influence of Adsorbed Antibiotics on Water Quality and Soil Microbes |
| **Project Number:** | 2010WI285O |
| **Start Date:** | 7/1/2010 |
| **End Date:** | 6/30/2013 |
| **Funding Source:** | Other |
| **Congressional District:** | WI 2nd |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | Water Quantity, Geochemical Processes, Sediments |
| **Descriptors:** | |
| **Principal Investigators:** | Zhaohui Li |

## Publications


1. Chang, P.-H., Li, Z., Jean, J.-S., Jiang, W.-T., Wang, C.-J., Lin, K.-H. (2012) Adsorption of tetracycline on 2:1 layered non-swelling clay mineral illite, Appl. Clay Sci., 67-68, 158-163. http://dx.doi.org/10.1016/j.clay.2011.11.004
2. Wu, Q., Li, Z., Hong, H. (2012) Influence of types and charges of exchangeable cations on ciprofloxacin sorption by montmorillonite, J. Wuhan Univ. Technol. - Mater. Sci. Ed., 27, 516-522. http://dx.doi.org/10.1007/s11595-012-0495-2
3. Lv, G., Liu, L., Li, Z., Liao, L., Liu, M. (2012) Probing the interactions between chlorpheniramine and 2:1 phyllosilicates, J. Colloid Interface Sci., 374, 218-225. http://dx.doi.org/10.1016/j.jcis.2012.01.029
4. Wu, Q., Li, Z., Hong, H. (2013) Adsorption of the quinolone antibiotic nalidixic acid onto montmorillonite and kaolinite, Appl. Clay Sci., 74, 66-73. http://dx.doi.org/10.1016/j.clay.2012.09.026
5. Jiang, W.-T., Wang, C.-J., Li, Z. (2013) Intercalation of ciprofloxacin accompanied by dehydration in rectorite, Appl. Clay Sci., 74, 74-80. http://dx.doi.org/10.1016/j.clay.2012.07.009
6. Jiang, W.-T., Chang, P.-H. Wang, Y.-S., Tsai, Y., Jean, J.-S., Li, Z., Krukowski, K. (2013) Removal of ciprofloxacin from water by birnessite, J. Hazard. Mater., 250-251, 362-369. http://dx.doi.org/10.1016/j.jhazmat.2013.02.015
7. Wu, Q., Li, Z., Hong, H., Li, R., Jiang, W.-T. (2013) Desorption of ciprofloxacin from clay mineral surfaces, Water Res., 47 (1), 259-268. http://dx.doi.org/10.1016/j.watres.2012.10.010
8. Chang, P.-H., Li, Z., Jean, J.-S., Jiang, W.-T., Wang, C.-J., Lin, K.-H. (2012) Adsorption of tetracycline on 2:1 layered non-swelling clay mineral illite, Appl. Clay Sci., 67-68, 158-163. http://dx.doi.org/10.1016/j.clay.2011.11.004
9. Wu, Q., Li, Z., Hong, H. (2012) Influence of types and charges of exchangeable cations on ciprofloxacin sorption by montmorillonite, J. Wuhan Univ. Technol. - Mater. Sci. Ed., 27, 516-522. http://dx.doi.org/10.1007/s11595-012-0495-2
10. Lv, G., Liu, L., Li, Z., Liao, L., Liu, M. (2012) Probing the interactions between chlorpheniramine and 2:1 phyllosilicates, J. Colloid Interface Sci., 374, 218-225. http://dx.doi.org/10.1016/j.jcis.2012.01.029

11. Wu, Q., Li, Z., Hong, H. (2013) Adsorption of the quinolone antibiotic nalidixic acid onto montmorillonite and kaolinite, Appl. Clay Sci., 74, 66-73. http://dx.doi.org/10.1016/j.clay.2012.09.026
12. Jiang, W.-T., Wang, C.-J., Li, Z. (2013) Intercalation of ciprofloxacin accompanied by dehydration in rectorite, Appl. Clay Sci., 74, 74-80. http://dx.doi.org/10.1016/j.clay.2012.07.009
13. Jiang, W.-T., Chang, P.-H. Wang, Y.-S., Tsai, Y., Jean, J.-S., Li, Z., Krukowski, K. (2013) Removal of ciprofloxacin from water by birnessite, J. Hazard. Mater., 250-251, 362-369. http://dx.doi.org/10.1016/j.jhazmat.2013.02.015
14. Wu, Q., Li, Z., Hong, H., Li, R., Jiang, W.-T. (2013) Desorption of ciprofloxacin from clay mineral surfaces, Water Res., 47 (1), 259-268. http://dx.doi.org/10.1016/j.watres.2012.10.010

# Annual Progress Report

**Selected Reporting Period:** 7/1/2011 - 6/30/2012

**Submitted By:** Zhaohui Li
**Submitted:** 4/30/2013

## Project Title

WR10R006: Influence of Adsorbed Antibiotics on Water Quality and Soil Microbes

## Project Investigators

Zhaohui Li, University of Wisconsin-Parkside
Maria MacWilliams, University of Wisconsin-Parkside

## Progress Statement

The goal of this research is to investigate the influence of adsorbed antibiotics on water quality and soil microbes. To achieve this central goal, we conducted the following experiments.
1. Determined the desorption kinetics of tetracycline (TC) and ciprofloxacin (CIP) from external surfaces of nonswelling clays or from the interlayer of swelling clays at different loading levels and their effect on water quality.
2. Determined the desorption of TC and CIP form the clays under different pH conditions.
3. Determined the influence of the presence of different types of cations on the desorption of TC and CIP.
4. Determined the antimicrobial activity of TC and CIP bond to external surfaces of kaolinite and in the interlayer spaces of montmorillonite against TC sensitive and TC resistant strains.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

A swelling clay mineral montmorillonite and a nonswelling clay mineral kaolinite were preloaded with antibiotics tetracycline and ciprofloxacin at varying concentrations and bioassays were conducted to examine whether the antibiotics still inhibited bacterial growth in the presence of montmorillonite. Escherichia coli was incubated with montmorillonite or antibiotic-adsorbed montmorillonite, and then the number of viable bacteria per mL was determined. The antimicrobial activity of tetracycline was affected in the presence of montmorillonite, as the growth of non-resistant bacteria was still found even when extremely high TC doses were used. Conversely, in the presence of montmorillonite, ciprofloxacin did inhibit E. coli bacterial growth at high concentrations. These results suggest that the effectiveness of antimicrobial agents in clayey soils depends on the amount of antibiotic substance present, and on the interactions between the antibiotic and the clays in the soil, as well.

## Awards, Honors & Recognition

| | |
|---|---|
| **Title** | Top cited article of the year |
| **Event Year** | 2012 |
| **Recipient** | Zhaohui Li |
| **Presented By** | Journal of colloids and interfacial Science |

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|---|---|
| **Description** | Awarded for the paper:<br><br>Zhaohui Li, Po-Hsiang Chang, Jiin-Shuh Jean, Wei-Teh Jiang, Chih-Jen Wang (2010) Interaction between tetracycline and smectite in aqueous solution. Journal of Colloid and Interface Science. 341(2) pp. 311-319 |

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Desorption of tetracycline from montmorillonite by aluminum, calcium and sodium: an indication of intercalation stability |
| **Author(s)** | Chang, P.-H., Li, Z., Jean, J.-S., Jiang, W.-T., Wu, Q., Lin, K.-H., Kraus, J. |
| **Publication/Publisher** | Int. J. Environ. Sci. Technol. |
| **Year Published** | In Press |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | http://dx.doi.org/10.1007/s13762-013-0215-2 |
| **Any Additional Citation Information** | |

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|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Influence of montmorillonite on antimicrobial activity of tetracycline and ciprofloxacin: a preliminary study |
| **Author(s)** | Lv, G., Pearce, Gleason, A., C.W., Liao, L., MacWilliams, M.P., Li, Z. |
| **Publication/Publisher** | J. Asian Earth Sci. |
| **Year Published** | In Press |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | http://dx.doi.org/10.1016/j.jseaes.2013.04.025 |
| **Any Additional Citation Information** | |

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| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Enrofloxacin uptake and retention on different types of clays |
| **Author(s)** | Wan, M., Li, Z., Hong, H., Wu, Q. |
| **Publication/Publisher** | J. Asian Earth Sci. |
| **Year Published** | In Press |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | http://dx.doi.org/10.1016/j.jseaes.2013.02.032 |
| **Any Additional Citation Information** | |

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|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Adsorption of the quinolone antibiotic nalidixic acid onto montmorillonite and kaolinite |
| **Author(s)** | Wu, Q., Li, Z., Hong, H. |
| **Publication/Publisher** | Appl. Clay Sci. |
| **Year Published** | In Press |
| **Volume & Number** | 74 |

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|---|---|
| **Number of Pages** | 66-73 |
| **Description** | http://dx.doi.org/10.1016/j.clay.2012.09.026 |
| **Any Additional Citation Information** | |

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|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Intercalation of ciprofloxacin accompanied by dehydration in rectorite |
| **Author(s)** | Jiang, W.-T., Wang, C.-J., Li, Z. |
| **Publication/Publisher** | Appl. Clay Sci. |
| **Year Published** | In Press |
| **Volume & Number** | 74 |
| **Number of Pages** | 74-80 |
| **Description** | http://dx.doi.org/10.1016/j.clay.2012.07.009 |
| **Any Additional Citation Information** | |

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| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Probing the interactions between chlorpheniramine and 2:1 phyllosilicates |
| **Author(s)** | Lv, G., Liu, L., Li, Z., Liao, L., Liu, M. |
| **Publication/Publisher** | J. Colloid Interface Sci. |
| **Year Published** | 2012 |
| **Volume & Number** | 374 |
| **Number of Pages** | 218-225 |
| **Description** | http://dx.doi.org/10.1016/j.jcis.2012.01.029 |
| **Any Additional Citation Information** | |

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| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Removal of ciprofloxacin from water by birnessite |
| **Author(s)** | Jiang, W.-T., Chang, P.-H. Wang, Y.-S., Tsai, Y., Jean, J.-S., Li, Z., Krukowski, K. |
| **Publication/Publisher** | J. Hazard. Mater. |
| **Year Published** | In Press |
| **Volume & Number** | 250-251 |
| **Number of Pages** | 362-369 |
| **Description** | http://dx.doi.org/10.1016/j.jhazmat.2013.02.015 |
| **Any Additional Citation Information** | |

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| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Desorption of ciprofloxacin from clay mineral surfaces |
| **Author(s)** | Wu, Q., Li, Z., Hong, H., Li, R., Jiang, W.-T. |
| **Publication/Publisher** | Water Res. |
| **Year Published** | In Press |

| | |
|---|---|
| **Volume & Number** | 47 |
| **Number of Pages** | 259-268 |
| **Description** | http://dx.doi.org/10.1016/j.watres.2012.10.010 |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Adsorption of tetracycline on 2:1 layered non-swelling clay mineral illite |
| **Author(s)** | Chang, P.-H., Li, Z., Jean, J.-S., Jiang, W.-T., Wang, C.-J., Lin, K.-H. |
| **Publication/Publisher** | Appl. Clay Sci. |
| **Year Published** | 2012 |
| **Volume & Number** | 67-68 |
| **Number of Pages** | 158-163 |
| **Description** | http://dx.doi.org/10.1016/j.clay.2011.11.004 |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Newsletter/Periodical (Peer-Reviewed) |
| **Title** | Influence of types and charges of exchangeable cations on ciprofloxacin sorption by montmorillonite |
| **Author(s)** | Wu, Q., Li, Z., Hong, H. |
| **Publication/Publisher** | J. Wuhan Univ. Technol. - Mater. Sci. Ed. |
| **Year Published** | 2012 |
| **Volume & Number** | 27 |
| **Number of Pages** | 516-522 |
| **Description** | http://dx.doi.org/10.1007/s11595-012-0495-2 |
| **Any Additional Citation Information** | |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Interactions of antibiotics with Clay Minerals |
| **Presenter(s)** | Zhaohui Li |
| **Presentation Type** | Seminar |
| **Event Name** | Invited talk to Geosciences department, University of Wisconsin - Milwaukee |
| **Event Location** | |
| **Event Date** | 11/10/2011 |
| **Target Audience** | |
| **Audience Size** | 50 |
| **Description** | |

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|---|---|
| **Title** | Interactions between antibiotics and clays in aqueous system |
| **Presenter(s)** | Zhaohui Li |
| **Presentation Type** | Seminar |
| **Event Name** | Invited talk to China University of Geosciences (Beijing) |
| **Event Location** | |

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|---|---|
| **Event Date** | 12/21/2011 |
| **Target Audience** | International organization |
| **Audience Size** | 50 |
| **Description** | |

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|---|---|
| **Title** | Interactions between antibiotics and clays in aqueous system |
| **Presenter(s)** | Zhaohui Li |
| **Presentation Type** | Seminar |
| **Event Name** | Invited talk to China University of Geosciences (Wuhan) |
| **Event Location** | |
| **Event Date** | 1/5/2012 |
| **Target Audience** | International organization |
| **Audience Size** | 30 |
| **Description** | |

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|---|---|
| **Title** | Stabilities of selected pharmaceuticals in the presence of geologic colloids |
| **Presenter(s)** | Zhaohui Li |
| **Presentation Type** | Poster session |
| **Event Name** | AWRA meeting on 3/1/2012 |
| **Event Location** | |
| **Event Date** | 3/1/2012 |
| **Target Audience** | |
| **Audience Size** | |
| **Description** | |

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|---|---|
| **Title** | A Mechanistic Study of Ciprofloxacin removal by Kaolinite |
| **Presenter(s)** | Roberta A. MacDonald, Zhaohui Li, Caren J. Ackley, Amanda L. Mihelich, Shannon M. Emard, Laura Schulz |
| **Presentation Type** | Poster session |
| **Event Name** | AWRA meeting |
| **Event Location** | |
| **Event Date** | 3/1/2012 |
| **Target Audience** | |
| **Audience Size** | |
| **Description** | |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Samantha Leick |
| **Campus** | University of Wisconsin-Parkside |
| **Advisor Name** | Zhaohui Li |
| **Advisor Campus** | University of Wisconsin-Parkside |
| **Degree** | Undergraduate |
| **Graduation Month** | May |
| **Graduation Year** | 2012 |

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|---|---|
| **Department** | Geosciences |
| **Program** | Environmental Geosciences |
| **Thesis Title** | |
| **Thesis Abstract** | |

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|---|---|
| **Student Name** | Roberta MacDonald |
| **Campus** | University of Wisconsin-Parkside |

| | |
|---|---|
| **Advisor Name** | Zhaohui Li |
| **Advisor Campus** | University of Wisconsin-Parkside |

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|---|---|
| **Degree** | Undergraduate |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Geosciences |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

## Undergraduate Students Supported

New Students: **1**
Continuing Students: **1**

# Simulating Lake Responses to Climate Change with a Mechanistic Water Quality Model

## Basic Information

| | |
|---|---|
| **Title:** | Simulating Lake Responses to Climate Change with a Mechanistic Water Quality Model |
| **Project Number:** | 2011WI266B |
| **Start Date:** | 3/1/2011 |
| **End Date:** | 2/28/2014 |
| **Funding Source:** | 104B |
| **Congressional District:** | WI-2 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Climatological Processes, Water Quality, Models |
| **Descriptors:** | |
| **Principal Investigators:** | Trina McMahon |

## Publications


1. Kara, Emily. 2012. Eutrophication processes and microbial ecology of Lake Mendota, Wisconsin. PhD Thesis. Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI. 177p
2. Hawley, Josiah (Jay). 2012. Simulating Lake Responses to Climate Change with a Mechanistic Water Quality Model. MS Thesis. Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI.
3. Kara, Emily. 2012. Eutrophication processes and microbial ecology of Lake Mendota, Wisconsin. PhD Thesis. Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI. 177p
4. Hawley, Josiah (Jay). 2012. Simulating Lake Responses to Climate Change with a Mechanistic Water Quality Model. MS Thesis. Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI.
5. Hawley, Josiah. 2012. Simulating lake responses to climate change with a mechanistic water quality model. MS Dissertation. Engineering, University of Wisconsin, Madison, WI.

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Katherine McMahon
**Submitted:** 5/14/2014

## Project Title

WR11R001: Simulating Lake Responses to Climate Change with a Mechanistic Water Quality Model

## Project Investigators

Katherine McMahon, University of Wisconsin-Madison

## Progress Statement

We calibrated and validated our coupled hydrodynamic-ecosystem process water quality model (DYRESM/CAEDYM) based on driver data and observations during the ice-free seasons, for Lake Mendota. We expanded this calibration and validation process beyond the 2008 data set to include years 2009 and 2010. Statistical analyses were done to quantify the closeness of fit between the modeled output and observed data. These analyses were part of the parameter sensitivity analysis to determine the multi-year parameter values to use in the climate change simulations. We identified periods of observation data in the 2001-2010, ten year driver data set that match the conditions of our climate change scenarios. These actual observation data were then merged with other driver data to simulate the entire ice-off period of the climate change scenario. We simulated 84 different scenarios corresponding to spring warming (all day, sun-up hours only, night-time hours only), summer warming (all day, sun-up hours only, night-time hours only), spring drought, summery drought, increased spring intense storm events, and increased summer intense storm events. We evaluated the effect of each scenario on model state variables including hypolimnetic dissolved oxygen, nitrate in the epilimnion and hypolimnion, phosphate in the epilimnion and hypolimnion, chlorophyll-a, total cyanobacteria, and total phytoplankton. The results were compiled in Josiah Hawley's masters thesis.

Josiah successfully defended his thesis in September 2012 and graduated in December 2012. We are currently working on preparing a manuscript based on the results of his work. Craig Snortheim was an undergraduate working on the project who is now working towards an MS in Civil and Environmental Engineering. He is finishing Josiah's work and is starting a new project in collaboration with Paul Hanson at the Center for Limnology related to the timing of summer hypolimnetic hypoxia under different climate change scenarios.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

We report a significant change in knowledge: Graduate students Emily Kara and Josiah Hawley advanced our knowledge on how to perform water quality modeling, including model calibration and validation. A deeper understanding of the impact of key parameters on the model output has been gained by expanding the simulations to include the 2009 and 2010 data sets. Calibrating and validating the models for multiple years is helped us to better constrain the range of reasonable parameter values for Lake Mendota and their effect on key water quality components. The climate change scenarios generated some surprising results that we are still trying to interpret. The driver datasets used for running scenarios are themselves a very valuable dataset and we continue to use them for other modeling purposes.

**Description**

Participant training and collaborations. Dr. Emily Kara received her PhD in Environmental Engineering in summer 2012. Emily calibrated and validated the water quality model that is the foundation for the project. She also conducted analyses of bacterial community composition data that we continue to interpret using the model outputs. Mr. Josiah Hawley obtained his MS in Environmental Engineering in Fall 2012. Josiah is further calibrating and validating the water quality model that is the

foundation for the project. Collaborators include: Dr. Paul Hanson, Scientist in the Center for Limnology. Dr. Hanson worked closely with Emily to calibrate and validate the model. He also performed spectral analysis on the model output to determine how well it captures variability at different temporal scales. Training and Professional Development: The project provided training and professional development opportunities to Dr.. Kara, Mr. Hawley and three undergraduate students majoring in Civil and Environmental Engineering (Douglas Chalmers, sophomore; Aaron Besaw, junior; and Craig Snortheim, junior). Craig Snortheim is continuing for an MS in Civil and Environmental Engineering, continuing to work with the model and scenarios.

## Committees, Memberships & Panels

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|---|---|
| **Group Name** | Dane County Lakes and Watershed Commission |
| **Description** | PI McMahon is a citizen representative sitting on the Dane County Lakes and Watershed Commission. The findings for this project will be communicated to the commission and factored into policy-level decisions for management of the Yahara watershed in Dane County. |
| **Start Date** | 7/1/2009 |
| **End Date** | 6/30/2015 |

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Thesis/Dissertation |
| **Title** | SIMULATING LAKE RESPONSES TO CLIMATE CHANGE WITH A MECHANISTIC WATER QUALITY MODEL |
| **Author(s)** | Josiah Hawley |
| **Publication/Publisher** | Masters Thesis |
| **Year Published** | 2012 |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | Many lakes currently experience significant stress due to excessive nutrient influxes and resulting eutrophication. Projected changes in climate could exacerbate these problems by increasing overland runoff and lake water temperatures. The impact of these climate changes on the timing and duration of toxin-producing cyanobacteria blooms are of special concern to both water quality managers and public health officials. We used a one-dimensional coupled hydrodynamic-biogeochemical model (DYRESM-CAEDYM) to simulate the effects of future climate change scenarios for southern Wisconsin on key in-lake response variables. The model was parameterized, calibrated, and validated using observational data from Lake Mendota, Wisconsin during the ice-free period of 2008-10. Climate change scenarios examined include changes in the timing, frequency, and intensity of precipitation events; the timing of ice breakup; and increases in spring nighttime and/or daytime temperatures. Hourly meteorological measurements matching these climate change scenarios were located and used as model drivers. Key response variables examined include the timing and magnitude of cyanobacterial blooms, the timing of epilimnetic phosphorus and nitrate depletion, and the timing of hypolimnetic hypoxia. Results of these simulations improve our understanding of these processes and provide local and regional governments such as the Wisconsin Department of Natural Resources, the Dane County Lakes and Watershed Commission, and the City of Madison with a tool to aid in watershed planning and management. |
| **Any Additional Citation Information** | |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Josiah (Jay) Hawley |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Katherine McMahon |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Masters |
| **Graduation Month** | December |

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|---|---|
| **Graduation Year** | 2012 |
| **Department** | Civil and Environmental Engineering |
| **Program** | Civil and Environmental Engineering |
| **Thesis Title** | SIMULATING LAKE RESPONSES TO CLIMATE CHANGE WITH A MECHANISTIC WATER QUALITY MODEL |
| **Thesis Abstract** | Many lakes currently experience significant stress due to excessive nutrient influxes and resulting eutrophication. Projected changes in climate could exacerbate these problems by increasing overland runoff and lake water temperatures. The impact of these climate changes on the timing and duration of toxin-producing cyanobacteria blooms are of special concern to both water quality managers and public health officials. We used a one-dimensional coupled hydrodynamic-biogeochemical model (DYRESM-CAEDYM) to simulate the effects of future climate change scenarios for southern Wisconsin on key in-lake response variables. The model was parameterized, calibrated, and validated using observational data from Lake Mendota, Wisconsin during the ice-free period of 2008-10. Climate change scenarios examined include changes in the timing, frequency, and intensity of precipitation events; the timing of ice breakup; and increases in spring nighttime and/or daytime temperatures. Hourly meteorological measurements matching these climate change scenarios were located and used as model drivers. Key response variables examined include the timing and magnitude of cyanobacterial blooms, the timing of epilimnetic phosphorus and nitrate depletion, and the timing of hypolimnetic hypoxia. Results of these simulations improve our understanding of these processes and provide local and regional governments such as the Wisconsin Department of Natural Resources, the Dane County Lakes and Watershed Commission, and the City of Madison with a tool to aid in watershed planning and management |

| | |
|---|---|
| **Student Name** | Emily Kara |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Katherine McMahon |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | PhD |
| **Graduation Month** | July |
| **Graduation Year** | 2012 |
| **Department** | Civil and Environmental Engineering |
| **Program** | Civil and Environmental Engineering |
| **Thesis Title** | Eutrophication processes and microbial ecology of Lake Mendota, Wisconsin |
| **Thesis Abstract** | Eutrophication of Lake Mendota, Wisconsin co-occurred with deforestation of the watershed by settlers in the mid 1850's. The characteristics of this aquatic ecosystem are representative of eutrophication occurring throughout the world in lakes, rivers and marine systems (abundant harmful algal blooms [HABs]), anoxic hypolimnia, and altered food webs). Although the flow of nutrients through lakes and the microbial communities responsible for cycling have been a topic of scientific study for more than a century, our understanding of the efficacy of nutrient management, HAB and heterotrophic bacterial community prediction, and phosphorus speciation at the in-lake level remains limited.<br>Enhanced nutrient management in the watersheds of impaired or threatened surface waters is the most common tool for mitigation of eutrophication, and is understood to be an effective tool to improve or prevent degradation of surface water due to excess nutrients. We used a mass balance approach to determine the net effects of nutrient management changes in the Lake Mendota, Wisconsin watershed occurring between 1995 and 2007, including farmers' adoption of enhanced nutrient management plans, reduced use of chemical feed supplements for dairy cattle, and an urban phosphorus ban. These three factors were attributed to be the cause of reduced, but positive accumulation in 2007, indicating that efforts to improve nutrient management have had limited effect on the overall P budget.<br>We set up, calibrated, and validated an aquatic ecosystem model to test its ability for the short- and long-term prediction of the dynamics of HABs in Lake Mendota. We found biological variables to have the poorest fit with observations, particularly at time scales > 1 month, with the use of high-frequency water quality observations and predictions, and assessed using wavelet analysis. We used numerical simulations to assess the effects of climate change scenarios on water quality, and to identify the most potentially important external factors for HAB dynamics in the lake.<br>Beyond HABs, heterotrophic bacterial communities are responsible for important ecosystem functions in lakes, and the interactions of heterotrophic bacteria with each other, with HABs, and with environmental variables over long time series is unknown. We determined the drivers of bacterial community characteristics (including diversity and co-occurrence network structure) using a decade-long record of bacterial community composition together with a long-term ecological research dataset and local similarity analysis. We found season to drive the complexity of interaction networks and patterns in diversity; variation of environmental variables did not explain the patterns observed. |

Finally, the chemical structure and dynamics of phosphorus compounds in Lake Mendota across space and time was assessed by 31P nuclear magnetic spectroscopy (NMR) to determine the prevalence and nature of non-**I**reactive phosphorus in particulate and dissolved fractions. We found particulate and dissolved fractions from all locations observed had significant temporal variability, while epilimnetic particulate P was more stable over 5 months, and was associated with dissolved reactive P dynamics.
This work addresses phosphorus cycling and microbial ecology of a eutrophic lake, leveraging and building upon the body of literature on anthropogenic eutrophication processes and microbial ecology in lakes.

## Undergraduate Students Supported

New Students: **0**
Continuing Students: **2**

# Climate Change Impacts on Stream Temperature and Flow: Consequences for Great Lakes Fish Migrations

## Basic Information

| | |
|---|---|
| **Title:** | Climate Change Impacts on Stream Temperature and Flow: Consequences for Great Lakes Fish Migrations |
| **Project Number:** | 2011WI267B |
| **Start Date:** | 3/1/2011 |
| **End Date:** | 2/28/2015 |
| **Funding Source:** | 104B |
| **Congressional District:** | WI-2 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Climatological Processes, Ecology, None |
| **Descriptors:** | |
| **Principal Investigators:** | Peter Biek McIntyre |

## Publications


1. Childress, Evan, J. David Allan, Peter McIntyre; In Press; Nutrient subsidies from native fish migrations enhance productivity in Great Lakes tributaries. Ecosystems Vol. 17. 12 pg.
2. McIntyre PB, C. Reidy Liermann, E. Childress, E.J. Hamann, J. Hogan, S.R. Januchowski-Hartley, A.A. Koning, T.M. Neeson, D.L. Oele, B.M. Pracheil. In Press. Conservation of migratory fishes in freshwater ecosystems. Conservation of Freshwater Fishes

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Peter McIntyre
**Submitted:** 5/1/2014

## Project Title

WR11R002: Climate Change Impacts on Stream Temperature and Flow: Consequences for Great Lakes Fish Migrations

## Project Investigators

Peter McIntyre, University of Wisconsin-Madison

## Progress Statement

Objective 1: Quantifying the historical timing of Great Lakes fish migrations in Wisconsin tributaries.

Large historical data sets are rare for fish migrations, and long term analysis of migration phenology has never yet been conducted for the Great Lakes. The US Fish and Wildlife Service collected a unique data set as part of their lamprey control program that includes data for multiple migratory species over a period of six decades. Our goal was to examine trends in migration timing in all migratory species for which there was sufficient data. Last year, we obtained the data from the USFWS, identified 13 migratory species that are well-sampled, and found that 8 of these species show earlier peak migration dates through time. The earlier migration timing of the majority of the species is consistent with the hypothesis that ever-warmer spring temperatures are advancing fish migration phenology.

We are now mid-way through developing a spatiotemporal Bayesian hierarchical statistical model to quantify shifts in migration timing simultaneously for multiple fish species in the Great Lakes. Using the species for which sufficient data exist, we have quantified the julian dates of the first and last fish each year, the peak of the run, and several percentiles of run timing. To complement the fish migration data, we have used NOAA data on remotely-sensed daily surface temperatures to extract temperature time series at the mouth of each of the 182 tributaries represented in the USFWS database for the period 1994 – 2011. These temperature data will be used to standardize timing across all rivers in the dataset, yielding greatly enhanced statistical power to detect phonological shifts using even poorly-sampled tributaries. Within the next few months, we expect to complete these statistical models to identify the temporal trend in first arrival and other metrics for all species.

A major benefit of this modelling approach is that we can quantify spatial variation in the phonological shift among individual tributaries. The code to estimate the model parameters and assess predictive performance has been completed. Our initial analyses of rock bass (non-migratory) and white sucker (migratory) indicate distinct spatial variation in trends in migration onset. Beyond the general trend toward earlier date of the first observation of these species, the model identifies both latitude and (to a lesser extent) longitude as being important influences. The trend toward earlier migrations is happening faster in the south and east than in the north and west, reflecting stronger shifts in the warmer, shallower lakes (Erie, Ontario) than in the colder, deeper lakes (Superior, Michigan). The next step is to integrate the remotely-sensed data into these analyses to standardize for spatial variation in spring warming dates, which will enable us to consolidate data from all tributaries into a single analysis for each species.

This work has also led us to collaborate with WDNR to analyse yellow perch and lake trout spawning timing shifts in the open waters of the Great Lakes, using analyses similar to those we are applying in the tributaries. We submitted a first manuscript on this work, but it was rejected so we are currently reformatting for another journal.

Objective 2: Monitoring the current migration timing along a latitudinal gradient of Wisconsin tributaries to identify temperature and flow levels that trigger the onset of migrations.

Citizen science is an effective way to engage citizens and educate them about the local impacts of climate change. Additionally, it provides a mechanism for collecting data simultaneously across a broad geographic range. In 2011 and 2012, we collaborated with WDNR and UW Extension to develop of network of volunteers to monitor the timing of sucker migrations across the Wisconsin coast of Lake Michigan. We also recorded stream temperature and discharge at each monitoring site.

These data will be added to the USFWS database discussed above to boost our representation of current phonological patterns. In 2013, migration phenologies from eight streams were added to the data set, bringing the total to 30 year-stream phenology observations. In addition, we conducted high-intensity fish migration monitoring (catching and measuring every fish) on two streams in 2013. These data enable us to confirm the validity of volunteer data, and better constrain the role of stream temperature and discharge as cues that may trigger migrations.

Objective 3: Predicting how the timing of migrations is likely to shift with future climate change, and evaluate the implications at the species, community, and ecosystem levels.

Understanding how climate change will influence particular aquatic species is essential for public education and to guide management responses. Our original goal was to leverage the latest USGS modeling of climate change effects on temperature and flow regimes in tributaries by merging forecasted stream patterns with our analysis of migration phenology and cues to determine the ecological consequences for fish migrations. Unfortunately, our collaboration with John Walker and Randy Hunt at the USGS Wisconsin Water Science Center on this topic has stalled due to funding cuts in their project to predict future stream flow and temperature of Great Lakes tributaries. Thus, we do not anticipate that our work will include projections of future migration timing.

However, we made good headway in monitoring community and ecosystem roles of fish migrations in 2013. In April-June, we monitored nutrients and productivity in a set of 10 tributaries on the Door Peninsula, where background nutrient loads range from low to high. Analyses of all 2013 samples have been completed. We found much higher background concentrations of nitrogen (specifically NO3) in some Door County streams than expected, yet we have been able to document a clear NH4 pulse entering many (but not all) streams at the time that the number of breeding suckers peaks. In addition, we used dissolved oxygen loggers to measure whole stream metabolism throughout the sucker migrations in three streams. These data have now been processed to quantify daily gross primary productivity (GPP) and ecosystem respiration (ER). Interestingly, we found sharp increases in both GPP and ER as the water warmed before the suckers arrived, but little evidence of an effect of fish on stream metabolism despite large inputs of nitrogen and phosphorus. This constitutes an interesting negative result; results from salmon research suggest that fish can drive stream ER, but it appears that Door County streams do not respond so strongly. We are in the process of writing a manuscript about these results.

To connect the timing of fish migrations to the ecology of resident sport fishes, we had planned to quantify consumption of sucker eggs and larvae by brook trout in certain streams. Trout diets consisted almost entirely of sucker eggs during the height of the migration, indicating strong linkages between these species. Unfortunately, the summer drought in 2012 killed all the brook trout in our study streams, so no 2013 data could be collected.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

Outreach activities:

A daily program educating the public about fish migrations, sucker life history, and the impacts of climate change was developed and implemented at the Crossroads at Big Creek Nature Center in 2011 and 2012 during the sucker migration. We prepared a brief lecture for the staff to present to visitors, after which visitors would observe sucker spawning in a local creek. Brief lectures were given to two volunteer groups about fish migration ecology and climate change. This project has been featured in newsletters for multiple citizen groups, as well as on the WRI Press Room website in August 2011 (http://wri.wisc.edu/pressroom/Details.aspx?PostID=1138).

Two unanticipated outreach opportunities have also arisen from this project. First, this project has led to a collaborative agreement with the Shedd Aquarium (Chicago, IL) to support a post-doctoral researcher studying Great Lakes fish migrations for three years starting in August 2012. The position is based in Chicago but involves close collaboration with my lab group at UW-Madison, thereby expanding the scope and impact of this WRI project enormously. The focus for 2013-2014 has been migrations of lake whitefish and northern pike into Green Bay tributaries, and use of newly restored breeding habitat by pike after dam removal. We hope to jointly design a display in the Shedd Aquarium to highlight Great Lakes migratory fishes, and how climate change and migration barriers could impact them. Second, informal presentations of our WRI results to WDNR has led to a collaboration with their researchers to test for coupled trends in lake water temperatures and spawning dates for walleye and yellow perch. We have completed those analyses, and are adjusting the manuscript after it was initially rejected by CJFAS.

Results of this WRI research project have been presented by Evan Childress at the American Fisheries Society annual meeting in 2012 and Ecological Society of America annual meeting in 2013 , and by Peter McIntyre in seminars at Tulane University, UW's Wednesday Nite @ the Lab, Great Lakes Fishery Commission, and Utah State University. We are working on developing a project webpage, and discussing how to package further results for publication. One paper from the project has been published in Ecosystems, one chapter manuscript is in press for a book on Freshwater Fish Conservation, one paper is in review at Freshwater Biology, and three more manuscripts are in preparation.

Supporting students and post-docs

Doctoral student Evan Childress has received a stipend for Spring and Summer 2012. To conserve WRI funds, I was able to support Evan's work on the project using other sources during Spring 2011, and hire a minority undergraduate summer student during summer 2013 to assist with sample processing. Evan earned a two-year dissertation fellowship in 2013, so my use of WRI funding to support him is now restricted to conference travel. As a result, I have requested a no-cost extension of the project to complete our data-mining and spatiotemporal modeling. This year, I hired a data analyst to process, distill, and mine the USFWS data and extract the surface temperature records at stream mouths from NOAA remote sensing data. Subsequently, I have just hired a part-time post-doc to execute the Bayesian hierarchicial models of shifts in migration timing. That work will consume all remaining project funds during 2014, and result in a very interesting manuscript led by the post-doc.

## Awards, Honors & Recognition

| | |
|---|---|
| **Title** | Graduate student fellowship |
| **Event Year** | 2013 |
| **Recipient** | Evan Childress |
| **Presented By** | NSF IGERT |
| **Description** | Evan earned a two-year graduate fellowship to continue his work on Great Lakes migratory fishes and climate change. |

## Committees, Memberships & Panels

| | |
|---|---|
| **Group Name** | Evan Childress graduate advisor |
| **Description** | I chair Evan's doctoral advisory committee. |
| **Start Date** | 8/30/2010 |
| **End Date** | 5/30/2013 |

| | |
|---|---|
| **Group Name** | LMS program Anna Grant Birge Award Committee |
| **Description** | In both 2012 and 2013, I have been a member of the selection committee for Birge Awards that support graduate research. |
| **Start Date** | 4/1/2012 |
| **End Date** | 5/30/2013 |

| | |
|---|---|
| **Group Name** | Great Lakes Connectivity Project |
| **Description** | I am on the advisory board of the Great Lakes Connectivity Project, which includes agency leads and academics from throughout the basin. Our goal is to develop barrier management strategies that balance ecological and societal considerations. |
| **Start Date** | 4/1/2013 |
| **End Date** | 5/1/2014 |

| | |
|---|---|
| **Group Name** | Great Lakes Environmental Assessment and Mapping Project advisory panel |
| **Description** | I am on the advisory panel of GLEAM, a cross-cutting research initiative based at the University of Michigan. |
| **Start Date** | 5/1/2012 |

| | |
|---|---|
| **End Date** | 5/1/2014 |

| | |
|---|---|
| **Group Name** | CILER Council of Fellows |
| **Description** | I am a member of the Council of Fellows of the NOAA Cooperative Institute for Limnology and Ecosystem Research at the University of Michigan. |
| **Start Date** | 5/1/2011 |
| **End Date** | 5/1/2014 |

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Nutrient subsidies from native fish migrations enhance productivity in Great Lakes tributaries |
| **Author(s)** | Evan Childress, J. David Allan, Peter McIntyre |
| **Publication/Publisher** | Ecosystems |
| **Year Published** | In Press |
| **Volume & Number** | 17 |
| **Number of Pages** | 12 |
| **Description** | This paper provides evidence that nutrient subsidies delivered to Great Lakes tributary streams by migratory fishes boost the productivity of the ecosystem. |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Comparing nutrient subsidy pathways from iteroparous fish migrations |
| **Author(s)** | Childress, E, and P.B. McIntyre |
| **Publication/Publisher** | Freshwater Biology |
| **Year Published** | In Review |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | This paper presents calculations of the pathway by which nutrient subsidies from Great Lakes migratory fishes enter stream food webs. |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Conservation of migratory fishes in freshwater ecosystems |
| **Author(s)** | McIntyre PB, Reidy Liermann C, Childress E, Hamann EJ, Hogan J, Januchowski-Hartley SR, Koning AA, Neeson TM, Oele DL, Pracheil BM |
| **Publication/Publisher** | Book chapter in: Conservation of Freshwater Fishes |
| **Year Published** | In Press |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | |
| **Any Additional Citation Information** | |

## Partners

| | |
|---|---|
| **Name/Organization** | John Walker & Randy Hunt |
| **Affiliation** | USGS Water Science Center |
| **Affiliation Type** | Federal |
| **Email** | |
| **Description** | Walker and Hunt are our collaborators to link past and future tributary discharge/temperature to fish migration phenology. |

| | |
|---|---|
| **Name/Organization** | John Lyons & Andrew Rypel |
| **Affiliation** | Wisconsin DNR |
| **Affiliation Type** | Local & State |
| **Email** | |
| **Description** | Lyons and Rypel are collaborating with us on an analysis of shifts in breeding phenology of yellow perch and walleye in Lakes Michigan and Superior. |

| | |
|---|---|
| **Name/Organization** | Patrick Doran |
| **Affiliation** | The Nature Conservancy |
| **Affiliation Type** | Non-Governmental Organizations |
| **Email** | pdoran@tnc.org |
| **Description** | Patrick is part of my larger team working on Great Lakes fish migrations and connectivity issues. |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Gametes and excretion from iteroparous migratory suckers subsidize spawning streams |
| **Presenter(s)** | Childress E, McIntyre PB |
| **Presentation Type** | Professional meeting |
| **Event Name** | Ecological Society of America |
| **Event Location** | Minneapolis |
| **Event Date** | 8/7/2013 |
| **Target Audience** | |
| **Audience Size** | 40 |
| **Description** | Conference talk |

| | |
|---|---|
| **Title** | Reconnecting the Great Lakes and their tributaries |
| **Presenter(s)** | McIntyre PB |
| **Presentation Type** | Seminar |
| **Event Name** | |
| **Event Location** | Tulane University |
| **Event Date** | 4/17/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 75 |
| **Description** | Invited seminar |

| | |
|---|---|
| **Title** | Reconnecting the Great Lakes to their tributaries |
| **Presenter(s)** | McIntyre PB |
| **Presentation Type** | Seminar |
| **Event Name** | |
| **Event Location** | Utah State University |
| **Event Date** | 11/14/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 150 |
| **Description** | Invited seminar |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Evan Childress |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Peter McIntyre |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | PhD |
| **Graduation Month** | May |
| **Graduation Year** | 2015 |
| **Department** | Zoology |
| **Program** | Limnology & Marine Science |
| **Thesis Title** | |
| **Thesis Abstract** | |

| | |
|---|---|
| **Student Name** | Aaron Ruesch |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Peter McIntyre |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Masters |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

| | |
|---|---|
| **Student Name** | Ben Stewart-Koster |
| **Campus** | Other |
| **Advisor Name** | Peter McIntyre |
| **Advisor Campus** | Other |
| **Degree** | Post Doc |
| **Graduation Month** | |
| **Graduation Year** | |

**Department**
**Program**
**Thesis Title**
**Thesis Abstract**

## Undergraduate Students Supported

New Students: **1**
Continuing Students: **1**

# Uncertainty and Variability of Wisconsin Lakes in Response to Climate Change

## Basic Information

| | |
|---|---|
| **Title:** | Uncertainty and Variability of Wisconsin Lakes in Response to Climate Change |
| **Project Number:** | 2011WI268B |
| **Start Date:** | 3/1/2011 |
| **End Date:** | 2/28/2015 |
| **Funding Source:** | 104B |
| **Congressional District:** | WI-2 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Climatological Processes, Water Quality, Geochemical Processes |
| **Descriptors:** | |
| **Principal Investigators:** | Chin H Wu |

## Publications

1. Magee M, and CH Wu (In Review) Long-term trends and variability in ice cover and thermal structure in three morphometrically different lakes in response to climate change. Limnology and Oceanography
2. Magee M, and CH Wu (In Review) Hanging climate on three lakes with differing morphometry. Water Research

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Chin Wu
**Submitted:** 5/1/2014

## Project Title

WR11R003: Uncertainty and Variability of Wisconsin Lakes in Response to Climate Change

## Project Investigators

Chin Wu, University of Wisconsin-Madison

## Progress Statement

The project investigates the physical responses of ice cover, water temperature, and evaporation in Wisconsin lakes to climate changes. During the third year of the project, we have been looking at lakes in southern Wisconsin to analyze the response to physical lake variables to climate. Specific lakes researched were Lake Mendota, Lake Wingra, and Fish Lake in Dane County. During the course of the year, we (i) improved the one-dimensional lake-ice model, DYRESM-I to simulate ice cover and water temperature at sub-hourly time intervals and added a component to simulate dissolved oxygen levels in the lakes, (ii) continued development and improvement of a three-dimensional ice/snow/hydrodynamic model that can simulate spatial distribution in ice cover and lake thermal structure, (iii) coupled three-dimensional model to one-dimensional dissolved oxygen model to simulate dissolved oxygen levels in a three-dimensional framework, (iv) continued investigation of the importance of climate drivers to water temperature and evaporation, (v) completed sensitivity studies closely analyzing the effects of changing air temperature and wind speed on both ice cover and thermal structure during the open water period, and (vi) conducted analysis looking at the effect of climate change on cold-water fish oxythermal stress.

Model development:
The one-dimensional lake-ice model, called DYRESM-I, was improved to simulate vertical distribution of water temperature and ice cover at a sub-hourly time interval. This model can continuously simulate lake hydrodynamics during open water the ice cover using thermodynamic principles. The final model has been calibrated in the hydrodynamic and temperature framework for each of the study lakes. Dissolved oxygen calibrations have been completed for Fish Lake and Lake Mendota. Additionally DO calibrations are being completed as needed. In addition, the one-dimensional model was used to project lake ice cover, lake level, and water temperature for use through the Interactive Nowcast/Forecast Operation System for Yahara Waters (INFOS) website. This website allows users to see real-time information on water temperature, ice cover, and water level of the Yahara Lakes (Mendota, Monona, Waubesa, Kegonsa)
The ice module from DYRESM-I was extended and coupled with the existing three-dimensional hydrodynamic (3DHD) model, and this new model is capable of simulating spatial distribution of ice/snow cover and under-ice water temperature. The model was used to run a scenario of winter 2009-2010 in Lake Mendota. Additionally, the model was used to run a scenario of winter 2011-2012 in Fish Lake and well as specific spring mixing and large wind events in Fish Lake. Further enhancement of the model added dissolved oxygen components (3DHD-DO) to simulate spatial distribution of dissolved oxygen during open water and under-ice conditions. This model new enhancement was used to run a scenario of open water in Fish Lake to determine changes in DO levels and corresponding cisco habitat response. Additionally, the 3DHD-DO model is currently being calibrated for Lake Mendota to analyze historic cisco changes for that lake.

Sensitivity of Ice Cover to changes in air temperature and wind speed:
Experiments were conducted to look at the effects of changing the air temperature by increases of 1°C to 10°C and changing the wind speed by changes of ±2%, ±5%, ±8%, and ±8%. Results show that, as expected, increasing air temperature results in decreasing ice cover duration and decreasing maximum ice thickness. Looking only at increases in air temperature, it is apparent that deeper lakes are more prone to experience ice-free conditions, while more shallow lakes may still have ice-cover conditions for short periods (<10 days) even with increase in air temperature of 10°C. Looking at changes in wind speed, in general, lower wind speed results in earlier ice formation and larger ice thicknesses, although there is significant variability due to the timing of air temperatures, which are the main climate driver for ice cover. For instances when air temperature was cold enough for ice cover conditions, ice only was able to form when wind speed was low. If, however, wind speed was low enough for ice cover condition, but air temperature was too warm for ice formation, wind speed did not affect ice cover onset.

Response of thermal structure in two dimictic lakes to climate change:
DYRESM-I was used to simulate the water temperature of Lake Mendota and Fish Lake to determine historical changes in thermal structure and also changes under potential climate scenarios during the open water season. Under the historical scenario, model results indicate earlier stratification onset, later fall overturn, warming epilimnion water, and cooling hypolimnion water. The increasing air temperature and decreasing wind speed have a doubling effect on the longer stratification duration, with wind speed playing a dominant role in determining the stratification onset, stratification overturn, and the hypolimnetic water temperatures. Under future climate scenarios, temperature perturbations from -10°C to +10°C indicate that warmer air temperatures lead to earlier stratification onset and later fall overturn for both lakes under all climate scenarios. When considering perturbations of wind speeds from -30% to +30%, decreasing wind speeds lead to earlier stratification onset and later overturn. The magnitude of these changes is larger for each degree or m/s of increase for Fish Lake than for Lake Mendota, indicating that Fish Lake is more susceptible to negative impacts of the changing climate.

Climate change effects on evaporation:
To better understand how a changing climate affects seasonal evaporation from different sized lakes, a one dimensional lake model is used with historical data to simulate lake evaporation and ice cover throughout the past one hundred years. Lake Mendota, and dimictic lake, and Lake Wingra, a polymictic lake were chosen to examine how lake thermal structure and mixing affect lake evaporation in each season. Results show that (i) spring evaporation is increased due to increased air temperature, (ii) summer evaporation is decreasing due to higher vapor pressure and wind speed decreases, (iii) fall evaporation is decreasing due to lower wind speeds, and (iv) winter evaporation is significantly increasing due to temperature-induced decreases in ice cover duration. The dimictic lake experienced greater increases in evaporation in the spring time due to slightly higher sensitivity to increasing temperature. In the fall, dimictic lakes remain warmer, resulting in greater sensitivity to the drops in wind speeds. Finally, the formation of ice at the beginning of winter is more sensitive for deeper lakes, resulting in greater increases in evaporation on deeper lakes.

Oxythermal stress in a dimictic lake in response to changing climate:
Using DYRESM-I, with a newly added dissolved oxygen simulation component, we studied the effect of changing climate on oxythermal stress of a cisco population in Fish Lake, Wi, USA. We investigated how the past changing climate has impacted fish stress caused by high temperatures and low dissolved oxygen levels over the last 100 years. A method was developed to quantify the number of days of fish stress per year, and this method applied under the future A1B climate scenario. Results indicate that under future scenarios, the frequency of fish stress and duration of stress will increase dramatically. Furthermore, we used a state-of-the-art 3D hydrodynamic model coupled with a 1D dissolved oxygen model to simulate the spatial extent of dissolved oxygen stress during the year.

Applications, Impacts, and Benefits (required)
The most direct benefit of the project is the development of the DYRESM-I lake-ice model and the 3DHD lake-ice model for use in investigation of past and future changes in climate. Use of the DYRESM-I model allows researchers and lake manager to quickly and accurately simulate lake temperature and ice cover response under specific climate conditions. The 3DHD model allows researchers to more accurately simulate the effect of specific climate situations on the full-lake scale. This allows for increased preparedness to climate changes. Use of the DYRESM-I model within the INFOS system has direct, positive benefits to the Madison, Wisconsin area, as it provides easily accessible lake information to the public.

Results of the investigation of the impact of changing climate to Wisconsin lakes provides quality information to lake managers and other researchers. Understanding the change of water temperature may allow regulatory agencies to determine which lakes may become at risk for invasive species. This allows agencies to direct their manpower to a few specific lakes to prevent species spread rather than having to monitor a variety of lakes, some of which may not be at risk to invasive species. Additionally, as water temperature greatly affects fish species within the lakes, understanding which lakes may be at risk for fish kills due to increasing stratified period or increasing water temperatures may allow for mitigation efforts to protect important fish populations.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

The most direct benefit of the project is the development of the DYRESM-I lake-ice model and the 3DHD lake-ice model for use in investigation of past and future changes in climate. Use of the DYRESM-I model allows researchers and lake manager to quickly and accurately simulate lake temperature and ice cover response under specific climate conditions. The 3DHD model allows researchers to more accurately simulate the effect of specific climate situations on the full-lake scale. This allows for increased preparedness to climate changes. Use of the DYRESM-I model within the INFOS system has direct, positive benefits to the Madison, Wisconsin area, as it provides easily accessible lake information to the public.

Results of the investigation of the impact of changing climate to Wisconsin lakes provides quality information to lake managers and other researchers. Understanding the change of water temperature may allow regulatory agencies to determine which lakes may become at risk for invasive species. This allows agencies to direct their manpower to a few specific lakes to prevent species spread rather than having to monitor a variety of lakes, some of which may not be at risk to invasive species. Additionally, as water temperature greatly affects fish species within the lakes, understanding which lakes may be at risk for fish kills due to increasing stratified period or increasing water temperatures may allow for mitigation

efforts to protect important fish populations

## Committees, Memberships & Panels

| | |
|---|---|
| **Group Name** | WICCI Water Resources and Coastal Community Working Group |
| **Description** | The Wisconsin Initiative on Climate Change Impacts (WICCI) assesses and anticipates climate change impacts on specific Wisconsin natural resources, ecosystems and regions; evaluates potential effects on industry, agriculture, tourism and other human activities; and develops and recommends adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders. |
| **Start Date** | 8/1/2010 |
| **End Date** | 4/16/2012 |

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Long-term trends and variability in ice cover and thermal structure in three morphometrically different lakes in response to climate change |
| **Author(s)** | Magee, M. and Wu, C.H. |
| **Publication/Publisher** | Limnology and Oceanography |
| **Year Published** | In Review |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | Climate trends and variability act as external drivers of lake dynamics, but individual lakes express the signals differently based on a variety of factors including lake morphometry (i.e. lake depth and lake surface area). A one-dimensional hydrodynamic lake model (DYRESM-I) is employed to simulate ice cover and water temperatures in Lake Mendota, Lake Wingra, and Fish Lake located in Madison, WI, USA over the period 1911-2010. The model is used to study the effect of lake thermal variables (water temperature, stratification, ice dates, and ice cover) to changes two important lake drivers, air temperature and wind speed for the three lakes, which have different morphometry. During the last century, epilimnetic temperatures have increased, hypolimnetic temperatures have decreased, and the length of the stratified season has increased for the study lakes. Additionally, the ice cover period has decreased due to earlier ice-on dates and later ice-off dates and the maximum ice cover thickness has decreased for the three lakes. Results indicate that the open water lake variables are more sensitive to differences in lake morphometry (i.e. lake depth and surface area) than are changes in the ice-cover lake variables. |
| **Any Additional Citation Information** | |

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Changing climate on three lakes with differing morphometry |
| **Author(s)** | Magee, M. and Wu, C.H. |
| **Publication/Publisher** | Water Research |
| **Year Published** | In Review |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | Previous research has indicated that climate is an important driver of lake ice cover, such as maximum ice thickness, ice cover duration, and ice growth. Three such climate drivers are (i) air temperature, (ii) wind speed, and (iii) precipitation. In addition, lake morphometry may impact the expression of these climate signals. A one-dimensional hydrodynamic lake model (DYRESM-I) is employed to simulate ice cover in Lake Mendota, Lake Wingra, and Fish Lake located in Madison, WI over the period 1911-2010. The model is used to study the effect of the three climate drivers on the study lakes which have differing morphometries. Using model results and climate data from the last century, it was determined that December to March air temperature is the climate driver most closely correlated with ice cover characteristics, with wind speed being the second most closely correlated, and precipitation having little correlation with maximum ice thickness or ice cover duration. |

Increasing air temperature is the primary driver for decreasing ice cover durations in the study lakes; however, decreasing wind speed acts to increase ice cover duration, which slightly mitigates the effect of increasing air temperature. An additional investigation of the effects of air temperature perturbations was also performed. It was determined from this that air temperature increases as small as 3°C may cause no ice cover on some lakes. Lake Wingra, the shallow study lake, was determined to be the most resilient lake as temperature increases as high as 10°C did

**Any Additional Citation Information**

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Response of Thermal Structure in Two Dimictic Lakes to Changing Climate |
| **Author(s)** | Madeline Magee and Chin H. Wu |
| **Publication/Publisher** | Boreal Environment Research |
| **Year Published** | In Review |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | A one-dimensional lake hydrodynamic model (DYRESM-I) is employed to simulate water temperature in Lake Mendota and Fish Lake near Madison, WI, USA to study the effect of changing air temperature and wind speed on dimictic lakes with differing surface areas, specifically looking at epilimnion and hypolimnion water temperatures and stratification and overturn dates. We use the model determine the effects of changing air temperature and wind speeds on the lake variables for the past 100 years and under perturbation scenarios. Results show that increasing air temperatures are well correlated with earlier stratification onset, later fall overturn, and increasing epilimnetic water temperatures for both lakes, while decreasing wind speeds are well correlated with earlier stratification onset, later fall overturn, and decreasing hypolimnetic water temperatures. Further, changes in wind speed are more greatly impacting the lake with larger surface area. Perturbation analysis show that increasing wind speeds increases variability in lake response to changes. Additionally, decreasing wind speeds enhance the effects of increasing air temperatures and increasing wind speeds mitigate those effects. |

**Any Additional Citation Information**

## Other Project Support

| | |
|---|---|
| **Source** | NSF Long Term Ecology Research |
| **Dollar Value** | $48,500 |
| **Description** | Research Assistant for supporting a graduate student |
| **Start Date** | 1/1/2012 |
| **End Date** | 12/31/2012 |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Response of Wisconsin Lakes (Ice Cover, Water level, and Thermal Structure) to Climate Change |
| **Presenter(s)** | Chin Wu |
| **Presentation Type** | Seminar |
| **Event Name** | WICCI Science Meeting |
| **Event Location** | WDNR |
| **Event Date** | 12/9/2011 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 30 |
| **Description** | The response of lake ice cover, water level, and thermal structure to the WICCI's future climate projections in Wisconsin will be obtained. Specifically we examine how the ice characteristics will change and how the change will affect the water level and lake thermal structure due to the changing climate. For this talk I focus on the following questions: (i) whether/how and to what degrees are the thermal structures of Wisconsin lakes in response to the climate condition? What would be the difference between the northern and southern lakes associated with changing climate variables (e.g. air temperature, snowfall, and snow depth) (ii) How would lakes with three different morphometry respond to the changing climate in |

Wisconsin?

| | |
|---|---|
| **Title** | Impact of Climate Change on Ice Cover and Thermal Structure in Three Southern Wisconsin Lakes with Differing Morphometry |
| **Presenter(s)** | Madeline Magee and Chin Wu |
| **Presentation Type** | Professional meeting |
| **Event Name** | Wisconsin American Water Resources Association |
| **Event Location** | Wisconsin Dells, Wisconsin |
| **Event Date** | 3/1/2012 |
| **Target Audience** | |
| **Audience Size** | 50 |
| **Description** | Climate variability and change are very important external drivers of lake dynamics, but individual lakes may express the signals differently based on a variety of factors including lake morphometry (i.e. lake depth and surface area). This study employs a one-dimensional hydrodynamic lake-ice model (DYRESM-WQ-I) to simulate ice cover and water temperature in Lake Mendota, Lake Wingra, and Fish Lake located in Madison, WI, USA, which have three different morphometry characteristics. The model studied (a) the effect of lake thermal variables (water temperature, stratification, ice dates, and ice cover) to changes in air temperature and wind speed over the period 1911-2010 and (b) under the condition of temperature and wind speed perturbations to analyze sensitivity to changes in lake drivers. This allows for the investigation of the effects of lake morphometry on response to the experienced changing climate and for investigation into how morphometry impacts the sensitivity of the response to future climates.<br>Several findings were revealed. During the last century, epilimnetic temperatures have increased, hypolimnetic temperatures have decreased, and the length of the stratified season has increased for the study lakes. Additionally, the ice cover period has decreased due to earlier ice-on dates and later ice-off dates and the maximum ice cover thickness has decreased for the three lakes. The open water lake variables are more sensitive to differences in lake morphometry over the past 100 years than are changes in the ice-cover lake variables. Response to temperature perturbations for all lake variables also appears to be impacted by morphometry. |

| | |
|---|---|
| **Title** | Oxythermal Stress of a Dimictic Lake n Response to Changing Climate |
| **Presenter(s)** | Madeline Magee and Chin Wu |
| **Presentation Type** | Professional meeting |
| **Event Name** | Annual Meeting of the American Water Resources Associations - Wisconsin Section |
| **Event Location** | Brookfield, Wisconsin |
| **Event Date** | 3/7/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 50 |
| **Description** | While much research has been devoted to determining how lakes will respond to changing climate, the effects of climate change on dissolved oxygen are still not well understood.<br>Research suggests climate change impacts lake thermal structure, and there is a strong link between the thermal structure of lakes and the corresponding dissolved oxygen levels. For example, oxygen solubility decreases with rising water temperatures. Increases in the period of thermal stratification and changes in the thermocline depth in stratified lakes isolate hypolimnetic water from access to atmospheric oxygen, creating anoxic conditions. The duration of anoxic conditions in hypolimnetic waters is especially detrimental to cold-water fish species, resulting in periods of oxygen stress. Understanding how these periods of oxygen stress will respond to changing climate is essential to prepare for unknown future climates.<br><br>Fish Lake, located in Dane County, WI, USA, is a small, deep, dimictic lake. Our previous study shows that as air temperature increases, lake water temperature and stratified periods will increase. In this talk, we aim to investigate how the past changing climate has impacted dissolved oxygen levels during the stratified season. Employing a one-dimensional lake model (DYRESM), we will simulate dissolved oxygen levels over the past 100 years. Specifically, the duration of oxygen stress under the changing climate will be obtained. Furthermore, we will simulate the spatial distribution of oxygen stress in Fish Lake using a state-of-the-art 3D hydrodynamic model. Afterwards, the changing oxygen stress duration under several future |

scenarios will be modeled and discussed.

| | |
|---|---|
| **Title** | Seasonal Evaporation of Two Different Morphometry Lakes Under Changing Climate |
| **Presenter(s)** | Nathan Gerdts and Chin Wu |
| **Presentation Type** | Professional meeting |
| **Event Name** | 37th Annual Meeting of The American Water Resources Associations - Wisconsin |
| **Event Location** | Brookfield, Wisconsin |
| **Event Date** | 3/7/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 50 |
| **Description** | As temperatures increase from climate change, annual lake evaporation increases. However, to date the seasonable response of lake evaporation is not yet fully understood. In this study a one-dimensional hydrodynamic lake model (DYRESM-I) with a newly implemented energy method is used to simulate lake evaporation over the one-hundred year period from 1911 to 2010. Seasonable lake evaporation is compared with linear trends of air temperature, solar radiation, vapor pressure, wind speed, and ice cover. Furthermore analysis is conducted on both a deep dimictic lake and a shallow polymictic lake to examine how lake thermal structure and mixing will affect seasonable lake evaporation responses. Results show an increase in the spring and winter evaporation and a decrease in the summer and fall evaporation. The increases in spring and winter evaporation correlate with increasing temperature, leading to decreases in ice-cover duration. These increases in evaporation occur despite decreases in wind speed and short wave radiation. Decreases in summer evaporation correlate with increasing vapor pressure while decreases in fall correlate with decreasing wind speed. Lastly, synthesized future climate scenarios show greater decreases in evaporation in the spring for the shallow polymictic lake and greater decreases in the fall for the deeper dimictic lake. |

| | |
|---|---|
| **Title** | Oxythermal Stress of Cisco in Fish Lake in Response to Changing Climate |
| **Presenter(s)** | Madeline Magee |
| **Presentation Type** | Seminar |
| **Event Name** | NTL-LTER (Northern Temperate Lakes-Long Term Ecological Research Study Young Scientists Meeting |
| **Event Location** | Madison, WI |
| **Event Date** | 4/10/2013 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 30 |
| **Description** | Presentation on current research of oxythermal stress of cisco fish in FIsh Lake in respone to the changing air temperature and wind speeds in Madison, Wisconsin. |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Nathan Gerdts |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Chin Wu |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Masters |
| **Graduation Month** | August |
| **Graduation Year** | 2014 |
| **Department** | Civil and Environmental Engineering |
| **Program** | |
| **Thesis Title** | |

| | |
|---|---|
| **Student Name** | Madeline Magee |
| **Campus** | University of Wisconsin-Madison |
| **Advisor Name** | Chin Wu |
| **Advisor Campus** | University of Wisconsin-Madison |
| **Degree** | Masters |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Civil and Environmental Engineering |
| **Program** | Environmental Fluid Mechanics and Water Resources Engineering |
| **Thesis Title** | Effect of Lake Morphometry on Response to Climate Change |
| **Thesis Abstract** | Lakes may have dampened or heightened response to changing climate based on differences in lake morphometry. To investigate this aspect of lake response, we looked at Lake Mendota, Lake Wingra, and Fish Lake in Dane County, as the three lakes have experienced the same climate over the past 100 years, but have differing surface area and depths. Trends, variability, and periodic cycles for the three lakes were compared to each other and to air temperature and wind speed data. Results show that there are the same statistically significant increasing and decreasing trends for ice cover and water temperature variables in all three lakes, but the inter-annual variability and significant periodic cycles differ. For all three lakes there have been decreasing ice cover duration and ice thickness over the past 100 years in addition to increasing stratification duration, increasing epilimnetic temperature, and decreasing hypolimnetic temperature. The fact that each lake is experiencing the same trend of increasing or decreasing lake variables indicates that the climate has been causing significant changes in the lake's physical structure. Differences in magnitude of trend, variability, and periodic cycle indicate that morphometric differences among the lakes also plays a significant role in determining the exact physical response of lakes to changing clim |

## Undergraduate Students Supported

New Students: **1**
Continuing Students: **0**

# Award--GLMRIS Water Quality Modeling (Marquette U.)

## Basic Information

| | |
|---|---|
| **Title:** | Award--GLMRIS Water Quality Modeling (Marquette U.) |
| **Project Number:** | 2011WI288S |
| **Start Date:** | 9/12/2011 |
| **End Date:** | 9/30/2013 |
| **Funding Source:** | Supplemental |
| **Congressional District:** | |
| **Research Category:** | Water Quality |
| **Focus Category:** | Surface Water, Water Quality, Management and Planning |
| **Descriptors:** | aquatic invasive species, separating watersheds |
| **Principal Investigators:** | Anders W. Andren, Charles Steven Melching |

## Publications

There are no publications.

# Annual Progress Report

**Selected Reporting Period:** 3/1/2012 - 2/28/2013

**Submitted By:** Charles Melching
**Submitted:** 5/28/2013

## Project Title

WR11R008: GLMRIS Water Quality Modeling

## Project Investigators

Charles Melching, Marquette University

## Progress Statement

Background

The GLMRIS feasibility study is being undertaken by the U.S. Army Corps of Engineers (Corps) to develop a long-term solution to prevent aquatic invasive species from traveling between the Great Lakes and Mississippi River watersheds. One primary goal of the study is to assess the feasibility of hydrologically separating the two watersheds, which are currently connected via the manmade Chicago Sanitary & Ship Canal and Cal-Sag Channel. These waterways were constructed in the early 20th Century, which allowed the Chicago River and other area waterways to flow to the Illinois River, instead of to Lake Michigan. Re-separating the watersheds will radically alter the existing flow patterns in the system, and is expected to cause significant water quality changes. Modeling and analysis of water quality impacts to both the CAWS and Lake Michigan are needed to ensure any selected alternative will be in compliance with Illinois water quality standards and with the Clean Water Act.

Objective

The existing DUFLOW model (developed by Marquette University for the Metropolitan Water Reclamation District of Greater Chicago, MWRDGC) will be utilized to provide supporting data to quantify water quality impacts to area waterways resulting from hydrologic separation alternatives.

Tasks and Progress

The existing DUFLOW model shall be updated and recalibrated to model water quality in the Chicago Area Waterways System (CAWS). Waterways within the scope of this project include:

- North Shore Channel (NSC)
- North Branch Chicago River (NBCR) downstream of confluence with NSC
- Chicago River Main Stem
- South Branch Chicago River (SBCR)
- South Fork of South Branch Chicago River (SFSBCR) or Bubbly Creek
- Chicago Sanitary & Ship Canal (CSSC)
- Cal-Sag Channel
- Little Calumet River (LCR) from Cal-Sag Channel to junction with Calumet and Grand Calumet Rivers
- Little Calumet River from Cal-Sag Channel to South Holland
- Calumet River

The capability of modeling the stretch of the Calumet River from the lakefront to O'Brien Lock and Dam shall be added to the DUFLOW model.

Progress: The channel geometry and layout data for the Calumet River have been added to the DUFLOW model, appropriate boundary conditions for this reach have been determined, and hydraulic and water quality runs for the Calumet River have been made. The accuracy of the DUFLOW model of the Calumet River was tested for the flow reversal to Lake Michigan during the storm of September 13-16, 2008.

Modeling Scenarios

Five distinct hydrologic scenarios shall be modeled. Additional scenarios may be identified as the GLMRIS study progresses, in which case these scenarios may be added to the modeling scope of work as options to the contract.

Progress: Because the time period for the GLMRIS study was shortened from ending in 2016 to ending in 2013, the number of distinct hydrologic scenarios to be simulated was reduced from five to three. These three scenarios are the (1) "No Project" scenario where no separation of the watersheds is applied, (2) the "Lakefront Separation" scenario in which impenetrable barrier is assumed to be constructed at the Wilmette Pump Station, the Chicago River Controlling Works, and a point on the Little Calumet River (north) just upstream of the junction with the Grand Calumet River, and (3) the "Midsystem Separation" scenario wherein the impenetrable barriers are placed near the original watershed divides in the Chicago and Calumet river systems. By the reporting deadline the "No Project" scenario had been completed for Water Years (WYs) 2003 and 2008 for both baseline and future conditions and the "Lakefront Separation scenario had been completed for WY 2008 for both baseline and future conditions.

Flow Conditions

Water quality for each hydrologic scenario shall be modeled for wet (2008), dry (2003), and average (2001) year flow conditions in the waterways. Additionally, the system shall be modeled both with and without all MWRDGC TARP reservoirs (currently under construction) in operation. Expected flow data necessary for modeling reservoirs in operation shall be provided by the Corps.

Progress: All needed flow data and stage for WYs 2001, 2003, and 2008 were obtained from the MWRDGC and U.S. Geological Survey (USGS). Also, the Corps provided to the project team simulated gravity combined sewer overflow (CSO) flows reflecting current, baseline conditions (Thornton Reservoir and McCook Reservoir Stage 1 operational), and future conditions (Thornton Reservoir and McCook Reservoir Stages 1 and 2 operational) for each of the three years. Table 1 lists the percentage of CSO flows captured by the McCook Reservoir Stage 1 and Stages 1+2 for WYs 2001, 2003, and 2008, and Table 2 lists the percentage of CSO flows captured by the Thornton Reservoir for WYs 2001, 2003, and 2008. This high capture of CSO flows results in a substantial reduction in storm caused drops in DO concentrations for "No Project" conditions relative to current conditions. The lower percentage capture in WY 2008 results because storms earlier in September filled the reservoirs so that the large storm on September 13-16, 2008, was minimally captured by the reservoirs.

Table 1. Percentage of combined sewer overflow (CSO) flows captured by the McCook Reservoir Stages 1 and 2 for gravity CSO flows and CSO flows from the Racine Avenue Pumping Station (NAPS) and North Branch Pumping Station (NBPS).

| Year | Gravity CSOs | | RAPS | | NBPS | |
|---|---|---|---|---|---|---|
| | Stage 1 | Stage 1+2 | Stage 1 | Stage 1+2 | Stage 1 | Stage 1+2 |
| 2001 | 90.0 | 94.0 | 98.3 | 99.3 | 99.5 | 99.7 |
| 2003 | 83.6 | 96.4 | 95.7 | 100.0 | 84.4 | 97.5 |
| 2008 | 60.2 | 73.2 | 85.4 | 95.0 | 77.1 | 89.0 |

Table 2. Percentage of combined sewer overflow (CSO) flows captured by the Thornton Reservoir for gravity CSO flows and CSO flows from the 125th Street Pumping Station (125PS).

| Year | Gravity CSOs | 125PS |
|---|---|---|
| 2001 | 99.8 | 100.0 |
| 2003 | 95.7 | 96.8 |
| 2008 | 49.9 | 76.5 |

Water Quality Parameters

The following water quality parameters are required for modeling. If the DUFLOW model did not originally model a parameter it is indicated with a * below, the capability of modeling the parameter was added during the first six months of the project and improved during the reporting period as detailed in the subsequent "Progress" sections.

- DO
- Ammonia
- Nitrate/Nitrite
- BOD
- TSS
- Total Phosphorus
- Fecal Coliform*
- Temperature*
- pH*
- Chloride*

A version of the DUFLOW model that simulates fecal coliform concentrations did exist at the start of this project, but it needed to be updated to consider the extension of the downstream boundary from Romeoville to the Lockport Controlling Works, the increase in representative combined sewer overflow (CSO) locations from 28 to 43, and any new fecal coliform data collected by the MWRDGC since 2005 (when the original fecal coliform model was developed).

In the original DUFLOW model of the CAWS, temperature is not simulated, rather hourly temperatures measured at the MWRDGC continuous measurement sondes are used in the model. Experience filling in missing temperature data has indicated that temperatures at all sonde locations in the CAWS can be reasonably estimated from the temperatures measured at nearby sondes. Thus, the changes in temperature along the waterways may be reliably estimated via statistical models. Such statistical models will be developed for each sonde location and mass balance model principles will be applied at each proposed separation point to consider the reduction in cooler Lake Michigan water (daily Lake Michigan temperature data are available from the Chicago Department of Water Management) reaching various reaches of the CAWS after separation. After the change in water temperature in the vicinity of the point of separation is determined by mass balance, the temperature changes will propagate downstream through the CAWS using the statistical relations between points.

Modeling of chloride in the CAWS will be difficult for the following reasons.

1) Chloride is measured only once per 7 days at the outfalls of the Stickney and North Side Water Reclamation Plants (WRPs) and no chloride data are available for the outfall of the Calumet WRP.
2) Chloride concentration data for the CSOs is sparse, i.e. single samples during a CSO event are available for the three CSO pumping stations as opposed to event mean concentrations.

Progress:

Fecal Coliform Modeling

The necessary revisions to the domain of the model and the number of CSO input points were made and fecal coliform concentrations were simulated for WYs 2001 and 2003 in the first six months of the project. In the current reporting period, fecal coliform concentrations were simulated for WY 2008, and generally good agreement between simulated and measured fecal coliform concentrations was obtained at all measurement locations for WY 2008. In the past fecal coliform modeling no fecal coliform data were available for post-TARP CSOs in Chicago. Thus, Milwaukee data was applied because Milwaukee also has a deep tunnel system.

a) The median value for grab samples in Milwaukee was 170,000 CFU/100 mL.
b) For storms causing flow reversals to Lake Michigan the MWRDGC takes intensive bacteria measurements near the lakefront structures. For these events in 2001 and 2002, a fecal coliform concentration of 1,100,000 CFU/100 mL yielded good agreement between simulated and measured values.

In 2007, the MWRDGC took a large number of fecal coliform measurements in the flows at the NBPS (70) and RAPS (119). The statistics of these measurements are listed in Table 3, and the median value was used in the modeling done here (with the NBPS value also applied to the CSOs discharging to the Calumet River system). The results shown in Figure 1illustrate the reasonableness of the assumed fecal coliform concentrations for CSOs.

Table 3. Statistics of fecal coliform concentrations measured in 2007 for the combined sewer overflows at the North Branch and Racine Avenue pumping stations in coliform forming units per 100 mL.

| Pumping Station | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|
| North Branch | 160,000 | 4,700,000 | 862,000 | 485,000 |
| Racine Avenue | 38,000 | 18,000,000 | 1,696,000 | 810,000 |

Chloride Modeling

Researchers have found a strong correlation typically exists between total dissolved solids (TDS) and chloride in water. Thus, a linear regression relation was derived between chloride and TDS for the Stickney WRP effluent and this relation was used to estimate the chloride concentration in the Calumet WRP effluent. Similarly, a limited amount of data on chloride concentrations and conductivity values were available for storm sewers in Evanston and Crestwood, IL. From these data, linear regression relations between chloride and conductivity were developed that were used to estimate chloride concentrations in CSO flows on the basis of available conductivity data for CSOs in snow and non-snow periods throughout the year.

Using the foregoing estimates for the chloride concentrations for the Calumet WRP and the CSOs, chloride concentrations throughout the CAWS were simulated for WYs 2001 and 2003 in the first six months of the project. During the current reporting period, these regression relations were applied to WY 2008, and generally good agreement between simulated and measured chloride concentrations was obtained at all measurement locations for WY 2008.

pH

Available pH data on CSOs and flows in the TARP drop shafts were used to estimate typical pH values for the northern (to the NSC and NBCR), central (to the Chicago River Main Stem, SBCR, and CSSC), and southern (to the LCR and Cal-Sag Channel) CSOs. Daily pH data were obtained from the Chicago Department of Water Management for 1998 and 1999 and 2005 through 2011. Simulation of pH for WY 2008 using Lake Michigan data for that year and data for other years showed that using the typical annual fluctuation in Lake Michigan pH yielded nearly equal quality results to those obtained using the daily values for WY 2008. The relative percent error in simulated pH values generally is less than 5% at all locations in the CAWS.

Temperature

In the early 1990s, the University of Iowa developed the CHARIMA Model to simulate temperature for 55 miles of waterway from Roosevelt Road on the SBCR to Dresden Island Dam on the Illinois River in a project done for Commonwealth Edison. Short segments of Bubbly Creek, Cal-Sag Channel, Des Plaines River, Hickory Creek, DuPage River, and Kankakee River are included in the model where they flow into the waterway. The CHARIMA model computed the flows using the de Saint Venant Equations (also used in DUFLOW) solved on a one-mile spatial grid at a 30 min time step and computed temperature using an Advection-Diffusion-Source equation for unsteady transport of a fully mixed, dissolved constituent. A key part of the temperature model was the Source/Sink Term for Heat Exchange Between Water and the Atmosphere, which comprised detailed expressions for the physical processes of water heating due to incoming short-wave and long-wave radiation and condensation, water cooling due to outgoing long-wave radiation and evaporation, and water heating due to conduction. Also, time-dependent discharges and water temperatures were specified at the primary model inflow point and all tributary inflows, including the Stickney WRP. The 6 generating stations were modeled as links that withdraw the condenser flow rate from the main channel, heat it by an amount proportional to the temperature rise at full load using the specified time-dependent generation schedule, and return it to the channel. This complex, physics-based model yielded results typically with errors on the order of ±1°F (0.556°C). Thus, it was hoped that the statistical model could yield predictions with similar standard errors (i.e. ≤0.556°C).

Statistical relations to estimate daily temperature at 29 monitoring locations internal to the CAWS have been developed. For 16 of these locations the standard error of the predicted temperature was less than 0.556°C, indicating that the simple statistical temperature model could yield similar results to the much more complex, physics-based CHARIMA model. These results indicate that the statistical models are adequate for the purposes of the GLMRIS study. Further, periods were identified during which the Fisk Power Plant or Crawford Power Plant were shut down and regression relations were developed to reflect the rise in temperatures across these plants when they are not operational. These relations are very important because the Fisk and Crawford plants were retired in 2012, and, thus, the simulation of baseline and future conditions in this study must reflect temperatures in the CAWS with these plants shut down.

Summary

Simulations of all three scenarios for baseline and future flow conditions for all three water years will be completed by early June 2013 and a draft summary report will be provided to the Corps by the middle of July. The project report will be revised as per the Corps' review comments and the final report will be provided to the Corps by September 30 (the requested, revised ending date for this project).

## Principal Findings and Significance

## Principal Findings and Significance

**Description** Because the project was still in progress at the end of the reporting period and no comparisons of all three scenarios had been completed the "Applications, Impacts, and Benefits" of this project cannot yet be reported. A draft summary report was provided to the U.S. Army Corps of Engineers (Corps) in January 2013 titled "Comparison of Current, Baseline, and Future Dissolved Oxygen Concentrations in the Chicago Area Waterways System for Without Project Conditions" that focused on the results for WY 2008. Also, in February 2013, a summary of the loads to Lake Michigan during the flow reversal of September 13-16, 2008, was provided to the Corps in order for the Lake Michigan modelers to test their models. The draft report, Lake Michigan loading information, periodic progress report meetings (discussed later), and other responses to information requests have met the Corps' needs to date.

## Interactions

**Description** GLMRIS Water Quality Modeling—Progress Report Meeting with the U.S. Army Corps of Engineers in Chicago, IL

**Event Date** 4/6/2012

| | |
|---|---|
| **Description** | GLMRIS Water Quality Modeling—Progress Report Meeting with the U.S. Army Corps of Engineers in Chicago, IL |
| **Event Date** | 10/2/2012 |

| | |
|---|---|
| **Description** | GLMRIS Water Quality Modeling—Progress Report Meeting with the U.S. Army Corps of Engineers in Chicago, IL |
| **Event Date** | 2/12/2013 |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Modeling the Water Quality Impacts of the Potential Ecological Separation of the Great Lakes and Mississippi River Basins at Chicago for Invasive Species Control |
| **Presenter(s)** | Charles S. Melching |
| **Presentation Type** | Professional meeting |
| **Event Name** | Wisconsin Section Meeting of the American Society of Civil Engineers |
| **Event Location** | Pewaukee, WI |
| **Event Date** | 9/7/2012 |
| **Target Audience** | Regional organization |
| **Audience Size** | 40 |
| **Description** | The presentation summarized the goals of the GLMRIS project in general and the specific goals of the water-quality modeling study and the steps that must be executed to achieve these goals. |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Jin Liang |
| **Campus** | Marquette University |
| **Advisor Name** | Charles Melching |
| **Advisor Campus** | Marquette University |
| **Degree** | PhD |
| **Graduation Month** | December |
| **Graduation Year** | 2010 |
| **Department** | Civil and Environmental Engineering |
| **Program** | Civil and Environmental Engineering |
| **Thesis Title** | Evaluation of Runoff Response to Moving Rainstorms |
| **Thesis Abstract** | |

# The Effects of Particulate Organic Carbon Quantity and Quality on Denitrification of Groundwater Nitrate

## Basic Information

| | |
|---|---|
| **Title:** | The Effects of Particulate Organic Carbon Quantity and Quality on Denitrification of Groundwater Nitrate |
| **Project Number:** | 2011WI297O |
| **Start Date:** | 7/1/2011 |
| **End Date:** | 6/30/2013 |
| **Funding Source:** | Other |
| **Congressional District:** | 6th |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | Hydrogeochemistry, Sediments, Water Quality |
| **Descriptors:** | |
| **Principal Investigators:** | , Robert Scott Stelzer |

## Publications

There are no publications.

# Annual Progress Report

**Selected Reporting Period:** 7/1/2011 - 6/30/2012

**Submitted By:** Robert Stelzer
**Submitted:** 5/27/2013

## Project Title

WR11R006: The Effects of Particulate Organic Carbon Quantity and Quality on Denitrification of Groundwater Nitrate

## Project Investigators

Lynn Bartsch, Other
J. Thad Scott, Other
Robert Stelzer, University of Wisconsin-Oshkosh

## Progress Statement

During the period between July 1, 2011 and June 30, 2012 we made significant progress on the project "WR11R006: The effects of particulate organic carbon quantity and quality on denitrification of groundwater nitrate". One experiment funded by this award was successfully completed and the details of the experiment and stage of completion are provided in more detail below.

Experiment 1- 2011 The effects of particulate carbon quantity on nitrogen processing deep stream sediments.

The interface between groundwater and surface water in streams is known to be a hotspot for nitrogen processing. However, the role of buried organic carbon in nitrogen transformation at this interface is not well understood, and inferences have been largely based on descriptive studies. Our main objective was to determine how buried particulate organic carbon (POC) affected denitrification and nitrate retention in groundwater of an upwelling reach within a sand plains stream in Wisconsin. POC was manipulated in mesocosms inserted in the sediments. Treatments included Low and High quantities of conditioned red maple leaves (buried beneath combusted sand), Ambient sediment (sand containing background levels of POC), and a Control (combusted sand). Denitrification rate in sediments was measured by acetylene block assays in the lab and by changes in N2 concentrations in the field using membrane inlet mass spectrometry. Nitrate, ammonium, and dissolved organic nitrogen (DON) retention were measured by changes in concentrations and fluxes along groundwater flow paths within the mesocosms. POC addition drove oxic groundwater to severe hypoxia, lead to large increases in dissolved organic carbon (DOC) and strongly increased denitrification rates and nitrogen (nitrate and total dissolved nitrogen) retention relative to the Control. In situ denitrification accounted for 30 to 60 % of nitrate retention. Collectively, our results suggest that buried POC stimulated denitrification and nitrate retention by producing DOC and by creating favorable redox conditions for denitrification.

All of the tasks for this experiment have been completed, with the exception of revision of a manuscript that stems from this work (see below)

Dr. Stelzer was invited to submit a manuscript about this work in a special issue of Freshwater Science about groundwater-surface water interaction in streams and rivers. The manuscript, entitled "Buried particulate organic carbon stimulates denitrification and nitrate retention in stream sediments at the groundwater-surface water interface" will be submitted to Freshwater Science in 2013 for the special issue.

## Principal Findings and Significance

## Principal Findings and Significance

**Description** The principle finding from our project is that buried particulate organic matter quantity had positive effects on nitrate retention and denitrification in stream sediments. We think these results will impact the fields of biogeochemistry and aquatic

ecology because they suggest mechanisms by which nitrate in groundwater can be removed along upwelling flow paths in sediments. Our results reinforce the importance of linked biogeochemical cycles, in this case the carbon and nitrogen cycles. Furthermore, our results suggest that intact riparian zones and forested watersheds can promote nitrate retention at the groundwater-stream water interface by providing a supply of fixed carbon to support nitrate retention (including denitrification). Our results may have implications for stream restoration. Restoration techniques in the watershed and stream channel that promote the accumulation of terrestrial fixed carbon and deposition and burial of this carbon in stream sediments will likely increase nitrate retention.

## Committees, Memberships & Panels

| | |
|---|---|
| **Group Name** | Wisconsin AWRA Board of Directors |
| **Description** | Dr. Stelzer served as Vice President of the Wisconsin Section of the American Water Resrources Association during the dates indicated below |
| **Start Date** | 3/8/2011 |
| **End Date** | 3/7/2012 |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Buried particulate organic carbon stimulates denitrification and nitrate retention in stream sediments |
| **Presenter(s)** | R.S. Stelzer, J. T. Scott, L.A. Bartsch |
| **Presentation Type** | Professional meeting |
| **Event Name** | Society for Freshwater Science Annual Meeting |
| **Event Location** | Louisville, KY |
| **Event Date** | 5/21/2012 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 100 |
| **Description** | Invited presentation in a Special Session on sediment processes |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Jennifer Krueger |
| **Campus** | University of Wisconsin-Oshkosh |
| **Advisor Name** | Robert Stelzer |
| **Advisor Campus** | University of Wisconsin-Oshkosh |
| **Degree** | Undergraduate |
| **Graduation Month** | August |
| **Graduation Year** | 2011 |
| **Department** | Biology |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

| | |
|---|---|
| **Student Name** | Michael Louison |
| **Campus** | University of Wisconsin-Oshkosh |
| **Advisor Name** | Robert Stelzer |

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| **Advisor Campus** | University of Wisconsin-Oshkosh |

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|---|---|
| **Degree** | Expected Masters |
| **Graduation Month** | December |
| **Graduation Year** | 2013 |
| **Department** | Biology |
| **Program** | MS |
| **Thesis Title** | |
| **Thesis Abstract** | |

| | |
|---|---|
| **Student Name** | Alyssa McCumber |
| **Campus** | University of Wisconsin-Oshkosh |
| **Advisor Name** | Robert Stelzer |
| **Advisor Campus** | University of Wisconsin-Oshkosh |

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|---|---|
| **Degree** | Undergraduate |
| **Graduation Month** | December |
| **Graduation Year** | 2012 |
| **Department** | Biology |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

# Establishing the Long-Term Range of Variability in Drought Conditions for Southwest Wisconsin

## Basic Information

| | |
|---|---|
| **Title:** | Establishing the Long-Term Range of Variability in Drought Conditions for Southwest Wisconsin |
| **Project Number:** | 2013WI313B |
| **Start Date:** | 3/1/2013 |
| **End Date:** | 2/28/2015 |
| **Funding Source:** | 104B |
| **Congressional District:** | 3rd |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Drought, Models, Management and Planning |
| **Descriptors:** | None |
| **Principal Investigators:** | Evan Reed Larson, Christopher Underwood |

## Publications

There are no publications.

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Evan Larson
**Submitted:** 5/6/2014

## Project Title

WR13R003: Establishing the long-term range of variability in drought conditions for Southwest Wisconsin

## Project Investigators

Evan Larson, University of Wisconsin-Platteville

## Progress Statement

During the first year of our project we have developed tree-ring chronologies from approximately 200 trees spread across 22 different sites in the Driftless Area of southwest Wisconsin. The samples were collected from living trees, remnant stumps, and the timbers of three historical structures. In addition to collecting the samples that produced this data set, we spent considerable efforts in outreach through multiple press releases through the University of Wisconsin-Platteville public relations office as well as working with staff from Wisconsin Public Radio, the Wisconsin Natural Resources Magazine, the Wisconsin Department of Natural Resources, the Water Resources Institute, and the SeaGrant Program to promote the project. These efforts have laid a solid foundation for identifying additional sampling locations within our study area and obtaining sampling permission for these sites. We are now at the midpoint of our project and have successfully sampled approximately half of our proposed project. During this time we have also trained several undergraduate researchers, honed our techniques for seeking trees and obtaining sampling permission, and developing a master chronology for the region that will facilitate all future tree-ring sample analyses.
We are unable to core living oak trees during the summer due to concerns about oak wilt. We will therefore focus our efforts on lining up additional sites to sample in the fall and collecting tree-ring samples from historical structures in the study area.
The winter of the second year will be spent sampling the remaining sites, processing all remaining samples, developing a set of drought reconstructions including one for the region as a whole, as well as at county and local scales in order to examine both the temporal and spatial variability of drought in Southwest Wisconsin. A presentation reporting this work will be made at the 2015 Meeting of the Association of American Geographers and manuscripts reporting this work will be submitted soon thereafter.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

Although we have not completed our spatial network of collection sites and cannot examine the spatial variability of drought for our study area, when combined into a regional mean ring-width chronology our tree-ring samples produce a tree-ring chronology that spans the years 1710–2013 with robust sample depth to 1739. Initial analyses of the climate-tree growth relationships exhibited by this combined chronology indicate a significant correlation ($r > 0.6$, $p < 0.05$) with summer drought in the form of mean June and July Palmer's Drought Severity Index. The spatial structure of this signal is centered over the Driftless Region of Southwest Wisconsin, indicating that the final combined chronology produced through this project will provide a robust estimate of past drought conditions back to at least the early 1700s.
The 10 driest years indicated by the current chronology are, in order from the driest year, 1800, 1753, 1895, 1801, 1934, 1752, 1988, 1931, 1772, 1839, while the wettest years are largely focused in the 1700s and include: 1745, 1744, 1762, 1739, 1866, 1761, 1993, 1758, 1759, and 1751. Additional sample depth in the 1700s will help determine if these years are in fact the wettest in the past 300 years or a product of lower sample depth. A prolonged period of drought that exceeds the Dust Bowl drought of the 1930s is indicated in the mid 1800s. This suggests that the instrumental record does not capture the full range of variability in drought conditions for Southwest Wisconsin.
These results provide a preliminary glance into the drought history of Southwest Wisconsin and hint at the potential value of this project in terms of providing a more expansive temporal data set on which to calibrate and verify climate change models

to better capture extreme conditions in the past and predict future conditions. These data also begin to illustrate the broader range of hydrologic conditions that are possible for Southwest Wisconsin and may provide information that will help water managers prepare for future worst-case scenarios.

## Awards, Honors & Recognition

| | |
|---|---|
| **Title** | None to date |
| **Event Year** | |
| **Recipient** | |
| **Presented By** | |
| **Description** | |

## Committees, Memberships & Panels

| | |
|---|---|
| **Group Name** | None to date |
| **Description** | |
| **Start Date** | |
| **End Date** | |

## Interactions

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|---|---|
| **Description** | Interviewed for That Tree, a production by Andrew Batt for Iowa Public Television that featured Mark Hirsch and his photo project on That Tree as well as an interview by Evan Larson on oaks, their ability to record environmental change via their rings, with mention of the project. Available at: http://www.iptv.org/series.cfm/23629/that_tree.<br>Event Date: First airing on IPTV March 13–16, 2014, with subsequent airings on Minnesota and Wisconsin Public Television |
| **Event Date** | 3/13/2014 |

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|---|---|
| **Description** | Forestry Merit Badge activities with Cub Scouts. Several students along with Sara worked with local Cub Scout groups to discuss tree-ring research and drought reconstructions in particular to fulfill requirements for their Forestry Merit Badge. |
| **Event Date** | 2/20/2014 |

## Journal Articles & Other Publications

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|---|---|
| **Publication Type** | Newsletter/Periodical (Not Peer-Reviewed) |
| **Title** | The Driftless Oaks: An environmental history of southwest Wisconsin |
| **Author(s)** | Sara Allen, Evan Larson |
| **Publication/Publisher** | Wisconsin Natural Resources Magazine |
| **Year Published** | In Review |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | This is a short paper describing the oak project, its justification, our current status, and where the project will go over the next year. It describes the science of dendrochronology, the value of paleoclimate data, and puts out a call for help in identifying new and additional sites to sample. |
| **Any Additional Citation Information** | |

## Presentations & Public Appearances

| | |
|---|---|
| **Title** | Establishing the long-term range of variability in drought conditions for southwest Wisconsin using oak tree-ring chronologies |

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|---|---|
| **Presenter(s)** | Sara Allen, Evan R. Larson |
| **Presentation Type** | Professional meeting |
| **Event Name** | Connections in Nature Student Research Symposium |
| **Event Location** | Riveredge Nature Center, Saukville, Wisconsin |
| **Event Date** | 11/9/2013 |
| **Target Audience** | Mixed |
| **Audience Size** | 40 |
| **Description** | Presentation on the preliminary results of the project and a call for help in expanding network of sites. |

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|---|---|
| **Title** | Undergraduate research in the Tree-Ring, Earth, and Environmental Sciences Laboratory (TREES Lab) at UW-Platteville |
| **Presenter(s)** | Cassie Jorgenson, Jaime Teutschmann, Gabriel Brownell, Steven LaBarge, Sara Allen, J. Elmo Rawling 3rd, Evan R. Larson |
| **Presentation Type** | Poster session |
| **Event Name** | Posters in the Rotunda |
| **Event Location** | The Capitol Building in Madison, WI |
| **Event Date** | 3/12/2014 |
| **Target Audience** | State government agency |
| **Audience Size** | 200 |
| **Description** | Presented research by undergraduate students to state legislators |

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|---|---|
| **Title** | Establishing the long-term range of variability in drought conditions for southwest Wisconsin |
| **Presenter(s)** | Sara Allen, Evan R. Larson |
| **Presentation Type** | Professional meeting |
| **Event Name** | Annual Meeting of the Association of American Geographers |
| **Event Location** | Tampa, Florida |
| **Event Date** | 4/8/2014 |
| **Target Audience** | Scientific audience |
| **Audience Size** | 40 |
| **Description** | Presented research at largest gathering of tree-ring researchers in the country |

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|---|---|
| **Title** | Tales of people and the land told through tree rings: Historical dendroarchaeology of the Gratiot House |
| **Presenter(s)** | Jamie Jefferson, Evan R. Larson, Lane Johnson, and James Hibbard |
| **Presentation Type** | Professional meeting |
| **Event Name** | Wisconsin History Symposium |
| **Event Location** | University of Wisconsin-Platteville |
| **Event Date** | 4/5/2014 |
| **Target Audience** | Mixed |
| **Audience Size** | 40 |
| **Description** | Conference attended by historians, academics, and researchers from across Wisconsin. This presentation focused on our use of timbers from historical structures to expand our tree-ring data set. |

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|---|---|
| **Title** | The tales trees tell: The science of dendrochronology |

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|---|---|
| **Presenter(s)** | Evan R. Larson |
| **Presentation Type** | Speech |
| **Event Name** | Fried Green Tomatoes University |
| **Event Location** | Fried Green Tomatoes Restaurant and Bar, Galena, Illinois |
| **Event Date** | 12/3/2013 |
| **Target Audience** | Public |
| **Audience Size** | 25 |
| **Description** | This was an evening Pub Science lecture that lasted about one hour and described the science of dendrochronology, the insights it provides on climate change, and a specific case study from the oak project funded by WRI |

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|---|---|
| **Title** | UW-Platteville Wants Public's Help in Hunt for Old Oak Trees |
| **Presenter(s)** | Evan R. Larson |
| **Presentation Type** | Radio interview |
| **Event Name** | Wisconsin Public Radio |
| **Event Location** | Wisconsin Public Radio |
| **Event Date** | 7/10/2013 |
| **Target Audience** | Public |
| **Audience Size** | 5000 |
| **Description** | Story by Wisconsin Public Radio describing the Driftless Oaks project and placing a call for help in identifying trees to be included in the study. Available: http://www.wpr.org/uw-platteville-wants-publics-help-hunt-old-oak-trees |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Sara Allen |
| **Campus** | University of Wisconsin-Platteville |
| **Advisor Name** | Evan Larson |
| **Advisor Campus** | University of Wisconsin-Platteville |
| **Degree** | Other |
| **Graduation Month** | August |
| **Graduation Year** | 2015 |
| **Department** | |
| **Program** | |
| **Thesis Title** | |
| **Thesis Abstract** | |

## Undergraduate Students Supported

New Students: **8**
Continuing Students: **0**

# Impacts of Climatic and Land Use Changes on Streamflow and Water Quality in the Milwaukee River Basin

## Basic Information

| | |
|---|---|
| **Title:** | Impacts of Climatic and Land Use Changes on Streamflow and Water Quality in the Milwaukee River Basin |
| **Project Number:** | 2013WI314B |
| **Start Date:** | 3/1/2013 |
| **End Date:** | 2/28/2015 |
| **Funding Source:** | 104B |
| **Congressional District:** | 4th |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | Hydrology, Water Quality, Models |
| **Descriptors:** | None |
| **Principal Investigators:** | Woonsup Choi, Changshan Wu |

## Publications

There are no publications.

# Annual Progress Report

**Selected Reporting Period:** 3/1/2013 - 2/28/2014

**Submitted By:** Woonsup Choi
**Submitted:** 4/30/2014

## Project Title

WR13R004: Impacts of climatic and land use changes on streamflow and water quality in the Milwaukee River basin.

## Project Investigators

Woonsup Choi, University of Wisconsin-Milwaukee

## Progress Statement

The project has four work packages (WPs). WP1, land use change modeling, is complete. We have developed two cellular automata (CA) models to simulate the spatial dynamics of residential and commercial land uses. With the collected residential and commercial data, the period of 1990-2000 was used for the model construction and calibration, and the years of 2000-2005 were employed for the model validation. With all identified parameters, the residential and commercial growth models were applied for simulating residential and commercial growth in 2005. Results indicate that, both the residential and commercial growth models work well. With the identified future residential and commercial land uses, a linear regression approach was employed to distribute impervious surfaces fractions (ISF). Nine factors, including elevation, slope, distance to city, distance to village, distance to lake, distance to river, distance to railway, distance to road, and population density, were selected as driving forces, and the NLCD 2001 Percent Developed Imperviousness data was employed as the dependent variable for model construction.

WP2, watershed modeling, is complete. We set up and calibrated the HSPF (Hydrological Simulation Program-Fortran) model for the study area. We used the daily gridded temperature and precipitation data for Wisconsin, created by colleagues at the UW-Madison, as main input. We calibrated and validated the model against measured streamflow and water quality data. Statistical measures indicating model performance are satisfactory.

WP3, future projection, is in progress. We recently obtained downscaled climate models data from UW-Madison and began to analyze them. We are in the process of creating some codes to read and analyze the NetCDF files. Regarding simulations with land use scenarios, because land use scenarios have been generated in WP1, new HSPF simulations can be made as soon as we process the downscaled climate models data.

WP4, impact assessment, has yet to begin. All the remaining technical work is to be completed by the end of August.

Overall, we are making good progress of the project. A manuscript is almost ready for submission to a journal (attached in the report), and we made a few presentations in scientific meetings in March and April of 2014, which will be reported in detail in the final report.

## Principal Findings and Significance

## Principal Findings and Significance

**Description**

The general results from the land use change modeling (WP 1) can be summarized as follows: First, the proposed integrated residential/commercial growth and linear regression model can effectively model the percent impervious surfaces area with a promising accuracy (RMSE=17.92%, SE=4.27%, and MAE=13.52%). Second, a comparative analysis was conducted between the proposed integrated residential/commercial growth impervious surface distribution model and three traditional approaches. It was found that the proposed approach outperformed the traditional ones. Third, with the validated integrated residential/commercial growth and impervious surface distribution model, the impervious surfaces fraction of Milwaukee River Basin in 2020 was estimated, and predicted results indicate that the medium ISF will be mainly distributed surrounding downtown area as residential area, and high ISF will majorly located in downtown area as commercial area. The findings from WP 1 led to a side project that examined their influences on hydrological simulations.

During the watershed modeling process, we tested the effects of the different approaches to assigning percent imperviousness on the model simulation results. Total impervious areas for the entire basin remained the same in each approach. The approaches resulted in substantially different surface flows simulated by HSPF, and the differences grew in more urbanized areas of the basin. In very rural subbasins, there were virtually no differences, but the differences were very substantial in highly urbanized subbasins, suggesting it is necessary to obtain detailed information on imperviousness in urbanized areas.

## Journal Articles & Other Publications

| | |
|---|---|
| **Publication Type** | Journal Article/Book Chapter (Peer-Reviewed) |
| **Title** | Future urban impervious surface distribution Prediction using cellular automata and regression analysis |
| **Author(s)** | Wenliang Li, Changshan Wu, Woonsup Choi |
| **Publication/Publisher** | In preparation for submission to a journal |
| **Year Published** | |
| **Volume & Number** | |
| **Number of Pages** | |
| **Description** | |
| **Any Additional Citation Information** | |

## Students & Post-Docs Supported

| | |
|---|---|
| **Student Name** | Wenliang Li |
| **Campus** | University of Wisconsin-Milwaukee |
| **Advisor Name** | Changshan Wu |
| **Advisor Campus** | University of Wisconsin-Milwaukee |
| **Degree** | Expected PhD |
| **Graduation Month** | May |
| **Graduation Year** | 2015 |
| **Department** | Geography |
| **Program** | Geography |
| **Thesis Title** | Large Scale Urban Impervious Surfaces Estimation through Incorporating Temporal and Spatial Information into Spectral Mixture Analysis |
| **Thesis Abstract** | N/A |

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|---|---|
| **Student Name** | Feng Pan |
| **Campus** | University of Wisconsin-Milwaukee |
| **Advisor Name** | Woonsup Choi |
| **Advisor Campus** | University of Wisconsin-Milwaukee |
| **Degree** | Expected PhD |
| **Graduation Month** | |
| **Graduation Year** | |
| **Department** | Geography |
| **Program** | Geography |
| **Thesis Title** | N/A |

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|---|---|
| **Thesis Abstract** | N/A |

# WR12R001 - Identifying the Controls on Flow and Contaminant Distribution in Siliciclastic Bedrock Aquifer Systems

## Basic Information

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|---|---|
| **Title:** | WR12R001 - Identifying the Controls on Flow and Contaminant Distribution in Siliciclastic Bedrock Aquifer Systems |
| **Project Number:** | 2013WI326O |
| **Start Date:** | 7/1/2012 |
| **End Date:** | 6/30/2014 |
| **Funding Source:** | Other |
| **Congressional District:** | |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | Groundwater, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | David Hart |

## Publications

There are no publications.

# Progress Report

**Reporting Period:** 07/01/2012 - 06/30/2013

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**Project**
WR12R001 - Identifying the Controls on Flow and Contaminant Distribution in Siliciclastic Bedrock Aquifer Systems

**Principle Findings and Significance**
We furthered development of a method to measure borehole flows in wells. We used distributed temperature sensing (DTS) with an electric heater to identify zones of inflow and outflow in wells. DTS uses a fiber optic cable to measure temperatures along the length of the cable. The heater raises the temperature of the water in the borehole. Flow in the borehole carries the heated water that is then detected by the fiber optic cable.

We have used this method in a wide variety of geologic settings, from sandstones and shales to crystalline rock. Figure 1 in the Files section shows flows in a well located in a shallow and deep aquifer, separated by a shale aquitard. Time is plotted on the x-axis and depth is plotted on the y-axis. Temperature is shown as color. The heat pulses are evident as higher temperature lines, usually light blue, and the movement of water is apparent as either higher temperature moving upward or downward with time. The plots provide a quick analysis of flow rate since the slope of the temperature pulse (change in distance/change in time) give a velocity. The slope changes where groundwater enters or exits the well. Above 60 meters depth, the flow is upward and below that depth flow is downward. From video logs we can see a fracture at around 60 meters. The DTS testing shows that water enters the well from the fracture and diverges with some part flowing upward and another part flowing downward. The water flowing upwards abruptly exits the borehole at around 30 meters. The water flowing downwards gradually exits the borehole as seen by the gradual decrease in flow velocity or curve in slope from 80 to 90 meters.

The method works well and provides a more dynamic broader range of borehole flow measurements than is available from the more traditional heat pulse or spinner flow meters. It has become a tool we use for lower and intermediate borehole flows.

**Number of Personnel Involved**
2 Participating faculty/staff
1 Supported post-docs

**Students Supported**

**Name**
Steve Sellwood

**Affiliation**
University of Wisconsin-Madison

**Degree**
PhD/DSci

**Major/Specialization**
Hydrogeology

**Graduation**
5/2015

## Conference Participation

**Title**
American Water Resources Association – Wisconsin Chapter

**Location**
Brookfield, WI

**Dates**
March 7-8, 2013

**Number of supported students attending**
1

**Presentations by Students**
(Oral) Borehole Flow Characterization Using Discrete In-well Heat Tracer Tests Monitored by DTS, Steve Sellwood

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**Title**
Geologic Society of America – Annual Meeting

**Location**
Denver, CO

**Dates**
October 27-30, 2013

**Number of supported students attending**
1

**Presentations by Students**
(Oral) Identification of variations in heat exchange capacity with depth in a borehole using heat dilution tests, Steve Sellwood.

**Journal Articles and Other Publications**
No journal articles and other publications reported.

**Awards and Achievements**
No awards and achievements reported.

**Research Patent or Copyright**
No research patents or copyrights reported.

# WI12R002 - Effects of Nuanced Changes in Lot Layout and Impervious Area Connectivity on Urban Recharge

## Basic Information

| | |
|---|---|
| **Title:** | WI12R002 - Effects of Nuanced Changes in Lot Layout and Impervious Area Connectivity on Urban Recharge |
| **Project Number:** | 2013WI327O |
| **Start Date:** | 7/1/2012 |
| **End Date:** | 6/30/2014 |
| **Funding Source:** | Other |
| **Congressional District:** | |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Category:** | None, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | Steven Loheide |

## Publications

There are no publications.

# Progress Report

**Reporting Period:** 07/01/2012 - 06/30/2013

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**Project**
WR12R002 - Effects of Nuanced Changes in Lot Layout and Impervious Area Connectivity on Urban Recharge

**Principle Findings and Significance**
STUDY SYNOPSIS
The objectives of this study are to determine the extent to which the amount, arrangement, and connectivity of impervious area in urban residential lots impact recharge in urban watersheds and to investigate the sensitivity of this increase or decrease in recharge to the arrangement of impervious areas under a range of lots and soil types. Our project involves two phases: 1) development and testing of a fully-coupled 2D surface water-3D subsurface water model and 2) simulation of a spectrum of residential lot types from low-density suburban layouts to highly urban, largely impervious layouts to determine the extent to which urban development and management can affect groundwater recharge.

MODEL DEVELOPMENT AND VALIDATION
The first phase of the project is nearing completion; the fully coupled, COMSOL-based model has been developed and extensively tested under 1D surface water-2D subsurface water conditions. For 100-day simulations, cumulative water balance errors are typically < 1%.

The customized surface water model has been validated by comparison with the MacCormack explicit finite difference solution of a diffusion-wave shallow water flow problem presented in several studies led by Kazezyilmaz-Alhan (2005). In the simulated scenario, rainfall occurs at 2 in/hr over a 600 ft long parking lot for 30 min and drainage is observed for an additional 30 min. The average relative error in water depth along the length of the parking lot for the entire scenario is less than 5% (Figure 2). In all cases where relative error appears high (> 10%), the surface water depth is so close to zero that the absolute error is negligible (< 2.2x10-4 m). The favorable comparison for surface water depth and runoff at the outlet can be seen in Figures 3 and 4.

The coupling of the surface water and subsurface water models has been validated by comparison with both laboratory measurements (Abdul and Gillham, 1984) and finite element solutions of the same scenario (VanderKwaak, 1999). In the simulated scenario, rainfall occurs at 4.3 cm/hr for 20 min over sand which has a 12-degree slope on the upper surface. The initial water table is set to the elevation of the outlet of the upper slope (74 cm). The COMSOL model captures the steady-state portion of the simulation well and early- and late-time discharge is reasonably similar to VanderKwaak's results (Figure 5). VanderKwaak attributed differences

with laboratory measurements to air entrapment which occurs in laboratory experiments.

SIMULATION OF ARCHETYPICAL SCENARIOS
Archetypical residential lots that represent the range of development common in Wisconsin have been constructed based on Madison zoning code and Madison assessor property statistics. Two lots represent typical lot sizes and building footprints in the least dense residential zone in Madison (SR-C1), two lots represent typical lot sizes and building footprints in the most urban residential zone (TR-C4), and one lot represents a townhouse unit (SR-V1, SR-V2, TR-V1) (Figure 1). The placement of houses, driveways, and accessory structures are designed to capture a spectrum of total percent impervious cover (Table 1) as well as alternative layouts for lots with similar total percent impervious cover (Lots A-C). We plan to complete 40 simulations (Table 2) to isolate the effects of individual management or zoning interventions on groundwater recharge. Our work is beginning to reveal the extent to which parcel-scale arrangement and connectivity of impervious surfaces spatially redistributes water, creating focused areas with deeper and faster penetrating wetting fronts which alter groundwater recharge at the lot scale. This work is improving our understanding of the effects of land-use change and different styles of residential development on groundwater recharge, thus enabling us to better manage our groundwater systems in urban settings.

**Number of Personnel Involved**
1 Participating faculty/staff
0 Supported post-docs

**Students Supported**

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**Name**
Jeffrey Miller

**Affiliation**
University of Wisconsin-Madison

**Degree**
MA/MS

**Major/Specialization**
Civil and Environmental Engineering

**Graduation**
12/2012

**Job Placement**
Industry

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**Name**
John Sourbeer

**Affiliation**
University of Wisconsin-Madison

**Degree**
MA/MS

**Major/Specialization**
Civil and Environmental Engineering

**Graduation**
12/2013

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**Name**
Carolyn Voter

**Affiliation**
University of Wisconsin-Madison

**Degree**
PhD/DSci

**Major/Specialization**
Civil and Environmental Engineering

**Graduation**
5/2017

## Conference Participation

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**Title**
American Water Resources Association Wisconsin Section Annual Meeting

**Location**
Brookfield, WI

**Dates**
3/7/13-3/8/13

**Number of supported students attending**
1

**Presentations by Students**
poster presentation “Modeling the effects of nuanced changes in lot layout and impervious area connectivity on

urban recharge in COMSOL", Carolyn B. Voter, Jeffrey F. Miller, Steven P. Loheide II

**Journal Articles and Other Publications**

No journal articles and other publications reported.

**Awards and Achievements**

No awards and achievements reported.

**Research Patent or Copyright**

No research patents or copyrights reported.

# WR12R003 - Transport of Manure-derived Escherichia coli within Naturally-Fractured Dolomite

## Basic Information

| | |
|---|---|
| **Title:** | WR12R003 - Transport of Manure-derived Escherichia coli within Naturally-Fractured Dolomite |
| **Project Number:** | 2013WI328O |
| **Start Date:** | 7/1/2012 |
| **End Date:** | 6/30/2014 |
| **Funding Source:** | Other |
| **Congressional District:** | |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | None, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | Shangping Xu |

## Publications

There are no publications.

# Progress Report

**Reporting Period:** 07/01/2012 - 06/30/2013

**Project**
WR12R003 - Transport of Manure-derived Escherichia coli within Naturally-Fractured Dolomite

**Principle Findings and Significance**
The focus of this research is to examine the transport of manure-derived Escherichia coli within naturally fractured dolomite rocks. We obtained the fractured dolomite samples from a quarry located in Waukesha with the help of Halquist Stone. A photo of one of the samples used is shown below:

https://pantherfile.uwm.edu/xus/www/photo.JPG

As planned, we have constructed an experimental system that can seal the dolomite samples and allow for water, as well as cell suspensions, to travel through the dolomite fractures. We have tested the transport of a manure-derived E. coli within the fractures under a range of chemistry conditions. Our results suggested that, as expected, E. coli has high mobility within the fractured rocks.
In the coming year, we will continue the experimental test for various chemistry and flow conditions, examine the potential release of previously immobilized E. coli cells as a result of perturbation, and to examine the energy interactions between the cells and the surface of dolomite rocks. We will also try to apply a transport model to describe the transport of E. coli cells within the naturally fractured dolomite rocks.

**Number of Personnel Involved**
1 Participating faculty/staff
0 Supported post-docs

**Students Supported**

**Name**
Lucia Feriancikova

**Affiliation**
University of Wisconsin-Milwaukee

**Degree**

PhD/DSci

**Major/Specialization**
Groundwater Hydrology, Contaminant Transport

**Graduation**
2014

## Conference Participation
No conferences reported.

## Journal Articles and Other Publications
No journal articles and other publications reported.

## Awards and Achievements

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**Title**
Graduate Student Research Award, 2012-2013

**Recipient(s)**
Lucia Feriancikova

**Awarded By**
Department of Geosciences, UW-Milwaukee

**Type of Award**
Research

**Description**
Lucia received the graduate student research award for her research performance during the academic year 2012-2013 while she was being supported by this research grant.

**Number of students receiving award**
1

## Research Patent or Copyright
No research patents or copyrights reported.

# WR12R004 - An Evaluation of the Distribution and Sources of Dissolved Strontium in the Groundwater of Eastern Wisconsin, with a Focus on Brown and Outagamie Counties

## Basic Information

| | |
|---|---|
| **Title:** | WR12R004 - An Evaluation of the Distribution and Sources of Dissolved Strontium in the Groundwater of Eastern Wisconsin, with a Focus on Brown and Outagamie Counties |
| **Project Number:** | 2013WI329O |
| **Start Date:** | 7/1/2012 |
| **End Date:** | 6/30/2014 |
| **Funding Source:** | Other |
| **Congressional District:** | |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | None, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | John Luczaj, Michael Edward Zorn |

## Publications

There are no publications.

# Progress Report

**Reporting Period:** 07/01/2012 - 06/30/2013

**Project**
WR12R004 - An Evaluation of the Distribution and Sources of Dissolved Strontium in the Groundwater of Eastern Wisconsin, with a Focus on Brown and Outagamie Counties

**Principle Findings and Significance**
Dissolved strontium in parts of the Cambrian-Ordovician aquifers of northeastern Wisconsin exceeds the lifetime and short-term EPA Health Advisory Limits of 4 mg/L and 25 mg/L, respectively. These elevated strontium levels occur along the western rim of the ancestral Michigan Basin.
Our research on the distribution and sources of dissolved strontium in northeastern Wisconsin had two main objectives:
1. To determine the regional and stratigraphic distribution of dissolved strontium (Sr) in the groundwater of eastern Wisconsin, with a focus on Brown and Outagamie counties.
2. To evaluate potential sources of Sr in bedrock aquifers present in the region.

Our study used several strategies to accomplish these objectives. These included sampling of groundwater from wells, whole-rock geochemical analysis of drill core and cuttings samples, isotopic evaluation of dissolved and whole-rock 87Sr/86Sr compositions, evaluation of well construction reports, and GIS mapping of results. Groundwater sampling of over 110 wells was completed between July 2012 and late Summer 2013. A few remaining wells will be sampled that are related to the project, likely within the next two weeks. Data analysis and GIS mapping are ongoing, but preliminary maps showing the distribution of dissolved strontium in the aquifers of eastern Wisconsin are shown in Figures 1 & 2. Elevated dissolved strontium has been observed in wells open to the Sinnipee Group dolostones through the Cambrian Sandstones. Over 60% of the samples collected had dissolved strontium values over the lifetime Health Advisory Limit. For this study, the highest strontium value recorded was 29.4 mg/L, although an earlier unpublished dataset shows dissolved strontium as high as 41.2 mg/L in the region.
The highest whole-rock strontium concentrations exist in the Sinnipee and Prairie du Chien Group dolostones as well as localized areas of the St. Peter and Cambrian sandstones, especially in areas further eastward. However, none of the whole-rock bedrock samples analyzed appear sufficiently enriched in Strontium to explain the high levels of dissolved strontium in the aquifers, in comparison to other dissolved ions.
The primary source of dissolved strontium in the groundwater of northeastern Wisconsin seems to originate from the dissolution of heterogeneously distributed celestine ($SrSO_4$) (Figure 3) and possibly strontianite ($SrCO_3$). This conclusion is supported by three principal arguments. First, the typical concentration of Sr in bedrock in the region is < 165 ppm, which is insufficient to explain the high dissolved concentrations in the

aquifers. Second, plots of groundwater in the region approaches the saturation index of celestine as sulfate concentrations increase. Third, the 87Sr/86Sr isotopic signature of available celestine and strontianite mineral samples from eastern Wisconsin is consistent with the isotopic signature of dissolved Sr in Ordovician and Cambrian aquifers in northeastern Wisconsin (Figure 4).
The regional distribution of elevated dissolved strontium is likely controlled by two main factors. First, eastward flow in the Cambrian-Ordovician aquifer system from the recharge areas west of the study area takes relatively fresh water toward the ancestral Michigan basin. This flow path allows dissolved Sr concentrations to increase over time while in contact with celestine and other Sr-rich minerals in the aquifer. A second, more surprising result has been that aquifer compartmentalization appears strongly related to the presence of regional dip-slip faults in northeastern Wisconsin. In fact, not only does the dissolved Sr concentration change dramatically across these faults, but also the general aquifer chemistry is starkly different across some of the faults.

**Number of Personnel Involved**
2 Participating faculty/staff
0 Supported post-docs

**Students Supported**

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**Name**
Joseph Baeten

**Affiliation**
University of Wisconsin-Green Bay

**Degree**
MA/MS

**Major/Specialization**
Environmental Science & Policy

**Graduation**
12/2013

**Thesis Title**
Spatial Distribution and Source Identification of Dissolved Strontium in Eastern Wisconsin’s Aquifers

**Job Placement**
Government

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**Name**
Mick Kiehl

**Affiliation**

University of Wisconsin-Green Bay

**Degree**
BA/BS

**Major/Specialization**
Geoscience (with minor in Urban & Regional Studies)

**Graduation**
8/2013

## Conference Participation

**Title**
Spatial Distribution and Source Identification of Dissolved Strontium in Eastern Wisconsin's Groundwater Aquifers.

**Location**
AWRA – Wisconsin Section Annual Meeting in Brookfield, Wisconsin

**Dates**
March 7-8, 2013

**Number of supported students attending**
1

**Presentations by Students**
TITLE: Spatial Distribution and Source Identification of Dissolved Strontium in Eastern Wisconsin's Groundwater Aquifers. Authors: Joseph Baeten (graduate student), John Luczaj (UWGB), Michael Zorn (UWGB), Dave Johnson (WIDNR)

## Journal Articles and Other Publications
No journal articles and other publications reported.

## Awards and Achievements
No awards and achievements reported.

## Research Patent or Copyright
No research patents or copyrights reported.

## Completion Summary

Stratigraphic analysis, GIS mapping, and limited groundwater sampling is ongoing. In addition, Sr-isotopic analysis of remaining groundwater samples is planned for mid-September through a collaborative relationship with an outside lab (University of Illinois). As a result, some aspects of our final conclusions have yet to be determined.

# WR12R005 - Hexavalent Chromium (Cr(VI)) in WI Groundwater: Identifying Factors Controlling the Natural Concentration and Geochemical Cycling in a Diverse Set of Aquifers

## Basic Information

| | |
|---|---|
| **Title:** | WR12R005 - Hexavalent Chromium (Cr(VI)) in WI Groundwater: Identifying Factors Controlling the Natural Concentration and Geochemical Cycling in a Diverse Set of Aquifers |
| **Project Number:** | 2013WI330O |
| **Start Date:** | 7/1/2012 |
| **End Date:** | 6/30/2014 |
| **Funding Source:** | Other |
| **Congressional District:** | |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | None, None, None |
| **Descriptors:** | |
| **Principal Investigators:** | Patrick Gorski, Martin Shafer |

## Publications

There are no publications.

# Progress Report

**Reporting Period:** 07/01/2012 - 06/30/2013

**Project**

WR12R005 - Hexavalent Chromium (Cr(VI)) in WI Groundwater: Identifying Factors Controlling the Natural Concentration and Geochemical Cycling in a Diverse Set of Aquifers

**Principle Findings and Significance**

To bolster recent Cr(VI) research of the Madison, WI aquifer (Gotkowitz et al. 2012), as well as expand knowledge to the entire state, sampling sites were focused in Dane County and locations along the mineralized basin edges of WI. With help of WNDR, and limited first year funding, fresh well cuttings of aquifer material were collected usually every 20 ft from major geological strata during replacement well drilling in La Crosse, Tomah, Pulaski, Appleton and municipal well drilling in Dane and Verona (Dane County). Well cuttings were sieved, rinsed, frozen and stored sealed after purging with nitrogen to prevent oxidation.

Aquifer material was ground by ball mill, digested in an acid matrix, and analyzed by Sector Field ICP-MS for a wide range of metals. For replacement wells, metal concentrations in the well cuttings were not consistently correlated to metal concentrations in water (Table 1). As predicted, some metals that had high concentrations in cuttings also had high concentrations in well water(Al, Fe, Mg, Mn), but some cuttings that had low concentrations had corresponding high concentrations in water (As, Cr, Cu, Co, Ni, Zn), suggesting conditions favorable for enhanced metal release or transport. Metals often decreased with depth (Table 2). In Dane County samples, the deeper Mt. Simon aquifer had lower concentrations of Cr compared to the shallow Tunnel City aquifer (Table 3), which corresponds to Cr(VI) concentrations reported in water samples (Gotkowitz et al. 2012).

More progress was made after July 1, 2013 when graduate student funding started. In preparation of controlled laboratory experiments to study Cr(VI) formation, deep aquifer groundwater was collected (Madison Well #19) and used as surrogate water for the study. We passed the water through chelex resin to remove metals associated with Cr(VI) oxidation and reduction (e.g., Cr, Fe and Mn, confirmed by ICP-MS analysis). Bubbling high purity nitrogen through the water (~12-15h) achieved dissolved oxygen concentrations < 1 mg/L. With minor method modifications, dissolved iron (Stookey 1970), soluble oxidized manganese (Majestic et al. 2007), and sulfide (Cline 1969) were measured in both type I water and surrogate groundwater (Figure 1) and determined that concentrations are sufficiently low enough to not interfere with Cr(VI) speciation .

For our first experiment well cutting samples were selected based on characterization of Cr, Mn and Fe (Table 4). Reactors contained an aquifer suspension density of 2 g/L and stored in a glove box to maintain anoxic conditions for the duration (0 h, 24 h and 11 days). Time-specific subsamples were analyzed for: bulk chemistry, pH, dissolved oxygen, temperature, chromium speciation, iron speciation, manganese speciation, water soluble organic carbon, inorganic ions and sulfide. An anoxic atmosphere was successfully maintained

(Table 5). We observed a slight increase in Cr(VI) concentrations in a majority of the reactors (Table 6). Nitrate, phosphate and sulfate remained similar but chloride increased in 85% of the samples (Table 7). Unfortunately, results of iron, manganese and sulfide speciation methods were skewed by initially high blanks which decreased over time. Follow-up tests indicated an instrument issue needs to be resolved; pH was not the cause, and spectrophotometric analysis of sample background and reagent blanks showed that they did not interfere with absorbance measurements.
We also observed an unexpected increase in pH (~7.5 to 9.5) and later determined buffering capacity was lost due to nitrogen bubbling (Figure 2). The buffer TRIS-maleate will be utilized in the next experiments to maintain pH ~ 7.5.
Having defined and resolved issues associated with our study design, we plan to execute more reactor experiments in 2013-2014, although due to defunding of the Stoughton Synchrotron Radiation Center, x-ray absorption measurements may not be possible.

**Number of Personnel Involved**
4 Participating faculty/staff
0 Supported post-docs

**Students Supported**

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**Name**
Zana Sijan

**Affiliation**
University of Wisconsin-Madison

**Degree**
MA/MS

**Major/Specialization**
Environmental Chemistry and Technology

**Graduation**
5/2014

**Thesis Title**
Geochemical Cycling of Hexavalent Chromium in Wisconsin Aquifers and the Development of a Method for the Assessment of Inflammation Induced by Atmospheric Particulate Matter

**Conference Participation**

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**Title**
AWRA, WI Section

**Location**
Brookfield, WI

**Dates**
March 7-8, 2013

**Presentations by Staff**
Poster, Assessing Different Aquifer Material in WI as Possible Natural Sources of Chromium (VI). Gorski P, Sijan Z, Shafer M and Hurley J.

## Journal Articles and Other Publications

**Title**
NA

## Awards and Achievements

No awards and achievements reported.

## Research Patent or Copyright

**Title**
NA

**Description**
NA

**Type**
Patent

# Information Transfer Program Introduction

None.

# University of Wisconsin Water Resources Institute - 5 Year Information Transfer Program

## Basic Information

| | |
|---|---|
| **Title:** | University of Wisconsin Water Resources Institute - 5 Year Information Transfer Program |
| **Project Number:** | 2011WI265B |
| **Start Date:** | 3/1/2012 |
| **End Date:** | 2/29/2016 |
| **Funding Source:** | 104B |
| **Congressional District:** | WI-2 |
| **Research Category:** | Not Applicable |
| **Focus Category:** | Education, Climatological Processes, Groundwater |
| **Descriptors:** | |
| **Principal Investigators:** | Moira Harrington |

## Publications


1. White, Elizabeth; Carolyn Rumery Betz; Aaron Conklin; Moira Harrington; Ann Moser. 2011, Volume 1 Aquatic Sciences Chronicle 8 pages
2. White, Elizabeth; Carolyn Rumery Betz; Aaron Conklin; Moira Harrington; Ann Moser. 2011, Volume 2 Aquatic Sciences Chronicle 8 pages
3. White, Elizabeth; Carolyn Rumery Betz; Aaron Conklin; Moira Harrington; Ann Moser. 2011, Volume 3 Aquatic Sciences Chronicle 10 pages
4. White, Elizabeth; Carolyn Rumery Betz; Aaron Conklin; Moira Harrington; John Karl; Ann Moser. 2011, Volume 4 Aquatic Sciences Chronicle 12 pages
5. Karl, John Streams Neutralize Nitrates in Groundwater 2011 5:51-minute video
6. Harrington, Moira; Aaron Conklin. wri.wisc.edu program website
7. Moser, Anne; Sarah Leeman. aqua.wisc.edu/waterlibrary program website
8. Conklin, Aaron; Carolyn Rumery Betz; Moira Harrington. facebook.com/UWiscSeaGrant Facebook page for University of Wisconsin Water Resources Institute and University of Wisconsin Sea Grant Institute
9. Conklin, Aaron; Carolyn Rumery Betz, Moira Harrington. @UWiscSeaGrant Twitter address for both University of Wisconsin Water Resources Institute and University of Wisconsin Sea Grant Institute
10. Rumery Betz, Carolyn; et al. 2011,35th Annual Meeting Program and Abstracts Wisconsin's Role in Great Lakes Restoration, American Water Resources Association, Wisconsin Section. 76 pages
11. Babiarz, Christopher; James P. Hurley; David P. Krabbenhoft; James G. Wiener July, 19, 2011, Wisconsin Leads the World in Mercury Research opinion-page column, 2 pages
12. Rumery Betz, Carolyn; Kevin Masarik.March 7, 2011 Spring is a Good Time to Test Well Water news release, 2 pages
13. Rumery Betz, Carolyn; Kevin Masarik.March 2, 2011 Celebrate Groundwater Awareness Week by Properly Filling and Sealing Unused Wells news release 2 pages
14. Rumery Betz, Carolyn; Kevin Masarik March 1, 2011 Dispelling Groundwater Myths news release 2 pages

15. White, Elizabeth; Aaron Conklin; Moira Harrington; Ann Moser; Marie Zhuikov 2012, Volume 2 Aquatic Sciences Chronicle 12 pages
16. White, Elizabeth;Aaron Conklin; Moira Harrington; Ann Moser; Marie Zhuikov 2012, Volume 3 Aquatic Sciences Chronicle 12 pages
17. White, Elizabeth; Aaron Conklin; Moira Harrington; Ann Moser; Marie Zhuikov 2012, Volume 4 Aquatic Sciences Chronicle 12 pages
18. White, Elizabeth;Aaron Conklin; Moira Harrington; John Karl; Ann Moser; Marie Zhuikov 2013, Volume 1 Aquatic Sciences Chronicle 8 pages
19. Karl, John What's a Spring 2012 27-second video
20. Harrington, Moira; Aaron Conklin; Marie Zhuikov wri.wisc.edu program website
21. Moser, Anne; Peter Rudrud aqua.wisc.edu/waterlibrary program website
22. Moser, Anne water.wisc.edu portal website
23. Conklin, Aaron; Marie Zhuikov; Moira Harrington facebook.com/UWiscSeaGrant Facebook page for University of Wisconsin Water Resources Institute and University of Wisconsin Sea Grant Institute
24. Conklin, Aaron; Marie Zhuikov; Moira Harrington @UWiscSeaGrant Twitter handle for both University of Wisconsin Water Resources Institute and University of Wisconsin Sea Grant Institute
25. Moser, Anne. @WiscWaterLib Twitter handle for Wisconsin's Water Library
26. Moser, Anne. Facebook page for Wisconsin's Water Library facebook.com/WiscWaterLib
27. White, Elizabeth; et al. 2012,36th Annual Meeting Program and Abstracts Science-Based Policy for Wisconsin's Water Resources, American Water Resources Association, Wisconsin Section. 93 pages
28. Andren, Anders March 7, 2012, Consider the Tide Under Your Feet, opinion-page column, 2 pages
29. Harrington, Moira April 9, 2012 New Director of Sea Grant Institute and Water Resources Institute Chosen news release, 2 pages
30. Zhuikov, Marie January 2, 2013 Study Shows Mercury Deposited Into Lakes Quickly Finds Its Way Into Fish news release, 2 pages
31. Babiarz, Chris; Marie Zhuikov October 2012 Nitrates in Groundwater fact sheet, 4 pages
32. Babiarz, Chris; Marie Zhuikov October 2012 Arsenic in Groundwater fact sheet 4 pages
33. White, Elizabeth; Aaron Conklin; Moira Harrington; Anne Moser; Marie Zhuikov, 2013 Volume 2 Aquatic Science Chronicle, 8 pages
34. White, Elizabeth; Aaron Conklin; Moira Harrington; Anne Moser; Marie Zhuikov, 2013, Volume 3 Aquatic Sciences Chronicle 8 pages
35. White, Elizabeth; Aaron Conklin; Moira Harrington; Anne Moser; Marie Zhuikov, 2013 Volume 4 Aquatic Sciences Chronicle 12 pages
36. White, Elizabeth; Aaron Conklin; Moira Harrington; Anne Moser; Marie Zhuikov, 2014 Volume 1 Aquatic Sciences Chronicle 8 pages
37. Zhuikov, Marie June 13, 2013 Climate Change is Focus of New Water Resources Institute Projects, news release 1 page
38. Harrington, Moira June 26, 2013 Downloadable, Free Resource on Flooding news release 1 page
39. Zhuikov, Marie July 10, 2013 Ancient Oaks Help Scientists Study Climate in Southwestern Wisconsin news release 1 page
40. Zhuikov, Marie January 14, 2014 Researchers Find Strontium in Northeastern Wisconsin Wells news release 2 pages
41. White, Elizabeth; et al. 2013 37th Annual Meeting Program and Abstracts Managing Wisconsin's Urban Water Resources American Water Resources Association, Wisconsin Section, 86 pages
42. Harrington, Moira; Aaron Conklin, Marie Zhuikov wri.wisc.edu program website
43. Moser, Anne; Erin Anthony aqua.wisc.edu/water library program website
44. Moser, Anne water.wisc.edu portal website
45. Conklin, Aaron; Moira Harrington, Marie Zhuikov facebook.com/UWiscSeaGrant Facebook page for the University of Wisconsin Water Resources Institute and University of Wisconsin Sea Grant Institute

46. Conklin, Aaron; Moira Harrington, Marie Zhuikov @UWiscSeaGrant Twitter handle for the University of Wisconsin Water Resources Institute and the Wisconsin Sea Grant Institute
47. Conklin, Aaron; Moira Harrington, Marie Zhuikov @UWiscSeaGrant Twitter handle for the University of Wisconsin Water Resources Institute and the Wisconsin Sea Grant Institute
48. Moser, Anne @WiscWaterLib Twitter handle for Wisconsin's Water Library
49. Moser, Anne facebook.com/WiscWaterLib, Facebook page for Wisconsin's Water Library
50. Bocast, Chris February 28, 2014 Groundwater, Soil and Dr. Dirt 22:34 minute audio podcast
51. Bocast, Chris February 28, 2014 Aquifers, Websites and Water Tables 11:15 minute audio podcast
52. Bocast, Chris February 28, 2014 Waters Within Waters - Working With Watersheds 15:33 minute audio podcast
53. Karl, John Look Ma! No Hands! Remote Water Quality Monitoring 25:41 minute video
54. Karl, John Automation for the People: pH, Alkalinity and Conductivity 14:09 minute video
55. Karl, John The Phosphorous (Analysis) Blues 44:58 minute video
56. Karl, John Come On In! The Water’s Fine! Or Is It? (Part One) 18:40 minute video
57. Karl, John Come On In! The Water’s Fine! Or Is It? (Part Two) 40:32 minute video
58. Karl, John Keeping it Clean: Techniques and Laboratory Practices for Mercury Analysis 23:39 minute video
59. Karl, John Toxic and Tricky: Analyzing Methylmercury 19:48 minute video
60. Karl, John Going for the Gold III 21:32 minute video
61. Karl, John Analyzing Water for Organic Chemicals 1:22:37 minute video

The University of Wisconsin Water Resources Institute (WRI) Information Transfer Program ensures delivery of education and outreach related to long-term water planning, policy development and resource management to water researchers, professionals and resource managers. Another target audience is broad—members of the general public—so as to deepen knowledge of Wisconsin's water assets and engender greater stewardship. It is an ongoing project.

In this reporting period, the information transfer program produced and distributed publications, messages through four news releases, social media outlets, four issues of a quarterly newsletter, 11 videos and three episodes of an eight-part audio podcast series; maintained websites; co-sponsored and assisted in planning and conducting a major statewide conference on water resources; maintained and expanded a library on water resources that also conducts outreach through presentations.

Much of WRI's information is shared via an online publication store, *http://aqua.wisc.edu/publications*. A publication about rain gardens was the most popular WRI download in the publications store. There were about 20,300 downloads in this reporting period. An additional roughly 9,800 items were distributed through the mail. These included items such as bookmarks, aquatic invasive species watch cards, posters and brochures. Sales from this online site totaled about $3,600.

A notable achievement in media relations was the distribution of information about WRI-funded research on strontium in Wisconsin's most-populous region, the eastern and northeastern portions of the state. The major newspapers in the area, along with television and radio stations, shared the information that the naturally occurring mineral can cause health problems, particularly for children, when ingested. The research and following publicity raised awareness and prompted contacts to the state's health department by citizens who wanted to blunt the effects of this mineral in their water supply.

Social media offers the means to communicate in real time and without typical editorial filters. WRI is active on Facebook and Twitter. Through the two platforms, a weekly average of 1,300 people receive water-related messages. If that original group of people shared WRI messages, there was the potential to reach more than 347,000 people. WRI also uses the social media tools Flickr and YouTube.

The Aquatic Sciences Chronicle is published quarterly. It highlights water research and the people who conduct water research and outreach. At *aqua.wisc.edu/chronicle*, all issues of the publication are archived and searchable. This quarterly publication circulates to an audience of roughly 3,200 people, which includes local and state water management agencies, and water-related non-governmental organizations. Readers are found in Wisconsin and across the country. In 2013, the Chronicle surveyed its readers on a number of topics. Those results have provided direction for future content and layout changes to the publication to better serve research resource manager audiences.

WRI's video catalog includes "What's a Spring," "Streams Neutralize Nitrates in Groundwater," "Testing Well Water for Microorganisms" and "A New Measure of Groundwater Flow."

Additionally, WRI continued work on a video to explain Wisconsin's Groundwater Monitoring Network, partnering with the state of Wisconsin's Geological and Natural History Survey. When complete, it will be shared through the program's website and its YouTube channel, *http://www.youtube.com/user/UWASC/*.

WRI also created 11 videos highlighting the protocols of in-laboratory water testing. The video segments were shot at two USGS labs, a regional and a national one; the Wisconsin State Laboratory of Hygiene to focus on algal toxins and metals analysis; and the Racine Public Health Laboratory to explore Great Lakes issues.

WRI's director used the video in classroom instruction and received positive feedback from students. He was also asked to share his experience with educational innovations on the UW-Madison campus to incorporate its principles in further curricula undertaken by colleagues.

At *http://itunes.apple.com/WebObjects/MZStore.woa/wa/viewPodcast?id=430421609*, visitors can download a WRI-sponsored seven-part audio podcast series. "Water, Wisconsin and the Mercury Cycle" details mankind's historic uses of mercury, Wisconsin's water resources and mercury in Wisconsin waters. A major part of the series also focuses on WRI-funded research on mercury. At the iTunes university site, WRI has been able to garner its own artist's page. Pages such as these are reserved only for those who reach a certain threshold of content. The special pages allow for a richer display of water-related content. Moreover, they provide a so-called "sticky" experience where users are attracted to the site and then stick around for additional, related information.

The "Aquifers and Watersheds" audio podcast series was also conceptualized in this reporting period and three of an eventual eight in the series were produced. In the series, experts explain in plain words the foundational ideas underlying the science of hydrology. Episodes are at bit.ly/1e5a1jQ.

The WRI website *http://www.wri.wisc.edu* orients visitors to the Wisconsin. One of the site's main audiences is researchers. To that end, the site provides a clear navigational path to the WRI project listing, project reports, a groundwater research database, funding opportunities and conference information sections. The areas are updated on a regular basis to ensure currency of information transfer. The WRI site had 42,962 visitors in this reporting period. That is a 17 percent increase in visitors over the previous reporting period. The Web page linking to various WRI publications was the most popular.

**AWRA 2013 Annual Conference**

The Wisconsin Section of the American Water Resources Association conducts an annual meeting. WRI assists with meeting planning and provides material support. WRI joined other conference sponsors—the University of Wisconsin-Stevens Point Center for Watershed Science and Education, Wisconsin Department of Natural Resources, Wisconsin Geological and Natural History Survey and the U.S. Geological Survey's Wisconsin Water Science Center—to stage the event that attracted about 200 people.

**Wisconsin's Water Library**

Wisconsin's Water Library is a unique resource for researchers, resource managers and all Wisconsin citizens. It contains more 30,000 volumes of water-related information about the Great Lakes and other waters of Wisconsin. The library includes a curricula collection, dozens of educational videos, children's collection, and more than 20 journals and 100 newsletters. Each year, about 1,400 publications circulate among interested users.

Wisconsin's Water Library continues to catalog all groundwater research reports from WRI projects into WorldCat and MadCat, two library-indexing tools that provide both statewide and worldwide access to the science.

In addition to archival benefits, the library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. It provides a water research guide (*http://researchguides.library.wisc.edu/waterresearchguide*). It is active on social media and goes out into the community to offer presentations (more on that below). It prepares recommended reading lists on topics such as climate change, groundwater, water conservation and water supply.

During the reporting period, in partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library continued its outreach to current and future wastewater operators of Wisconsin. The library cataloged the essential technical manuals into the library catalog and provided loans to WWOA members around the state in support of their required state license examinations as well as in support of the educational needs of their daily work.

The library maintains several information transfer tools to reach library patrons and the most frequently accessed is the library's website (*http://www.aqua.wisc.edu/waterlibrary*), which had nearly half a million visitors during this reporting period. The 440,243 visitors represented a 73 percent increase over the previous reporting period.

In addition to its website, Wisconsin's Water Library uses other technology tools to reach library patrons. Using email, the library sends out a bimonthly "Recent Acquisitions List" to roughly 500 contacts. The message also includes recent updates to the library website and contact information for users to ask any water-related question. In addition, the library supports an email account at *askwater@aqua.wisc.edu*, which is monitored daily.

The library uses social media for real-time relationships with interested patrons. It is active on Twitter, Facebook and maintains a blog. In fact, during this reporting period, the library submitted an abstract on the use of social media to the 2014 SAIL **International Association of Aquatic and Marine Science Libraries and Information Centers** conference. It was accepted and library staff presented in May 2014, just outside of this reporting period.

During this reporting period, WRI library staff also was integral to the content-population of *http://www.water.wisc.edu*. The site is a portal to the breadth and depth of water-related work on the state's flagship campus, the University of Wisconsin-Madison, and serves as the first stop for anyone interested in water research. Additionally, graduate students can search for

departments offering courses and degrees that fit their interests and staff and faculty can search for colleagues working on topics complementary to their own to facilitate greater interdisciplinary collaboration and exploration. In this reporting period, there were about 2,502 visitors to the site.

**Outreach Events**

Wisconsin's Water Library held bimonthly sessions with children ages 3 through 6 at Ho Chunk Nation facilities in Wisconsin Dells, Wis. An average of 20 children attended each time. The sessions presented age-appropriate water-related stories and activities. In each instance, the water librarian shared water sustainability stories and activities in age-appropriate ways. Furthermore, the library staff will build on established partnerships with preschool educators and librarians throughout the state to undertake teach the teacher workshops in 2014. The workshops will provide educators with best practices for early educational STEM learning. Introducing STEM concepts in the preschool years is an emerging trend and interest in this training to teach three- to six-year-olds is high. Within this reporting period, library staff conducted a pilot workshop to Head Start educators along the Mississippi River. That region will serve as the foundation for future workshops.

One other public outreach event was a rain garden demonstration and rain barrel display at the Wisconsin State Fair. The day-long display attracted the interest of about 250 people who stopped to have a conversation about these two tools to enhance water quality that individual home and property owners can undertake. Such an empowering message was helpful to share with people from all over Wisconsin, since the fair attracts attendees from all corners of the state.

# USGS Summer Intern Program

None.

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 NCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 6 | 3 | 0 | 5 | 14 |
| **Masters** | 2 | 0 | 1 | 4 | 7 |
| **Ph.D.** | 1 | 2 | 2 | 3 | 8 |
| **Post-Doc.** | 0 | 0 | 0 | 2 | 2 |
| **Total** | 9 | 5 | 3 | 14 | 31 |

# Notable Awards and Achievements

1. University of Wisconsin Water Resources Institute researchers discovered strontium in the drinking water of people living in the most populous area of Wisconsin, the eastern and southeastern portions of the state. This type of strontium is not the radioactive version that is a byproduct of nuclear fission, but rather is contained within a mineral known as celestine. Strontium dissolves in water and has no taste or odor, and can cause health problems when ingested, especially for children. It mimics calcium and can therefore cause teeth mottling and, more seriously, rickets.

The WRI-funded study not only highlighted an important public health issue it was also prompted by curious high school students in an extracurricular science club. In 2007, the Seymour, Wis., science club was awarded a prestigious Toyota TAPESTY grant to study the connection between 23 heavy metals found in well water along with naturally occurring arsenic. The students worked with a private contractor from a nearby city. That contractor suggested the students broaden their inquiry, which led to discovering elevated strontium levels. That group eventually connected with a Wisconsin Department of Natural Resources hydrologist, and a researcher at the University of Wisconsin-Green Bay who conducted the WRI-funded work.

Through social and traditional media, messages about the mineral reached households throughout the affected area. At least two area residents contact WRI staff directly to inquire about the situation in an effort to protect their families. The media attention was also rewarding to the students first involved in the project, providing them with well-deserved notice and motivating others in their school and larger community to notice and value science-based inquiry on behalf of water resources.

Also thanks to this study, the Wisconsin Department of Health Services is considering formulating a formal advisory to cover the affected area, again raising public awareness.

2) The “Aquifers and Watersheds” audio podcast series was conceptualized during this reporting period and three of an eventual eight in the series were produced. The series looks at what’s beneath Wisconsinites’ feet and what encircles villages, towns and cities—aquifers and watersheds.

WRI’s audio specialist sought out USGS, WRI and academic experts to explain in plain words the foundational concepts underlying the science of hydrology. The brand-new series digs into two geologic features that shape the culture and commerce of the state. The first three episodes are titled Groundwater, Soil and Doctor Dirt; Aquifers, Websites and Water Tables; and Waters Within Waters—Working With Watersheds.

Episodes are at bit.ly/1e5a1jQ. These were first posted at the end of February. In two months, the podcast series had already attracted nearly 150 online visitors. Furthermore, audiences can find the series at http://itunes.apple.com/WebObjects/MZStore.woa/wa/viewPodcast?id=430421609. At the iTunes university site, WRI has been able to garner its own artist’s page. Pages such as these are reserved only for those who reach a certain threshold of content. The special pages allow for a richer display of water-related content. Moreover, they provide a so-called “sticky” experience where users are attracted to the site and then stick around for additional, water-related information.

3) WRI staff produced a new collection of 11 videos through which viewers can step into the inner sanctum of water-chemistry labs or tag along on field sampling of Wisconsin waters.

Officially, the videos were produced for students enrolled in an environmental chemistry class at the University of Wisconsin-Madison. Unofficially, they will eventually serve as an online run-through of lab procedures that can be accessed by anyone with an interest in the topics when they are posted to

youtube.com/uwasc.

What are the covered topics? A handful of video titles offer a clue. Their lively monikers also indicate the informative yet accessible tone of the material—“Look Ma! No Hands! Remote Water Quality Monitoring,” Come On In! The Water's Fine! Or Is It?” and “The Phosphorus (Analysis) Blues.”

WRI Director Jim Hurley explained the impetus for series, “Traditional approaches used to teach environmental laboratory courses are becoming more difficult to deliver. In order to pay proper attention to major instrumentation that a student entering the workforce would typically encounter, a teaching laboratory would need to be equipped with an array of expensive instrumentation that easily exceeds constrained budgets of many university departments. Furthermore, students find it difficult to fit a four-hour laboratory into their complex schedules.”

Hurley received positive feedback from students about the videos. He was also asked to share his experience with educational innovations on the University of Wisconsin-Madison campus to incorporate its principles in further curricula undertaken by his colleagues.

# Publications from Prior Years

1. 2010WI286 ("Transport of Manure-Derived, Tetracycline Resistant Escherichia Coli in Unsaturated Soil") - Articles in Refereed Scientific Journals - Feriancikova, L.; Bardy, S. L.; Wang, L. X.; Li, J.; Xu, S. P., Effects of Outer Membrane Protein TolC on the Transport of Escherichia coli within Saturated Quartz Sands. Environmental Science & Technology 2013, 47 (11), 5720-5728.
2. 2010WI286 ("Transport of Manure-Derived, Tetracycline Resistant Escherichia Coli in Unsaturated Soil") - Articles in Refereed Scientific Journals - Feriancikova, L.; Wang L.; Li J.; Xu S. P., Transport of manure-derived Escherichia coli with different tetracycline resistance characters within partially saturated soil, Water Research, submitted for review 5/2014.
3. 2010WI286 ("Transport of Manure-Derived, Tetracycline Resistant Escherichia Coli in Unsaturated Soil") - Dissertations - Feriancikova, L., The spread of emerging contaminants in the soil-groundwater system, Ph. D. thesis, UW-Milwaukee, 5/2014.
4. 2009WI216B ("Combination of Co-Precipitation with Zeolite Filtration to Remove Arsenic from Contaminated Water") - Articles in Refereed Scientific Journals - Lv, G., Li, Z., Jiang, W.-T., Ackley*, C., Fenske*, N., Demarco*, N. (2014) Removal of Cr(VI) from water using Fe(II)-exchanged zeolite, Chem. Engineer. Res. Design, 92, 384–390.
5. 2009WI216B ("Combination of Co-Precipitation with Zeolite Filtration to Remove Arsenic from Contaminated Water") - Articles in Refereed Scientific Journals - Liu, C.-C., Kar, S., Jean, J.-S., Wang, C.-H., Lee, Y.-C., Sracek, O., Li, Z., Bundschuh, J., Yang, H.-J., Chen, C.-Y. (2013) Linking geochemical processes in mud volcanoes with arsenic mobilization driven by organic matter. J. Hazard. Mater., 262, 980–988.
6. 2009WI311O ("Forecasting Impacts of Extreme Precipitation Events on Wisconsin's Groundwater Levels") - Articles in Refereed Scientific Journals - Gotkowitz MB, Attig JW, McDermott T, 2014. Groundwater flood of a river terrace in southwest Wisconsin, USA. Hydrogeology Journal DOI 10.1007/s10040-014-1129-x
7. 2010WI282O (" Groundwater Research Characteristics and Subsurface Nutrient Dynamics Under Alternate Biofuel Cropping Systems in Wisconsin") - Dissertations - Ryan Stenjem, University of Wisconsin - Madison, Department of Biological Systems Engineering, M.S. completed January 2013, Thesis title: "Subsurface water and nutrient dynamics of cellulosic biofuel cropping systems".
8. 2010WI282O (" Groundwater Research Characteristics and Subsurface Nutrient Dynamics Under Alternate Biofuel Cropping Systems in Wisconsin") - Dissertations - Kristi Freitag, University of Wisconsin - Madison, Department of Biological Systems Engineering, B.S. completed May 2012.
9. 2010WI282O (" Groundwater Research Characteristics and Subsurface Nutrient Dynamics Under Alternate Biofuel Cropping Systems in Wisconsin") - Dissertations - Josh Accola, University of Wisconsin - Madison, Department of Biological Systems Engineering, B.S. completed May 2012