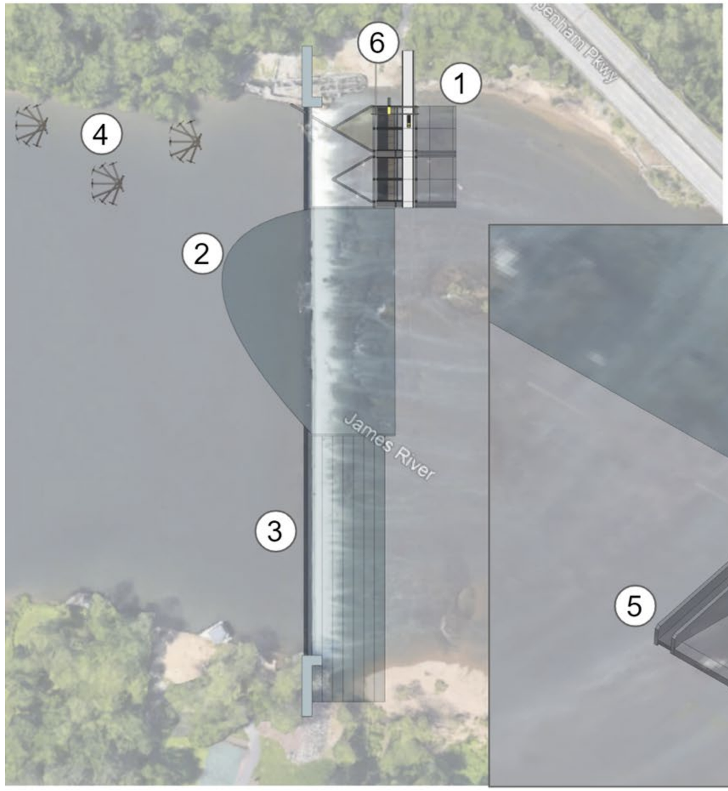
EE0008777 - Restoration Hydro: A Watershed Approach to Standard Modular New Hydropower



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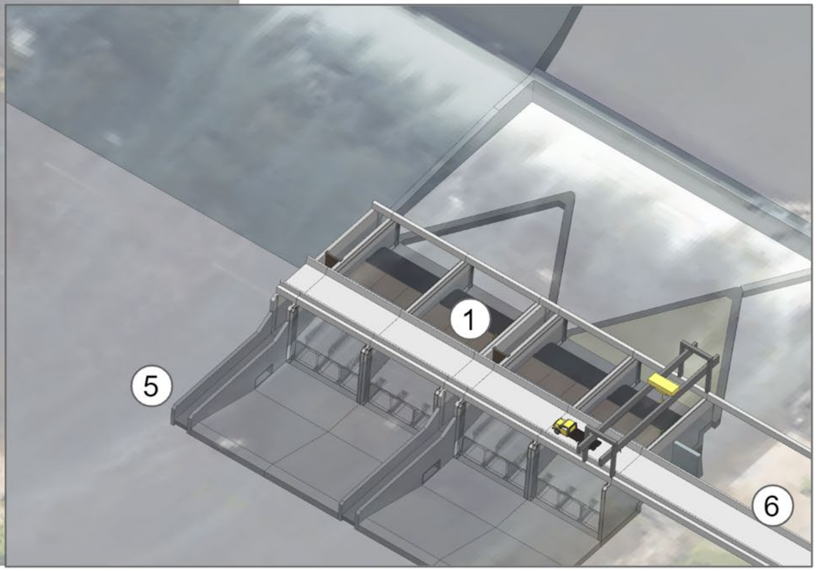

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July 27, 2022

Project Overview

Project Summary

The goal of this project is to complete design, engineering, construction sequence, and techno-economic analysis of a Restoration Hydro project. The project team proposes Restoration Hydro as a concept for low-head hydropower projects that feature standardized generation, passage, and foundation modules and produces significant environmental and societal benefits installed at a cost less than $3,500/kW. Guided by the principles of standardization, modularity and environmental compatibility, Restoration Hydro is grounded in a nature-based engineering approach for watershed restoration and a focus on cost reductions through reduced dewatering requirements, naturally-reinforcing civil designs, and modular construction.

Intended Outcomes

- Scalability: Demonstrate the scalability of these standardized, modular designs by showing applicability of design to different sites.
- Nature-Based Engineering: Apply natural analogues and best practices of natural restoration to passage and foundation module design. Natural ecosystem benefits must outweigh ecosystem impacts. Recreation co-benefits must outweigh recreation impacts.
- Modular Civil Works: Develop construction plans to demonstrate low-cost implementation capable of integrating appropriate low head turbine technologies.
- Low cost: Create a concept that has modeled costs demonstrating a path to total installed cost of <$3,500/kW.

Project Information

Principal Investigator(s)

- Abe Schneider

Project Partners/Subs

- Natural Systems Design
- McLaughlin Whitewater (Merrick)
- Small Hydro Consulting/ Wells Engineering
- UC Berkeley, Environmental Systems Dynamic Laboratory
- Oak Ridge National Laboratories

Project Status

Sunsetting: Completing July 31, 2022

Project Duration

- August 2018
- July 2022

Total Costed (FY19–FY21)

$1,376,519

Project Objectives: Relevance

Relevant Challenges	Relevant Approaches	Project Objectives	Long Term Outcomes
Limited opportunities for new affordable growth	Innovate new tech incorporating ecological + social objectives	Facility design concepts to achieve ecosystem restoration AND hydropower production	New, low-impact run-of-river project opportunities
Addressing environmental impacts	Leverage new manufacturing and materials	Scalable design concepts technically applicable to wide range of potential sites and power levels	Increased environmental resiliency of turbines and plants
Lack of access to information to support decision-making	Support testing and testing infrastructure	Visibility to cost-competitiveness	Mitigation of environmental impacts and curtailment via retrofits
	Develop monitoring and mitigation technologies	Application of and recommended improvements to the SMH EDES	Improved regulatory and design decision-making
	Establish metrics and support research on environmental impacts		
	Support development of systems and standards		

Project Objectives: Restoration Hydropower Approach

Unique approach equally values restoration and economically competitive energy generation

0. Hydro

- Does the reach meet the minimum hydrologic criteria?
  - 500 kW based on 25% of the 80% exceedance probability
  - Maximum 1,500 ft intake length

1. Protect

- Restoration hydro project instead of a new blocking dam?
- Restoration hydro project instead of traditional electricity generation?

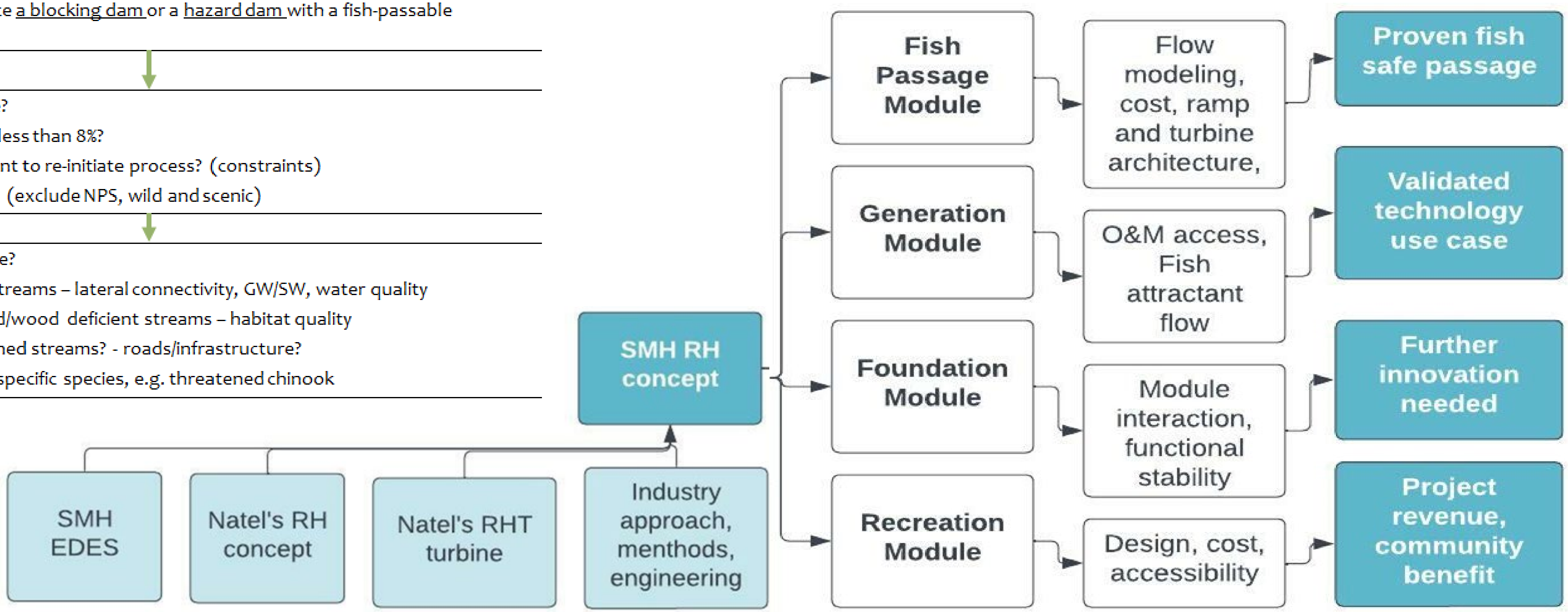
2. Re-Connect

- Opportunity to replace a blocking dam or a hazard dam with a fish-passable structure?

3. Restore Process and/or Improve Quality

- Is restoration feasible?
  - Stream gradient less than 8%?
  - Sufficient footprint to re-initiate process? (constraints)
  - Land ownership? (exclude NPS, wild and scenic)
- Is restoration valuable?
  - Restore incised streams – lateral connectivity, GW/SW, water quality
  - Restore simplified/wood deficient streams – habitat quality
  - Restore constrained streams? - roads/infrastructure?
  - Presence/use by specific species, e.g. threatened chinook

3 sites evaluated:
low head (4 m) alluvial pocket
low head (3 m) stream reach
moderate head (10 m) stream reach



Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- New morphology and draft algorithms for hydro site identification (alluvial pockets) having high potential for simultaneous watershed restoration, with hydropower development.
- New hydro facility design concepts integrating seamless downstream and upstream fish and sediment passage
- Current assessment of costs and trends in fish exclusion
- Hydropower generation modules may cost <$3500/kW, but additional funding will be needed to cover the cost of river-connecting elements (e.g. rock ramp).

Intended Outcomes:

- Paradigm shift in thinking: Hydropower can be river-connecting, not river-dividing
- Hydropower projects can be river restoration projects
- Facility design can simultaneously solve classic hydropower facility operating problems, while mitigating river degradation (e.g. fish safe turbines, integrated sediment passage)
- Concepts of Restoration Hydropower can apply to non-powered dams (NPD) as well as new stream-reach development (NSD) projects

Project Timeline

FY 2019 (9/19-12/19)

- Quantify and qualify site selection criteria.
- Identify drivers of foundation types.
- Site screening within the US.

FY 2020

- Focus on head control design: rock ramp construction, slope (fish passage, recreation, length vs cost)
- Refine selection criteria
- Generation module placement evaluation: in-channel vs bank, intake
- Initial conceptual design of Restoration Hydro with SMH principles applied
- Initial cost model based on the components of the conceptual design
- ORNL fish exclusion cost research
- Initial sediment and foundation module details

FY 2021

- Go/NoGo on rock ramp construction- selected a "rocks- in-a-box" method for cost savings and functionality
- GNG on final site selection: Primary site Bosher Dam, Clark Fork and John Sevier
- No-go: stopped work on Sevier- dam removal did not meet FOA objectives
- Go: Bosher Dam as a dam removal and new stream reach site: high restoration value; Dam removal and SMH RH has high applicability

FY 2022

- CFD modeling of generation module and complete design-informed a modification in the module placement (moved in-stream) and the rock ramp design
- Alluvial pocket white paper highlighting the value of the sites in SMH RH
- Final design completion: future work recommendation on innovation to the foundation module and rock ramp for reduced cost and novel engineering

Project Budget

Total Project Budget – Award Information		
DOE	**Cost-share**	**Total**
$1,000,000	$376,519	$1,376,519

FY19	FY20	FY21	FY22	Total Actual Costs FY19–FY22
Costed	**Costed**	**Costed**	**Costed**	**Total Costed**
$52,654	$381,668	$472,734	$138,726	$1,045,782

- The project budget stayed true from the original budget. It is expected that the full amount will be billed by each subcontractor in the grant.
- Internal to the budgets, more funding was spent on site selection than originally estimated. This funding was able to be reallocated internal to each subcontractors budget.
- No additional funding sources were required for the project. All funds were provided by DOE and Natel's cost share.

End-User Engagement and Dissemination

Restoration Hydropower benefits all river stakeholders: fisherpersons, Native Americans, recreational boaters, hydropower plant owners. Restoration Hydropower is an embodiment of principles of energy justice. Natel conducted both programmatic and voluntary stakeholder outreach in this project.

Programmatic stakeholder engagement:
An Independent Advisory Group (IAG) was created and carried out annual meetings facilitated by Kearns & West, reviewing the project from the perspectives of environmental agencies, electric utilities, hydro regulators, and the hydropower industry.

Voluntary stakeholder engagement:
The project team also conducted stakeholder engagement with agency representatives both on general issues such as fish protection standards and trends, as well as on site specific issues. For example, the project team organized a meeting with a group of stakeholders regarding the Bosher site and continued to maintain contact with them throughout the project.

The project team has shared the Restoration Hydropower concept widely, in conferences, working groups, on the Natel website, and in the **Uncommon Dialogue**.

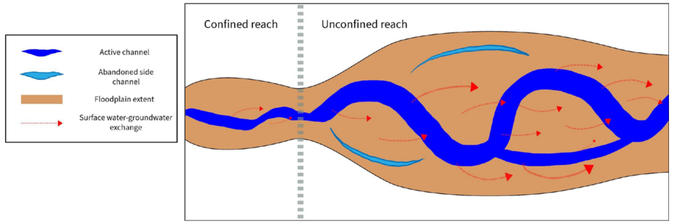
Performance: Accomplishments and Progress

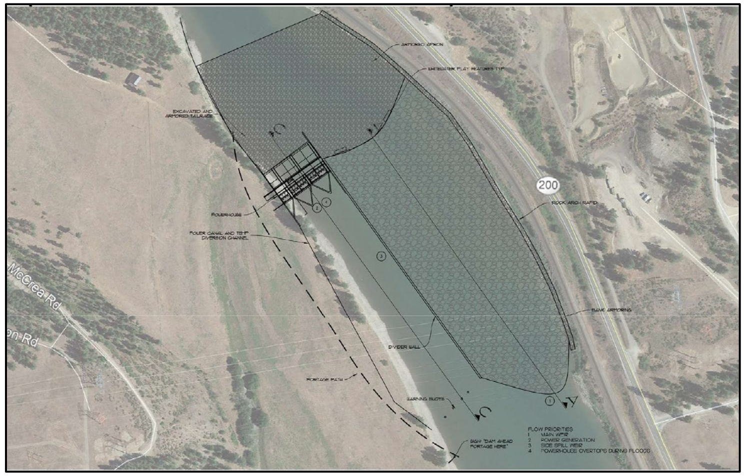
Identified new geomorphological archetype (alluvial pockets) and associated site identification algorithm enabling simultaneous watershed restoration and new hydropower development

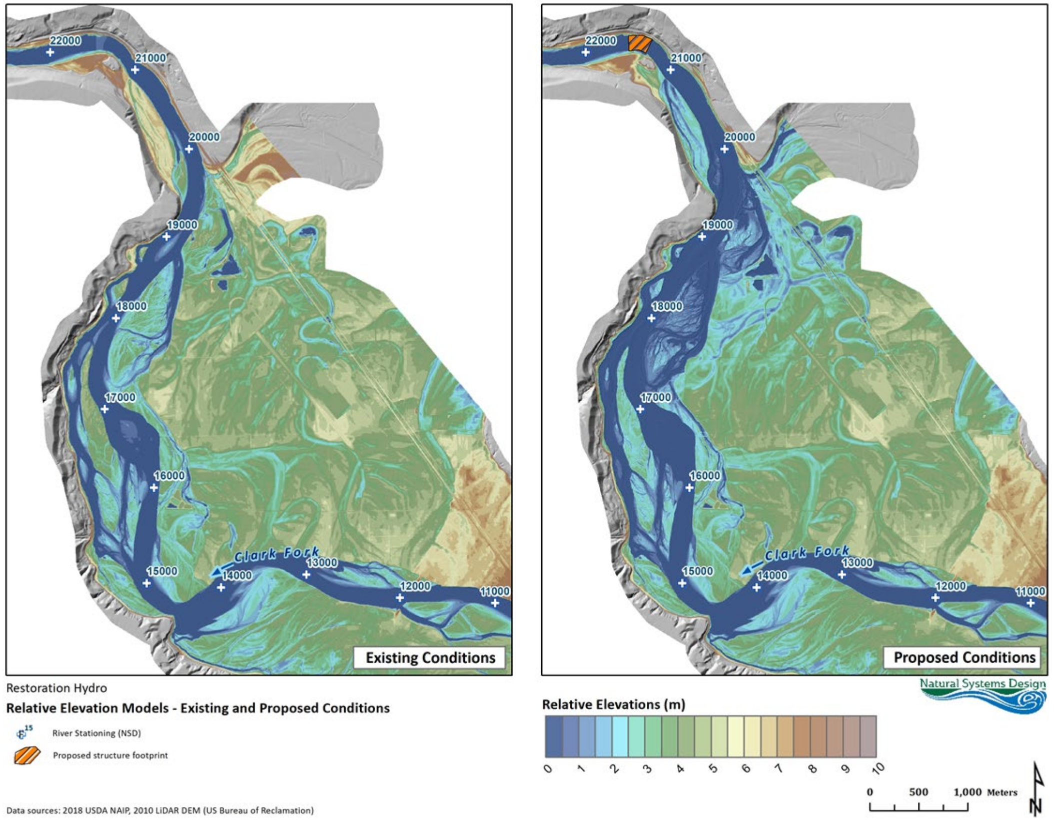
Clark Fork: Increase water storage and floodplain habitat

raise alluvial pocket floodplain upstream of the site ~10’
inundate 82 ha of additional floodplain
reconnect 9km of relic side channels
restore ~650 ac-ft of water storage within shallow alluvial aquifer

4.3 MW / 22.6 GWh hydropower



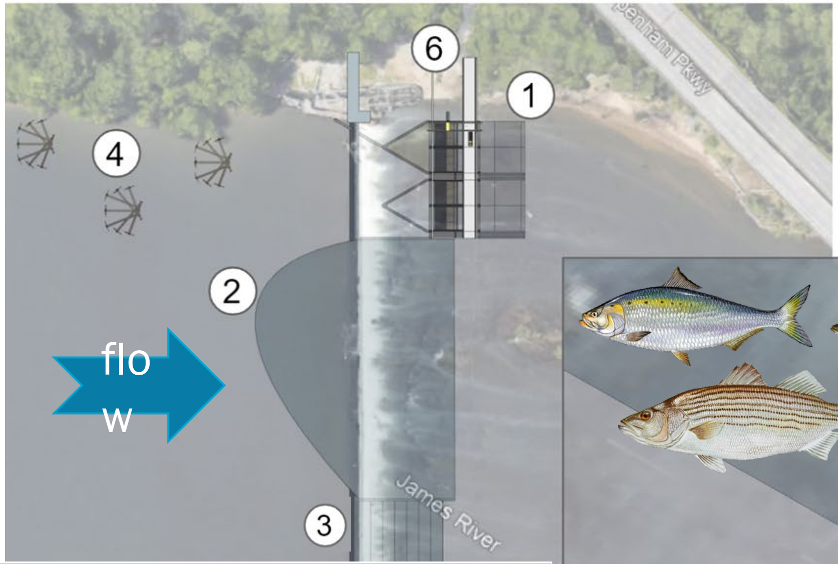




Performance: Accomplishments and Progress

- Created facility site design concept for river-connecting hydropower
- Demonstrated integration of multiple modules to accomplish environmental and energy objectives

<u>Bosher: 3.5 MW \$3500/kW not including rock ramp (\$10M)</u>
reconnect river, remove recreational hazard, improve bedload transport



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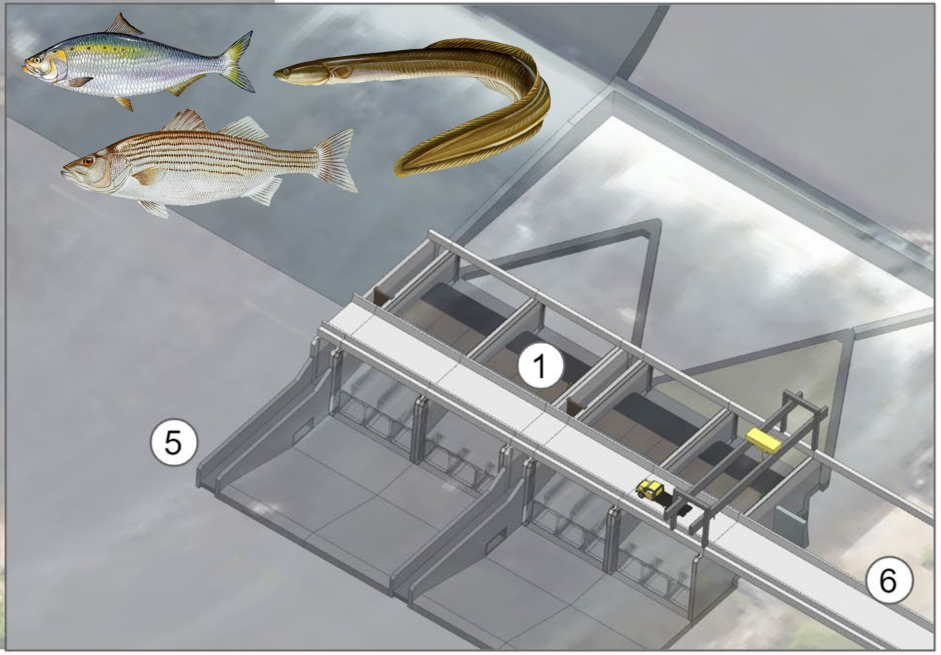
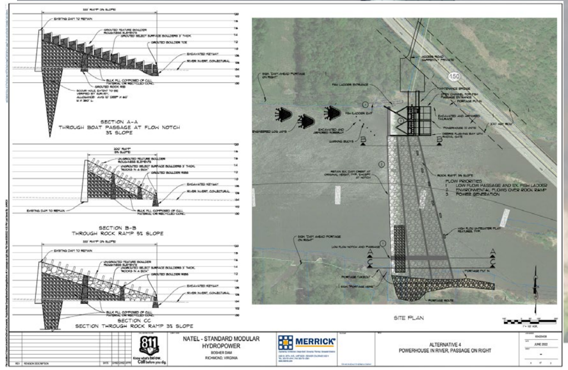
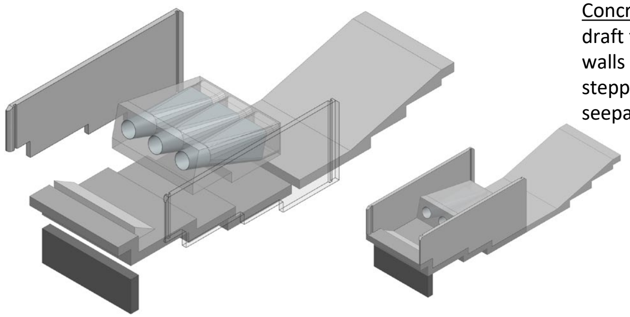




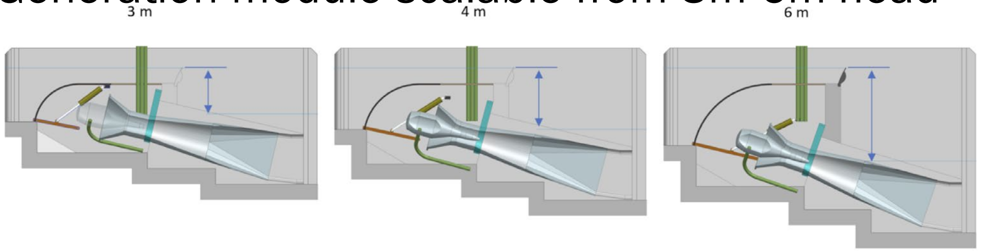
Generation module foundation:



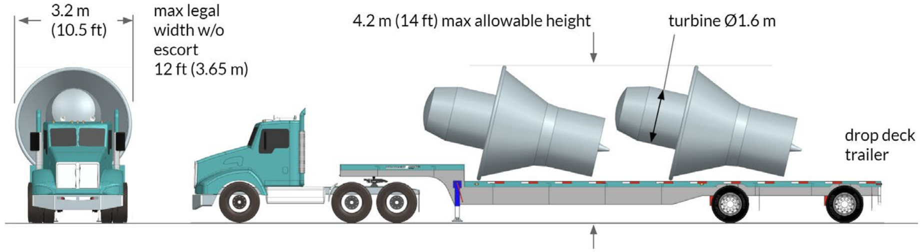
Concrete quantities:

draft tubes	238 m^3	(8400 ft^3)
walls	160 m^3	(5700 ft^3)
stepped foundation	530 m^3	(18700 ft^3)
seepage cutoff	42 m^3	(1500 ft^3)

Generation module scalable from 3m-6m head



Transportable turbine-generator modules

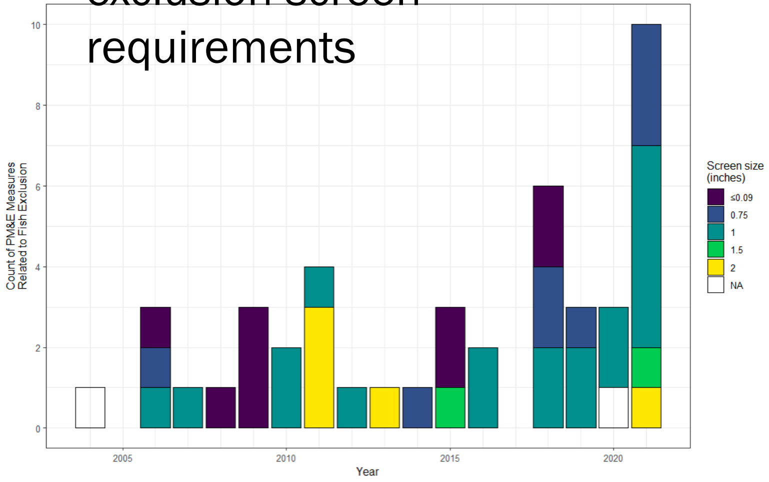


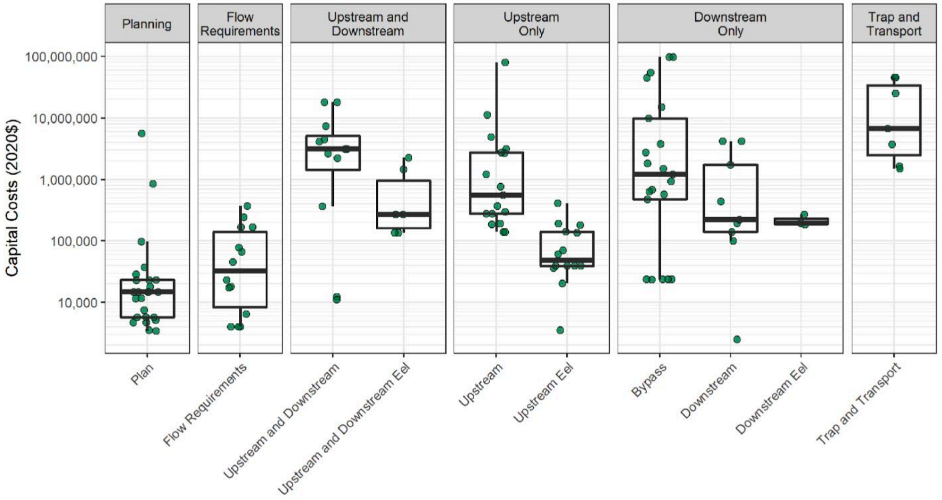
Performance: Accomplishments and Progress (cont.)

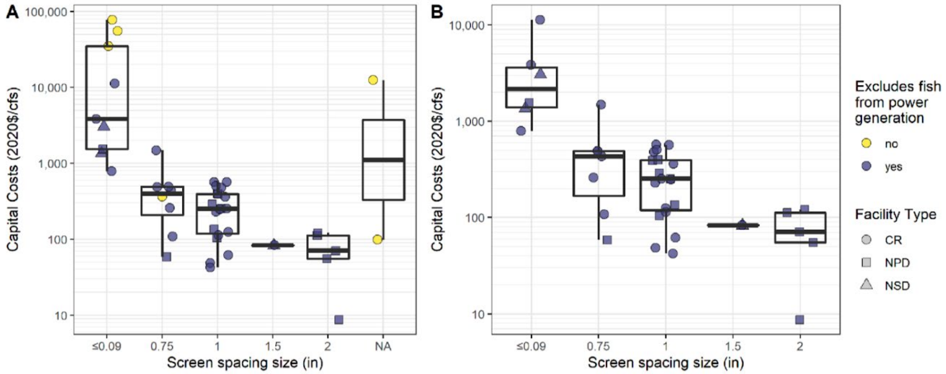
Authored two technical papers:

- Fish exclusion status and trends
- Alluvial pocket site identification

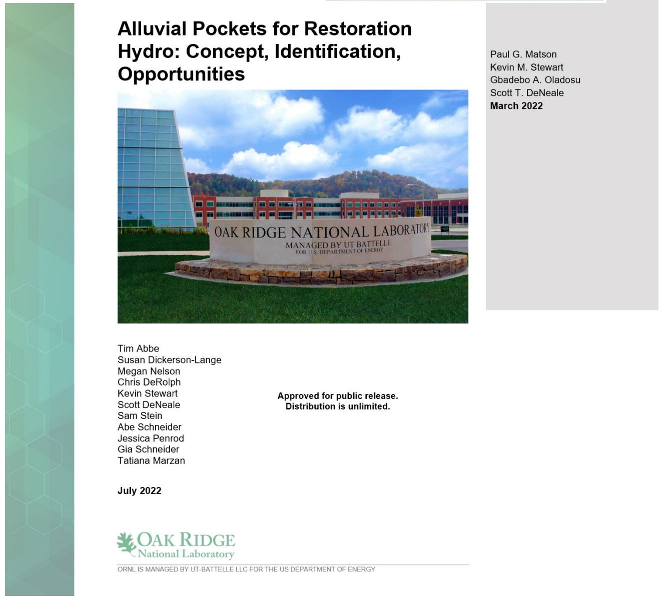
Increasing prevalence of fine exclusion screen requirements







Fine screens can add $100-1000/kW to the project capital cost and will create additional operating and maintenance costs and potentially lost generation due to additional head loss, compared to fish racks.



Future Work

The project is concluding. However, potential future work could include:

- Demonstration of Restoration Hydropower in real-life project
- Adaptation of Restoration Hydropower SMH concepts to NPD sites
- Development of rock ramps, both improving technical performance (upstream fish passage efficacy, operation and maintenance cost, resilience to ice and other debris)
- Development of facility-scale CFD modeling methods, including modeling of hyporheic exchange
- Advancement of alluvial pocket site identification algorithm; inclusion in tools such as SMH or NPD Explorer

Q&A