

**Environment and Natural Resources Trust Fund  
2019 Request for Proposals (RFP)**

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**Project Title:**

**ENRTF ID: 215-F**

Evaluation and Improvement of Aeration in Lakes

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**Category:** F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

**Sub-Category:**

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**Total Project Budget: \$** 312,228

**Proposed Project Time Period for the Funding Requested:** June 30, 2022 (3 yrs)

**Summary:**

We will measure concentrations of oxygen and nutrients in lakes with/without aeration, develop prediction model, and propose strategies on the proper deployment and use of aerators to improve lake ecosystems.

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**Name:** Lian Shen

**Sponsoring Organization:** U of MN

**Title:** Director and Professor

**Department:** St. Anthony Falls Laboratory

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Minneapolis MN 55455

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**Web Address**

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**Location**

**Region:** Statewide

**County Name:** Statewide

**City / Township:**

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**Alternate Text for Visual:**

Aeration effects on nutrient recycling and oxygen concentration need investigation. Through measurement and modeling, we will develop novel strategy on how to properly use aeration to improve lake ecosystems.

<input type="checkbox"/>	Funding Priorities	<input type="checkbox"/>	Multiple Benefits	<input type="checkbox"/>	Outcomes	<input type="checkbox"/>	Knowledge Base
<input type="checkbox"/>	Extent of Impact	<input type="checkbox"/>	Innovation	<input type="checkbox"/>	Scientific/Tech Basis	<input type="checkbox"/>	Urgency
<input type="checkbox"/>	Capacity Readiness	<input type="checkbox"/>	Leverage	<input type="checkbox"/>		TOTAL	<input type="checkbox"/> %
<input type="checkbox"/> If under \$200,000, waive presentation?							



**PROJECT TITLE: Evaluation and improvement of aeration in lakes**

**I. PROJECT STATEMENT**

**Already applied in about 300 lakes in Minnesota to protect fish from winterkill, can aeration do better in improving the ecosystem of lakes?** The objective of the proposed research is to (1) monitor the concentrations of oxygen and nutrients in lakes with and without aeration, (2) build a virtual experiment platform to evaluate the change in the concentrations of oxygen and nutrients induced by aeration, and (3) provide guidance on how to deploy aeration and how to optimize the use of it.

**Background:** Near the lake bottom, the low concentration of oxygen makes it hard for fish to survive. In winter, the lack of oxygen is more serious as the lake surface is covered by thick ice. Human activities such as sewage discharges, agricultural run-off, or over-baiting a fishing lake can also reduce the oxygen concentration in lakes. Water aeration is often applied in water bodies to increase the dissolved oxygen, which has already been used in about 300 lakes in Minnesota.

**Motivation:** It is pointed out on the website of the Minnesota Department of Natural Resources (DNR) that **“the effects of aeration on algal blooms and nutrient recycling are less predictable. There are important questions that need to be answered prior to pursuing lake aeration.”** To properly use the installed aeration system and to guide the future installation of aeration system, the three questions below need to be answered:

- 1) How to evaluate the change in the concentrations of oxygen and nutrient caused by the aeration system?
- 2) How to predict the change in ecosystem, if a new aeration system is deployed?
- 3) How to make executable plan to optimize the use of aeration to improve the ecosystem?

**Proposed research:** We will collect data of the concentrations of oxygen and nutrients in representative lakes with and without aeration. We will also conduct experiments in laboratory water tank at the St. Anthony Falls Laboratory (SAFL). We will then analyze the data to develop a model to predict the effect of aeration on the water flow and the concentrations of oxygen and nutrients. We will also build a virtual experimental platform to conduct numerical experiments to collect more data. Based on the comprehensive data collected in field, laboratory, and virtual experiments, we will identify what is the best distribution of aerators, and when to turn them on/off so that the concentrations of oxygen and nutrients can reach the best status for the lake ecosystem.

**II. PROJECT ACTIVITIES AND OUTCOMES**

**Activity 1: Measure concentrations of oxygen and nutrients in representative lakes with/without aeration.**

The research activity will start with data collection. We will **monitor representative lakes** with aeration (such as the Snelling Lake and Lake Minnetonka). We will also measure lakes without aeration for the purpose of comparison. The environmental conditions of these lakes will be imported into laboratory experiment to collect complementary data. By analyzing the data collected in field and laboratory, we will **develop a model** to predict the evolution of oxygen and nutrients in lakes, and to evaluate the change in the concentrations of oxygen and nutrients induced by the aeration.

**ENRTF BUDGET: \$124,892**

<b>Outcome</b>	<b>Completion Date</b>
1. Collect data of environmental conditions of representative lakes with/without aeration	October 2020
2. Measure concentrations of oxygen and nutrients in field	October 2021
3. Measure concentrations of oxygen and nutrients in SAFL laboratory	October 2021
4. Develop model to predict the effect of aeration on the concentrations of oxygen and nutrients	March 2022



**Activity 2: Develop a virtual experiment platform**

We will also build an **unprecedented virtual-lake experiment platform** to study the interactions among important components in the ecosystem of lakes, including water, fish, vegetation, oxygen, nutrients, and algae. This virtual experiment platform will be extensively calibrated and validated using the data collected in activity #1. It will then be used to perform experiments that are infeasible to carry out or too expensive in the field. For example, we will systematically test the change in the concentration of oxygen and nutrients induced by various distributions and types of aerators.

**ENRTF BUDGET: \$108,057**

<b>Outcome</b>	<b>Completion Date</b>
1. Design and build the virtual-lake experiment platform	December 2020
2. Calibrate and validate the platform	November 2021
3. Conduct numerical experiments	January 2022

**Activity 3: Develop an optimal control strategy on the use of aeration**

Based on the results of activities #1 and #2, we will obtain the optimal control strategy on the use of aeration. The strategy can vary with lakes. It will account for the species in the lake, bottom topography, seasonal climate change (especially ice thickness in winter), and human activities near the lake. Based on these factors, the ideal status of the concentrations of oxygen and nutrients will be determined. To achieve this goal, we will provide a guidance on when to turn on/off which aerator in the lake, and on how to better deploy the aerators in other lakes where aeration has not been used. The model developed in activity #1 and the results of virtual experiments obtained from activity #2 will be used to develop the strategy.

**ENRTF BUDGET: \$79,279**

<b>Outcome</b>	<b>Completion Date</b>
1. Select representative lakes, monitor their species and climate conditions, and conduct survey of human activities near the lake.	January 2021
2. Provide guidance on when to turn on/off which aerators, if they have already been deployed.	March 2022
3. Provide guidance on which type of aerator to choose and how to distribute the aerator, if aeration has not been deployed.	June 2022

**III. PROJECT PARTNERS:**

**IV. LONG-TERM- IMPLEMENTATION AND FUNDING:**

The proposed research aims to improve the concentrations of oxygen and nutrients in lakes and to propose strategies on the deployment and use of aerators. The performance of the strategies will be monitored over long term. We will continue tracking the status of the lakes where the proposed strategies will be applied. The collected data will also be shared with state environmental specialists through a user-friendly website interface, supporting them for policy consideration related to the ecosystem improvement and protection.

**V. TIME LINE REQUIREMENTS:**

The project is planned for 3 years beginning on July 1, 2019 and ending on June 30, 2022.

**VI. SEE ADDITIONAL PROPOSAL COMPONENTS:**

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

## 2019 Proposal Budget Spreadsheet

**Project Title: Evaluation and improvement of aeration in lakes**

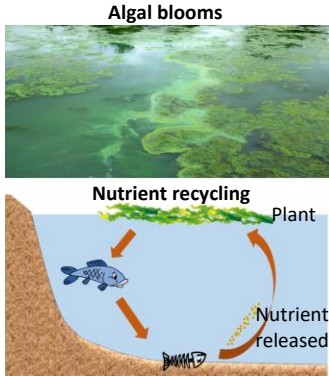
**IV. TOTAL ENRTF REQUEST BUDGET: 3 years**

BUDGET ITEM	AMOUNT
<b>Personnel:</b>	\$ 295,728
Prof. Lian Shen, project manager (75% salary, 25% benefit); 6.25% FTE (i.e., 0.75 month of summer salary) for each of 3 years. (\$48,697)	
Postdoctoral Associate, experiment and modeling research (82% salary, 18% benefit); 100% FTE for each of 3 years. (\$191,368)	
IT Research Staff, data analysis and model development (75% salary, 25% benefit); 15% FTE for each of 3 years. (\$41,263)	
Undergraduate Assistant, measurement and data analysis (100% salary); 3 months for each of 3 years. (\$14,400)	
<b>Professional/Technical/Service Contracts: N/A</b>	\$ -
<b>Equipment/Tools/Supplies:</b>	\$ 15,000
Cost of setting up aerator system (\$3000) in laboratory, and purchasing velocimetry (\$3,500), oxygen concentration sensors (\$2,200), nutrition monitor (\$2,500), and lab materials and supplies (\$3800).	
<b>Acquisition (Fee Title or Permanent Easements): N/A</b>	\$ -
<b>Travel:</b>	\$ 1,500
Transportation within Minnesota state for data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage \$0.545/mile x 1000 miles = \$545; Incidental expense during travel \$200; Lodging \$755.	
<b>Additional Budget Items: N/A</b>	\$ -
<b>TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND \$ REQUEST =</b>	<b>\$ 312,228</b>

**V. OTHER FUNDS** (This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)

SOURCE OF FUNDS	AMOUNT	Status
<b>Other Non-State \$ To Be Applied To Project During Project Period:</b>	\$ -	N/A
<b>Other State \$ To Be Applied To Project During Project Period: N/A</b>	\$ -	N/A
<b>In-kind Services To Be Applied To Project During Project Period:</b> 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).	\$ 160,503	Secured
<b>Past and Current ENRTF Appropriation:</b> Prof. Lian Shen is a co-investigator of the project "Enabling extracting of solar thermal energy in Minnesota" (ML 2017, Chp. 96, Sec. 2, Subd 07a) from 7/1/2017 to 6/30/2020 (Project Manager Fillippo Coletti, co-investigators Jane Davidson and Lian Shen). The total budget is \$250,000. Prof. Shen's portion of budget is approximately \$74,000.	\$ 74,000	Secured
<b>Other Funding History: N/A</b>	\$ -	N/A

# MOTIVATION



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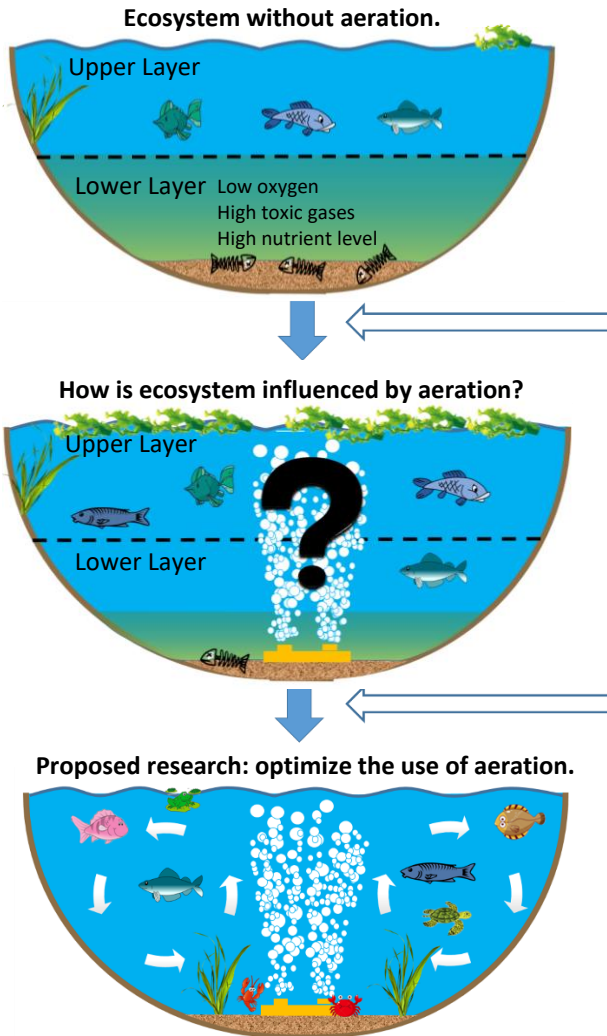


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Already applied in about 300 lakes in Minnesota to protect fish from winterkill, **Can aeration do better in improving the ecosystem of lakes?**

# PROPOSAL



*DNR: "the effects of aeration on algal blooms and nutrient recycling are less predictable. There are important questions that need to be answered prior to pursuing lake aeration."*

*Conduct field, laboratory, and virtual experiments to study the change in concentrations of oxygen and nutrients induced by aeration, and to develop strategy on how to use aeration to achieve ideal status of ecosystem in lake.*



### **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 the International Journal of Computational Methods and the Ocean Systems Engineering journal. Prof. Shen has also 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 many 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 21 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 measuring environmental flows at SAFL, which has 16,000 ft<sup>2</sup> of research space dedicated to physical modeling and experimentation. The facility, which has recently been upgraded with a \$16M renovation, has 15 general purpose flumes, tanks, and channels readily configurable to the needs of projects. The primary water source is the Mississippi River. SAFL's maximum flow capacity is 300 ft<sup>3</sup>/s (8.5 m<sup>3</sup>/s), which can be sustained indefinitely, allowing long-duration experiments. This project will utilize the main channel, SAFL's largest research channel, which is a straight, concrete channel capable of nearly 300 ft<sup>3</sup>/s flow rates of river water. The channel is equipped with a wave generator, sediment flux monitoring and recirculation system, and a data acquisition carriage. The channel can be run in flow-through mode or as a ponded system.

The proposed project will also use the Outdoor StreamLab (OSL), which is a premier research facility developed at SAFL. The OSL is an experimental stream channel system designed to host experiments on the interactions between physical, chemical, and biological processes with water diverted from the Mississippi River. The OSL is equipped to: a) quantify environmental fluid flow processes from microscopic to reach scales with high-resolution laboratory-quality measurements; b) conduct hydrological and ecological field-scale experiments under controlled conditions; and c) impose and repeat steady and unsteady inlet hydrographs, including floods. Located across the Mississippi River from downtown Minneapolis, OSL is frequently visited by the public. The proposed project will provide an excellent opportunity for public education and outreach.