



## Environment and Natural Resources Trust Fund

M.L. 2023 Approved Work Plan

### General Information

**ID Number:** 2023-026

**Staff Lead:** Mike Campana

**Date this document submitted to LCCMR:** June 6, 2023

**Project Title:** Wind Wave and Boating Impacts on Inland Lakes

**Project Budget:** \$415,000

### Project Manager Information

**Name:** Jeffrey Marr

**Organization:** U of MN - St. Anthony Falls Laboratory

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### Project Reporting

**Date Work Plan Approved by LCCMR:** June 22, 2023

**Reporting Schedule:** April 1 / October 1 of each year.

**Project Completion:** June 30, 2026

**Final Report Due Date:** August 14, 2026

### Legal Information

**Legal Citation:** M.L. 2023, Chp. 60, Art. 2, Sec. 2, Subd. 04c

**Appropriation Language:** \$415,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the St. Anthony Falls Laboratory to conduct a field study to measure the impacts of boat propeller wash and boat wakes on lake bottoms, shorelines, and water quality compared to the impacts of wind-generated waves.

**Appropriation End Date:** June 30, 2026

## Narrative

**Project Summary:** Field study to measure the impacts of boat propeller wash and boat wakes on lake water quality, and compare them to the impacts of wind-waves.

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

This research project seeks to develop new understanding for how recreational boating is linked to lake water quality and riparian health. Recreational boating on Minnesota lakes and rivers is growing in the number of boats, as well as their overall size, weight, and power. With the emergence of the sport of wakesurfing, there has been an increase in the engine size and power of boats operating on our lakes - some with engines as large as 600 horsepower. Wakesurfing also introduces a new mode of operating boats - at moderate sub-planing speeds where water is plowed to generate large surfable wakes. Additionally, the propeller of all boats produces a turbulent jet of water, termed propeller wash, that penetrates the water column. Recent research completed by this team has shown that different recreational boat types and usage scenarios represent a significant shift in wave height, energy, and power that our lakes and rivers have not seen before. SAFL-UMN has received hundreds of communications over the last two years from stakeholders seeking guidance on proper usage of recreational boats to address concerns over perceived threats to water clarity, shoreline erosion, personal property, and human and wildlife safety.

**What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.**

We are proposing a field-based research project to investigate the impacts of common recreational boats (non-wakesurf and wakesurf boats) for both shallow near-shore zones and deep-water zones. We will study both boat-generated waves and propeller wash produced by a number of boats operated under a range recreational activities at varying distances from shore and water depths. Additionally, the project will measure wind-generated waves to give a baseline for comparison.

Propeller wash research will investigate how deep the propeller wash jet penetrates the water column, the jet velocity, and any associated sediment suspension. Data will be collected on the vertical water column mixing, interaction with the lake bottom (e.g., suspension of inorganic/organic solids), and aquatic vegetation damage due to propeller wash.

Boat-generated and wind-generated waves will be studied by carefully documenting the wave activity at four study shorelines. These sites will be fully characterized at the beginning of the project and, over two field seasons, we will document the characteristics and frequencies of boat and wind waves, and how different wave exposures are linked with lake bottoms, shorelines and water quality.

**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?**

1. Measure the propeller wash penetration depth for various wakesurf and non-wakesurf boats and, using available data, develop a method for predicting depth of penetration based on the vessel size, speed, pitch angle and engine power.
2. Document the characteristics of large and sustained wind-generated waves and large boat-generated waves and measure the local impact on the nearshore zone and water quality.
3. Measure characteristics of wind-generated waves and boat-generated waves typical to inland lakes and produce a summary of these characteristics including the similarities, differences and practical implication for the lake environment.

## 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

## Activities and Milestones

### Activity 1: Investigate propeller wash impacts within near-shore and deep water zones of inland lakes

**Activity Budget:** \$153,002

#### Activity Description:

Activity 1 will involve field-based research examining the propeller wash interactions with the water column and lake bottom. Two locations within a metropolitan area lake will be selected for deploying instrumentation. One site will be “deep water” (~20 ft depth) where we expect minimal interaction of the propeller wash with the lake bottom and the second site will be “shallow water” (~10 ft depth), where we expect propeller wash to interact with the lakebed. Baseline measurements will be collected at both sites to characterize bottom sediment, aquatic vegetation, and water quality.

At each site, we will evaluate the propeller wash of up to four recreational boats. The boats will be operated at different speeds replicating various recreational activities (e.g., wakesurfing, wakeboarding, waterskiing, cruising, etc.). Sensors placed on the lake bottom will measure the water velocity generated by the propeller wash as the test boats pass over. Underwater cameras will document movement of sediment and vegetation. Intensive water sampling will be performed before, during, and after testing. Water samples will be analyzed for total suspended sediments and composition. Post-testing water samples will be collected to document the time necessary for water quality to return to baseline condition.

#### Activity Milestones:

Description	Approximate Completion Date
Research and select lake, test sites and test boats	August 31, 2023
Complete testing Site A and Site B on four test boats	October 31, 2023
Complete data analysis, complete interim report and submit for external peer review	February 28, 2025

### Activity 2: Impacts of wind and boat waves on water quality within near-shore and deep water zones of a metro area lake

**Activity Budget:** \$102,299

#### Activity Description:

Activity 2 will be a field-based research study examining interactions between waves (wind and boat-generated) and lake bottoms, suspended sediments, aquatic vegetation and shorelines. The study sites (two shorelines) in Activity 2 will be on a single lake within the Twin Cities, representative of typical metro-area inland lakes. The sites will be fully characterized early in the project (e.g. bottom sediment, aquatic vegetation, bathymetry, prevailing winds, etc.)

Wave monitoring sensors will be deployed at the site to capture wave height, wavelength, period, energy and power. For wind waves, we will capture moderate and high wind days when little recreational boating is occurring on the lake. The team will monitor wind forecast and mobilize as appropriate. For boat-generated waves, we will operate test boats during low wind days under various operational conditions. For both wind and boat waves, water velocities will be measured and intensive water sampling will be performed. Water samples will be analyzed for suspended sediments and composition. We will document the characteristics of boat and wind waves and how they are linked to lake bottom properties, shorelines and water quality. Water quality measurements by the project team will be supplemented with citizen water quality measurements.

#### Activity Milestones:

Description	Approximate Completion Date
Research and select lakes, test sites and test boats	October 31, 2023
Begin field study of Twin Cities Lake	June 30, 2024
Complete wind and boat wave evaluations on Twin Cities lake site	October 31, 2024

### Activity 3: Impacts of wind and boat waves on water quality within near-shore and deep-water zones of a northern Minnesota lake

**Activity Budget:** \$159,699

**Activity Description:**

Activity 3 is a continuation of wave research but will take place on a northern Minnesota lake. We will select study sites (two shorelines) within a single northern Minnesota lake, where recreational boating is very popular but the environmental attributes of the lake are different from the metro area lake (e.g. bottom sediments, water clarity, aquatic vegetation, etc.). As in Activity 2, we will study interactions between waves (wind or boat-generated) and lake bottoms, suspended solids, aquatic vegetation and shorelines.

Again, like Activity 2, wave monitoring sensors will be deployed at the site to capture wave height, wavelength, period, energy and power. For wind waves, we will capture moderate and high wind days when little recreational boating is occurring on the lake. For boat-generated waves, we will operate test boats during low wind days under various operational conditions. For both wind and boat waves, water velocities will be measured and intensive water sampling will be performed. Water samples will be analyzed for suspended sediment and composition. Water quality measurements by the project team will be supplemented with citizen water quality measurements.

Activity 3 also includes synthesis of data from Activity 2 and 3 and creation of a report.

**Activity Milestones:**

Description	Approximate Completion Date
Research and select lakes, test sites and test boats	October 31, 2024
Begin field study of northern Minnesota lake	June 30, 2025
Complete wind and boat wave evaluations on northern Minnesota lake	October 31, 2025
Complete data analysis, complete interim report and submit for external peer review	March 31, 2026
Publish Activity 2 and 3 report on wind and boat wave impacts and disseminate results to stakeholders	June 30, 2026

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
William Herb	University of Minnesota - St. Anthony Falls Laboratory	Dr. Bill Herb is Co-PI and will oversee field and laboratory research characterizing boat-generated waves and interaction with sediment and vegetation. Herb is a Research Associate at SAFL and led a LCCMR-funded project studying wind-wave energy and nearshore fish habitat in Minnesota lakes.	Yes
Jessica Kozarek	University of Minnesota - St. Anthony Falls Laboratory	Dr. Jessica Kozarek is Co-PI and will oversee field and laboratory research characterizing boat-generated waves and interactions with sediment and vegetation. Kozarek is a Research Associate at SAFL and is Manager of the SAFL Outdoor StreamLab.	Yes
Mathew Lueker	University of Minnesota - St. Anthony Falls Laboratory	Research Engineer: Literature review for characterization of wakes from boat hulls and propellers to aid design of datalogging equipment. Experimental design for laboratory testing. Analysis and reporting. Lueker is lead hydraulic modeler at SAFL with over 15 years of project experience.	No
Andrew Riesgraf	University of Minnesota - St. Anthony Falls Laboratory	Project Coordinator, Research Scientist - Andy will serve as day-to-day project coordinator and will be a primary researcher on all activities.	No
Jeffrey Marr	University of Minnesota - St. Anthony Falls Laboratory	Project Manager/Principal Investigator. Jeff will provide oversight of the project along with budgetary, and schedule management. He will be involved in all activities of the project including development of final reports.	No
Kimberly Hill	University of Minnesota - SAFL & Department of Civil, Environmental and Geo-Engineering	Associate Professor Hill is Co-PI and will guide field and laboratory research in all areas with special focus on characterizing the propeller wash and impingement on lake sediments. Hill is an expert in particle physics and sediment transport with applications to lake, reservoir, river, and pond environments.	No

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**

The information generated in this research is sought by a large stakeholder community. We will produce a final project report from this research, which will be freely available through the UMN Digital Conservancy (UDC). Data and associated metadata collected as part of this project will be published and made freely available through the University of Minnesota Data Repository (DRUM). Both the UDC and DRUM are long-term repositories managed by UMN for research finding and data.

Implementation of the research will be via stakeholders, boat owners, and resource managers who will use the findings to make management decisions about recreational boating and resource preservation. The report described above will be written to a practitioner audience. Our intention will be to present findings of the study via an online/virtual seminar series accessible to stakeholders such as through Minnesota Lakes and Rivers Advocates or Minnesota Coalition of Lake Associations. We will also present findings at the annual Minnesota Water Resources Conference. It is likely the team will be invited to present at other conferences and board meetings and we will take advantage of these opportunities.

The research will also be submitted for publication in an academic journal. The scope of the research is large and likely more than one journal paper will be submitted for publication.

Environment and Natural Resources Trust Fund will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENTRF Acknowledgment Guidelines.

### 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 work be funded?**

The information generated in this research is sought by a large stakeholder community. We will produce a final project report from this research, which will be published as a Project Report that will be freely available through the UMN Digital Conservancy. Implementation of the research will be via stakeholders, boat owners, and resource managers who will use the findings to make management decisions about recreational boating and resource preservation. The scope of this project may be expanded with additional funding from other sources for work on shoreline erosion due to boat- and wind-generated waves.

### Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
MAISRC Subproject 21.2: Field Validation of Multibeam Sonar Zebra Mussel Detection	M.L. 2017, Chp. 96, Sec. 2, Subd. 06a	\$0
Enhancing Spawning Habitat Restoration in Minnesota Lakes	M.L. 2017, Chp. 96, Sec. 2, Subd. 08e	\$294,000

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Jeff Marr		Project Manager/Research engineer			33.5%	0.06		\$26,740
William Herb		Researcher - William will serve as a research lead on the project focusing on Activity 2 and Activity 3			33.5%	0.12		\$35,681
Jessica Kozarek		Researcher - Jessica will serve as a lead researcher focusing on water quality and hydraulics for all three Activities.			33.5%	0.24		\$72,889
Kimberly Hill		Advisor - Kimberly will serve as technical advisor on this project			33.5%	0.03		\$11,777
Andrew Riesgraf		Project coordinator/researcher - Andy will serve as day-to-day project coordinator and primary researcher on all activities.			28.7%	0.3		\$72,054
Matthew Lueker		Research engineer - Matt will serve as a researcher on this project, responsible for design and data collection of watercraft performance			28.7%	0.27		\$63,155
Ben Erickson		Research support technician - Ben will provide technician support to field campaign and open water safety.			28.7%	0.21		\$53,705
Chris Milliren		Research Engineer - Chris will support development and deployment of data acquisition systems.			33.5%	0.06		\$15,758
Undergraduate Researchers		UMN undergrad will provide field support.			0%	0.12		\$11,912
							<b>Sub Total</b>	<b>\$363,671</b>
<b>Contracts and Services</b>								
							<b>Sub Total</b>	-
<b>Equipment, Tools, and Supplies</b>								
	Tools and Supplies	Water sampling and analysis	Sample bottles and supplies to perform water quality analysis on collected samples					\$7,600
	Tools and Supplies	Wave Monitoring Sensor	structural mast, sensors and data logger for measuring waves at test shorelines					\$5,429



	Tools and Supplies	Water velocity measurement	Sensors and structural mounts to deploy water velocity measurements in all Activities of the project. Acoustic Doppler Velocimeters will be mounted on rigid frames made of aluminum and steel and deployed with steel cable. The costs of the raw materials for these frames is estimated based on previously constructed mounts. A single Acoustic Doppler Current Profilers will also be deployed on a structural frame. In total, three frames will be fabricated at \$4,000 each.					\$12,000
	Tools and Supplies	Undewater video capture	Supplies needed to support underwater cameras needed to capture sediment movement at lake bottom.					\$1,000
	Tools and Supplies	Boat Gas	Fuel to operate test boats during data collection					\$3,000
							<b>Sub Total</b>	<b>\$29,029</b>
<b>Capital Expenditures</b>								
							<b>Sub Total</b>	-
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	Miles/ Meals/ Lodging	mileage reimbursement for instate travel to metro area field site	travel is in support of field work. (Activity 1)					\$2,000
	Other	Truck rental	work truck rented for Activity 1 to support research activities					\$3,000
	Miles/ Meals/ Lodging	meals out of town work	meal per diem for work occurring in northern Minnesota (Activity1)					\$1,700
	Miles/ Meals/ Lodging	Travel to field twin cities field site	mileage reimbursement for travel to local field sites (Activity 2)					\$1,900

	Miles/ Meals/ Lodging	Travel to northern MN field site	Mileage reimbursement for travel to northern Minnesota field site (Activity 3)					\$2,600
	Miles/ Meals/ Lodging	housing for work at field sites	housing reimbursement for northern Minnesota field work (Activity 3)					\$5,800
	Miles/ Meals/ Lodging	per diem for out of town work	meal reimbursement for northern Minnesota field work (Activity 3)					\$3,300
							<b>Sub Total</b>	<b>\$20,300</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
							<b>Sub Total</b>	-
<b>Other Expenses</b>								
		Mobile cell phone service to upload data from field	data collected remotely in the field will need to be uploaded through cellular network continually during data collection.	X				\$2,000
							<b>Sub Total</b>	<b>\$2,000</b>
							<b>Grand Total</b>	<b>\$415,000</b>

## Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Other Expenses		Mobile cell phone service to upload data from field	Data sensors will be placed remotely in the field and cell network is the most economical means to collect this data reliably.

Non ENRTF Funds

Category	Specific Source	Use	Status	\$ Amount
<b>State</b>				
			<b>State Sub Total</b>	-
<b>Non-State</b>				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	\$228,250
			<b>Non State Sub Total</b>	<b>\$228,250</b>
			<b>Funds Total</b>	<b>\$228,250</b>

## Attachments

### Required Attachments

#### *Visual Component*

File: [5a7d07d5-e63.pdf](#)

#### *Alternate Text for Visual Component*

The visual component summarizes the motivation and objectives of the project. The MOTIVATION is Larger boats and newer recreational activities like wakesurfing are increasing wave energy and vertical mixing in Minnesota lakes. PROJECT OUTCOMES will include two reports that will be publicly available....

### Optional Attachments

#### *Support Letter, Photos, Media, Other*

Title	File
Letter of Support - University of Minnesota	<a href="#">5bdb510a-698.pdf</a>
Letter of Support - Minnesota Coalition of Lake Associations	<a href="#">ac9a3df9-8c1.pdf</a>
Letter of Support - Gull Chain of Lakes Association	<a href="#">15352054-dd3.pdf</a>
Letter of Support - Hubbard County Coalition of Lake Associations	<a href="#">d6904faa-b59.pdf</a>
Letter of Support - MN Association of Watershed Districts	<a href="#">328b0dbd-5d7.pdf</a>
Letter of Support - Minnesota Lakes and Rivers Advocates	<a href="#">f50ac0f4-bee.pdf</a>
Letter of Support - Lake Minnetonka Conservation District	<a href="#">973face9-2d9.pdf</a>
Letter of Support - Whitefish Area Property Owner's Association	<a href="#">d229fad1-05b.pdf</a>
Letter of Support - Watson - Whitefish Area Property Owners Association	<a href="#">1b8f7b68-557.pdf</a>
Letter of Support - Michigan Lakes and Streams Association	<a href="#">b2829fd9-224.pdf</a>
Letter of Support - Clear Lake Property Owners Association	<a href="#">daeb8e32-305.pdf</a>
Background Check Certification	<a href="#">65fc6589-000.pdf</a>
Final Approved Research Addendum	<a href="#">cad8e2d2-845.pdf</a>

## Difference between Proposal and Work Plan

### *Describe changes from Proposal to Work Plan Stage*

- For Activity 1 we reduced the number of field sites from 4 to 2 (i.e. reduced to one lake with two sites rather than two lakes with two sites each). We made this change to save resources as establishing two additional field sites on a second lake will be costly with little benefit. We can actually collect more data if we focus on a single lake.
- For Activity 1 we reduced the length of time of the field work and compressed schedule to complete the field work by fall of 2023. In the proposal we had additional field work scheduled in 2024 but this is not an efficient use of resources. The same amount of work will be accomplished in the first field season.
- Activity 2 and 3 – no substantive changes made to text.
- Budget – Budget reduced to \$415,000. We reduced salaries for people to accommodate the reduction in funding.

## Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

**Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?**

N/A

**Do you agree travel expenses must follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**

Yes, I agree to the Commissioner's Plan.

**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