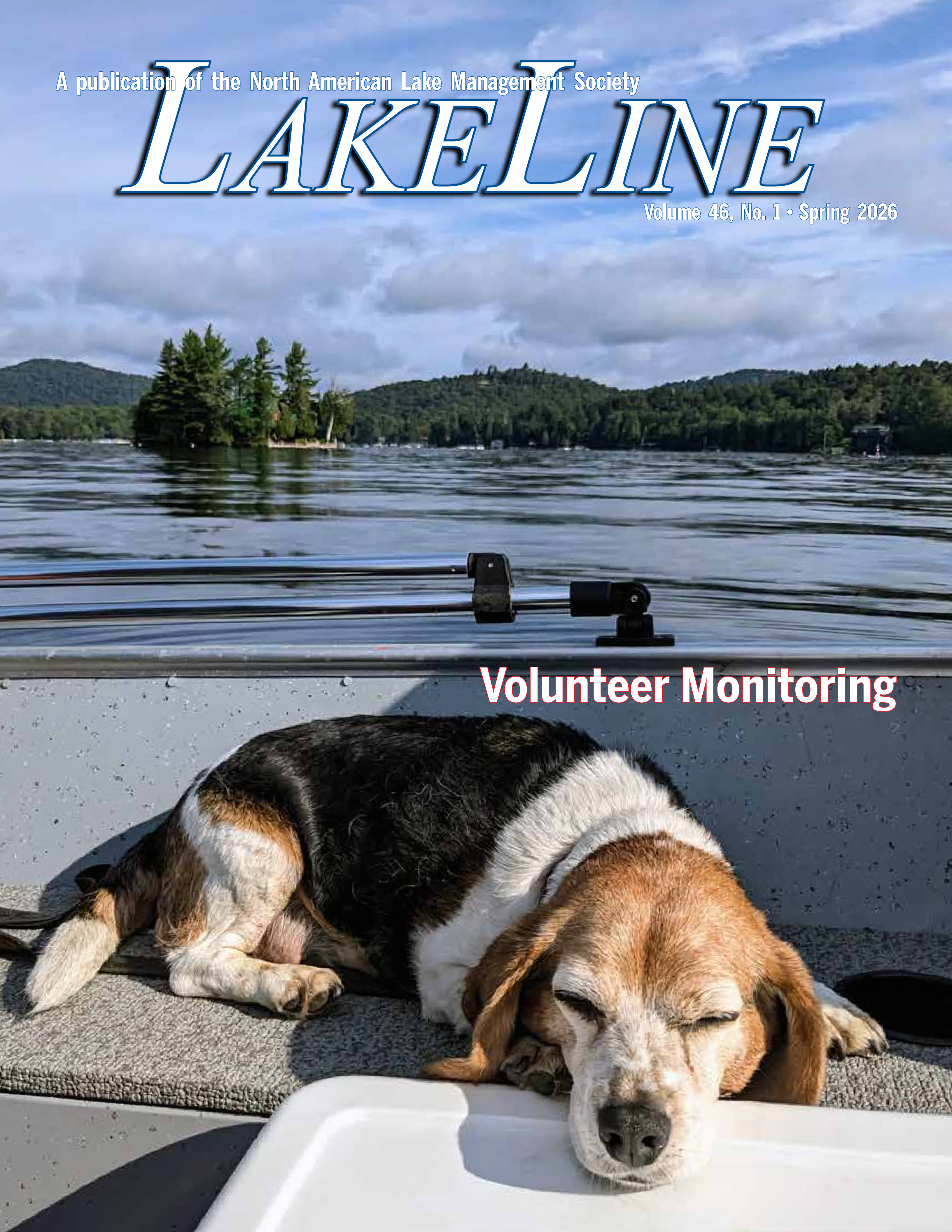
A publication of the North American Lake Management Society

LakeLine

Volume 46, No. 1 • Spring 2026



Volunteer Monitoring

NALMS 2026
KELOWNA, BC

46th International Symposium of the North American Lake Management Society

Swimming Upstream: Tackling Environmental Challenges through Partnership, Innovation, & Science

November 2-6, 2026 -- Kelowna, British Columbia, Canada

Kelowna appears to have abundant water, but this city is in the most water-scarce region of Canada. The water resources in this semi-arid setting are under increasing pressure, compounded by watershed-scale disturbance and a warming climate. Warmer, drier conditions in the growing season means agricultural needs, urban use, and environmental flow needs frequently exceed the available water resources.

To discuss these, and other, issues, NALMS is pleased to return to Canada (after ten years) for NALMS 2026! The program will feature the below topics (and more), workshops, field trips, presentations, networking events, and vendor displays.

Potential topics include:

Aquatic Invasive Species
Climate Change
Paleolimnology
Harmful Algal Blooms
Community-Based Science
Emerging Technologies & Methods
Eutrophication & Nutrient Management
Indigenous-Led Monitoring & Stewardship
Managing Impacts of Extreme Events
Mining & Resource Extraction Impacts
Science & Management of Salmon Lakes
Urban Lakes & Stormwater Ponds

For sponsorship or general information, visit www/nalms.org/nalms2026 or contact nalms2026@nalms.org. For other details, contact Conference Coordinator, Sara Peel (speel@arionconsultants.com) or Conference Chairs, Hamish Kassa (hamishkassa@gmail.com) and Kellie Merrell (Kellie.Merrell@vermont.gov).

THE AQUATIC PLANT MANAGEMENT SOCIETY, Inc.
PO Box 754
Holly Springs, NC 27540
www.apms.org

ANNOUNCEMENT

Michael D. Netherland
GRADUATE STUDENT RESEARCH GRANT
2027-2028 JOINT SOUTHEAST US FOCUSED RESEARCH AWARD

The Aquatic Plant Management Society (APMS) is pleased to announce a Graduate Student Research Grant (GSRG) to support research in aquatic plant or algae management or ecology. This academic award is cosponsored by regional APMS chapters including Florida, Midwest, Northeast, Texas with additional financial support from the South Carolina and Midsouth chapters.

Southeastern and Midsouth Regional Collaboration

APMS, the South Carolina Aquatic Plant Management Society (SCAPMS), and the Midsouth Aquatic Plant Management Society (MSAPMS) are jointly offering a scholarship focused specifically on issues relevant to the southeastern and midsouth regions of the United States.

The goal of this collaboration is to support applied research that can be implemented into active management programs and provide practical guidance to aquatic ecosystem managers addressing problematic species or management challenges within the region. By combining resources, the societies are able to offer a larger, more impactful award that supports robust research efforts and participation in annual society meetings.

The scholarship committee will give particular consideration to proposals that:

- Build on existing knowledge,
- Include both mesocosm and field components, and
- Provide clear, actionable management recommendations.

While the Southeast focused research topics, below, were identified by the scholarship committee and chapter representatives and will receive grant preference, all research topics and proposals will be considered:

- Vallisneria (eelgrass)
- Lyngbya control
- Harmful algal blooms

Objective

The purpose of this grant is to support a full-time graduate student conducting research on:

- Aquatic plant or algae management techniques (used alone or in combination with other management approaches), or

- Aquatic ecology related to the biology or management of regionally or nationally recognized nuisance aquatic vegetation, including macrophytes, algae, or cyanobacteria.

Eligibility

Proposals may be submitted by any full-time faculty member or graduate student affiliated with an accredited U.S. academic institution. If a graduate student submits the application, a faculty sponsor must be identified.

Award Amount and Duration

- Total Award: $55,000 (APMS does not pay overhead or indirect costs)
- Duration: Two (2) years
  - $27,500 per year

Award Notification and Disbursement

The selected faculty member will be notified of the award in time to make arrangements to attend the 66th APMS Annual Meeting, to be held July 13–16, 2026, at the Renaissance Downtown Phoenix Hotel in Phoenix, Arizona. The recipient will be formally announced during the Annual Meeting.

The grant will begin in the 2026–2027 academic year. Payments of $27,500 will be issued prior to January 31, 2027, and January 31, 2028.

Proposal Deadline

Completed applications must be received by the APMS GSRG Coordinator no later than May 31, 2026.

Proposal Guidelines

Proposals should include a concise description of the project, clearly outlining its purpose and justification. The proposal should also include sections addressing:

- Study objectives
- Methodology
- Project schedule
- Budget
- Planned publication of results

Additional requirements include:

- Resumes for the faculty applicant and graduate student (if known), each not to exceed two (2) pages.
- A proposal length not to exceed ten (10) pages.
- Signatures from the principal investigator and an appropriate university official.
- Copies of, or links to, the applicant's five (5) most recent peer-reviewed publications.
-

Recipient Requirements

Grant recipients must meet the following conditions:

- Progress Reporting:
  Semi-annual progress reports must be submitted to APMS by June 30 and December 31 of each year of the grant.

- Participation:
  The faculty member and graduate student must participate in at least one APMS Board of Directors meeting and attend the APMS Annual Meeting.

- Research Presentation:
  The graduate student must present results from the funded research at least once during the grant period. Annual presentations are strongly encouraged.

- Final Report:
  A final report must be submitted to APMS upon completion of the project.

Award Consideration

If a proposal with a southeastern-focused emphasis is not selected, the award amount will revert to $40,000 total over two years.

For more information on the APMS
Michael D. Netherland Graduate Student

Research Grant
Visit the APMS website: http://www.apms.org

Inquiries: Matt Johnson

APMS Vice President

MattJ@aquaticcontrol.com

LakeLine

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On the cover:
"Lake sampling is ruff work." Photo by Paul Bukaveckas, submitted as an entry to the NALMS 2025 photo contest.

Advertisers Index

Published quarterly by the North American Lake Management Society (NALMS) as a medium for exchange and communication among all those interested in lake management. Points of view expressed and products advertised herein do not necessarily reflect the views or policies of NALMS or its Affiliates. Mention of trade names and commercial products shall not constitute an endorsement of their use.

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From the Editor

Amy P. Smagula

This issue of *LakeLine* focuses on the efforts of the many volunteers who dedicate their time as stewards to our natural resources. The articles in this issue cover volunteer monitoring efforts on lakes and ponds and streams and rivers. Efforts range from local to international, and across a range of parameters, from water monitoring to biomonitoring, and ice in/out to shoreline habitat assessments. Volunteers do it all and do it well.

Whatever term you prefer to use, volunteer monitor, water steward, citizen scientist, or something else, these dedicated volunteers contribute hugely to the science of our water resources. Because many of them live next to or near a waterbody, they literally are the eyes on the water, seeing the day to day changes in and around these waterbodies, which is something that a biologist in academia, or government (state, federal, or provincial) or the private sector can't possibly do, given their need to focus on tens or hundreds or even thousands of waterbodies under their purview.

Volunteers who engage in monitoring waterbodies have a vested interest in the resource, and a passion for maintaining it and understanding it. Their efforts at monitoring are solid, following often detailed quality assurance and quality control methods and quality assurance project plans so that the data they collect are rigorous and sound, and can stand up equally with the data collected by trained scientists, and contribute to larger data sets in meaningful ways. Volunteers also work locally to share their knowledge and raise public awareness about water quality and protection efforts, often presenting their data at local association meetings, municipal events, and sometimes even professional scientific conferences. Their contributions are greatly appreciated, as evidenced by the articles contained within this issue.

Chris Joseph with Keep Tahoe Blue shares an array of volunteer based activities around Lake Tahoe. From water quality "snapshot day," where volunteers collect water quality data from tributaries around the lake, to aquatic invasives species surveys and reporting, and outreach and education related to aquatic invasive species, and citizen scientists reporting on litter and algae blooms, there are hundreds of trained and active volunteers around the shores of this very large lake.

Since 1994, the "Robert Carlson Secchi Dip-In" has been a long-running effort whereby volunteers can collect and upload Secchi disc data across the United States and Canada to report on the clarity of lakes across North America. **Lisa Borre**, **Kathleen C. Weathers**, **Michael Forcella**, **Julie Chambers**, **Philip Forsberg**, and **Mark LeBaron** provide an overview of the evolution of this program, and how today it is an important part of annual NALMS activities.

Matthew Scott, **Scott Williams**, **and Linda Bacon** discuss the formation and evolution of Maine's network of volunteer monitors, now in it's 55th year. Initially formed under the Maine Department of Environmental Protection and then converted into a non-government organization under the Volunteer Lake Monitoring Program, the program has grown over the years to include a number of parameters and a strong network of dedicated volunteers, supporting a state and local partnership with lakes in mind.

In an article by **Amanda McQuaid**, **Georgia Bunnell**, **Alyssa Daigle** and **Bob Craycraft**, we hear about the two statewide volunteer water quality monitoring programs that have each been active for decades in New Hampshire.

Next, we hear from the staff of **Living Lakes Canada** in British Columbia, Canada, about a unique and collaborative shoreline survey of Kalamalk Lake and Wood Lake. Through a partnership between the Okanagan Indian Band and Living Lakes Canada, the shorelines of both lakes are being surveyed with an eye towards not just science, but the cultural and archaelogical values and of these lands as well.

Also included in this issue, we hear about the great work being done by the Lake Partner Program in Ontario, Canada. **Gavin Vance** discussed the evolution of the program from a guided "self-help" approach at lake monitoring, to a much more organized and still growing effort engaging hundreds of volunteer monitors on lakes across Ontario.

Gabrielle Parent-Doliner highlights the importance of the Lake Erie Rangers in filling gaps in data collection outside of typical summer water quality monitoring period. These volunteers number over 200, and monitor as many locations throughout the Lake Erie watershed. They have proven invaluable in collecting chloride data during ice and snow melt, as well as furthering an outreach and education campaign targeting salt users at the source. They are also developing additional programs and test kits for bacteria, nutrients and algae, and also moving into restoration efforts as well. Their data are shared through publicly accessible data platforms. Water Rangers is a growing program, now active across 20 countries, with the biggest level of activity in Canada, the United States and the United Kingdom providing publicly accessible data, test kits, and more.

Faith Ferrato, **Sapna Sharma**, **Patrick Collins**, **Debra Kundert**, **Bill Raaths**, **Greg Sass**, **Georgina Shafer**, **Cathie Taylor** and **Jennifer Tice** share the efforts of a dedicated group of volunteers participating in the Community Lake Ice Collaboration (CLIC). The program, started by Dr. Kenton Stewart, dates back to the 1980s and is focused on gathering data on ice in and ice off dates for lakes across Maine, Michigan, Minnesota, New York and Wisconsin. Data from this effort helps to inform climate studies and more. The co-authors share personal stories and experiences about what motivates them to dedicate their time and contribute their observations to the science of lakes.

Volunteer Monitoring efforts supporting the StreamSmart Citizen Science Program in the Beaver Lake watershed (a drinking water supply) in northwest Arkansas are highlighted by **Olivia Schaap**, **Erin Scott** and **Ayla Grace**. The StreamSmart program relies on a network of 37 volunteers across 15 monitoring sites, collecting a range of parameters throughout the year. Many of their volunteers are naturalists who are recruited from the northwest Arkansas Master Naturalists program, while others range from college students to retirees. The crux of the program relies on sustaining a volunteer monitoring program within a network of complementary organizations, all working together and supporting one another and the efforts of all.

Gianna Lourenco, **William O'Connor**, and **Alexia DiLorenzo** write about community involvement with electrofishing activities in the Woonasquatucket River. This effort integrates outreach, education, volunteer participation, and discovery of what lives in the river, despite environmental pressures from an urban watershed. Efforts incorporate more than 1200 youth, who ultimately participated in raising trout and studying other elements of the river system.

Our Lakespert, Steve Lundt, shares his experiences over the years with volunteer monitoring programs, and offers some insights into important elements of a volunteer program.

In the Student Corner, master of science candidate, **Claire Paul**, highlights some of her work on Budd Lake in New Jersey.

In a new invited column titled "Tools of the Trade" **Jen Stamp**, **Tim Martin**, and **Erik Leppo** provide a review of NALMS Shiny Apps Service, which is an array of *R* based apps intended to help automate data processing and analysis, and quality assurance of large continuous data sets, among other utilities. These useful apps are housed on the NALMS website at **NALMS Shiny Apps Home Page** and are free for use.

And, while not tied to volunteer monitoring, but still an important issue in lake management, **Paul Hudak** shares an article about shoreline erosion at a lake in Lewisville, Texas, and efforts to stabilize the loose soil.

Finally, please find a Call for Abstracts for the NALMS 2026 symposium in Kelowna, British Columbia, and an advertisement for the NALMS 2026 Student Poster Contest.

We hope you enjoy the number of articles focused on volunteer monitoring in this issue, and that this information leverages local action to monitor and protect waterbodies near you this upcoming season!

Amy P. Smagula is the Chief Aquatic Biologist and Director of the Jody Connor Limnology Center at the New Hampshire Department of Environmental Services.

PROGRAMS
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From Julie Chambers the President

Throughout North America and beyond, scientists, agencies, and everyday citizens collect data from lakes. These waterbodies are dynamic systems that are impacted by excess nutrients, sedimentation, algal blooms, seasonality, and much more. The overall need for credible scientific water monitoring data is fundamental to ensuring the quality of lakes.

Understanding water resources is essential to preserving the quality of life for all residents and supporting the economy. These resources supply water to communities and contribute millions of dollars annually through recreational activities. Providing the public, scientists, and decision-makers with accurate information about the condition of lake resources is vital for effective stewardship and sustainable management. One of the biggest challenges agencies and organizations face is that they cannot monitor every lake as frequently as needed due to limited funding and staffing. These limitations create gaps in the data record that inhibit our understanding of these dynamic waterbodies. Long-term datasets are valuable for identifying trends, setting priorities in sampling programs, and informing policy and decision-making in lake management.

Volunteer monitoring and citizen science play a key role in data collection for lakes and are an important part of environmental stewardship. By measuring water clarity, temperature, oxygen levels, and other parameters, volunteer monitors help build a continuous record of a lake's health. These efforts from the volunteers help fill in monitoring gaps, creating more continuous datasets across a wider range of waterbodies than agencies could manage alone. Volunteer monitoring is not just about data, it's also about a personal connection to the environment, and many of us have memories of our favorite lake or lakes that make stewardship important to us and part of who we are. With the support of proper training programs and new technologies such as mobile apps and low-cost sensors, more people than ever can contribute to the collection of lake data in a meaningful way. As these programs continue to grow, they not only strengthen our understanding of lake systems but also build a more engaged and informed community of stewards dedicated to protecting them.

Julie Chambers leads the Oklahoma Water Resources Board's Beneficial Use Monitoring Program (BUMP) Lake Monitoring section. She has 25 years of experience in statewide water quality management, from program design through data collection, management, reporting, and dissemination of information. Over the last 22 years her program has thrived and is responsible for conducting water quality studies, assessments, and bathymetric surveys on reservoirs across Oklahoma, as well as managing lake and wetland projects funded through federal grants and other contracts. Julie serves on the water quality steering committee for the EPA's National Lake Assessment as well as on several state technical workgroups focused on the assessment of lakes and field protocol development. Julie has been an active member of The North American Lake Management Society (NALMS) for 20 years

NALMS STUDENTS: SUBMIT YOUR ARTICLE FOR THE LAKELINE STUDENT CORNER!

As shared at this year's NALMS Symposium, we are looking for student authors who are interested in publishing a piece in the "Student Corner" of *Lakeline*!

Lakeline, a quarterly e-magazine published by the North American Lake Management Society, is a mix of reflection, research, and science communication. Typically, articles are 1-2 pages in length and can include photos of you, your field work, or any related figures. Submissions are accepted Jan 1, April 1, July 1, and Oct 1.

The "Student Corner" is a great place to share results of a research project you have been working on or simply reflect on your life as a student studying lakes and reservoirs. As a magazine, a publication in *Lakeline* can be cited on your CV and may be a refreshing exercise in non-academic writing. If interested, please contact student@nalms.org or lakeline@nalms.org for more information.

UPCOMING IN *LAKELINE*

Below is a list of the proposed topics for upcoming issues of *LakeLine*. Please take a look and consider submitting an article for a topic of interest. Articles are generally 2000 words or less in length, and should include photos, graphs and/or tables. Co-authors are welcome.

SUMMER 2026: DNA BARCODING IN LAKE STUDIES – *Draft articles are due by June 30, for publication in July.*

More and more we are hearing about the use of DNA barcoding, eDNA, and metabarcoding to monitor our surface waters. What is it, how is it used, what is it used for, and who's using it? These are all topics that are being sought for articles to round out this issue. Are you working with DNA barcoding in your lake(s)? Please consider submitting an article about your work!

FALL 2026: FISHERIES – *Draft articles are due by September 30, for publication in October.*

Topics related to fisheries ecology, biology, food webs, and management, along with toxins in fish tissue, fish habitat, and other fisheries related topics are welcome.

WINTER 2026: AGRICULTURE IN WATERSHEDS – Draft articles are due by December 30, for publication in January.

A range of topics related to agriculture in watersheds is welcome, including farm pond management, nutrient runoff, erosion, agriculture BMPs for lake protection, and more.

Please contact Amy Smagula, *LakeLine* Editor, with any questions, or to propose an article for one of the above-listed themes. Do you have a topic that doesn't match a theme? That's ok, we can include the article in any of these issues or use it to build a themed issue. Amy can be reached at Lakeline@nalms.org.

Volunteer education, empowerment, and **water quality monitoring at Lake Tahoe**

Chris Joseph

Lake Tahoe is perched at 6,223 feet above sea level in the Sierra Nevada mountain range, straddling the California-Nevada border. Granitic peaks tower 10,000-feet over the lake's 72 miles of shoreline and famously blue water whose clarity plunges to an average depth of 65 feet. Around 15 million people live within a half-day drive of Tahoe, its 13 ski resorts, and 250 average days of sunshine per year.

The destination absorbs approximately 17 million annual visits, about four times as many as Yosemite National Park. Yet Tahoe is not a national park, despite several failed attempts to make it one. People come to ski and snowboard in the winter; swim, paddle, and boat in the summer; and enjoy stunning natural beauty year-round.

That is a very expansive way to say that the Lake Tahoe Basin is popular. This popularity puts pressure on the natural environment, especially water quality and clarity, in the form of litter, fine sediment pollution from roads and urban areas, and aquatic invasive species.

Fortunately, Tahoe enthusiasts are willing to donate their time and effort to protect the place through citizen science volunteering. The environmental nonprofit "Keep Tahoe Blue" mobilizes thousands of volunteer hours each year. This donor-funded, science-based organization of environmental experts and Tahoe lovers has worked to protect and restore the Lake Tahoe Basin's health, sustainability, and scenic beauty since 1957.

In addition to its work in science, advocacy, and innovation, Keep Tahoe Blue engages the lake's diverse community of residents and visitors in hands-on water quality monitoring programs and events. They include "Snapshot Day," an annual water quality monitoring event; "Eyes on the Lake," an aquatic invasive species identification and reporting program; and "Citizen Science Tahoe," a web-based app where anyone can report environmental observations with nothing more than a phone.

Tahoe-Truckee "Snapshot Day"

This is an annual event held each May in which volunteers collect water quality data from streams, creeks, ponds, and lakes in the Tahoe-Truckee region for a moment-in-time "snapshot" of the Truckee River watershed's health (Figure 1). Keep Tahoe Blue, together with partner organizations, trains community members to sample sites from the Truckee River's headwaters, around Lake Tahoe, then along the river to Reno and through to its inland terminus at Pyramid Lake.

The event began in 2001 and has run every year without interruption, even through the COVID-19 pandemic. Since 2014, Keep Tahoe Blue has organized the southern zone, which has included 89 sampling sites spanning 25 different water bodies. The nonprofit staff members visit each sampling site before the event and assign a priority level based on past monitoring results, current conditions, and accessibility. They also calibrate sampling equipment, including multiparameter water meters. Around 100 volunteers, grouped into teams of three to six people, participate each year. Team leaders go through a training session of classroom instruction and practice with testing equipment about a week before they lead their teams into the field.

Although it occurs just once a year, Snapshot Day is a fan favorite that draws many volunteers back year after year. One such volunteer, a professor at the local community college, has participated in every one of the event's 25 years, and many more people are four-, five-, and six-time returners. In 2025, one team even had shirts custom embroidered with their adopted team name, the "Trout Creekers." They are joined by full-time residents, second homeowners, frequent visitors, and high school and community college students whose class curricula features Snapshot Day.

The event partners who conduct sampling in the other zones are just as varied. Over the years, they have included research institutes, utility districts, water providers, resource conservation districts, public agencies, and land managers. In 2026, two Native American tribes, the Washoe Tribe of Nevada and California and the Pyramid Lake Paiute Tribe, will join.

During the event, volunteer teams collect:

Field Measurements

- *Water temperature* is a key indicator of ecosystem health. In mountain streams and lakes, cooler water provides better habitat for aquatic life.
- *pH* measures how acidic or basic a water sample is, on a scale from 0 (very acidic) to 14 (very basic). Most aquatic life prefers a pH close to 7.
- *Dissolved oxygen* is the amount of gaseous oxygen dissolved in water – an essential ingredient for fish and other aquatic life. When levels drop, many species become stressed.
- *Electrical conductivity* measures how easily water can carry an electric current. Sudden or

Figure 1. A Snapshot Day volunteer team collects water samples and makes visual observations on the northern shore of Fallen Leaf Lake, California, in May 2024.

significant changes in conductivity can signal new discharges entering the water.

- *Total dissolved solids* are a measure of the inorganic and organic particles dissolved in water. Shifts can indicate new inputs from runoff, pollution, or other sources.

Visual Observations

- *Weather observations*, like cloud cover and wind, provide context about short-term conditions that may affect water quality. A major storm, for example, could increase runoff or erosion in the sampling area.
- *Water sample observations*, like water odor and color, offer qualitative clues that can help explain measurements at a site.
- *Sampling site conditions*, including in-stream flow and water clarity, add more context to measurements. For example, evidence of a new pipe or storm drain can help explain unexpected results.

Samples for Lab Testing

- *Nutrients* support the growth of plants and algae at the base of the aquatic food web, but at elevated levels, they can become a problem, increasing the potential for harmful algae and aquatic invasive species. Nitrogen and phosphorus are the two most important nutrients monitored, and both occur in several different forms.
- *Bacteria* are present in every natural system, but elevated levels can indicate contamination from wastewater, wildlife, or other inputs. *E. coli,* in particular, is monitored for potential risks to human health.
- *Turbidity* measures how cloudy the water is, caused by suspended particles like sediment, algae, or organic matter. Sudden changes can indicate erosion or other inputs upstream (Figure 2).

The data collected across all sampling zones are compiled into an annual report and made publicly available at www.tahoetruckeesnapshotday.org.

Keep Tahoe Blue also prepares annual reports for public land managers, as many sampling sites are located on national forest, state park, or conservancy agency land. Land managers may add the data to their own environmental monitoring portfolios or use it to address areas of concern highlighted in the measurements. Keep Tahoe Blue recently released a 25-year cumulative report as an online, interactive StoryMap available at www.keeptahoeblue.org/ssd. The trends and overall picture are encouraging: tributaries and lakes across the Tahoe-Truckee watershed consistently show healthy water quality. Yet this doesn't mean every result is perfect. When something looks off, like an unusually high bacteria reading, event organizers follow up with land managers to find the source and if needed, resample. In some cases, measurements can reveal point-source pollution, such as livestock let loose in a meadow above a sampling site.

Beyond a quarter-century of data, Snapshot Day's qualitative benefits are just as valuable. The event connects the community to its watershed, exposes

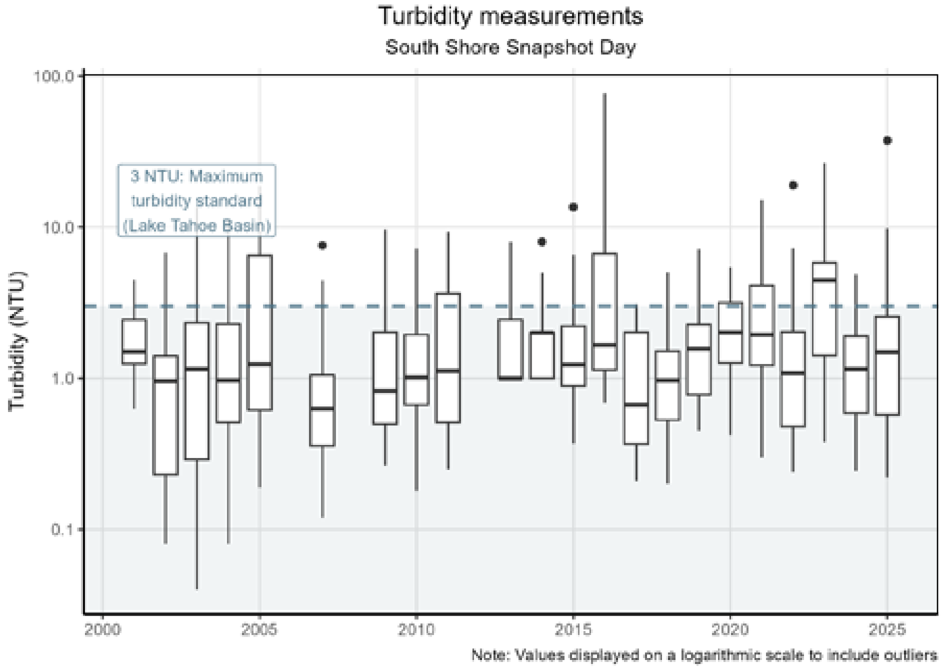


Figure 2. Twenty-five years of South Shore Snapshot Day turbidity data are charted using box-and-whisker plots. Eighty percent of these turbidity readings fall below the 3 NTU standard set for shallow waters near Lake Tahoe's tributaries.

students to environmental science, and fosters environmental stewardship in everyone involved.

Eyes on the Lake

Eyes on the Lake is Keep Tahoe Blue's citizen science program to help prevent the spread of aquatic invasive species (AIS), which pose the biggest threat to Lake Tahoe's delicate ecology and water quality. Program volunteers "protect while they play" by learning about aquatic invasive species in Tahoe, conducting self-paced field surveys while they enjoy the lake, and reporting their observations through a web app available at citizensciencetahoe.org.

Where Snapshot Day is a time-bound, one-day event, Eyes on the Lake was created by Keep Tahoe Blue in 2013 to meet Lake Tahoe enthusiasts where they are – on or near the water, whenever that may be. By making participation simple and unscheduled, the program creates a stream of real-time, GPS-located, crowd-sourced water monitoring data.

The first step is education. Multiple training sessions are held each year, both in person and online, where participants learn how to distinguish invasive species from their native look-alikes and what to do if they think they've spotted one (Figure 3). Members of the public are trained for free, alongside staff from agencies like California State Parks and the California Tahoe Conservancy, as well as the people who operate Tahoe's 13 marinas. Marinas are required to attend an Eyes on the Lake training each year as part of their operating permits. As frontline workers, their ability to spot and report aquatic invasive species is key to protecting the lake's water quality.

For folks who can't attend a training, the Citizen Science Tahoe web app is built with prompts and sample photos to help users determine whether what they're seeing is a native species like northern milfoil (*Myriophyllum sibiricum*), or an invasive species like Eurasian watermilfoil (*Myriophyllum spicatum*).

Keep Tahoe Blue's staff review observations shortly after they are submitted through Citizen Science Tahoe. If a submission indicates a possible new infestation of aquatic invasive plants or mollusks, the *Early Detection and Rapid Response* protocol can be triggered. This system lays out clear steps for Keep Tahoe Blue, the Tahoe Regional Planning Agency, and the Tahoe Resource Conservation District to contact the property owner, conduct a site assessment, determine the appropriate response, designate a lead agency, and secure funding to perform the work. The goal is to move quickly and in coordination to root out populations of aquatic invasive species before they can establish.

Here is a typical example: A paddler sees what they think may be curlyleaf pondweed (*Potamogeton crispus*) growing near a marina. They submit a photo, GPS coordinates, and other information through the Citizen Science Tahoe web app. Within a few days, scuba divers are in the water to remove the few problem plants before they can proliferate (Figure 4).

Figure 3. Volunteers practice aquatic plant identification using samples and printed ID guides as part of an Eyes on the Lake training in 2025.

Figure 4. A diver examines an aquatic plant specimen removed from the lake floor below a Tahoe marina to determine whether it is curlyleaf pondweed. The action was part of a 2021 deployment of Tahoe's Early Detection and Rapid Response Protocol to prevent aquatic invasive species from spreading.

Figure 5. Eyes on the Lake Outreach Team volunteers educate recreators about the threat of invasive golden mussels in the summer of 2025. They also provide instructions for how to clean, drain and Dry water gear.

The Eyes on the Lake program has trained 680 volunteers and generated 1,506 aquatic invasive species surveys. That volunteer effort has led to the identification and prevention of eight aquatic invasive species infestations in Lake Tahoe – eight instances where the lake's water quality was protected because citizen scientists were empowered and active.

Tahoe's environmental agencies use the data to determine where additional monitoring is needed to track the extent of aquatic invasive species in the lake. The compiled survey data has guided the creation of scuba diver transects.

Eyes on the Lake also includes a proactive element: the Outreach Team. These volunteers get special training before roaming beaches during the summer season to speak with beachgoers face to face. They offer education about the dangers invasive species pose to Lake Tahoe's health and share simple steps recreators can take to stop invasives from spreading, such as making sure all water gear is clean, drained, and dry before it touches the water (Figure 5).

Citizen Science Tahoe

The Citizen Science Tahoe web app was designed to collect much more than sightings of aquatic invasive weeds. It was built using ArcGIS's Survey123 and includes six surveys where people can share observations of nearshore water quality, algae, litter, and graffiti, among other things (Figure 6).

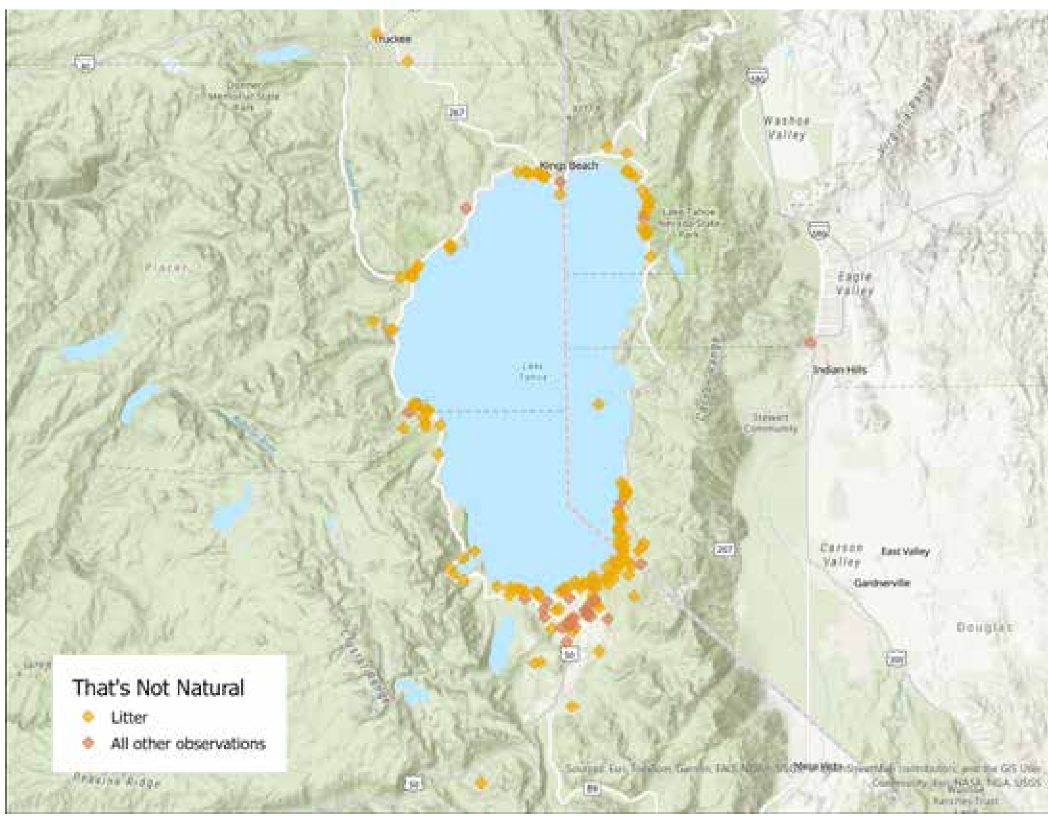


Figure 6: The Citizen Science Tahoe web app displays the observations that users submit in real time. This map shows pollution observations submitted through the That's Not Natural survey.

The web app is a collaborative venture between the University of California Davis Tahoe Environmental Research Center, the Desert Research Institute, and Keep Tahoe Blue. Observations of pollution, in any form, are collected using the web app's *That's Not Natural* survey. A simple set of questions prompts the user to input information about what they saw, how much, when, and where, including dropping a GPS map pin and submitting photos (Figure 7).

Just like with Eyes on the Lake survey submissions, these reports are all reviewed and flagged for importance. As the dataset grows, it can reveal trends that prompt managerial action. For example, recurring reports of overflowing dumpsters can point to a developing litter hotspot. This can lead to changes in what trash and restroom infrastructure are placed in that area and how frequently they are serviced.

Through events like Snapshot Day and programs like Eyes on the Lake and Citizen Science Tahoe, businesses, agencies, and the public have an open door to monitor and protect Lake Tahoe's unique water quality.

Figure 7. Before picking up litter near the shoreline, a paddler reports it using the Citizen Science Tahoe web app. Observations like this help identify and address litter hotspots.

Chris Joseph is communications director for Keep Tahoe Blue. He oversees the organization's science communications, strategic writing, marketing, and public relations. Chris holds a B.S. in geography from UCLA and M.Sc. in biodiversity conservation & management from Oxford University. Learn more about Keep Tahoe Blue's work at www.keeptahoeblue.org.

The Secchi Dip-In technology and **data evolution**

Lisa Borre, Kathleen C. Weathers, Michael Forcella, Julie Chambers, Philip Forsberg, and Mark LeBaron

A brief history of the Secchi Dip-In

Three scientists at Kent State University organized the "First Great American Secchi Dip-In" as a pilot study in 1994. In that first year, 800 volunteers in six states participated from Indiana, Illinois, Michigan, Minnesota, Ohio, and Wisconsin. Drs. Bob Carlson, Dave Waller ,and Jay Lee expanded the program the following year across the US and into two Canadian provinces. At its peak under Dr. Carlson's leadership, in 2001, the Dip-In had nearly 200 programs and 45 provinces and states participating. The program was designed as a way to get people involved and know what is changing in lakes.

By 2015, Dr. Carlson was ready to retire, and a long-term agreement was reached to transfer operation of the Dip-In program and management of the Dip-In database to NALMS. By then, participation had begun to decline (Figure 1), but an Access database had been created for volunteers to submit data, and volunteer monitoring programs could send their data in a spreadsheet format. It was still possible to mail or fax a paper form as in the early days, but most volunteers had shifted to entering data via an online form (Figure 2). Transfer of the Secchi Dip-In program to NALMS created a quandary with inheriting an out-of-date database. It was also an opportunity for a new data management system and new technologies to support the popular community science program (Figure 3).

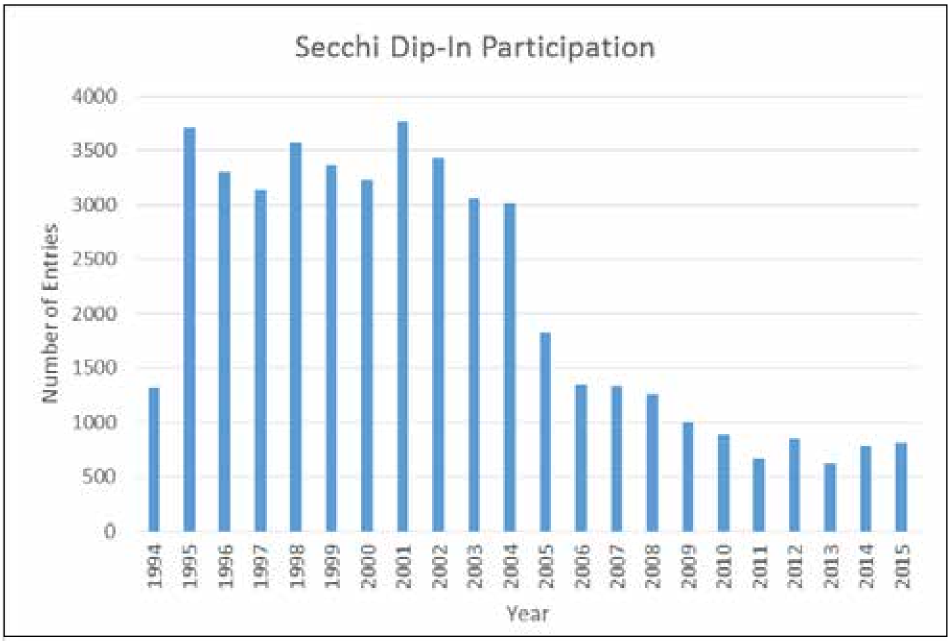


Figure 1. Secchi Dip-In participation under Dr. Carlson's leadership, 1994-2015.

Data and technology partnership

In addition to upgrading the Dip-In database technology, NALMS and USEPA partners were interested in creating a mobile app for data entry. In 2015, staff at USEPA discovered that computer and environmental scientists of the Global Lake Ecological Observatory Network (GLEON, www.gleon.org) had developed and were evolving the Lake Observer mobile app (www.lakeobserver.org). A partnership was formed to explore whether existing data management tools and technologies among these three groups could be adapted or re-used to support the Dip-In. In addition to NALMS, four other partners began meeting regularly to migrate the Dip-In database to a new platform and conduct a pilot project to use Lake Observer:

- **EPA** manages the Water Quality Exchange (WQX), a national data format and mechanism for sharing water quality data used by state and federal agencies, Tribal water programs, local governments, universities and non-governmental organizations to share their monitoring information. Data submitted to WQX is combined with data collected by USGS and made publicly available via the Water Quality Portal (WQP).
- **Gold Systems**, a software development company, developed the Ambient Water Quality Monitoring System (AWQMS), a water quality database now part of their GS Elements software package. EPA also contracts with Gold Systems to manage WQX.
- **Cary Institute of Ecosystem Studies (www.caryinstitute.org)**, a nonprofit research organization, coordinates GLEON and leads the Lake Observer app project.
- **Oklahoma Water Resources Board** (OWRB) uses the AWQMS software application and has become Oklahoma's largest supplier of environmental data to WQX. OWRB has worked in close partnership with

The Secchi Dip-In Entry Form

Please submit the data at our website (http://www.secchidipin.org) and keep this form as a record. If you have no computer access, mail this form to the Secchi Dip-in address given at the end of this form.

Person Taking Reading:

Last Name: [ ] **First Name:** [ ]

Telephone Number (____) ____________________ **E-mail Address:**________________________________

Your Monitoring Program Name (if applicable):________________________________

Please enter the following information on your waterbody

Waterbody Name:____________________ **State/Province**______________ **Country**______________

County/Region ____________________ **Zip/Postal Code of waterbody nearest town to site**____________

Longitude of Site: _______________ Degrees ________Minutes _____Sec_______

Latitude of Site: _______________ Degrees ________Minutes _____Sec_______

Please include map locating the waterbody and site if you don't know the map coordinates.

Waterbody Type: O Natural Lake/Pond (No Dam) O Reservoir (Dam) OStream/River OEstuary OMarine
O Other waterbody type ________________

Size (Lake or Reservoir Only) O Less than 5 Acres O 5-10 Acres O 10-100 Acres O 100-500 Acres O> 500 Acres

Actual Size (If known):___________ O Acres O Hectares **Depth at Site** (If known):__________ O Ft O Meters

Please enter the transparency measurement below.

Date of Reading: Month: OJune OJuly Enter Date: _______ Year: 20___

Time of Observation: _______ OAM OPM (To the nearest 15 minutes)

Site Name or Site Number (As Used in Your Normal Program Monitoring): ________________

Weather: O Sunny O Partly Cloudy O Overcast O Rain

The reading was taken from a O Boat/canoe O Dock O Bridge O Wading O Other______________

	Secchi Disk	Turbidity Tube	LaMotte Turbidity	Vertical Black Disk	Turbidity Meter
Reading:					

Figure 2. Original Secchi Dip-In entry form.

EPA and NALMS through the National Water Quality Monitoring Council.

A beta test of the Lake Observer mobile app in Indiana was successful in demonstrating the potential for using it along with existing software linked to EPA's database for data collection and transfer. OWRB then took the lead on behalf of NALMS to secure two EPA Exchange Network Grants, in 2018 and 2022, to support upgrading the Dip-In database to the AWQMS software package and modifying the Lake Observer app to streamline the way that community scientists record and share water quality data while working in the field. Leveraging the existing technologies enabled all partners to obtain the desired capabilities most efficiently. The project goals included (Figure 4):

- Adopt and enhance the GLEON Lake Observer mobile app
- Provide proper training and/or user materials
- Adopt and enhance the Ambient Water Quality Monitoring System (AWQMS) as a long-term solution
- Provide proper training and/or user materials
- "Point" Lake Observer to the NALMS AWQMS Database
- "Flow" Dip-In data to WQX on a regular basis.
- Ensure both NALMS Dip-In data and other organizations' (states) Dip-In data in WQX are tagged with the Dip-In project ID
- Ensure NALMS Dip-In data would not duplicate other organizations' (states) Dip-In data in WQX

Why AWQMS? Mainly because it is an existing system that allows for the import, validation, analysis and export of data in a format that can be submitted to the WQX data flow. AWQMS is a secure, cloud-based water quality information system that allows NALMS to consolidate data, use built-in batch data import capabilities and data entry forms. It also provides data management, editing and analysis tools.

In addition to customizing the Lake Observer app for use in the Dip-In, project partners needed to figure out a way to have data flow from the app's database to AWQMS. The goal is to allow program participants to enter data via the mobile app, a web app, or through a bulk data upload tool.

Figure 3. Secchi Dip-In event with members of the Pennsylvania Lake Management Society (PALMS).

With a direct connection to a publicly accessible, federal database, Dip-In data are now available for research, monitoring, and even 'ground truthing' remote sensing data. Data entry can be done online with forms provided or by creating custom data import configurations when adding data for a volunteer monitoring program.

Lake Observer's evolution: "We need an app for that!"

Unrelated to the Secchi Dip-In, development of an Android data collection app for the Lake Sunapee Protective Association began in 2010 as a student side-project of a National Science Foundation grant, led by Kathleen Weathers and Kenneth Chiu, a computer scientist at Binghamton University, in collaboration with community scientists at Lake Sunapee, which is a GLEON research site. Project partners were interested in supporting Community Science and crowdsourcing efforts on the lake (Figure 5). At the time, nearly two-thirds of Americans owned a smartphone, and researchers wanted to capitalize on what is becoming a common tool. They also recognized that a mobile app could conveniently capture time, date, and location information automatically, and thus have the potential for increasing the spatial extent and frequency of data collection. Data could then be captured in a publicly accessible, online database.

Research scientists and computer scientists were involved in the project team. They identified a short list of specifications: (1) record data normally collected by citizen scientists, (2) easy to use for field observations, (3) store data for later submission if offline, and (4) data storage and retrieval possible from the app.

With funding from a National Science Foundation grant supplement, GLEON

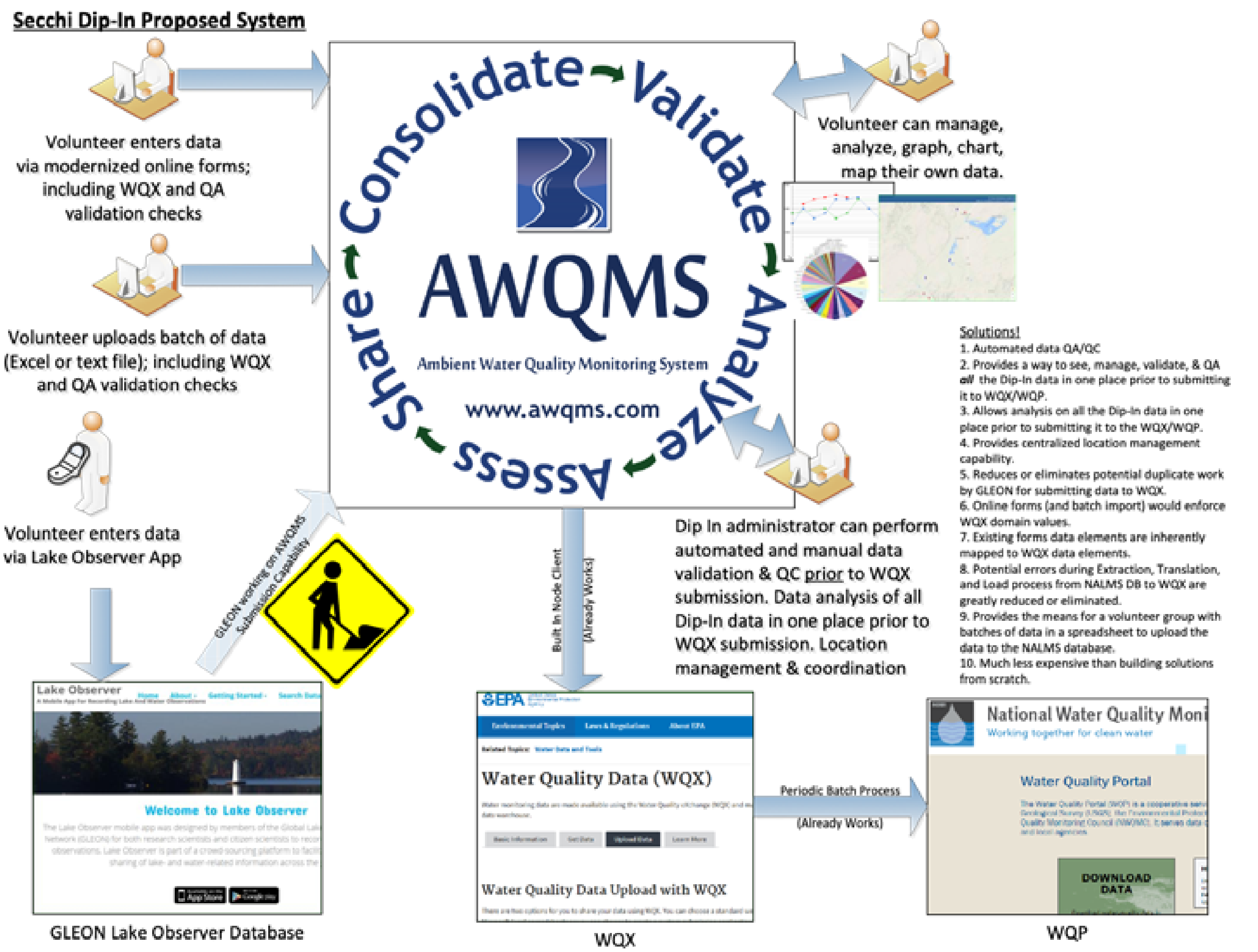


Figure 4. Diagrams showing current and proposed data management system in 2018 for the Dip-In after a pilot project was conducted (Source: Mark LeBaron, Gold Systems).

Figure 5. Work on the Lake Observer app began as a community science project on Lake Sunapee in New Hampshire. Photo courtesy of M. Eliassen.

researchers, including Weathers, Chiu, Holly Ewing at Bates College, and students began development of the current version of Lake Observer in 2014. The goal was to develop native Android and iOS versions of the app and a backend MySQL database. All initial programming was done by students. Now one of those former students, Michael Forcella, is a senior app developer at Cary Institute where he continues to work on Lake Observer and helps NALMS manage the Dip-In database. In addition to serving as a tool for Dip-In, Lake Observer is part of a crowd-sourcing platform to facilitate the collection and sharing of lake- and water-related information across the globe. Lake Observer App development continued through the pandemic years with generous support from an anonymous donor (Figures 6 and 7).

Lake Observer now has 27 active projects monitoring 312 waterbodies. Users have collected 69,490 water quality and related observations, including 5.308 Secchi Depth measurements.

Current status and next steps

NALMS' Secchi data collection program is now known as the Robert Carlson Secchi Dip-In, in memory of Dr. Carlson. Serendipity, partnerships and financial support were key in making the transition of the program from its founder to NALMS and in upgrading data entry and management systems.

Participants in the Secchi Dip-In now have the option of submitting current and historical data directly to AWQMS via batch data import tools and manual data entry forms or by using the Lake Observer mobile or web app to submit water quality observations and bulk data uploads. All Dip-In data are then flowed to WQX and WQP databases. The various options provide tools for individuals, lake associations, or larger volunteer water monitoring programs to participate in the program and share data through publicly accessible government databases.

As of the end of March 2026, NALMS has sent over 400,000 water quality observations from 287,000 sampling activities to WQX, including 193,000 Secchi depth results from more than 250 individual users and 650 conducting organizations (Figure 8).

Project partners (Figures 9 and 10) continue to collaborate to maintain the AWQMS database, Lake Observer app, and data submissions to WQX and WQP. If you are interested in learning more or getting help to sign up or submit data, send a message to secchidipin@nalms.org.

Lisa Borre is a Senior Research Specialist and Development Officer at Cary Institute of Ecosystem Studies where she coordinates GLEON and is part of the Lake Observer app development team. She is a past president (2021), board member (2016 -2019), and member of the Robert Carlson Secchi Dip-In program team for NALMS. She has a BA from the University of Vermont and an MES from Yale University.

Kathleen C. Weathers is a Distinguished Senior Scientist at Cary Institute of Ecosystem Studies, Millbrook, NY, where she studies how ecosystem

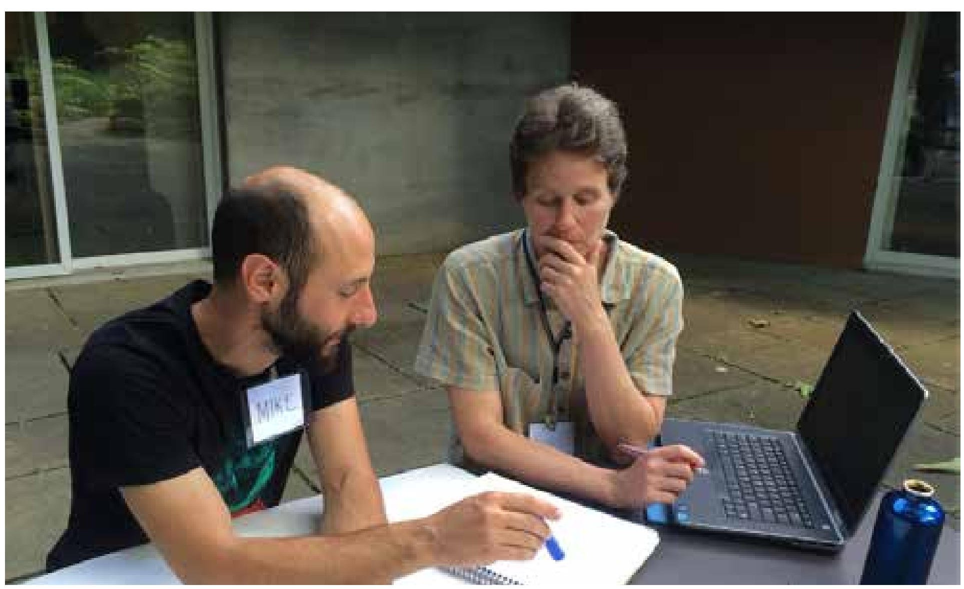
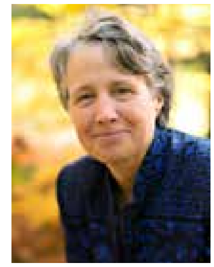


Figure 6. Michael Forcella (on left), now senior programmer for the Lake Observer app, and Holly Ewing, a member of the app development team, in a workshop at Cary Institute.

Figure 7. Lake Observer app in use.

Secchi Dip-in and Lake Observer App Timeline

- 1994 – Secchi Dip-In pilot study in 6 states
- 1995 – Dip-In expanded across U.S. and to 2 Canadian provinces
- 2010 – GLEON partners begin development of the Lake Observer mobile app
- 2015 – Dip-In operations and database transferred to NALMS
- 2016 – Current Data and technology partnership forms
- 2018 – EPA grant awarded to upgrade the database to AWQMS and use Lake Observer app
- 2020 – Data submitted and managed via AWQMS and Lake Observer
- 2023 – Renamed "The Robert Carlson Secchi Dip-In" in memory of Dr. Carlson



processes are affected by global changes within and among aquatic, airborne, and terrestrial systems. She is co-chair emerita of the Global Lake Ecological Observatory Network (GLEON) Steering Committee and Volunteer Research Director for the Lake Sunapee Protective Association. She has a PhD from Rutgers University and an MFS from Yale University.

Michael Forcella is a Senior Research Support Specialist and Data Scientist at Cary Institute of Ecosystem Studies. With a BS in Biology from SUNY New Paltz, Michael worked for several years as a

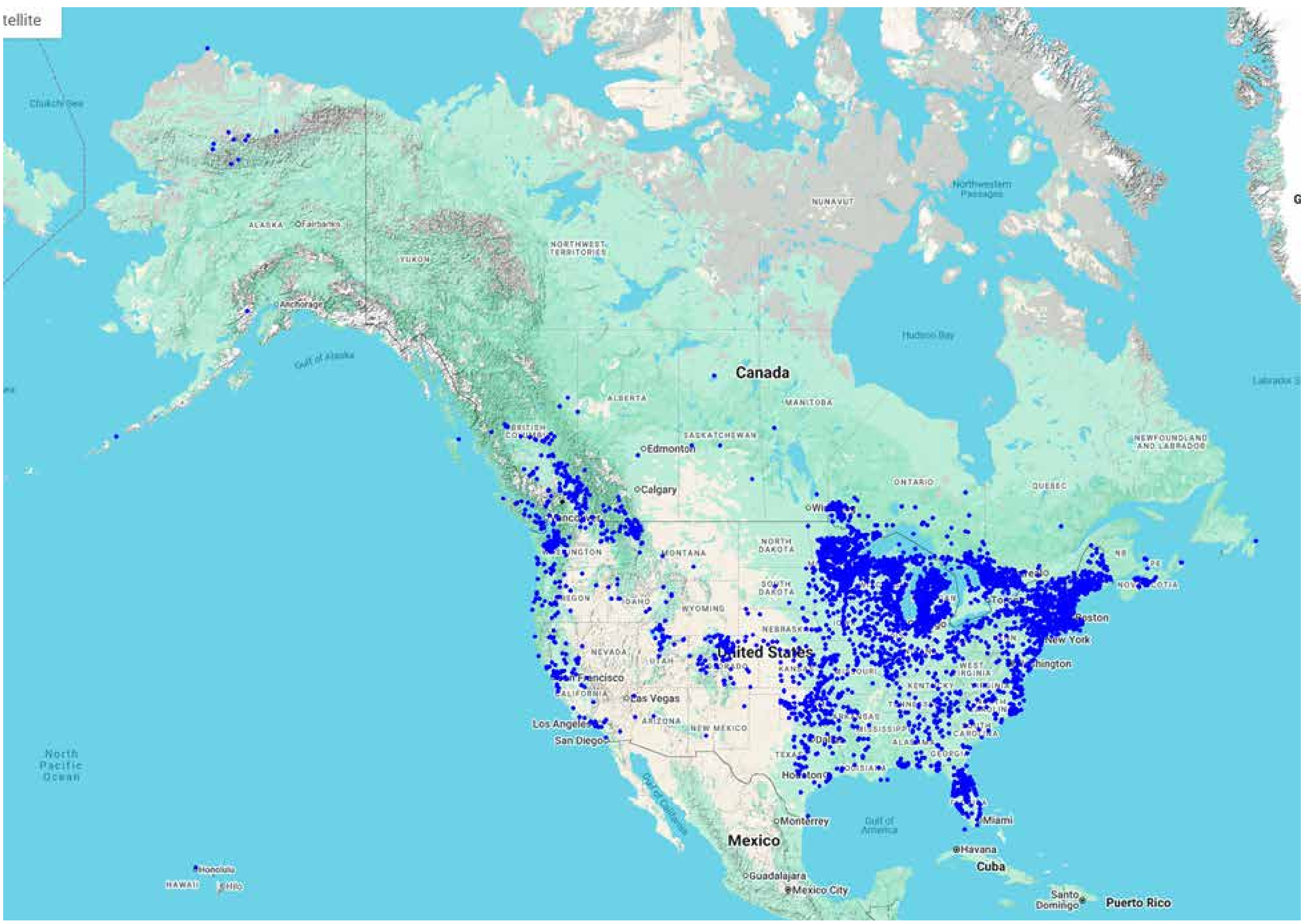


Figure 8. Map of Secchi Dip-In sampling locations in north America (Credit: AWQMS).

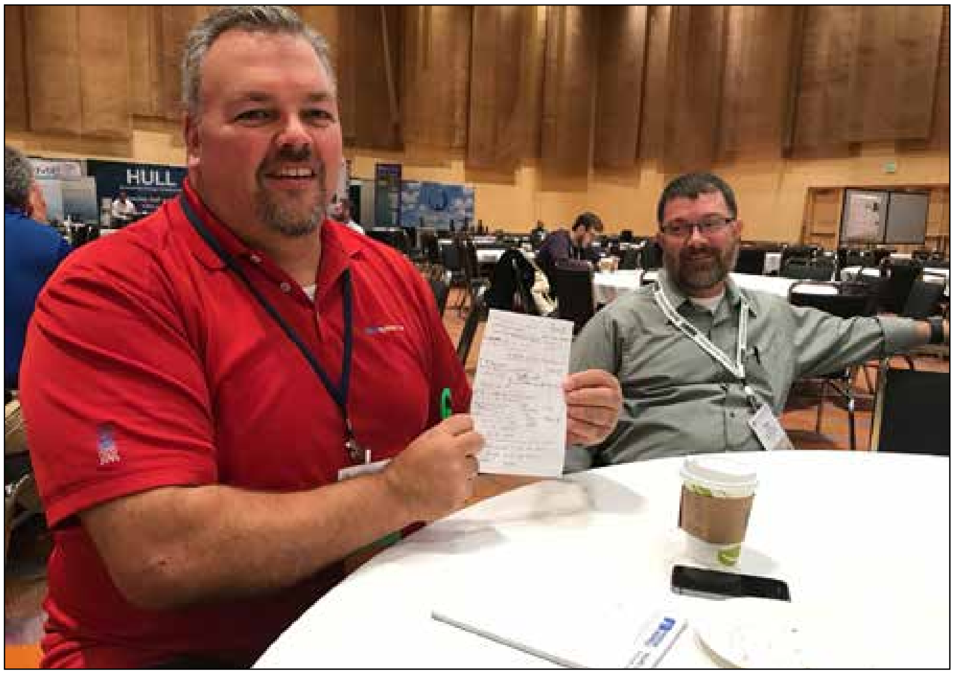


Figure 9. Mark LeBaron (L) and Philip Forsberg meeting over coffee at the NALMS symposium where a "back of the envelope" concept to upgrade the Dip-In database turned into a multi-year project to re-use existing tools.

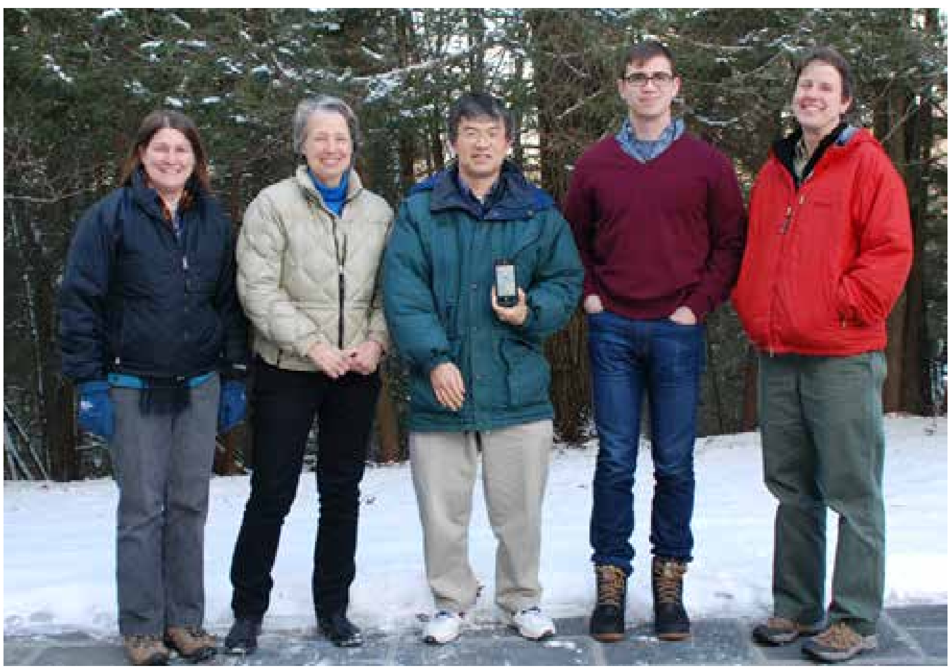


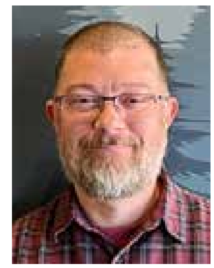
Figure 10. Lake Observer app development team at Cary Institute (L to R): Lisa Borre, Kathleen Weathers, Ken Chiu, Benjamin Chrobot, and Holly Ewing.

Links to more information and resources:

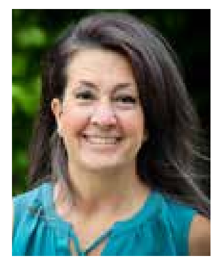
https://www.nalms.org/secchidipin/
https://www.lakeobserver.org/
https://gleon.org/
https://www.caryinstitute.org/
https://goldsystems.com/
https://www.epa.gov/waterdata/water-quality-data

forestry technician in Wyoming. He later returned to New York to pursue a Master of Science in Computer Science and spent time working alongside aquatic ecologists to deploy environmental sensors. He has been the lead developer for the Lake Observer web and mobile app since 2017.

Mark LeBaron works as a Senior Information Systems Analyst and Project Manager for Gold Systems, Inc. in Salt Lake City, UT. Mr. LeBaron has been instrumental in implementing and supporting several environmental data management and analysis systems for the EPA, states, tribes, and volunteer groups. He has a B.A. from Utah State University in Business Information Systems and an M.S. in Data Analytics from Western Governors University.



Philip Forsberg is the Executive Director of NALMS and a member of the Robert Carlson Secchi Dip-In program team. He started his career with NALMS as an intern in 1997 and has since held several positions with the organization and performed many disparate tasks from graphic design to accounting to grant management to conference planning. Philip earned a BS in Natural Resources and Environmental Management from Ball State University and an MS in Urban and Regional Planning from the University of Wisconsin.



Julie Chambers leads the Oklahoma Water Resources Board's Beneficial Use Monitoring Program (BUMP) Lake Monitoring section. She has 25 years of experience in statewide water quality management, from program design through data collection, management, reporting, and dissemination of information. Over the last 22 years her program has thrived and is responsible for conducting water quality studies, assessments, and bathymetric surveys on reservoirs across Oklahoma, as well as managing lake and wetland projects funded through federal grants and other contracts. Julie serves on the water quality steering committee for the EPA's National Lake Assessment as well as on several state technical workgroups focused on the assessment of lakes and field protocol development. Julie has been an active member of The North American Lake Management Society (NALMS) for 20 years serving on various committees and representing as past president since 2016.

55 years(!) of the nation's first & longest-standing volunteer lake monitoring program!

Matthew Scott, Scott Williams, and Linda Bacon

While Maine's several thousand lakes are among the clearest and cleanest in the nation, they are also sensitive and thus very much threatened by the perfect storm of present-day challenges. Regional climate change has resulted in warmer temperatures and more intense storms, both of which affect lake water quality. Warmer water and a longer growing season, have a profound influence on lake biota making conditions prime for invasive species to displace native populations and promoting harmful algal blooms. Nutrient additions via stormwater runoff exacerbate these effects by carrying mineralized nutrients to our waterways from destabilized post-glacial soils.

Coincident with these are increased demand for year-round shorefront homes, expansive upland watershed development due to increases in population, and longer construction seasons. Impervious surfaces, overtaxed absorbative capacity of soils, and aging septic systems, some of which are in some degree of failure, have resulted in the Maine Department of Environmental Protection (DEP) expanding its list of threatened or impaired lakes, and prioritizing additional lake watersheds for remediation. Lake protection through raising public awareness and protection efforts is less costly than restoration.

Some of these threats to lake ecosystems were recognized at the passage of the Clean Water Act in the early 1970s and provided the impetus for developing a cost-effective means for gathering credible lake data from Maine lakes.

Fifty-five years ago in 1971, the Volunteer Monitoring Program (VMP) was established in statute by the Maine Legislature. This program resulted from early discussions initiated by DEP (Matt Scott) among University of Maine and Maine college scientists. Numerous meetings were held to determine which parameter would be the best choice for members of the public to collect.

Following lengthy talks and consultations, Secchi Disk transparency was chosen. Lake clarity is a simple, intuitive indicator of water quality and lake health, easily understood by the public. The legislation allowed members of lake communities to be trained and involved in the collection of data under the supervision of staff in the Maine Department of Environmental Protection (DEP).

Maine now has an extensive quality-assured data set on nearly 900 lakes, gathered by more than 1,000 volunteers. Comparisons of these volunteer-acquired results to data collected by limnological professionals have demonstrated that trained volunteers are capable of collecting credible information according to established QAQC protocols, of research and regulatory quality, capable of withstanding any legal challenge. Maine's program became a national model and catalyst for similar volunteer efforts as there are now at least 900 volunteer-monitoring initiatives in the U.S according to United States Environmental Protection Agency (EPA) estimates!

Unfortunately, state funding became an issue in the early 1990s putting the program in jeopardy. A committee was formed to explore options for saving the program. The final solution was to create the Maine Volunteer Lake Monitoring Program (VLMP) (Figure 1), a private 501(C)3, non-governmental organization (NGO), which eventually fell under Lake Stewards of Maine (Figure 2) umbrella (LSM-VLMP). The DEP has continued to provide partial funding for the organization, and because the program is an NGO, it has been able to successfully supplement state and federal funds with donations from individuals, lake associations, and charitable foundations.

Who are the volunteers of VLMP?

Formerly known as volunteer lake monitors, our *Community Scientists* come from all walks of life, with their passion for lakes in common. They are driven by a strong sense of lake stewardship, which gets to the core of why Maine's program has been so successful. Many volunteers have been continuously active gathering data on their lakes for multiple decades. Volunteers are essentially the eyes of professionals in the field. With thousands of Maine lakes within public domain, sufficient funding for state agency professionals to gather the data necessary to understand and protect them is unlikely. In Maine, volunteers collect valuable data used by several state agencies, including the departments of Inland Fisheries and Wildlife, Marine Resources, and Agriculture, Conservation and Forestry. Although the objectives and agency missions vary, agency staff depend on trained members of the public to gather essential data for decision making.

Evolving the program

Through the years, many additional parameters have been added to the program, including sampling for total phosphorus, and gathering temperature and dissolved oxygen profile data (Figure 3). The growing threat of aquatic invasive plants has drawn in several hundred additional volunteers who have received

Figure 1. A photo array of Lake Stewards in action.

Figure 2. Lake Stewards of Maine logo.

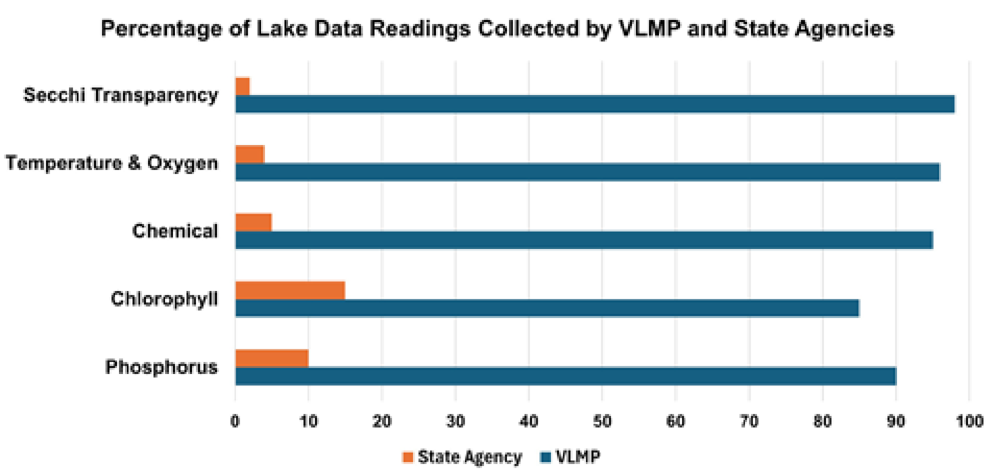


Figure 3. Graph showing the percentage of data collected by volunteers (blue bars) compared to state agencies (orange bars).

training ranging from invasive plant screenings to full shoreline plant species surveys. Interested volunteers may also be trained to participate in "lake watershed surveys" to detect and help resolve land uses that contribute to lake degradation. All of this requires additional training with a continued strong emphasis on quality assurance of the data.

It was recognized early on that success of the program would be dependent on valuable feedback to volunteers concerning their work. In the early days, paper reports were provided to volunteers; now data are presented and summarized on the Lakes of Maine website. Presently, regular meetings with volunteers at training and recertification workshops, newsletters, online technical support sessions, webinars, and an annual conference are the norm. Conference presenters highlight the ways in which volunteer data has been used to help understand and protect their lakes, and individual volunteers are recognized for their longevity in the program.

In order for the LSM-VLMP to be successful over time, there will need to be continued financial support from both the public and private sectors. Legislation has been passed since 1971 to provide dedicated funding to the DEP for lake resources (1974, 1987, 1998, 2023, 2025), but cuts often roll these allocations back. Because LSM-VLMP has provided a stable platform for volunteers, lake data gathering has weathered these state cutbacks and the data gathered by volunteers continues to be available to all interested stakeholders.

Impressively, the time and resources that volunteers provide through their work is of considerable value, estimated to be over $721,000 annually!

In retrospect, the transition of the VMP from the DEP to an NGO was probably good fortune: the organization continues to benefit from working closely with the powerful technical support and quality assurance overview provided by the DEP Lakes Program, while having the flexibility of being an independent organization that has the ability to raise funds from diverse sources, and to act quickly when opportunities arise that benefit the program and its constituents. It is the author's goal of this report to recognize Maine's volunteer lake monitors for their 55 years of dedicated efforts, and to encourage new volunteers to become involved. The State of Maine is deeply appreciative of your good work!

Acknowledgements

Success of Maine's community scientist-based lake monitoring program would not have been possible without the help of an incredible team of shepherds over the past 55 years – too numerous to list. Special recognition goes to Roy Bouchard who succeeded the senior author upon his retirement as the Lakes Section leader in 1988, followed by co-author Linda Bacon who recently retired and passed the torch to Jeremy Deeds. Co-author Scott Williams deserves special credit for his dedication and success growing the program after it became a non-profit organization. Special thanks to Alison Cooney, current Executive Director of Lake Stewards of Maine (LSM), and Barbara Welch, recent President, now Vice President of the LSM Board.

Matt Scott, a founder of the Lakes Section at the MEDEP, and founder of the VMP, is now in his retirement. He started with three volunteers! Matt is the past president of NALMS (1988-89) and the 2024 recipient of the NALMS Secchi Disk Award.

Scott Williams was the Executive Director of LSM-VLMP for 26 years, during which time the organization expanded substantially the numbers of lakes, volunteers and scope of operation. He continues to monitor a number of Maine's lakes and to share his experience and passion with volunteers and lake communities. He was the recipient of NALMS Technical Excellence Award in Public Education and Research in 2000.

Linda Bacon, Limnologist, is currently serving as President of the LSM Board of Directors. She retired as DEP's Lake Assessment Section's Leader in 2025 after working closely with LSM on QA/QC protocols and data management. Prior to that, Linda worked on lake acid rain projects while earning her master's degree at the University of Maine (Orono).

Summers are short, but volunteer participation **is long-term in New Hampshire**

Amanda McQuaid, Georgia Bunnell, Alyssa Daigle, and Bob Craycraft

A nearly 50-year history of water quality monitoring in New Hampshire

The University of New Hampshire's (UNH) Lakes Lay Monitoring Program (LLMP) is a citizen-based monitoring program that was established in 1979 and has since grown to become one of the largest and longest-running volunteer lake monitoring programs in the Unites States. UNH LLMP originated in response to public concerns around declining water quality and changing watersheds. UNH faculty, staff, and students pioneered the incorporation of trained volunteers for frequent, cost-effective monitoring in New Hampshire lakes. Shortly after, in 1985, the New Hampshire Department of Environmental Services (NHDES) added a program of their own, the Volunteer Lake Assessment Program (VLAP). Together, the two programs have covered water quality monitoring for over 300 lakes in the Granite State.

Each year, hundreds of volunteers contribute thousands of hours collecting and processing water samples that inform statewide assessments and long-term trend analyses (Figure 1). Along the way, volunteers receive hands-on training in scientific monitoring techniques and learn to identify emerging threats to lake health – from aquatic invasive species and harmful cyanobacteria blooms to the impacts of stormwater runoff. Their dedication not only deepens our understanding of New Hampshire's lakes but also helps ensure these treasured waters remain healthy for generations to come.

Figure 1. LLMP interns train volunteer monitors on how to use sampling equipment.

Figure 2. Georgia Bunnell prepares a set of total phosphorus samples to be analyzed.

How low can the LLMP go when testing low-nutrient lakes?

For over 40 years, LLMP has run

their nutrient samples by hand (Figure 2). The phosphomolybdate ascorbic acid method allows the lab to measure total phosphorus concentrations as low as 0.8 ppb, and 0.3 ppb for orthophosphate. Precise detection limits are crucial for many New Hampshire waterbodies that are oligotrophic, meaning they naturally contain very low nutrient concentrations. These analytical techniques provide a better understanding of how the lakes are biologically changing over time, even at the smallest scale. Total nitrogen is also analyzed spectrophotometrically, with a detection limit of 100 ppb.

Although these techniques can be intricate and time-sensitive, they provide competitive laboratory skills and freshwater chemistry knowledge to student interns that they will carry with them into their future careers. As one of the only laboratory facilities in the state that utilizes these methods, LLMP conducts comprehensive water quality monitoring from 118 waterbodies historically. With nearly 1,000 lakes in the state, there is always more to do!

A statewide network of volunteer lake monitors

Each year, VLAP brings together hundreds of volunteer monitors for a workshop focused on reinforcing lake ecology concepts, retraining volunteers on EPA-approved water sampling methods, and highlighting emerging threats such as aquatic invasive species, stormwater runoff, and harmful boating practices (Figure 3). The workshop also provides an opportunity for volunteers to connect directly with state biologists at NHDES, strengthening communication and support across the program. Educating volunteers provides them with the necessary training to carry out monitoring independently, sustaining the program's long-term success.

The Jody Connor Limnology Center at the NHDES offices in Concord processes most of the samples for the majority of waterbodies participating in VLAP, but with over 180 lakes in VLAP, the program relies heavily on the Colby-Sawyer College (CSC) satellite lab in New London, NH, managed by Teriko MacConnell and operated in partnership with the Lake Sunapee Protective Association.

Figure 3. Volunteer monitors attend the annual VLAP workshop at the Lake Sunapee Protective Association Center.

This facility extends program capacity by supporting sample analysis and volunteer coordination, effectively bridging monitoring efforts between the Sunapee region and the rest of the state. VLAP and LLMP also collaborate with several partner organizations that engage local communities in water quality monitoring efforts, such as the Green Mountain Conservation Group, Winnisquam Watershed Network, Lake Winnipesaukee Alliance, Acton-Wakefield Watershed Alliance, Newfound Lake Region Association, Wentworth Water Association, and Squam Lakes Association. Additionally, several lakes participate in both VLAP and LLMP, which strengthens monitoring efforts across programs and provides a more comprehensive dataset to inform additional research questions.

A future of collaboration and comprehensive monitoring

As lakes throughout New Hampshire and the world continue to experience adverse impacts from warmer temperatures and extreme weather events, the need for more freshwater monitoring has increased to better understand how our lakes are changing with the climate (Figure 4). LLMP and VLAP both advocate for more sampling during critical periods, such as late summer when lakes are fully stratified as well as after lake turnover, so both researchers, lake managers and volunteers alike can analyze the seasonal behavior of lakes, especially as cyanobacteria blooms and phosphorus loading continue to become prevalent issues. Open communication between volunteer programs and the public is key to strengthening education and research while building relationships with lake communities.

New Hampshire's water quality monitoring efforts are effective because of strong coordination between NHDES, VLAP volunteers, CSC, UNH, LLMP volunteers, and partner organizations operating under standardized methods. This allows multiple volunteer programs to function as a cohesive network, generating high-quality data that feed into the state's Environmental Monitoring Database to inform lake management decisions and keep the public informed through the NHDES Lake Information Mapper and the LLMP Lake Reports. Monitoring New Hampshire's lakes is a unique collaborative effort that is made possible by the hundreds of dedicated volunteer monitors across several programs and organizations.

Figure 4. A loon on Squam Lake, one of the lakes participating in LLMP.

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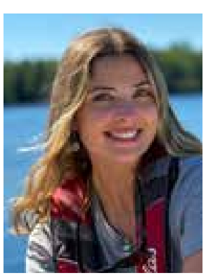

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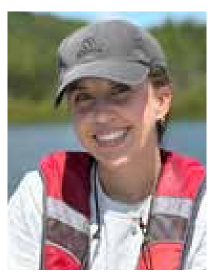

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Send comments by letter or e-mail to editor Amy Smagula (see page 5 for contact information).

Reassessing the shoreline, **reconnecting with place**

Andrew Miller, Georgia Peck, and Tammy Davies

In British Columbia, Canada, a landmark shoreline survey is bringing Indigenous Knowledge and Western science together to guide the future of Kalamalka Lake (Figure 1) and Wood Lake (Figure 2).

Kalamalka Lake, named after a Syilx leader whose village once stood at its head, and nearby Wood Lake lie within Syilx Okanagan territory, where water has long been central to life, culture, and identity. These lakes were once places of gathering, healing, and abundance, supporting fisheries, travel routes, and settlement for generations.

Over the past century, however, development, privatization, and increasing recreational use have reshaped these shorelines. Access has been restricted,

Figure 1. Kalamalka Lake, known as k´ək´maplqs, before 1913. Museum and Archives of Vernon Photo.

Figure 2. Wood Lake and Cariboo Trail in 1897. Source: Lake Country Museum and Archives Photograph Collection.

ecological integrity has been compromised, and longstanding relationships between people and water have been disrupted.

Today, a new collaborative effort is working to better understand, and ultimately restore, these lakes. Co-led by the Okanagan Indian Band (OKIB) and Living Lakes Canada, a comprehensive shoreline survey is documenting both ecological conditions and cultural values, offering a more complete picture of what these lakes are, and what they can become.

At the heart of the project is a commitment to seeing the landscape through more than one lens. Rooted in the principle of Two-Eyed Seeing, the work brings together Indigenous Knowledge and Western science in a way that allows both to inform decision-making. A Local Indigenous Knowledge and Values Framework, co-developed by Living Lakes Canada and the Upper Nicola Band, guides the process, ensuring that cultural perspectives are not added on, but embedded from the outset.

To assess ecological conditions, the team is applying the Foreshore Integrated Management Planning (FIMP) protocol, revisiting surveys first conducted in 2009. Using boats (Figures 3 and 4), drones, and field observations, the survey maps shoreline habitats, evaluates ecological health, and tracks how the lakes have changed over time.

Running alongside this work is a Cultural Overview Assessment led by OKIB in partnership with Kwusen Research. Through conversations with Knowledge Keepers, the assessment documents cultural and archaeological values that have long defined these waters but have often been overlooked or excluded from formal planning processes.

For the Okanagan Nation, the significance of these lakes extends far beyond their physical characteristics. At the head of Kalamalka Lake, known as k´ək´maplqs in nsyilxcən, land once designated as reserve was taken in 1913 under the McKenna–McBride Commission, cutting off direct access to the water. This loss was not only physical, but deeply cultural and spiritual.

"The surrounding lake was regarded as a medicinal lake, where medicine men treated ailing people," recalled a descendant of Chief Kalamalka in a 1979 interview. "It has been said that if a person entered the lake while it was changing colour from the sun's rays, they could be cured."

Today, barriers to access remain. Privatized shorelines, development pressure, and experiences of discrimination have limited Indigenous use of these lakes. As one cultural advisor reflected, "It was pretty obvious that the new white people that came in really enjoyed that beach and enjoyed it much more without any Indians on it."

Despite these challenges, the knowledge and stories tied to these places endure. Through the Cultural Overview Assessment, several Culturally Sensitive Areas have been identified, sites of deep historical and cultural importance. While many archaeological features have been lost to development, their significance

Figure 3. Kalamalka Lake FIMP Training. LLC Photo.

Figure 4. Kalamalka Lake FIMP Training. LLC Photo.

continues through community memory and cultural teachings.

By documenting these values alongside ecological data, the project creates space for voices that have too often been excluded, helping to shape a more inclusive approach to shoreline management.

The work is also building capacity within the OKIB community (Figure 5). Eight members completed a Living Lakes' two-day training program that combined scientific methods with cultural perspectives on shoreline assessment. Four of those participants went on to join field crews, collecting data and capturing drone imagery alongside environmental consultants.

For those involved, the experience is more than technical training, it is a reconnection with place.

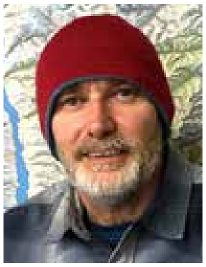
Looking ahead, the survey covers 42 kilometres of Kalamalka Lake shoreline and 13 kilometres of Wood Lake. Results, expected later this year, will map ecological value, identify areas of disturbance, and inform new Foreshore Development Guidelines.

But the impact of the work is already being felt.

For Living Lakes Canada, this project represents an evolution in how shoreline assessments are conducted, moving from purely technical exercises toward approaches that recognize the importance of relationships, history, and lived experience.

For OKIB, it reflects the continuation of Syilx stewardship within their territory, supported by new tools and strengthened partnerships.

Together, the project offers a model for how freshwater management can be approached differently, one that respects Indigenous leadership, integrates multiple ways of knowing, and responds to both ecological and cultural realities. In doing so, it moves beyond understanding the shoreline as a boundary, and instead re-establishes it as a place of connection, responsibility, and care.



Andy Miller brings a career in project management and operations to the Deputy Director role at Living Lakes Canada. Born and raised in the UK, he arrived in Canada, then to the East Kootenay, after working across England, Scandinavia, and Spain. He brings more than 30 years of experience in working with, developing and supervising multiple teams, and planning and executing organizational demands across a variety of industries: manufacturing, engineering, transportation, tourism, communications and marketing, retail and, most recently, the environmental nonprofit sector.

Georgia Peck is the Lakes Program Manager at Living Lakes Canada, where she has led the Foreshore Integrated Management Planning (FIMP) program since 2020. In this role, she oversees nationally recognized, community-driven lake stewardship initiatives that support evidence-based decision-making across Canada. With a professional background spanning public outreach, environmental education, and the management of local stewardship organizations, Georgia brings a strong applied perspective to freshwater governance. She holds a Bachelor of Science in Conservation Biology from Trent University and is currently completing a Master of Environmental Practice at Royal Roads University. In 2022, Georgia co-authored the "Local Indigenous Knowledge and Values Framework," a foundational advancement for lake assessments that meaningfully bridges Indigenous Knowledge systems and Western science within a federally developed protocol. Her work has helped embed reconciliation, respect, and practical collaboration into lake management practices nationwide.

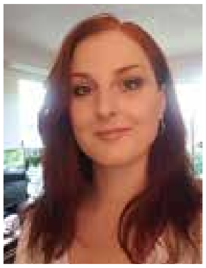


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Figure 5. Kalamalka Lake shoreline during the FIMP training with OKIB. LLC Photo.

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The Lake Partner Program:
Empowering passion

Gavin Vance

Lakes are the backbone of the cultural zeitgeist in Ontario. Lounging on docks in Muskoka and beach days along the Great Lakes are core memories for many. But what happens when these lakes are under threat?

The creation of the Lake Partner Program (LPP) in Ontario

For many in Ontario the realization that lakes were under threat began in the late 1960s, when Lake Erie was famously declared dead due to intense eutrophication. This triggered the rise of public concern around lake health across Ontario. In response, the Ministry of the Environment (now the Ontario Ministry of the Environment, Conservation and Parks; MECP) introduced a "self-help" program in the early 1970s which encouraged individuals to monitor their own lakes for chlorophyll-*a*.

The success of the original "self-help" program, alongside educational work led by partner organizations such as the Federation of Ontario Cottagers' Associations (FOCA) for, among other topics, acid rain (Figure 1), helped raise public awareness around lake health in Ontario. In the late-1990s, MECP and FOCA partnered to form the Lake Partner Program (LPP), a community science water quality monitoring program that replaced the "self-help" program. In its current form, the LPP engages hundreds of volunteers and community scientists across Ontario to sample lakes for concentrations of total phosphorus, calcium, chloride, sulphate, and water clarity.

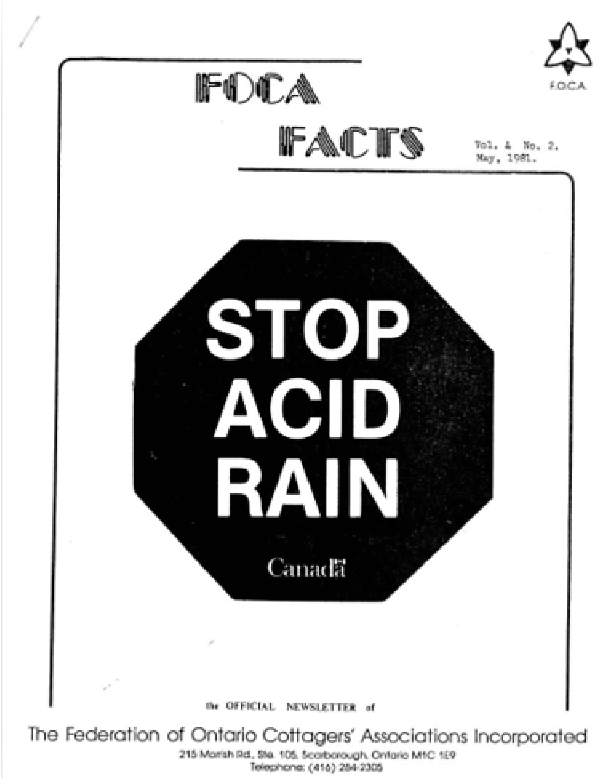

Figure 1 shows a 1981 FOCA publication that discusses acid rain. FOCA was part of the "Who'll Stop the Rain?" campaign in the US that led to changes to prevent acid rain impacts across North America,

Long-term datasets

The LPP offers a path for dedicated volunteers to help protect the lakes they love. An important outcome of the LPP is the maintenance of a long-term, publicly accessible database of water quality for Ontario's inland lakes. As of 2026, over 2000 volunteers (and counting) have participated in the LPP. Collectively, these volunteers have sampled thousands of lakes across Ontario.

To understand if a lake is changing, we must first understand what a lake's baseline is, and how water quality varies naturally over time. This requires long-term data. As of 2025, the LPP has established reliable long-term water quality data for over a thousand lakes in Ontario. For example, there are currently more than 1,120 lakes in the LPP program with at least three years of monitoring data, and over 570 lakes with at least 10 years of data. Impressively, there are 236 lakes with more than 20 years of data, making the LPP the most comprehensive public inland lake dataset in the province of Ontario (Figure 2).

When accompanied by other inland lakes' datasets in Ontario, the LPP can provide important insights into what may be driving trends in water quality, as has been shown in many examples throughout the history of the program. Indeed, the LPP shows the power of volunteer action that, when combined with professional research can be turned into real world solutions for communities across Ontario.

Data in action

Scientific research requires patience and diligence, and there is often little fanfare when it is complete. Volunteer samplers may not always see how tracking LPP data directly contributes to improving our understanding of freshwater lakes over time. The more that LPP volunteers become aware of how their data are being used, the more they appreciate and can share the fruits of their labor.

One of the most important steps in the development of the program's database has been ensuring that the methods used to collect data generate accurate results. Early LPP data helped establish the best methods and protocols for measuring long-term trends in total phosphorus concentrations across Ontario lakes. For

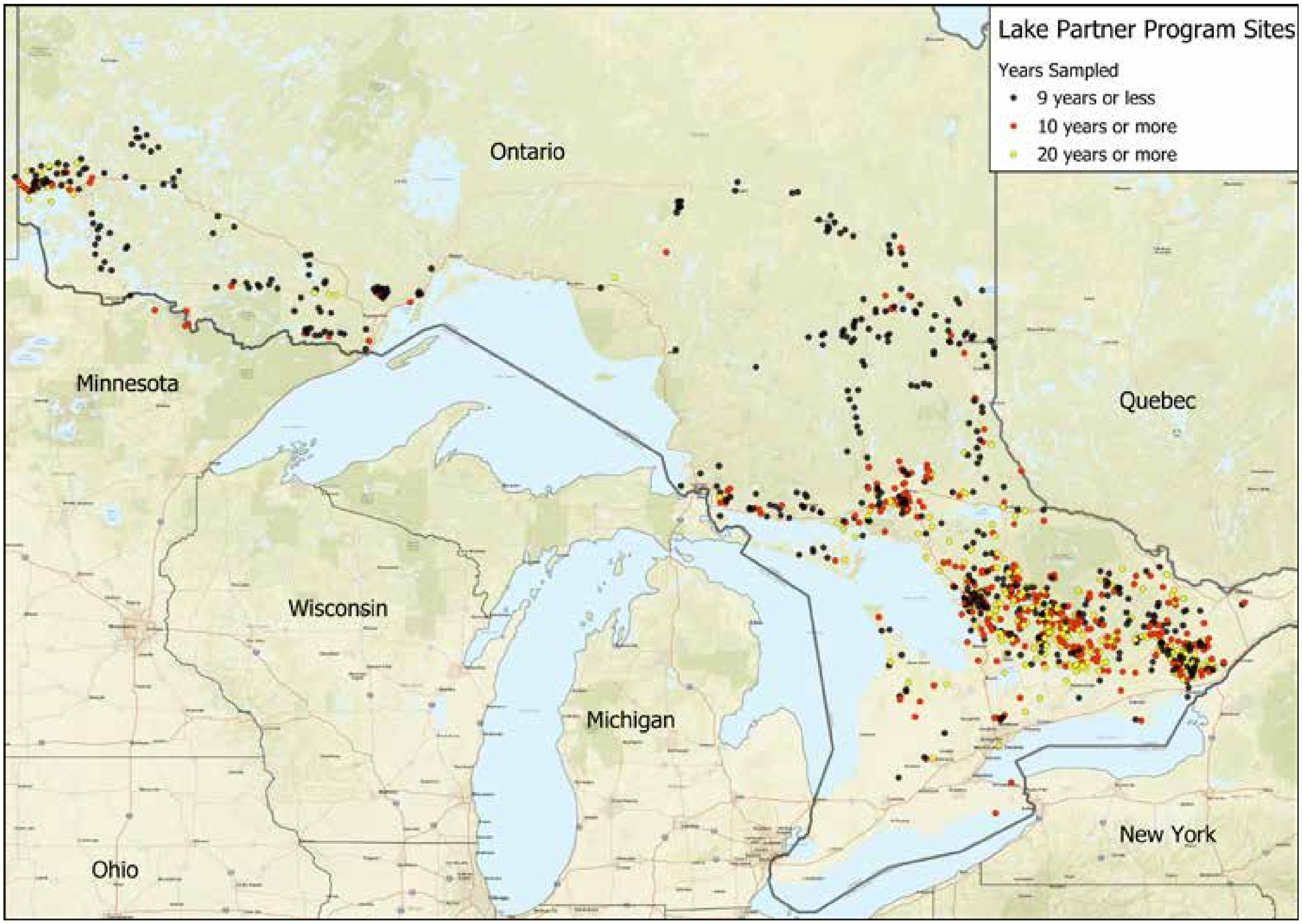

Figure 2 shows distribution of 1129 LPP sites, as of 2025. Sites with 3-9 years of data (554 total) are represented with black dots, sites with 10-19 years of data (337 total) with red dots, and sites with 20 plus years of data (236) in yellow dots. Basemap from Esri. (n.d.). National Geographic World Map [Basemap]. ArcGIS Online. https://services.arcgisonline.com/ArcGIS/rest/services/NatGeo_World_Map/MapServer

example, Clark et al (2010) reported that sources of variation in total phosphorus measurements could be reduced through precise laboratory analysis, sampling directly into the same borosilicate glass tubes used to digest the samples prior to analysis, and by coarse filtering water samples to remove large zooplankton. This work confirmed that the LPP methods produce reliable long-term phosphorus trends, paving the way for broader use of the data in lake research.

LPP data were subsequently used by Favot et al (2023) to explore possible reasons for an increase in public reports of toxic algae blooms in Ontario lakes over the last two decades. LPP data helped determine the nutrient status of many of the lakes examined in the study and bolstered the finding that recent climate warming may be creating more favorable conditions for blooms in lakes that previously did not experience them.

Recently, LPP data have been used by community scientists to examine the effects of road salt on *Daphnia* populations and lake health more generally (Arnott et al. 2020; Greco et al. 2021). For example, Sorichetti et al (2022) included LPP data in a recent assessment showing widespread increases in chloride levels in freshwater lakes and streams across Ontario from the 1960s to 2019. Such papers have been cited by LPP volunteers, local lake associations, municipalities and other stakeholders, as they negotiate policy changes to reduce road salt overuse during winter months in Ontario.

Empowering and sustaining volunteer passion

Community science can be demanding on volunteers. In the case of the LPP, it involves getting up early in the summer months, getting out on the boat and staring into the lake bottom while others are sipping coffees on the patio or dock. Now don't get it wrong: many of our volunteers find the sampling process fun, but it is also a big commitment and a lot of unpaid work for little fanfare.

The LPP began because of the passion that individuals hold for their lakes. Volunteers first transform this passion into taking lake samples and for some the engagement stops there. But for those whose passion drives them to dive deeper, the program provides resources to educate volunteers on wider related topics of lake health and science. This allows for them to deepen their knowledge of lake health topics based on their own pace and personal levels of interest.

This is where the partnership with FOCA is particularly important for the program. Since 1963, FOCA has thrived as a not-for-profit membership organization that has provided seasonal cottagers and lake residents more broadly with educational information on a wide swath of environmental topics. By hosting LPP publications on FOCA's website and social media pages, they enable volunteers to learn about why they are sampling their lake, and how the parameters they measure affect lake health. These public-facing communications have had the added benefit of helping to recruit new volunteers to the program (Figure 3)

Through a process of self-education, volunteers transform into community scientists by sharing what they have learned about lake water quality at local community events and lake association meetings, providing overviews of last year's sampling results alongside related topics of local interest.

This interaction between LPP volunteers and their communities not only educates others about water quality but also motivates them to get involved in the stewardship of their lakes. What starts simply as lake sampling can transform into lake wide programs that focus on shoreline naturalization, invasive species identification and removal, septic system education and reinspection programs, fish habitat restoration, and other important lake stewardship activities. As community scientists become more established in the program, they use LPP data to inform the stewardship of their lakes at community, township, and even provincial levels through lake plans, municipal by-law and Official Plan engagement, and environmental advocacy.

When it all comes together

The LPP is a product of a special blend of the right people coming together at the right time, including passionate individuals, communities, organizations, and a provincial Ministry that recognized a public need and determined a means to serve it, while developing a low-cost community-science implementation model that is well suited to a large province with hundreds of thousands of lakes.

This partnership continues today, as passionate community members use the program and its resources – sampling equipment, lab analysis, lake reports and other educational resources – to bring their communities together to protect and conserve their lakes and surrounding ecosystems. What makes the LPP a success is not just the cost-savings, the broad spatial coverage, the equipment provided, or even the data collected; it is the volunteers who dedicate their time to monitoring our lakes. As long as these devoted lake stewards remain enthused and supported, the data they collect will continue to advance the protection of Ontario's lakes and the communities that rely upon them.

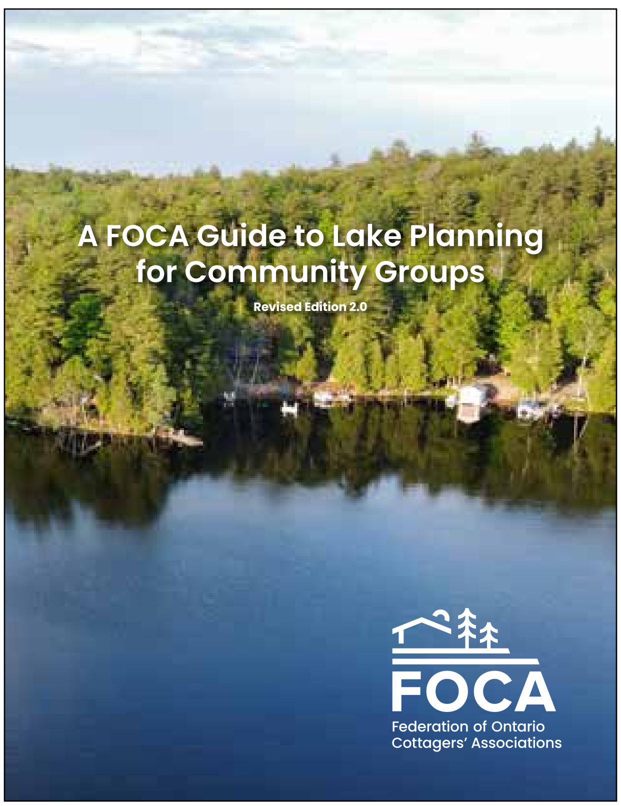

Figure 3 shows FOCA's Lake Planning Guide that was revised in 2026. This publication brings together information and experience from lake associations across Ontario.

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Lake Erie Rangers:
Community scientists on the frozen frontline

Gabrielle Parent-Doliner

In February of 2026, Tom Liszt stood at the edge of a stormwater pond in Fonthill, Ontario, dipped his chloride test strip into the water, and watched the numbers climb. It had been a historically cold and icy winter across the Lake Erie basin, so elevated chloride was expected. Still, when his result registered 2,427 mg/L, nearly four times the acute guideline set by the Canadian Council of Ministers of the Environment (CCME), it was shocking. Nearby, another Lake Erie Rangers volunteer monitoring a stormwater pond near the Hamilton International Airport recorded 6,507 mg/L. That's more than ten times the acute guideline for freshwater health.
These weren't industrial spills or chemical accidents. The culprit was road salt (Figure 1).

Figure 1. Lake Erie Rangers winter road salt chloride test strip.

An invisible threat

Salt has been used to de-ice Canadian roads since experiments in the 1940s. By the 1970s, it had become the dominant method of winter road maintenance: cheap, abundant, and genuinely effective. Spread on roads, sidewalks, stairs, and parking lots, sodium chloride lowers the freezing point of water, melting existing ice and preventing new ice from forming. Studies suggest it reduces road accidents by an estimated 80 percent.

But salt doesn't disappear after use. It dissolves, separating into sodium and chloride ions that run off into soils, streams, wetlands, and groundwater. And once chloride enters a watershed, it accumulates.

The consequences ripple through the entire food web. Aquatic invertebrates form the base of the food chain and are among the most sensitive organisms, with some species experiencing toxic effects at concentrations at 10-20mg/L, well below the CCME's chronic guideline of 120 mg/L. Fish are affected both directly through gill function and osmotic stress, and indirectly through the collapse of their prey. Elevated salinity disrupts the natural stratification of lakes and ponds, reducing oxygen circulation and creating dead zones in deeper waters. Wetland and riparian plants, many of which are salt intolerant, show reduced germination and growth with increasing chloride exposure, degrading the buffer zones that protect waterways from further contamination. The cumulative effect is a slow but measurable decline in biodiversity across affected watersheds.

Despite these serious concerns, road salt remains largely unregulated in Canada, and there are significant gaps in the data we have about chloride in our freshwater bodies. Most water monitoring happens in the warmer months, April through September, meaning the entire winter salting season goes largely untracked, including the critical salt-loading events that follow spring melts, heavy rains, and mid-winter thaws. Spatially, coverage is thin. Outside of government and conservation authority programs, very little testing gets done. Those gaps are exactly what the Lake Erie Rangers were built to fill.

Water Rangers is also working to address the problem at the source. Their Keep It Fresh campaign educates homeowners, businesses, and municipalities about the impacts of winter salt use on freshwater and offers practical guidance on how to use salt more efficiently. Simple changes – like applying salt before a storm rather than after, removing snow before salting, and using no more than a coffee mug's worth for a standard driveway – can significantly reduce how much chloride ends up in local waterways. The campaign reflects a core belief at Water Rangers: that protecting freshwater requires both better data and better habits, and that individuals have a real role to play in both.

Water Rangers: Community science at scale

To understand Lake Erie Rangers, it helps to understand the organization behind it. Water Rangers is a Canadian not-for-profit social enterprise founded in 2015 by Kat Kavanagh on a simple but powerful idea: that the people who live closest to a body of water are among its most important guardians, and that giving them the right tools can help them monitor water and generate freshwater data that governments and institutions simply can't collect on their own.

The Water Rangers program develops affordable, accessible water quality testing equipment and pairs it with an open data platform where results can be logged, visualized, and shared. The platform is free to use, designed for non-specialists, and built so that data flows not just to individual users but into broader databases that researchers, policymakers, and conservationists can draw from. Every test taken by a Water Rangers volunteer becomes part of a growing, publicly accessible record of freshwater health across Canada and beyond. Water Rangers is active in 20 countries, with serious hubs of community science activity in the United States and United Kingdon.

The organization has run community science programs on lakes and rivers across the country, but Lake Erie, one of the most ecologically stressed and densely populated watersheds in North America, represents one of its most ambitious efforts to date. With support from a three-year, $330,000 grant from the Canada Water Agency's Freshwater Ecosystems Initiative (2024-2027) and Ontario's Great Lakes Local Action Fund, Water Rangers launched Lake Erie Rangers in 2024 with a mandate to develop new community science tools, fill data gaps, expand the monitoring season, and bring communities into active participation in the lake's recovery. Turning data to action is a central goal of the project.

Getting their hands wet

The Lake Erie Rangers program now has nearly 200 active volunteers monitoring the lake's watershed at over 200 locations, with hubs in both the east and west ends of the lake. They include individuals, high school classes, college and university students, retirees, and families. What these community scientists share is not a background in science but a connection to the lake and a motivation to do something about what's happening to it. To date, the program has collected more than 20,000 freshwater data points.

The program is managed by Water Rangers' director, Gabrielle Parent-Doliner, and community data coordinator, Kiersten Garside.

Tom Liszt (Figure 2) is one of 80 volunteers who've been monitoring winter road salts as part of the program. A trained Environmental Technician and semi-retired Inspector with the Canadian Food Inspection Agency, Liszt spent his career monitoring invasive plants, insects, and fungi for plant health. Now he channels that same scientific rigor into his five monthly monitoring sites across Welland, Wainfleet, and Fonthill.

"Without monitoring and sampling, we have no facts to act upon," he says, "and without our science-based knowledge we cannot initiate change. The open-access water quality data and observations I gather help our local communities understand the health of our streams, rivers and waterways. Healthy water has never been more important in Canada than it is today."

Together, Lake Erie Rangers' road salt monitors have taken 515 chloride tests at over 170 locations since 2024 (Figure 3). Of those results, 12 percent exceeded the CCME acute guideline of 640 mg/L, and 34 percent exceeded the chronic guideline of 120 mg/L, a striking dataset that simply wouldn't exist without community scientists willing to go out in January.

But the work goes well beyond collecting samples. Lake Erie Rangers volunteers are active participants in developing and refining the very tools they use in the field. Water Rangers' winter road salt monitoring test kit was iterated and improved with input from the people using it in real conditions. Volunteers also helped test safety equipment, including a

Figure 2. Selfie photo of Tom Liszt.

Figure 3. Lake Erie Rangers winter road salt chloride test strip.

3D-printed throw bucket designed to collect water samples while keeping volunteers safely away from unstable ice at the water's edge.

Monitoring protocols have evolved too. When Lake Erie hit 100 percent ice cover during the 2025-26 winter, a historically rare event, the program adapted quickly. Rather than suspend operations, volunteers pivoted to ice-on/ice-off observations, documenting the progression and recession of ice cover across the lake with photos and field notes. They recorded 187 ice observations over the season, adding a layer of phenological data that complements the chemical monitoring and contributes to a longer-term picture of how the lake is changing.

Beyond chloride, the Lake Erie Rangers are working to expand what community scientists can measure. The program is developing an *E. coli* monitoring kit using Roth R.Cards, focused on understanding fecal contamination for both environmental health and recreational water quality. In partnership with McMaster University, volunteers are also piloting a new nutrient monitoring method that uses periphyton, the algae and microorganisms that colonize underwater surfaces, as a biological proxy for phosphorus and chlorophyll-a levels. Rather than relying solely on chemical tests, this approach reads the health of the ecosystem itself, using living organisms as indicators of nutrient stress. (Figures 4 and 5).

All data collected is uploaded to Water Rangers' open data platform and automatically shared with the Great Lakes DataStream, where it's available in both interpreted and raw formats to anyone who needs it. By feeding into open platforms, Lake Erie Rangers volunteers don't just generate local knowledge – they contribute to a basin-wide picture of freshwater health that researchers, conservation authorities, and government agencies can act on.

The program's partnerships reflect that ambition. Water Rangers works alongside the Niagara Peninsula Conservation Authority and the Essex Region Conservation Authority, McMaster University, the University of Windsor's Real-Time Aquatic Ecosystem Observation Network (RAEON), Niagara College, First Nation communities, and NGOs like Swim Drink Fish. Because Lake Erie straddles the Canada-US border, the program also collaborates closely with the Lake Erie

Figure 4. E. coli *kit in action.*

Figure 5. Perisplates in action – McMaster student Karolina with Lake Erie Rangers volunteers getting device ready for deployment.

Volunteer Science Network, a binational community science effort overseen by the Cleveland Water Alliance and the Ohio EPA, ensuring that data and methods are consistent and comparable across the whole lake.

From Monitoring to restoring

Understanding a lake's health has a way of deepening your commitment to it. For many Lake Erie Rangers volunteers, monitoring the water wasn't enough, they wanted to help heal it.

That impulse has taken root most visibly in the western basin. The northwestern shoreline of Lake Erie has lost a staggering proportion of its original wetlands since European settlement. In Essex Region alone, approximately 97 percent of the original wetland area has been lost (Snell, 1989, as cited in Essex Region Conservation Authority, 2013). Agricultural drainage, shoreline development, diking, and land conversion transformed what was once one of the most productive freshwater ecosystems in North America into a largely degraded landscape.

These wetlands weren't just habitat for fish and wildlife. They were natural filters, absorbing and processing the nutrient runoff, particularly phosphorus and nitrogen, that now fuels the harmful algal blooms Lake Erie has become known for. Restoring even a fraction of this lost habitat is essential to the lake's long-term recovery.

In Windsor-Essex County, Lake Erie Rangers volunteers have joined the Essex Region Conservation Authority in three wetland planting events, getting their hands into the soil alongside conservation staff to plant native species: button bush, swamp milkweed, blue flag iris, cardinal flower, and butterfly milkweed. Each of these plants plays a specific role in a restored wetland ecosystem, providing habitat for pollinators, stabilizing shorelines, filtering runoff, and supporting the birds and amphibians that depend on this wetland habitat (Figure 6).

Figure 6. Essex region planting event volunteers.

Figure 7. Lake Erie Rangers volunteers.

In the Niagara region, volunteers participated in a tree planting event in Thorold's Ashby Park, helping to improve ecosystem health and reduce flood risk along another stretch of the watershed by planting over 600 native trees on the banks of the stream.

The people at the water's edge

The data is compelling. The numbers, 6,507 mg/L of chloride, 20,000 data points, 90 percent of wetlands gone, tell a real and urgent story about a lake under pressure. But the deeper story is the people.

It takes something beyond duty to stand on the frozen bank of a creek in January, test the near-freezing water, and record what you find. It takes love. Love for a place, and a clear-eyed refusal to look away from what's happening to it no matter how hard it is to see. That's what Lake Erie Rangers volunteers share: not credentials or affiliations, but a conviction that their lake is worth showing up for, season after season, in all kinds of weather.

The program is still growing. New hubs are expanding westward and even beyond the Lake Erie basin into other watersheds. The volunteer base continues to build. The monitoring protocols are getting sharper, the data richer, and the partnerships deeper. There is still a great deal of work to be done, more gaps to fill, more shoreline to restore, more winters to get through. But on the banks of Lake Erie, in communities from Windsor to Niagara, people are already doing it. (Figures 7 and 8).

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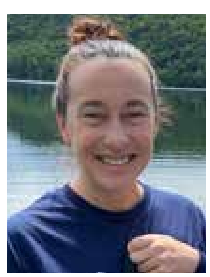
Figure 8. Lake Erie Rangers volunteers.



Gabrielle Parent-Doliner is a national leader in community-based water quality monitoring and Director at Water Rangers, a Canadian non-profit that empowers people to test and understand the health of their local waters. Her career has been focused on making water data more accessible and actionable and she led multiple community-based recreational water quality labs in Ontario and worked with researchers to pilot tools for community scientists. Through Water Rangers, she brings together local monitoring groups, municipalities, researchers, and environmental organizations across Canada, providing training, equipment, and easy-to-use tools that help communities collect, share, and understand their water data. A frequent speaker on community science and water stewardship, Gabrielle has presented at the Great Lakes Beach Association annual conference, the International Association of Great Lakes Research, with the International Joint Commission, and the State of the Lakes conference. She is driven by a simple vision: that giving people the tools to understand and protect their waters creates safer, more resilient, and more connected communities.

Preserving the legacy of lake ice records: Insights from a long-term community science network

Faith Ferrato, Sapna Sharma, Patrick Collins, Debra Kundert, Bill Raaths, Greg Sass, Georgina Shafer, Cathie Taylor, and Jennifer Tice

Introduction

Lake ice is a critical foundation for many northern communities. Lake ice forms the basis for cultural and recreational activities, from ice fishing and skating to community gatherings (Magnuson and Lathrop 2014; Knoll et al., 2019). In remote communities, seasonal ice cover also provides transportation and essential services, including access to food, fuel, and medical care (Hori et al. 2017). As lake ice becomes less reliable, the ecological, cultural, and social systems connected to it are increasingly disrupted.

Lake ice records collected directly by community scientists, some long before the advent of meteorological stations and even the start of the third Industrial Revolution, reveal that lakes are rapidly losing ice cover. Ice duration has declined by 18 days/century in lakes across the Northern Hemisphere, with rates of ice loss six times faster in the past 25 years (Sharma et al. 2021). Through consistent observations collected over decades to centuries, community scientists have helped build some of the most valuable long-term lake ice records available today (Sharma et al. 2022).

One such effort is the Community Lake Ice Collaboration (CLIC), established in the 1980s by Dr. Kenton Stewart to gather ice-on and ice-off observations from individuals across Maine, Michigan, Minnesota, New York, and Wisconsin (Sharma et al. 2023). These records have been used by scientists to study climate impacts on freshwater systems while also strengthening relationships between researchers and the communities most closely tied to these lakes. In this article, we share five perspectives from community scientists, each with their own motivations for contributing to scientific research (Figure 1). Together, we highlight the human side of community science and the powerful role individuals play in advancing our understanding of the world in a changing climate.

Honoring a family legacy

Bill Raaths entered into the world of limnology not through formal training or career ambition, but family connection. Bill Raaths is the brother-in-law of Kenton Stewart, a professor at the University of Buffalo who formally started the CLIC program in the 1980s. With a 15-year age gap, Ken became a big brother to Bill when Ken married Bill's older sister Ardis, shaping his life in lasting ways. Ken was Bill's first introduction to lake science, where he joined Ken on many early mornings of field sampling as a young adult.

Ken's passion for science was contagious, with Bill recalling his mother's refrigerator being crowded with water samples and quickly learning the importance of careful scientific methodology as one mistake meant starting over. These small moments left a lasting impression on Bill, remembering the time, care, and dedication that went into studying lakes.

Although Bill eventually built a successful career in business, his connection to lake science was rooted in these experiences as a young adult with Ken. Years later, after purchasing a cottage on Hills Lake in Wisconsin, Bill began recording ice dates for CLIC in 2013. He was hesitant at first, as this meant early mornings and long drives, a familiar reminder of the commitment and work that was required. However, Bill came to see this participation as a way of carrying forward a small piece of Ken's life passion.

Over the years, Bill has noticed changes in the lake, with less snow and more variability in snow and ice conditions between years. Still, his motivation to continue monitoring is less rooted in climate advocacy, but more in respect and love for Ken. For Bill, collecting ice data is a way of honoring Ken, preserving the care and discipline that defined his approach to science. In doing so, Bill feels he is maintaining a small but meaningful portion of Ken's legacy, or as he puts it, Ken's "magic."

Forging a community connection

For Georgina Shafer and Jennifer Tice, Fishers Lake in Three Rivers, Michigan, is more than just a place to live; it is the heart of their community and identity. Both have long ties to the lake, with family histories rooted in the same shoreline. For generations, seasonal activities like skating, swimming, and family gatherings have shaped life along the water. They see it not as a separate place, but an extension of their home and a central part of community life. Their participation in community science through CLIC is closely tied with the continuation of the annual ice pool in Fishers Lake. Each year, community members contribute 25 cents to guess the date of ice-off, with the closest guess securing the winnings.

The ice pool tradition began in the 1970s with Molly Roth, known as the "ice queen," and her family. It then expanded beyond the Roth family to a shared community event as Molly welcomed broader participation and fostered a sense of collective ownership. It is likely that Ken Stewart had contacted Molly in the 1980s, inviting her to contribute these ice-off dates to CLIC and formally linking

Figure 1. Photographs illustrating the diverse culture, recreational, and scientific dimensions of lake ice: (A) appreciating natural beauty, shown by Fishers Lake frozen in winter (photo by Georgina Shafer); *(B) fostering community connections, featuring ice boats and a plane landed on the shoreline of frozen Lake Kegonsa* (photo by Debra Kundert)*; (C) winter recreation, depicted through communal ice fishing on Perch Lake* (photo by Pat Collins)*; (D) scientific monitoring, showing members of the Wisconsin DNR beginning spring sampling in Vilas county* (photo by Greg Sass)*; and (E) familial ties, featuring Bill Raaths with his brother-in-law Dr. Ken Stewart, founder of CLIC* (photo by Bill Raaths).

the local tradition with long-term scientific records. Now in its 48th year, the ice pool continues to bring the community together while generating invaluable long term ice data. By sustaining this tradition and contributing to CLIC shortly before Molly passed in 2021, Georgina and Jennifer honor Molly's legacy while strengthening community bonds. Their commitment reflects a responsibility to Molly Roth and honoring past traditions, as well as a desire to pass on environmental values to the future generations of people who will live on this lake.

Love for the environment

Pat Collins' long-term monitoring efforts reflect a lifelong interest in environmental systems and the belief in the power of consistent observations. His love for the environment is an extension of his 35 year long career at the Wisconsin Department of Natural Resources. Pat brought this passion home to Perch Lake in Wisconsin, where his family has lived since 1991. Perch Lake is a small, endorheic lake and very sensitive to precipitation making it particularly responsive to changes in the environment.

Pat has recorded ice dates, water levels, water clarity and water quality, viewing his backyard as a personal laboratory. He sees the lake as a living system that is deserving of careful attention. Over time, he and his family have witnessed fluctuations in water levels and a high increase in recreational pressure, reinforcing the importance of maintaining long term records.

This work is deeply meaningful to Pat because it provides undeniable and grounded evidence that lakes are changing in ways that affect people's everyday experiences. He takes pride in contributing his observations to the broader CLIC community, believing sustained local data helps ensure these changes are recognized beyond his own lake and within a broader understanding of a changing world.

Fostering lake stewardship

At Lake Kegonsa in Wisconsin, long-term ice monitoring is embedded in a broader culture of lake stewardship and community care. Through the Friends of Lake Kegonsa Society, a non-profit established in 1988 with roughly 500 members, Debra Kundert and Cathie Taylor help coordinate ice data collection alongside water quality monitoring, cleanup projects, education, and advocacy, all aimed at protecting the long-term health of Lake Kegonsa.

Ice records on this lake go back to 1902. It is believed that data was initially documented by the University of Wisconsin Centre for Limnology and then later individuals living on the lake. This includes Doug and Ardys Pfundheller and Sheryl Renslo, who independently kept extremely detailed handwritten ice records in a diary, reflecting a long tradition of close observation by lakeside residents. In 2016, the responsibility for recording ice dates formally transitioned to the Friends of Lake Kegonsa Society, ensuring the work would persist beyond a single observer.

Having lived on the lake for decades, Deb and Cathie have witnessed significant changes in development, water quality, and winter weather. For them, a key part of their stewardship is to continue to protect the lake itself, as well as its history. Ensuring these records continue beyond any single person is vital to stewardship, showing a commitment to learning from the past while also preparing future generations to care for the lake. By embedding ice monitoring within a stable organization, they guarantee the data will continue and inform future generations.

Commitment to open data science

Greg Sass' contribution to long-term monitoring stems from his commitment to open science and the communities that depend on these lake systems. As the fisheries research team leader with the Wisconsin Department of Natural Resources, Greg oversees five experimental fisheries research lakes in Vilas County, where ice observations have been recorded consistently since the Northern Highland Fishery Research Area founding in the 1940s.

Although the ice observations were not central to the original research objectives of fisheries-related projects, the continuation of these ice observations are now invaluable since being passed onto CLIC. Greg inherited responsibility for maintaining these records through his position and is committed to carry the work forward until it comes time to pass it on to the next individual. Greg's motivation does not lie in why these records began, but instead ensuring their continuity for whoever and whatever comes next. Over time, Greg has observed changes in ice duration and variability, recognizing ice cover as one of the most visible environmental signals for lake users with implications for recreation and local winter economies.

Shorter and more variable ice seasons disrupt activities such as ice fishing, snowmobiling, and skiing, creating cascading impacts for tourism-dependent communities in a region with few permanent residents. By contributing data to CLIC, Greg helps ensure that long term records remain widely available for scientific research and public understanding. For him, this data serves as a bridge between scientific observation and lived experience, strengthening awareness, informing local management decisions, and supporting the lakes and communities that rely on them.

Conclusions

Community based monitoring programs such as CLIC highlight the value of community science. Through sustained participation, community scientists generate long-term, *in situ* observational datasets that would otherwise be impossible to maintain through traditional funding sources alone, particularly at the vast spatial scales covered by CLIC community scientists (Lopez et al. 2023). The value of these long-term records is further amplified by the unique scientific insights they provide. *In situ* observations enable researchers to track ice phenology across hundreds of lakes, including smaller systems that are frequently missed by satellites or unrepresented in large-scale analyses.

Many of these community ice records also extend back decades to centuries, making them indispensable for long-term climate assessments (Sharma et al. 2022). Notably, many of the CLIC lakes are located in regions experiencing rapidly warming winters and some lakes are at high risk of losing seasonal ice cover in the coming decades. As a result, community-based monitoring provides critical data for understanding where and how ice regimes are changing.

Beyond the data they generate, community-based monitoring programs foster deep connections between people and the lakes they observe, encouraging stewardship rooted in lived experience and long-term relationships with the lakes. By grounding scientific research in local knowledge and ongoing observations, these programs help ensure that research remains relevant to the people most directly affected by changing ice conditions.

Partnerships between researchers and community scientists also build trust, strengthening the credibility and impact of scientific findings. In this way, volunteer engagement transforms data collection into a joint initiative that strengthens long-term environmental research and stewardship. As climate change continues to alter freshwater systems, volunteer monitoring programs will remain vital for generating the long-term datasets needed to document these shifts, affirming that meaningful environmental science is built through collaboration with the people whose commitment sustains both the research and the lakes themselves.

Acknowledgements

We are indebted to the late Dr. Kenton Stewart for his commitment and perseverance to establishing and growing the Community Lake Ice Collaboration (CLIC) for 35 years. We thank the hundreds of CLIC community scientists for their dedication to collect lake ice phenology records year after year. We are also grateful to the Natural Sciences and Engineering Research Council (NSERC) Discovery Grant, New Frontiers in Research Funds-International "Arctic Routes" project, and the York University Research Chair programme for providing funding to SS to continue this program.

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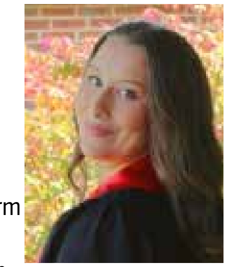
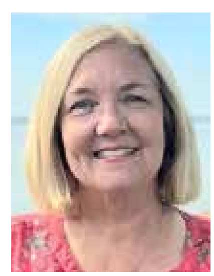


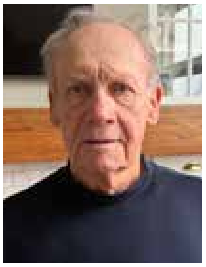
Faith Ferrato is a Research Assistant in the Department of Biology at York University working in the field of limnology. She recently completed a Master of Science degree at York University, where her research focused on lake ice phenology and how changing climate conditions influence freshwater ecosystems. Faith now works on collaborative research projects that use long-term datasets to examine climate-driven changes in lake ice and their implications for northern aquatic systems.

Sapna Sharma is a Professor and York Research Chair in Global Change Biology in the Department of Biology at York University. Her research aims to understand how lakes worldwide respond to climate change, including rapid ice loss, warming water temperatures, degrading water quality, and changing fish distributions. She is also a dedicated science communicator aiming to create more inclusive science communities, for example by founding SEEDS, an outreach program for refugee families, and serving as the Inaugural Founding Academic Director of the United Nations Institute for Training and Research (UNITAR) Global Water Academy. Sapna can be reached at sharma11@yorku.ca.

Patrick Collins has been a member of the Community Lake Ice Collaboration for 30+ years. Before he retired, he worked for the Wisconsin Department of Natural Resources as an environmental hydrogeologist. He enjoys hiking, biking, camping and spending time with his family and friends.



Debra Kundert is a retired Registered Nurse, Ultrasonographer who is enjoying lake life on Lake Kegonsa in southern Wisconsin. She volunteers her time on the Friends of Lake Kegonsa Society Board of Directors. Deb has been involved with numerous activities including organizing several educational presentations, performing end of pier water monitoring, installing Wood Duck houses, and monitoring the lake's ice events.



Bill Raaths retired as CEO and Chair of the Board of Great Northern Corporation, a leading packaging business headquartered in Appleton, Wisconsin. Bill is a graduate of the University of Wisconsin-Madison and a Vietnam veteran. Bill attributes his love for lakes to the many trips to Wisconsin and New York collecting lake samples with his brother-in-law and program founder, Ken Stewart.

Greg Sass is Fisheries Research Team Leader and Director of the Northern Highland Fishery Research Area in the Office of Applied Science with the Wisconsin Department of Natural Resources based in Boulder Junction, WI. His research primarily focuses on fisheries management and ecology, whole-lake experiments, and long-term ecological studies. You can contact Greg at Gregory.sass@wisconsin.gov.

Georgina Shafer is a retired Geographic Information Systems (GIS) Specialist with a background in Earth Science and Hydrogeology. She has led Fisher Lake's participation with the Community Lake Ice Collaboration (CLIC) since 2020; and along with her retired Environmental Engineer husband Eric, has collected data for the Cooperative Lakes Monitoring Program (CLMP) since 2010. She hopes to instill her love of the environment and nature with her grandchildren and future generations. You can contact Georgina at goldin.shafer@gmail.com.

Cathie Taylor grew up within walking distance to three of the five lakes surrounding Madison, WI – Lake Mendota, Lake Monona, and Lake Wingra, and spent summers swimming at their beaches with her friends. It was always her dream to live on a lake and in 1970, she and her husband, Emerson, bought their first lake house on Lake Kegonsa, the 5th lake of the chain of lakes connected by the Yahara River. Cathie joined the Board of Friends of Lake Kegonsa Society (FOLKS) in 2011 and was active on the Board until 2023. Having lived on this lake for 55 years, she has observed many changes. But nothing has changed her love for living on this lake and doing what she can to make sure it remains healthy for all of us to enjoy.

Jen Tice is a retired English teacher and public librarian with a broad background in the sciences. She is a prolific reader of nonfiction, especially Great Lakes geology. Jen has lived on Fisher Lake for 48 years and has family who live on the lake. Jen considers the lake to be an extension of her front yard and seeks to nurture the lake just as she does her family and gardens. Her favorite hobby is rock and fossil collecting.

Small streams fuel big insights:
Volunteer monitoring in the Beaver Lake Watershed

Olivia Schaap, Erin Scott, and Ayla Grace

In Northwest Arkansas, Beaver Lake is a vital water resource, supplying drinking water to over 600,000 people—roughly one in every five Arkansans. It also supports outdoor recreation, agriculture, and economic growth in a rapidly developing region. The lake – an impoundment of the White River – is situated in a 1,186-square-mile watershed of forests, pastures, and urban areas, all on top of sensitive karst geology characteristic of the Ozarks. Water quality monitoring across this watershed is a vital pillar of the source water protection plan (SWPP) for Beaver Water District (BWD), the largest of four water utilities on the lake. However, comprehensive monitoring within the watershed is a task no single entity can accomplish alone.

To support monitoring efforts and engage community members, a volunteer-powered water quality monitoring program, StreamSmart, was established in 2013. StreamSmart is coordinated by nonprofit H2Ozarks in partnership with BWD and a state-certified laboratory, the Arkansas Water Resources Center (AWRC). For over 12 years, trained citizen scientists (Figure 1) have been collecting water samples at smaller creeks and streams across the watershed to establish a robust dataset on small tributary sites not monitored by other organizations.

The StreamSmart Citizen Science Program exemplifies how community engagement strengthens watershed protection. By combining volunteer effort with scientific oversight, StreamSmart provides a cost-effective, long-term approach to monitoring the health of Beaver Lake's tributaries. The result, more than a decade later, is one of the longest and highest-resolution water quality datasets available for the streams that feed one of Arkansas's most important drinking water reservoirs.

Figure 1. StreamSmart Program Manager, Ayla Grace, collecting a water sample during volunteer training.

How the StreamSmart program works

StreamSmart manages 37 volunteers across 15 active monitoring sites, with volunteers sampling quarterly – in March, June, September, and December. Volunteers collect water samples (Figure 2) during baseflow conditions, and deliver them to the AWRC Water Quality Laboratory for analysis of the following:

- Total nitrogen (TN)
- Total phosphorus (TP)
- Total suspended solids (TSS)
- Total dissolved solids (TDS)
- Alkalinity
- Conductivity
- pH
- Turbidity

Figure 2. Two volunteers collecting water samples.

Figure 3. A group of new StreamSmart volunteers, many of whom are master naturalists, receiving training on macroinvertebrate identification.

Volunteers also collect site observations, temperature, and measure dissolved oxygen (D.O.). During warmer monitoring periods in June and September, they use kick nets to collect and identify macroinvertebrates. These aquatic organisms are excellent indicators of water quality and are many volunteers' favorite aspect of the program. Uncovering small creatures like mayflies and water pennies from seeming obscurity provides the kind of up-close encounter with nature that many volunteers treasure.

All volunteers are trained and follow standard operating procedures outlined in a Quality Assurance Project Plan (QAPP), which ensures data consistency, accuracy, and reliability. These data are eligible for submission to state agencies and have been incorporated into watershed-scale planning efforts such as an EPA-approved Watershed Management Plan.

Volunteer engagement and retention

One of StreamSmart's most effective strategies for recruiting and retaining volunteers is through a strong relationship with the Northwest Arkansas Master Naturalists (NWAMN). The NWAMN is a local chapter of volunteer naturalists who educate and work to protect their local natural areas. H2Ozarks teaches a class to new master naturalist cohorts as part of their training curriculum. This class introduces participants to basic water quality concepts, and goes over the StreamSmart program, mission, and impact. Some Naturalists-in-Training choose to join as volunteers upon their graduation, helping sustain the program (Figure 3).

This partnership benefits both organizations. Master naturalists gain reputable educators, technical training, and a unique volunteer opportunity. StreamSmart gains a recurring pipeline of dedicated, passionate volunteers. Not all our volunteers are master naturalists, and our support ranges from college students to retirees, to curious citizens.

Retention, in any volunteer program, is as important as recruitment. The relatively low frequency of monitoring periods (once quarterly) prevents excess demand on volunteers' time which could fuel burnout or disengagement. We see that volunteers who understand their impact and are connected to a community will return year after year. Volunteers work in teams, rather than individually, to ensure their safety and support. We strive to communicate the value of the data they collect. Knowing that their efforts create impactful data used in real management decisions gives volunteers a sense of purpose. Most of our StreamSmart volunteers have been actively involved for many years, some since the program's inception (Figure 4).

Leveraging partnerships to sustain the program

StreamSmart's sustainability rests on strong partnerships. BWD funds the program, with a direct stake in its success: the data support their monitoring efforts and their SWPP. The AWRC provides laboratory infrastructure that is implausible for a small nonprofit to replicate. H2Ozarks provides staff to manage the program. Master naturalists promote the program to their volunteer network. Each partner contributes their expertise to the mutual benefit of one another.

This model – anchoring a volunteer monitoring program within a network of complementary organizations rather than operating independently – has proven successful and could be replicated for programs in other watersheds.

Data help answer questions in War Eagle Creek

The value of volunteer monitoring becomes most apparent when the data are put to work on a real problem. Within the Beaver Lake watershed flows War Eagle Creek (WEC), one of the most beloved waterways in Northwest Arkansas (Figure 5). WEC is known for its scenic bluffs, clear water, and a famous craft fair on its banks. It is also one of the largest tributaries flowing into Beaver Lake. In 2022, the Arkansas Department of Environment Quality (ADEQ) added

Figure 4. A team of StreamSmart volunteers, self-named the "Stream Muskateers."

Figure 5. War Eagle Creek, Site Photo Taken by a StreamSmart Volunteer, May 2025*.*

WEC to its 303(d) list of impaired waterways for low D.O. (ADEQ, 2022). Dissolved oxygen is like breathable air for fish, mussels, and other aquatic life. When oxygen levels drop too low, these aquatic organisms struggle to survive. Low D.O. can occur when excess nutrients like nitrogen and phosphorus enter waterways and cause excess algal growth. ADEQ hasn't fully determined the cause or the subwatersheds contributing most to War Eagle Creek's impairment, listing it as agricultural and unknown (ADEQ, 2022).

Meanwhile, StreamSmart volunteers have been monitoring six sites in the WEC subwatershed since 2013 – one on the creek itself and five on the smaller streams that drain into it. That tributary-level resolution is the program's advantage. State monitoring programs typically sample at larger mainstem sites but cannot trace nonpoint source pollution back to individual headwaters or smaller tributaries. StreamSmart data can help pinpoint potential hotspots for nutrient loading.

To analyze the StreamSmart data, linear regression analyses were used to evaluate trends in nutrient concentrations over time (Figures 6 and 7). For all statistical analyses, a p-value of ≤ 0.05 was considered statistically significant. Overall, StreamSmart data does show clear and statistically significant trends: nitrogen and phosphorus concentrations are increasing at several tributary sites.

At Glade Creek, total nitrogen has nearly doubled since monitoring began in 2013, rising from roughly 2.5 mg/L to close to 5 mg/L. Total phosphorus at the same site has more than tripled. Clear Creek shows statistically significant increases in both nutrients as well. These trends are consistent with nutrient enrichment that can fuel excessive algal growth, deplete D.O., and degrade the aquatic life that WEC is designated to support.

The sources of these increases are still being investigated. It's well understood that land use impacts water quality, but by its very nature, nonpoint source pollution is difficult to trace (H2Ozarks, 2025). StreamSmart's data provide key benefits by capturing local, high-resolution insight at headwaters sites. These tributaries can show the earliest signs of potential issues. StreamSmart data can turn a broad, watershed-wide concern into a set of specific locations to prioritize. Over time, as the data set grows, StreamSmart's value will only increase.

The broader value of volunteer monitoring

StreamSmart's role in monitoring in the Beaver Lake Watershed illustrates several principles that can apply broadly to other volunteer monitoring programs: First, citizen scientists and volunteers produce valuable scientific data that supports other agencies' work. StreamSmart's QAPP ensures data meet the criteria for inclusion for some management decisions. Across the Beaver Lake watershed, there are 94.5 miles of impaired waters (ADEQ, 2022). As in War Eagle Creek, understanding what is driving those impairments requires data throughout the system, not just at mainstem sites. Citizen scientists can generate data that agencies and managers rely on.

Second, the StreamSmart program is not driven by a single group, but through many strong and dedicated partnerships. It exists because many organizations and volunteers bring their skills and expertise

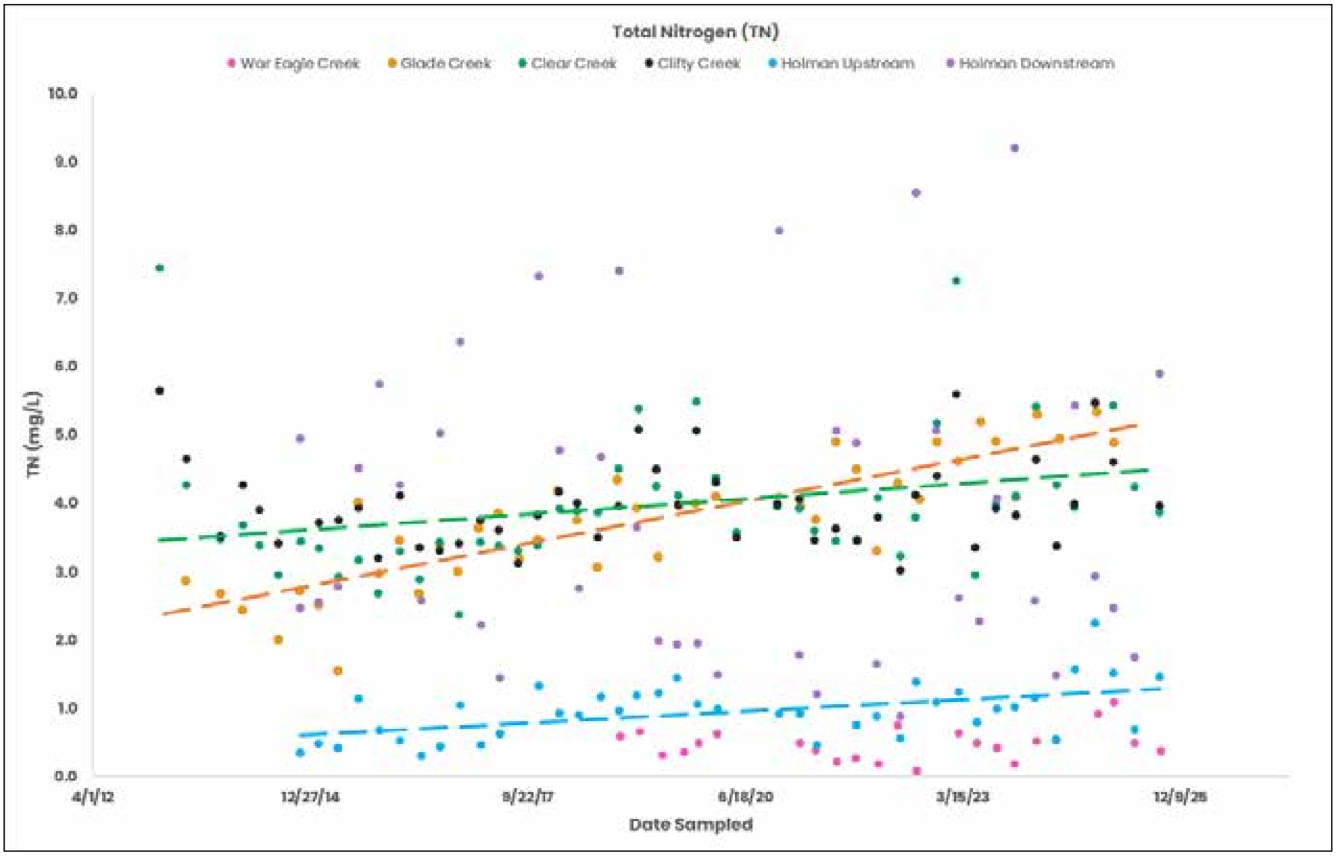


*Figure 6. Total nitrogen concentrations over time at each site in the WEC subwatershed. *Dashed lines indicate statistically significant increases over time.*

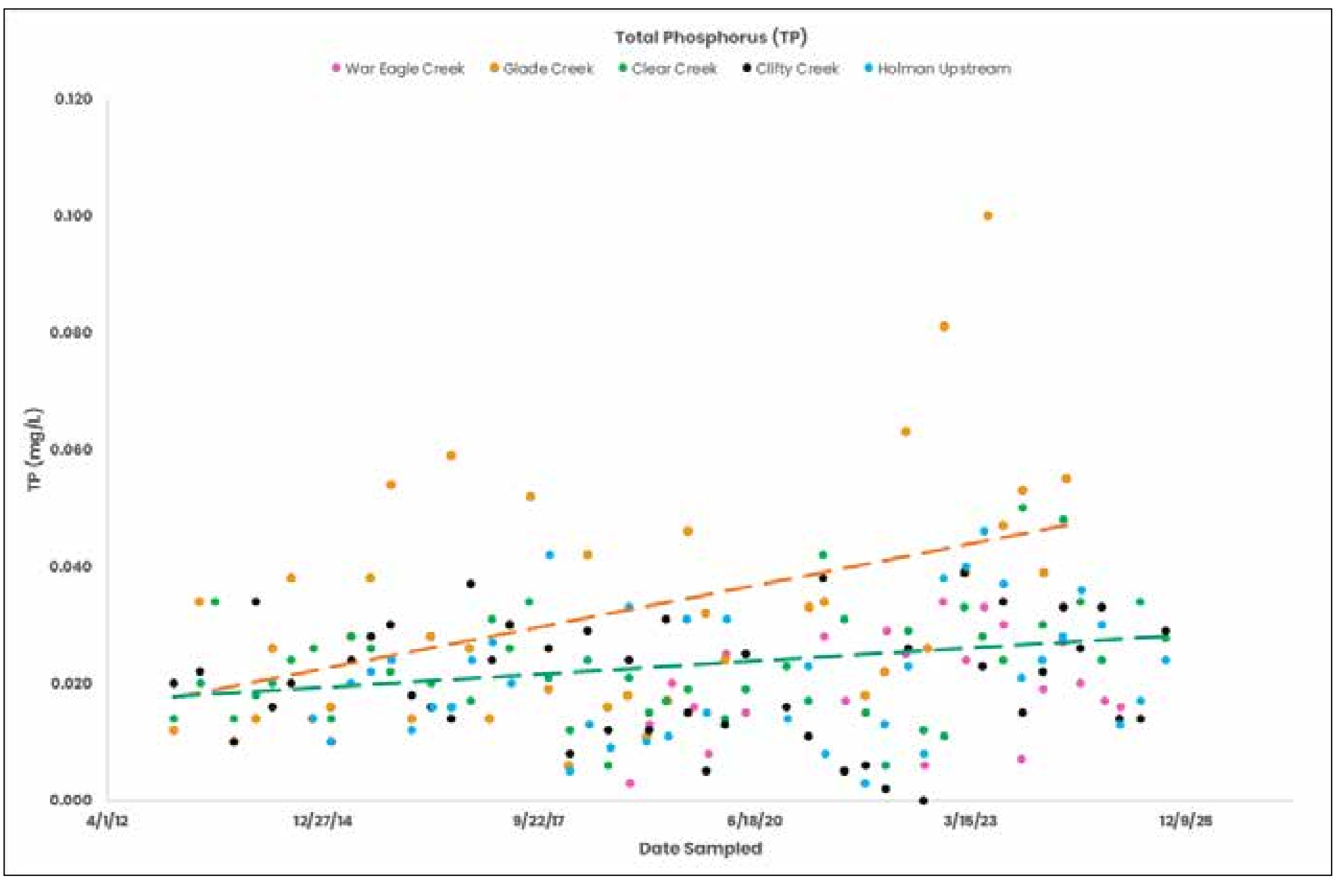


*Figure 7. Total phosphorus concentrations over time at each site in the WEC subwatershed. *Dashed lines indicate statistically significant increases over time. **Holman Downstream had such high phosphorus values (0.024-1.042 mg/L) that it was removed to prevent axis distortion.*

to benefit one another. These relationships are what make the program possible. Third, community investment in volunteer monitoring becomes an investment in water quality broadly. Volunteers who spend years watching a stream change develop a relationship with it that no agency can replicate. They notice changes. They talk to their neighbors. They show up to public meetings. That first spark of interest in a volunteer program can grow into a community of strong advocates for watershed protection.

As Northwest Arkansas continues its rapid growth, the pressures on Beaver Lake and its watershed will only increase. StreamSmart, strengthened by dedicated volunteers and partners, is positioned to track those changes and help managers respond to them.

For lake and watershed managers interested in launching or strengthening a volunteer monitoring program, StreamSmart offers a replicable model – one with strong partnerships, robust protocols, and data that make a difference. To learn more, visit www.H2Ozarks.org/arkansas-streamsmart.

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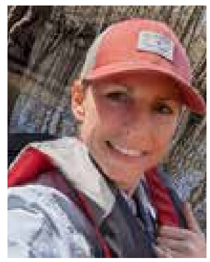
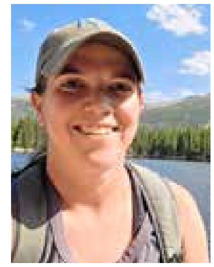


Erin Scott joined H2Ozarks in 2020 as their Senior Policy and Program Director. Previously, she spent several years working at the Arkansas Water Resources Center at the University of Arkansas and is currently pursuing her PhD in Public Policy. Having spent most of her life in Fayetteville, Erin is passionate about protecting water and environmental quality for the community. She enjoys spending time outdoors with her husband and two children.



Ayla Grace is the StreamSmart Program Manager and joined H2Ozarks in late 2024. Prior to H2Ozarks, she split her career between water quality research and public education. She obtained a Master of Science in Biology, focusing her research on aquatic ecology, and a Master of Arts in Education from the University of Arkansas. In her free time, Ayla enjoys spending time with her family, gardening, coaching, and traveling to National Parks.

Olivia Schaap joined H2Ozarks in early 2025 as their Content Coordinator. Her background is in communications within the water industry, and she takes deep interest in translating complex water topics into accessible and actionable stories for communities. She graduated from the University of Arkansas in 2022 with an English degree. Olivia joined the Northwest Arkansas Master Naturalists chapter in 2025.

Electrofishing the Woonasquatucket:
Science, recovery, and community in action

Gianna Lourenco, William O'Connor, and Alexia DiLorenzo

The farmhouse lingers, though averse to square
With the new city street it has to wear
A number in. But what about the brook
That held the house as in an elbow-crook?
I ask as one who knew the brook, its strength
And impulse, having dipped a finger length.

~ *"A Brook in the City,"* Robert Frost

The question posed by Robert Frost, what happens to the brook when development reshapes the land still remains deeply relevant today. In Providence and its surrounding communities, that question finds a powerful answer in the work of the Woonasquatucket River Watershed Council (WRWC).

The Woonasquatucket River, designated an American Heritage River in 1998, begins in North Smithfield, Rhode Island, flows through the urban core of Providence, and empties into Narragansett Bay. Along its 19-mile journey, it tells a story of industrialization, pollution, resilience, and renewal. WRWC's mission is to restore this river and its watershed while strengthening community connections to the natural world by addressing not only environmental degradation, but also the sense of disconnection from nature that often accompanies urban life.

At the center of this work is education.

WRWC's education efforts began in the 1990s with a simple but urgent goal to create urban green spaces so local children would have a safe place to play. The post-industrial Woonasquatucket River and disused lands surrounding it were the perfect opportunity to turn dangerous neglected piles of rubble into thriving park spaces. At the time, many neighborhood youth swam and fished in the river for lack of anywhere else to go, unaware of contaminants such as dioxin. In response, WRWC launched outreach initiatives to teach river safety and awareness, first through a volunteer Junior River Rangers Camp Program and later through staff-led in-school and after-school programs like the "Dos and Don'ts of the Woonaquatuck-et River." Beyond the classroom, WRWC leads a wide range of programming, including community workshops, river cleanups, habitat restoration projects, greenway bike rides, environ-mental monitoring initiatives, and hands-on educational experiences in collaboration with the Rhode Island Department of Environmental Management (RIDEM).

Among WRWC's most impactful educational tools is electrofishing, a scientific method used to monitor the overall health of aquatic ecosystems, specifically in the Woonasquatucket Watershed.

Electrofishing is a widely used, non-lethal technique that allows researchers to assess fish populations in rivers and streams (Figure 1). By introducing a controlled electric current into the water, fish are attracted and temporarily stunned, netted, and collected so they can be identified, measured, and released unharmed.

Figure 1. Electrofishing the Woonasquatucket River

The process is carefully regulated and conducted by trained professionals to ensure both human and animal safety.

The equipment typically includes a backpack unit powered by a battery, which generates the electrical current, and a handheld rod that directs the current into the water. When used properly, electrofishing is one of the most efficient and minimally invasive ways to study fish communities.

For WRWC, electrofishing is more than a monitoring technique; it is an opportunity to engage the community directly in science.

On a hot summer day in August 2016, volunteers gathered along the river at Rising Sun Mills in Providence (Figure 2). Pulling on waders and gloves (Figure 3), they worked together to survey a 100-foot stretch of river using electrofishing equipment. Their goal was simple: document the types and numbers of fish in a historically polluted urban waterway.

As the in-water team moved upstream, carefully netting stunned fish, another team on shore identified and measured each catch (Figure 4 and 5). Fish were temporarily held in buckets to keep them cool before being released back into the river.

What they discovered was remarkable.

In that small stretch of river, the team recorded 176 fish, including two species identified as "Species of Greatest Conservation Need" by the Rhode Island Department of Environmental Management (RIDEM): the American eel and the blacknose dace. The presence of blacknose dace was especially significant, as it had rarely been documented in the Woonasquatucket River system.

This finding told a story of resilience and recovery. Even in a river long impacted by pollution, biodiversity was returning.

The survey also highlighted broader environmental challenges. Rising water temperatures, increased stormwater runoff, flooding, and drought all linked to climate change, continue to threaten aquatic ecosystems. Solutions such as planting trees, restoring riverbanks, and managing stormwater runoff are critical to protecting these fragile habitats.

Figure 2. Volunteers assisting with fish collection.

Figure 3. Waders ready to go.

Building on efforts like the 2016 survey, WRWC continues to integrate electrofishing into both research and education.

In 2025 alone, WRWC's Education Department led four electrofishing outings and 17 field trips, reaching more than 1,200 youth learners. Students participated in hands-on programs that included raising trout, studying bird ecology, and exploring the river through guided field experiences.

In October 2025, WRWC partnered with the Wheeler School to bring AP Environmental Science students into the field. Across multiple sites along the river, students conducted electrofishing surveys, collecting real-world data and observing how ecosystem health changes along the river's course.

Their findings mirrored broader ecological patterns. In upstream areas like Smithfield, students observed greater species diversity and larger numbers of fish, which is an indicator of healthier conditions. In more urban sections of Providence, species such as the American

Figure 4. Volunteers learning to use identification keys for fish species.

Figure 5. Taking a closer look at collected fish species.

eel and pollution-tolerant macroinvertebrates were more common, reflecting ongoing environmental pressures.

WRWC's work extends beyond data collection. In partnership with RIDEM and the United States Environmental Protection Agency (EPA), the organization contributes to long-term monitoring efforts while also leading restoration initiatives like planting vegetation, improving river access, reducing stormwater runoff, and helping migratory fish navigate past dams to access their native spawning grounds.

Equally important is the organization's commitment to community engagement. By involving residents, students, and volunteers in hands-on science, WRWC fosters a deeper connection between people and their environment.

Electrofishing, once a purely technical process, becomes something more, a shared experience that builds knowledge, curiosity, and care.

Like the brook in Frost's poem, the Woonasquatucket River continues to flow – reshaped but not forgotten. And through the efforts of WRWC and its community, it is not only being restored, but reimagined as a living classroom, a shared resource, and a source of collective pride.

Gianna Lourenco is the Director of Environmental Education at the Woonasquatucket River Watershed Council.

Will O'Connor is the Education Assistant at the Woonasquatucket River Watershed Council.

Alexia DiLorenzo is currently working on her undergraduate degree in elementary education and teaching.

Student Corner

Claire Paul

Early evidence of shoreline bog collapse in a eutrophying New Jersey lake

It's a beautiful summer day and we are out kayaking on Budd Lake for a community kayaking event coordinated by Raritan Headwaters Association, a local nonprofit dedicated to watershed health within the Upper Raritan Basin. Raritan Headwaters has been tasked to conduct a year-long baseline study of the lake by Mt. Olive Township. Part of our effort is to include community engagement with the study, so we are on one of the handful of free events we've offered over the summer. We are exploring the shoreline of the lake and have just passed by Lover's Cove, a local landmark, when someone notices what appears to be section of the bog separating from the shoreline and sinking into the lake.

As a graduate student in Western Colorado University's Master's in Environmental Management Program, I've been trained to look at ecosystems through a systems approach. I'm intrigued by our in-person observations and start to wonder whether this is a singular event or part of a *greater* trend, and what implications it might have for a eutrophying lake.

History of Budd Lake/Hattacawann:

Budd Lake is a 374-acre shallow (maximum depth 10') glacial lake located in Mount Olive Township, New Jersey. It is the largest naturally formed lake in the state. Budd Lake was formed at the terminal moraine of the late Wisconsin glaciation, approximately 21,000 years ago (Witte 1998).

Budd Lake has historically been known as Hattacawanna Lake (Dixler 2001). Hattacawanna lies within the Lekawe of the Lenapehoking, home of the Munsee Delaware Lenape Peoples (Native Land Digital n.d.). The lake is also ancestral homeland to the Mohican Peoples (Native Land Digital n.d.). The Stockbridge-Munsee Community, who call Hattacawanna home, are known as the "People of the waters that are never still" (Stockbridge-Munsee Community 2026). Archeological remains indicate that the southwestern corner of Hattacawanna was an important meeting place for nomadic Peoples (NPS 2026).

In the 19th and early 20th Century, Hattacawanna Lake was a well-known summer destination for urban dwellers from Newark, New York City, and Philadelphia (Hilbert 2001). Many recreators came to swim or boat in the lake, relax at the hotels or tent camps, and experience the natural springs known for their healing and commercial drinking water supply (Hilbert 2001). Following the replacement of dirt tracks with the paved US-46 in the mid 20th century, as well as the establishment of water infrastructure in the area, people began living in Budd Lake year-round (Dixler 2001). Contemporarily, Budd Lake is predominantly residential, with a mix of urban, forested, and some agricultural land uses (DEP 2024).

The lake is still known for recreation; however, summer use is threatened by persistent cyanobacterial harmful algae blooms (cyanoHABs). For over 50 years, efforts have been made to address the lake's eutrophication, including small installations of floating wetlands, algaecide treatments, and nutrient binding agents. An analysis of historic (1973) phytoplankton community assemblage as compared to contemporary (2020s) data shows a shift from seasonally successive communities to a system dominated by *Microcystis aeruginosa* and *Dolichospermum flos-aquae*, lacking any apparent succession (EPA, 1973; Harris et al., 2025). Further studies in 2024 found consistently elevated levels of microcystin – at times exceeding state regulatory levels – thus severely impairing recreation and community use of the lake (Harris et al. 2026).

The approximately 3,200-acre headwaters watershed is bounded by the Allamuchy Mountains to the northwest and Turkey Brook Park to the southeast. There are a number of small, mostly unnamed, stormwater- and spring-fed tributaries leading from the surrounding ridges into Budd Lake. Hattacawanna is the headwaters source of the South Branch Raritan River, which feeds the Spruce Run and Round Valley Reservoirs, contributing drinking water supply for approximately 2 million people (WSA 2017).

Bog study

One of the unique characteristics of Budd Lake is the Sphagnum dominant peat bog along its northern shore (Figure 1). The lake is one of two natural waterbodies found at the terminal moraine of the late Wisconsin glacier and the only waterbody in the glaciated portion of New Jersey to contain pure Sphagnum peat (Waksman 1943). The wetland covers 7,595 feet or about 45 percent of Hattacawanna's shoreline. A mix of interesting species live in the bog, including one of the southernmost locations for a forest of Black Spruce (*Picea mariana*) and Tamarack (*Larix laricina*), and rare, geographically isolated species like carnivorous pitcher plants (Waksman 1943).

Sphagnum wetlands play an outsized role in regulating water, storing carbon, and supporting biodiversity. They perform key hydrological regulation, due to their quick absorbance and slow release of water (Rochefort 2000). Sphagnum-based wetlands have been shown to increase water quality through their absorbent nature of nutrients (Tsujino et al. 2010). Wetlands perform significant global atmospheric regulation by deposition of carbon into peat

Figure 1. The bog at Budd Lake.

mass accumulation (Rochefort 2000). These ecosystems are important seed bank sources, particularly when there is significant disruption (Rochefort 2000). Due to the long term accumulating process of peat creation, the systems provide factual archives for historical environmental conditions (Rochefort 2000). Wetlands are known as nature's nursery, providing cover for many young species and contributing to their value towards biodiversity hotspots (Rochefort 2000). Excessive nutrient supply from runoff and atmospheric deposition have been called major threats to wetland ecosystems (Berger et al. 2017).

Humans have significant relationships with peat wetlands. Historical records indicate that the Stockbridge-Munsee Community may have been drawn to the area for the spring-fed water, hunting opportunities and *Sphagnum* moss (Rochefort 2000). Indigenous practice included using *Sphagnum* as absorbent padding material for infants (Rochefort 2000). Analogous with their historical environmental information, bogs may contain anthropogenic archeological information as well (Rochefort 2000).

Methods

To assess whether the bog collapse observed may be part of a significant ecosystem change, I sought to assess whether the visually observed bog collapse may be part of a broader ecosystem change in Budd Lake. I used map layers from the New Jersey Department of Environmental Protection depicting aerial imagery of the lake dating back to 1930 and as contemporary as 2020. I used the oldest possible map to compare long-term differences in the bog. Using ArcGIS Pro (v 3.6.1), I analyzed the maps in two ways: first, I compared the maps for the bog's shoreline changes, and second, I calculated the area of the bog in each map.

For the bog shoreline changes, I compared 9 points against a far (southern) shore reference point. Site selection included 5 targeted sites – 4 tributary stream outputs (BTO) plus 1 local landmark known as Lover's Cove (LC) – and 4 nontargeted sites (A-D) – selected halfway between the targeted sites (Figure 2). I identified each site with coordinates to ensure comparability between maps. I assessed changes in the bog's shoreline by measuring the distance between the nine points to the reference point on each map, using reference markers such as road crossings to align positioning of the maps (Table 1). To measure the area of the bog, I layered the 2020 (Figure 2) aerial map on top of the 1930 map and used polygons to calculate the changes in the area (Figure 3). I used a base R function (v 4.4.2) to analyze these data with a paired t test.

Results and discussion

With the exception of Lover's Cove, all sites showed recession between 1930 and 2020 (Table 1). The greatest sections of bog shoreline loss were found at the outlets of Budd Lake tributary 5 and the combined outlet of tributaries 2 and 3 (Figure 1). The area outlined marking changes in the bog over time showed a reduction of 200,726.5 ft2.

Results show significant differences between the shoreline distances from 1930 and 2020 ($p = 0.0345$, $t = -2.5439$). Results also show small but insignificant difference between tributary sites and non-tributary sites ($p = 0.1201$, $t = -2.061$). However, two tributary output sites showed far greater decline (138.3, 188.0 ft) than all other points (all others < 48 ft) These results support the anecdotal observations that the bog habitat is receding. Not only is the overall habitat in decline, but it is in decline at various rates; outputs of tributary 5 and combined output of tributaries 2 and 3 have eroded more (Table 1). Analyses with higher spatiotemporal resolution that incorporate historic weather patterns will be important to improve our understanding of this initial finding.

Erosive forces, such as waves, have a negative impact on Sphagnum growth due to the disturbance of substrate stability (Rochefort 2000). Sections of the bog that receive both wave action from the lake and

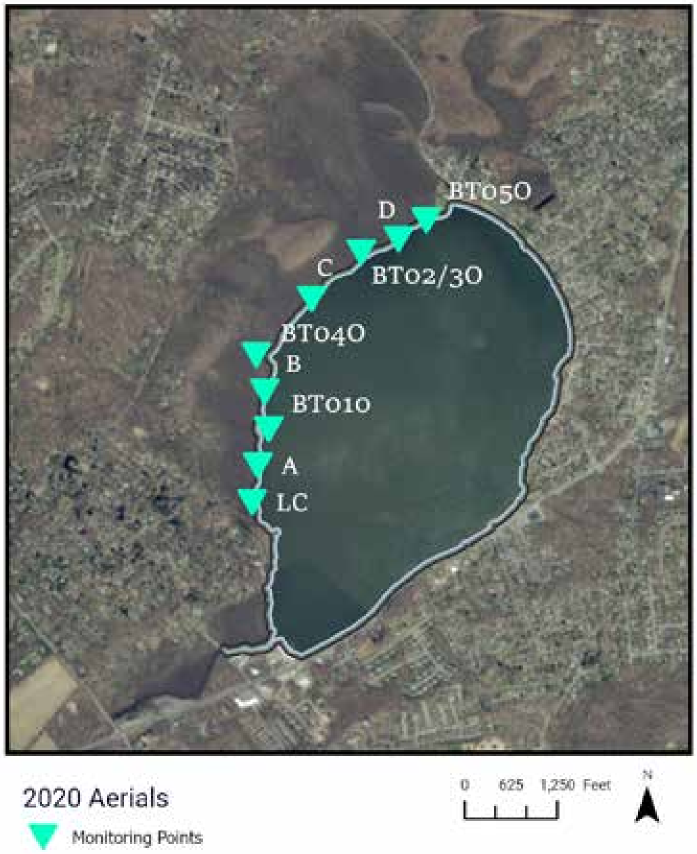


Figure 2. 2020 map of Budd Lake with Site IDs used to measure shoreline distances.

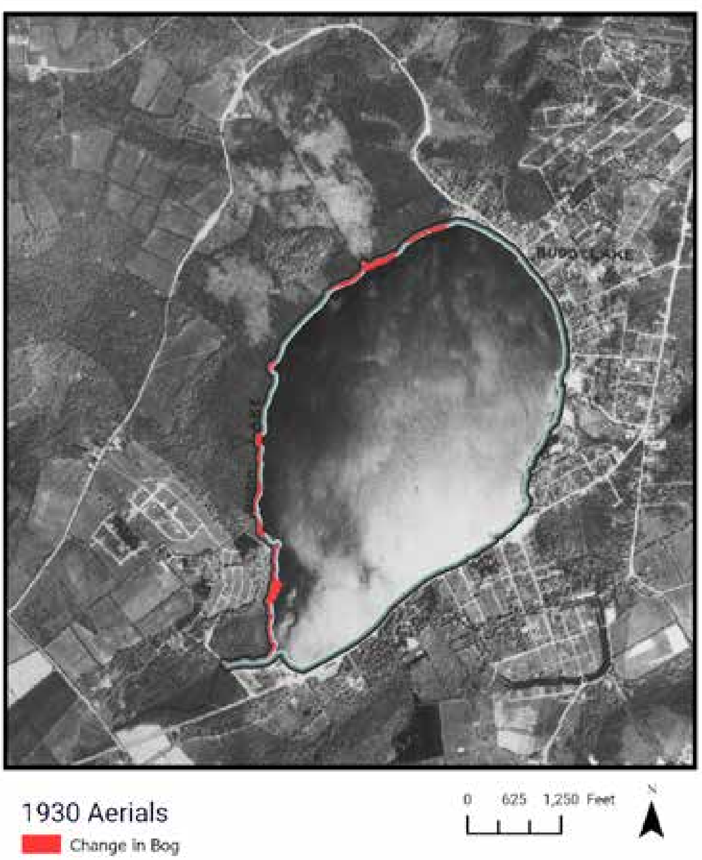


Figure 3. 1930 map of Budd Lake depicting changes in area of the bog.

streamflow from tributary output understandably undergo more intensive erosive force. Furthermore, the lake's polymictic regime may contribute to increased physical action along the shoreline. This relates to the findings of some shoreline loss across all study sites, with the greatest loss at tributary outputs.

Downstream of residential development and bordered by a eutrophying lake, the Budd Lake Bog is ideally located to receive excess nutrients. This long-term exposure to high nutrient levels may be contributing to the bog's decline, as exposure over a period of years has been shown to have a detrimental effect on Sphagnum growth (Gunnarsson et al. 2000). Though known as nutrient and carbon sinks, wetlands can also become significant sources when they break down (Berger et al. 2017). Li et al. recommended regular Sphagnum harvesting in the early winter to prevent nutrient release from floating wetlands into the waterbody (Li et al. 2010). Given the bog's age and ready access to nutrients from the lake and tributaries, it is possible the bog's compounding upward growth and thus water table disconnect may drive this instability.

Restoration

Sphagnum has been shown to be a keystone species in wetland habitat restoration (Rochefort, 2000). Rochefort (2000) identifies three steps to restoration of Sphagnum habitat: (1) active reintroduction of moss diaspores, (2) presence of protective mulch cover, and (3) rewetting of the site. As a Sphagnum-dominant wetland ecosystem, utilizing these steps is key to an informed restoration of the Hattacawanna Bog. To address hydrology connectivity, interesting work has been performed by Bill Zydek and Van Clothier (2014) on process-based restoration efforts aimed to increase stream meandering and reconnecting floodplain. Use of stabilizing structures such as log jams could provide supportive natural structures to address shoreline stability.

Floating wetlands have been shown as effective tools to address excess nutrients in water (Li et al. 2017, Tsujino et al. 2010). Since eutrophic lake water could be damaging the growth of the Hattacawanna bog, an interception of the nutrients through a protective buffer of floating wetlands between the edge of the bog and the greater lake body could be an appropriate application of the technique. This restoration would support historic conditions: floating Sphagnum-based peat is noted in a 1943 assessment of the lake (Waksman 1943).

The Hattacawanna bog study is part of a larger characterization effort to understand the current state of Budd Lake to inform restoration and management efforts. The identification of the Bog experiencing significant shoreline loss demonstrates that a possible restoration aim could be active stabilization of the shore. An important finding here is the significant spatial differences of bog collapse. This finding can inform targeted restoration needs to protect the bog shoreline, prevent potential further eutrophication, and maintain critical habitat and biodiversity of this region.

Acknowledgement

Special thanks to Benjamin Harris and Melissa Thomas at Raritan Headwaters Association (RHA), the Budd Lake project volunteers, the Township of Mount Olive, the New Jersey Department of Environmental Protection (NJDEP), and Western Colorado University, in particular Dominque Naccarato, in the making of this article. Funding was provided by the New Jersey Highlands Water Protection and Planning Council (Agreement #09-033-011-1427) via the Township of Mount Olive, New Jersey (Resolution #184-2025) to

Table 1. Measurements of shoreline distances.

Site Type	*SiteID*	*1930 Distance (ft)*	*2025 Distance (ft)*	*Change in Shoreline (ft)*
Tributary	BT050	3916.5	4054.8	-138.3
Shoreline	D	3931.7	3965.8	-34.1
Tributary	BT03/20	3849.2	4037.2	-188
Shoreline	C	3836.6	3884	-47.4
Tributary	BT040	3587.5	3633.1	-45.6
Shoreline	B	3489.9	3503.4	-13.5
Tributary	BT010	3829.1	3867.7	-38.6
Shoreline	A	3668	3672.9	-4.9

RHA. This analysis was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been verified by NJDEP and is not state-authorized. Any findings or recommendations discussed here are those of the author and do not necessarily reflect the views of the NJDEP, the Township of Mount Olive, the New Jersey Highlands Water Protection and Planning Council, or the State of New Jersey.

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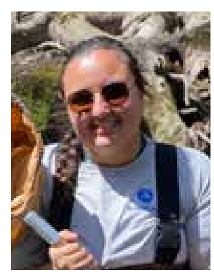


Claire Paul is a student at Western Colorado University working towards a master's degree in environmental management on the Integrated Public Land Management track, with a certificate in Ecosystem Restoration. She splits her time in two roles, as the Lake Research Technician for Raritan Headwaters Association and an Environmental Specialist with the New Jersey Department of Environmental Protection. Her research has focused on harmful algal bloom management of freshwater lakes in New Jersey.

Tools of the Trade

Lowering the barriers: How the NALMS SHINY APPS SERVICE is expanding access to powerful data tools

Jen Stamp, Tim Martin ,and Erik W. Leppo

For many water resource professionals, the mention of *R* is enough to end a conversation. It is often associated with dense code, steep learning curves, and technical expertise that feels out of reach. Yet behind that single letter lies a growing ecosystem of tools that is changing how data are processed, analyzed, visualized, and shared—often with no programming required from the end user.

At the center of this shift are **Shiny applications**. They are lowering barriers to advanced data workflows while helping biologists, analysts, and managers make better use of the data they already collect. And the **NALMS Shiny Apps Service** is making these apps available to more people.

What is a Shiny App?

Shiny is an add-on package for the R statistical programming language that allows developers to turn R code into **interactive web applications**. These applications look and function like modern websites. Users click buttons, choose options from dropdown menus, upload files, and view results instantly.

The significance of Shiny apps is not only what they can do, but **who can use them**.

Users do not need to install R, download packages, or understand code. All that is required is an internet connection and intermediate level computer skills, such as navigating a web page and uploading or downloading files. For many water resource professionals, this turns advanced analyses from something theoretical into something practical.

Behind the scenes, Shiny apps rely on the same statistical and visualization tools that make R so powerful. But those details remain invisible to the user.

A central hub for water resources tools

For several years, NALMS has hosted a growing collection of Shiny applications designed specifically for water resource management. These tools support activities such as:

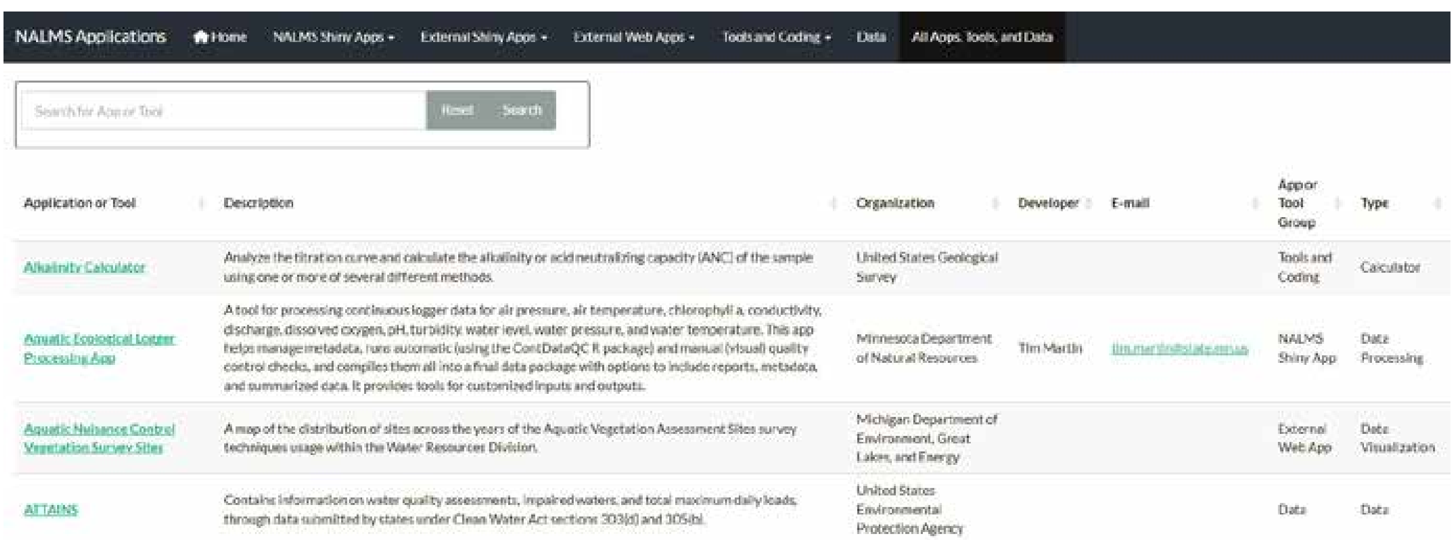
- Processing and quality controlling continuous sensor data
- Analyzing and visualizing lake and water quality datasets
- Sharing monitoring protocols and technical resources
- Learning about Shiny applications

These tools are centralized on the [NALMS Shiny Apps Home Page] (Figure 1). In addition to apps hosted directly by NALMS, the site includes links to Shiny and nonShiny applications hosted elsewhere, along with related datasets, tools, and code repositories.

The goal is straightforward: **make useful tools easy to find and easy to use**.

Why NALMS created a hosting service

Building a Shiny app is only part of the process. To be accessible, it must be hosted on a server so users can reach it through a standard web browser. That requirement presents a major challenge.



Application or Tool	Description	Organization	Developer	E-mail	App or Tool Group	Type
Alkalinity Calculator	Analyze the titration curve and calculate the alkalinity or acid neutralizing capacity (ANC) of the sample using one or more of several different methods.	United States Geological Survey			Tools and Coding	Calculator
Aquatic Ecological Logger Processing App	A tool for processing continuous logger data for air pressure, air temperature, chlorophyll a, conductivity, discharge, dissolved oxygen, pH, turbidity, water level, water pressure, and water temperature. This app helps manage metadata, runs automatic (using the ContDataQC R package) and manual (visual) quality control checks, and compiles them all into a final data package with options to include reports, metadata, and summarized data. It provides tools for customized inputs and outputs.	Minnesota Department of Natural Resources	Tim Martin	tim.martin@state.mn.us	NALMS Shiny App	Data Processing
Aquatic Nuisance Control Vegetation Survey Sites	A map of the distribution of sites across the years of the Aquatic Vegetation Assessment Sites survey techniques usage within the Water Resources Division.	Michigan Department of Environment, Great Lakes, and Energy			External Web App	Data Visualization
ATTAINS	Contains information on water quality assessments, impaired waters, and total maximum daily loads, through data submitted by states under Clean Water Act sections 303(d) and 305(b).	United States Environmental Protection Agency			Data	Data

Figure 1. Screenshot of the 'All Apps, Tools and Data' page on the NALMS Shiny Apps server: https://nalms.shinyapps.io/NALMS_Shiny_Home/

Many agencies face IT restrictions, security concerns, or funding limitations that make hosting Shiny apps difficult or impossible. Even when hosting is allowed, individual developer accounts on commercial platforms often come with usage limits that restrict how widely an app can be shared.

As a result, many well-designed tools never reach the audience they were created for.

The NALMS Shiny Apps Service addresses this gap by providing a **neutral, independent platform** capable of hosting applications without the constraints common within government agencies. At the same time, it serves as a curated repository, allowing NALMS to bring together tools developed by different organizations in one location.

Sensor data as a catalyst

The need for this service became clear through work on the Regional Monitoring Networks (RMNs) and the Minnesota Sentinel Lakes Program. Both initiatives rely heavily on continuous sensor data (Figure 2), which pose unique challenges related to quality control, data volume, and long-term management.

Many partners collecting sensor data struggled to keep pace. They needed tools that could standardize workflows, reduce manual effort, and quickly visualize results. Spreadsheet-based approaches were no longer sufficient.

In response, Erik Leppo of Tetra Tech, with support from EPA ORD, developed the **ContDataQC** R package and accompanying Shiny app (Pennino et al. 2025) to support automated and visual quality control of continuous data. Building on that foundation, Tim Martin, who works for the Minnesota Department of Natural Resources (MN DNR), developed the **Aquatic Ecological Logger Processing App**, integrating QC, metadata collection, and data visualization into a single workflow.

While these tools proved effective, sharing them broadly remained difficult. They turned to NALMS with a request for help to distribute them widely. As an independent organization bound by fewer constraints, NALMS agreed to fund a shinyapps.io subscription, enabling the creation of what is now the **NALMS Shiny Apps Service**.

Figure 2. MN DNR field crews preparing to deploy a sensor array in one of Minnesota's sentinel lakes.

A non-programmer's perspective

Jen Stamp of Tetra Tech, who served as overall coordinator of the RMNs (with support from EPA ORD), describes her role as a User Interface (UI) tester who articulates needs to programmers like Erik and Tim, who then write the code. "I tell programmers like Erik what I want, and they make it happen. It's like magic!"

She has seen both the challenges and the benefits of Shiny apps firsthand.

"Some people dismiss Shiny apps immediately because they associate them with R code and assume they will be beyond their comfort level and skill set," she says.

She is quick to clarify that programming experience is not required. For those who prefer working directly in R, she notes that the underlying code for many apps is available and can be run offline once the necessary packages are installed.

From her perspective, the impact of Shiny apps has been substantial.

"They have been a real game changer, at least in the realm that I operate in," Jen says. "They put the power in biologists' and scientists' hands. Having the ability to put apps on the NALMS Shiny App server improves accessibility and helps break down IT barriers."

A programmer's perspective

Tim Martin and Erik Leppo are currently maintaining the NALMS Shiny Apps Service in a volunteer capacity. They approach Shiny from different paths but share similar conclusions about its value.

When Tim joined the Sentinel Lakes Program, he inherited a backlog of more than nine years of raw sensor data, with new data continuing to arrive each year. The processing demanded a more efficient system than traditional spreadsheets.

"I needed a way to standardize the process and make it repeatable," Tim says. "Shiny allowed me to do that."

By wrapping existing R code in a graphical interface, Tim created tools that could be used consistently across users without requiring them to understand the underlying calculations.

"I was largely self-taught," he adds. "If you're familiar with R and basic web design, you can learn how to use Shiny"(Figure 3).

Erik's entry into Shiny also began with a practical need.

"I started working with Shiny apps in 2017 when we needed to modify an existing app and make it more general," he says. "I had the programming background, but I was new to Shiny."

For Erik, Shiny's strength lies in its efficiency and reach.

"The development timeline is much shorter, and the app stays close to the original R code," he explains. "You can get tools to far more people, and all they need is a web browser."

Tim notes that Shiny's potential extends beyond data processing.

Figure 3. One of the features that sets Tim Martin's [Aquatic Ecological Logger Processing App](#) apart is an interactive time series plot with data points color-coded by flag test results (pass, suspect, fail).

"I've used Shiny for displaying and analyzing data, learning about lakes, storing and distributing documents, and even quizzing people on aging fish structures," he says.

Hosting, linking, and sharing tools

Not all tools listed on the NALMS Shiny Apps Home Page are hosted directly by NALMS. Some are hosted by partner organizations and simply linked from the site. One example is the **EPA's TADA app**, which supports analysis of discrete water quality data and is located on the EPA Shiny server.

For developers with their own hosting solution, inclusion in the NALMS repository is straightforward. Sharing a link along with basic metadata allows an app to be added without transferring hosting responsibility. This approach allows the repository to grow while remaining flexible.

An invitation to the community

The NALMS Shiny Apps Service is open to the broader water resources community – for both using existing tools and contributing new ones.

Submitting nonShiny content, such as links to external web applications, tools, datasets, or code repositories, is simple. Requests can be sent to **shinyapps@nalms.org**. Requirements for hosting Shiny apps directly are outlined on the NALMS Shiny Apps Home Page.

Jen hopes increased visibility will allow more people to benefit.

"We have this great resource but not many people know about it," she says. "We really need people to help spread the word. These free tools could be a big difference maker for some water resource programs. They can help improve efficiencies and elevate data analyses and reporting to a new level."

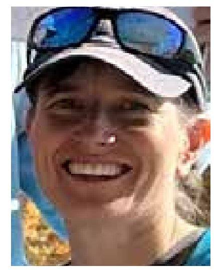
Erik has seen the community evolve since he first began working with Shiny.

"Early on, it was hard to convince people to implement Shiny apps," he says. "Now there's far more interest and collaboration, and many people are eager to share their tools."

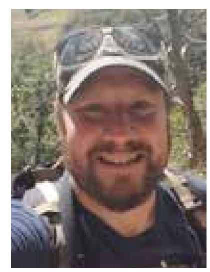
You do not need to be a programmer to benefit from these applications. And if you are not a programmer but see an opportunity, finding a programmer to partner with can open new doors. Whether you actively use the tools or simply help spread the word, the NALMS Shiny Apps Service depends on community awareness to reach its full potential.

References

Pennino, M. J., Stamp, J., Leppo, E., Gibbs, D., & Bierwagen, B. G. 2025. ContDataQC: An R package and Shiny app for quality control of continuous water quality sensor data. *SoftwareX*, 30, 102124. https://doi.org/10.1016/j.softx.2025.102124



Jen Stamp is an aquatic ecologist and data scientist at Tetra Tech with more than 20 years of experience in water resources science. She has played a key role in designing and coordinating long-term Regional Monitoring Networks (RMNs) in streams and lakes, serving as overall coordinator while conducting technical analyses and facilitating national and regional meetings, trainings, and workshops.



Tim Martin is a data and water resources scientist working for the Sentinel Lakes Program in the Fisheries section of the Minnesota Department of Natural Resources. He is responsible for processing, managing, analyzing, and distributing data collected for this program at many trophic levels, ranging from water temperature up to fish. Through this work he creates data tools and applications and develops analytical methods that utilize the breadth of the Sentinel Lakes' large datasets.

Erik W. Leppo is a data and environmental scientist at Tetra Tech with over 30 years of experience applying data analysis, visualization, and custom tools to environmental applications. His work focuses on turning complex environmental data into interactive tools that support water quality and ecological decision-making.

Variable earth material, backshore erosion, and mitigation at Lewisville Lake, Texas

Paul F. Hudak

Introduction

Backshore erosion is a maintenance and environmental concern at many lakes worldwide. This process degrades land while increasing turbidity that harms aquatic ecosystems. The problem is amplified in multi-purpose lakes, as displaced sediment and brush take up storage, thus compromising critical flood control and water supply services. Measuring rates of backshore erosion can help prioritize stabilization efforts to enhance lake function. A recent study involving satellite imagery and field observations examined shoreline erosion at Lewisville Lake in north-central Texas, U.S.

Study Area

Lewisville Lake is impounded by an earthen dam on the Elm Fork of the Trinity River in north-central Texas (Figure 1). This multi-purpose lake controls flooding while supplying water and supporting recreation. The lake loses approximately 540 acre-feet of capacity each year from stream deposition and eroding backshore (TWDB, 2007). As the lake (periodically) approaches and exceeds maximum normal operating level, waves attack the backshore shelf. Winds are prevalent from the south-southeast (SSE), with a directional mode of 20 degrees east of south (S20E). The main branch of the lake also aligns approximately S20E, thus amplifying wave fetch and energy.

Vulnerable, SSE-facing segments of backshore consist of two Upper Cretaceous bedrock formations (Woodbine and Eagle Ford) and Quaternary alluvium. The Woodbine consists of loose to moderately-well cemented sand and laminated sandy clay. Fissile clayey shale makes up the Eagle Ford. Quaternary terrace deposits of sand, gravel, and clay discontinuously cover bedrock along the backshore.

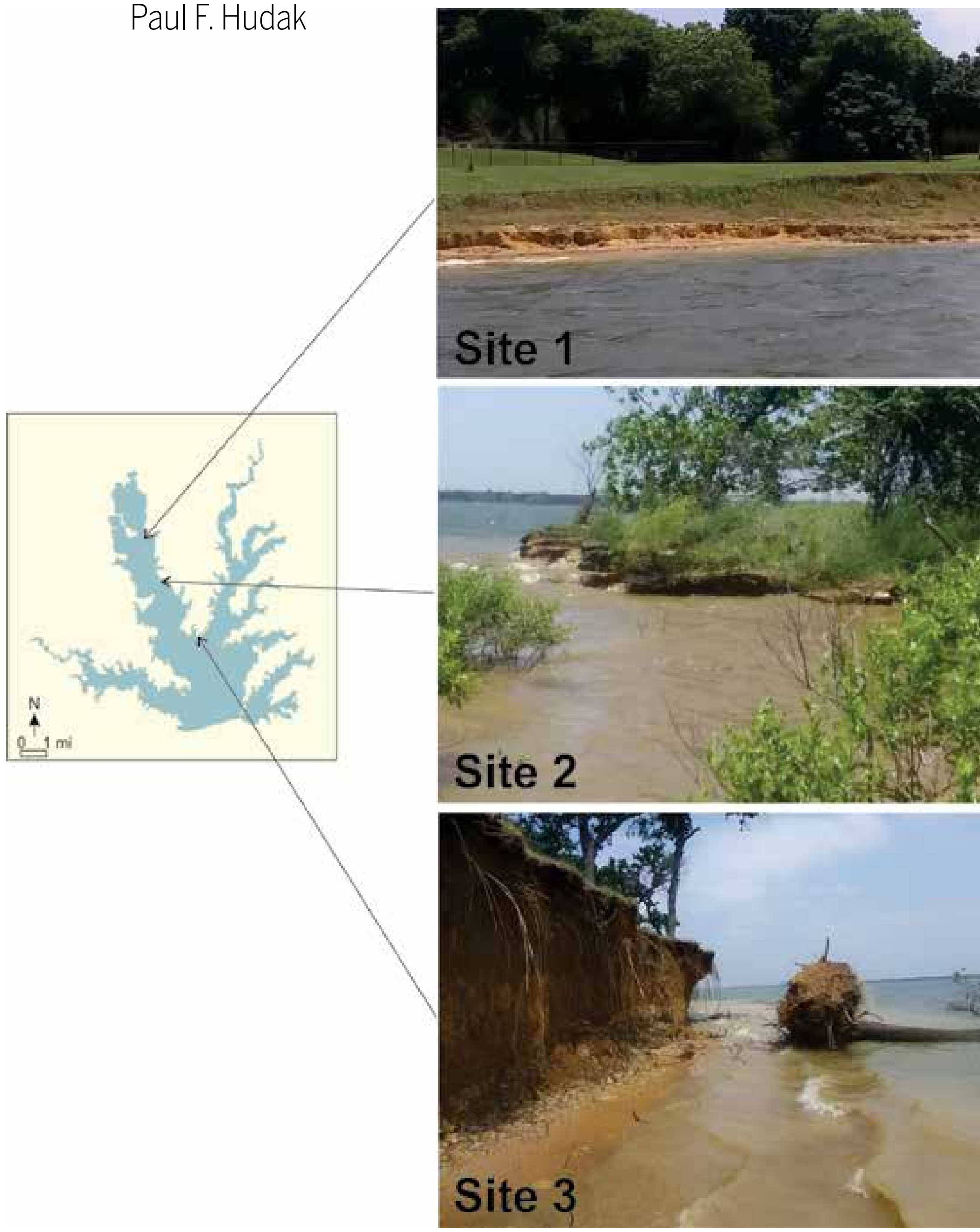


Figure 1. Sites 1 – terrace, 2 – sandstone, and 3 – shale.

Observations

Satellite images from February 2001 and 2024 were analyzed at three SSE-facing sites: one each in terrace deposits, sandstone, and shale (Figure 1). Images were obtained from Google Earth (Google Corporation, Mountain View, CA). Along S20E transects, digitized imagery produced erosion estimates of 3.2 feet/year for terrace deposits, 2.4 feet/year for sandstone, and 7.4 feet/year for shale. During field visits at high lake level, water was visibly turbid from silt and clay washed away from the shale and terrace backshore. Shale was further weakened by repeated wetting (swelling) and drying (shrinking) cycles, leading to extensive fragmentation. Vegetation also fell from the backshore into the reservoir (Figure 1). Ultimately, driftwood provides habitat but is also a significant boating hazard in the lake.

Limestone rip rap – typically, a rock blanket on landscape fabric – is used to slow erosion in the study area. However, waves tend to wash away sand and fine sediment beneath the fabric, which then sags and tears, causing rocks to subside and move downslope. Figure 2 shows the eastern edge of a 330-foot-long rock blanket at Site 1. Installed in 2020, the rock blanket has slowed erosion by about 0.7 feet/year when compared to adjacent, unprotected backshore. In 2024, rocks were added to fill gaps that formed in the original structure.

Better-prepared substrates beneath rip rap might lead to better outcomes. Such preparation might involve thorough compaction; wire mesh and sprayed concrete; or anchored geosynthetics less prone to sagging and tearing. Sturdy wire mesh around boulders (gabions) could prevent downhill movement but would still sag as the supporting substrate washed away. Hybrid approaches involving artificial structures such as gabions on augmented substrates, with intervening spots for native plants, might enhance aesthetics while providing better erosion control than sagging structures in the study area. For example, common buttonbush, which thrives along the wave-ravaged backshore, anchors soil while supporting various birds and insects.

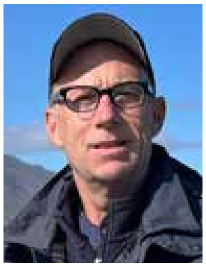
Conclusion

Earth material and prevailing wind orientation strongly influence rates of backshore shelf erosion at Lewisville Lake. Shale backshore receded 2.3 and 3.1 times as fast as terrace deposits and sandstone, respectively. A limestone rock blanket slowed the erosion rate by about 22 percent at a terrace site. Better substrate preparation and rock retaining features would likely perform better.

Figure 2. Rock blanket at Site 1; large (beige) rocks placed in 2020; smaller (grey) rocks added in 2024.

Reference

TWDB (Texas Water Development Board). 2007. Volumetric and Sedimentation Survey of Lewisville Lake. Texas Water Development Board, Austin, Texas.



Paul F. Hudak is a professor in the Department of Geography and the Environment at the University of North Texas. He received a B.S. from Allegheny College, M.S. from Wright State University, and Ph.D. from the University of California at Santa Barabara. Paul's teaching and research involves studies in water resources, lakes and wetlands, and environmental geology.

Empowering community scientists
to integrate data, monitor & protect Long Island Sound

Matthew Zane

Growing environmental pressures across Long Island Sound have intensified the need for readily accessible, known and trusted scientific information that guides responsible water management. A broad spectrum of data collection programs have long faced challenges to consolidate data from different sources & in different formats, validate and share water quality data that would allow for region-wide analysis of ecological conditions.

Dedicated to protecting and improving the land, air and water of Connecticut and Long Island Sound, Save the Sound wanted to address long-standing barriers. Fragmented datasets, inconsistent report formats & limited opportunities for inter-organizational collaboration hindered stakeholders from understanding and making informed decisions that protect both public health and ecological integrity of the vital estuarine system.

Save the Sound partnered with KISTERS to develop QuickDrops, an innovative water quality data platform & visualization tool free for use for the full community of stakeholders. Designed for ease of use, standardized data handling, and compatibility with the national reporting system, the online technology fills a critical need for centralizing information, achieving data consistency, and easing both conjunctive analysis & publishing of watershed-specific data.

The QuickDrops map interface displays extensive water quality data collection across the Long Island Sound, especially by volunteers. The free platform provides registered stakeholders with data visualization, upload & EPA WQX submission tools.

Community science organizations register with Save the Sound. Then they can access the platform to upload newly collected data, digitize and contribute historical datasets that may otherwise remain in silos. Once verified and incorporated, community data can be submitted to the U.S. EPA.'s Water Quality Exchange, ensuring that local monitoring efforts contribute to broader scientific and regulatory frameworks.

Educators and researchers can access integrated visualization tools to examine spatial & temporal trends in water quality parameters – temperature, salinity, dissolved oxygen, nitrogen concentrations and fecal indicator bacteria – enabling more communication of complex environmental patterns to multiple stakeholders: students, policymakers, and the general public.

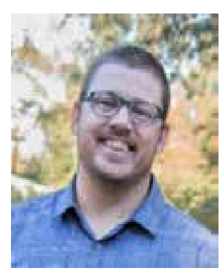
Health department and other water resource managers who evaluate beach water safety, assess nutrient loading, and respond to pollution events all benefit from a comprehensive and consistent flow of quality-assured information.

Peter Linderoth, Director of Healthy Waters & Lands for Save the Sound explained, "People who use data always benefit from access to more, higher quality data (which) leads to a better understanding of water quality challenges facing a waterbody, which drives smarter solutions."

Since QuickDrops launched a year ago, 100,000+ data points from 700 locations across New York & Connecticut have been uploaded. The breadth of available parameters reflects the diverse environ-mental indicators needed to evaluate marine life health, swimming safety & ecosystem function. Physical, chemical & microbiological measurements enable detection of trends across sites or the region, comparison of stressors, and identification of potential warning signs of ecological degradation.

Katie O'Brien-Clayton of the Connecticut Department of Energy and Environmental Protection described QuickDrops as invaluable for reviewing quality-assured volunteer-collected data to fulfill Clean Water Act assessment requirements.

Scientific partners Dr. Sarah Crosby of the Maritime Aquarium at Norwalk and Dr. Jamie Vaudrey of the University of Connecticut underscored the system's ability to unlock previously inaccessible community-science data and strengthen collaborative research and management across the Long Island Sound.



Matthew Zane is a water quality consultant at KISTERS. With more than 15 years of ag & urban program management, he is enthusiastic about program design as well as data interoperability and automation.

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Rev. 1/19

"Lakespert" –

Lake Volunteer Lessons

Steve Lundt, CLM #00-05M

I have had the pleasure of coordinating two vastly different state-wide volunteer lake monitoring programs over the years. I helped coordinate a long-running program during my graduate school years. Later in my career, I started a program (modeled on the first one), but it only lasted ten years. What did I learn from these experiences? First, it takes an array of people, old and young, to make it work. Second, coordinating lake volunteers is a full-time, year-round job.

It takes no lakespert to know that a diverse group of lake-loving people are the key to a successful and meaningful volunteer program. Volunteer monitoring requires people who have a strong passion for water and lakes. It is important to have a wide range of volunteers – old, young, wake boarders, anglers, lake residents, and lake users. Welcome all.

I quickly learned that you cannot rely on one demographic. For example, I was enjoying state park employees, and I annoyingly found out that park staff shuffle from park to park each year. Having a constant jumble of volunteers made it a challenge to keep the program up and running at each lake. Many Secchi disks and volunteer training booklets were lost in the shuffle.

Communication and recruitment are two major drivers for year-round coordination. Volunteers need to stay engaged, and there is always a need for new and more volunteers throughout the year. Trainings, lakes appreciation celebrations, cleanups, watershed efforts, and lake restoration projects all require communication with lake volunteers. Full-time coordination is a must for any volunteer program.

The biggest enjoyment I got from running volunteer programs was working with life-learning people that were excited to be out on the water (Figure 1). It was rewarding to see volunteers see their lake in a new light. Volunteers are always excited and upbeat with a natural aura. These days, I often hear people say that they feel helpless and do not know what to do to help improve things. One way is to join a volunteer lake monitoring program. Volunteering is a wonderful way to get outdoors, feel like you are part of the solution, and find common interests with others. A common theme with everyone is that we all want cleaner and healthier lakes across the country.

I will end with this challenge. I think every NALMS member, consultant, lake manager, board member, and regulator should be a lake volunteer at least once. Being a lake volunteer is the true essence to loving lakes and reservoirs. So, get out there and volunteer!

Steve Lundt, Certified Lake Manager, has monitored and worked to improve water quality at Barr Lake (Denver, Colorado) for over 20 years. Steve is active with the Colorado Lake & Reservoir Management Association and is a past Region 8 director for NALMS and an active member since 1998.

Figure 1. Official Secchi depth reading on Grand Lake, Colorado by a local resident with three generations in the boat.

LAKE AND RESERVOIR MANAGEMENT

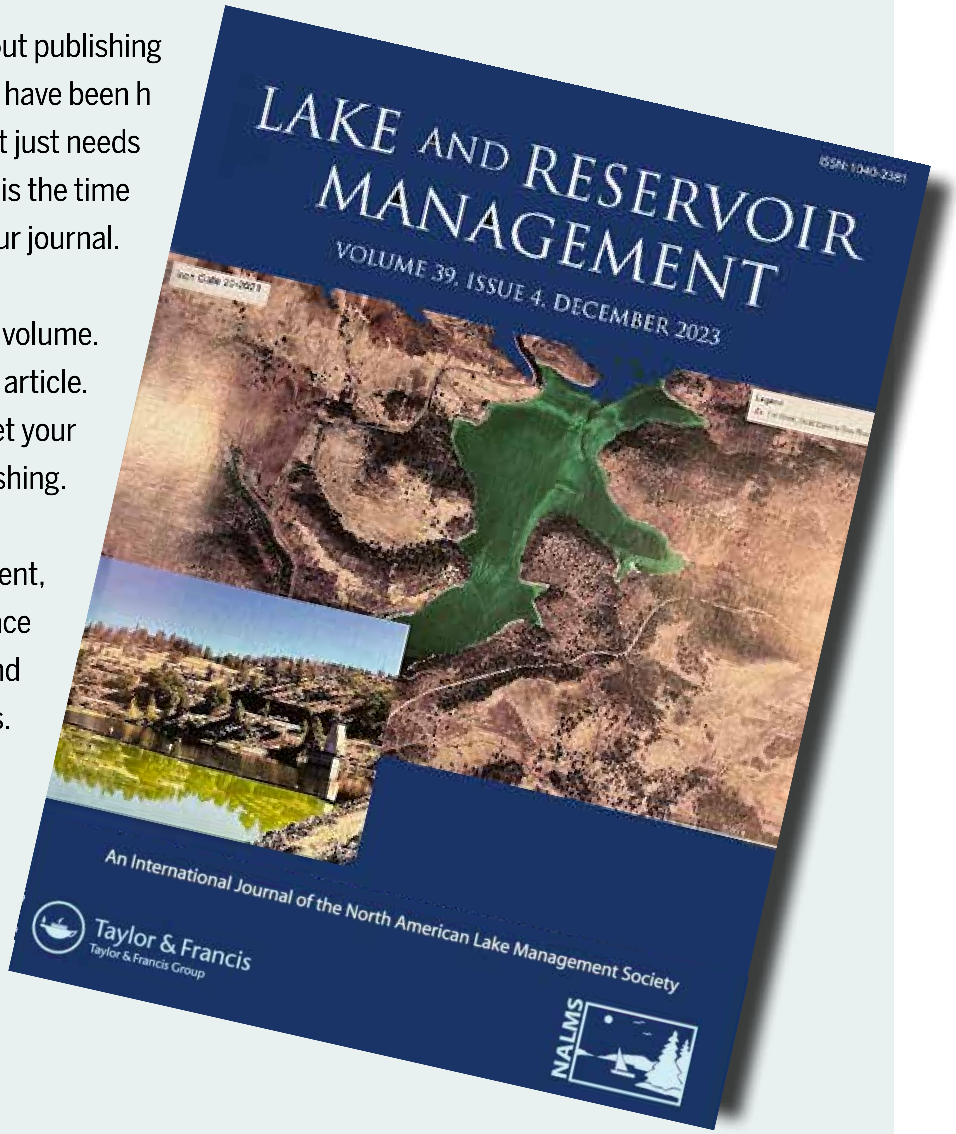
A scientific publication of NALMS published up to four times per year solicits articles of a scientific nature, including case studies.

If you have been thinking about publishing the results of a recent study, or you have been h anging on to an old manuscript that just needs a little more polishing, now is the time to get those articles into your journal.

There is room for your article in the next volume. Don't delay sending your draft article. Let the editorial staff work with you to get your article ready for publishing.

You will have a great feeling of achievement, and you will be contributing to the science of managing our precious lakes and reservoirs.

Anyone who has made or plans to make presentations at any of the NALMS conferences, consider writing your talk and submitting it to the journal. It is much easier to do when it is fresh in your mind.



Send those articles or, if you have any questions at all, contact:
Tom James, Editor, *Lake and Reservoir Management*; lrmeditor@nalms.org.

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