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

Project Title: **ENRTF ID: 096-B**

Occurrence of Algal Toxicity in Minnesota Waters

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 351,446

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

Summary:

We propose to develop real-time and technologies and prediction models to quantify the onset, transport, and mitigation of algal toxicity in Minnesota waters.

Name: Miki Hondzo

Sponsoring Organization: U of MN

Job Title: Professor

Department: Civil, Environmental, and Geo- Eng; St. Anthony Falls Lab

Address: 2 Third Ave SE

Minneapolis MN 55414

Telephone Number: (612) 625-0053

Email mhondzo@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Real-time techniques to quantify the onset, transport, and mitigation of algal toxicity in Minnesota waters

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

PROJECT TITLE: Occurrence of Algal Toxicity in Minnesota Waters

I. PROJECT STATEMENT

Real-time and cost-effective techniques to quantify the onset, transport and mitigation of algal toxicity in Minnesota waters are urgently needed. Cyanobacteria are a common component of the algal community in Minnesota's waters. The rapid growth of cyanobacteria often leads to blooms that cannot only degrade water quality but also produce cyanotoxins. The cyanotoxins can bio-accumulate in fish, mussels, and zooplankton and affect the liver, kidney, and reproductive system of living organisms. The most commonly found cyanotoxin in Minnesota's water is Microcystin (MC). Over the past three years (2016 ENRTF Appropriation), we have developed and tested unique *in situ* monitoring technologies of water quality and algal biomass and formulated simple predictors of algal biomass based on water temperatures, meteorological conditions, and morphometry in three Minnesota lakes. The funding, ending this year, has helped us increase our understanding of harmful algal blooms (HABs), develop an automated continuous water quality station (buoy), acquire drone technology to measure algal biomass and temperature, and initiate the annual ***MN Harmful Algal Bloom Workshop*** training over 100 water resources professionals and practitioners. An urgent need is to implement the developed technologies and models to a wide range of Minnesota lakes and to document prediction tools to detect the onset, transport, and mitigation of cyanobacterial toxins. Our collaborative team; including Minnesota Pollution Control Agency (MPCA), Minnesota Department of Health (MDH), University of Minnesota (UMN) St. Anthony Falls Laboratory (SAFL), and UMN Extension; proposes to:

1. Quantify Microcystin concentrations using the buoy, spectroradiometer, and drone technologies to develop cyanotoxin early detection protocols and prediction models;
2. Apply and verify the cyanotoxin detection protocols and models in 12 Sentinel lakes in Minnesota; and
3. Disseminate the findings and provide hands-on training to the public, regulators, and stakeholders to detect and mitigate cyanotoxins in Minnesota waters.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Quantify Microcystin concentrations using the buoy, spectroradiometer, and drone technologies to develop cyanotoxin detection protocols and prediction models*

In collaboration with MPCA, one lake will be selected for high-resolution algal, water quality, and cyanotoxin monitoring by drone, buoy, toxin (ELISA) testing kits, and real-time spectroradiometer measurements. The spectroradiometer measurements (e.g., ASD FieldSpec) will detect the solar irradiance, surface reflectance and water leaving radiances at the different growth stage of cyanobacteria. The measurements will provide a unique opportunity to discover the role of environmental variables in increasing algal biomass and Microcystin concentrations in Minnesota lakes. The unique features within visible and near-infrared (VNIR) bands will specify the most sensitive wavelengths for the detection of cyanobacteria and Microcystin concentrations. The specified wavelengths are crucial for the development of prediction models and accurate detection of algal biomass and Microcystin concentrations by spectroradiometer and drone technologies. The prediction models of cyanotoxin concentrations and algal biomass will be explored by simple Excel spreadsheet models with input from handheld spectroradiometer, and areal models with input from the spectral drone measurements.

Outcome	Completion Date
1. Water samples collected, analyzed for cyanobacterial biomass and Microcystin concentrations, and the corresponding spectral bandwidth.	12/1/2021
2. Formulate spreadsheet type prediction models (point and areal) for the detection of Microcystin concentration and algal biomass.	12/1/2021

Activity 2: *Apply and verify the cyanotoxin detection protocols and models 12 Sentinel lakes*

The proposed outcomes of Activity 1 will be verified in 12 Sentinel lakes in collaboration with the MPCA. We will augment the existing sampling protocol of MPCA by simultaneously collecting the handheld spectroradiometer measurements and flying the drone over the specified lakes. The proposed field monitoring over the range of lakes and ecoregions will provide a unique opportunity to verify the proposed models and assess the reliability of

using the drone and spectroradiometer technologies to detect real-time Microcystin and algal concentrations.

Outcome	Completion Date
1. Quantify Microcystin concentration and algal biomass, by collecting water samples, spectroradiometer, and drone technology in 12 Sentinel lakes in Minnesota.	12/1/22
2. Verification and documentation of accuracy of the Microcystin concentrations and algal biomass measurements by the comparison of water sample laboratory analysis, *in situ* spectroradiometer and drone technology detection.	12/1/22
3. Establish prediction models and protocols for sensing algal biomass and Microcystin concentrations by drone and spectroradiometer technologies.	06/1/23
4. Document mitigation strategies (physical/chemical and mechanical) of algal toxicity by implementing real-time and *in situ* spectroradiometer and drone technologies.	06/30/23

Activity 3: *Educational outreach: Disseminate the findings and provide hands-on training to the public, regulators, and stakeholders to detect and mitigate cyanotoxins in Minnesota waters*.

We will actively seek end-users inputs on how they would want to use the proposed spreadsheet-type models, spectroradiometer, and drone technology through the existing HABs website[1]. We will do this by delivering an interactive session at the Feb. 2020 MN Extension Lake Workshop series. We propose to produce a series of tutorial videos to educate potential users on how to a) conduct spectroradiometer and drone measurements, b) upload files, c) visualize the data, d) interpret the cyanobacterial biomass and Microcystin concentrations, and e) apply feasible mitigation strategies including the effectiveness of clays in flocculating and removing the HAB cells, and dispersing the HAB cells by *in situ* aeration. We will offer on-demand online webinars and two in-person training workshops on the use and the proposed technologies. The training will provide the water resource practitioners a much-needed tool for detecting and mitigating cyanotoxins in Minnesota waters. We will also provide live training on board using the new MN HAB Educational Trailer throughout the State.

Outcome	Completion Date
1. User survey and input sessions to identify top desired features among end users	20/02/20
2. Tutorial materials, video productions, and integration in HABs website	12/1/21
3. Online webinar training and hands-on in-person training workshops	06/30/23

III. PROJECT PARTNERS AND COLLABORATORS: A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Miki Hondzo	Professor	U of MN, CEGE	Lead Investigator
Ardeshir Ebtehaj	Assistant Prof.	U of MN, CEGE	Co-investigator
Shahram Missaghi	Extension Professor	U of MN, Extension	Co-investigator

IV. LONG-TERM IMPLEMENTATION AND FUNDING: The **outcomes** will lead to predictive models and leverage drone sensing technology for real-time monitoring and forecasting of cyanotoxin and algal biomass in Minnesota's waters. Through the UMN Extension program, Dr. Missaghi will facilitate **outreach** of the project. In the available website[1], we will design an online education module tentatively entitled "Environmental Factors and Drone Sensing of Cyanotoxins." The project will **benefit the economy** of Minnesota's recreation industry, water treatment plants, and fisheries by a) ensuring the public can use lakes safely, free from exposure to cyanotoxins, b) establishing **early detection technologies** and forecast models to predict cyanotoxin bloom events with a 1-3 day lead time to resource managers, and c) documenting feasible mitigation strategies. The MPCA supports the project through scientific and field-scale **collaborations**. At least four meetings will be organized with MPCA's research scientists Dr. Matt Lindon and Dr. Emily Brault for knowledge exchange. The second year of the project will include working with MPCA to validate the spectroradiometer and drone technologies in 12 Sentinel lakes.

V. TIMELINE REQUIREMENTS: The proposed project will be completed in three years.

[1] https://extension.umn.edu/shoreland-property-owners/blue-green-algae-minnesota-lakes

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Miki Hondzo
Project Title: Occurrence of Algal Toxicity in Minnesota Waters
Organization: Regents of the University of Minnesota
Project Budget: $351,456
Project Length and Completion Date: 3 years, June 30, 2023
Today's Date: April 8, 2019

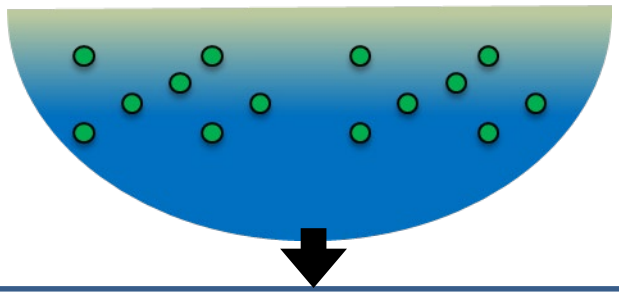
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 287,456	$ -	$ 287,456
Miki Hondzo, Project Manager (76% salary, 24% fringe benefits). 8% FTE (1 nonth) for years 1 - 3. Lead Task 1, co-lead Task 2 & 3 studies. ($68,222)			
Ardeshir Ebtehaj, co-Project Manager (76% salary, 24% fringe benefits). 6% FTE (0.5) months for years 1 - 3. Overall project coordination, Lead Task 2. ($22,355)			
Shahram Missaghi, co-Project Manager (76% salary, 24% fringe benefits). 6% FTE (0.5 months) for years 1 - 3. Lead Task 3, co-lead Task 2. ($14,278)			
Graduate student Research assistant, (58% salary, 42% fringe benefits) Perform field measurements, formulate prediction models (Task 1 &2) assist with the educational outreach (Task 3)(54% salary, 46% fringe benefits) 50% FTE for years 1,2, &3. ($153,922)			
Christopher Ellis, (92% salary, 8% fringe benefits) assist with bouy operation, data telemetric transfer, and data analysis 40 hrs in Years 1,2,& 3. ($8,026)			
Research Scientist (B. Erickson), (77% salary, 23% fringe benefits) Assist with assembly, testing, deployment of bouy in the specified lake, assist with spectroradiometer and drone measurements, 80 hrs in Years 1,2 & 3. ($9,773)			
Undergraduate researcher. Assist with sample collection in summers Year 1 -3 (100% salary), 25% FTE ($10,880)			
Equipment/Tools/Supplies			
Laboratory supplies - glassware, laboratory safety supplies, laboratory toxicity kits, chlorophyll standards	$ 21,000	$ -	$ 21,000
Capital Expenditures Over $5,000			
Hyperspectral VNIR Spectroradiometer (ASD FieldSpec)	$ 23,000	$ -	$ 23,000
Spectrophotometer (PerkinElmer Lambda 950)	$ 12,000	$ -	$ 12,000
Travel expenses in Minnesota			
Mileage, hotel, and meal expenses associated with training, field data collection, and outreach	$ 5,000	$ -	$ 5,000
Other			
Open access publication fees to allow papers to be available immediately	$ 3,000	$ -	$ 3,000
COLUMN TOTAL	$ 351,456	$ -	$ 351,456

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Because the project is overhead free, laboratory space, electricty, and other facilities/adminstrative costs (54% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	secured	$ 144,198	$ -	$ 144,198

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Assessing the Increasing Harmful Algal Blooms in Minnesota Lakes (07/01/2016-06/30/2019)		$ 341,000	$ 292,389	$ 48,611

Real-time techniques to quantify the onset, transport and mitigation of algal toxicity in Minnesota waters are urgently needed

Normal lake conditions with few algae

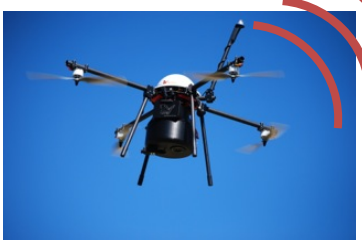


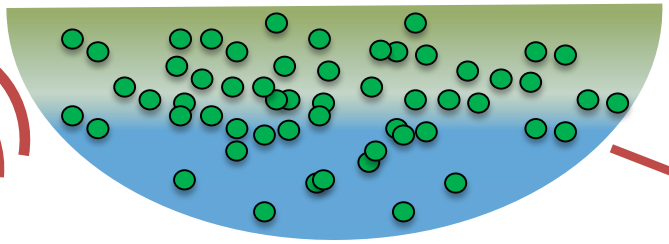
Excessive nutrient input with algal favorable physical conditions

Rapid algal growth and toxin production

Sentinel Lakes

Drone with spectral camera





Spectroradiometer

Key Outcomes

1) Assess cyanotoxins in 12 Sentinel Lakes,
2) Quantify cyanotoxin detection by spectroradiometer and drone real-time technologies,
3) Establish *in situ* early detection technologies and forecast models to predict cyanotoxin bloom events with a 1-3 day lead time, and
4) Disseminate the findings and provide hands-on training to the public and regulators to detect and mitigate (physical/ chemical, mechanical) cyanotoxins in Minnesota waters.

Project Manager Qualifications and Organization Description

Miki Hondzo (PI), James L. Record Professor
Department of Civil, Environmental, and Geo- Engineering, University of Minnesota
M.Sc., Surface Water Hydrology, 1988, Free University of Brussels, Belgium
Ph.D., Civil Engineering, 1992, University of Minnesota, Twin Cities, MN, United States
Dr. Hondzo will be responsible for the development and guidance of the detection of cyanotoxins under field and laboratory conditions using the proposed drone and spectral camera technologies. He will guide the development of Excel spreadsheet-type models for the early detection and prediction of cyanotoxins in Minnesota waters. Dr. Hondzo has 20 years of experience in physical limnology and water quality monitoring and modeling in lakes. Furthermore, he will be responsible for exploring and documenting the proposed mitigation strategies of harmful algal blooms and cyanotoxins. A physical/chemical mitigation strategy will be investigated in the field and outdoor bioreactors at SAFL by adding clay particles for the aggregation and dispersal of cyanobacteria and associated toxins. A mechanical mitigation strategy will be investigated at SAFL and in the field by injecting air bubbles for the dispersal of cyanobacteria and cyanotoxins. Dr. Hondzo will be responsible for the submission of yearly progress reports. Dr. Hondzo is an Associate Editor of the Environmental Fluid Mechanics journal.

Ardeshir Ebtehaj (Co-PI), Assistant Professor
Department of Civil, Environmental, and Geo- Engineering, University of Minnesota
M.Sc., Mathematics, 2012, University of Minnesota, Twin Cities, MN, United States.
Ph.D., Hydrology, 2013, University of Minnesota, Twin Cities, MN, United States.
Dr. Ebtehaj will be responsible for the development of the analytical models that relate the cyanotoxin concentrations and the measurements of the spectroradiometer. He will guide the detection of cyanobacteria and cyanotoxins by remote sensing using the drone and hyperspectral camera technologies. He has been studying remote sensing of environment and water systems for ten years. Dr. Ebtehaj is an associate editor of the Journal of Hydrometeorology. He was a NASA's Earth and Space Science Fellow in 2014 and won a NASA's new investigator (Early Career) award in 2018 for his contribution in remote sensing sciences.

Shahram Missaghi (Co-PI), Extension Professor
Minnesota Extension, University of Minnesota
M.Sc., Biology, 1988, Bemidji State University, Bemidji, MN.
Post B.S. Certificate, Stream Restoration, 2009, University of Minnesota, Twin Cities, MN, United States.
Ph.D., Limnology, 2014, University of Minnesota, Twin Cities, MN, United States.
Dr. Missaghi will be responsible for research outreach and lake water quality modeling. He will lead the setup, configuration, and coupling of the 3D hydrodynamic and ecological modeling with the collected remote sensing field data. Project outreach and extension will include creating a project website with available online instructions and training for the Early Detection and Prediction of Cyanotoxins Model for both natural resources managers and the general public. A series of locally tailored workshops will be conducted throughout the State to demonstrate and train natural resources practitioners on the developed Cyanotoxins mitigation strategies. Dr. Missaghi is experienced in conducting lake water quality modeling and has 20 years of experience in lake management, outreach, and extension.

Organization Description

The proposed research will be conducted by the St. Anthony Falls Laboratory (SAFL), University of Minnesota. SAFL a unique laboratory located on an island just downstream of the only major waterfall on the Mississippi River – St. Anthony Falls. SAFL also houses several smaller labs, including wet chemistry, sediment analysis, and a biological laboratory with phytoplankton-growth chambers, incubators, and outdoor bioreactors. The EcoFluids Laboratory, developed by PI Hondzo, allows SAFL researchers to study the interactions among fundamental fluid mechanics, microbiological processes, and chemical reactions that are mediated by biological organisms. Several bioreactors with computer controlled operation and data collection have been developed and will be used in the evaluation of proposed mitigation strategies. The laboratories and offices of the PI and Co-PIs contain the necessary fixed and moveable equipment and facilities needed for the proposed studies.