Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-155

Proposal Title: Optimal Sampling Design for Tracking Impairments in Streams

Project Manager Information

Name: Kun Zhang

Organization: U of MN - Duluth

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Project Basic Information

Project Summary: Because agencies have limited resources and capacity to monitor streams at adequate resolution to assess stream health, we will use advanced computational approaches to develop and evaluate optimal sampling designs.

ENRTF Funds Requested: $247,000

Proposed Project Completion: June 30, 2028

LCCMR Funding Category: Small Projects (H)
Secondary Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?
Region(s): NE

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

Narrative

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

Stormwater management issues, including mitigating transport of legacy and emerging contaminants to receiving waterbodies, present a serious challenge to Minnesota communities, especially when faced with increased storm activity and intensity under climate change. Comprehensive water quality monitoring data are required to inform stormwater management decisions and watershed management strategies, but limited resources and capacity hamper the ability of state and regional agencies to collect data at adequate spatial and temporal resolution. Basically, it is not cost-effective or even practical to measure numerous water quality measures across numerous aquatic ecosystems at the frequency required to protect our treasured lakes and streams. New computational algorithms, such as data-driven sparse-sensing, can mine existing datasets to optimize sampling design for stream monitoring programs, thereby providing adequate monitoring data for management needs at a fraction of the cost (i.e., less sampling events and associated analytical costs). Additionally, volunteer-collected water quality data can help increase spatial and temporal resolution at minimal costs if done properly.

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.

Water quality variables assessing stream impairments do not vary randomly, but instead follow specific patterns influenced by rainfall and landscapes. These relationships enable predicting changes in under-sampled water quality variables leveraging information from routinely monitored data. Data-driven sparse sensing (DSS) is a computational framework capable of discerning embedded patterns within environmental datasets, enabling the determination of the optimal sampling locations and times that produce satisfactory results in system dynamics with minimal sampling efforts and costs. This project proposes to utilize DSS to optimize the stream water quality sampling designs in Duluth, MN, and estimate contaminant loads into Lake Superior and the St. Louis River Estuary. First, we will utilize DSS to identify the best times for taking samples based on historical datasets (discharge, conductivity, and temperature). Second, we will sample three streams at the calculated optimal times for chloride, total suspended solids, nitrogen, and phosphorus to evaluate the accuracy of annual load calculations based on the optimal (reduced) sampling design versus current approaches. Citizen scientists will assist with collecting and analyzing chloride and E. Coli samples, additional variables linked to stream impairments. Finally, we will meet with partners to turn our findings into a water quality monitoring recommendation report.

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?

Watershed management plans and restoration strategies are built from comprehensive monitoring data, which are costly and challenging to collect based on current approaches. Our proposed study will identify the optimal sampling design for collecting essential contaminant data (nutrients, sediment, chloride, E. coli) utilizing readily measurable variables like flow discharge, temperature, and conductivity. We will estimate contaminant loads into Lake Superior and the St. Louis River Estuary using limited measurements with professional and citizen scientists. The successful implementation of this approach can reduce the efforts and costs in monitoring by the City and agencies for trout habitat protection and watershed planning.

Activities and Milestones

Activity 1: Develop Optimal Sampling Design for Duluth Streams

Activity Budget: $75,959

Activity Description:
We will synthesize historical high frequency sensor data (15-minute observations of stream discharge, temperature, turbidity, and conductivity) from 12 North Shore streams using the Watershed Pollutant Load Monitoring Network (WPLMN) and Duluth Streams databases. We will utilize the dataset as our training dataset to identify the most representative watersheds for sampling and the optimal times for grab sampling based on the DSS framework described above. Specifically, we will organize the time series data as a matrix and further perform Singular value decomposition (SVD), a dimensional-reduction technique, to yield the optimal least-square approximation to the data followed by a QR factorization. Based on previous research (Manohar et al., 2018), the product of QR factorization informs the optimal times (or locations; depending on how the time series data is organized) for collecting samples. We will gradually add variables into the training data (start with stream discharge followed by temperature, turbidity, and conductivity) and compare the results for each set of training variables to quantify the information value of each candidate variable.

Activity Milestones:

Description	Approximate Completion Date
Collect and synthesize data	October 31, 2025
Compare the optimal sampling designs for different training variables	February 28, 2026
Produce an optimal sampling design to be tested in Activity 2	March 31, 2026

Activity 2: Validate the Accuracy of Optimal Sampling Design through Field Trials

Activity Budget: $141,875

Activity Description:
To validate the accuracy of optimal sampling times obtained in Activity One, we will perform a two-year field sampling trial at three case study watersheds – Tischer Creek, Miller Creek, and Amity Creek. We will collect 30 grab samples each year at the optimal times identified in Activity One at each location. The water samples will be analyzed for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and chloride by NRRI. Additionally, we will work with a group of volunteering citizen scientists to collect water samples at the same location and analyze for chloride and E. coli as supplementary data. Discrete water chemistry and bacteria measurements will be integrated with the optimal least-square approximations identified from historical data through SVD in Activity One to reconstruct the contaminant time-series and estimate their annual loads. We will compare annual loads based on different numbers of samples to explore the minimum required samples to obtain adequate annual load calculations. We will also compare the results of professionally collected samples with those augmented by citizen science data to determine the effectiveness of leveraging citizen science programs to improve water quality assessments.

Activity Milestones:

Description	Approximate Completion Date
Site visits to identify sampling locations	April 30, 2026
Collect and analyze water quality samples in Year 1	October 31, 2026
Collect and analyze water quality samples in Year 2	October 31, 2027
Nutrient load estimation and comparison	March 31, 2028

Activity 3: Develop Water Quality Sampling Recommendations with Partners and Practitioners

Activity Budget: $29,166

Activity Description:

We will use the findings of Activity One and Two to answer important management questions such as: which watersheds best represent the hydrologic and biogeochemical processes in the North Shore?, when is the best time to collect water quality samples?, and what is the minimum number of samples required for accurate water quality load estimation? We will organize kick-off and wrap-up workshops with our partners at City of Duluth, Minnesota Pollution Control Agency (MPCA), and Minnesota Department of Natural Resources (MNDNR) and practitioners specializing in water quality monitoring in the region. We will collect input from our partners about the existing sampling approaches in kick-off workshops prior to field trials. We will disseminate the findings of this project, discuss possible water quality sampling recommendations, and explore future funding models to support water quality monitoring and sampling in the state in the wrap-up workshops. To expand the project's reach, we will present findings at regional meetings, such as the St. Louis River Summit and the Water Resources Conference, and international conferences. Through project reporting and scientific publications, we will share our findings so that other state agencies and tribes may use them to guide their water quality sampling efforts.

Activity Milestones:

Description	Approximate Completion Date
Host kick-off workshops and get advice from partners prior to field trials	March 31, 2026
Host wrap-up workshops to deliver project outputs, discuss possible sampling recommendations, and future funding models	June 30, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Christopher Filstrup	U of MN - Duluth - NRRI	Filstrup leads NRRI's Central Analytical Water Testing Lab and will be responsible for the analytical testing of water samples. He will assist with field sampling, data analysis and interpretation, project reporting and manuscript development, and outreach.	Yes
Jerry Henneck	U of MN - Duluth - NRRI	Henneck is a senior research scientist specializing in field sampling and instrumentation. He will be responsible for the field sampling.	Yes
Tiffany Sprague	U of MN - Duluth - NRRI	Sprague works with a citizen scientist group in Duluth. Sprague will be responsible for communicating with the group and perform field sampling.	Yes
Eva Hendrickson	U of MN - Duluth - NRRI	Hendrickson is a researcher at the NRRI's Central Analytical Lab. She will assist with the analytical testing of water samples.	Yes
Dan Wisniewski	U of MN - Duluth - NRRI	Wisniewski is a researcher specializing in field biology at NRRI. He will assist with field sampling.	Yes
Ryan Granlund	City of Duluth	Granlund and City of Duluth are operating a Municipal Separate Storm Sewer System (MS4); City of Duluth will provide feedback on transferring the findings of this project into management decisions.	No
Tom Estabrooks	MPCA	Estabrooks and MPCA will provide feedback on transferring the findings of this project into management decisions.	No
Andy Kasun	South St Louis SWCD	Kasun and South St. Louis Soil & Water Conservation District will provide feedback on transferring the findings of this project into management decisions.	No

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?

Project activities, including data collection, data analysis and interpretation, and tool development, will be completed during this project. Institutional funds will be used to fund products that are developed afterwards, such as publications or scientific presentations. Implementation of the research will be via professionals and agencies who will use the findings to make management decisions about stream monitoring and sampling. If new research directions are developed from LCCMR's investment in this project, partners will seek new funding from other grant opportunities.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Catch and Reveal: Discovering Unknown Fish Contamination Threats	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04g	$246,000

Project Manager and Organization Qualifications

Project Manager Name: Kun Zhang

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.

Zhang will be responsible for project management and administration, and has the scientific expertise and project management experience to successfully complete this research. Zhang directs UMD Civil Engineering's Data-Model Integration in Urban Hydrology group specializing in using data-driven and process-based models to solve contemporary issues in urban hydrology. He has studied hydrology and water quality issues in urban watersheds for ~ 7 years, including quantifying the water balances and optimizing the design of green stormwater infrastructure in urban watersheds.

Zhang also specializes in working with large complex datasets from existing monitoring programs to generate new knowledge from publicly funded data. Zhang currently manages one federal and several UMD funded projects, including serving as PI on a $200K NSF-funded project investigating the interventions of sewer networks and soil profiles on water balances. Most related to this project, Zhang was previously awarded funding from the U.S. Army Engineer Research and Development Center (ERDC) to develop a data-driven model for water quality prediction; while this project applied a similar approach to predict stream water quality concentrations and loads, it only focused on nutrients and did not validate the model through field sampling. More importantly, it did not transfer the results into implementable sampling suggestions.

Organization: U of MN - Duluth

Organization Description:
Swenson College of Science and Engineering (SCSE) (PI Zhang) is the largest college in U of MN – Duluth and is the third largest college in the U of MN system. It is the home of the Large Lakes Observatory, Integrated Biosciences graduate program, Water Resources Science graduate program, and Advanced Materials Center. SCSE also has close affiliations with the Natural Resources Research Institute (NRRI) and the Minnesota Sea Grant program. SCSE's mission is to inspire the next generation of STEM professionals to solve complex problems. SCSE provides the students with a good opportunity to engage in active learning and conduct world-class research with faculty, the community, and regional partners. The Lake and Stream Ecosystem Ecology Lab (PI Filstrup) at NRRI has the necessary experience, equipment, and infrastructure to monitor Duluth streams and analyze water chemistry samples. The lab has been monitoring Duluth streams for 25 years and has a long-term dataset that can be analyzed for this project. The lab also includes the Central Analytical Laboratory, a state-certified water chemistry laboratory specializing in the detection of low level nutrients in low productivity aquatic ecosystems, that will be responsible for analyzing nutrient, suspended sediment, and chloride samples.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Kun Zhang		Zhang will serve as the project PI and will be responsible for project administration, modeling, data analysis and interpretation, project reporting and manuscript development, and outreach.			27.1%	0.21		$24,705
Christopher Filstrup		Filstrup will serve as the co-PI of this project. He will assist with field sampling, data analysis and interpretation, project reporting and manuscript development, and outreach.			27.1%	0.27		$34,613
Jerry Henneck		Henneck will be responsible for the field sampling.			25.1%	0.3		$30,382
Tiffany Sprague		Sprague will be responsible for communicating with the group and perform field sampling.			27.1%	0.36		$34,723
Eva Hendrickson		Hendrickson will assist with the analytical testing of water samples.			25.1%	0.12		$7,434
Dan Wisniewski		Wisniewski will assist with field sampling.			25.1%	0.18		$6,457
Graduate Research Assistant		TBD graduate student will assist with data-driven sparse sensing modeling to identify optimal sampling locations and times, data analysis and interpretation, and manuscript development.			25.1%	0.69		$76,574
Undergraduate Research Assistant		TBD undergraduate research assistants will be hired in the summers to assist with field sampling, and processing and analyses of water samples.			0%	0.15		$3,230
							Sub Total	**$218,118**
Contracts and Services								
Central Analytical Laboratory	Internal services or fees (uncommon)	We have budgeted funds for water chemistry analyses. Analytical rates are based on published Central Analytical Laboratory fees multiplied by the number of samples. Water quality analytical fees in each of Y1 & Y2. Y2 has 3% inflation added.				0		$14,007
							Sub Total	**$14,007**
Equipment, Tools, and Supplies								

	Tools and Supplies	Field Supplies	Field supplies required to complete work in Years 1, 2.					$5,650
	Tools and Supplies	Citizen Scientist Supplies	Citizen scientist supplies required to complete work in Years 1, 2. 252 samples for E. coli and Chloride will be monitored in each project year.					$5,000
	Tools and Supplies	Citizen scientist appreciation event	Budgeted as $501 for one event held in each of Years 2, 3. Costs include a recognition and thank you take-away and certificate and a meal for each volunteer, including a meal for the research team members attending the appreciation party (20 individuals maximum per year).					$1,002
							Sub Total	**$11,652**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Field travel to collect samples and record stream observations in each of Y1 & Y2. 3% inflation per year included.	Travel required to conduct fieldwork near North Shore.					$3,223
							Sub Total	**$3,223**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								

							Sub Total	**-**
							Grand Total	**$247,000**

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	UMN unrecovered indirect costs are calculated at the UMN federally negotiated rate for research of 55% modified total direct costs	Indirect costs are those costs incurred for common or joint objectives that cannot be readily identified with a specific sponsored program or institutional activity. Examples include utilities, building maintenance, clerical salaries, and general supplies. (https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs)	Secured	$121,430
			Non State Sub Total	**$121,430**
			Funds Total	**$121,430**

Total Project Cost: $368,430

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: bae1c076-cd9.pdf

Alternate Text for Visual Component

Urban streams suffer from impairments such as nutrients, sediments, chloride, bacteria, and thermal impact due to stormwater runoff (top graphics). This study aims to develop a optimized method for sampling stream water quality from prior data (middle graphics), potentially enhancing stream health outcomes (bottom graphics)....

Supplemental Attachments

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

Title	File
Letter of Support from City of Duluth	e9bfd726-7be.pdf
Letter of Support from the South St Louis SWCD	849a8d9e-fd7.pdf
Letter of Support from MPCA	f38e2f39-678.pdf
Submission Approval Letter	58b5c572-a80.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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?

Yes

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: