# Environment and Natural Resources Trust Fund

2027 Request for Proposal

## General Information

**Proposal ID:** 2027-446

**Proposal Title:** Hardware-in-the-Loop Coastal Wave Energy Conversion: Minnesota's Blue Energy

## Project Manager Information

**Name:** Craig Hill

**Organization:** U of MN - Duluth

**Office Telephone:** (218) 726-7412

**Email:** cshill@d.umn.edu

## Project Basic Information

**Project Summary:** Using wave buoys, Great Lakes wave models, physics-based wave energy converter (WEC) simulations, and a hardware-in-the-loop dynamometer, we assess real WEC power potential, guiding coastal Lake Superior blue energy production.

**ENRTF Funds Requested:** $384,000

**Proposed Project Completion:** June 30, 2030

**LCCMR Funding Category:** Energy (E)

## Project Location

**What is the best scale for describing where your work will take place?**

Region(s): NE

**What is the best scale to describe the area impacted by your work?**

Region(s): NE

**When will the work impact occur?**

During the Project and In the Future

## Narrative

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

Coastal structure integrated and nearshore wave energy converters (CSI-WECs) are among the most successful global WEC demonstrations. Minnesota's Lake Superior coastline provides ocean-like sea states and opportunities for addressing challenges faced by global WEC developers while identifying pathways towards diverse energy access with end-use across multiple Minnesota sectors and communities. Recent reporting on CSI-WECs (NLR 2026) identifies opportunities to continue research and development for global implementation, with added benefits beyond energy production. Additionally, marine energy technologies used for observation systems and coastal energy are identified by the Marine Technology Society and Ocean Enterprise Initiative as potentially disruptive innovations with market changing impact. Aligning with growing interest to use Lake Superior as a marine technology development and test bed (MPR News 2026), CSI-WECs provide opportunities to power observation systems, integrate into coastal infrastructure, and adapt to other translational technologies. Levering ongoing work modeling Lake Superior wave conditions while building upon recently completed wave energy assessments (Pheifer and Hill 2024), we approach realizing Lake Superior as a test bed for challenging engineering pursuits, linking observations, physical laboratory hardware, and numerical simulations. Enabling these capabilities while advancing towards real field deployments targets building workforce capacity and enhancing Minnesota's natural resource use for energy.

**What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.**

We propose coupling real-time hardware-in-the-loop (HIL) emulations of Lake Superior wave conditions with coastal WEC power simulations to understand technical WEC power feasibility along Minnesota's Lake Superior coastline. This approach uses field observations (Spotter Buoy), long-term statistical analysis from wave models (WaveWatch III), a physics-based WEC simulation tool (WEC-Sim), and emulated physical conditions using a HIL dynamometer to understand real power potential for two WEC types; an oscillating plate and heaving buoy. The generator dynamometer will test a realistic 600-watt generator typical to existing WEC power take-off systems, driven by real-time HIL feedback control servo motors. This approach enables emulating realistic sea states on physical WEC power components. Statistical analysis of high resolution wave modeling will utilize coastal Lake Superior wave observations to validate and assess wave energy potential. Statistics and time-varying wave fields allow reconstructing realistic wave-by-wave timeseries, serving as input into HIL dynamometer tests and WEC-Sim modeling of WEC technologies. These realistic wave profiles mimic hydrodynamic force inputs to real mechanical components and generators. Through this multi-faceted approach, we reduce the risk of early-phase on-water technological failures by emulating conditions in the laboratory to inform designs, control systems, power potential, and dynamic loads for emerging WEC technologies.

**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?**

This project advances Minnesota's public purpose seeking to enhance natural resources by exploring real potential for coastal WEC production through a coupled field-numerical-physical HIL testing approach. Specific outcomes include detailed high-resolution wave energy assessments in Lake Superior's Minnesota waters, assessing theoretical vs. real technical power potential of WEC technologies, and understanding how Minnesota's coastal communities and maritime industry could benefit from and support new WEC technologies that have both regional and global impact. We also integrate activities into education, provide experiential learning, and build workforce while evaluating capacity and economic impact of WEC technologies for coastal Minnesota blue energy production.

## Activities and Milestones

### Activity 1: Develop real-time hardware-in-the-loop wave energy converter (WEC) emulator and virtual WEC simulation environment

**Activity Budget:** $138,826

**Activity Description:**
Using an existing benchtop generator dynamometer, the system will be upgraded with a 600-watt generator and driving servo motor. Existing sensors will be integrated into Beckhoff data acquisition modules to measure shaft torque, angular position, among other parameters. A real-time control system driven by a Speedgoat machine provides feedback control capabilities for the hardware-in-the-loop (HIL) setup, allowing emulation of field characteristics onto physical generator components typical to wave energy converter (WEC) power take-off systems. The real-time feedback control system, developed in Simulink, will be tested with various input signals, including constant rotation, sinusoidal oscillatory rotation, and variable frequency mixed spectrum oscillations more representative of random sea states. This HIL system uses physical components to simulate the physical environment to allow for assessing true generator efficiencies when exposed to semi-realistic field conditions. The physical dynamometer and data acquisition system will be integrated into a WEC-Sim virtual environment of the WEC model, allowing for real-time modeling and feedback control. Primary goals for this activity include fully assembling the physical dynamometer, building the WEC-Sim virtual model for two coastal WEC technologies (oscillating surge converter and heaving point absorber), and testing the HIL system signal flow and work procedure.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Purchase and integrate upgraded servo motor and drive components with generator | May 31, 2028 |
| Establish Simulink real-time control program enabling both theoretical and measured wave spectrum as input | August 31, 2028 |
| Develop WEC-Sim virtual model of an oscillating surge converter and heaving point absorber WEC | December 31, 2028 |

### Activity 2: Real-time wave monitoring - Coastal Lake Superior

**Activity Budget:** $20,838

**Activity Description:**
Validating nearshore wave energy assessments is critical, and this activity provides real-time buoy observations of coastal Lake Superior waves (height, period, direction) near Silver Bay Marina to assess actual energy availability, validate numerical modeling, and enable realistic wave surface profile inputs for HIL testing in later phases of the project. The deployment location is representative of coastal structures along Minnesota's Lake Superior coastline, and an area currently lacking marine observation systems. This activity leverages existing equipment in Dr. Hill's laboratory and his experience deploying monitoring systems on Lake Superior. This activity includes annually deploying and recovering a small Spotter wave buoy in approximately 200 meter deep water. Real-time wave and water temperature data will be made available on Seafull, a public data dashboard developed by the Great Lakes Observing System. The small buoy will be deployed from the University of Minnesota Duluth vessel, the RV Kingfisher, between approximately late April through mid November (weather and ice conditions permitting, each year, and the start and ending years of the project will have shortened deployments). While not a primary goal, providing publicly accessible Lake Superior conditions is a valuable asset to marina users and visitors to Minnesota's North Shore of Lake Superior.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Deploy Spotter Buoy and route real-time data to GLOS Seagull data dashboard | July 31, 2027 |
| Recover Spotter Buoy for 2027 observation season and summarize observation data | December 31, 2027 |
| Deploy and recover Spotter Buoy system for the 2028 observation season and summarize observation data | December 31, 2028 |
| Deploy and recover Spotter Buoy system for the 2029 observation season and summarize observation data | December 31, 2029 |

## Activity 3: Historical wave climate and wave energy availability analysis - Coastal Lake Superior

**Activity Budget:** $128,386

**Activity Description:**

Leveraging recent wave energy assessments (Pheifer and Hill 2024), this activity aims to improve nearshore wave energy assessments using long-term high-resolution wave model output. The previous coarse-grid energy assessment (10km x 10km) completed by Dr. Hill's group limits spatial and temporal resolution along Minnesota's Lake Superior coastline. Currently, the Cooperative Institute for Great Lakes Research is nearing the end of high-resolution highcast wave modeling (1980 to present, 3km x 3km grid or smaller) using WaveWatch III (WW3), and Dr. Hill's collaborators will share model output both publicly and directly upon completion of the study (estimated Fall 2026). To supplement WW3 model output, we will use historical model output from the US Army Corps of Engineering WIS (Wave Information Study), providing hourly model output at 3-4km grid resolution along Lake Superior's coastline from 1979-present. Using both WW3 and WIS model output, a graduate research assistant will process wave statistics following IEC TS 62600-101 (International committee technical standards for wave energy resource assessments). Goals for this activity include developing a comprehensive quantitative assessment of wave energy density and theoretical wave energy potential for coastal Lake Superior while validating model output to buoy observations from Activity 2.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Collection and archival of WW3 and USACE WIS hindcast model output | December 31, 2027 |
| Quantify wave energy density and theoretical wave energy potential along Minnesota's Lake Superior coastline | December 31, 2028 |
| Compare buoy observations to recent model output generated during project period | December 31, 2029 |
| Summarize wave characteristics and energy metrics at man-made infrastructure sites along Minnesota's Lake Superior coastline | December 31, 2029 |

## Activity 4: Assessing WEC technical power potential via real-time hardware-in-the-loop simulations using reconstructed waves

**Activity Budget:** $55,718

**Activity Description:**

Following development of the real-time HIL dynamometer system and Simulink WEC-Sim virtual models, we will assess power potential for two WEC technologies (oscillating surge converter and heaving point absorber). Using results from buoy observations (Activity 2) and historical wave energy assessments (Activity 3), we will reconstruct wave elevation time-series profiles to use as driving input for both the WEC-Sim virtual model and the physical HIL setup driving the 600-watt generator. These wave-by-wave profiles represent both observed and modeled wave characteristics, translating field conditions via transferred torque through the dynamometer shaft to the generator. Because generator efficiencies change based on operating conditions, we cannot linearly extrapolate technical power potential. Instead, using combined virtual and physical HIL testing, we drive the generator representative to a WEC while measuring

necessary parameters to quantify time-varying efficiencies. Additionally, using both WEC-Sim and the physical dynamometer, we will simulate a matrix of varying sea-states (significant wave height vs. wave energy period) to develop a power matrix for each of the two WEC technologies. When combined with sea state joint probability distributions from buoy observations and model output (Activities 2-3), we will quantify the technical power potential for each WEC technology under Lake Superior sea states.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Reconstruct wave elevation time series to serve as HIL dynamometer and WEC-Sim virtual model input | August 31, 2028 |
| Simulate (WEC-Sim) and emulate (dynamometer) 10th, 50th, 90th percentile sea states to quantify power potential | October 31, 2028 |
| Simulate (WEC-Sim) and emulate (dynamometer) a sea state matrix to develop WEC power matrices | December 31, 2029 |
| Quantify technical power potential for each WEC technology under Lake Superior sea states | January 31, 2030 |

## Activity 5: Energy economic study, data synthesis, and knowledge transfer

**Activity Budget:** $40,232

**Activity Description:**
This final activity aggregates all information from the project to deliver an economic analysis comparing theoretical vs. technical power potential for coastal and nearshore WECs. Theoretical energy production will assume standard WEC efficiencies from other reported WEC theoretical studies, whereas technical production potential integrates output from HIL dynamometer and WEC-Sim virtual environment simulations. Knowing typical Lake Superior sea states along Minnesota's coastline, theoretical and technically achievable WEC generator efficiencies, energy production potential, and industry levelized cost of energy (LCOE) thresholds, we can estimate economic impact for wave energy implementation at key locations along Minnesota's Lake Superior coastline. Additionally, the research team will work on synthesizing all project activities and data into a final report while also producing a peer reviewed journal publication. Knowledge transfer will occur at marine energy technology conferences in Years 2 and 3 of the project. This will most likely occur at the UMERC+METS annual conference (University Marine Energy Research Community + Marine Energy Technology Symposium). Throughout the project period, knowledge transfer will also occur in Dr. Craig Hill's courses he teaches in the UMN Duluth Mechanical and Industrial Engineering Department, including marine engineering, controls and dynamics, and sustainable energy related coursework.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Present findings on HIL dynamometer and WEC-Sim development and testing at UMERC+METS 2028 conference | October 31, 2028 |
| Present findings on power potential along Minnesota's Lake Superior coastline at UMERC+METS 2029 conference | October 31, 2029 |
| Estimate economic impact for wave energy implementation at key locations along Minnesota's Lake Superior coastline | April 30, 2030 |
| Develop final project report and peer reviewed journal paper submission | June 30, 2030 |

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**
This project and its various activities will be discussed in several ways during and after the project period. While they are not specifically called out in the project activities, PI Dr. Craig Hill frequently engages in public outreach events discussing his work relating to marine energy systems and observation technologies on Lake Superior. Examples of this include the Science on Deck event hosted by the UMN Duluth Large Lakes Observatory, volunteering as a guest speaker for local middle and high school STEM classes and clubs, UMN Duluth Swenson College of Science and Engineering Discovery Days, among other local and regional opportunities. Dr. Hill also plans to incorporate many of the project concepts into his coursework in Mechanical Engineering, including ME 3140 System Controls and Dynamics, ME 4495 Applied Maritime Engineering, and ME 5325 Sustainable Energy Systems, all of which contribute to project content dissemination and workforce development in this space.

What is included in project activities related to dissemination includes attending the primary US-based marine energy conference in Years 2 and 3 of the project. This conference (UMERC+METS) brings together academia, industry, and government organizations working on marine energy and engineering challenges. PI Dr. Hill recently ended his term on the Board of Directors for UMERC, and is the Chair of the Board of Directors for the METS (Marine Energy Technology Symposium), and hosted this annual conference in Duluth in 2024. While not guaranteed, there is the potential for this conference to return to Duluth and the Great Lakes region in 2028 or 2029. Additionally, as part of his faculty role at UMN Duluth and the Large Lakes Observatory, Dr. Hill and the Graduate Research Assistants involved in this work will target a published peer-reviewed scientific journal in the journal Renewable Energy (where Dr. Hill's previous work on a Great Lakes wave energy assessment was published and accessed globally).

In general, Dr. Hill frequently works with the University of Minnesota Duluth Public Relations team to create public stories about his work, and has been featured on UMN stories, local news agencies, statewide clean energy organizations (e.g. Clear Energy Resource Teams), and on UMN systemwide commercials for wave energy pursuits on the Great Lakes. For this project, he will convey the work and progress to UMPR and local news outlets to engage the broader public on research and development activities in this space.

A final, accessible report summarizing the project's results will be produced and published on the University Digital Conservancy (DRUM), which is publicly accessible. We will acknowledge the Environmental and Natural Resources Trust Fund (ENRTF) by using the trust fund logo or attribution language on all project print and electronic media, publications, signage, and other communications and outreach materials, in accordance with the ENRTF Acknowledgement Guidelines.

## 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 work be funded?**
Results will be communicated through publications, conferences, and to industry partners. Additionally, the University of Minnesota Duluth is applying to become a TEAMER open-water test facility (Testing and Expertise for Marine Energy), enabling new funding opportunities and partnerships. Future phases will leverage this project's outcomes to inform field-scale WEC designs for Lake Superior testing while also conveying scaling opportunities for technology development to coastal ocean sites. Results will be discussed during and after this project in seminars and public outreach

opportunities. Ongoing work will seek funding through private industry partnerships in Duluth, across the Nation, among other government funding opportunities.

## Project Manager and Organization Qualifications

**Project Manager Name:** Craig Hill

**Job Title:** Associate Professor, Mechanical & Industrial Engineering, University of Minnesota Duluth

**Provide description of the project manager's qualifications to manage the proposed project.**
Dr. Craig Hill is a McKnight University Presidential Fellow within the University of Minnesota System and brings extensive experience from marine energy and marine observation system design, modeling, laboratory, and field deployments in Lake Superior and beyond. He is affiliated with the UMN Large Lakes Observatory and collaborates closely with Minnesota Sea Grant to explore the capabilities of new, lower-cost multi-sensor observation systems for marine ecosystems, blending disciplines from mechanical engineering, water resources, computer science, and environmental science. Prior to his faculty position at UMN Duluth, Dr. Hill worked as a marine research engineer where he designed and deployed large multi-sensor moorings for deep-water Lake Superior environments, designed and built small and large multi-sensor surface observation buoys for the Great Lakes, and worked in other environmental science and water resources related research at UMN St. Anthony Falls Laboratory. Dr. Hill manages multiple graduate and undergraduate student researchers and leads multi-institutional research projects between UMN Duluth, Oak Ridge National Labs, and private industry. Recent projects from Dr. Hill's research team have focused on characterizing wave energy resource availability across all five Great Lakes, deploying wave observation buoys to monitor nearshore risks for rip currents and coastal erosion, and exploring the feasibility of an expanded real-time lake monitoring network for NE Minnesota. Additionally, he leads a research team developing new, low-cost wave and water quality monitoring buoys for coastal and inland lake monitoring applications. Dr. Hill teaches courses in fluid mechanics, marine engineering, controls and dynamics, sustainable energy, and data acquisition systems, and is guiding the development of a new marine engineering curriculum at UMN Duluth. He is an active member of the Marine Technology Society, Board Member for the Marine Energy Technology Symposium, and regular contributor to activities for the Great Lakes Marine Technology community.

**Organization:** U of MN - Duluth

**Organization Description:**
The University of Minnesota Duluth (UMD) is a comprehensive regional university. Undergraduate students can choose from 17 bachelor degrees in 89 majors and 76 minors as well as five certificates. UMD also offers graduate programs in 24 fields, 12 minors, and six certificates. The Mechanical and Industrial Engineering (MIE) Department at UMD is the largest engineering department within the Swenson College of Science and Engineering at UMD and is developing a new specialized track in marine sensors and technology. With over 20 faculty members and an active student body of more than 500 students, the department excels in integrating research into undergraduate MIE curriculum and collaborating with regional companies on multidisciplinary senior design projects. Faculty in the department share affiliations with the Advanced Materials Center, Large Lakes Observatory, among other campus-affiliated and community-based organizations. The MIE Department also houses two graduate degree programs, including the MS in Mechanical Engineering and MS in Environmental Health and Safety. Within the MIE Department and across the UMD campus, faculty are dedicated to providing applied teaching and research experiences sharing a common thread of sustainability while developing life-long learners from our graduates.

## Budget Summary

| Category / Name | Subcategory or Type | Description | Purpose | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | $ Amount |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| Dr. Craig Hill, PI | | Dr. Hill will oversee all activities for the project and lead field buoy deployments for Activity 2 and final reporting. He will serve as research advisor for the GRAs and be closely involved in Activities 1, 3, 4, and 5 while also leading Final Reporting. One month summer salary and one academic year course buyout each year. | | | 26.8% | 0.36 | | $70,043 |
| Master's Graduate Research Assistant | | Over the course of the project, there will be 3 MS GRAs. During Years 1 and 2, one will lead HIL dynamometer and WEC-Sim virtual model development while a second GRA will lead WW3 and WIS wave energy assessments. In year 3, a third GRA will lead Activity 4 HIL emulation and WEC-Sim simulations to assess technical power potential. GRAs will work 75% time during the summer on the project. The calculation for % benefits includes tuition remission valued at $18,720 per academic year per GRA. | | | 45.7% | 2.43 | | $287,397 |
| | | | | | | | **Sub Total** | **$357,440** |
| **Contracts and Services** | | | | | | | | |
| Sofar | Service Contract | Monthly required data transmission fee for Spotter Buoy operations (July-Nov 2027, April-Nov 2028, April-Nov 2029) to transmit wave statistics and location from buoy while deployed. Paid directly to Sofar, the company that makes the Sofar Spotter Buoy. | | X | | 0 | | $630 |
| UMD RV Kingfisher | Internal services or fees (uncommon) | RV Kingfisher use (1 day in 2027, 2 days in 2028, 2 days in 2029) for deploying and recovering Spotter Buoy for wave observations | | | | 0 | | $6,200 |
| | | | | | | | **Sub Total** | **$6,830** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Equipment, Tools, and Supplies** | | | | | | | | |
| | Equipment | Non-capitalized field equipment | The HIL dynamometer system is driven by a servo motor and gearbox, connected to the main motor driver via cables (all items from Applied Motion). Power transmission components (couplings, etc.) connect the driving servo motor through rotary torque and encoder sensors to the 600W rotary generator. Feedback control and data acquisition Beckhoff modules acquire sensor data. The estimated cost of these components includes anticipated shipping costs. | | | | | $8,440 |
| | Tools and Supplies | Field supplies | Consumables needed for field work, including mounting hardware, wires, mounting brackets, and more. | | | | | $2,000 |
| | | | | | | | **Sub Total** | **$10,440** |
| **Capital Equipment** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Acquisitions and Stewardship** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel In Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel Outside Minnesota** | | | | | | | | |
| | Conference Registration Miles/ Meals/ Lodging | Conference registration and travel to out-of-state conference UMERC+METS in 2028 and 2029 for two GRA students each year. Lodging and per diem for 4 days and 4 nights, including two travel days. | To present research project findings | X | | | | $7,790 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Sub Total** | **$7,790** |
| **Printing and Publication** | | | | | | | | |
| | Publication | Publication fees in the journal Renewable Energy | Peer reviewed journal publication presenting project results | | | | | $1,500 |
| | | | | | | | **Sub Total** | **$1,500** |
| **Other Expenses** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| | | | | | | | **Grand Total** | **$384,000** |

## Classified Staff or Generally Ineligible Expenses

| Category/Name | Subcategory or Type | Description | Justification Ineligible Expense or Classified Staff Request |
|---|---|---|---|
| **Contracts and Services** - Sofar | Service Contract | Monthly required data transmission fee for Spotter Buoy operations (July-Nov 2027, April-Nov 2028, April-Nov 2029) to transmit wave statistics and location from buoy while deployed. Paid directly to Sofar, the company that makes the Sofar Spotter Buoy. | It is the only company to pay for this service since it directly integrates with their buoy. |
| **Travel Outside Minnesota** | Conference Registration Miles/Meals/Lodging | Conference registration and travel to out-of-state conference UMERC+METS in 2028 and 2029 for two GRA students each year. Lodging and per diem for 4 days and 4 nights, including two travel days. | Primary US marine energy conference rotates locations and was in Duluth, MN in 2024 (may return in 2028 or 2029, but not guaranteed yet). |

## Non ENRTF Funds

| Category | Specific Source | Use | Status | Amount |
|---|---|---|---|---|
| **State** | | | | |
| In-Kind | UMN unrecovered indirect costs are calculated at the UMN negotiated rate for research of 54% modified total direct costs. | Indirect costs are those costs incurred for common or joint objectives that cannot be readily identified with a specific sponsored program or institutional activity. Examples include utilities, building maintenance, clerical salaries, and general supplies. (https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs) | Secured | $156,816 |
| | | | **State Sub Total** | **$156,816** |
| **Non-State** | | | | |
| | | | **Non State Sub Total** | **-** |
| | | | **Funds Total** | **$156,816** |

**Total Project Cost: $540,816**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

*Visual Component*

File: bc73a7b1-9f1.pdf

*Alternate Text for Visual Component*

Visual flow chart of project activities and their links to each other, including Lake Superior wave numerical modeling contour maps with nearshore gaps, photo of small wave buoy on Lake Superior, generator dynamometer for hardware-in-the-loop testing, virtual wave energy converter simulation environment, and example Lake Superior coastal infrastructure photo....

### Supplemental Attachments

*Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other*

| Title | File |
|---|---|
| Authorization Letter | 35825356-b81.pdf |
| Proposed Buoy Deployment Map and Details | e0b780c6-fc7.pdf |

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**

Yes, I understand the UMN Policy on travel applies.

**Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?**

No

**Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?**

N/A

**Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?**

N/A

**Does your project include original, hypothesis-driven research?**

Yes

**Does the organization have a fiscal agent for this project?**

No

**Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?**

No

**Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care,**

**treatment, education, training, instruction, or recreation to children")?**

No

**Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:**

umdspa@d.umn.edu (Claudia Carranza, UMN Duluth); jaco2565@d.umn.edu (Michael Jacob, UMN Duluth)

**Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements**

Yes, I understand