EE0008945 – Development of a Modular Helical Fish Passage for Low Head Applications

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Project Overview

The Critical Driver for the Innovation:
The high cost and complexity of conventional fish passages absolutely requires new cost-effective modular fish passage technologies be developed for future small hydro-plants

- **Current Fish Passage Costs projected to exceed the cost of the Small Hydropower plant-works**

### Project Summary

This Project will Develop a Helical Fish Passage Module that operates as a rotating weir to connect upstream and downstream habitats and fish species

**Technical Approach:**
- Leverage recent patented work of Percheron Power on the Composite Archimedes Hydrodynamic Turbine
- Perform computational analysis and laboratory testing of scale models prior to full-sized prototype testing
- Utilize advanced manufacturing methods to produce modular, easily-assembled components of inexpensive composite materials
- Perform live fish testing of full-size prototype at the Aquatics Research Lab of PNNL to validate

### Intended Outcomes

The project goal is to dramatically lower the cost of fish passage solutions and to manufacture the components in the U.S.

**Key Benefits and Impact:**
- Safer and quicker volitional passage for fish
- Order of magnitude improvement in cost over conventional fish passes
- Brings U.S. supplier/expertise into world market for new advances in fish passage

### Project Information

**Principal Investigator(s):**

- Percheron Power, LLC (Lead)

**Project Partners/Subs:**

- Pacific Northwest National Laboratory
- Oak Ridge National Laboratory
- Utah Water Research Laboratory/USU
- Plastic Injection Molding, Inc.
- Biomark, Inc.

### Project Status

- Ongoing

### Project Duration

- **Start:** Feb 1 2021
- **End:** May 31 2023

### Total Costed (FY19-21)

- **$710 K** ($ 549 K Federal; $161 K Match)
Percheron Power’s Key Project Objectives

1. Design and develop a helical fish pass that operates as a “rotating weir” for safe fish passage.
2. Demonstrate that the Fish Pass Helix provides appropriate conditions for safe, timely and effective fish passage and validate that fish will pass through of their own volition.
3. Provide a recommended design and cost predictions for the Fish Pass Helix module of the small hydropower plant.
Project Objectives: Relevance

This project is WPTO mission centric: it involves research, development, testing and commercialization of an innovative new fish passage device which:

- Leverages new manufacturing methods/materials to dramatically lower costs of components and systems
- Enables new or existing small hydropower plants to incorporate ecological and social objectives, including providing, improving, connecting (or reconnecting) aquatic/riverine habitats, and
- Employs new technology to advance and lower the costs of next-generation hydropower thereby driving innovation to support hydropower growth
- Provides a critical modular solution for the WPTO Standard Modular Hydropower (SMH) vision that standardization, modularity, and preservation of stream functionality must become essential and fully realized features of next-generation hydropower technologies and project designs
Project Approach

Design and Development of Helix Component

Utilize an interactive phased approach, including:

- Mathematical analyses/modeling of the water “slugs” in the helix for different designs
- Development and Bench Testing of Laboratory-scale Models
- CFD modeling regarding turbulence, etc. for various designs/conditions
- FEA analyses for structural design
- Fabrication and Testing of Full-scale prototype at PNNL Aquatics Research Lab (BP2)
Validation and Risk Reduction Approach: 3 Stages of Testing

**Mini Laboratory Scale Tests – Complete**

- 3-inch diameter X 8.5-inch long helices
  - Test and Compare various designs
  - Select optimum designs for CFD and Bench Tests

**Bench Testing of Laboratory Scale Models – Complete**

- 10-inch diameter X 6-ft long helix
  - Select 2 helix designs and Perform Computational Fluid Dynamics prior to testing
  - Physically test models and compare to CFD results

**Full-sized Prototype Testing – Upcoming - Ongoing**

- 36-inch diameter X 15-ft long helix
  - Select, Design and Fabricate up to 2 Prototypes
  - Fish Testing with several species at PNNL ARL
Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

• A totally new bi-directional fish passage device — which has been performance-validated through hydraulic and physical modeling as well as full-scale laboratory testing
• 3 sizes, or scales of the device are developed and tested
  • Cumulative knowledge rapidly pushes the design/validation process forward
  • Wildlife agencies/regulators involved throughout - in setting and validating desired passage parameters

Outcomes:

• Following required field testing, the Bi-directional Fish Pass Helix is accepted by wildlife agencies/regulators as equivalent or best available technology for fish passage of multiple species
• Site owners, hydropower developers and other entities adopt new technology in U.S. and worldwide, and at dramatically lower cost than conventional passages
• Multiple market applications for the Fish Pass Helix, at hatcheries, diversions, and other aquatic barriers not associated with hydropower, as well as hydropower plant applications --- will further expand the market potential and acceptance of the modular device while decreasing its unit costs
Fish Passage Project Phases and Schedule

Phase 1/BP 1: Design, Modeling and Lab-scale Testing (May 2020 to Sep 2021)

Phase 2/BP 2: Full-scale Prototype Fab and Testing with Live Fish (Jan to Nov 2022) and Plant Design/Market/Cost Analyses (Apr 2022 to Mar 2023)

Phase 3: Optimization/Field Testing (Jan 2023 forward)

Phases 1 and 2 are Budget Periods 1 and 2 funded by DOE under this Award
All Milestones and Tasks Successfully Completed for Budget Period 1
Go/No-Go Documentation submitted in September 2021
Budget Period 2 contract provided by WPTO/executed April 2022 – all Tasks moving forward as planned
Materials and fabrication costs have increased significantly since 2019 proposal and 2021 Go/No-Go Update

Project timeline has expanded ~ 1 year due to DOE contract process with increased labor costs

- Available fixed funding under this contract results in one prototype being fabricated/tested instead of two and increased cost share from Percheron
- Additional funds being sought to expand live fish testing at PNNL Aquatics Research Lab
End-User Engagement and Dissemination

During the pre-proposal stage, Percheron identified wildlife agency/regulator involvement as being critical to adoption of any new fish passage device

- per NOAA/NMFS, innovative/experimental fish passages must provide equivalent or better passage to conventional approaches:
  
  "There is potential for future development of new passage devices that may safely pass fish at a rate comparable with conventional technology. These new concepts are considered "experimental" until they have been through the process described herein and have been proven in a prototype evaluation validated by NMFS." and "results of both laboratory tests and field prototype evaluations must demonstrate a level of performance equal to or exceeding that of conventional fish passage devices before NMFS may support permanent installations".

- Formed and Fish Pass Helix Advisory Group as one of first tasks

- Engaging with other Stakeholders (Biologists/Hatcheries/Equipment Manufacturers/Tribes, etc.)
- ORNL providing support in Market Analyses to determine key species/regions to assist in helix sizing and market commercialization strategy
- Expect multiple other non-powered sites to be interested in the Fish Pass Helix (existing diversions/dams and other aquatic barriers)
- Identifying key sites for next steps/field testing of the device, which have wildlife agency support
Role of Fish Pass Advisory Group

Percheron and PNNL established a Fish Pass Advisory Group at project outset to guide development and testing of the device (inc. NOAA, USGS, USFWS, WA DFW, PNNL)

The Group’s desired key contributions to the project

• Refining and providing Percheron with functional and performance requirements (constraints) or targets for the fish pass
• Reviewing the planned testing program for the fish pass, and overseeing and evaluating the results
• Helping formulate future study plan for field testing expected to be required by wildlife agencies prior to commercial adoption
Performance: Accomplishments and Progress

All Milestones and Deliverables for BP 1 achieved, received positive Go/No-Go decision, and BP 2 underway and on target

Key Accomplishments

• Developed a proprietary/patent pending design for a Bi-Directional Fish Pass Helix
  • Used rapid prototyping/3-D printing to quickly and efficiently test/evolve 10 different helix designs and select best design for full-sized prototype
  • Demonstrated that the new Fish Pass Helix should enable fish to volitionally pass in both directions
  • Hydraulic modeling shows low and very acceptable turbulent kinetic energies and velocities throughout the device
Performance: Accomplishments and Progress (cont.)

• Biological Performance Models (BioPA) of PNNL predict negligible probability of impact to fish
• Live fish testing at bench scale (10-in dia) showed successful passage of juvenile trout in both directions

• Evaluated multiple advanced fabrication methods
  • Developed an innovative design and process for fabrication of the helix with an integral outer cylinder
    • Utilize Plastic Injection Molding of multiple small radial and axial sections which are designed to interlock for assembly
  • Validated the concept by 3D-printing and assembling some full-sized prototype segments

• Filed Provisional Patent Application for Bi-Directional Fish Pass Helix on 10/6/20
Key Results and Benefits Expected

- Utilized ORNL, PNNL Support and Literature to scope current fish passage costs and performance issues at low head hydropower projects
  - Mandatory Fish passage costs averaged $1 - $3 M per site with a range to $12 M
  - Expect the new Fish Pass Helix cost to be an order of magnitude less (~$250K)

- The Fish Pass Helix also may provide multiple improvements over conventional volitional fish passes (the baseline technologies)
  - Decreased Fish Passage Time
  - Decreased Fish Stress/Injury/Mortality Rates
  - Decreased Water needed for Fish Passage
  - Decreased Maintenance and Operations
  - Decreased Footprint at installation Site
  - Decreased Construction Time
  - No Sediment/Trash Buildup
Future Work

• Full-sized Prototype Fish Pass Helix in final design for fabrication
  • 3 ft Diameter X 15 ft long with water tanks above and below
  • Test with various fish species at PNNL Aquatics Research Laboratory this Fall
  • Seeking additional funding for expanded testing and future field sites

• Market Analyses and Cost Predictions/Comparison work with ORNL support continues
  • Teamwork to Develop “Commercialization Roadmap” and Strategy for Fish Pass Helix
Q&A