Cedar Lake – A Lesson in Persistence

David Bucaro

As we all know, lake management is not for the faint of heart. It can be a long, drawn-out process of lengthy planning and consensus-building, fundraising, and finally, implementation. Results, as demonstrated by visible lake improvements, may take many more years. Plans often change or require regular updating. This is a story about one small lake community that has worked for over 40 years to improve the condition of their lake. After many small successes, they are on the verge of the "Big One."

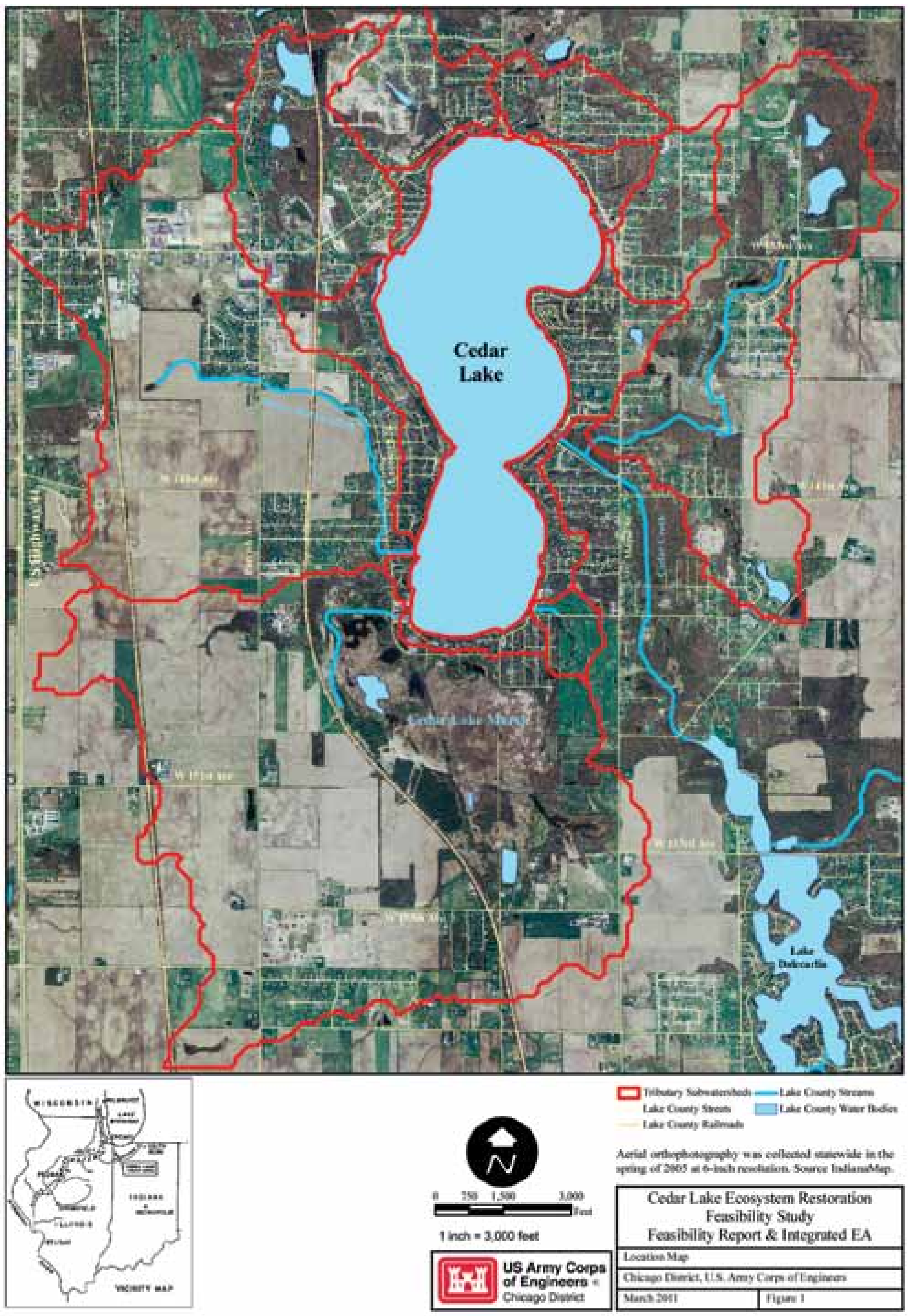

Figure 1. Location Map of Cedar Lake, Indiana.

Background

Cedar Lake is a 781-acre kettle lake located in northwest Indiana, just 18 miles south of the shores of Lake Michigan (Figure 1). The lake is shallow with a maximum depth of only 14 feet and a mean depth of 7.9 feet. Cedar Lake's watershed is small (4,800 acres), largely because the north-south Continental Drainage Divide lies immediately to the north of the lake. Thirty-six percent of the watershed is in agricultural use. The Town of Cedar Lake and adjoining residential areas make up 31 percent of the watershed.

The "Lake of the Red Cedars" was impacted by humans as early as the early 1870s when ditches were cut to lower the lake to better drain local farmlands. The Indiana Commission of Fisheries began stocking the lake with black bass and northern pike as early as 1905. With the establishment of a railway in the 1870s, Cedar Lake rapidly became a popular resort area, with many vacationers arriving via rail from Chicago. The resident local population in 1950 was estimated as 3,900 but as many as 25,000 tourists would visit the lake on a typical summer day. By 1960 the permanent population had grown to over 5,700. All of the residences had on-site sewage septic systems and raw or inadequately treated sewage entering the lake was a common problem, resulting in disagreeable algal blooms and high fecal coliform bacteria counts. Sanitary sewer lines were installed around the lake and in the town in 1972 but infiltration and other problems caused untreated sewage to enter the lake for many years following.

Previous Studies

At the urging of local residents, the Indiana Legislature appropriated funds in 1979 for a comprehensive study to diagnose Cedar Lake's water quality problems. This study and another in 1982 funded by the U.S. Environmental Protection Agency (USEPA) Clean Lakes Program were both undertaken by the Indiana University School of Public and Environmental Affairs (Echelberger and Jones 1984). This effort found that:

- Cedar Lake has a meromictic circulation – no permanent thermal stratification was detected. A long fetch of 2.1 miles and shallow water depths keep the lake well-mixed by prevailing winds.
- Sediment accumulation exceeded 17 feet from the original glacial bottom. Surficial sediments were enriched with organic matter, phosphorus, lead and zinc. The latter two were likely airshed effects of the steel industry along Lake Michigan.
- Brief periods of calm, even as short as overnight, allow the bottom waters to go anoxic due to high BOD and nutrient enrichment of the surficial sediments. This allows temporary internal phosphorus release that mixes throughout the water column when winds and recreational boat traffic resume.
- Modeling and direct measure determined that areal internal phosphorus loading rates were as high as 2.0 g/m^2-yr (86 percent of total areal phosphorus loading).
- Total phosphorus concentrations in the water exceeded 300 µg/L; 60 percent were in soluble form. Ammonia-nitrogen concentrations exceeded 1.8 mg/L. Chlorophyll-*a* concentrations exceeded 130 µg/L.

This study recommended a remediation plan that included watershed management, an in-lake alum treatment, and a complete fisheries renovation. Dredging for nutrient control was not recommended because tests demonstrated that although removing enriched surficial sediments would reduce internal phosphorus loading, the lake would continue to be highly eutrophic due to residual internal phosphorus release and watershed loadings. The recommendations in the completed Phase I Report could not be implemented due to lack of local, state, and federal funds.

A 1991 study funded by the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program focused on diagnosing specific watershed sources and identifying solutions (Jones and Marnatti 1991). Recommendations included agricultural and urban BMPs, correction of sewer system surging and overflows, wetlands enhancements, rerouting a previously diverted inlet back into the lake, repairs to the lake's outlet control structure, and a carp management program.

A 2001 Section 319 watershed study (Harza 1998) focused on identifying specific sources of non-point source pollution in the five subwatersheds draining into Cedar Lake. This study identified priority watersheds to focus remediation efforts on. Remediation recommended included constructed wetlands for NPS control, streambank stabilization, agricultural BMPs, and golf course nutrient management among others.

Local Efforts

State and federal resources, along with limited local monies, have funded these many studies to characterize the lake and diagnose its problems. However, funds to implement study recommendations have been in hard to come by. In the meantime, local efforts have undertaken a number of ambitious projects to improve the lake and its environs.

In addition to making significant improvements to the sanitary sewer system to prevent surcharges to the lake, the Town of Cedar Lake completed a comprehensive plan in 2007 that outlines a long-term plan for controlled development within the lake's watershed. The Town also passed stormwater management and zoning ordinances along with a stormwater user fee to address non-point source sediment and nutrient inputs to the lake. Through these efforts watershed loadings have continued to dramatically decline.

The Cedar Lake Enhancement Association is a non-profit grass roots organization with the goal of making Cedar Lake a more valuable resource and has been a long standing advocate for ecosystem restoration within the watershed. Over the past three decades, they have implemented a number of projects through locally-raised money and an aggressive and constant pursuit of state and federal restoration grants. Projects implemented include bank erosion protection (wetland creation, enhancements and plantings), inlet channel stabilization, and lakeshore or streambank stabilization, all of which have reduced watershed loadings and improved conditions within the Lake and its tributaries.

Current Feasibility Study

In 2002, the Cedar Lake Enhancement Association partnered with the U.S. Army Corps of Engineers, Chicago District to evaluate opportunities to restore the aquatic ecosystem of Cedar Lake. Based upon the significance of the resource, the Corps identified a federal interest in conducting a comprehensive feasibility study to address ecosystem degradation within the lake (USACE 2002).

The overall problem within Cedar Lake is the holistic decrease in biodiversity due to a history of dramatic manipulations to functional processes and physical habitat structure. Cedar Lake is a vulnerable system due to its small drainage area and its natural condition as an oligotrophic lake. These factors limit natural processes from repairing past damages to physical and chemical components. The lake efficiently traps watershed inflows that contain sediment and nutrient loads that are both physically and chemically unsuitable to the natural system. The result is an ecosystem that exhibits a host of problems including the absence of suitable substrates for aquatic macrophytes, macroinvertebrates, and fishes; absence of submerged aquatic macrophyte beds and emergent marshes within the littoral zone; absence of a functioning native glacial lake fish assemblage; and overall physical and chemical impairments that allow for nonnative invasive species including algae to dominate.

Even though several studies had been conducted on Cedar Lake, the mechanisms causing nutrient recycling were not entirely understood. Additional detailed studies were performed in order to establish baseline conditions for restoration. In partnership with Sandia National Laboratories, a three-dimensional hydrodynamic, sediment transport, and water quality EFDC model was developed of the lake with the goal of accurately reflecting how boundary-condition perturbations affect sediment resuspension, water quality, and overall lake health (Figure 2). A significant amount of field work was done that fed the modeling analyses, which included a new bathymetric survey, sediment core and grab sampling to determine physical and chemical characteristics (Figure 3), measuring potential sediment erodibility using a portable ASSET flume (Figure 4), biological sampling, and conducting long-term water quality sampling (Figure 5).

The model illustrates the strong correlation between sediment phosphorus concentrations, algal concentrations, dissolved oxygen, and ecosystem health, which reinforces the identification of phosphorous as the nutrient of concern in the Cedar Lake system. Internal phosphorus loadings were determined to account for nearly 90 percent of the total annual loading followed by 9 percent from the watershed and 1 percent from atmospheric deposition (James 2007). Internal phosphorus loadings are due to advection-diffusion from the bed and sediment resuspension from both wind and boat induced waves. The Carlson Trophic State Index was used as an indicator of ecosystem health, which varied over the year with a maximum reaching 76 in the late summer corresponding to hypereutrophic conditions. Over most of the year the lake displays either eutrophic or hypereutrophic conditions. Available sediment phosphorus in the surficial sediments was measured as much as 200 mg/kg. Many of the sediment samples collected had a thick (up to several inches) coating of algae growing on them (Figure 6). There was a distinct gradient of algae from the north basin to the south basin, with the greatest growths observed in the south basin, which coincides with the prevailing wind direction to the south. Microscopic analysis revealed the algae present in the overlain sediments to be mainly cyanobacteria, which are associated with water column blooms (specifically, *Microcystis* and *Planktolyngbya*), not the expected benthic growths that should be present. After the algal layer was removed (Figure 7), sediments were shown to be very light and lumpy in most cases, having the appearance of cottage cheese, which are easily resuspended.

Through these detailed modeling and field analyses a clear restoration strategy for Cedar Lake was established to include addressing the internal nutrient recycling, further reducing watershed loadings, and restoring the physical aquatic habitat. Several restoration plans were formulated

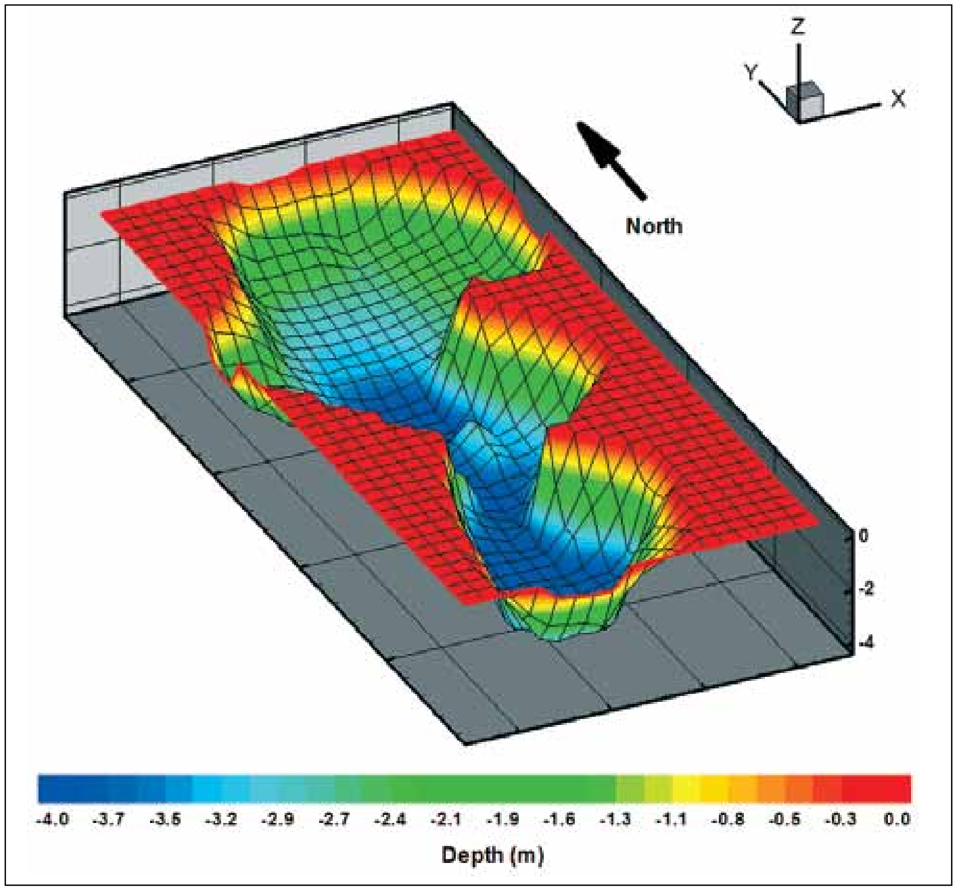

Figure 2. 3-D Environmental Fluid Dynamics Code (EFDC) Model developed by Sandia National Laboratories (SNL).

Figure 3. Sediment core sampling taken 7/13/2005; pictured are Dirk O'Daniel, SNL and David Bucaro, USACE.

Figure 4. Sediment erodibility testing using a Mobile Adjustable Shear Stress Erosion and Transport (ASSET) Flume taken 7/13/2005. Pictured is Jesse Roberts, SNL.

Figure 5. Deploying a YSI Water Quality Sonde in the lake taken 7/13/2005. Pictured is Casey Pittman, USACE.

to address ecosystem degradation of the lake. Specific habitat types targeted for restoration are fringe marsh, shallow and deep littoral zones, and the bathypelagic zone in order to improve biodiversity. Alternatives were derived from several restoration measures including sediment removal, nutrient inactivation, dilution and flushing, creation of in-lake structures, littoral vegetation restoration, fish community management, and institutional controls. All plans were evaluated for completeness, effectiveness, efficiency, and acceptability. A habitat suitability index was developed to estimate the benefits of each plan on biological function and habitat structure within the laucustrine ecosystem. A total of 396 alternative plans were formulated based upon 14 restoration measures. A cost-effective and incremental cost analysis was performed on the suite of plans and determined there were nine “best buy” plans that would provide the greatest increase in output for the least increase in costs. From these plans that have the lowest incremental costs per unit of output, a single plan was identified as the National Ecosystem Restoration (NER) Plan that most efficiently achieves the restoration goals for Cedar Lake and could be Federally supported.

Recommendations of the Ecosystem Restoration Management Plan

The recommended NER plan (Figure 8) includes a combination of six restoration measures that address both the functional and structural ecosystem impairments existing at Cedar Lake:

Figure 6. Algal coating taken from the surface of bed sediments; taken 4/01/2008.

- Sediment Removal – Mechanical dredging of 140,000 yd^3 of the highest phosphorus-concentrated sediments and algal layers in the south basin. Material would be slurried using recycled effluent and hydraulically pumped 8,000 feet to a 96-acre sediment dewatering facility that encompasses containment dikes, storage and clarification cells and a temporary treatment facility. Upon completion, the placement site would be developed for recreational use including ball fields.
- Nutrient Inactivation – Treating 400 acres across the lake with aluminum sulfate (alum) with spatially varying dosages in order to target residual

Figure 7. Cedar lake sediments after algal coating removed; taken 4/1/2008.

available sediment phosphorus concentrations to less than 20 mg/kg.

- Dilution and Flushing – Reconnect Founders Creek back to its historic connection to Cedar Lake by rerouting 1,400 feet of the channel and creating a 100-foot riparian stream corridor.
- Littoral Macrophyte Restoration – Restore 35 acres of emergent and 95 acres of submergent aquatic vegetation along the shoreline of the lake with depths up to 4 feet.
- Fish Community Management – Renovate the fish community through a single treatment of Rotenone and the introduction of predatory and native glacial lacustrine fish species.
- Institutional Controls – Increase no wake zones along the perimeter of the lake from 200 to 400 feet and place additional marker buoys.

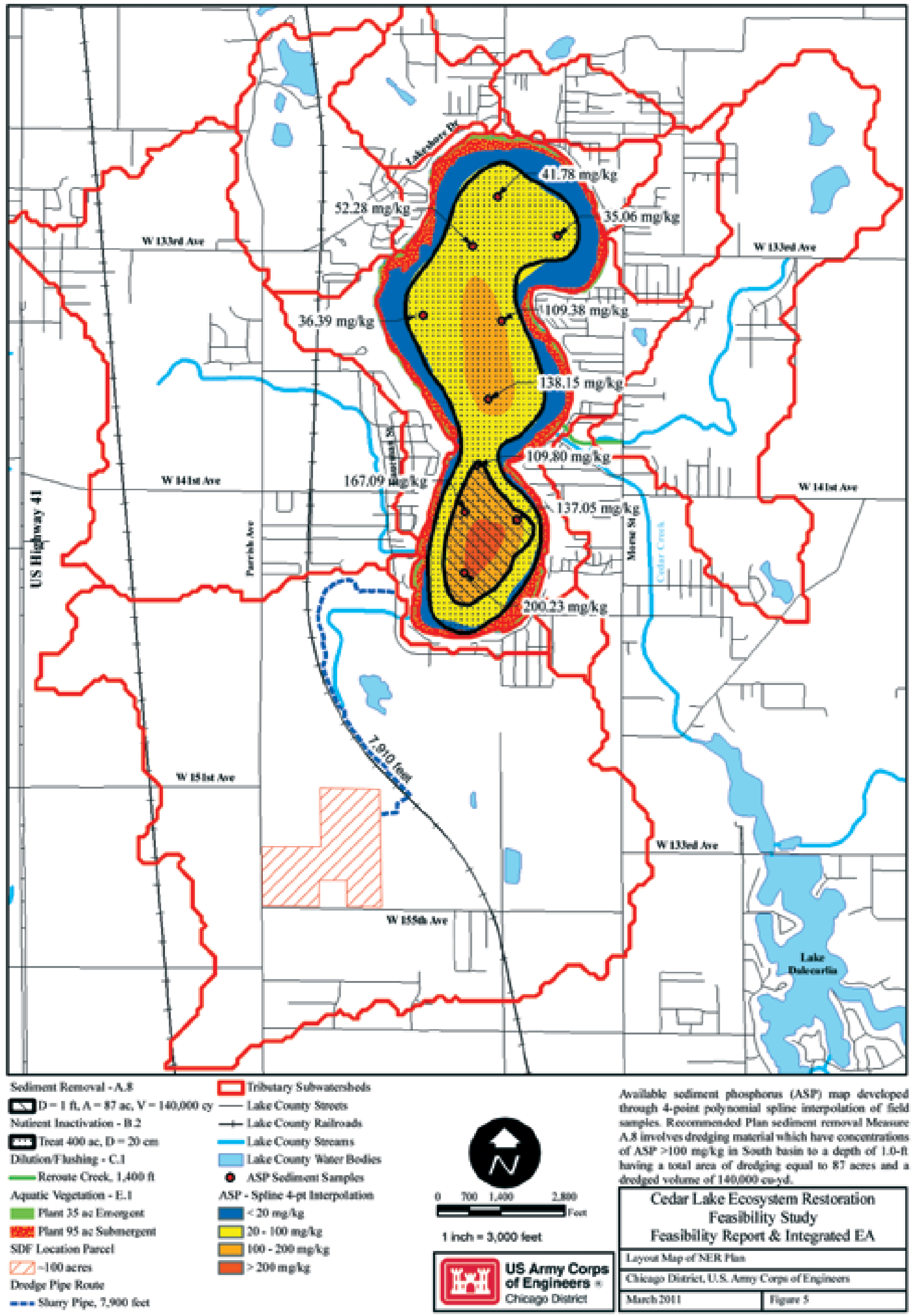

Figure 8. Layout map of National Ecosystem Restoration Plan.

Implementation of the ecosystem restoration management plan would be phased over four years beginning with construction of the sediment dewatering facility, rerouting Founders Creek, applying a single Rotenone treatment, dredging, applying a single alum treatment, increasing no-wake zones, planting littoral aquatic vegetation and restocking of native fish species.

The total first cost of the NER Plan is estimated to be $20 million, which would be cost-shared 65 percent federal and 35 percent non-federal. The Town of Cedar Lake has requested consideration of an additional $7 million in dredging be performed, that would be a 100 percent non-federal responsibility.

Next Steps

The feasibility study is scheduled to be complete in 2013. Design and implementation would follow execution of a formal partnership agreement. The first phase of the restoration plan is anticipated to begin in 2015. The entire community has been working toward implementation of a comprehensive restoration plan for decades and is very excited to see the work of so many over so long come to fruition. Their longlasting commitment to Cedar Lake is remarkable and the U.S. Army Corps of Engineers is proud to be a partner in the restoration of this valuable resource.

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David Bucaro is a civil works planner and civil engineer for the U.S. Army Corps of Engineers. For nearly 15 years he has worked on several large flood risk management, navigation, and environmental restoration planning studies within the Chicago District. He enjoys the challenges associated with helping engineer solutions to the many water resources problems facing our nation. He can be reached at: david.f.bucaro@usace.army.mil.

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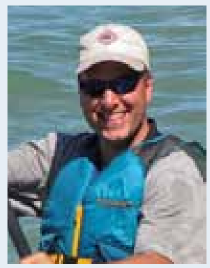
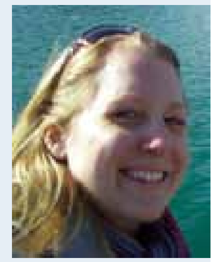
workgroups related to assessment of lakes and field protocol development. She was recently appointed as president-elect for the Oklahoma Clean Lakes and Watershed Association (OCLWA), Oklahoma's state affiliate of NALMS. Julie graduated from the University of Central Oklahoma in 1995 with a BS in biology.

REGION 10 DIRECTOR – FRANK WILHELM



Frank Wilhelm earned BS and MS degrees from Trent University, and a Ph.D. from the University of Alberta. After a NSERC post-doc at the University of Otago he joined the faculty at Southern Illinois University in 2001. In 2007, he moved to the University of Idaho, where he is currently an associate professor in the Department of Fish and Wildlife Sciences. Frank teaches freshmen limnology and current issues in the aquatic sciences to seniors, and advanced limnology to graduates. Research with graduate students focuses on using large mesocosms to examine the remediation of cyanobacteria; the use of experimental flumes to examine methods to reduce Didymo; and examining the role of Mysis in lake food webs. He attends NALMS conferences, is a CLP, presents workshops, and is an associate editor of *Lake and Reservoir Management*. Since 2008, he has served as the chair of the scholarship committee on the board of WALPA.

STUDENT AT-LARGE DIRECTOR – LINDSEY WITTHAUS



Lindsey's love of lakes began at young age with frequent family trips to local reservoirs and grew during her undergraduate career at the University of Pittsburgh, where she studied past climate using lake sediments from the Yukon Territory. Recently, she completed her MS degree in environmental science utilizing in-lake nutrient empirical models. Currently, she is a doctoral student and NSF IGERT Fellow at the University of Kansas in the Environmental Science Program studying the implications of extreme climate events on water quality in Kansas reservoirs. Lindsey's first interaction with NALMS was at the fall 2010 meeting. Following the fall meeting, Lindsey worked with Dana Bigham and others in the NALMS student committee.