**PROJECT TITLE:****NEW SOLUTION FOR STREAMBANK EROSION AND ENERGY CONVERSION IN RIVERS**

**I. PROJECT STATEMENT**

Erosion protection systems can reach up to 1200$ per linear foot of streambank in urbanized areas, down to 125$ in rural areas with a total estimated annual cost of 0.6M per river mile in large scale restorations. This is expected to increase significantly in the next decade with the increasing frequency of flood and erosion damages. The main problem with standard and affordable concrete bank protection systems is that erosion is not eliminated but just transferred downstream of the protected areas. Nature-inspired protection systems with rocks, logs and vegetation are designed to dissipate some of the flow energy while sheltering the banks, but are more costly and require continuous maintenance. What we propose is a new solution to absorb 20-30% of the energy at the river streambank and convert a portion of it into electricity, reducing the flow velocity. Thus, not just shifting the problem downstream, but reducing the overall ability of the river to erode.

The proposed technology is based on an array of horizontal baffled wheels partially embedded in the bank, placed where the stream flow is more energetic, i.e. at the outer bank of meandering channels. While the flow sustains the wheel rotation and continuously produces electric energy, the stream velocity near the bank is reduced, along with the sidewall erosional rate. We have a preliminary design and a working scaled model (**see visual**). Further support is however needed for advanced experimentation and prototype construction, in order to have a market-ready product. The main tasks are: **1) Quantifying the efficiency of erosion-protection** by testing reduced-scale models in controlled meandering streams at the St. Anthony Falls Laboratory; **2) Prototype construction, deployment and performance assessment**, using a full-scale channel and a river chosen in collaboration with the MN Department of Natural Resources and the Minnesota Watershed Districts.

**II. PROJECT ACTIVITIES AND OUTCOMES**

**Brief technical overview and a rationale for safe operation**: *to reduce erosion the stream velocity has to diminish, implying that flow resistance elements have to be introduced in the river. We can choose between fixed rough elements (standard bank protection design), or smart rough elements that can vary the resistance based on the desired flow conditions. Our horizontal “Minnerota” wheel can achieve that by operating at different velocities and offering variable (smart) resistance, including a free-spinning mode in which it would be essentially invisible to the flow. For instance, under high flood we may decide to offer minimal resistance and avoid any water level increase. Each wheel is envisioned to operate at river mid-depth, ensuring the capability to work without interfering with ice and debris (e.g. wood branches, logs) floaters or canoes, as well as high sediment transport and migrating bedforms. Thanks to the low operating velocity (never larger than the current) the horizontal wheel will not be harmful to fish, beavers or swimmers. The partial exposure of the**device to the flow**guarantees decent energy conversion performance while keeping the gearbox, generator and all major electrical components away from the water, reducing deployment and maintenance costs, failure risks, and providing easy access to utility connection. The**torque is generated by momentum transfer (as e.g. a Pelton hydropower turbine), which reduces biofouling effects due to leaves and algae build-up, ensuring all-season performance. Based on the available power coefficient estimates for laboratory models, the expected net power output of each device scaled up to a 5ft diameter is in the 0.1-0.2KW range (enough for one LED-based street light). More power extraction and stream bank protection can be achieved by vertically staggering devices along the river meander, so that 5-6 devices should power a river cabin or illuminate a bike trail.*

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| **Activity 1:** *Measuring reduced erosion rates in a controlled meandering stream*  | **Budget: $86,481** |

Because of the specific purpose of preventing bank erosion, experiments will be conducted in the Outdoor Stream meandering flume at the St Anthony Falls Laboratory. Experiments will be performed during the summer months by a dedicated PhD student and two research undergraduates, under a range of discharge conditions. Experiments will be focused on the assessment of the energy performance and erosion protection during summer and winter months, to make sure that the device can operate as planned throughout the year. A critical factor to quantify is the velocity reduction near the streambank suggesting the optimal separation between devices.

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| **Outcome: *Meandering flume advanced* testing** | **Completion Date** |
| *1. Design a structural system for model deployment in the outdoor stream laboratory* | *March. 2021* |
| *2. Assess the device performance with and without moving sediments* | *Sept. 2021* |
| *3. Quantify downstream erosion potential under varying operating regimes* | *March 2022* |

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| **Activity 2:** *Simulating, fabricating and field-testing a full scale prototype*  | **Budget: $191,863** |

The blade and rotor geometry will be scaled-up and integrated with available mechanical components for prototype fabrication. The device will be built in-house and tested in the SAFL Main Channel under both clear water and active sediment transport conditions. The channel is 278ft long, 9ft wide, and able to operate with a mean flow velocity 3ft/s, at depth up to 4ft, thus representative of a small-medium scale river in Minnesota. Flow rate, sediment discharge, and stream depth will be controlled during experimental tests designed to quantify both side-bank sheltering and power extraction capabilities. The channel bathymetry and flow field will be monitored to ensure that no localized erosion will be developing. In a second phase, i) the anchoring system for river deployment will be designed, ii) a stream near Minneapolis will be selected and monitored; iii) the prototype will be deployed and

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| **Outcome: Prototype construction and field testing** | **Completion Date** |
| *1. Build and test a prototype able to operate in a 0.5-1.5m depth channel*  | *July 2022* |
| *2. Select a field site, obtain necessary permits, and collect velocity measurements near the stream bank: pre-deployment feasibility study, baseline measurements for comparison* | *September2022* |
| *3. Deploy the prototype in a Minnesota river, assess performance and wake velocity*  | *June 2023* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

The principal investigator (PI), prof. Michele Guala (Civil Environmental and Geo- Eng., UMN), is the patent holder, and the responsible for the product development, laboratory experimentation and field testing; co-PI Jeff Marr (Associate Director for Engineering) and Lian Shen (SAFL Director) will contribute to the prototype design, fabrication and field testing. The team has expertise in stream restoration, river engineering, and sediment transport (Guala, Marr), mechanical engineering and structural design (Marr, Shen), energy conversion (Guala, Shen).

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:** The overarching goal is to provide a novel stream-restoration technology to river managers, home owners and/or tourist infrastructure near water bodies in pristine ecosystems, integrating river bank protection with local renewable energy production at the lowest environmental costs (invisible, inaudible). **The intellectual property is currently protected under US Patent App. 15/914,183 (pending) filed through the UMN Office of Technology and Commercialization (OTC).** In 2017 we received seed funding for the development of a reduced scale model and for preliminary experimental testing that we are currently conducting (see visual). **Recently we joined a pilot project of the OTC to assess our technology readiness level and define the value proposition of our product:** with the multitude of streams and water front properties in Minnesota, this technology could resonate with a large segment of riverfront private residents or with environmental monitoring programs. In addition of **reducing stream erosion** the benefit of local electricity production will be directed to **illumination, security and motions sensors, wildlife monitoring and water quality stations**, and so on. Because of the design dual-purpose, we anticipate deployments in natural parks, independent riverfront properties, or at the riverside of state, county or cycling roads. Future steps will include creating a startup company and seek support from the Department of Energy through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR).