Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-281

Proposal Title: Protecting Stream Banks Producing Energy

Project Manager Information

Name: Michele Guala

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: The proposed research project focuses on advancing a hybrid renewable energy - bank protection system to operate in rivers of small-medium size extracting energy and preventing erosion.

Funds Requested: $198,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable Energy (E)

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?

In the Future

Narrative

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

Streambank stabilization, or protecting streambanks from erosion, is critical in many areas to protect property, infrastructure, and reduce sediment pollution to streams. Streambank stabilization measures can range from placing riprap (large rocks) to planting vegetation to full channel reconstruction and watershed approaches to reduce extreme flows. In the context of local bank protection, many practices aim to divert high velocity flows away from eroding banks, such as weirs and vanes made of rock, concrete, or logs, and slowing flow by changing channel configuration or enhancing streambank roughness with rock or vegetation. These projects present an opportunity to design environmentally-friendly local energy production within the bank protection measures, allowing energy extraction while slowing flow adjacent to eroding streambanks. These systems can be used to provide illumination for nearby roads, bike or walking paths or to provide power to remote properties working in synergy with solar panels to ensure off-the-grid energy supply.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

This research project aims to scale-up a design of environmentally-friendly hydropower generator installed within bank protection systems. This technology is based on a set of vertical axis turbines (wheels) partially embedded in the stream bank, placed where the stream flow is more energetic, i.e. on the outside of meandering channels. While the flow sustains the wheel rotation and continuously produces electric energy, the stream velocity near the bank is reduced, thus mitigating streambank erosion. The wheel system has been already tested in the laboratory and simulated numerically; its patent is secured thanks to a $150,000 seed grant we received in 2017 from the Institute on the Environment (UMN). New support is requested here to advance the technology readiness level to prototype scale. The design of this system has been devoted to producing energy while minimizing 1) the impact to fish and other aquatic organisms, 2) sediment pollution, 3) risk and impact to water-body users (canoers and swimmers), and 4) maintenance. This project has two main activities: 1) testing in an outdoor, 1ft deep laboratory controlled, meandering stream, exposing the device to snow and ice; and 2) testing in a larger flume to evaluate prototype-scale performance and stream-bank protection.

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?

Through this project, we will leverage our tested laboratory design to build and operate a working prototype able to achieve renewable energy production with minimal environmental impacts and the benefit of protecting streambanks from erosion. Thanks to the low wheel velocity, kept as a fraction of the stream flow, the device is safe for fish, beavers or other aquatic organisms, canoers or swimmers. We target local, renewable energy production with added environmental benefits that could be a showcase of sustainable innovation for environmental centers, remote energy source for environmental sensors, and/or low-cost power for lighting on trails and pathways.

Activities and Milestones

Activity 1: Measuring reduced erosion rates in laboratory experiments using the SAFL outdoor meandering flume

Activity Budget: $112,000

Activity Description:
The proposed wheel system will be installed in the Outdoor StreamLab (OSL), a field-scale experimental meandering channel adjacent to St Anthony Falls Laboratory (SAFL;see visual). The meandering planform of the OSL allows for testing wheel performance in complex flows present in natural streams. The performance of the prototype will be tested both in terms of energy production, and streambank protection will be tested during the summer months by a PhD student and undergraduate students, under a wide range of flow conditions. In the winter months we will work on the anchoring system, and on the design of prototype components. The OSL has flow year-round, and thus the prototype will also be evaluated in winter to ensure that the device can operate efficiently below the ice cover and is resilient freezing/thawing conditions.

Activity Milestones:

Description	Completion Date
Improved blade design and test performance in meandering streams	2022-04-30
Quantify power production at different flow rates	2022-09-30
Quantify erosion rates in a meandering stream with and without the device in place	2022-09-30

Activity 2: Fabricating and testing an intermediate scale prototype able to operate in 0.5-1.5 m depth rivers

Activity Budget: $86,000

Activity Description:
In the second year, the blade and rotor geometry tested during Activity 1 will be scaled-up and integrated with off-the-shelves mechanical components for prototype fabrication. Keeping the gearbox and the generator enclosed with the river bank ensures that major electrical components will be out of the water and accessible, reducing deployment costs, maintenance costs, and failure risks, while providing easy connection to nearby utilities. The turbine rotor will be built using an air-tight aluminum shell ensuring neutral buoyancy, thus minimizing bearing friction, as well and fatigue loads. It is envisioned to operate at river mid-depth, ensuring the capability to work below floating ice, debris, logs or canoes, and above migrating dunes and ripples. The device will be built in-house and tested in the SAFL Main Channel. The Main Channel is 278ft long, 9ft wide, and able to operate with a mean flow velocity ~3ft/s, and is representative of a small-medium scale straight river in Minnesota. Erosion and water velocity in the vicinity of the wheel will be monitored to optimize longitudinal spacing for multi-unit installations. Depending on the results, on progress in anchoring design, and appropriate permitting we hope to test the device a real stream.

Activity Milestones:

Description	Completion Date
Build a functioning prototype able to generate electricity	2023-02-28
Perform preliminary experiments to optimize layout for power production and erosion prevention	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jessica Kozarek	St. Anthony Falls Laboratroy	Research scientist. Dr. Kozarek will co-supervise the graduate student during the experiments in the Outdoor Stream Lab (OSL) . She will manage the undergraduate students and setup the instrumentation for bathymetry and velocity measurements. Part of the requested funding will cover her salary to direct experiments in the OSL.	No

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 be funded?

We secured a patent for this system in 2019, we performed laboratory-scale experiments in 2019-2020, and numerical simulations to improve blade design. With the requested funding we will increase the technology readiness level to have a tested functional prototype. This is a necessary step before field testing and commercialization. Because of the hybrid design of this technology we anticipate deployments in natural parks, river front properties or small communities or near trails and outdoor recreation facilities. The simple, modular and robust design is is a novel, low-impact option for any communities aiming at environmental and energy sustainability

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Assessing the Increasing Harmful Algal Blooms in Minnesota Lakes	M.L. 2016, Chp. 186, Sec. 2, Subd. 04b	$270,000

Project Manager and Organization Qualifications

Project Manager Name: Michele Guala

Job Title: Associate Professor and Associate Director of St Anthony Falls Laboratory, UMN

Provide description of the project manager's qualifications to manage the proposed project.

In the last 9 years at UMN I graduated 5 PhD students, I was promoted to tenured associate professor and I received funding from the National Science Foundation, US Department of Energy, Excel Energy and, as co-PI, from MnDOT and LCCMR. My current position, as Associate Director for Research at the St Anthony Falls Laboratory, gave me the opportunity to witness operations and management at a larger scale, and to contribute to define long term strategies for the laboratory finance and for its recognition at the federal level.

The proposed activities are aligned with my thrust area of research, since I am the holder of the device patent, I am familiar with wind and in-stream turbine renewable energy systems, river hydraulics and sediment transport with more than 70 published works and 2000 citations.

My collaborator, Dr. Jessica Kozarek, is the Outdoor StreamLab (OSL) research manager and research associate at SAFL. She is an expert in stream restoration, flow-sediment-biota interactions, and large-scale experimental designs. She will help direct the experiments in the OSL. Dr Kozarek received funding for "Conserving Minnesota's Native Freshwater Mussels"(2014) and within the MAIRSRC ENTRF Appropriation (2013, 2017).

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:

The St. Anthony Falls Laboratory is an interdisciplinary center of the University of Minnesota and one of the most recognized research laboratories in the US in the field of environmental fluid mechanics and , fluvial and delta morphodynamics, and earth sciences. In the last decade we expanded our interests and research breadth to include living organism, as algae, mussels and fish, as well as renewable energy systems to extract kinetic energy from moving fluids. Research work has been performed on in-stream river turbines, hydro power components, and wind energy at the EOLOS Wind Research Field.

SAFL is well instrumented for the study of turbulence in rivers and streams and for the study of interactions between fluid mechanics and biota with expertise and equipment for measuring flow and turbulence at a range of scales including acoustic Doppler velocimeters (ADVs). The experimental portion of this project is centered at SAFL because of the data collection systems that allow for the careful positioning of instrumentation (http://www.safl.umn.edu/services/measurements) with sub-millimiter accuracy. SAFL also has a sediment laboratory available for grain size analysis of substrate.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Michele Guala		Project manager and student supervisor			27%	0.08		$15,541
Jessica Kozarek		Supervise experiments in the outer stream lab			27%	0.12		$13,378
graduate student(including tuition)		conduct experiments, process the data and contribute to the final design			43%	1		$104,224
Chris Feist		SAFL engineer supervising the construction of the experimental setup and prototype			27%	0.16		$13,970
Erik Steen machinist		Build the prototype and anchoring system			24%	0.24		$12,978
undergraduate students		help performing experiments in the Outer Stream Lab.			0%	0.5		$12,688
							Sub Total	**$172,779**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	new rotor for the existing turbine model, anchoring system and turbine housing	missing components to perform experiments in the outer stream meandering flume					$5,000
	Equipment	A variable induction motor and power generator for the intermediate scale prototype	These are essential components to allow the prototype to produce electricity, instead of measuring torque.					$5,000
	Tools and Supplies	implementation of an erodible bank (4600$) and bank reconstruction and replanting (4000$) and a portion of yearly maintenance operations (5000).	Building the housing system in the meandering flume stream bank					$14,021
	Equipment	dedicated laptop for graduate student	the laptop is important for data acquisition in the meandering flume, where no PC can be setup					$1,200
							Sub Total	**$25,221**

Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$198,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	$85,059
			Non State Sub Total	**$85,059**
			Funds Total	**$85,059**

Attachments

Required Attachments

Visual Component

File: 2689dbb9-d9f.pdf

Alternate Text for Visual Component

The documents include pictures from experiments and numerical simulations testing the turbine design.
It also provide a view of the Outer Stream Laboratory flume, where new experiments are proposed, and a sketch of potential multi-turbine installation in meandering flumes.

Optional Attachments

Support Letter or Other

Title	File
UMN sponsor project office endorsement	ff9f9ef8-2a3.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

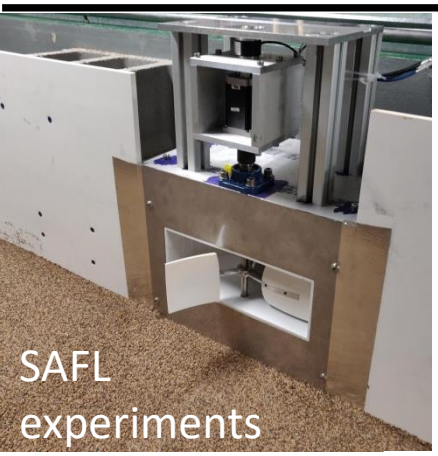
Does the organization have a fiscal agent for this project?

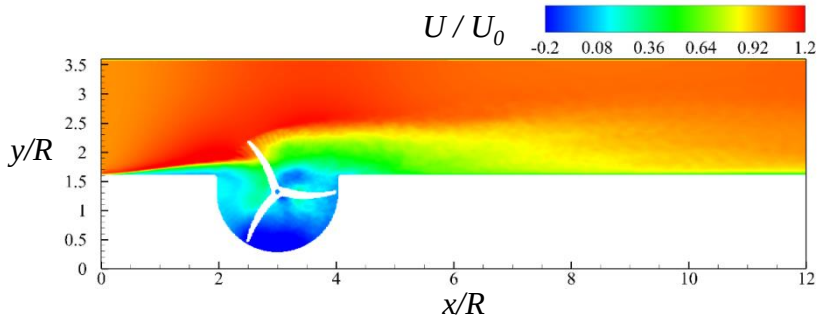
Yes, Sponsored Projects Administration

PROTECTING STREAM BANKS PRODUCING ENERGY

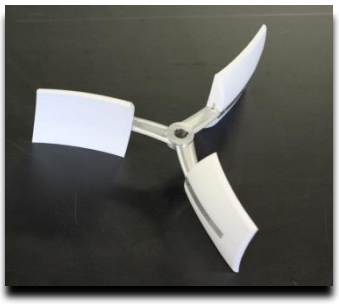
GOAL 1: ENERGY PRODUCTION
provide access to local electricity

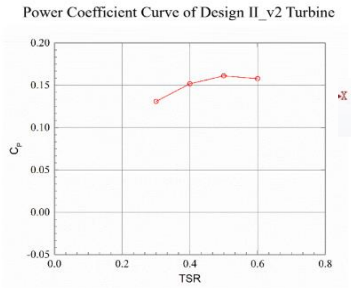
GOAL 2: STREAM BANK RESORATION
mitigate side bank erosion,
limit sediment entrainment
ensure water clarity

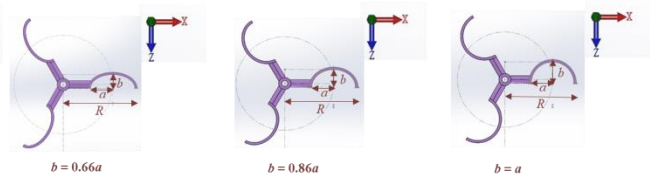

SAFL experiments



On-going computational work







Potential deployment location of single- or multi- unit ★ systems


Outer Stream Lab flume at SAFL