Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-233

Proposal Title: Wave-vegetation interaction research for shoreline protection and environment

Project Manager Information

Name: Lian Shen

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: We will conduct experiments and computer simulations to study the roles of vegetations in lakeshore limnology and ecology, to guide the revegetation for shoreline protection and wetland restoration in Minnesota.

Funds Requested: $300,000

Proposed Project Completion: June 30 2025

LCCMR Funding Category: Methods to Protect, Restore, and Enhance Land, Water, and Habitat (F)

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

Narrative

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

The length of the shoreline in Minnesota is more than those in California, Florida, and Hawaii combined. Shoreline erosion has become a serious problem in Minnesota. The erosion is often caused by the removal of native vegetation, which protects the lakeshore from the waves and freezing-thawing cycle. Revegetation with native plants is a natural solution to the erosion problem because the plants can stabilize sediments with their roots and thus protect the shoreline. Another benefit of revegetation is that the plants provide habitat for microorganisms, insects, and fish. The plants can also produce oxygen, and absorb excessive nutrients that would otherwise lead to harmful algae blooms.

It is well known that water waves can damage young plants in the revegetation process. A remedial strategy is to temporarily deploy wave breakers near the shore to damp the strong waves and protect the plants. The revegetation program with native plants and wave breakers is a complicated system involving interactions among waves, vegetation, sediments, and wave breakers. The interaction dynamics among them, the effects of wave breakers on the revegetation process, and the optimal design of the wave breakers are critical to lakeshore restoration, and will be studied in this project.

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

In this project, we will conduct laboratory experiments, field measurements, and supercomputer simulations to address the problem discussed above. Specifically, we will conduct laboratory experiments in the SAFL water channel and the Outdoor StreamLab. Leveraging on the advanced instruments in SAFL, we will obtain the dataset accurately and reliably. Moreover, we will measure and collect data in representative Minnesota lakes. We have also developed a computational model that can simulate the interactions among plants, water waves, sediments, and wave breakers under various environment configurations. Using the data from the above three sources, we will establish a comprehensive database of the revegetation system. Based on the database, we will develop an accurate model for predicting wetland growth and sediment transport. This model can also be used for the optimal design of wave breakers, including the breaker geometry and the deployment location and time, and help stakeholders to achieve the maximal effectiveness for protecting shoreline vegetation. We will share the research outcomes and database with state agencies (including MPCA, BWSR, and DNR), water quality managers, lake management associates, landowners, and the public via a publicly accessible website that will be set up at SAFL.

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 following outcomes are expected: (1) comprehensive database for quantifying the roles of wave and wind and the effects of wave breakers in the revegetation process; (2) accurate prediction model for quantifying the effectiveness of wetland restoration; (3) optimal design of wave breakers in terms of their size, geometry, and deployment location and time; (4) guidance and suggestions to revegetation programs; (5) publicly accessible website and collaborative network with state agencies (including MPCA, BWSR, and DNR), water quality managers, lake management associates, landowners, and the public to promote knowledge sharing and communication on revegetation and shoreline protection.

Activities and Milestones

Activity 1: Collect data on the interactions among plants, water flow, sediment, and wave breakers.

Activity Budget: $150,000

Activity Description:

We will utilize the advanced and unique experimental capability at SAFL to collect the dataset. Specifically, we will conduct laboratory experiments with wave breaker models in the water channel, where the temperature, plants, sediment condition, currents, and waves can be measured precisely. More experiments will be performed in the Outdoor StreamLab to better match the environment of the lakes in Minnesota. The data of temperature, water flow speed, wave height and length, and wind speed will be collected by the installed measurement devices, such as thermometer, current meter, high-speed camera, and wind speed meter gauge. We will also set up computer simulations of lakes and streams on the supercomputers of Minnesota Supercomputing Institute, and the simulation results will be compared with the measurement data, and will then be used to predict the evolution of shorelines. The data collected in laboratory, field, and computer simulations will be compiled to establish a comprehensive database. All the data from different sources will be transferred into the same format and will be stored structurally for easy access. The combination of the laboratory experiments, field measurements, and computer simulations will ensure the high accuracy and reliability of the experiments and computer models.

Activity Milestones:

Description	Completion Date
Conduct measurements and collect data in SAFL Outdoor StreamLab	June 30 2023
Conduct measurements and collect data in SAFL Outdoor StreamLab.	September 30 2024
Conduct computer simulations and collect data on the supercomputer of the Minnesota Supercomputing Institute.	December 31 2024

Activity 2: Develop prediction model for wetland growth rate and soil sediment transport

Activity Budget: $120,000

Activity Description:

Using the comprehensive database obtained by conducting the experiments and simulations in activity #1, in this activity #2, we will analyze the data thoroughly to understand the underlying mechanism of the interactions among waves, plants, and wave breakers. We will quantitatively examine the effectiveness of the wave breaker and its improvement in the growth rate of the plants by comparing the results between datasets with and without deployment of the wave breakers. Furthermore, we will develop a prediction physical model for measuring the effectiveness of wetland restoration. This model will be established by making connections among temperature, wind condition (wind speed and direction), wave condition (water flow speed and direction), plant condition (plant species and plant coverage of the shore), wave breaker conditions (geometry, deployment location, and time), sediment transport, and wetland growth rate based on the physical laws and database obtained in activity #1. Specifically, given the wind speed, water current speed, temperature, wave breaker conditions, and plant species, the model can help us to assess the wetland growth rate and soil sediment transport rate accurately. Using this model, a comprehensive guideline will then be established to advise on how and where to deploy the artificial wave breakers.

Activity Milestones:

Description	Completion Date
Acquire and analyze lab measurement data on flow diversion and sediment accumulation.	December 31 2023
Analyze the data to understand the interactions among waves, plants, and wave breakers.	June 30 2024
Develop a predictive model for the performance of wave breakers to provide practice guidance.	December 31 2024

Activity 3: Disseminate knowledge of revegetation and wave breakers design and deployment to state agencies and the public

Activity Budget: $30,000

Activity Description:

Based on our prediction model, one can evaluate the effects of and revegetation and wave breakers. For example, one can predict and quantify the influence of the wave breakers on the wetland growth rate and soil sediment transport rate at a specific lake to determine if it is suitable for the deployment of the wave breakers. Moreover, we will obtain the best design of the wave breakers and provide suggestions on where and when to deploy the wave breakers. Our prediction model, the optimal design of wave breakers, and our datasets will be provided to state agencies, including MPCA, BWSR, and DNR. The results will also be shared with water quality managers, lake management associates, landowners, and the public via a publicly accessible website that will be set up at SAFL. The research in this project will also provide excellent materials for education, for which we will work with high school students and teachers, including Native American students through the gidakiimanaaniwigamig ("our Earth lodge" in Anishinaabe, the language of the Ojibwe people) youth science immersion program. Moreover, citizen scientists will be enlisted for data collection and analysis.

Activity Milestones:

Description	Completion Date
Create a user-friendly, publicly accessible web portal to share data	June 30 2024
Produce a comprehensive set of online tutorials and offer virtual workshops.	December 31 2024
Give demonstrations to citizen scientists, students, teachers, and the public.	June 30 2025

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 be funded?

The impact of this project will be significant. It will overcome the technical barriers for using revegetation in a cost-effective way for shoreline protection and wetland restoration. It will provide an accurate prediction model that can be used for many years. The long-term strategy is to ensure that the model will be provided to state agencies including MPCA, BWSR, and DNR. The results will also be shared with water quality and lake/wetland managers, landowners, and concerned citizens. Moreover, if other environmental or climate factors emerge in the future, our model can rerun on computers with relative ease.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Extraction of Solar Thermal Energy in Minnesota	M.L. 2017, Chp. 96, Sec. 2, Subd. 07a	$250,000
Assess and Develop Strategies to Remove Microscopic Plastic-Particle Pollution from Minnesota Water Bodies	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04b	$300,000

Project Manager and Organization Qualifications

Project Manager Name: Lian Shen

Job Title: Professor and Director

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

Dr. Lian Shen is the Director of the St. Anthony Falls Laboratory and the Kenneth T. Whitby Professor in the Department of Mechanical Engineering at University of Minnesota, Twin Cities. He earned his Doctor of Science degree from Massachusetts Institute of Technology in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University in 2004. In 2012, he was recruited by University of Minnesota to join its faculty. Dr. Shen is a world expert on the study of environmental fluid flows and renewable energy. He is currently serving on the national committee of ASCE Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment. He is also on the editorial boards of four internal academic journals. Dr. Shen has organized several national and international conferences and symposiums, and has participated in a large number of research projects funded by federal and state agencies, including the Minnesota Environment and Natural Resources Trust Fund. On wind energy research, Dr. Shen is currently serving as the Co-Chair of the Advisory Group of the National Offshore Wind Energy Research and Development Consortium, which has 40 organizations nationwide. At University of Minnesota, Dr. Shen has been serving as the Director of the EOLOS Wind Energy Research Center since 2015. Dr. Lian Shen served as the Associate Director for Research of St. Anthony Falls Laboratory in 2014-2017, and has been serving as its Director since 2017.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:

This project will be performed at the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational institution. It has 22 faculty members and 37 research and administrative staff members. SAFL is a world-renowned research laboratory specialized in environmental and engineering fluid mechanics. SAFL researchers have been performing many innovative

environmental studies for the state of Minnesota. Some of the projects were/are funded by the Minnesota Environment and Natural Resources Trust Fund. The proposed research leverages on the unique and advanced capability of simulating and measuring environmental flows at SAFL, which has 16,000 square feet of space dedicated to research. The facility, which has recently been upgraded with a $16M renovation, has a wind tunnel and 15 general purpose flumes, tanks, and channels readily configurable to the needs of the projects.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager		Oversee the whole project and lead the research planning and reporting			27%	0.12		$36,508
Postdoctoral Associate		Design and establish computational model and carry out computer simulations			20.2%	3		$193,799
Undergraduate Student Assistant		Assist experiment data analysis and model validation			0%	0.75		$7,200
IT Staff		Assist computational model development			24%	0.45		$39,106
							Sub Total	**$276,613**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	Cost of five ultrasonic water level gauge meter ($200 each)	To measure the wave height for validating simulation results.					$1,000
	Tools and Supplies	Cost of materials for fabricating models to be tested in experiments.	To conduct laboratory and field measurements for validating simulation results.					$1,637
							Sub Total	**$2,637**
Capital Expenditures								
		Cost of one digital velocimetry	To measure the velocity distribution					$20,000
							Sub Total	**$20,000**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
	Miles/ Meals/ Lodging	Field experiment	Miles and meals to conduct field experiments					$750
							Sub Total	**$750**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

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	Support of SAFL facilities where research will be conducted.	Secured	$154,000
			Non State Sub Total	**$154,000**
			Funds Total	**$154,000**

Attachments

Required Attachments

Visual Component

File: 64cb2ea1-bc4.pdf

Alternate Text for Visual Component

This project aims to improve the understanding of wave-vegetation interaction along Minnesota's lakeshores and to quantify the effects of wave breakers. Laboratory experiments, field measurements, and simulations on supercomputers will be conducted....

Optional Attachments

Support Letter or Other

Title	File
Approval of proposal submission by University of Minnesota	d86e26c4-f73.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?

No

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

N/A

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

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

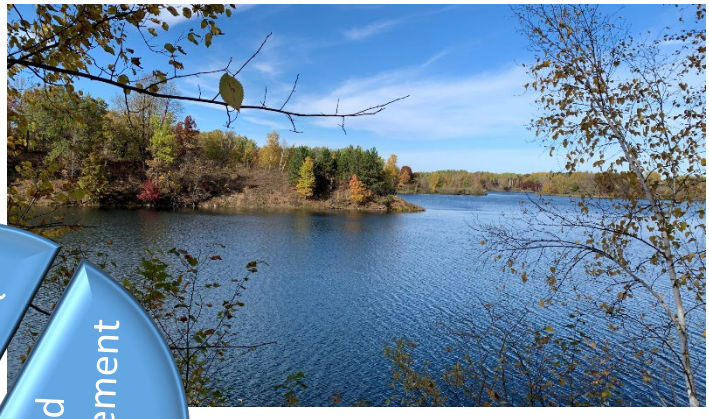
Motivation

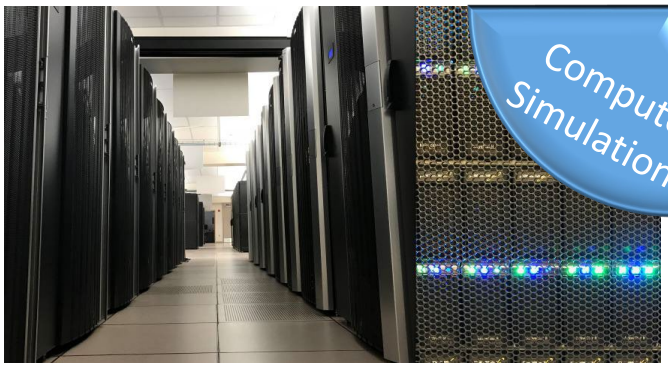
How?

Research Plan

Main channel at St. Anthony Falls Lab

Field measurement on lakes





Supercomputers

Outdoor Stream Lab at St. Anthony Falls