Environment and Natural Resources Trust Fund
2016 Request for Proposals (RFP)

Project Title: **ENRTF ID: 079-B**

Development of Models for Oil Spill Trajectory Prediction

Category: B. Water Resources

Total Project Budget: $ 300,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2016 to June 2019

Summary:

We propose to develop a computer simulation tool for oil slick trajectory prediction in lakes, for Minnesota to be better prepared for hazardous water contamination events such as oil spill.

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

There are three figures provided as visual to help illustrate the computer simulation and prediction capability we propose to develop. Figure 1 shows an example of the water waves we simulated using computer computation. It illustrates that the complex waves at the water surface can be modeled accurately and realistically using computer simulation. Figure 2 plots an example of our results of wind blowing over water waves, to show that the turbulent wind can be faithfully captured in computer simulation. Figure 3 plots a computer simulation result of the distribution of water current velocity in Lake Superior (detailed information at specific locations, such as in the Duluth–Superior harbor, can also be provided). This figure illustrates how the final product of this project, a computer modeling and prediction tool for oil spill trajectory in surface water, will look like.

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

PROJECT TITLE: Development of Models for Oil Spill Trajectory Prediction

I. PROJECT STATEMENT

Being a state with substantial water bodies, Minnesota needs to be well prepared for hazardous events of water contamination such as oil spills. Major oil pipelines run near the Great Lakes. Despite the great efforts made for their safe operations, pipeline rupture accidents happen occasionally. Examples include the spill in Talmadge Creek, MI, 2010, for which the costs for remediation have exceeded one billion dollars. Other accidents at smaller scales include the ones in Romeoville, IL, 2010; Regina, Canada, 2014; and Viking, MN, 2014. Moreover, recent expansion of oil sands drilling in the upper Midwest has made the Great Lakes an attractive venue for oil transport, with near-Minnesota locations such as Superior, WI being discussed. While the proposed new work has modern construction and safety regulations in mind, one cannot completely rule out the possibility of oil spills.

In the event of spilled oil leaking into water, it is of paramount importance to have accurate prediction of the oil slick trajectory. Unfortunately, present-day modeling capabilities are still far from satisfactory due to the complexity of the problem. For example, the GNOME (General NOAA Operational Modeling Environment) model is a prevailing tool for oil spill modeling. However, as stated upfront in GNOME User's Manual, it cannot and is not supposed to be used to make real predictions. From our discussions with researchers and staff in the Minnesota Pollution Control Agency, the Large Lakes Observatory, and the Coast Guard Marine Safety Unit at Duluth, it is clear that there is a critical need for the development of a high-fidelity computer prediction model for oil spill trajectory in lake water.

In this project, we propose to develop a computer simulation tool for the trajectory prediction of spilled oil in lake water. We will take into account the effect of turbulent wind, which is the main driving force of the surface water movement in lakes. The complex and yet extremely important wind-induced processes such as water waves and circulations will also be accurately modeled in our simulation. The proposed work builds on the unique expertise of the research group of the Project Manager, Prof. Lian Shen, who is an expert in the computer simulation of surface water motions interacting with water waves and turbulent wind. Upon the completion of this project of 36 months, we will deliver a computer simulation tool that can be used for the prediction of oil slick trajectory in lake water under realistic wind and wave conditions.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Development of model for wave effect on oil slick motion **Budget:** $90,000

We will use a state-of-the-art wave simulation tool called high-order spectral method to perform computer simulations of water waves at small scales to study the flow dynamics (see Figure 1 in Visual), based on which wave-effect model on oil slick motion will be developed. The model will be calibrated using field measurement data reported in literature and provided by colleagues.

Outcome	Completion Date
1. Obtain data on water waves from computer simulation	June 30, 2017
2. Develop model for wave effect on oil slick motion in water	June 30, 2018
3. Test and validate wave-effect model	Dec. 31, 2018

Activity 2: Development of model for wind effect on oil slick motion **Budget:** $90,000

We will first use a powerful tool for turbulence simulation called large-eddy simulation to compute the wind blowing over water surface (see Figure 2 in Visual). Model for the wind effect on oil slick motion in water will then be developed and tested using field measurement data from literature and collaborators.

Outcome	Completion Date
1. Establish database of wind field	Dec. 31, 2017
2. Develop wind-effect model for oil slick motion in water	June 30, 2018
3. Test and validate wind-effect model	Dec. 31, 2018

Activity 3: Development of oil slick trajectory prediction tool **Budget:** $120,000

We will build our oil spill trajectory prediction tool upon an open-source code called FVCOM, which is a versatile computer program for simulating water flows in coastal and lake environment (see Figure 3 in Visual). We will add the feature of oil slick motion to it. Models for the wave and wind effects will be incorporated to the computer program. Finally, the oil spill trajectory prediction tool will be tested and validated using field data.

Outcome	Completion Date
1. Convert FVCOM into a computation framework for oil slick trajectory prediction	Dec. 31, 2017
2. Incorporate wave-effect model to oil slick trajectory prediction tool	Dec. 31, 2018
3. Incorporate wind-effect model to oil slick trajectory prediction tool	Dec. 31, 2018
4. Test and validate oil slick trajectory prediction tool	June 30, 2019

III. PROJECT STRATEGY

A. Project Team/Partners

This work will be carried out by Prof. Lian Shen as Project Manager, with the assistance of a postdoctoral associate and a graduate research assistant. This project will be performed in close collaboration with state and federal agencies and other researchers in Minnesota. We have had interactions with Mr. Dan Breneman at Minnesota Pollution Control Agency, Mr. Lawrence DiDomenico of the Coast Guard Marine Safety Unit at Duluth, and Prof. Jay Austin at the Large Lakes Observatory. We expect to obtain field data and input from them for our model test and validation. We will also collaborate with researchers in oil spill study nationally and internationally. Prof. Shen is active in this research community and has been playing a leading role (e.g., he recently gave an invited speech at the 2015 Gulf of Mexico Oil Spill and Ecosystem Science Conference).

B. Project Impact and Long-Term Strategy

The impact of this project will be significant. It addresses an urgent issue in the preparation for disastrous events of water contamination of oil spill, namely the lack of a prediction tool for the trajectory of oil slick in lake water. The computer prediction tool proposed here will be a measurable outcome. It can be utilized by decision makers and state agencies to respond in better ways to protect resident's properties, livelihood, and health. We will align the proposed work with ENRTF's six-year strategic plan. This proposal directly responds to the RFP priorities of Area B, water resources. It also have multiple benefits in other areas, including: Area A (the data from our computer simulation and the field data compiled will be valuable information for foundational natural resource), Area E (oil slick can affect air quality once the oiled droplets are airborne by wind), and Area C (through our educational efforts including seminars and a Native American youth science immersion program).

The long term strategy of the project is to provide a useful tool for the prediction of contaminant trajectory in water if there is a hazardous event of water contamination. Once developed, the prediction tool will be the state-of the-art and can be used for many years. It utilizes the most advanced simulation methods for wind, waves, and currents, and is innovative in the modeling approach. This work builds on the unique research expertise of the Project Manager's group, leverages on other projects and collaboration, and is ready to go.

C. Timeline Requirements

We plan to complete the project within 36 months. This research builds on the strength of our research group. The project is ready to go. We are confident the project will be completed on time.

2016 Detailed Project Budget

Project Title: Development of Models for Oil Spill Trajectory Prediction

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

BUDGET ITEM	AMOUNT
Personnel:	
Prof. Lian Shen, Project Manager (75% salary, 25% benefit); 11% FTE for each of 3 years	$ 48,995
1 Postdoctoral Associate, model development (82% salary, 18% benefit); 100% FTE for each of 3 years	$ 177,812
1 Graduate Research Assistant, data analysis (59% salary, 41% benefit (including tuition)); 25% FTE for each of 3 years	$ 71,528
Professional/Technical/Service Contracts: N/A	$ -
Equipment/Tools/Supplies: Cost of computer softwares for data analysis	$ 1,065
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel: Trips from Minneapolis to Duluth for research collaboration meetings with researchers and staff in Duluth.	$ 600
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 300,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Unrecovered F&A	$ 141,602	Secured
In-kind Services Prof. Lian Shen will contribute 5% inkind salary/fringe for the duration of the project.	$ 21,401	Secured
Cash match: Prof. Lian Shen's discretionary fund at University of University to be used for additional support for graduate research assistant and educational outreach activities.	$ 10,000	Secured
Funding History: N/A	$ -	N/A
Remaining $ From Current ENRTF Appropriation: N/A	$ -	N/A

Figure 1. Computer simulation result of waves at water surface.

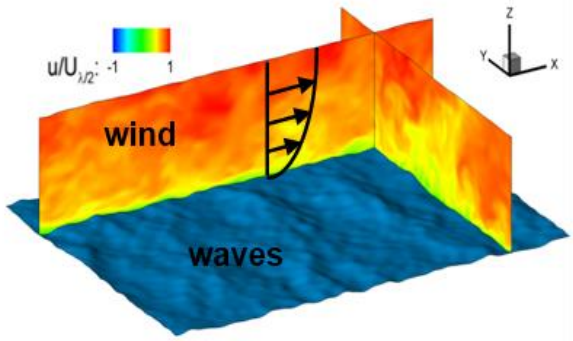

Figure 2. Computer simulation result of wind blowing over water waves.

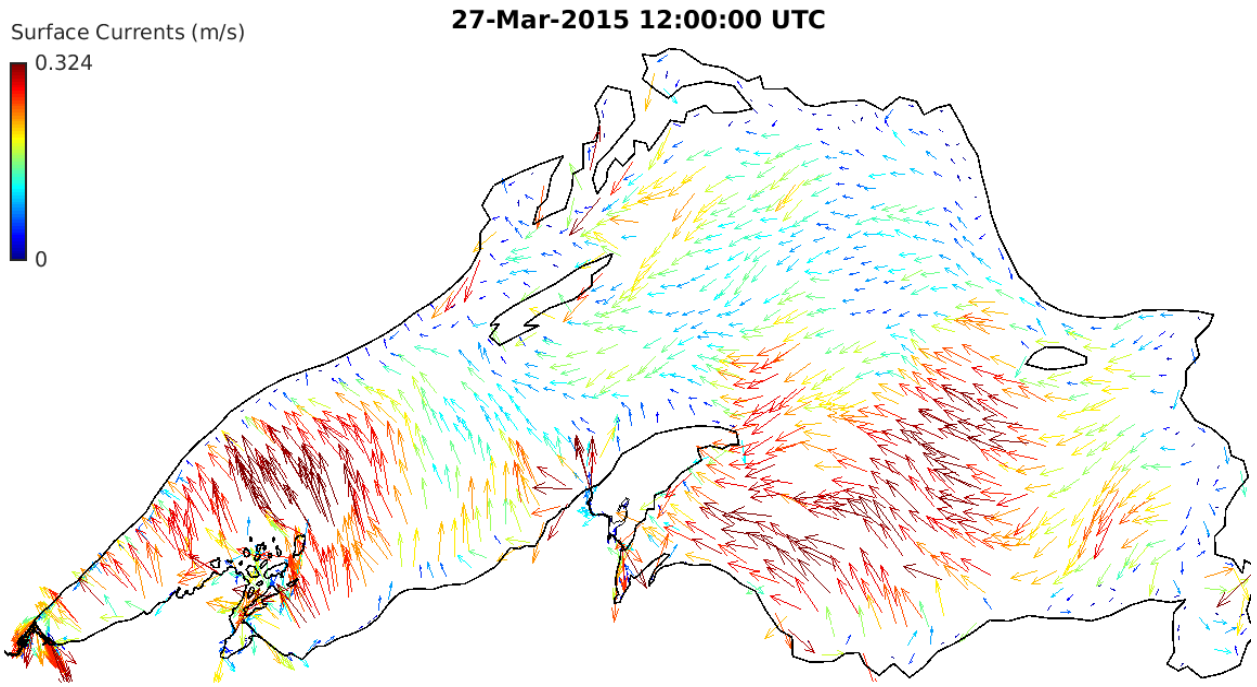

Figure 3. Computer simulation result of water currents in Lake Superior. The plot was made by Dr. Jay Austin at University of Minnesota, Duluth.

This project will be led by Dr. Lian Shen as Project Manager. Dr. Shen currently holds the position of Benjamin Mayhugh Associate Professor at University of Minnesota, Twin Cities. He is an expert in the study of environmental fluid flows. Dr. Shen 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 at 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. At University of Minnesota, Dr. Shen has been performing cutting-edge research on surface water flows under the actions of wind and water waves. His research group is the only one in the world that is capable of simulating surface water currents, such as the ones in lakes, coupled with turbulent wind and nonlinear wave motions, and is well suited and readily prepared to carry out this proposed project.

This project will be performed in 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 17 faculty members, 26 research staff, 8 administrative staff, and about 50 graduate students. Dr. Shen is the lab's Associate Director for Research overseeing the lab's research and academic activities. 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.