Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 066-B**

Predicting Impact of Oil Spill in Minnesota Lakes

Category: B. Water Resources

Total Project Budget: $ 394,948

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

We will develop urgently-needed monitoring, measurement, and prediction tools for trajectory estimation and remediation strategy of spilled oil in Minnesota lakes, to assist decision makers in coping with oil spills.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Oil spills pose great threats to the aquatic environment of Minnesota lakes. Spilled oil may float at water surface, suspend at various depths of water column, or sink to lake bottom, with different distribution patterns. For clean-up strategy, there is a critical need for accurate monitoring and modeling of the whereabouts of spilled oil. We will develop advanced monitoring and prediction tools for oil spill in Minnesota lakes.

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

PROJECT TITLE: Predicting Impact of Oil Spill in Minnesota Lakes

I. PROJECT STATEMENT

The goal of this project is to develop urgently-needed monitoring and prediction tools for the trajectory estimation and remediation strategy of oil spills in Minnesota lakes. We will develop advanced monitoring and measurement techniques for spilled oil, collect data on the physical properties and motions of oil slicks and oil droplets, develop efficacious models for spilled oil, and implement the models in state-of-the-art computer simulation tools that will be used by state agencies to assist decision makers in coping with oil spills in the state.

Being a state with substantial water bodies, Minnesota needs the ability to effectively manage small-scale oil spills occurring frequently and needs to be well prepared for hazardous spill events. While catastrophes such as the Deepwater Horizon spill in the Gulf of Mexico in 2010, which leaked about 400,000 tons of crude oil, have received substantial attention, what is less known and probably more severe is that oil spills at various scales happen frequently due to vessel operational discharge, tanker accidents, pipeline ruptures, and natural seeps. A recent study by the National Research Council showed that more than a million tons of oil is discharged to aquatic environment each year. In the Great Lakes area, oil spills have occurred recurrently in recent years. A pipeline rupture in 2010 released 834,000 gallons of oil into the Talmadge Creek within the Lake Michigan watershed. In 2010, a similar spill leaked 256,000 gallons of crude oil in Romeoville, IL, just miles from the Lake Michigan watershed. In 2014, a refinery in Indiana spilled 1200 gallons of oil directly into Lake Michigan. Near Lake Superior, oil pipelines raptured in Viking, MN in 2013 and in Regina, Canada twice in 2014. The heavy traffic of ships in the Duluth-Superior area and the numerous boats in other lakes in Minnesota all pose risks of oil spilling into lake water.

In the event of oil spill, it is of paramount importance to monitor the situation closely, have an accurate assessment of the potential consequences, and make accurate prediction on the trajectories of oil slicks to form a sound remediation strategy. Unfortunately, present-day measurement and prediction capabilities are far from satisfactory. For example, the GNOME model is a prevailing tool used in the scientific community and by some federal and state agencies for oil spill modeling. However, as stated upfront in the User's Manual of GNOME, it is a research tool for idealized scenarios and is not supposed to be used to make real-life predictions. The motions of oil spills highly depend on the wind speed and the distance and direction of wind relative to the shoreline. Ongoing research efforts in the nation mainly focus on open ocean environment, and the lake environment is largely neglected. From our discussions with the 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 accurate and effective measurement and monitoring techniques and high-fidelity computer prediction model for oil spills in lake water, which is the aim of this project.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop accurate and effective measurement and monitoring techniques for oil slicks and oil droplets **Budget:** $118,485

Depending on the oil droplets size and density and local wind, wave, and current conditions, spilled oil can float at water surface, suspend in the water column at various depths, or sink to the bottom. These different destinations of spilled oil require different clean-up strategies. The present prediction capability for the oil trajectories is poor, due to the lack of accurate data as limited by existing monitoring and measurement technique. We will develop advanced measurement techniques for the properties of oil slicks and oil droplets.

Outcome	Completion Date
1. Measurement techniques for oil slicks and droplets motions	March 31, 2019
2. Measurement techniques for oil droplets size distribution and physical properties	June 30, 2019
3. Calibration and validation in lab experiments and field tests	Sept. 30, 2019

Activity 2: Collect data on the motions and trajectories of oil slicks and oil droplets **Budget:** $148,105

We will use advanced measurement techniques to perform laboratory experiments in tanks, flumes, and channels, together with field measurements. Based on the data collected, we will distill the complex fluid flow phenomena down to tractable problems based on barebone physical ingredients. The object of this activity is to elucidate the physical mechanism behind the complex flow phenomena, based on which improved oil spill models can be developed for operational prediction tools.

Outcome	Completion Date
1. Dataset on oil slicks and droplets velocity and ambient flow velocity	Dec. 31, 2019
2. Dataset on oil droplets size distribution and physical properties	March 31, 2020
3. Recommendation for model improvement in operational prediction tools	June 30, 2020

Activity 3: Improve oil spill prediction tool, disseminate to state agencies, and outreach **Budget:** $128,358

Based on the valuable data collected, we will implement models for oil diffusion and mixing in lake waters in operational prediction tools. Collaborating closely with state and federal agencies, we will use their field data for our model test and validation. Our improved models will be provided to state agencies, including the Minnesota Pollution Control Agency, Minnesota Board of Water and Soil Resources, and Minnesota Department of Natural Resources, as well as the Coast Guard Marine Safety Unit. The results of our research will also be shared with other stakeholders in the state, such as the water quality and lake managers, and concerned citizens.

Outcome	Completion Date
1. Improvement of oil spill model in operational prediction tools	Sept. 30, 2010
2. Test and validation of new oil spill prediction tools	Dec. 31, 2020
3. Delivery of new oil spill prediction tools to state agencies	Mar. 31, 2021
4. Outreach to stakeholders and the public via lab demonstration and online workshops	June 30, 2021

III. PROJECT STRATEGY

A. Project Team/Partners

This work will be carried out by Dr. Sungyon Lee as Project Manager, together with Drs. Filippo Coletti and Lian Shen with the assistance of two graduate research assistants. The project will be performed in close collaboration with state and federal agencies and other researchers in Minnesota. For example, we have been interacting and will continue to work with Mr. Dan Breneman in the Minnesota Pollution Control Agency, Mr. Lawrence DiDomenico in the Coast Guard Marine Safety Unit in Duluth, and Prof. Jay Austin at the Large Lakes Observatory in Duluth.

B. Project Impact and Long-Term Strategy

The impact of this project on the safety of Minnesota aquatic ecosystem will be immediate. It addresses an urgent need in protecting Minnesota water resources. The measurement techniques and prediction models to be developed in this project will be measurable outcomes. They can be utilized by decision makers and state agencies to better respond to oil spills. The financial gain can be tremendous. Take the aforementioned Talmadge Creek oil spill as an example. In that disaster, fortunately, the oil was contained in the Kalamazoo River upstream of Lake Michigan, and containment in a riverine system is considerably more manageable than in an open lake water scenario. Nevertheless, costs for the remediation of that spill have exceeded one billion dollars. While this occurred in Michigan, similar threat exists in Minnesota. Indeed, the Grand Rapids spill happened in Minnesota in 1991 is the largest inland oil spill in US history. Upon the completion of this project, we will provide a state-of-the-art monitoring and prediction tool to state agencies.

C. Timeline Requirements

This project will be conducted over a 3-year period from July 1, 2018 to June 30, 2021.

2018 Detailed Project Budget

Project Title: Predicting Impact of Oil Spill in Minnesota Lakes

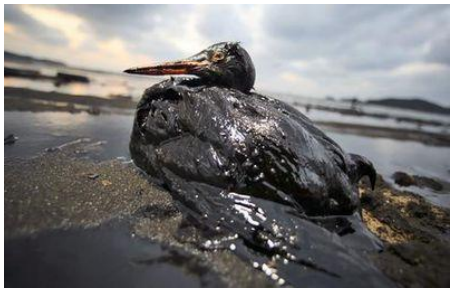
IV. TOTAL ENRTF REQUEST BUDGET: 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ 368,448
Dr. Sungyon Lee, project manager and laboratory measurement and modeling study (75% salary, 25% benefit); 6.25% FTE (i.e., 0.75 months of salary) for each of 3 years. ($33,698)	
Dr. Filippo Coletti, experimental measurement study (75% salary, 25% benefit); 4.2% FTE (i.e., 0.5 months of salary) for each of 3 years. ($22,333)	
Dr. Lian Shen, computer simulation study (75% salary, 25% benefit); 2.1% FTE (i.e., 0.25 months of salary) for each of 3 years. ($12,493)	
Graduate Student Research Assistant, experiment and modeling research (59.8% salary, 40.2% benefit); 100% FTE for each of 3 years. ($144,562)	
Graduate Student Research Assistant, modeling and computer simulation research (59.8% salary, 40.2% benefit); 100% FTE for each of 3 years. ($144,562)	
Undergraduate Student Assistant, assisting measurement and data analysis (100% salary); 2 months for each of 3 years. ($10,800)	
Professional/Technical/Service Contracts: N/A	$ -
Equipment/Tools/Supplies: Cost of setting up oil-in-water experiment facility in laboratory tank, flume, and channel ($5,000), and the purchasing of LED light sources ($10,000) and high-speed camera ($10,000) for the measurements of oil-droplet size, velocity, and trajectory and ambient flow in this project.	$ 25,000
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel: Tranportation within Minnesota state for field data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage $0.535/mile x 1000 miles =$535; Incidental expense during travel $200; Lodging $765.	$ 1,500
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 394,948**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: This project will be performed in collaboration with Dr. Lian Shen's project funded by the Gulf of Mexico Research Initiative on oil spill. That project focuses on open ocean environment, while the project proposed here addresses the Minnesota lake environemnt specifically. There is no duplication in the efforts of these two projects. Meanwhile, they can complement and benefit each other.	$ 400,000	N/A
Other State $ To Be Applied To Project During Project Period: N/A	$ -	N/A
In-kind Services To Be Applied To Project During Project Period: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs (graduate tuition and equipment are excluded).	$ 150,946	Secured
Funding History: N/A	$ -	N/A
Remaining $ From Current ENRTF Appropriation: N/A	$ -	N/A

Oil spills pose great threats to the aquatic environment of Minnesota lakes.



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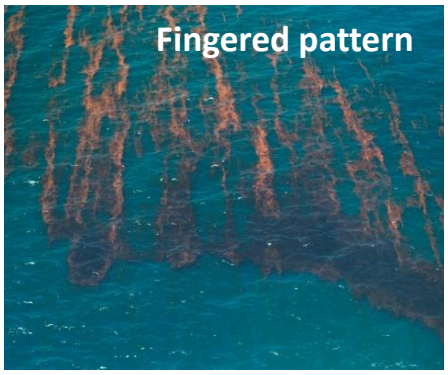

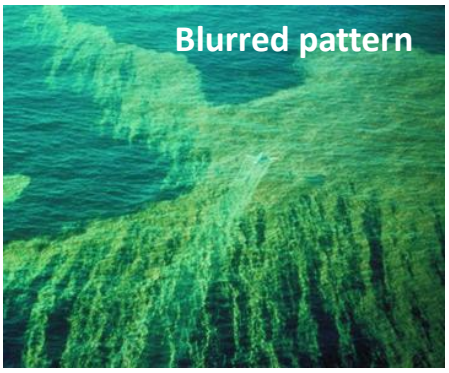

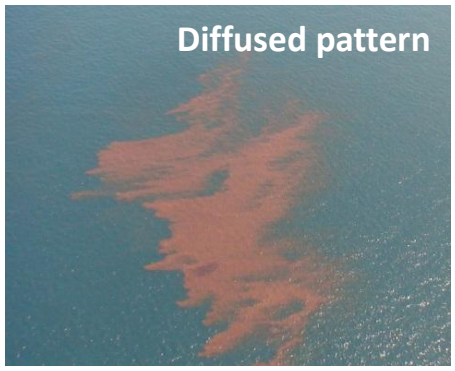

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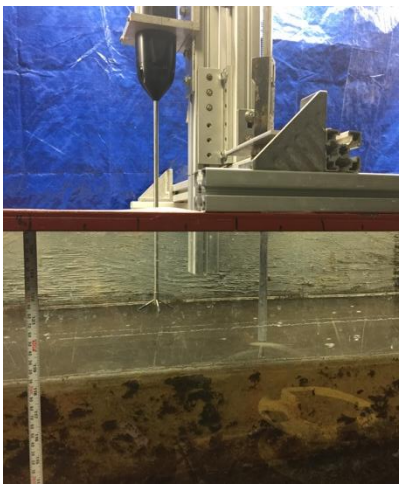
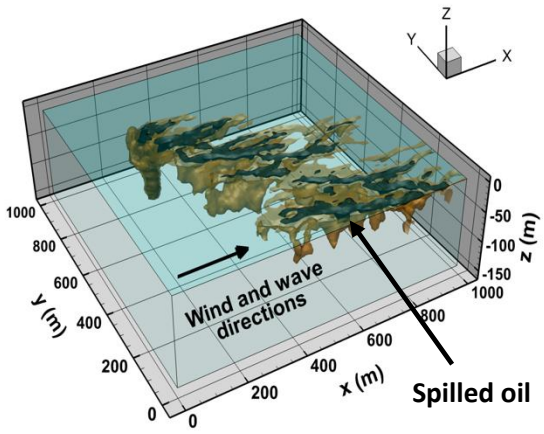


Measurements

Computer simulations



Predictive models

PROJECT MANAGER QUALIFICATIONS

The overall proposed research will be led by Dr. Sungyon Lee, who is joining the Department of Mechanical Engineering at the University of Minnesota in 2017 as an assistant professor. Having completed her doctorate degree at Massachusetts Institute of Technology, Lee started her academic career in the Department of Mechanical Engineering at Texas A&M University from 2013 to 2017. Her overarching vision in research is to uncover fundamental physical mechanisms that govern complex engineering applications and natural processes. Consistent with that vision, her research group identifies fluid flow phenomena that are motivated by important challenges in nature and in industry and rationalizes them through experiments and reduced mathematical modeling. Lee's current research topics constitute interfacial, multiphase flows, such as drops, bubbles and suspensions, which are directly relevant to environmentally significant geophysical flows. Her research has been published in major journal publications, such as *Physical Review Letters* and *Lab on a Chip* and is being supported by the National Science Foundation as well as the UK Royal Society Exchange Program.

The experiment component of the proposed research will be led by Dr. Filippo Coletti, Assistant Professor of Aerospace Engineering and Mechanics at the University of Minnesota. Coletti performed his doctoral studies at the von Karman Institute and at the University of Stuttgart (Germany), where he obtained his Ph.D. in Aerospace Engineering in 2010. From 2011 to 2013 he was postdoctoral fellow at Stanford University, before joining the University of Minnesota in 2014. Dr. Coletti has been conducting research in environmental fluid mechanics, focusing on the transport of particles in the environment. He uses advanced imaging techniques both in the laboratory and in the field, where he is part of a team that investigates settling speed of hydrometeors. His research is funded by federal agencies including the National Science Foundation (NSF) and the National Institute of Health (NIH), as well as by major companies including 3M and Boston Scientific. Dr. Coletti has published over 60 refereed journal articles and conference papers on transport phenomena and experimental fluid mechanics. A list of his recent honors include the CAREER Award from the National Science Foundation and the Non-Tenured Faculty Award from the 3M Company.

The computational component of the proposed research will be led by Dr. Lian Shen, Professor in the Department of Mechanical Engineering at the University of Minnesota. Shen earned his doctoral degree in fluid mechanics from Massachusetts Institute of Technology in 2001. Prior to coming to the University of Minnesota, he was at the faculty in Department of Civil Engineering at the Johns Hopkins University. Dr. Shen's computational fluid dynamics (CFD) research group at the University of Minnesota has developed high-fidelity simulation tools for modeling turbulent hydrodynamics and particle transport problems in real-world environments. Being a world expert on CFD, Dr. Shen has been active in professional societies, including American Geophysical Union and American Society of Civil Engineering. He is also on the editorial boards of the International Journal of Computational Methods and the Ocean Systems Engineering journal. Dr. Shen is currently serving on the national committee of the Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment.

ORGANIZATION DESCRIPTION

This project will be performed at the University of Minnesota, the state's land-grant university and one of the most prestigious public research universities in the nation. Recently, the university has identified five research areas as the "Grand Challenges". In particular, the results of the proposed research will directly address one of the Grand Challenges, namely, "Assuring Clean Water and Sustainable Ecosystems." Hence, the PIs expect a strong endorsement and support from the university to conduct the proposed research. The studies in this project will be carried out jointly in the Department of Mechanical Engineering and Department of Aerospace Engineering and Mechanics. The laboratories and offices of the PIs contain state-of-the-art equipment and facilities that will enable the proposed studies.