2007 WATER RESOURCES YEAR IN Review

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*for* Muskegon County

Sometimes the pace of change seems glacial, especially when it comes to advancing our environmental values. But looking back six or seven years ago before the Lake Michigan Center opened its doors, you realize that real progress has been made on many fronts. The presence of the GVSU Annis Water Resources Institute at the Lake Michigan Center has had a huge and very positive impact on the Muskegon region. There has been measurable progress in all of our watersheds and we know so much more about our local lakes and streams. We have gained much by having the Institute here. The accomplishments that Dr. Steinman and his staff have achieved in a few short years benefit all of us in the lakeshore region.

# Science that matters

*Dr. Alan Steinman, Director*

In the classroom, I like to use a quote from Peter Gleick, president and co-founder of the Pacific Institute for Studies in Development, Environment, and Security: "It's very difficult to make good public policy without good science, and it's even harder to make good public policy with bad science."

As director of the Annis Water Resources Institute, I interact with individuals from many arenas — government officials, business and community leaders, local decision makers, fellow scientists and researchers, administrators, citizens, and others concerned about the environment. Although we each have a different orientation and purpose, we all recognize the value and importance of good science in making informed decisions about our natural environment. But what constitutes "good" science? I joke, half-seriously, that many people think that science is "good" as long as it produces results that support their own position. Rather, science can be defined as good if its results can withstand the rigor of peer review and are reproducible by others.

At the Institute, we are dedicated to the pursuit and practice of good science. In doing so, we are able to offer dependable and accurate scientific results that we can share with others. Our multidisciplinary approach allows us to tackle environmental problems from a variety of perspectives. And by integrating our research results with outreach and education, we ensure that this information gets into the hands of our stakeholders, who range from students of all ages to elected officials responsible for enacting policies that influence our day-to-day existence.

Our philosophy of conducting multidisciplinary research and integrating scientific results with education and outreach is reflected, once again, in the projects we have undertaken this past year. These projects — some of which are highlighted in the following pages — are directed to topics that are relevant to the complex environmental concerns and challenges facing our region both today and in the years ahead. It is good science with an applied benefit and real world application. It's science that matters.

**Integrating research, education, and outreach to enhance and preserve freshwater resources**

**Graduate student**

**Nichol De Mol**

Nichol De Mol loves bugs, aquatic bugs in particular. That's one of the reasons why obtaining a masters degree in biology with an aquatic science emphasis has been an important part of her career path. She considers herself very fortunate to be both a part of the Annis Water Resources Institute's and Department of Biology's graduate program. Her major advisor, Dr. Eric Snyder, is an Assistant Professor in the Department of Biology and collaborates with scientists at AWRI.

"As a graduate student, I have lots of resources here at the Institute that I can take advantage of," says Nichol, who received her Bachelor of Science degree in Natural Resource Management from the University of Michigan in 1999. "Not only do I have access to the latest technology, like GIS capability, but I also receive professional input from my colleagues and mentors. I get lots of helpful advice."

Nichol has worked for the Institute for the past seven years as a research assistant and a project manager. Her interests and skills lie in watershed management, stream ecology, aquatic insects, water quality monitoring, and project management. She defended her thesis on benthic macroinvertebrate response in October of last year and was named Outstanding Graduate in the Master of Science in Biology program for Fall 2007.

"I am trying to determine how road-stream crossing improvements and bank stabilization occurring in the Manistee Watershed affect the physical habitat of the stream and response of the biota to these improvements. I am specifically looking at how the physical habitat and macroinvertebrates change as a result of these improvements," she says. "Being a part of the graduate program here at the Institute has given me the confidence I needed to put my thesis together. It's been a wonderful experience and definitely worth the effort."

## Institute Helps Define Green Space Value

How much would you pay for the sound of a bullfrog, a breath of fresh air, the view from a sand dune, or a handful of clear water? We tend to believe these things are free until, of course, someone puts a price on them. How much are they worth in dollars? How would it change our perceptions and our decisions if we placed a dollar value on them?

In collaboration with the West Michigan Strategic Alliance, and with funding from a $65,000 grant from People and Land through the W.K. Kellogg Foundation, the Annis Water Resources Institute led an economic valuation study of ecosystem services in seven west Michigan counties. The goals of the project were to determine the preliminary monetary economic value of these services and to develop a web-based cost/benefit tool that provides a more balanced and honest assessment of the value of green infrastructure in the region.

"People tend to see the value of a piece of property in terms of its development and how it can be used. They can quantify, for example, the amount of taxes it could generate," says Alan Steinman, principal investigator for the project and a member of the multidisciplinary team composed of ecologists and economists from AWRI, GVSU's Seidman College of Business, Michigan State University, and IRN Inc., "We're saying there is currently an undefined value in green infrastructure, and once decision makers are aware of that monetary value, they will be able to make more informed and responsible choices. In other words, how much is a parcel of land worth? Even though it is 'just sitting there', it is providing ecosystem services that we take for granted and do not typically monetize. For example, the land is sequestering carbon dioxide through photosynthesis by plants, allowing rainwater to infiltrate and recharge our aquifers, and purifying that water as it percolates through the soil. Can we put a dollar figure to it? This study is making a first stab at that valuation process."

Green infrastructure in our region is defined as dunes, grassland, forest, wetlands, lakes, rivers and streams, shorelines and riparian habitat, farmland, and watersheds. The team selected key ecosystem services provided by green infrastructure such as raw materials, fish and wildlife habitat, recreation, waste assimilation, pollination, erosion control, water regulation, nutrient recycling, and aesthetic amenities, and then identified the economic value or benefits to humans generated by these services.

Following an extensive process in which the team took existing studies and adjusted the data for the west Michigan market and its demographic features, the study

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estimated that our green infrastructure provides a minimum of ~$1.6 billion of ecosystem services to the region each year. This value is recognized as an underestimate because the valuation process did not include all possible land uses or ecosystem services; however, it does provide an important starting point for valuing ecosystem services in the region. The team determined a range of values per acre for different land uses, which is accessible through an interactive web tool at http://invest.wri.gvsu.edu/.

"It is clear that West Michigan's natural resources have value that is not being fully considered by its residents and decision-makers," says project manager Elaine Sterrett Isely, an adjunct research associate at the Institute. "We are hoping the Web-Tool will give local policy-makers an added resource to use when they make critical decisions about the costs and benefits of developing or protecting these resources."

## Rain Gardens: A Beautiful Way to Solve Water Quality Problems

Everyone understands how important rain is to the balance of life on earth, and Mother Nature has a good way of dealing with precipitation through natural processes. Water is an essential part of how this world functions and how we humans survive, but too much in areas not suited to rainfall causes problems, especially when we change or hinder water's natural flow or when we build impervious surfaces that create damaging stormwater runoff.

Within the past two years, the Information Services Center (ISC) of AWRI finished construction of four rain gardens located in McBain, Marne and the City of Walker. The projects were funded by Clean Michigan Initiative Non-point Source Pollution grants from the Michigan Department of Environmental Quality. These rain gardens, or bioretention systems as they are also called, will help manage stormwater on site, allowing water to infiltrate into the ground. Capture and infiltration of stormwater runoff removes contaminants, such as oil, grease, and nutrients, and minimizes the amount and rate of water flowing over land. High volume and fast flowing stormwater encourages erosion of stream banks, which leads to more sedimentation and loss of critical aquatic habitats in our rivers and streams.

Building these bioretention areas is a good example of a best management practice that will end up saving thousands if not millions of dollars that would otherwise be needed for fixing problems related to uncontrolled stormwater runoff. It is a structural solution that deals effectively with a potentially costly problem, and in the process provides an added benefit as it becomes a beautiful

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**Graduate Student**

**Keto Gyekis**

Growing up in rural North Central Pennsylvania, Keto Gyekis has always been interested in nature and ecology, yet his background is quite different from most typical biology graduate students. He started out at Penn State University in the civil engineering program but soon switched to Environmental Resource Management with an aquatic emphasis. After college, he worked as a forester for his father's small consultant forestry firm for several years before he went into business for himself building and developing Web sites. Woolrich (The Original Outdoor Clothing Company) hired him as a fulltime Web developer, and he spent the next four years designing and managing the company's huge e-commerce site.

"The web developer career was not quite right for me. I was sitting at a desk way too much and not really enjoying my work anymore. When my wife Katie received the opportunity to go for her dream job as a food scientist with Kellogg's corporate headquarters in Battle Creek, we decided to pick up and go for it. I quickly made the decision to get myself into an ecology grad program somewhere locally in Michigan," he says.

Interested in checking out GVSU's new biology graduate program, Keto enrolled in two upper-level aquatic ecology programs. The next semester he was offered a research assistantship at AWRI and started working on his graduate thesis under the mentorship of Dr. Don Uzarski on Great Lakes coastal wetland fragmentation.

"After doing my undergrad education at a huge Big Ten research university, it was refreshing to have small class sizes and professors who were very passionate about their field and cared about their teaching," comments Keto, who now works as a wetland ecologist for the Michigan Department of Environmental Quality. "And at the well-funded research lab at AWRI, I was able to pursue an extremely relevant wetland ecology research topic that was very interesting to me. The scientists at AWRI are first-rate and proficient at obtaining large research grants. So I felt like I could take advantage of the best of both worlds — small classes, big research. To others who are considering a masters degree at GVSU through the Institute, I say, 'Go for it' — especially if you are serious about aquatic ecology."

*Left: ISC staff plant seedlings at the McBain Park rain garden.*

*Below: Maintenance of rain garden in second year of growth at City of Walker Library.*

feature of the landscape. Rain gardens attract birds, butterflies, and other desirable wildlife. Plus, they greatly improve water quality.

Constructing a functional rain garden takes more than just planting a few flowers and some green vegetation. The ISC staff worked with numerous partners, including garden designers at the West Michigan Environmental Action Council, thereby capitalizing on the experience they have acquired as part of their Rain Gardens in West Michigan Program. ISC staff undertook a preliminary assessment of each site, determining the size of garden needed for the maximum amount of rainfall it may sustain. With the help of two engineering firms, Prein & Newhof and Fishbeck, Thompson, Carr, & Huber, ISC staff created very detailed stormwater protection structures. The ground was excavated to specified dimensions and then filled with layers of different soil — underlying gravel, then a filtering composite material, and finally a nutrient-rich mixture that can store water and keep topsoil in place. Hardy native species of plants contribute to the surrounding aesthetic appeal, as well as ensure low maintenance and future sustainability.

Building a rain garden is a great example of how we can address existing and potential challenges, says ISC program manager John Koches. We can identify current problem sites that would benefit from a rain garden, and once constructed the area will naturally take care of ongoing issues with excess water flow and contamination. But we can also start earlier in the planning stage when an area is targeted for development by including rain gardens in the master plan. With advanced planning we have the potential to anticipate and prevent future stormwater issues. If you can prevent a problem from occurring in the first place, then you won't have to spend the money to fix it later.

## Toxic Cyanobacteria May Pose Concern

Now there is another reason to be concerned about a certain kind of cyanobacteria that grows on the surface of our lakes and ponds. Not only does this group of organisms (formerly called blue-green algae) choke off sunlight from reaching below the surface of the water and compete with more desirable algae for nutrients, it also can produce a toxic chemical that is harmful to aquatic and terrestrial organisms and human health.

This past year, under the direction of Dr. Rick Rediske, an investigation was completed that analyzed cyanobacteria blooms from seven lakes in the west Michigan area. Dr. Rediske also worked in collaboration with researchers at the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory on

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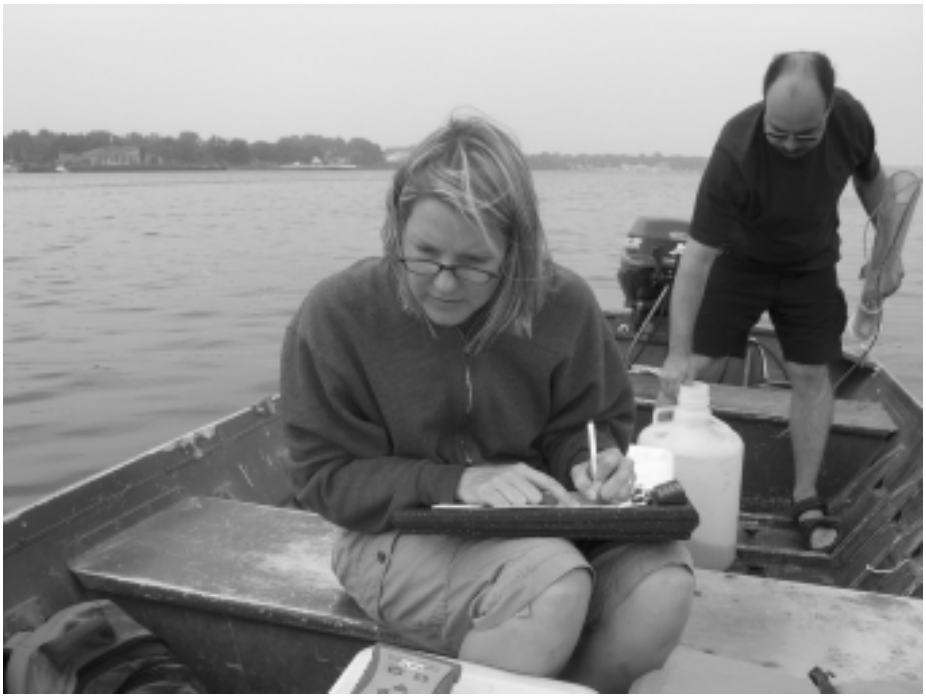

*Brian Scull and Janel Hagar sample for harmful algae in Lake Macatawa.*

investigations in Lake Erie and Saginaw Bay.

"This particular type of cyanobacterium is very resilient and can pose significant health and environmental risks if blooms occur," comments Rediske. When a certain gene structure is present, *Microcystis* can produce a group of toxins called microcystins. Cyanobacteria are 3.5 billion years old and have survived because of their ability to utilize nitrogen from the air and to tolerate adverse environmental conditions that would destroy other organisms. They also can be found in high amounts because many aquatic organisms avoid feeding on cyanobacteria, instead preferring to chow down on green algae and diatoms. Invasive species, such as zebra and quagga mussels, have exacerbated the problem, as these mussels usually avoid consuming cyanobacteria, allowing these potentially toxic organisms to grow and proliferate. The cyanobacteria can grow anywhere and in any aquatic environment but prefer warm water and calm, sunny conditions.

Based on results from samples collected this past summer, it seems that cyanobacteria blooms are common in west Michigan. "The increase in cyanobacteria is probably due to elevated nutrients from more nonpoint source pollution as well as increased water temperatures this season," says Rediske.

The cyanotoxins, which primarily affect liver function, can produce a variety of symptoms ranging from skin rashes to flu-like reactions, depending on the method of contact. Fatalities in the United States are rare, however. Human health-related issues are more common in tropical climates.

Thankfully, cyanobacteria blooms are short-lived, but it's best to avoid contact with any visible scum when you see it. Not all cyanobacteria are toxic, yet threats to public health are still possible. Decision makers need reliable, accurate data to help them determine the degree of risk and formulate plans for dealing with potentially harmful situations. Dr. Rediske's lab utilized three analytical methods in their research: Enzyme-linked Immunosorbent Assay (ELISA), Liquid Chromatography/ Mass Spectrometry (HPLC/MS), and Protein Phosphatase Inhibition Assay (PPIA). PPIA and ELISA were found to be reliable screening tools. However, because of the presence of a number of different microcystin compounds in the samples, HPLC/MS was the best method to determine human health risks associated with exposure.

## Puddles Become Object of Study

We can't resist smiling when we watch a small child stomp with abandon through a series of puddles, except perhaps the parent who must deal with the soggy aftermath. Our delight comes in watching the child, not the puddle. But this past year, a team of researchers and students at the Annis Water Resources Institute has taken a keen interest in watching and learning about puddles.

AWRI Principal Investigator Dr. Michael (Xuefeng) Chu led the research team on a project to test, quantify, and develop computer modeling software that illustrates what happens to water in puddles as it flows over land under different soil conditions. These conditions range from wet to dry and include different microtopographical features, ranging from uneven rough surfaces to uniform smooth slopes. The ultimate goal of the study is to improve understanding of how water flows over land and infiltrates into soils, especially as it forms and flows from puddle to puddle. The new methods to be developed in this study will further help us characterize the transport and fate of nonpoint source pollutants, such as excess fertilizers added to landscapes and farmland, or gas and oil from roads and parking lots.

The first phase of the project, completed in 2007, involved designing and constructing an overland flow

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*Visiting PhD Student Researcher Lili Mao and GVSU graduate student Jessica Higgins check soil water movement in the overland flow lab.*

laboratory, outfitted with a rainfall simulator, sophisticated computerized equipment, and a series of soil boxes. The team is currently conducting tests under a variety of conditions in the laboratory and in the field. The data they are collecting will be used to develop a user-friendly education software program. The final product will incorporate new modeling techniques, multimedia presentations, 3-D visualization tools, and a self-learning center that teachers and students ranging from elementary to higher education will find beneficial in and out of the classroom.

The project is a result of a prestigious, five-year $519,413 CAREER grant from the National Science Foundation (NSF), awarded to Dr. Chu at the beginning of 2007, which is titled "CAREER: Microtopography-Controlled Puddle-filling to Puddle-merging (P2P) Overland Flow Mechanism: Discontinuity, Variability, and Hierarchy." The NSF established the Faculty Early Career Development program in 1994 to recognize and reward efforts that integrate research and education, and foster a natural connection between the processes of learning and discovery. CAREER grants are reserved for those projects that "propose creative, integrative, and effective research and education plans, developed within the context of the mission, goals, and resources of their organization, and which will build a firm foundation for a lifetime of integrated contributions to research and education."

"Being awarded a CAREER grant is a great opportunity for us to develop important hydrological modeling approaches in an area not well defined or researched," says Dr. Chu. "It also enables us to create an exciting interactive, computer software program that will improve hydrology education in a variety of venues."

## Putting Numbers to Restoration

Over twenty years ago, the International Joint Commission designated over forty water bodies in the Great Lakes as Areas of Concern (AOC) due to negative impacts on these systems from past and current practices. Two of the AOCs are located right here in Muskegon County: Muskegon Lake and White Lake. In the last 20 years there has been a huge effort to curtail or eliminate harmful practices and initiate restoration efforts with an overall goal to remove these lakes from the AOC list and restore a healthier aquatic ecosystem. One of the major challenges in "de-listing" the lakes is determining when that end goal of a healthier system has been achieved.

"It's very difficult to set targets for delisting a lake when you don't know what the lake was like in its pristine state. How do you quantify when you've reached a point when the health of the lake has been restored? It's a huge problem in any restoration project," says Dr. Carl Ruetz, principal investigator at the Annis Water Resources Institute. "When do you know when enough is enough?"

This past year Dr. Ruetz has worked with faculty and staff in collaboration with the Muskegon Lake Watershed Partnership to set delisting targets for two beneficial use impairments, namely the degradation of fish population and the loss of fish habitat. The team is using annual fish-sampling records collected between 2004 and 2006 to set a multi-metric index, termed an index of biotic integrity, or IBI for short. The IBI gives a score or number that reflects the overall ecosystem health of the lake; a high score suggests better health, whereas a low score indicates degrading conditions or continual concerns.

The plants and animals that live in a body of water can give us the most information about the condition of the lake itself, its overall habitat and water quality. They also can reveal both episodic and cumulative distur-

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*Carl Ruetz and undergraduate student Betsy Shafer measuring and recording length of fish collected from Muskegon Lake.*

bances in the system, most often caused by humans. Once that information is collected and "scored," then decisions can be made about where and how to focus future restoration and preservation efforts.

Fish are obvious indicators of the health of a lake, and typical IBIs generated for fish include the number and kinds of species sampled, a focus on indicator species that are most sensitive to water quality and habit alterations, and groups of organisms that have similar feeding modes.

The team looked at six drowned river mouth lakes in the west Michigan area (Pentwater, Kalamazoo, Muskegon, White, Lincoln, and Pigeon Lakes) and determined an IBI score for each year that samples were collected. Results of the project show that Pentwater Lake consistently had the highest IBI score with Muskegon and White Lakes close behind. Kalamazoo and Pigeon Lakes tended to have the lowest IBI scores and the poorest ecosystem health among the lakes sampled. The next steps in the process are to set delisting targets and select monitoring sites for future sampling, which will help identify trends over time. The team proposes a three-year monitoring program to begin in 2009.

"The results we are seeing are good news for those who have invested both time and money in restoring Muskegon and White Lakes, which have had major negative impacts over the years," says Ruetz. "With IBI scores, we now have a way to measure whether those efforts are working, and we're able to set targets that will help determine when those lakes can be delisted. Of course, delisting a lake doesn't mean that we can then ignore what happens afterward. Rather, continued monitoring and assessment with IBIs will help decision makers choose the best possible course of action when it comes to restoring, protecting and improving the fisheries in these lakes. It is making a big difference."

## Brown Trout: Better with Diversity

With its high number of freshwater lakes, rivers, and streams either surrounding or within it, Michigan can certainly lay claim to its title as "water wonderland." Fishing is, of course, a great attraction, and hundreds of fishing enthusiasts, outfitted with fishing licenses and appropriate gear, flock to these lakes and rivers to hook a few.

Brown trout have been a popular game fish in Michigan ever since European settlers brought the species to America about 120 years ago. The fish is a naturalized, not a native species, and because of biological constraints, it hasn't taken over its natural environment, like some invasive species. In fact, as a game fish, brown trout is highly prized, which is one reason why Michigan's Department of Natural Resources (DNR) manages this fish so heavily.

Each year, the DNR replenishes the population of brown trout fish stock in many rivers and streams by introducing several thousand young fish that were raised in hatcheries. This process is labor intensive and often compromises critical fish characteristics, such as genetic composition and natural wildlife behaviors that may make the difference between a vibrant, healthy, abundant population versus an unhealthy one.

"Many hatchery programs may alter the natural ratio of males and females observed spawning in the wild because it is more efficient," comments Dr. Mark Luttenton, who has been collaborating with GVSU colleague Dr. Alex Nikitin and graduate students Todd Tiano and Shelby Johnson in the Department of Biology to identify key genetic markers and sequences in brown trout. "In a natural environment, each female spawns with two or three different males, ensuring that the next generation has genetic

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diversity. Genetic variation in a fish population as a whole is important because it allows for that species to be able to respond to changes in the natural system and still survive. Fisheries management needs to recognize how important genetic makeup is to the overall health and survival of the fish population in the wild."

In the past six years, the research team has defined and applied an efficient, practical method for identifying different genetic strains of brown trout in Michigan streams, using mitochondrial DNA and gene sequences. By examining a small tissue sample from approximately 50 fish, usually a tiny clipping from the fin, they can determine the strain of the trout and the variety of different strains in that stream with much less effort and cost than what is generally required. Typically, fishery managers fin clip thousands of fish before they are released into streams and then collect several hundred to visibly inspect the different clippings in order to track the strains and health of that particular fish population — a process that is time-consuming and costly.

The GVSU team continues to perfect the process and expand on the potential applications for this method. This past year, they were able to identify different forms of enzymes within different strains of brown trout, which raises interesting questions. Does one form of enzyme have some ecological advantage over another? Does one perform better under certain environmental conditions? Is one more efficient in energy production? In a hatchery program, what happens if one type of enzyme gets lost because of narrow breeding processes? How will that affect the fish population if environmental conditions change?

"We've only scratched the surface of what can be gained by using genetic information to identify different fish strains and help them survive and thrive in their natural environment," comments Dr. Luttenton. "Maintaining a viable recreational fish population through a successful management program gives a huge economic boost to the state because it generates tens of thousands of dollars. But we can also apply this knowledge to other areas, such as the survival of endangered species. The ramifications and potential benefits of this type of work are significant."

## Sinkholes: Underwater Wonder World

It's ideal material for a great sci-fi movie: a trip through an uncharted, mysterious territory filled with unknown creatures that live in an environment so different from our own.

Science fiction? Not so much fiction as real science in some aquatic areas of our world. Researchers have known and explored unusual ecosystem anomalies in marine vent ecosystems for quite some time, as captured in the IMAX film, Aliens of the Deep. Yet in the last few years, a similar phenomenon has been uncovered in certain hotspots of the Great Lakes. These habitats are what scientists refer to as Karst submerged sinkholes, and they have been the subject of intense investigation at the Annis Water Resources Institute.

AWRI research scientist Dr. Bopi Biddanda, in collaboration with researchers from NOAA's Great Lakes Environmental Research Laboratory, Thunder Bay National Marine Sanctuary, and the University of Wisconsin-Stout, has spent the last four years discovering and exploring these extraordinary environments and capturing details about the novel organisms and unique ecosystem processes of these submerged sinkholes.

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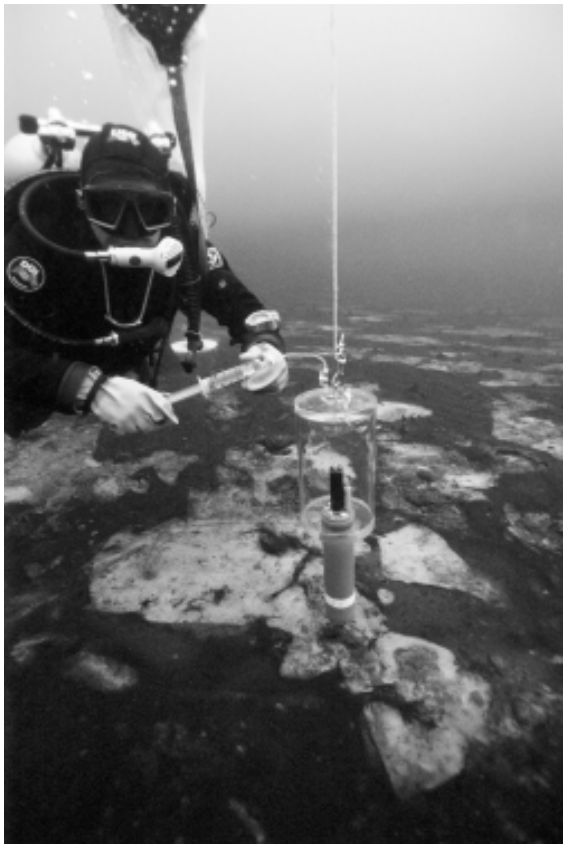

*Divers use syringes to collect samples from inside the chambers custom-developed by AWRI.*


*Scientists on Zodiac boats direct divers over the Middle Island sinkhole.*

Since 2001 when the first submerged sinkhole was discovered, the team has identified and is studying three sinkhole communities in the Thunder Bay National Marine Sanctuary, located in Lake Huron. They postulate that sinkholes were created when the ancient limestone bedrock of Lake Huron slowly dissolved, opening up passages or holes in the rock and allowing groundwater to vent into Lake Huron. The captured and now released groundwater could be thousands of years old and constitutes a suite of highly unusual microorganisms and a chemical composition radically different from the rest of the lake.

"The discovery of these remarkable ecosystems is quite exciting since no one has identified or investigated these submerged sinkholes in the Great Lakes," comments Dr. Biddanda, who refers to these sinkholes as the "coral reefs of the Great Lakes." "They are quite colorful and highly unusual in so many different aspects. It offers scientists, educators, and laypersons alike the opportunity to observe and explore a quite diverse habitat."

Based on data collected to date, a typical sinkhole exhibits unusual conditions, such as warmer water temperatures, higher conductivity, a different chemical composition, low or no dissolved oxygen, and a diverse microbial community that survives in a radically different environment compared to the surrounding fresh water. These organisms, especially the ones in the deepest of sinkholes where light cannot reach, obtain their energy via chemosynthesis (meaning they produce energy from chemicals), as opposed to via photosynthesis (from the sun), creating rare ecosystem processes that researchers can study.

In addition, the interaction between the sinkhole community and the freshwater habitat may create atypical visible occurrences, such as colorful benthic mats and nepheloid-like cloudy plumes, depending on the depth of the sinkhole and the composition of groundwater released. The results of their findings were printed in the September 2006 issue of Ecosystems, a highly prestigious scientific journal.

Submerged sinkholes represent a great find for the scientific community, yet the topic also offers exceptional learning opportunities for educators and students. This past year Dr. Biddanda conducted and participated in several workshops geared to elementary, middle, and high school educators, and other interested scientists and researchers. Dr. Biddanda and his team also created an educational CD and curriculum materials targeted to students in grades 5 through 12 that highlight and catalogue many of the unusual features of submerged sinkholes.

"With the materials we're producing, we hope to capture the imagination of students and teachers, who want to learn about this exciting and highly unusual phenomenon," comments Dr. Biddanda. "We want to open up conversations, to get people talking about what submerged sinkholes are and what they represent. It is a whole new world just waiting to be explored further. We have just touched on the potential opportunities and applications these unique environment could offer us in the future."

## Hands-on Learning Goes to the Heart

Amanda Callaghan tosses the beach ball to one of the girls in the circle. She catches it in midair, looks at where her right index finger is positioned on the ball, and announces, "water." Amanda records the response and asks the child to toss the ball to another girl, who does the same thing. Yet this time, the girl says, "land." As the "game" continues, a pattern begins to emerge. "Water" is clearly winning.

Odd game to play in the middle of November, but Amanda and the girls aren't really on the beach and "water" isn't really winning. The girls belong to the Michigan Pine & Dunes Girl Scouts, and they will spend the next few hours in the R.B. Annis Educational Foundation Classroom at the Lake Michigan Center, home of

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*Cherry Creek Elem. students participate in educational opportunities at LMC.*

AWRI, learning about aquatic systems.

Their teacher Amanda, an AWRI summer intern in 2006 and currently an educational assistant at the Institute, is their guide through a host of fun activities that will stimulate their imaginations and help them understand key concepts about our water world. The beach ball they toss back and forth looks like a globe, and the point of the exercise is to demonstrate that this world's surface area is covered largely by water — about 70%, she informs the group.

The Globe Toss is just one of five different activities that the girls will participate in during the afternoon. Through hands-on learning experiences this group of girls, who vary in age from 8 to 12 years old, will grasp many complicated concepts of aquatic systems, including water cycles, watersheds, point and nonpoint source pollution, invasive species, and water quality. They discover how these aquatic systems operate and what humans do to alter them.

"It's one thing to talk about how water flows or how we can negatively impact aquatic ecosystems. But it is a whole different matter when students actually see or experience these concepts for themselves," says Dr. Janet Vail, coordinator of AWRI's Water Resources Outreach and Education Program.

Throughout the year, the Institute will conduct classroom programs, tailoring their curriculum to provide a full range of educational opportunities. The R.B. Annis Educational Foundation Classroom is equipped like a K-12 science room — tables, microscopes, fish tanks, charts and graphs, and lots of specimens, both live and dead. The age-appropriate activities, which meet state standards, offer a stimulating, fun way of comprehending aquatic ecosystems and our relationship to them. Participants come away with not only a basic knowledge of our water world, but also an appreciation and respect for this delicately balanced system that is so much a part of their lives.

Classroom learning, such as what takes place at the Lake Michigan Center, is only one way the Institute reaches out to students and other community members. The Water Resources Outreach Education Program offers teacher education through Project WET (Water Education for Teachers), Michigan Environmental Education Curriculum Support units, and Global Learning and Observation to Benefit the Environment (GLOBE). Members of the staff are involved with many events such as water festivals, workshops, and onsite tours. In 2007, more than 6,300 individuals spent time onboard either the *D.J. Angus* or the *W.G. Jackson*, the Institute's research vessels, to conduct experiments and learn about what's happening to this precious natural resource that we often take for granted.

"The Institute has always been about reaching out to the community about issues and concerns that affect our water resources," comments Dr. Vail. "We hope that our teaching approach, with an emphasis on hands-on learning whether it is in the classroom, field, or on our vessels, fosters an understanding and inspires an appreciation of the aquatic environment."

*Amanda Callaghan (second from right) instructs Michigan Pine and Dunes Girl Scouts.*

## New Principal Investigator Fills Niche at AWRI

The Annis Water Resources Institute has always focused on a multi-disciplinary approach that relies on investigative teamwork and synergistic collaborations. With the addition of Dr. Ryan Thum to its staff, an aquatic ecologist with a specialization in molecular genetics, AWRI can now provide expertise in an essential area of aquatic research and education.

"I am interested in factors that form, maintain, and alter biological communities, particularly aquatic communities because they represent important natural resources that I value and that are threatened by what humans do to the environment," says Dr. Thum, who received his Ph.D. from Dartmouth College and recently served as a postdoctoral fellow at Cornell University and the University of Illinois. Thum integrates studies of historical biogeography, phylogeny, evolution, and ecology using diverse methods including molecular genetics, field and laboratory experiments, and multivariate statistics. "What I'm interested in and what the Institute offers in terms of research projects in protecting water resources seem to be a great fit. It's very satisfying to be here and to be part of this team."

Increasingly, Dr. Thum's work has gravitated toward studying and identifying aquatic invasive species. As he explains, we can take appropriate action to control or eradicate invasive species only when we can recognize them.

But it's not so easy to identify some species correctly. For example, water milfoils in the genus *Myriophyllum* contain both native and invasive species. The plants are similar in many aspects, yet misidentification can cause a host of problems. If not recognized and dealt with at an early stage, invasive species can grow out of control and take over an aquatic environment.

On the other hand, if a harmless species is misidentified and treated as an invasive species, money spent on control methods is wasted. Plus, eliminating the plant may just facilitate the growth of an actual invasive species that was vying for the same resources.

*Dr. Ryan Thum*

The identification of aquatic plants through molecular ecology using sophisticated genetic tools can be quicker and more accurate than other methods, thus saving critical resources and protecting the natural aquatic environment. This type of work is becoming increasingly important as biologists recognize that much of the planet's biodiversity is not readily identifiable on the basis of morphology alone (i.e., lots of species are "cryptic") and natural evolutionary changes make proper identification even more difficult.

"Much of my work is in the laboratory and in front of my computer, looking at charts and interpreting DNA sequences. It has a very practical application, especially as living organisms continue to evolve," comments Thum. "Using molecular genetic tools is and will be very much a part of how we deal with protecting and preserving our natural resources."

# AWRI Faculty and Staff Highlights for 2007

## Ecological Research Group

### Dr. Bopi Biddanda (biddandb@gvsu.edu)

• Collaborative Research: Explored submerged sinkhole ecosystems in Lake Huron with NSF funding. Students presented findings at undergraduate and graduate symposia.

• Collaborative Research: Continued long-term collaborative work on pelagic metabolism in Lake Michigan using NOAA ship time. Two manuscripts are in press in the following journals: Limnology and Oceanography, Journal of Great Lakes Research.

• Research: Completed fifth year of AWRI's long-term environmental study of Muskegon Lake.

• Research: Participated in the Muskegon River watershed and Non-point source pollution impact study.

• Student Projects: Student projects studied the fate of land carbon in a West Michigan watershed, contributions of nutrients and carbon from four major West Michigan rivers to Lake Michigan, and the significance of microbial production at submerged sinkholes to surrounding lake (Huron) food webs.

• Education and Outreach: Prepared, presented and distributed an Education and Outreach CD emphasizing the educational and outreach components to teachers, researchers and the public on the NSF underwater research project in Lake Huron through seminars and teacher workshops.

• Service: AWRI Seminar Committee and College of Liberal Arts and Sciences Staff Advisory Council.

• Service: Editorial Boards of Journal of Plankton Research and Aquatic Microbial Ecology.

## Dr. Michael Chu (chux@gvsu.edu)

• Received a 5-year NSF CAREER grant and conducted modeling and experimental studies on microtopography-controlled puddle-filling to puddle-merging (P2P) overland flow.

• Set up a new Overland Flow Laboratory (OFL). Funded by NSF.

• Initiated the study of surface runoff from US31/Seaway on Little Black Creek. Funded by U.S. DOT.

• Completed the hydrologic modeling for the Tamarack Creek Watershed. Funded by MDEQ.

• Completed hydrologic monitoring studies in Bear Creek. Funded by U.S. EPA.

• Served on the U.S. EPA FIFRA Scientific Advisory Panel and attended the panel meeting.

• Member of ASCE-EWRI Surface Water Hydrology Committee

## Dr. Mark Luttenton (luttentm@gvsu.edu)

• Continued biological monitoring and assessment of the Henry's Fork River, Idaho. Funded by the Henry's Fork Foundation

• Continued collaboration with Dr. Alex Nikitin (GVSU) to examine the genetic identity of Michigan brown trout.

• Completed the nutrient loading study of White Lake. Funded by MDEQ.

• Began working on the ecology of the Asian clam in the Grand River near Lansing, Michigan.

• Chair of the GVSU Graduate Council

## Dr. Rick Rediske (redisker@gvsu.edu)

• Evaluated sources of nutrient loading in the Bear Lake watershed. The investigation involved stream and lake surveys, hydrological modeling, and land use change analyses. Funded by U.S. EPA Region V.

• Investigated the ability of *Cladophora* to concentrate *E. coli* and microcystins in the nearshrore environment of Saginaw Bay and Grand Traverse Bay. Northern Michigan College is a partner in the project. Funded by MDEQ.

• Completed work on the Federal Advisory Committee for Detection and Quantitation (FACDQ). The FACDQ met in 2006 and 2007 to develop a new procedure to determine analytical detection and quantitation limits for Clean Water Act Programs. A new procedure was recommended for adoption by U.S. EPA along with guidance for implementation and regulatory uses. http://www.epa.gov/waterscience/methods/det/faca.

• Continued research on fish contaminants and cyanobacteria toxins for grants with MDEQ, NOAA, and University of Michigan.

• Analyzed over 1,100 water samples for *E. coli* as part of Great Lakes beach monitoring programs for the Muskegon County and District 10 (Oceana, Mason, and Manistee Counties) Health Departments.

## Dr. Carl Ruetz (ruetzc@gvsu.edu)

• 4 peer-reviewed articles published or in press.

• 9 technical presentations (most co-authored with students).

• Continued long-term monitoring of fish populations in Muskegon Lake. Funded by Muskegon Lake Research Fund.

• Worked to set delisting targets for fish habitat and population beneficial use impairments for Muskegon and White lake AOCs. Funded by GLNPO and National Fish & Wildlife Foundation.

• Mentored three graduate students completing thesis research and one undergraduate conducting a summer research project.

• Served as President-Elect of the Michigan Chapter of the American Fisheries Society.

• Received an Outstanding Faculty Mentor Award from the Graduate and Professional Student Organization at GVSU.

## Dr. Alan Steinman (steinmaa@gvsu.edu)

• 6 new grants funded as PI or co-PI (~$580,000); 7 continuing grants as PI or co-PI (~$1,000,000).

• 7 peer-reviewed articles published or in press; 4 technical reports.

• 34 presentations: 4 invited [technical]; 11 contributed [technical]; 19 invited [community service].

• Member of MI Groundwater Conservation Advisory Council.

• Member of International Joint Commission's Upper Great Lakes Study Public Interest Advisory Group.

• External reviewer (site visit) for a new M.S. in Natural Science program at SUNY Plattsburgh.

• Member of US EPA's Science Advisory Board for review of 2007 Report on the Environment.

• Organizer of Plenary Session (Freshwater Conservation: Science and Engagement) at Annual Meeting of the North American Benthological Society, Columbia, SC.

• Editorial Board of Journal of the North American Benthological Society.

• Steering committee member for Workshop on Pathogens in Michigan's water.

• Member of Muskegon Rotary Board of Directors, Institutional Review Board at Hackley Hospital, One Muskegon Committee, and Green Infrastructure Leadership Council.

• Co-organizer of Muskegon Café Scientifique.

### Dr. Don Uzarski and Matt Cooper (coopmat@gvsu.edu)

• 6 papers published in peer-reviewed journals in 2007 (Uzarski, Cooper, students).

• 7 presentations at national and international conferences in 2007 (Uzarski, Cooper, and students)

• Served on the Project Management Team (PMT) of the Great Lakes Coastal Wetlands Consortium made up of 150 Great Lakes scientists, managers, and NGOs (Uzarski).

• Co-Chair of the Great Lakes Coastal Wetland Consortium Science Committee (Uzarski).

• Member of Association of State Wetland Managers (ASWM) Regional Advisory Committee and the MDEQ Michigan Wetland Rapid Assessment Development Committee (Uzarski).

• Editorial Board of the Canadian Journal of Pure and Applied Sciences (Cooper).

## Information Services Center (ISC)

### John Koches (kochesj@gvsu.edu) and ISC Staff

• Completed land use and cover inventory and hydrologic analysis for Bear Lake Watershed Project. Funded by U.S. EPA.

• Completed land use inventory for Jordan Lake. Funded by Jordan Lake Improvement Association.

• Completed Phase II Zoning Implementation Project in the White River Watershed. Funded by the Fremont Area Community Foundation.

• Completed "Modeling the Future of Zeeland Township" Project. Funded by the Macatawa Area Coordinating Council.

• Completed the Muskegon River Transition/Implementation 1 Project, which included preparation of a hydrology report for the headwaters of the Tamarack Creek Subwatershed, established a conservation easement along waterways in the Tamarack Creek Subwatershed, and installed a rain garden to handle storm water runoff from the Village of McBain High School parking lot. Funded by MDEQ/U.S. EPA.

• Finalized web tool and GIS analysis for Economic Valuation Green Infrastructure Project. Funded by People and Land, Kellogg Foundation.

• Developed Environmental Indicators for the West Michigan Strategic Alliance Regional Indicators Project. Funded by The Grand Rapids Foundation, Steelcase Foundation, and others.

• Assisted in the organization of the Muskegon Area Sustainability Coalition and the creation of the first "Prosperity Index" for Muskegon County as part of the Muskegon Area Sustainability Coalition.

• Hosted the Remote Sensing Event – "Mars" for the Michigan's Regional Science Olympiad.

• Constructed two stormwater bioretention (rain garden) BMP's at sites in Marne for the Sand Creek CMI Project. Funded by MDEQ.

• Completed streambank erosion and in-stream BMP's at sites in Marne for the Sand Creek CMI Project. Funded by MDEQ.

• Continued to support the Muskegon River Watershed Mega Model Project. Funded by the Great Lakes Fishery Trust.

• Continued work on the Muskegon River Watershed Education Project. Funded by MDEQ, the Wege Foundation, and the Muskegon River Watershed Assembly Board.

• Continued support for the Grand River Watershed Project including website development and Information/Education programming.

• Began work on the "Critical Lands Mapping Project". Funded by The Fremont Area Community Foundation – Ice Mountain Stewardship Program.

• Began work on the Lower Grand River Watershed Wetland Initiative. Funded by U.S. EPA.

• Began land use inventory, hydrologic analysis, and population modeling for the Spring Lake Stormwater Project. Funded by Michigan Sea Grant.

• Began update of the Rogue River Watershed Management Plan to meet the EPA nine criteria. Funded by MDEQ/U.S. EPA.

• Began preparation of the White River Watershed Management Plan. Funded by MDEQ.

## Outreach and Education Initiatives

### Janet Vail (vailj@gvsu.edu) and Science Instructors

• Provided educational opportunities for over 6,300 people on the *D.J. Angus* and the *W.G. Jackson* research and education vessels.

• Facilitated activities for over 1,500 students and others in the LMC's Education Classroom. Supported by the R.B. Annis Educational Foundation Outreach Program Endowment.

• Presented educational cruises in Milwaukee, Wisconsin and Waukegan, Illinois as part of the Making Lake Michigan Great Tour of the *W.G. Jackson*. Funded by the U.S. EPA Great Lakes National Program Office.

• Provided a special series of educational cruises for the general public on the *D.J. Angus*. Funded by the Grand Haven Area Community Foundation through its Youth Advisory Council.

• Hosted a special open house with the Grand Haven Loutit Library at the new *D.J. Angus* dock.

• Conducted educator training at the Global Change Workshop at Michigan Tech, the Michigan Science Teachers Association conference, and the National Science Teachers Association conference.

• Participated in a salmon release day for a local school, career fairs, and reverse job shadow events.

• Partnered with GVSU Regional Math & Science Center for GLOBE and other workshops.

• Helped facilitate Michigan Project WET water festivals reaching almost 1,000 people, and trained new facilitators for Michigan Project WET. Funded by Nestle Waters and Project WET, USA.

• Continued work on the Chemical Management in Schools project. Funded by the Michigan Department of Environmental Quality.

• Organized the 12th Annual Hazardous Waste Management Workshop in partnership with MDEQ and the West Michigan Chapter of the Air & Waste Management Association.

• Co-chair of the U.S. EPA Lake Michigan Forum, Board of Directors of the Michigan Alliance for Outdoor and Environmental Education, Air & Waste Management Association West Michigan Chapter, and Great Lakes Association of Science Ships. Member of GVSU Grant Leadership Advisory Team, Environmental Studies Minor Development Team, and Center for Excellence in Science and Mathematics Education and the Regional Math and Science Center Advisory Boards (Dr. Vail).

## Peer-Reviewed Publications (AWRI staff in bold)


**Biddanda, B., A. Steinman, L. Nemeth, R. Rediske, Y. Hong and S. Kendall**. 2008. Nutrient bioassays of plankton biomass and metabolism in an urbanized drowned river-mouth lake, Mona Lake, Michigan. Journal of Freshwater Ecology 23:41-53.

Johengen, T. H., **B. A. Biddanda** and J. B. Cotner. In Press. Stimulation of Lake Michigan plankton metabolism by sediment resuspension and river runoff. Journal of Great Lakes Research.

Kerfoot, C. R., J. W. Budd, S. Green, J. B. Cotner, **B. A. Biddanda** and D. J. Schwab. In Press. Doughnut in the desert: late-winter production in southern Lake Michigan. Limnology and Oceanography.

**Chu, X.** and M. A. Marino. 2007. IPTM-CS: A windows-based integrated pesticide transport model for a canopy-soil system. Environmental Modeling & Software 22:1316-1327.

**Chu, X.** and Marino, M. 2007. Space and time issues in comparison and evaluation of different pesticide transport models in the vadose zone, p. 1-9. In: Restoring our Natural Habitat. (Ed. Karen C. Kabbes). American Society of Civil Engineers.

**Gajewski, B.** 2007. "Meredith Rouse Davis: Environmental Public Relations Practitioner", p 123. In: Contemporary Legends of Public Relations. (Eds. Betty J. Pritchard, APR and John D. Stipe and Assistant Editor Maggie Porter). Grand Valley State University.

**Hrodey, P. J.**, and T. M. Sutton. In Press. Fish community responses to half-log additions in warmwater streams. North American Journal of Fisheries Management.

Hendricks, S. and **M. R. Luttenton**. 2007. Benthic algae taxa (exclusive of diatoms) of the Little River Basin, Western Kentucky, 2000-2003. Journal of the Kentucky Academy of Science 68:31-36.

Wiley, M. J., B. C. Pijanowski, R. J. Stevenson, P. Seelbach, P. Richards, C. M. Rinseng, D. W. Hyndman, **J. K. Koches**. 2008. Integrated Modeling of the Muskegon River, p. 247-258. In: (Ed. Wei Ji) Wetland and Water Resource Modeling and Assessment: A Watershed Perspective. CRC Press.

**Cookingham, M. G. and C. R. Ruetz III**. In Press. Evaluating passive integrated transponder tags for tracking movement of round gobies. Ecology of Freshwater Fish.

**Cooper, M. J., C. R. Ruetz III, D. G. Uzarski**, and T. M. Burton. 2007. Distribution of round gobies in coastal areas of Lake Michigan: Are wetlands resistant to invasion? Journal of Great Lakes Research 33:303-313.

**Ruetz, C. R., D. G. Uzarski**, D. M. Krueger, and E. S. Rutherford. 2007. Sampling a littoral fish assemblage: Comparison of small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825-831.

**Steinman, A. D., B. Biddanda, X. Chu, K. Thompson, and R. Rediske**. 2007. Environmental analysis of groundwater in Mecosta County, Michigan. Environmental Monitoring and Assessment 134:177-189.

**Steinman, A. D., X. Chu, and M. Ogdahl**. In Press. Spatial and temporal variability of internal and external phosphorus loads in Mona Lake, Michigan. Aquatic Ecology.

**Steinman, A. D. and M. Ogdahl**. 2008. Ecological effects following an alum treatment in Spring Lake, Michigan. Journal of Environmental Quality 37:22-29.

**Steinman, A. D., M. Ogdahl, R. Rediske, C. R. Ruetz III, B. A. Biddanda, and L. Nemeth**. 2008. Current status and trends in Muskegon Lake, Michigan. Journal of Great Lakes Research 34:169-188.

Swain, H., P. J. Bohlen, K. L. Campbell, L. O. Lollis, and **A.D. Steinman**. 2007. Integrated ecological and economic analysis of ranch management systems: an example from south central Florida. Rangeland Ecology and Management 60:1-11.

Bhagat, Y. J. J. H. Ciborowski, L. B. Johnson, T. M. Burton, **D. G. Uzarski**, S. A. Timmermans and **M. Cooper**. 2007. Testing a fish index of biotic integrity for Great Lakes coastal wetlands: stratification by plant zones. Journal of Great Lakes Research 33: 224-235

Burton, T. M. and **D. G. Uzarski** In Press. Freshwater marshes-non-forested wetlands. In: (Ed. G. Likens) Encyclopedia of Inland Waters. Elsevier Science.

Burton, T. M.and **D. G. Uzarski**. In Press. Lake Huron's ignored wetlands: biodiversity and bioassessment of protected coastal wetlands. Aquatic Ecosystem Health and Management.

**Cooper, M. J., D. G. Uzarski**, and T. M. Burton. In Press. Benthic invertebrate fauna, wetland ecosystems. In: (Ed. G. Likens) Encyclopedia of Inland Waters. Elsevier Science.

**Cooper, M. J., D. G. Uzarski**, and T. M. Burton. 2007. Macroinvertebrate community composition in relation to anthropogenic disturbance, vegetation, and organic sediment depth in four Lake Michigan drowned river-mouth wetlands. Wetlands 27 (4): 894-903.

Stevenson R. J., M. J. Wiley, S. H. Gage, V. L. Lougheed, C. M. Riseng, P. Bonnell, T. M. Burton, R. A.Hough, D. W. Hyndman, **J. K. Koches**, D. T. Long, B. C. Pijanowski, J.Qi, **A. D. Steinman, and D. G. Uzarski**. 2008. Watershed science: essential, complex, multidisciplinary and collaboratory, p. 231-245 In: (Ed. Wei Ji) Wetland and Water Resource Modeling and Assessment: A Watershed Perspective. CRC Press.

**Uzarski, D. G.** In Press. Wetlands of large lakes. In: (Ed. G. Likens) Encyclopedia of Inland Waters. Elsevier Science.

**Uzarski, D. G., A. T. Bosch, M. J. Cooper** and T. M. Burton. In Press. Wetland ecology and management for fish, amphibians and reptiles. In: (Ed. G. Likens) Encyclopedia of Inland Waters. Elsevier Science.

**Uzarski, D. G.**, T. M. Burton, Kolar, R. E. and **M. J. Cooper**. In Press. Lake Huron's coastal wetlands under fire: science vs. politics? Aquatic Ecosystem Health and Management.

## Technical Reports & Manuals 2007

**De Mol, N.** 2007. Update to the Muskegon River Watershed management plan – implementation tasks and evaluation. 2007 Addendum to MR-2002-4.

Nobes, G. and **N. De Mol**. 2007. Muskegon River Transition/Implementation 1 final report.

**Denning, R.** 2007. Sand Creek Watershed CMI project Cole Park improvements final report. TM-2007-23.

**Hanson, B.** 2007. Modeling the future of Zeeland Township. Atlas. MR-2007-5.

**Hanson, B.** 2007. Upper Tamarack Creek Watershed hydrologic study. TM-2007-11.

MacDonald, N., **R. R. Rediske, and B. Scull.** 2007. Monitoring soil solution, soil chemistry, and vegetation responses to municipal solid waste leachate applications at the Fenske landfill. 2006 monitoring report. MR-2007-1.

**Luttenton, M., R. R. Rediske, and A. D. Steinman.** 2007. White Lake water quality assessment, final report. MR-2007-2.

**Rediske, R. R., A. D. Steinman, X. Chu, B. Scull, M. Ogdahl, K. Thompson.** 2007. Bear Lake nutrient study. MR-2007-3.

**Rediske, R. R., J. Hagar, Y. Hong, J. O'Keefe, and A. D. Steinman**. 2007. Assessment of Cyanobacteria and associated toxins in west Michigan Lakes. MR-2007-4

**Rediske, R. R.** 2007. Development of numerical targets for the delisting of beneficial use impairment in the Muskegon Lake and White Lake areas of concern. TM-2007-4.

**Steinman, A.D., M. Ogdahl, C. Ruetz III**. 2007. An environmental assessment of Little Black Lake.

## 2007 AWRI Staff

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Heidi Feldpausch, Office Coordinator
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Dan McCormick, Captain DJA
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Jim Rahe, Deckhand WGJ
George Thibault, Deckhand DJA
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Matt Cooper, EPA STAR Grant Fellowship
Janel Hagar, AWRI Assistantship
Jessica Higgins, AWRI Assistantship
Kelli Johnson, AWRI Assistantship
William Keiper, AWRI Assistantship
Kristin Nelson, AWRI Assistantship
Thomas (Garry) Sanders, AWRI Assistantship
Michael Shoemaker, AWRI Assistantship
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Beth Walker

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Brent Kasza
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Gary Lamberti, University of Notre Dame
Peter Meier, University of Michigan (emeritus)
Don Scavia, University of Michigan, MI Sea Grant

AWRI provides opportunities for students to pursue their interests in our environment. The following students received internships during 2007.

*D. J. Angus-Scientech Educational Foundation Interns:*
Michael Baker
Joe DeVol
Jonathan Putney
Matthew Tardiff

*Herbert VanderMey Intern:*
Brent Kasza

*Allen Hunting Intern:*
Jonathan VanderMolen

*Air & Waste Management Intern:*
Amanda Callaghan

*Summer Student Scholars*
Matt Altenritter

*Bill and Diane Wipperfurth Scholarship*
Matt Altenritter

* currently at Central Michigan University
** deceased

For more information about AWRI's programs, please call us at (616)331-3749 or (231)728-3601, fax us at (616) 331-3864, contact us through the internet at http://www.gvsu.edu/wri/, or write us at Annis Water Resources Institute, Lake Michigan Center, 740 W. Shoreline Drive, Muskegon, MI 49441.

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