Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID: 043-B**

Enhanced Microbial Nitrate Removal in Minnesota Waters

Category: B. Water Resources

Total Project Budget: $ 333,763

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

We will measure and predict physical and chemical field conditions that enhance microbiological nitrate removal (denitrification hot spots) with minimal nitrous oxide emission in streams, flood plains, and wetlands.

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Sponsoring Organization: U of MN

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Web Address

Location

Region: Statewide

County Name: Hennepin, Nicollet

City / Township: Minneapolis

Alternate Text for Visual:

Denitrification hot spots: Enhanced nitrate removal

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

PROJECT TITLE: Enhanced Microbial Nitrate Removal in Minnesota Waters

I. PROJECT STATEMENT

Excessive nitrogen loading in aquatic ecosystems leads to water quality issues including loss of stream biodiversity, eutrophication, and algal blooms. The large hypoxic zone in the Gulf of Mexico has been caused predominately by excess nitrogen loads in the Mississippi River. The state of Minnesota (MN) is one of the largest exporters of nitrate (~500 kg/km^2/year) to the Mississippi River. In aquatic systems, denitrification acts as a nitrogen sink by converting soluble nitrate into nitrogen gas and gaseous nitrous oxide. While nitrogen gas makes up the majority of our atmosphere (~78%), nitrous oxide is a significant greenhouse gas which has been documented to be an important product of denitrification. Small areas of enhanced denitrification activity, termed denitrification hot spots, frequently account for a high percentage of nitrate removal in a variety of engineered surface and ground water features including ditches, compound channels, detention/retention basins, wetlands, and underground bioreactors. A fundamental question underlining the effectiveness of nitrate removal from the surface and ground waters is: What combination of physical and chemical processes determine the formation, operation, and disappearance of denitrification hot spots of microbial activity with minimal nitrous oxide emission over the Minnesota landscape?

An overall objective of this research is to quantify and model the specific range and combination of physical, chemical, and microbiological conditions that generate denitrification hot spots with minimal nitrous oxide emission in MN waters. Our specific objective are:

1) Explore the applicability of recently developed MoboSens technology, a smartphone based sensor, for spatially distributed nitrate concentration measurements in MN waters;
2) Quantify physical, chemical, and microbiological variables that determine enhanced denitrification rates (hot spots) with minimal nitrous oxide emission; and
3) Inform water managers, engineers, farmers, and the public on the feasibility, design, and management of enhanced nitrate removal with minimum nitrous emission in streams, flood plains, and wetlands.

To meet the proposed objectives, we will utilize a combination of field data collection at the Outdoor StreamLab (OSL) experimental facility, a unique field-scale research facility at St. Anthony Falls Laboratory (SAFL), and field measurements at the Seven Mile Creek (SMC) in Nicollet County, MN.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Spatially Distributed Measurements of Nitrate and Nitrous Oxide **Budget: $116,739**

Nitrate input and nitrate removal in aquatic ecosystems are spatially and temporally distributed over landscapes. A smartphone based nitrate sensor technology, MoboSens, has been developed to quantify nitrate concentrations under field conditions. The sensor can quantify nitrate concentrations in water samples in 1-2 minutes with the lower limit of detection at about 0.05 mg/L. The sensor is connected into smartphone via the audio jack, combined with GPS and mobile broadband. We propose to verify the MoboSens technology under field conditions at fifteen field sites across the state of Minnesota. The field sites will include streams, wetlands, rivers, and drinking water wells. Concurrent water samples will be collected for independent laboratory analysis and compared to the corresponding MoboSens measurements. The activity will provide data on how accurate MoboSens technology is so that it could be reliably used by the public and researchers across the state. Furthermore, a spatially distributed nitrate and nitrous oxide network will be developed and tested at the OSL. The network will sample nitrate and nitrous oxide concentrations at three sites within the OSL, and the data will be transferred through a wireless network and displayed over the Internet. During the testing procedure, the data collected by the network will be compared to the laboratory measurements of nitrate and nitrous oxide concentration in the OSL. The network will provide a technology to simultaneously quantify nitrate and nitrous oxide concentrations at the proposed field sampling locations.

Outcome	Completion Date
1. Nitrate field measurements at fifteen field sites across the state by MoboSens technology	October , 2015
2. Develop spatially distributed network for simultaneous nitrate and nitrous oxide measurements at three locations within the OSL experimental site	June, 2016

Activity 2: Quantify Physical, Chemical, and Microbiological Variables that Determine Denitrification Hot Spots **Budget: $131,379**

We will use a two-tiered approach in quantifying denitrification hot spots. The OSL experimental site will enable field-scale experiments at high-resolution under controlled hydraulic, nitrate, moisture, and organic material concentration distribution. Measurements will consist of soil properties, soil water content, sediment microbiota, microorganism DNA analysis, potential denitrification, nutrient concentration, dissolved oxygen concentration, fluid flow velocities, carbon content, and nitrous oxide concentration. The measurements will be conducted in a meandering stream, flood plain, and vegetated basin. The experiments will identify denitrifier populations, chemical, and physical conditions that generate denitrification hot spots with minimal nitrous oxide emission. The SMC field site is selected to quantify nitrate removal and nitrous oxide emission by denitrification hot spots in open channel, adjacent flood plain, and wetland. The field site will be sampled to identify the specific microorganisms responsible for enhanced nitrate removal and minimal nitrous oxide emission.

Outcome	Completion Date
1. Document enhanced nitrate removal with minimal nitrous oxide emission in OSL and SMC	Oct 2016, 2017
2. Document the spatial and temporal distribution of denitrification hot spots	March, 2018

Activity 3: Educating the MN Water Quality Stake Holders **Budget: $85,645**

Activity 1 and Activity 2 will provide physical, chemical, and microbiological field data that determine denitrification hot spot formation in streams, flood plains, and wetlands. The data will be integrated into simple prediction relationships that can be used to design and manage denitrification hot spots. A one day workshop will be organized for approximately 50 participants at SAFL to train water managers, engineers, and farmers on how to design and manage denitrification hot spots. The workshop will be augmented by hands-on measurements in the OSL. Additional effort will be devoted to educate the public on how to use the MoboSens technology for nitrate measurements in the field. The technology and concept of denitrification hot spots will be demonstrated to the public through demonstrations at the OSL.

Outcome	Completion Date
1. Formulate simple prediction relationships that determine denitrification hot spots in streams, flood plains, and wetlands	May, 2018
2. Train water quality stake holders how to design and manage denitrification hot spots	June, 2018
3. Engage the public to use the MoboSens for spatially distributed nitrate measurements	June , 2018

III. PROJECT STRATEGY

A. Project Team/Partners

University of Minnesota, St. Anthony Falls Laboratory: Prof. Miki Hondzo (Project Manager), Dr. Jessica Kozarek (Research Associate); Department of Soil Water and Climate, Prof. Michael Sadowsky

B. Project Impact and Long-Term Strategy

We propose fundamental microbiological and engineering research under field conditions that will provide mechanistic understanding and prediction of denitrification hot spots in MN waters. The project introduces a new smart phone technology, for spatially distributed nitrate measurements in the field. The long-term strategy is to use the MoboSens technology across the state to minimize nutrient loading in MN waters.

C. Timeline Requirements

Three years of work are planned beginning in July 2015 to June 2018.

2015 Detailed Project Budget

Project Title: Enhanced Microbial Nitrate Removal in Minnesota Waters

IV. TOTAL ENRTF REQUEST BUDGET 3 years

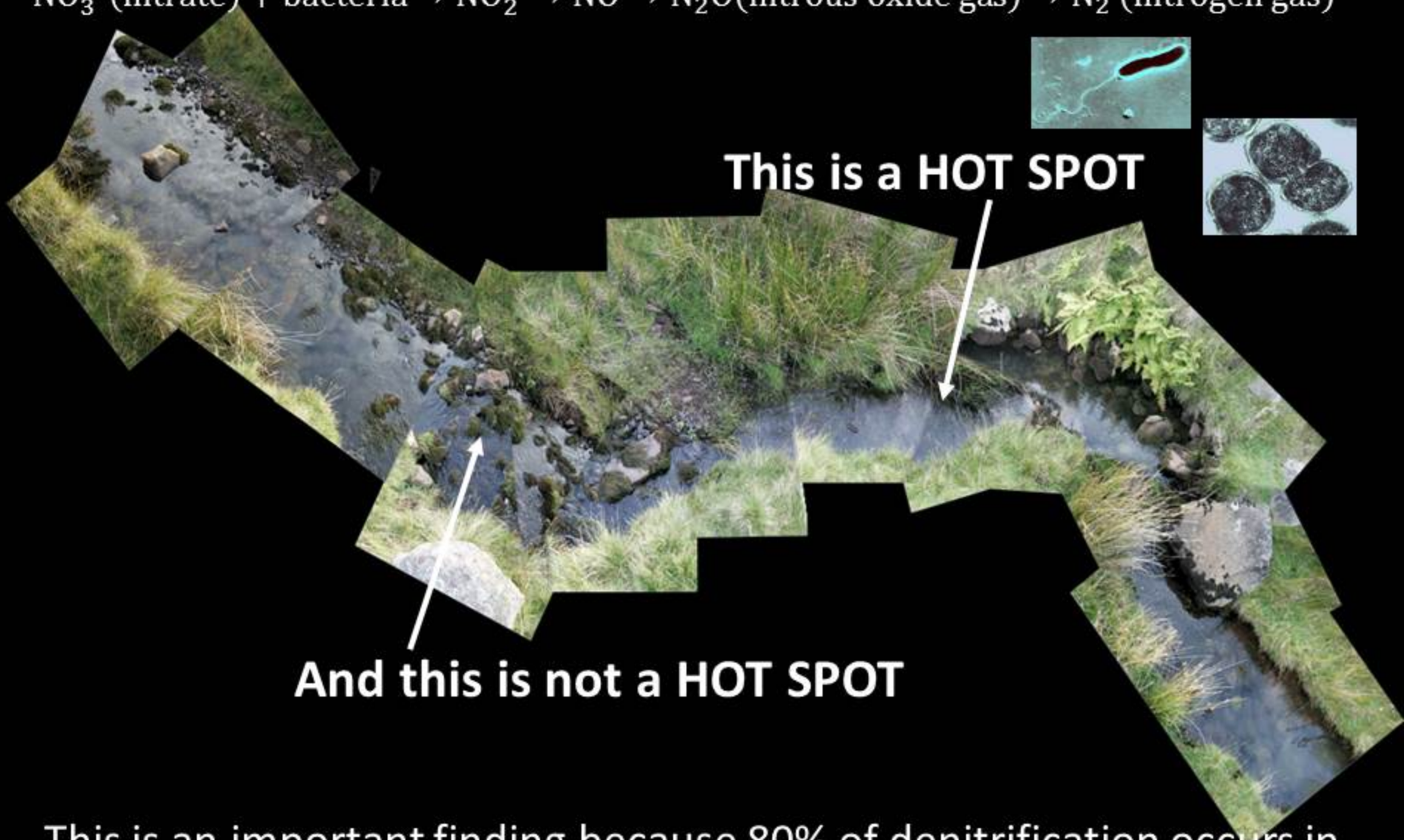
BUDGET ITEM	AMOUNT
Personnel:	
Professor: Miki Hondzo (33.6% benefits, 8% time yrs 1-3)	$57,630
Research Associate: Jessica Kozarek (33.6% benefits, 20% time yrs. 1-3)	$48,718
Instrumentation Specialist: (33.6% benefits, 2% time yrs. 1-3)	$7,587
Technician (36.8% fringe, 2% time yrs. 1-3)	$4,602
Professor: Mike Sadowsky	$0
Undergraduate research assistants (7.4% benefits, 25% time yrs. 1, 58% yr 2)	$19,243
Graduate Student	$125,803
Contracts:	
	$0
Equipment/Tools/Supplies:	
Nitrous oxide sensors (4x$1000=$4,000), nitrate MoboSens sensors ($3,000), spatially distributed nitrate sensing network (nitrate sensors $3,000, 3 data loggers $3,000, wireless data transfer $2,000)	$15,000
OSL supplies	$10,000
Laboratory supplies (chemical, nitrate, etc.)	$10,000
Microbial analysis	$30,000
Travel:	
in-state (15, day trips for 2 reasarchers, yrs 1-3, 140 mi at $0.565, no lodging, $18 per diem)	$5,180
Additional Budget Items:	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$333,763

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
In-kind Services During Project Period:		
n/a		
Funding History:		
MN Clean Water Fund: Analyzing and optimizing denitrification in agricultural surface waters PIs: Jessica Kozarek, Miki Hondzo and Michael Sadowsky	$ 396,935	on-going

HOT SPOT: Enhanced activity of denitrifying bacteria

NO_3^- (nitrate) + bacteria $\rightarrow NO_2^- \rightarrow NO \rightarrow N_2O$(nitrous oxide gas) $\rightarrow N_2$ (nitrogen gas)



This is an important finding because 80% of denitrification occurs in hot spots, which make about 16% of a stream reach

PROJECT MANAGER QUALIFICATIONS

Miki Hondzo, Professor, Associate Director for Research and Development, St. Anthony Falls Laboratory, Department of Civil Engineering, University of Minnesota

Appointments

1999-present **University of Minnesota**, Department of Civil Engineering, Associate, Full Professor.

Awards/Recognitions

2008 **Samuel Arnold Greeley Award**. Environmental Engineering Division, American Society of Civil Engineers. Award for the best research paper "Modeling heavy metal removal by plant species and sediment."

2006 "**Outstanding** *Limnology and Oceanography* **Reviewer**." Recognized by *Limnology and Oceanography* journal for reviewing service.

2000 **Rudolph Hering Meda**l. Environmental Engineering Division, American Society of Civil Engineers. Award for most valuable contribution to the increase of knowledge in the environmental branch of the engineering profession for the paper, "Diffusional mass transfer at the sediment-water interface."

1997-2002 **CAREER AWARD**, **National Science Foundation**
(Division of Chemical and Transport Systems)

1997 **Founders Award** for the best paper "Long-term lake water quality predictors", appearing in the 1996 year of *Water Research*. The USA National Committee of International Association on Water Quality.

Selected Publications (relevant to this LCCMR proposal) :

Guentzel, K.S., **Hondzo**, M., Badgley, B.D., Finlay, J.C., Sadowsky, and M.J., and Kozarek J.L. (2014). Measurement and modeling of denitrification in sand-bed streams of varying land use, *Journal of Environmental Quality* **(**JEQ-2013-06-0249-TR), in press.

Hondzo, M., V.R. Voller, M. Morris, E. Foufoula-Georgiou, J. Finlay, V. Ganti, and M.E. Power (2013). Estimating and scaling stream ecosystem metabolism along channels with heterogeneous substrate, *Ecohydrology*, 4, 679-688.

Singh, A., J.A. Czuba, E. Foufoula-Georgiou, J.D.G Marr, C. Hill, S. Johnson, C. Ellis, J. Mullin, C.H. Orr, P.R. Wilcock, M. **Hondzo**, and C. Paola (2013). StreamLab collaboratory: Experiments, data sets, and research synthesis, *Water Resources Research*, 49(3), 1746-1752.

O'Connor, B.L., M.**Hondzo**, and J.W. Harvey (2010). Predictive modeling of transient storage and nutrient uptake: Implications for stream restoration, *Journal of Hydraulic Engineering*, 136(12), 1018-1032.

O'Connor, B. L., and M. **Hondzo** (2008). Enhancement and inhibition of denitrification by fluid-flow and dissolved oxygen flux to stream sediments, *Environmental Science & Technology*, 42(1), 119-125.

O'Connor, B. L., M. **Hondzo**, D. Dobraca, T. LaPara, J.C. Finlay, and P.L. Brezonik (2006). Quantity-activity relationship of denitrifying bacteria and environmental scaling in streams of a forested watershed, *Journal of Geophysical Research-Biogeosciences*, 111(G4), G04014.

ORGANIZATION DESCRIPTION

The proposed research will be conducted by the St. Anthony Falls Laboratory (SAFL), University of Minnesota. The Outdoor StreamLab (OSL), SAFL' s newest research facility, is located on Hennepin Island adjacent to the SAFL building. Two abandoned spillways, located on the left bank of the Mississippi River in downtown Minneapolis, are being transformed into a new outdoor laboratory for ecogeomorphology and environmental restoration. SAFL houses several smaller labs, including wet chemistry, sediment analysis, and a biological laboratory with plant-growth chambers, incubators and spectrophotometers.