Environment and Natural Resources Trust Fund

M.L. 2025 Approved Work Plan

General Information

ID Number: 2025-275

Staff Lead: Lisa Bigaouette

Date this document submitted to LCCMR: June 9, 2025

Project Title: Portable Arsenic and Nitrate Detector for Well Water

Project Budget: $358,000

Project Manager Information

Name: Tianhong Cui

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Project Reporting

Date Work Plan Approved by LCCMR: June 24, 2025

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2028

Final Report Due Date: August 14, 2028

Legal Information

Legal Citation: M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04v

Appropriation Language: $358,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop a small, cheap, and easy-to-use system to detect arsenic and nitrate in well water and determine whether well water is safe to drink.

Appropriation End Date: June 30, 2028

Narrative

Project Summary: We propose to develop a tiny, cheap and easy-to-use detector for arsenic and nitrate. It can be used for well water to determine if the water is safe to drink.

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

In Minnesota, arsenic and nitrate contamination in well water poses a significant public health threat. Data from the Minnesota Department of Health reveals that approximately 10% of private wells exceed the U.S. Environmental Protection Agency's standards for arsenic (10 parts per billion) and nitrate (10 parts per million). These contaminants are linked to various health issues, including cancer, cardiovascular problems, and methemoglobinemia, and are particularly hazardous for infants and pregnant women. The reliance on private wells for drinking water exacerbates the issue, as they often lack regulations and routine monitoring. Moreover, Minnesota's geological composition, characterized by arsenic-prone aquifers, complicates the situation. Current detection methods rely on periodic water sampling and testing, which is often time consuming and costly. This intermittent testing increases the risk of contamination going undetected for extended periods, amplifying health risks. Given these challenges, urgent action is necessary to develop portable arsenic and nitrate detectors for well water. These detectors would enable fast, cheap on-site testing, improving the safety of well water statewide. Investing in such technology is crucial to safeguarding public health and ensuring access to clean drinking water for all Minnesotans.

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.

Our proposed solution to the pervasive issue of arsenic and nitrate contamination in well water in Minnesota is to develop a new detector for accurately determining arsenic and nitrate levels in water. This involves cutting-edge detection technologies: a graphene ion-sensitive field-effect transistor (ISFET) with arsenic and nitrate ion-sensitive membranes. Graphene ISFETs offer unparalleled sensitivity, enabling the detection of minute concentrations of ions or species in water. By incorporating ion-sensitive membranes tailored specifically for arsenic ions and nitrate species, our device can accurately and rapidly detect the presence of these contaminants in well water samples. This innovative approach addresses the shortcomings of current detection methods, providing a portable, cheap, and user-friendly solution. The graphene ISFET technology allows for on-site detection, eliminating the need for laborious and expensive laboratory analysis. Moreover, its sensitivity ensures early detection of contamination, mitigating health risks associated with prolonged exposure. This includes sensor and membrane development, followed by performance optimization to enhance sensitivity, stability, and accuracy. In collaboration with the Minnesota Well Owners Organization, field test will validate the technology's real-world effectiveness. These steps ensure a reliable, portable, and cost-effective solution for safeguarding public health and ensuring safe water.

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?

The project to develop a new detector to identify and evaluate the concentration of arsenic and nitrate in well water using graphene ISFET technology to directly support Minnesota's environmental goals. By safeguarding water quality and preventing further degradation, it contributes to the conservation of groundwater and preservation of ecosystems. Early detection of contaminants promotes sustainable resource management and protects public health, aligning with the state's commitment to environmental stewardship. Ultimately, the project enhances the resilience of Minnesota's natural resources, ensuring they remain viable for future generations while promoting the well-being of communities reliant on clean water sources in Minnesota.

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 and In the Future

Activities and Milestones

Activity 1: Development of arsenic and nitrate detectors using graphene ion-sensitive field-effect transistors for laboratory testing of water

Activity Budget: $174,133

Activity Description:
The first activity aims to develop, manufacture, and assess individual sensors using graphene ion-sensitive field effect transistors (ISFETs) coupled with arsenic and nitrate ion-sensitive membranes (ISMs). Graphene is a monolayer of carbon atoms which is highly sensitive to pollutants in water. The following steps will ensure successful completion: Firstly, graphene ISFET sensing platform will be designed and fabricated, focusing on optimizing graphene channels, source-drain electrode design, and selecting cost-effective substrates while maintaining high sensing performance. Next, arsenic and nitrate ISMs will be synthesized by immobilizing ionophores within a polymer matrix to enable selective detection of different species in water. ISM compositions will undergo optimization to ensure long-term stability and heightened sensitivity. Subsequently, integration of arsenic and nitrate ISMs with graphene ISFETs will occur, followed by in-laboratory measurement and optimization. Validation of results will involve comparison with standard methods including ion chromatography (IC) for nitrate and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for arsenic. The sensors will be fabricated using microfabrication technology at the Minnesota Nano Center, University of Minnesota. Testing and evaluation of arsenic and nitrate detectors in laboratory settings will compare sensing results with standard methods such as Inductively Coupled Plasma Mass Spectrometry.

Activity Milestones:

Description	Approximate Completion Date
Design, fabrication, and testing of arsenic detectors as testing prototypes in laboratory	December 31, 2025
Design, fabrication, and testing of nitrate detectors as testing prototypes in laboratory	June 30, 2026
Improvement and optimization of arsenic and nitrate detectors in laboratory	June 30, 2026

Activity 2: Development of a portable detection system integrated arsenic and nitrate sensors, detector system parameter optimization, and field tests

Activity Budget: $183,867

Activity Description:
The second activity of the proposed project aims to develop a portable detector system suitable for field testing by non-trained individuals. This involves four key milestones: (1) Designing and fabricating an integrated graphene ISFET platform comprising arsenic and nitrate sensors, which will undergo testing and optimization with synthesized ISMs. (2) Developing the detector's readout circuit, portable chassis, and user-friendly interface, with a modular design allowing for easy sensor replacement. (3) Conducting laboratory testing to validate the detector's performance against standard techniques like Inductively Coupled Plasma Mass Spectrometry. (4) Field-testing the detector for onsite arsenic and nitrate detection in well water, where environmental scientists will utilize it, providing valuable feedback for further optimization. Field tests will be performed at the free well-testing clinics for private well-owners throughout Minnesota, led by the Minnesota Well Owners Organization, where traditional analytical techniques will be used to confirm the ISFET sensor accuracy and inform technology optimization. By integrating advanced technology with accessible design, this portable detector system ensures efficient and reliable onsite detection of arsenic and nitrate contamination. Such advancements are crucial for safeguarding public health and preserving natural water resources, ultimately contributing to the broader goal of environmental sustainability and clean water access.

Activity Milestones:

Description	Approximate Completion Date
Design, fabricating, and optimizing the integrated graphene ISFET platform for arsenic and nitrate detection	December 31, 2026
Design and fabrication of the detector's readout circuit, chassis, and user-interface	December 31, 2026
In-lab validation and field test of the portable arsenic/nitrate detector for well water	June 30, 2027
Field testing at MNWOO free testing clinics for accuracy assessments and technology optimization	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Cara Santelli	University of Minnesota	Co-PI; Be responsible for field tests and assessments of the developed sensors.	Yes
Jeffrey Broberg	Minnesota Well Owners Association	Organize and collaborate on nitrate and arsenic well-testing clinics for private well-owners.	Yes

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.
Our dissemination efforts will focus on engaging beneficiaries, improving resource management, ensuring the longevity of project outputs, promoting behavioral changes, and informing the public about the achievements of our portable arsenic and nitrate detector for well water. We will publish our findings in peer-reviewed journals and present at national and international conferences, such as those hosted by the American Society of Mechanical Engineers (ASME) and the Institute of Electrical and Electronics Engineers (IEEE). Additionally, we will host workshops and seminars at the University of Minnesota to disseminate our findings to academic and industry partners. Collaborations with the Minnesota Department of Health and local environmental organizations will be established to share research results and provide training sessions, ensuring practical applications and awareness among local water management authorities and well owners.

Educational outreach will include the development of brochures, fact sheets, and instructional videos to explain the importance of water testing and the use of the portable detector. We will conduct outreach programs in schools and community centers to raise awareness about water contamination and ensure safe drinking water. Online dissemination will be facilitated through a dedicated project website hosting data, publications, and resources for public access, as well as social media platforms to share updates, milestones, and results. Data and results will be submitted to open-access repositories for broad accessibility and long-term preservation, and physical samples and detector prototypes will be shared with research institutions and public health agencies. Community engagement will be fostered through meetings and forums to discuss project findings and gather feedback from stakeholders, with easy-to-understand summaries distributed to impacted communities. Through these comprehensive efforts, we aim to maximize the impact of our project, benefiting those who need it most and contributing to the betterment of Minnesota's environment and public health.

All dissemination materials, including publications, presentations, outreach materials, and digital content, will acknowledge the support of the ENRTF. The ENRTF logo and attribution language will be included in printed and electronic media, such as research papers, brochures, fact sheets, instructional videos, and the project website. Any public-facing presentations at conferences, workshops, and seminars will include a slide or statement recognizing ENRTF's contribution. Additionally, signage at outreach events and community engagement activities will display the ENRTF logo, ensuring clear visibility of the fund's role in supporting this work. These acknowledgments will adhere to the ENRTF Acknowledgment Guidelines to maintain consistency and transparency in communicating the project's funding source.

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?

A portable arsenic and nitrate detector will be developed. Patents based on the developed prototypes will be applied for commercialization. The systems will be used for well waters in Minnesota. Further work will focus on the highly integrated pre-processing and post-processing units and field tests for a broader area. Other federal funding from NSF (i.e., programs including the funded Convergence Accelerator, the funded Regional Innovation Engine, etc.), USDA (i.e., the AFRI Foundational and Applied Science Program), EPA, USGS, or private funds will be applied as potential funding sources for further development of arsenic and nitrate sensors.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tianhong Cui		Principal Investigator			27.06%	0.24		$56,399
Cara Santelli		Co-PI			27.06%	0.24		$37,240
Research Assistants		Research Assistants			42.97%	3		$185,757
							Sub Total	**$279,396**
Contracts and Services								
MNWOO	Subaward	Running well-testing clinics for local community members to bring well water samples. Arsenic and nitrate levels will be quantified by traditional analytical techniques and sensors will be tested to determine accuracy and optimization needs.				2		$27,000
UMN Nano Center	Internal services or fees (uncommon)	Scientific Service at the University of Minnesota's Minnesota Nano Center and the Characterization facility. Fabrication and characterization costs of the arsenic and nitrate detectors in central facilities				0		$21,000
							Sub Total	**$48,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Silicon wafers, polymer substrates, graphene, chemicals, and components for testing set-up	Materials and supplies for various items required to fabricate and characterize the arsenic and nitrate detector					$18,104
							Sub Total	**$18,104**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travels in Minnesota	Sampling and field tests in Minnesota waters					$12,500
							Sub Total	**$12,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$358,000**

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 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$167,626
			Non State Sub Total	**$167,626**
			Funds Total	**$167,626**

Total Project Cost: $525,626

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 469e0d75-692.pdf

Alternate Text for Visual Component

Comparison of the current and proposed technologies for detection of arsenic and nitrate...

Supplemental Attachments

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

Title	File
USGS Support Letter	cab3ae5b-8ec.pdf
MNWOO Letter	bfda9035-3ae.pdf
University Support Letter	ce2fcc8e-6d2.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

No Changes. Just an expansion from the original proposal to this work plan.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

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")?

Yes

Do you certify that background checks are performed for background check crimes, as defined in Minnesota Statutes, section 299C.61, Subd. 2, on all employees, contractors, and volunteers who have or may have access to a child to whom children's services are provided by your organization?

Yes

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

Alexandra Sullivan <sull1129@umn.edu>

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