Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 041-A**

Dangerous Current Prediction on Lake Superior Minnesota Coast

Category: A. Foundational Natural Resource Data and Information

Sub-Category:

Total Project Budget: $ 299,982

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

Establish a database of rip currents on Lake Superior Minnesota coast, train an artificial intelligence model for prediction, and develop a forecasting App to alert people of dangerous currents.

Name: Lian Shen

Sponsoring Organization: U of MN

Job Title: Dr.

Department:

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Location:

Region: Northeast

County Name: Statewide

City / Township: Minneapolis

Alternate Text for Visual:

Figures show examples of rip currents and their threats to life, database to characterize rip currents, artificial intelligence model for fast prediction, and smartphone App for alerting of dangerous currents.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Dangerous Current Prediction on Lake Superior Minnesota Coast

I. PROJECT STATEMENT

The goal of this proposal is to create a forecast and alert system for dangerous currents on the Minnesota coast of Lake Superior to provide warmings to the public. Dangerous currents can be life threating to beach-goers and kayakers. In this project, we will: (1) generate an extensive and scientific database characterizing dangerous currents, (2) develop a fast prediction model for dangerous currents, and (3) develop a smartphone app to alert users of dangerous currents and inform local communities. Our study will focus on rip currents.

1. What are rip currents?

Rip currents are strong and narrow currents of water flowing away from shore. They can be induced by wind and breaking waves on the water surface. Local geographical characteristics, such as the variation of the coastal bathymetry, sediment morphology, and man-made constructions, can all lead to rip currents. The size of rip currents can be large, reaching 100 feet in width and extending up to 1,000 feet from the shore.

2. Why are rip currents dangerous?

The speed of the rip currents is about 0.5 to 1 m/s. Some currents may reach up to 2.5 m/s (MacMahan et al., 2011), which is faster than the swimming speed of most of people or even athletic swimmers, making rip currents dangerous for beach-goers and kayakers. National Weather Service (NWS) reported that 80% of rescues were caused by rip currents. Based on the database of National Oceanic and Atmospheric Administration (NOAA), on average 57 people died from rip currents each year, and 70 died in 2017. Despite the danger, there are a large number of Minnesota beach goers unfamiliar with the danger of rip currents. According to a survey conducted by Jesse Schomberg at MN Sea Grant, 34% of beach users have never heard about rip currents (http://www.seagrant.umn.edu/downloads/schomberg_ripCurrents-09.pdf).

3. What are the impacts of rip currents on society?

Rip currents are not only life threatening but also highly relevant to socioeconomic health and water-related tourism. Tourism in coastal communities in Minnesota, such as the Duluth area, Two Harbors, Lutsen, Tofte, and Grand Marais, has grown steadily in the last two decades and contributes about $400 million to the economy per year (http://www.seagrant.umn.edu/recreation/overview). For example, the Park Point Beach attracts 3.5 million visitors every year (https://duluthchamber.com/visitors/). However, the reported drowning incidents induced by the rip currents have negative impacts on the reputation of the beach and harm the local economy. Moreover, the sediments carried by the wave and currents accumulate at the mouth of the harbor, posing dangers to boats and increasing the cost of dredging.

4. How can we solve this problem?

There are two major issues preventing the coastal communities on the Minnesota side of shore of Lake Superior from responding to dangerous currents promptly and precisely. First, we do not have enough knowledge about the local dangerous currents, which are transisient and site-specific. Second, no forecasting for the dangerous currents can cover the various coast sites in Minnesota. These two issues are pressing concerns for both tourists and lifeguards. In this project, we will generate an extensive database for rip currents, based on which to train an artificial intelligence (AI) model, and develop a fast and accurate prediction alert system.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Generate database characterizing rip currents on Lake Superior Minnesota coast
Description: We will collect data from the field. Remote sensing and field measurement techniques will be used to measure the wind, wave, currents information, such as the wind direction, wave surface elevation and current speed. We have also developed a software called WOW (Wave-Ocean-Wind), which is a powerful model for water and wind motions. In this project, we will use WOW to model the generation of rip currents on the various Lake Superior coast sites in Minnesota under different conditions, including waves with different

amplitudes and wavelengths, various bathymetries, and different sediment transport. We will compare our model data with measured data to validate and improve our methodology. The validated data will be used to establish a database characterizing rip currents on Lake Superior's Minnesota coast.

ENRTF BUDGET: $149,991

Outcome	Completion Date
1. Measurement data of rips currents	September 2021
2. Model data validated by measurements	June 2022
3. A comprehensive database on rips currents on Lake Superior's Minnesota coast	September 2022

Activity 2: Develop a fast prediction model to forecast dangerous currents on Lake Superior Minnesota Coast
Description: We will use the database generated in **Activity #1** to train a fast prediction model based on the neural network, which is a mature and broadly used technique of artificial intelligence (AI). The developed model will be efficient enough to predict the dangerous current events in advance, with the wind and wave information given by weather forecast as an input. We will test the model using historical data and field measurement data to be obtained in this project.

ENRTF BUDGET: $89,994

Outcome	Completion Date
1. An AI model trained using the database produced in **Activity #1**	December 2022
2. Validation of the model using measurement data	March 2023

Activity 3: Develop a smartphone app to alert dangerous currents and help local communities
Description: We will integrate the fast prediction model produced in **Activity #2** and a user-friendly interface to develop a smartphone app to forecast dangerous currents in Lake Superior. Our app will collect data of wind conditions and wave states 24/7 automatically and deliver the dangerous current report to users in a timely manner. This app will foster the social, economic, and environmental sustainability of the regions on Lake Superior in Minnesota by promoting the waterfront safety.

ENRTF BUDGET: $59,997

Outcome	Completion Date
1. Develop an app to alert dangerous currents on Lake Superior Minnesota coast	June 2023

III. PROJECT PARTNERS AND COLLABORATORS:

This project will leverage on two other projects of Prof. Lian Shen. The first is a project sponsored by Office of Naval Research on the study of coastal environment (collaborators include Pablo Carrica and Casey Harward at University of Iowa and Kenneth Weems at Naval Surface Warfare Center). The second is a joint Minnesota and Wisconsin Sea Grant project on the South Shore of Lake superior (collaborators include Chin Wu at University of Wisconsin and Jerald Henneck at Natural Resources Research Institute). While these projects can share research tools and data, it should be pointed out that only through the project proposed here can a forecast and alert system be developed for the entire Minnesota coast of Lake Superior.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

This project will be completed in three years. The long-term strategy is to ensure that the database and design model will be provided to state agencies. The smartphone app will also be provided to the public.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:

A. Proposal Budget Spreadsheet
B. Visual Component or Map
F. Project Manager Qualifications and Organization Description

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Lian Shen
Project Title: Waves and Currents on Lake Superior Minnesota Coast
Organization: University of Minnesota
Project Budget: $299,982
Project Length and Completion Date: 3 years; June 30, 2023
Today's Date: April 12, 2019

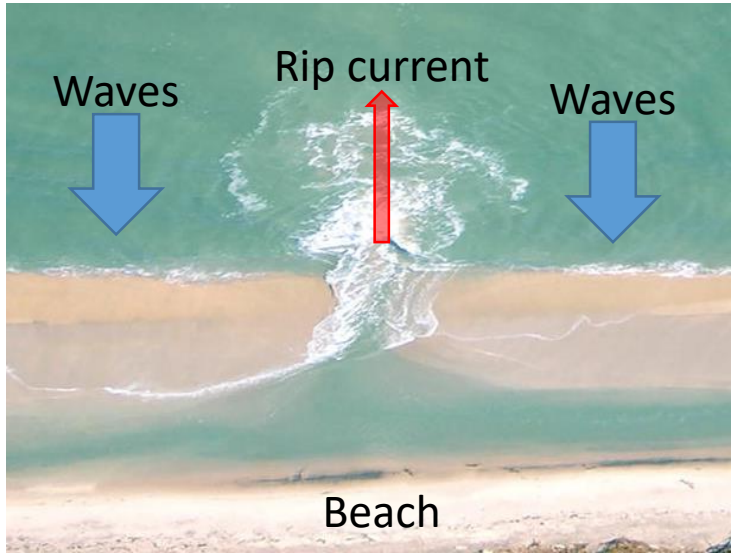
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 297,432	$ -	$ 297,432
Lian Shen, Program Manager (74% salary, 26% benefits); 3.7% FTE, 0.33 month per year. ($34,656)			
Postdoctoral Associate, experiment and modeling research (80% salary, 20% benefit); 100% FTE for each of 3 years. ($192,098)			
Graduate student, modeling study (84% salary, 16% benefit); 3 summers month per year for 3 years. ($20,892)			
Undergraduate Assistant, measurement study (100% salary); 1.5 months for each of 3 years. ($7,200)			
IT staff, data analysis and app design (85% salary, 15% benefit); 40% FTE for each of 3 years. ($39,224)			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Cost of anemometer ($300) to measure the wind speed, ADV sensor ($1,000) to measure current conditions, and wave buoy to measure wave conditions ($500).	$ 1,800	$ -	$ 1,800
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Tranportation within Minnesota state for field data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage $0.58/mile x 500 miles =$290; Incidental expense during travel $60; Lodging $400.	$ 750	$ -	$ 750
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 299,982	$ -	$ 299,982

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: Office of Naval Research	secured	$ 821,102	$ -	$ 821,102
State: Minnesota Sea Grant	secured	$ 126,229	$ -	$ 126,229
In kind: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs.		$ 161,990	$ -	$ 161,990

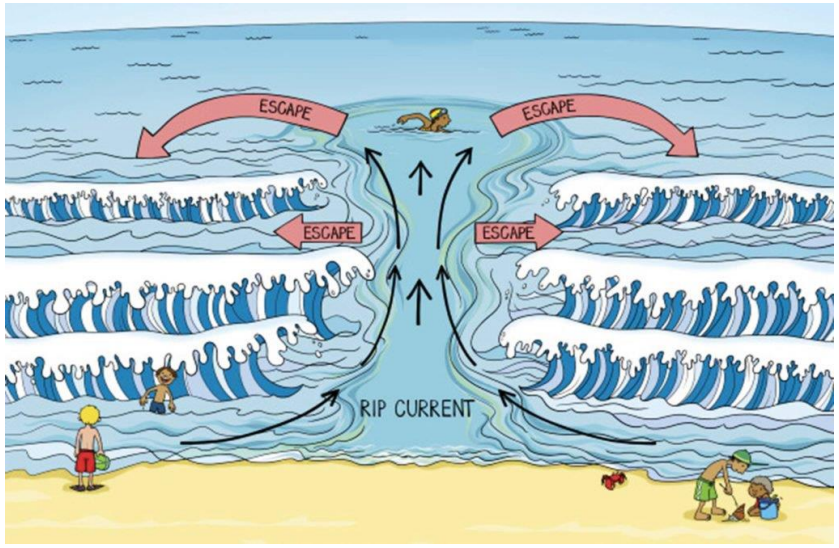
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

Dangerous Current Prediction on Lake Superior Minnesota Coast

Motivation



Rip current



Impact of rip current on swimmers

Warming of rip currents is critical

Proposed Work

Database

Artificial intelligence

Dangerous currents alert App

PROJECT MANAGER QUALIFICATIONS

This project will be led by Professor Lian Shen as program manager. Prof. Shen is the Director of the St. Anthony Falls Laboratory and a 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 (MIT) in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University (JHU) in 2004. At JHU, he performed extensive research on environmental water and air flows. In 2012, he was recruited by University of Minnesota to join its faculty.

Prof. Shen is a world expert on the study of environmental fluid flows. 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 three internal academic journals. Prof. Shen has been active in professional societies, including American Geophysical Union, American Society of Civil Engineers, American Society of Mechanical Engineers, and Association of Environmental Engineering and Science Professors. He has organized several national and international conferences and symposiums.

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 35 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 advanced capability of measuring environmental flows at SAFL, which has 16,000 ft^2 of research space dedicated to physical modeling and experimentation. 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 projects. SAFL field research is as broad as its laboratory work and includes establishing long-term monitoring sites as well as developing new methods and techniques for observing, measuring, logging, and communicating environmental processes. SAFL has tremendous experience in developing a field approach for a range of applications, such as remoting measurement of atmospheric and aquatic fluid flows and temperature.

The powerful cluster computers equipped at SAFL support the numerical modelling in the proposed research. Driven by the exponential growth of computational power, scientific computing is now radically transforming our research philosophy by enabling the simulation of many complex flow phenomena across a broad range of scales in natural and engineered systems with an unprecedented degree of realism. Coupled with the state-of-art measurement techniques and unique experimental facilities, SAFL's simulation-based expertise has uniquely positioned the laboratory to make far-reaching advances in the major societal problems in energy, the environment, and human health. SAFL has two High Performance Computing (HPC) Beowulf-style computer clusters with execution and compute nodes connected by low-latency/high-throughput local interconnects (InfiniBand).