Project Title: Demonstration of the Performance and Debris Mitigation Technologies for VIVACE River Energy Conversion Under Realistic Conditions in Alaskan Waterways

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Total project cost: $1,329,195
Grant funds requested: $744,707
Match committed: $584,488

Previous projects/applications: None

Previous abstracts:
**VIVACE Hydrokinetic Power Generator System: The Solution for Fish Protection and Debris Avoidance in Alaskan Rivers.** ABS Alaskan, Inc. 2012
(Abstract approved by EETF; proposal not submitted)

# 1. Project Summary

## 1.A. Project Description

The project team proposes to design, test, and monitor a modular hydrokinetic power generation device (HKD) tailor-made for Alaska's debris-infested waterways. The modularity of the device will allow power output to be scaled to demand and deployed in remote communities without using heavy equipment, Attempts to demonstrate HKD operations at Ruby and Eagle Alaska and Ft. Simpson, Yukon Territories ended because of river debris providing conclusive evidence that successful operation of HKD on most Alaskan rivers will require mitigating the problems of debris interaction with HKDs. The design consists of Vortex Hydro Energy's VIVACE (Vortex Induced Vibration for Aquatic Clean Energy; see Figs. 1-2) hydrokinetic power converter, modified to be debris tolerant, with the University of Alaska Fairbanks's (UAF) proven surface debris diversion device (SDDD; see Fig. 3) and advanced subsurface debris diversion system (SDDS) concepts. The proposed test-site is at the Alaska Hydrokinetic Energy Research Center's (AHERC) Tanana River Test Site (TRTS) in Nenana, Alaska. The HKD VIVACE, a lab and field-tested technology, will be improved upon and validated in the Alaskan river environment. The debris diversion technology for surface and subsurface debris was designed, developed and tested by AHERC.

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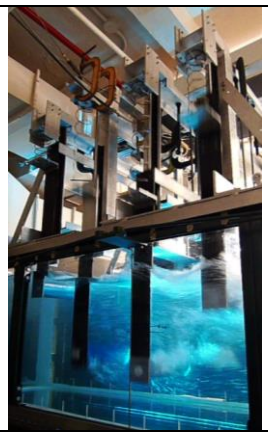
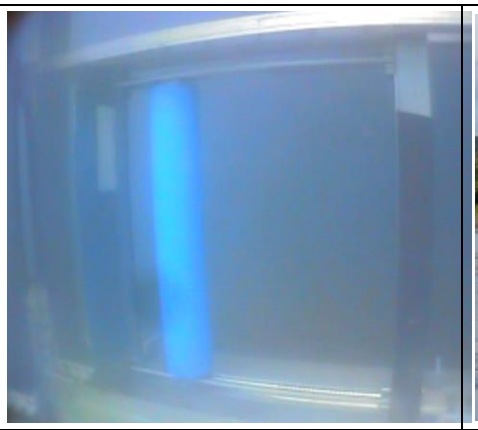
|  |  | |
| Figure 1: Four Alpha-2 Lab Prototypes | Figure 2: VIVACE Prototype Under Testing in the St. Clair River in Port Huron, MI in Fall 2012 | Figure 3: Surface Debris Diversion Device |

VIVACE is a novel technology that enhances vortex induced vibrations and galloping to generate energy from water currents (river or tidal). VIVACE uses cylinders, which are strong and impact-resistant, rather than turbine blades. It also mimics fish-school kinematics to harness energy in an environmentally compatible way. The technology has been well proven through tow-tank testing, deployments in the St. Claire River at Port Huron, MI, and in canals in the Netherlands.

AHERC's SDDD uses a freely rotating cylinder covered with high-density plastic at the apex of adjustable angle diversion pontoons. The large cylinder diameter prevents debris from catching at the pontoons' apex (a common problem with diversion devices) and the low-friction, high-density plastic allows debris to rotate around the pontoons' apex to be shed along pontoon surfaces. Tests at the TRTS have demonstrated the effectiveness of this design to divert surface debris and keep a debris-free path for a significant distance behind the SDDD. The SDDS is currently being designed to deflect subsurface debris for the deployed VIVACE.

To integrate and improve these technologies, the project will be comprised of three main tasks. Task 1 is to complete lab-testing of different designs of the AHERC SDDS integrated into a VIVACE prototype and field tests of the SDDS's ability to deflect subsurface debris and its effect on natural river currents. The outcome will be quantification of the effect of downstream turbulence from the SDDS on the efficiency of the VIVACE converter. Task 2 is to design and fabricate a rated 1.5kW scale debris diversion and VIVACE optimized integrated device to be installed at the AHERC test site on the Tanana River. This device will be designed to be modular for assembly in remote locations where resources are limited. The device will also have components that

have a break away capability to reduce the impact of debris collisions. Task 3 will be a 4-month deployment of the device in the Tanana River to test HKD energy conversion efficiency, debris diversion effectiveness, and reliability and maintenance cycles. The demonstration will assess the VIVACE's energy extraction effectiveness, its ability to resist debris, impacts on fish, reliability, maintenance requirements, and economic viability. The demonstration will also test the effectiveness of the debris diversion device.

For full commercialization, VHE-A has established a development process to take the VIVACE technology from its present stage to commercial demonstration. This process addresses the needs to systematically advance the development of the VIVACE converter through clearly defined stages that have minimum threshold values of performance. It closely follows DOE's TRL stages. VIVACE is currently at DOE TRL 6, and plans to install a full size commercial demonstrator unit by 2017.

### 1.B. Project Innovation

**VIVACE System -** The VIVACE system utilizes a novel approach to MHK power generation. The device takes advantage of river or ocean currents that flow around cylinders producing alternating vortex shedding. The vortex shedding produces an alternating lift force that causes the cylinder to oscillate transversely to the flow. The cylinder mechanical energy is then converted mostly to electricity and partly to collectable heat, thus, co-generating electricity and heat. An important advantage of the VIVACE converter compared to other hydrokinetic devices is that it is designed to use commercially available off-the-shelf components to keep manufacturing costs low and reduce maintenance costs. VIVACE employs multiple cylinders, which work synergistically like fish in schools, thus converting more MHL energy into mechanical energy. Further, VIVACE is scalable and can start moving at speeds as low as 0.32m/s (0.65knots) while turbines require a minimum of 4 knot flow speed.

**Debris Mitigation** – The SDDD, SDDS and VIVACE design features minimize the probability of debris damage or interference with operations. The SDDD diverts surface debris and the SDDS will divert subsurface debris under, or around, the VIVACE for deployments from floating platforms, which is our intended deployment method (depending on test results for the two SDDS concepts). For riverbed deployments, the SDDS will divert subsurface debris above, or around, the VIVACE. The VIVACE's narrow support frame and cylinder design reduce the probability of experiencing direct debris impacts. If a direct debris impact occurs, VIVACE release mechanisms will allow the cylinders to detach from the support frame and/or the support frame to release from its base attachment to rotate way from debris on hinge points. A self-deploying tether from the cylinders to the support frame base will allow detached cylinders to be recovered and reinstalled. Once the debris has passed by the VIVACE the frames can be rotated back into place and the release mechanisms reset.

### 1.C. Project Site and Demonstration Environment

The demonstration will be conducted at AHERC's TRTS, which has undergone extensive study of the river relevant to hydrokinetic testing (current velocity and turbulence, fish stocks, debris, sediment transport). The TRTS has an established anchor point and mooring buoy that has been used for the past two years for fish studies and testing of the SDDD. The mooring system is designed to support loads in excess of 40,000 lb-f. The site has been permitted to operate by ADNR and ADF&G for the past four years of study, and AHERC is working with ADF&G to establish requirements to permit HKD testing.

### 1.D. Priority

(1) UAF is part of the University of Alaska, and this project includes the participation of Vortex Hydro Energy – Alaska (VHE-A), which holds a State of Alaska Business License. (2) The University of Alaska at Fairbanks is the leading participant and PI for this project. (3) UAF and VHE-A are committing $584,488 in matching funds. (4) The VIVACE technology has the potential for widespread deployment in the state. This includes over 100 rural communities along Alaska's major rivers and communities near tidal sources or with intertie grids that can transmit power from tidal sources.

## 2. Technology Validation and Data Collection

### 2.A. Objectives

The objective of this project is to demonstrate the VIVACE's converter's energy extraction effectiveness and durability under Alaskan river conditions. This requires assessing its survivability using AHERC's surface and subsurface debris deflection systems, its maintenance requirements, and economic viability. This will lead to commercializing the VIVACE technology for Alaska within the next 5 years. The VIVACE can be installed in many different locations in Alaska – from industrial zones to remote location on rivers or in tidal zones.

The VIVACE Alpha 2 prototype will be tested in the University of Michigan Marine Renewable Energy Laboratory (MRELab) with several parametric variations of AHERC's subsurface debris diversion device upstream from VIVACE. This will establish the effect on HKD energy conversion efficiency of VIVACE. AHERC will also test its SDDS at the TRTS to examine its performance parameters and its affect on the river current velocity and turbulence. UAF and VHE-A will use the results of the laboratory and field tests to determine which debris diversion design to implement in the Tanana River at the rated 1.5 kW scale.

VHE-A will design and fabricate a prototype to install at the TRTS with the selected debris diversion device. This device will be strong enough to withstand debris that may escape the UAF device's protection, and be deployed from a floating installation platform. VIVACE will be modular and built in pieces that will allow the device to be built and assembled easily in remote locations with fewer resources. The VIVACE river prototype will also have breakaway components to decrease the damage inflicted upon the device if debris collides with it. If debris loads of large force impact the cylinders of the prototype, the cylinders will break away from the frame, and allow the debris to pass through the device. The cylinder will be tethered, so it can be retrieved with the rest of the device when it is removed for repair or reinstallation of the cylinder. If the cylinder is damaged it can be easily replaced by a new one. If it is not damaged, it can be immediately reinstalled on the frame to be put right back in the river. The prototype will be tested for functionality and performance metrics.

What results would constitute a successful project?

(a) Acceptable reduction in turbulence impact on efficiency evaluated from Task 1
(b) A UAF device that will reduce VIVACE efficiency to an acceptable level while allowing debris to go through the SDDS which is small enough for VIVACE to sustain their impact.
(c) At least a week of successful operation in realistic multiple scenarios of flow speeds and debris combinations.

### 2.B. Data Collection

Monitored parameters will include river hydrodynamic conditions (current velocity, power, turbulence, sediment transport), force on anchor lines and lines running to the pontoon boat, debris conditions, VIVACE power output, and VIVACE interaction with fish, debris and response to sediment abrasion. An underwater high-resolution sonar will document VIVACE operation and interaction with fish and debris. Fish interaction monitoring will be conducted to satisfy ADF&G permit requirements and to demonstrate VIVACE's fish-friendly performance. An economic analysis will be conducted using information about deployment costs, costs of maintenance and operation - to include periods of lack of availability.

## 3. Project Schedule and Project Budget

[Schedule is based on a January 2014 start date. Schedule will shift according to the actual start date.]
Jan-June 2014 – Design and fabricate debris diversion devices and field prototype for the SDDS.
July-Sept 2014 - Lab testing of the VIVACE and SDDD, SDDS and field-testing of SDDS prototype design.
September - December 2014 – Design of River Device. Go/No-Go milestone.
Jan - Apr 2015 –Develop and build debris diversion device and VIVACE. Plan for summer deployment.
Apr-May 2015 – Transportation, assembly and integration of technologies. Final preparations for river test.
June-Sept 2015 – In-river testing.
Oct-Dec 2015 – Remove equipment from river. Conduct analysis and prepare final reports.

**Project Budget**: Total project cost: $1,329,195; Grant funds requested: $744,707; Match committed: $584,488 – Vortex Hydro Energy ($425,000, in-kind) and University of Alaska Fairbanks ($159,488 cash match).

| Category | Budget Amount | UAF Match ($) | VHE-A Match (inkind) |
|---|---|---|---|
| Direct Labor and Benefits | $192,394 | | |
| Travel & Per Diem | $27,211 | | |
| Equipment | 0 | | $425,000 |
| Materials & Supplies | $28,660 | | |
| Contractual Services (vendor)<br>Subaward to Vortex | $2,500<br>$425,000 | $127,590 | |
| Management & Administration | $68,942 | $31,898 | |
| **Totals** | $744,707 | $159,488 | $425,000 |

## 4. Project Team Qualifications

The project team includes the AHERC hydrokinetic research team that includes: Dr. J. B. Johnson, Director AHERC; Dr. J. Kasper, hydrology and sonar operations; Mr. J. Schmid, research engineer; Dr. A. Seitz, fisheries biologist. The AHERC team has been conducting hydrokinetic-related studies since 2008 and has established the TRTS' capabilities to conduct HKD testing. Dr. Johnson will guide the overall project direction with special focus on debris mitigation and TRTS testing. Dr. Kasper will conduct hydrologic and sonar measurements to establish river hydrokinetic conditions and VIVACE interactions with the river environment (fish, sediment turbulence, debris), Mr. Schmid is responsible for supervising all on-water activities and implementation of HKD tests. He will work with VHE-A staff to ensure compatibility of VIVACE design with AHERC test facilities and test barge and will oversee testing at the TRTS. Dr. Seitz will conduct impact studies using fish capture gear and sonar data. Dr. M. Bernitsas will be heading the development of the VIVACE technology for this project. Rebecca Alter, chief-engineer of VHE-A and Jason Taipale will ensure daily operation of the VIVACE converter. VHE-A has been involved in this HKD technology since 2005. VHE-A has engineering and operational knowledge from four previous developments and deployments of VIVACE prototypes.

## 5. Discussion of Commercialization of Funded Technology

The proposed project will establish the commercialization potential of the Alaska tailor-made VIVACE technology and debris diversion in rivers and tidal locations within the next 5 years. Through monitoring performance characteristics such as debris resistance, maintenance requirements, and power output, it will be possible to (1) determine how well the VIVACE technology performs under this harsh environment, and (2) obtain valuable information that will be used to improve the device for follow-on installations. Potential customers for the VIVACE converter include over 100 rural communities along Alaska's major rivers. Additional customers include communities near tidal sources or with intertie grids that can transmit power from tidal sources. Rural community power depends on diesel and is some of the highest cost power in the U. S. Hydrokinetic power would replace part of diesel with renewable local energy. As fossil fuel costs continue to increase and hydrokinetic technology matures the economics will favor hydrokinetic generated power. Non-economic benefits include reducing greenhouse gases, reducing the need for handling diesel, and involving more local residents for fabrication and deployment.

## 6. Signed Applicant Certification

By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered.

Andrew M. Gray, Director, UAF Office of Sponsored Programs