Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-046

Proposal Title: Fate of Minnesota's Lakes in the Next Century

Project Manager Information

Name: Ardeshir Ebtehaj

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This proposal aims to answer this question: How would the water quality of Minnesota's lakes change in the next century under future scenarios of urbanization, agricultural growth, and climate change?

Funds Requested: $499,000

Proposed Project Completion: July 31, 2027

LCCMR Funding Category: Foundational Natural Resource Data and Information (A)

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?

In the Future

Narrative

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

When in 1848, Europeans settled next to the Great Salt Lake, it was perhaps out of the stretch of their imagination that the lake would lose more than 70% of its water and 60% of its surface area in the next 175 years. Every day, thousands of lakes are nurturing human life and the ecosystem in Minnesota. It seems imperative to ask this fundamental question. What would be the fate of lakes in Minnesota in the next century?

Climate projections based on different global Shared Socioeconomic Pathways (SSPs) of economic growth scenarios indicate that Minnesota will be wetter. Moreover, observations show annual precipitation has increased by 30% since 1900 across Minnesota. Therefore, it is unlikely that our lakes will dry up in the next century. However, more precipitation and potential agricultural growth imply additional runoff that can carry more nutrients into the lakes and accelerate eutrophication and the growth of algal blooms. Additionally, with increased air temperature and carbon dioxide concentration, algal blooms will have a much more favorable environment to grow, especially toxic cyanobacterial blooms (e.g., Microsistis) that can accumulate at the lake's surface. We hypothesize that the eutrophication of Minnesota's lakes will accelerate in the following decades.

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 proposal aims to study and quantify how the water quality in Minnesota's lakes will change over the next century in response to potential scenarios of climate and land use changes. The main challenge is that the climate model projections are available at 50-100 km resolution for key variables such as precipitation and temperature. Additionally, runoff, nutrient concentrations, and algal biomass data are not available in future climate projections. We currently do not have the cyberinfrastructure in Minnesota to process the climate data and inform decision-makers. To cope with these challenges, we propose the following activities.
(i) Develop modern artificial intelligence (AI) tools to increase the resolution of the climate projections over Minnesota to obtain future critical data (i.e., runoff, temperature, sediment, nutrients) for individual lakes in Minnesota.
(ii) Develop a modern parsimonious lake model that converts the high-resolution climate projections to the vertical profiles of temperature, nutrient, and algal biomass concentrations. We will validate the model based on historical climate data and observations over shallow and deep lakes in MN.
(iii) Develop an online web-server platform to compute and visualize future changes in water temperature, nutrients, sediments, ice covers, and algal biomass concentrations in all of Minnesota's lakes.

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 will provide predictive assessments, vulnerability maps, and an online modeling platform that can answer questions about when, where, and why the Minnesota lakes' water quality could be intolerable to humans and ecosystems in the next century. The online model outputs and maps can be traced back to the watershed nutrient export sources depending on potential future land use changes. Therefore, the results will provide decision-makers with quantitative information to explore sustainable economic growth solutions towards reducing the impacts, preparing for, recovering from, and adapting to potential changes in the MN lakes' water quality.

Activities and Milestones

Activity 1: Quantify future changes in nutrient runoff to Minnesota's lakes

Activity Budget: $145,861

Activity Description:
The idea is to develop new AI tools to increase the resolution of climate model projections through learning from a series of high-resolution historical observations. New emerging AI tools, namely deep neural networks, have enabled us to produce a high-resolution version of an image with unprecedented accuracy given a set of observed images at a lower resolution – a field known as super-resolution imaging. Using the AI tools, we will increase the resolution of critical meteorological data (e.g., precipitation, air temperature, solar radiation) from 50-100 to 1-5 km over Minnesota. The climate projections from the North American Regional Climate Change Assessment Program (https://www.narccap.ucar.edu/) and Coupled Model Intercomparison Project (CMIP6) will be used over MN. Climate simulations are also available historically from 1800 onward. We will use historical and future data to develop predictive tools that quantify the relationship between climate variables and nutrient runoff. The predictive skills of the tool will be validated based on past in situ observations over shallow (e.g., Lake Madison) and deep lakes. The tool will be applied to predict future changes in nutrient loads to all of Minnesota's lakes depending on different SSP scenarios and changes in land use.

Activity Milestones:

Description	Approximate Completion Date
Increase the resolution of climate projects of key meteorological variables	February 28, 2025
Develop tools to predict changes in nutrient runoff to the lakes in the next century	August 31, 2025
Validate the tool through comparisons with in situ observations	December 31, 2025
Disseminate the results through peer-reviewed publications	May 31, 2026

Activity 2: Predict changes in temperature, algal blooms, and ice cover over the next century

Activity Budget: $174,987

Activity Description:
Some sophisticated lake models predict the spatiotemporal distribution of temperature and algal blooms in lakes. However, these models are not suitable to predict the impacts of climate change on lakes, because they need detailed meteorological, bathymetrical, and hydrodynamic information, which is not available for all lakes in MN. To cope with this challenge, we will develop a parsimonious model called Minnesota Lake Climate (MinLake-C). The model will integrate basic meteorological data (e.g., precipitation, temperature), watershed nutrient runoff loads, and some readily available lake properties (i.e., location, average depth, fetch, transparency) to predict water temperature, nutrient, ice cover, and algal biomass concentrations.

The MinLake-C will be deployed to process the super-resolution climate data produced in activity-1 to quantify how future climate and land use scenarios will impact the occurrence and frequency of (harmful) algal blooms and lake ice. We will use multiple climate data to quantify the involved uncertainties and how they translate into predictions of lakes' water quality. As a consequence, we will be able to isolate the sources of nutrients that might contribute to the predicted changes at a level that would affect ecosystem health, water supply, fishing, and other recreational activities.

Activity Milestones:

Description	Approximate Completion Date

Develop lake water quality model MinLake-C (temperature, nutrient, and algal biomass concentrations)	August 31, 2025
Integrate meteorological and watershed data with MinLake-C	March 31, 2026
Verify the predictions with the past data in shallow and deep lake	August 31, 2026
Predict the water quality of Minnesota's lakes in the next century and disseminate the results	March 31, 2027

Activity 3: Provide an online web tool to make the finding available to stakeholders

Activity Budget: $178,152

Activity Description:

We aim to make the MinLake-C predictions available online so that a user with access to the internet can obtain future year-round lake water quality by providing publically available lake data including longitude, latitude, average depth, average length, and transparency. To that end, we will develop a GIS web server powered by the Google Colab cloud computing platform (https://colab.research.google.com/) that enables us to code and run the MinLake-C on the web. The web platform will automatically retrieve the super-resolution climate projection data and land use parameters to project the annual changes in algal biomass, lake temperature, and period of ice cover until 2100. For example, one can enter 44.945 (latitude) and 93.311 (longitude), a mean depth of 9 meters, lake fetch of 1200 m, and high turbidity (<1.0 m) to visualize how the algal biomass will change in the Lake Bde Maka Ska (Calhoun) in the years to come. The platform will also provide uncertainty measures to inform decision-makers about the unknown parameters that might affect the results. The tool will identify the origin of the nutrient sources to inform preventive and adaptive decision-making by the authorities.

Activity Milestones:

Description	Approximate Completion Date
Super-resolution climate data production and storage	March 31, 2027
Implementation of MinLake-C with Google Map and Colab	April 30, 2027
Make the platform public and disseminate the outcomes through publications	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Miki Hondzo	University of Minnesota	Co-I	Yes
Vipin Kumar	University of Minnesota	Co-I	Yes
IT Personnel	University of Minnesota	IT service and website development	Yes

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?

The project is interdisciplinary and fosters creative ideas across environmental and computer sciences. For future continuation, we aim to secure funding to maintain the web server of the online modeling platform and update our assessment of the lake's water quality when new versions of climate data become available. The project will also pave the way to target large-scale federal opportunities such as the NSF's Eco-CBET program (https://www.nsf.gov/pubs/2021/nsf21596/nsf21596.htm), which solicits research ideas to create practical solutions to our most pressing environmental and sustainability challenges through large-scale interdisciplinary projects (1.5 million dollars).

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Remote Sensing And Super-Resolution Imaging Of Microplastics	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08j	$309,000

Project Manager and Organization Qualifications

Project Manager Name: Ardeshir Ebtehaj

Job Title: Associate Professor

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

Ardeshir Ebtehaj will be responsible for overall project coordination and supervision of the study, including the development of the AI models for increasing the resolution of climate projection data over Minnesota, tools that connect the future rainfall changes to runoff, and web-based tools to make the results of the project available to the stakeholders. He has been studying remote sensing and climate change of rain and snowfall for more than 15 years. He has conducted peer-reviewed research in satellite remote sensing and climate change impacts on precipitation, soil moisture, vegetation, snow as well as plastic pollution in freshwater ecosystems. He has been the PI for numerous NASA projects and one LCCMR project. He has published more than 45 peer-reviewed papers and co-authored a book chapter on remote sensing of the environment in the handbook of environmental engineering in 2019. Dr. Ebtehaj is an associate editor of the Journal of Hydrometeorology, an affiliate member of the University of Minnesota Institute on the Environment, and a member representative of the University of Minnesota in the University Centers for Atmospheric Research (UCAR). He is the recipient of an editor award from the American Meteorological Society and a recipient of NASA's Earth and Space Science Fellowship in 2014, and NASA's new investigator (Early Career) award in 2018 for his contribution to Earth's remote sensing sciences.

Dr. Hondzo is an expert in lake modeling and biological aspects of HABs growth. Prof. Vipin Kumar is a regent professor of computer science whose research has been focused on advancing the predictability of changes in inland water lakes using modern advances in data science and AI. His work has been featured in the American Association for the Advancement of Science (https://www.eurekalert.org/news-releases/637676) and the National Science Foundation website (https://beta.nsf.gov/news/scientists-use-new-technique-identify-changes).

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://twin-cities.umn.edu/about-us). The laboratories and offices of the PI contain the necessary fixed and moveable equipment and facilities needed for the proposed studies. The PI will conduct the research in the Saint Anthony Falls Laboratory. The St. Anthony Falls Laboratory (SAFL) is an interdisciplinary hydraulic research lab and educational facility under the College of Science and Engineering at the University of Minnesota. There are engineers and scientists who collaborate across disciplines to solve water and pollution problems. The vision encompasses both science and practice, beginning with basic research and moving through application, decision-making, and management. Located on Hennepin Island in the Mississippi River in the heart of Minneapolis, SAFL serves as a resource for departments across the Twin Cities campus, the statewide University system, and the broader research community. We partner with local, state, and federal agencies; private consulting firms; businesses of many kinds; technical associations; and other educational institutions to expand knowledge and solve problems.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Ardeshir Ebtehaj (Associate Professor of Civil and Environmental Eng.)		PI			36.8%	0.24		$35,652
Miki Hondzo (Professor of Civil and Environmental Eng.)		Co-I			36.5%	0.12		$29,245
Vipin Kumar (Regent Professor of Computer Science)		Co-I			36.5%	0.06		$28,015
Graduate Student -1		Research Assistant			24.1%	3		$165,394
Graduate Student 2		Research Assistant			24.1%	3		$165,393
							Sub Total	**$423,699**
Contracts and Services								
TBD	Professional or Technical Service Contract	We aim to hire experts in web development to link the developed lake modeling tools with the Google cloud infrastructure to make the projections of water quality, for each lake in Minnesota, available to the public, decision-makers, and other stakeholders.				0.3		$50,000
							Sub Total	**$50,000**
Equipment, Tools, and Supplies								

							Sub Total	**-**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	2 trips per year for the 2 graduate students to American Geophysical Union Annual Conference	Presentation of the research outcome and exchange of knowledge with the community	X				$12,000
							Sub Total	**$12,000**
Printing and Publication								
	Publication	Cost of publications	Publish the outcomes of the research in peer reviewed journals					$7,944
							Sub Total	**$7,944**
Other Expenses								
		ISO Cost for Computer Sci Faculty	This standard is an emphasis on engineering practice leads the guide toward a strong relationship with the normative literature.					$191
		ISO Cost for Computer Sci Grad Student	This a charge for ISO standard for computer science department for an emphasis on engineering practice leads the guide toward a strong relationship with the normative literature.					$5,166

							Sub Total	**$5,357**
							Grand Total	**$499,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	2 trips per year for the 2 graduate students to American Geophysical Union Annual Conference	Presentation of the research outcome and exchange of knowledge with the community

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: 2dd0e703-09e.pdf

Alternate Text for Visual Component

The hypothesis, rationales, and proposed activities are summarized and visualized....

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
Board Letter	42194b9f-4d4.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

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?

Yes, Sponsored Projects Administration

Does your project include the design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

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?

No