Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 039-B**

Developing Sensors for River-Flow Turbidity and Sediment-Transport

Category: B. Water Resources

Total Project Budget: $ 311,367

Proposed Project Time Period for the Funding Requested: 3.5 years, July 2017 - September 2020

Summary:

The development of a low-cost automated sensor measuring bedload and suspended sediment load in Minnesota rivers is proposed, aiming to extend monitoring and reduce turbidity in the river network.

Name: Michele Guala

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

Address: 2 Third Ave SE

Minneapolis MN 55455

Telephone Number: (612) 625-9108

Email mguala@umn.edu

Web Address http://personal.ce.umn.edu/~guala/

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The attached visual highlights the connection between water clarity and distributed sediment monitoring in Minnesota rivers.

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

DEVELOPING SENSORS FOR RIVER-FLOW TURBIDITY & SEDIMENT TRANSPORT

I. PROJECT STATEMENT

The main goal of the proposed research is to build a low-cost turbidity and sediment transport measuring station that can be deployed in Minnesota rivers. The station is expected to provide estimates of the fine sediment load, suspended in the water column, as well as coarser sediment load, rolling at the bed surface and contributing to the formation and migration of ripples and dunes.

The Minnesota Pollution Control Agency in 2014 launched an effort to reduce the amount of sediments in Minnesota rivers. The strategy proposes interim targets that include a 25 percent reduction by 2020 and a 50 percent reduction by 2030. A 90 percent reduction from the current sediment loading is needed to meet the Minnesota River sediment Total Maximum Daily Load (TMDL) by 2040. The South Metro Mississippi River sediment TMDL requires a 50 percent reduction from current sediment loading.

What is truly needed to implement this mandate is an affordable technology that can be massively deployed to estimate reliably sediment transport at specific cross sections of a river reach. Current methods are intrusive and require a data collection team to deploy the instrumentation (typically sediment traps) and repeat measurements until statistical convergence is reached. Due to the randomness and variability in rainfall, streamflow hydrograph and transport processes, such operations are costly, not efficient, and not representative, resulting in large uncertainties in sediment flux estimates.

It is proposed to i) use continuous sonar measurements to monitor real-time bed elevations and turbidity at a fixed stream location; ii) develop the statistical tools to quantify bedload mass flux from observed characteristics of bedform migration; 3) integrate sensors and real-time analysis in one measuring station.

Ripples and dunes migrate while transporting sand grains downstream. Excluding the very fine sediment fraction suspended in the flow, which will be accounted for through direct turbidity measurements, the remaining sediment flux is transported near the bed surface mostly by migrating bedforms. Hence, by monitoring the size and the velocity of such bedforms we can provide an accurate estimate of sediment transport with no need of sediment trapping. Guala et al JGR (2014) validated this technique in a 3ft wide laboratory-scale channel

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Assessing bedform velocity scaling law for high flow rate and depth conditions* **Budget: $150,000**

To extend results obtained in the laboratory flume to natural rivers, new experiments are required to assess:

1) How bedform migration velocity scales with the flow depth and the flow discharge.

2) Whether the variety of bedform types and sizes observed in a real river can be accounted for in the computation of the mass flux and verified against direct sediment discharge measurements.

The SAFL Main Channel, which is a unique facility instrumented with state-of-the-art laboratory equipment, able to operate at depths and flow discharges per unit width comparable to Minnesota rivers, is chosen as an intermediate laboratory-field testing site.

Outcome	Completion Date
1. Reorganize previous experimental data and compile bedform size and migrating velocities; compare bedform-induced transport with direct sediment flux measurements.	*Dec 2017*
2. Perform experiments at high discharge in the SAFL Main Channel to *measure bed surface topography resolved in space and time simultaneously with sediment mass flux in time.*	*April 2018*
3. Validate, or correct, the Guala (2014) spectral formulation for bedform migration and mass flux computation under variable hydrographs.	*September 2018*

Activity 2*: Building a total mass flux sediment station:* **Budget: $161,000**

The total mass flux includes bedload transport and suspended sediment load. The signal strength of the sonar response will be used to estimate the integrated turbidity in the water column, thus both bedload and suspended sediment estimates will be performed by one sensor (alternatively a high quality, commercially

available fish-finder sonar will be tested). The instrumentation will be developed and deployed in the SAFL main channel; Resulting estimates of bedload and suspended sediment transport will be compared with direct measurements of turbidity and mass flux, obtained with the unique sediment weighting system available in the SAFL main channel. Because such measuring system is embedded in the channel, it cannot be deployed in a real river; hence, the movable, measuring station developed here will present several advantages:

1) A submerged sonar is affordable, at a cost of 300$ a piece, can be integrated with a data logger and a real-time streaming data software to collect bed elevation at adequate frequencies (0.1-1Hz).

2) Bedforms do not have to be classified or recognized by a dedicated person, because the proposed mathematical and statistical method is designed to provide scale-dependent information directly from bed surface elevation measurements (Guala et al. 2014). The sensor is deployed to work without an operating team.

3) Measurements are continuous; prediction and monitoring can be provided within an averaging window of a few hours, 7 days a week, 365 days a year, at no additional costs, aside of maintenance of the instrumentation.

(Reference Guala M., Singh A., BadHeartBull N. and Foufoula Georgiou E. "Spectral description of migrating bedforms and sediment transport", Journal of Geophysical Res. JGR Earth 118(3) 1908-1920, 2014)

Outcome	Completion Date
1. Build a deployable measuring system, solar powered for data collection and transmission including sonar bed elevation measurements and turbidity sensor	*December 2018*
2. Test the measuring station in the SAFL main channel under high flow discharge and different fine sediment distributions , progressively increasing suspended load	*September 2019*
3. Analyze the collected data and finalize the theoretical and statistical framework able to provide total mass flux estimates based on real-time input from the measuring station	*March 2020*
4. Test and deploy the measuring station in a Minnesota river (to be discussed with MPCA)	*September 2020*

III. PROJECT STRATEGY

A. Project Team/Partners

The project team includes: Principal Investigator (PI) Prof. Michele Guala, (SAFL, Civil Environmental and Geo-Eng., UMN) , co-PIs Arvind Singh (University of Central Florida) and Efi Foufoula-Georgiou (UMN), in addition to the PhD student Michael Heisel (UMN). The team already has a few high resolution datasets, acquired under the NSF Career project (PI Guala). An undergraduate student is performing preliminary analysis; however, support is sought for a dedicated PhD student (M. Heisel), who will bring the numerical and instrumentation design up to deployment stage. Prof Guala will supervise the experimental activities, will be the PhD student mentor, and will be responsible for project documentation and reporting. Prof. Singh will contribute with data analysis and SAFL main channel experimentation, while prof. Foufoula-Georgiou will bring expertise on river networks, real-time statistics, and optimal processing algorithms.

B. Project Impact and Long-Term Strategy

In order to lower sediment loading in Minnesota rivers and implement the MPCA mandate, it is of utmost importance to develop cheap sensors that can be 1) deployed in several nodes of the Minnesota river network and 2) integrated into a state-wide monitoring system. The project goal is to build, validate and deploy such a sensor; the long term goal is to instrument our rivers and obtain a fast response to any variation in water quality and sediment loads such to detect and map sink and sources in time. This will allow focusing the limited, available resources to specific areas of river-bank erosion or failure that mostly contribute to water turbidity in Minnesota rivers.

C. Timeline Requirements

The project will start in July 2017 and will end in September 2020. The project team will build, validate and deploy a new, affordable sediment transport measuring system able to estimate bedload and suspended mass flux in natural rivers (year 1-2) . The PI will work with the Minnesota Pollution Control Agency to review available sediment transport monitoring systems and to choose a river cross section in Minnesota where our device will be tested and compared real-time with current measurements (year 3).

2017 Detailed Project Budget

Project Title: DEVELOPING SENSORS FOR RIVER-FLOW TURBIDITY & SEDIMENT TRANSPORT

INSTRUCTIONS AND TEMPLATE (1 PAGE LIMIT)

Attach budget, in MS-EXCEL format, to your "2016 LCCMR Proposal Submission Form".

(1-page limit, single-sided, 10 pt. font minimum. Retain bold text and DELETE all instructions typed in italics. ADD OR DELETE ROWS AS NECESSARY. If budget item row is not applicable put "N/A" or delete it. All of "Other Funds" section must be filled out.)

IV. TOTAL ENRTF REQUEST BUDGET: $311,367.00 for 3 years

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel: *In this column, list who is getting paid to do what and what is the % of full-time employment for each position. List out by position or position type - one row per position/position type. For each, provide details in this column on the inputs: i.e., % dollars toward salary, % dollars toward benefits, time period for position/position type, and number of people in the position/position type.*	
Michele Guala, PI (75% salary, 25% benefits); 11% FTE for years 1 to 3.: Guala brings critically important expertise in the fluid dynamics, and sediment transport. His laboratory work will be focused on spatio-temporal measurements of bedform migration and evolution and integration of the deployed intrumentation. A graduate student will be advised by Guala M in collaboration with A Singh.	$ 41,622
Staff Engineer (78% salary, 22% fringe): 6 weeks per year of a staff engeener to build the measuring sta (year 1) and the support for field deployment (year 2 and 3).	$ 38,639
Graduate student (59% salary, 41% fringe): Michael Heisel, receipient of the Summerfeld felloship in Civi Engineering (UMN) will be funded during the three of the project, bringing him to PhD completion. He will be responsible for collecting field and laboratory data, postprocessing them and developing the analysis and	$ 137,306
Professional/Technical/Service Contracts: *In this column, list out proposed contracts. Be clear about whom the contract is to be made with and what services will be provided. If a specific contractor is not yet determined, specify the type of contractor sought. List out by contract types/categories - one row per type/category. If an RFP will be issued, state that.*	$ -
Equipment/Tools/Supplies: *In this column, list out general descriptions of item(s) or item type(s) and their purpose - one row per item/item type.*	$ -
Supplies: General supplies for laboratory and field setups are quantified based on previous experience. Year 1 & 2 ($12,000), Year 3 ($10,000). The amounts will also include 1) acquisition board and computer for the laboratory experiments , 2) solar panels, data logger, wifi antenna and transmission cables for the deployed instrumentation 3) parts and labor for field deployment.	$ 34,000
Supplies: sand of different grain size covering the Mian channel section 85m x 3m x 0.3m. Expected amount is 20 tonns, at a cost of 15,000$ including removal from the channel. Progresssive addition of fine sediment fraction that will need to be supplied continuously during turbidity measurements (10,000$)	$ 25,000
Equipment : A laboratory Acoustic Dopppler Velocimeter (Nortek) will be used for the proposed analysis of velocity and turbidity, via backscatter strength calibration of the sonar measurements.	$ 25,000
Acquisition (Fee Title or Permanent Easements): *In this column, indicate proposed number of acres and and name of organization or entity who will hold title.*	$ -
Travel: *Be specific. Generally, only in-state travel essential to completing project activities can be included.*	
During year 2 and 3 the graduate student will present research data and progress at the AGU, APS or ASCE conference. Based on previous experience we are requesting 1500$ per conference (1) per person(1), year (2). For a total of 3000$. This is the minimum for the educational enrichment of the student	$ 3,000
professor Arvind Singh will travel to UMN and participate during key phases of the experimentation. The travel cost are 400$ per travel, twice a year from UCF (Orlando, Florida). Five days accomodation are included for a total of 80$ per day. Note that he will not have a paid salary but only this reimbursement of expenses.	$ 4,800
Additional Budget Items: *In this column, list any additional budget items that do not fit above categories. List by item(s) or item type(s) and explain how number was determined One row per type/category.*	$ -
Publications fees for journals. Expected 4 publications, on which 2 may require fees at 1000$ each.	$ 2,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 311,367**

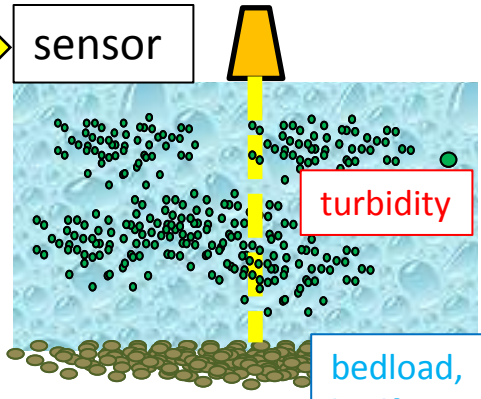
V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *NSF career project funding will be used for some of the supplies and equipment that will be shared in those project. In additio, the PhD student supported by the NSF grant will be involved in the current research activities for at least 2 years.*	$410,000	*secured*
Other State $ To Be Applied To Project During Project Period: *proposal to IONE research funding is focused on SAFL Main channel experiments. If granted it will provide additional resources for sand and equipment maintenance (about 30,000$) could be saved.*	$500,000	*pending*
In-kind Services To Be Applied To Project During Project Period: *Indicate any additional in-kind service(s) secured or applied for to be spent on the project during the funding period. For each type of service, list type of service(s), estimated value, and indicate whether it is secured or pending. In-kind services listed must be specific to the project.*	$ -	*Indicate: Secured or Pending*
Funding History: *Indicate funding secured but to be expended prior to July 1, 2016, for activities directly relevant to this specific funding request, including past and current ENRTF funds. State specific source(s) of fund and dollar amount.*	$ -	
Remaining $ From Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	$ -	*Indicate: Unspent? Legally Obligated*

GOAL: Reduce sediment loadings in Minnesota rivers

monitor

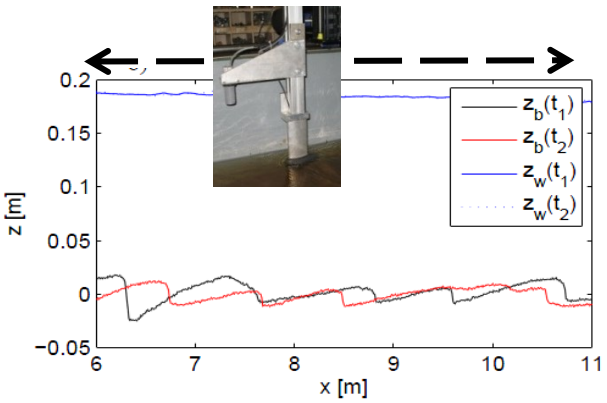
sensor

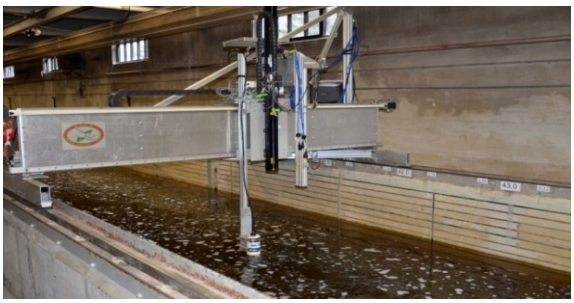


Measure sediment transport

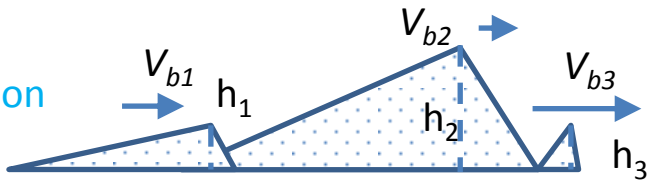
Bedload → bedform + **suspended load → turbidity direct measurements**

1) Laboratory measurements (SAFL)





2) Conceptual model of bedform migration



3) Field scale validation

PROJECT MANAGER QUALIFICATIONS

Michele Guala, assistant professor St. Anthony Falls Laboratory (SAFL), Department of Civil Environmental and Geo- Engineering CEGE, University of Minnesota, Minneapolis, 55414, MN, USA

Education

Ph.D. Hydraulic Engineering, 2003, University of Padova, Italy
Laurea (BS+MS) Civil and Environmental Engineering, 1998, University of Genova, Italy

Professional experience

UMN , SAFL & Department of Civil, Environmental, and Geo- Engineering, assistant professor 2011-present
Caltech Postdoctoral GALCIT, Caltech, Pasadena , 2008-2010
SLF, Davos Research scientist
ETH Zurich, CH Postdoctoral fellow at the Institute of Hydromechanics 2003-2006

Awards/Recognitions

Recipient of the **NSF CAREER award** "Geophysical Flow Control" (2014-2019)
Recipient of the **IREE Early Career Award** (UMN) "*Evaluating wind farm performance under realistic thermal and complex terrain conditions: the first path towards optimization*

Publications

(Relevant to this LCCMR proposal; out of a total of 57 publications → 1004 citations)

1) Guala M., Singh A., BadHeartBull N., Foufoula–Georgiou E.. Spectral description of migrating bed forms and sediment transport. **Journal of Geophysical Research: Earth Surface** 119 (2), 123-137 (**2014**)
2) Fan N, Zhong D., Wu B. ,Foufoula-Georgiou E. and M Guala, "A mechanistic-stochastic formulation of bed load particle motions: from individual particle forces to the Fokker-Planck equation under low transport rates", **Journal of Geophysical Res. JGR Earth,** 119(2), 123-137, (**2014**)
3) Hill C, Kozarek J. Sotiropoulos F., Guala M. "Hydrodynamics and sediment transport in a meandering channel with a model axial flow hydrokinetic turbine" **Water Resources Research** (**2016**)
4) Hill C. , M Musa , LP Chamorro, C Ellis, M Guala , "Local Scour around a Model Hydrokinetic Turbine in an Erodible Channel**" Journal of Hydraulic Engineering**, 140(8) 04014036, (**2014**).
5) Mariotti[†]G., Falcini F., Geleynse N., Guala M., Sun T., Fagherazzi S. "Sediment eddy diffusivity in meandering turbulent jets: Implications for levee formation at river mouths", **Journal of Geophysical Res. JGR Earth** 118(3): Pages: 1908-1920, (**2013**)
6) Singh A. , Guala M, Lanzoni S and Foufoula E.``Bedform effect on the reorganization of surface and subsurface grain size distribution in gravel bedded channels'' **Acta Geophys**. 60(6), 1607-1627 (**2012**)

ORGANIZATION DESCRIPTION: St. Anthony Falls Laboratory, University of Minnesota

The proposed research will be performed at the St. Anthony Falls Laboratory, University of Minnesota. SAFL faculty, staff and researchers have an excellent scientific reputation and experience in conducting and analyzing laboratory and field measurements of bedload and suspended sediment transport. Automated data collection, sampling protocols, wireless data transfer and display over the Internet have been developed for several state and federal funding agencies at the laboratory in the last decade. The SAFL Main Channel has been equipped with a laser scan device by Dr. Guala, allowing researchers to study the evolution of sediment bed at quasi-field scale under controlled depth and discharge conditions. Such device was designed and built here and is not available anywhere else.

TEAM DESCRIPTION/PARTNERS

Arvind Singh (assistant professor Civil Eng. UCF, and SAFL graduate) is an expert in sediment transport and experimental techniques. His PhD thesis at UMN was based on experiments performed in the SAFL main channel, which will be used in the proposed activities. Dr Singh and Guala are co-authors in 6 publications.
Efi Foufoula Georgiou (professor Civil Eng. UMN, and SAFL) is an expert in eco-hydrology, river and landscape evolution, statistical techniques and applied mathematics, among many other topics.