Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-531

Proposal Title: Preventing Algal Blooms with Real-Time Phosphate Monitoring

Project Manager Information

Name: Tianhong Cui

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This project aims to develop an affordable sensor network to monitor phosphorus in real time, helping detect algal bloom risks early and support proactive lake management across Minnesota.

ENRTF Funds Requested: $377,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Water (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Eutrophication and harmful algal blooms (HABs) are growing threats to the water quality and ecological health of Minnesota's lakes. Monitoring by the Minnesota Pollution Control Agency (MPCA) and its partners across 80 watersheds shows that about 25% of Minnesota lakes do not meet water quality standards because phosphorus and algae levels are too high. Phosphorus is a key driver of algal growth and eutrophication. When blooms occur, they can reduce oxygen in the water, cause fish kills, and degrade water quality for drinking and recreation. Warmer lake temperatures linked to climate change are also increasing the frequency of harmful algal blooms, creating additional risks for aquatic ecosystems and communities that rely on healthy lakes.

Current monitoring methods have limitations. Phosphorus is often measured using laboratory or automated analyzers that require chemical reagents and regular maintenance. These systems are large and expensive, making widespread deployment difficult. Many lake monitoring buoys instead measure indicators such as algae or dissolved oxygen, which often show impacts only after blooms have already formed. As a result, lake managers still lack practical tools to monitor phosphorus in real time and detect bloom risks earlier across Minnesota's lakes to better guide lake monitoring and management decisions.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

This project proposes to develop and demonstrate an AI-enabled, multi-parameter lake monitoring system for early warning of water quality problems that provides real-time detection of algal bloom risks in Minnesota lakes. The system will combine distributed field sensor nodes with a central data platform to continuously monitor environmental conditions related to harmful algal blooms and lake health. A key component of the system is a miniaturized phosphate sensor based on microelectromechanical systems (MEMS) technology, enabling compact, low-power, and potentially low-cost nutrient sensing suitable for long-term deployment in lakes. The research team has already completed proof-of-concept work demonstrating the feasibility of this sensing approach. Building on these results, the project will further improve the sensor and integrate it with additional sensors measuring dissolved oxygen, temperature, and sunlight to create multi-parameter monitoring nodes. These nodes will transmit data wirelessly to a central platform where data analysis tools will identify environmental conditions associated with increased bloom risk. The project will also refine system integration, wireless communication, and data management to ensure reliable operation of the monitoring network in lake environments. Funding will support sensor development, laboratory calibration and testing, and pilot deployment in Minnesota lakes to demonstrate the effectiveness of this monitoring approach.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

This project will deliver a scalable lake monitoring platform that enables real-time detection of algal bloom risks. By identifying conditions associated with harmful algal blooms and oxygen depletion earlier, the system will provide cost-effective monitoring tools for lake managers to support proactive water management decisions. Pilot deployments will demonstrate the feasibility of distributed sensor networks and data analysis tools for lake monitoring in Minnesota. The project outcomes will show the potential for statewide expansion of affordable monitoring technologies, helping protect aquatic ecosystems, improve water quality management, and support the long-term conservation of Minnesota's lakes and natural resources.

Activities and Milestones

Activity 1: Sensor Array and Monitoring Node Development

Activity Budget: $207,350

Activity Description:
We propose to develop and optimize a multi-parameter sensor array platform for real-time monitoring of lake conditions related to algal blooms. Building on Phase I proof-of-concept work, this activity will focus on advancing a small phosphate sensor and integrating it with other environmental sensors into a compact field monitoring node. The sensor system will be designed and fabricated to achieve high sensitivity, low power consumption, and scalable production for lake monitoring. In addition to the phosphate sensor, parameters such as dissolved oxygen, temperature, and sunlight will be measured using commercial sensors, which will be integrated into the monitoring platform. The system will also include power management and onboard data logging for reliable field operation. Key developments include: (1) phosphate sensor optimization, improving sensitivity, stability, and long-term performance in lake water; (2) sensor array integration, combining phosphate detection with dissolved oxygen, temperature, and sunlight sensors to monitor conditions linked to algal blooms; (3) compact field monitoring node design, enabling autonomous operation, wireless communication, and low-power deployment in lakes; and (4) laboratory calibration and validation, including controlled testing to evaluate sensor accuracy, repeatability, and reliability. The resulting prototype system will provide a reliable sensing platform ready for pilot deployment in Minnesota lakes.

Activity Milestones:

Description	Approximate Completion Date
Optimize the small phosphate sensor for improved sensitivity, stability, and reliable operation in water.	December 31, 2027
Integrate the phosphate sensor with oxygen, temperature, and light sensors into a monitoring node.	June 30, 2028
Complete laboratory calibration and validate overall system performance under controlled testing conditions.	June 30, 2029

Activity 2: Field Demonstration and AI-Based Risk Monitoring

Activity Budget: $169,650

Activity Description:
This activity will demonstrate the proposed monitoring system through pilot deployment in selected Minnesota lakes and develop methods to analyze the collected data. Field monitoring nodes developed in Activity 1 will be deployed to continuously measure phosphate and support environmental parameters, generating real-time data describing lake conditions. Several monitoring nodes will be installed in selected Minnesota lakes, including Lake Minnetonka, Lake Waconia, and Lake Pepin, to capture spatial and temporal variations in water quality conditions. Key components of this activity include: (1) pilot sensor deployment, installing monitoring nodes at representative lake sites to collect continuous environmental data; (2) wireless data transmission and centralized data management, enabling real-time transfer of monitoring data to a central platform; (3) data analysis, identifying environmental patterns associated with harmful algal blooms and oxygen depletion; and (4) system performance evaluation, comparing sensor data with existing monitoring datasets and assessing system performance under real lake conditions. Collected data will be organized and visualized through a simple monitoring interface to support interpretation of lake conditions during the pilot study. This field demonstration will confirm the feasibility of distributed real-time monitoring and show how the system can help detect algal bloom risks earlier in Minnesota lakes.

Activity Milestones:

Description	Approximate Completion Date
Deploy pilot monitoring nodes in selected Minnesota lakes to collect continuous water quality data.	December 31, 2028
Develop a central data platform and analysis tools for processing monitoring data.	December 31, 2029
Validate system performance through field testing and comparison with existing lake monitoring data.	June 30, 2030

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
Project results will be shared through peer-reviewed publications, conference presentations, and communication with Minnesota stakeholders involved in lake and water quality management. Sensor performance data, system design information, and pilot monitoring results will support future expansion of real-time lake monitoring efforts in Minnesota. The developed monitoring nodes, datasets, and analysis tools will help guide broader deployment of affordable phosphate and multi-parameter sensing technologies for early detection of algal bloom risks. Project materials and technical findings will be maintained at the University of Minnesota to support continued research, system improvement, and future scale-up. Outreach materials will communicate the project's value for protecting lake ecosystems and improving water quality management. All publications, presentations, and outreach products will acknowledge support from the Environment and Natural Resources Trust Fund in accordance with ENRTF requirements.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
As a product of this project, a MEMS-based multi-parameter sensing system for lake monitoring will be developed, enabling real-time detection of phosphate and key environmental parameters. Patents based on the developed sensor prototypes and system design will be pursued to support potential commercialization. The monitoring system will be deployed in selected Minnesota lakes and has the potential for broader implementation in statewide and national water monitoring programs. Future work will focus on further integration of sensing, data processing, and communication modules, as well as expanded field testing across a larger number of lakes. Additional funding from federal programs such as

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Portable Arsenic and Nitrate Detector for Well Water	M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04v	$358,000

Project Manager and Organization Qualifications

Project Manager Name: Tianhong Cui

Job Title: Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Tianhong Cui is a Distinguished McKnight University Professor at the University of Minnesota. He is a Professor in Department of Mechanical Engineering and an Affiliate Senior Member of the graduate faculty in Department of Electrical and Computer Engineering. He joined the faculty of the University of Minnesota in 2003. He is a Fellow of the American Society of Mechanical Engineering. He is also a member of European Academy of Sciences and Arts. Dr. Cui is an international leading expert on micro sensors and advanced manufacturing. He has 380 archived publications in scientific journals and prestigious conferences and 10 US patents. He is the founding Executive Editor-in-Chief for a Nature journal, Microsystems & Nanoengineering. He has received awards including the STA & NEDO Fellowships in Japan, the Alexander von Humboldt Fellowship in Germany, the Richard & Barbara Endowed Chair and the Distinguished

McKnight University Professorship from the University of Minnesota, the Blaise Pascal Chair Visiting Professorship in France (named after famous French scientist Blaise Pascal), the Distinguished Visiting Fellowship from the Royal Academy of Engineering and the Global Chair at the University of Bath in UK, a recent JSPS faculty fellowship at the University of Tokyo, and numerous best paper awards. Most recently Dr. Cui has received two NSF grants on micro chemical sensors for detection of water pollutants.
Dr. Cui will serve as the PI and project manager, responsible for overseeing the project, all reports, and deliverables. He will supervise one postdoc to work on design, fabrication, and characterization of the proposed sensors for detection of PFAS in water. He will hold weekly meetings and daily technical discussions with his advisee to ensure good progress of this proposed work. Dr. Cui and his postdoc will also be responsible for field tests and assessment of the proposed PFAS sensor.

Organization: U of MN - College of Science and Engineering

Organization Description:
All programs in the College of Science and Engineering at the University of Minnesota are ranked among the top 25 in the nation by U.S. News. The Department of Mechanical Engineering is recognized as one of the leading programs in the country, serving as a hub for education, research, and innovation. This project will be conducted at the University of Minnesota in the Technology Integration & Advanced Nano/Microsystems Laboratory (TIAN Lab), located in the Mechanical Engineering Building. Directed by Professor Cui, the TIAN Lab is equipped with state-of-the-art fabrication and characterization tools, enabling the design, production, and analysis of PFAS detection sensors. Professor Cui and his PhD assistant will use these facilities to develop and test the sensors. Some fabrication will take place at the Minnesota Nano Center, a premier facility for nanoscience and applied nanotechnology research. The Center maintains advanced equipment, enforces strict safety protocols, and provides training for researchers. Supported by the state, the NSF's NNCI program, and industry partnerships, the Center offers academic users significantly reduced rates—often less than half of the actual operational cost.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tianhong Cui		Principal Investigator			27.8%	0.24		$92,353
Graduate Student (1)		Research Assistant			45.44%	1.5		$203,790
							Sub Total	**$296,143**
Contracts and Services								
UMN Minnesota Nano Center and Characterization Facility	Internal services or fees (uncommon)	This budget is for the fabrication and testing of phosphate sensors and other type of sensors.				0		$42,000
							Sub Total	**$42,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Materials and supplies including silicon wafers, polymer substrates, graphene nanomaterials, chemicals, etc.	This budget is for the construction of phosphate sensors, other sensors, and the overall monitoring systems.					$29,857
							Sub Total	**$29,857**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	24 trips for 2 researchers	This budget is for the two researchers to conduct on-site					$9,000

			monitoring of algal blooms with real-time phosphate monitoring					
							Sub Total	**$9,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$377,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A calculated at 54% MTDC	Support of ME facilities where research will be conducted.	Secured	$170,928
			Non State Sub Total	**$170,928**
			Funds Total	**$170,928**

Total Project Cost: $547,928

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 7a2c3648-41f.docx

Alternate Text for Visual Component

Comparision of the current and proposed technologies...

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Institutional Support Letter	295836aa-d9d.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

No

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Alexandra Sullivan

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A