Environment and Natural Resources Trust Fund

M.L. 2024 Approved Work Plan

General Information

ID Number: 2024-046

Staff Lead: Tom Dietrich

Date this document submitted to LCCMR: June 6, 2024

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

Project Budget: $453,000

Project Manager Information

Name: Ardeshir Ebtehaj

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Project Reporting

Date Work Plan Approved by LCCMR: June 20, 2024

Reporting Schedule: June 1 / December 1 of each year.

Project Completion: July 31, 2027

Final Report Due Date: September 14, 2027

Legal Information

Legal Citation: M.L. 2024, Chp. 83, Sec. 2, Subd. 03d

Appropriation Language: $453,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to use new modeling techniques to quantify how water quality of Minnesota's lakes will change in the next century under future land use and climate change scenarios and to create an online web tool to display the results. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2028, by which time the project must be completed and final products delivered.

Appropriation End Date: June 30, 2028

Narrative

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?

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., Microcystis) 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.

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

Activities and Milestones

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

Activity Budget: $134,727

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: $157,726

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: $160,547

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

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.
The project will hire two graduate research assistants. The results of their work under the supervision of the PI and Co-Is will lead to 5 to 6 publications in reputable journals of the field. The project will package a set of available software tools for modeling future changes in phytoplankton functional groups of Minnesota lakes under different climate change scenarios using CMIP6 projections and a selected group of climate models with high sensitivity over Minnesota. This package of software tools will be released under the name of MinLake-C with relevant citations to the original subroutines. This set of software tools will be released on GitHub (https://github.com/aebtehaj) to be available to the science community in Minnesota.

The proposal aims to provide basic web-based visualization capability so that all Minnesotans with internet access and a desktop computer can learn how under different climate change scenarios, the concentration of algal blooms will change in any specific lake in Minnesota by providing minimum information about the lake such as depth, initial transparency, and lake fetch. We will attempt to link this web tool to the databases provided by the Minnesota Department of Natural Resources which contain ground surveys about the morphological and bathymetry of the Minnesota lakes. The web-based tool will serve as the main tool for public dissemination of the project's outcomes. Moreover, the LCCMR funding will be acknowledged in all peer-reviewed publications. We ex[etc 5 to 6 publications of peer-reviewed papers. The logo of LCCMR will be used in any associated statewide and national presentations.

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

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: The PI will oversee execution of all activities including modeling the tends in rainfall-runoff processes and their implications on the Minnesota's water quality. The tasks will involve AI modeling of climate projections as well as hydrologic and water quality modeling.			36.6%	0.24		$50,131
Miki Hondzo (Professor of Civil and Environmental Eng.)		Co-I: Professor Hondzo will provide expertise on modeling of algal population growth in lakes and rivers			36.6%	0.09		$18,940
Vipin Kumar (Regent Professor of Computer Science)		Co-I: Professor Kumar provide expertise in using AI for providing high-resolution projections of precipitation and temperature over the next 100 years, given coarse-scale climate model simulations.			36.6%	0.03		$14,571
Graduate Student -1		Research Assistant			23.2%	3		$170,181
Graduate Student 2		Research Assistant			23.2%	3		$170,180
							Sub Total	**$424,003**
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		$20,045
							Sub Total	**$20,045**
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	1 trip for one graduate assistant or the PI to disseminate the outcome of the research in the second or third year of the project to the American Geophysical Union.	Presentation of the research outcome and exchange of knowledge with the community	X				$3,000
							Sub Total	**$3,000**
Printing and Publication								
	Publication	Cost of publications for 5 to 6 peer reviewed paper.	Publish the outcomes of the research in peer reviewed journals					$5,952
							Sub Total	**$5,952**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$453,000**

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	1 trip for one graduate assistant or the PI to disseminate the outcome of the research in the second or third year of the project to the American Geophysical Union.	Presentation of the research outcome and exchange of knowledge with the community over a maximum of 7 days of travel to AGU $430 ticket + 7*288+7*79 ~$3000

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....

Supplemental Attachments

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

Title	File
Board Letter	42194b9f-4d4.pdf
Accepted revised Research Addendum	c0467b7a-f40.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

1- On the Project Partner Info page, you can delete the line-item for IT Personnel. It is not necessary to identify them as a partner here.

- Corrected. Thank you.

2- Under the opportunity and problem, you have a typo in the spelling of Microcystis.

- Corrected, thank you.

3- Under Activity 1, Milestone 1, there is a typo: "projects" instead of "projections".

-The word “projection” is correct in the context of “climate model projections”. The use of “project” as “CMIP6 project” is correct.

4- Under Travel and Conferences, please provide in your justification why out-of-state conferences are needed versus an equivalent in-state conference. In addition, provide a justification about why 2 trips/year are necessary for this project. Typically, only one person is allowed to travel out-of-state for one conference per project. Suggest reducing this budget item. If more than one person and more than one conference, justification should be very clear why it is needed to complete the project. Consider adding milestones to reflect this.

- We had budgets for two travels per year for two graduate assistants. In the academic world, we provide annual opportunities for graduate assistants to travel to national conferences (i.e., American Geophysical Union) to share their findings and receive feedback from the community through poster and oral presentations. This mechanism provides the opportunity to cross-check the findings, corroborate the correctness of the results with other research productions, and disseminate the information to the public. This process also fosters collaborations and helps to accelerate and expand the process of learning and discovering. Nevertheless, based on our phone conversation, I assumed that the travel expenses are not allowed based on the provided justification. I reduced the travel award to one travel per the entire project duration. In this circumstance, the PI must spend more time traveling, collecting community feedback, and communicating with the graduate assistants to properly execute the objectives of the project. The extra budget was added to the PI summer salary.

5- Under Other, please provide the specific ISO standard for each line-item and articulate in the purpose how the

standard relates to and is needed for this project.
-The computer science department has required network & computer service charges for all CS&E-related personnel based on hours worked. For the ISO Justification, the computer science department provides the following explanations: "Network & Computer Services - Networking and computer charges are expenses charged to sponsored and non-sponsored accounts to support the portion of networking and computer infrastructure used by sponsored and non-sponsored research projects. In a formula found to be Uniform Guidance compliant by the Office of Treasury Accounting and Internal/External Sales and Sponsored Projects Administration, research-specific computing is separated from general-purpose computing. The networking and computer support charge is based on FTEs and special projects that can be attributed to research-only projects."

6- Under Personnel, can you please provide additional detail about the specific role each PI and co-I will have in the project.
-Please see the added explanations.

7- Please include in the Dissemination section a statement about how Environment and Natural Resources Trust Fund will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENTRF Acknowledgment Guidelines.
- The following statement was added. The web-based tool will serve as the main tool for public dissemination of the project's outcomes. Moreover, the LCCMR funding will be acknowledged in all peer-reviewed publications. We expect 5 to 6 publications of peer-reviewed papers. The logo of LCCMR will be used in any associated statewide and national presentations.

8- Add how many publications are expected or add cost per publication to description.
-The following statement is added, consistent with the number of publications in the dissemination section. “Cost of publications for 5 to 6 peer-reviewed papers.” Please also see the previous comment.

9- We do not see obvious changes needed to your work plan related to peer review. If we have missed something, please make those changes now.
- Our accounting office updated the budget based on the latest rates. I do not see any required changes at this moment. Thank you Mike for your diligent attention.

10- We have uploaded your accepted revised Research Addendum on the Attachment page and marked your peer review complete. Thank you!
- Thank you.

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 agree travel expenses must 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 agree to the UMN Policy.

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?

Yes, Sponsored Projects Administration

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