



## Fishway Entrance Palisade

DE-EE0008340.000

Hydropower Program

October 9<sup>th</sup>, 2019

Kevin B. Mulligan<sup>1</sup>, PhD and  
Richard N. Palmer<sup>2</sup>, PhD

1. US Geological Survey
2. University of Massachusetts Amherst

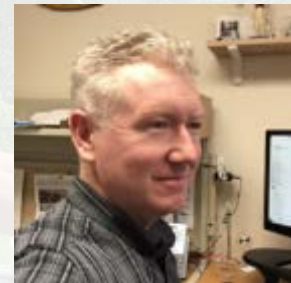


## PROJECT TEAM MEMBERS

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# Project Overview

Project Summary	Project Information
	Project Principal Investigator(s)
	Richard Palmer, University of Massachusetts Amherst
	WPTO Lead
	Carrie Noonan Nicholas Massey
	Project Partners/Subs
Project Objective & Impact	<ul style="list-style-type: none"><li>• Kevin Mulligan, U.S. Geological Survey</li><li>• Brett Towler, U.S. Fish and Wildlife Service</li><li>• Alex Haro, U.S. Geological Survey</li><li>• Bjorn Lake, National Marine Fisheries Service</li></ul>
	Project Duration
	<ul style="list-style-type: none"><li>• September 1, 2018</li><li>• March 31, 2020</li></ul>

## Project Summary

Fishway attraction is a common problem at hydroelectric dams. Competing flows (e.g. turbine discharge, spillage) and the small size of the entrance relative to width of the river can lead to migratory delays and ineffective fishway performance.

**Can the fish find  
the fishway?**

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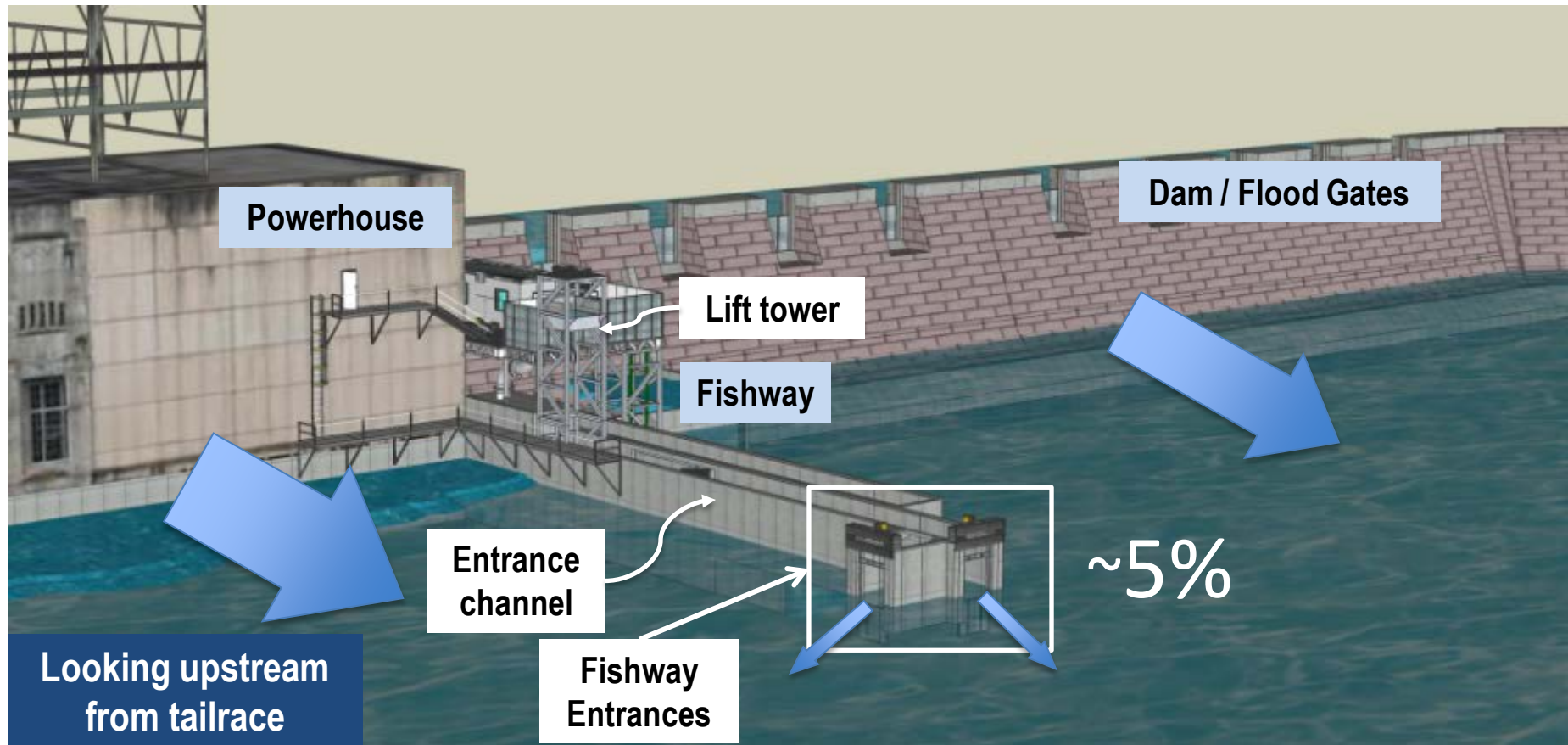
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# Fishway Entrance Example



Sketch created by Brett Towler,  
U.S. Fish and Wildlife Service

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EX HYDROELECTRIC  
COMPANY

Conventional  
Entrance  
Channel

Plan View

Flow from  
ladder / lift

Auxiliary Flow  
for Attraction  
Water

Floor Diffuser

Wall Diffuser

ENTRANCE CHANNEL

Entrance Gate

## Plan View

The diagram illustrates the flow of water and fish through the attraction system. It shows a vertical flow from the top, where water enters from a ladder or lift. This water then flows through a floor diffuser, which is a grid-like structure. From the floor diffuser, the water flows into a wall diffuser, which is a curved structure. The water then flows into an entrance channel, which is a narrow passage. Finally, the water flows through an entrance gate, which is a red line at the bottom of the channel. Fish are shown swimming in the water, following the flow of the water.

Flow from ladder / lift

Auxiliary Flow for Attraction Water

Floor Diffuser

Wall Diffuser

ENTRANCE CHANNEL

Entrance Gate



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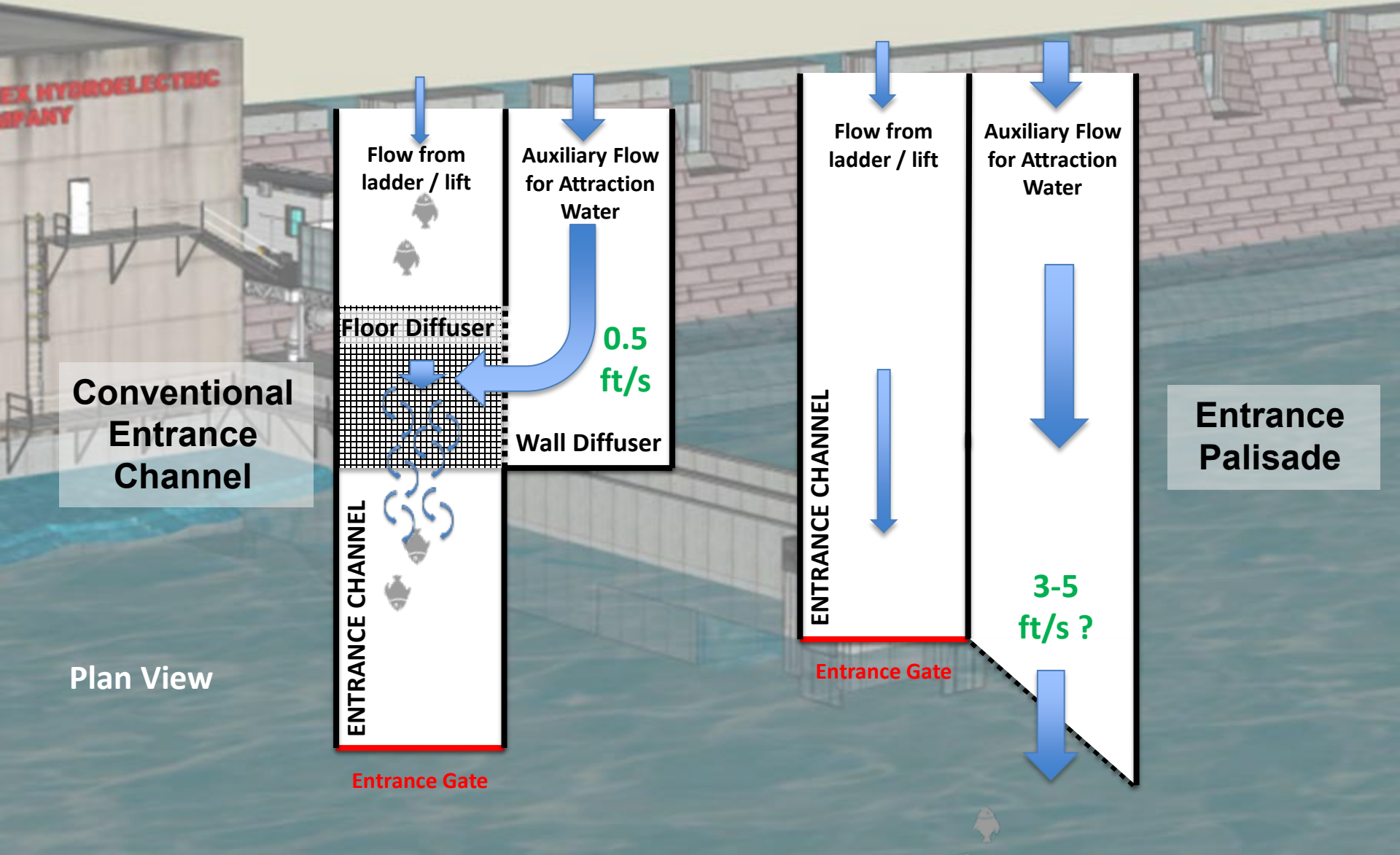
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# Fishway Entrance Channel

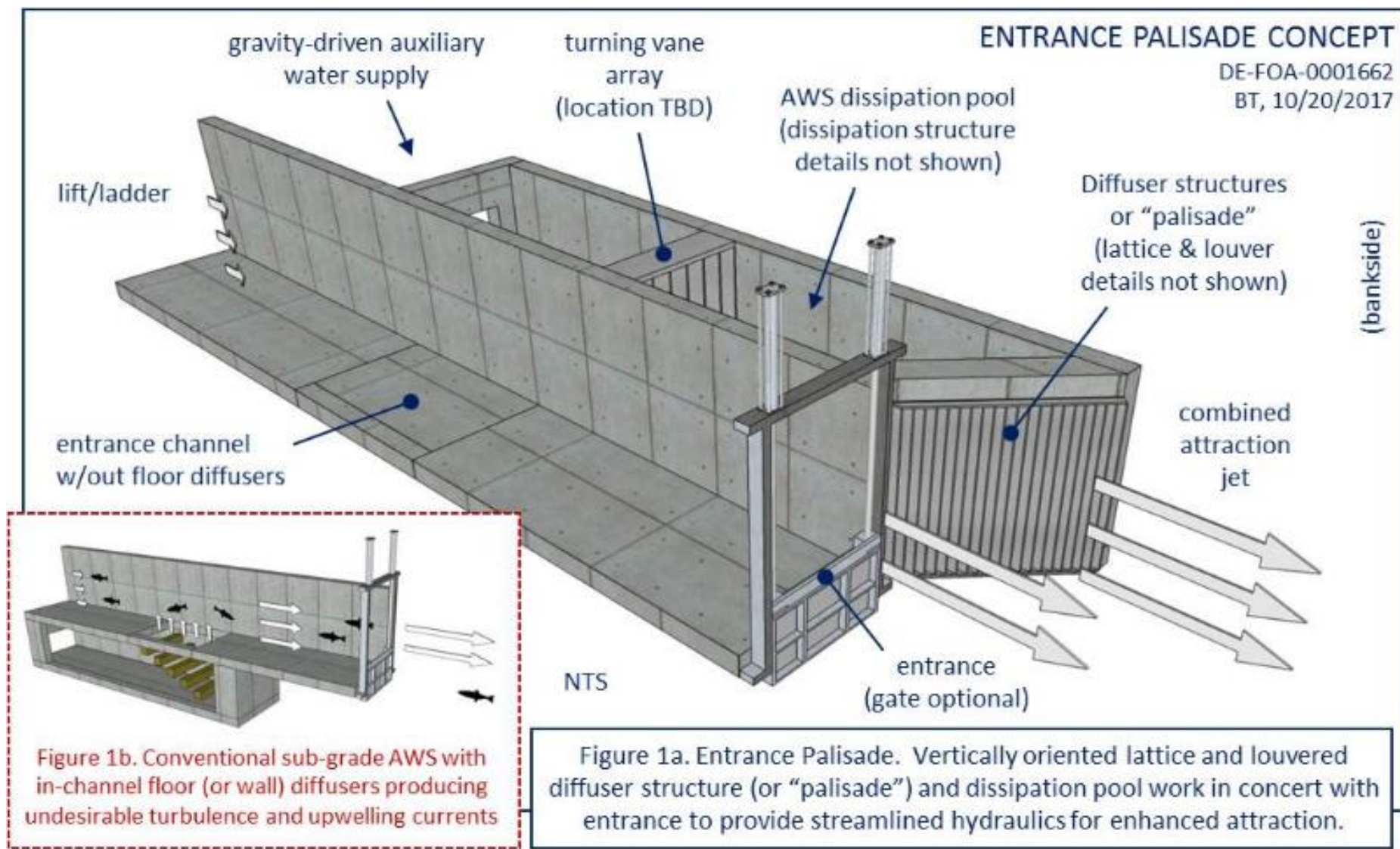
## Conventional vs Entrance Palisade



Conventional  
Entrance  
Channel

Plan View

Entrance  
Palisade





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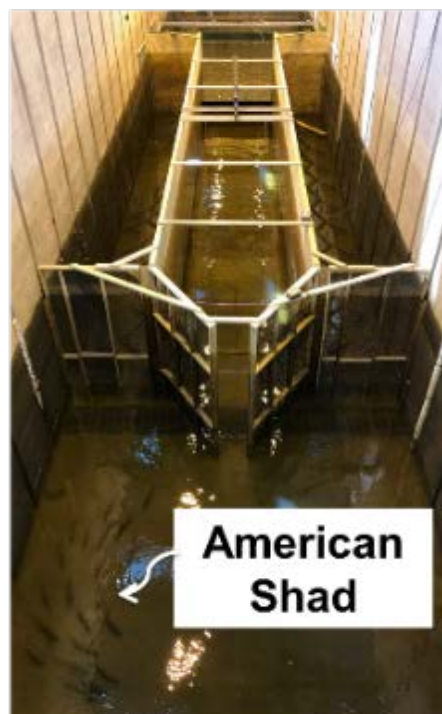
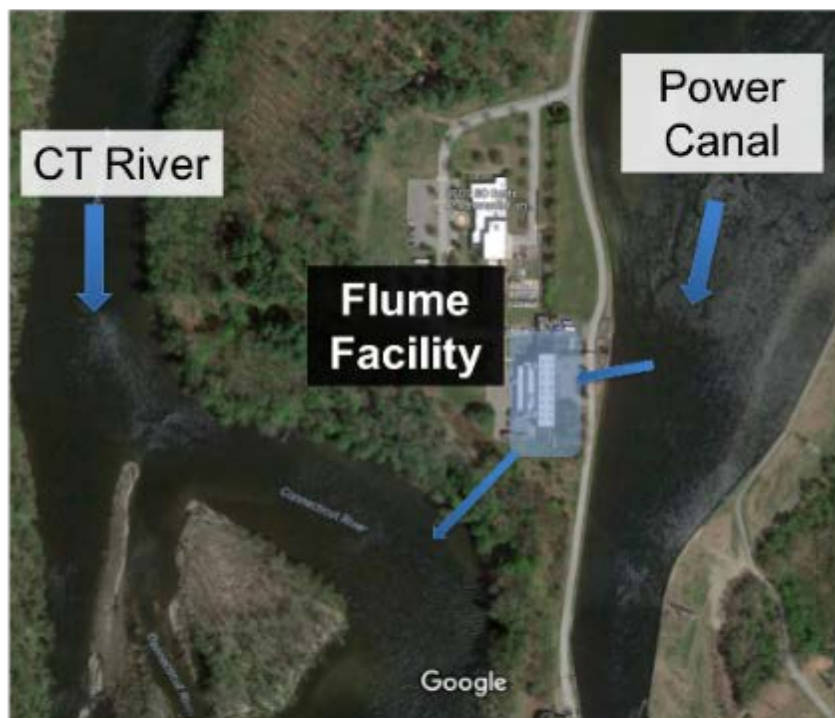
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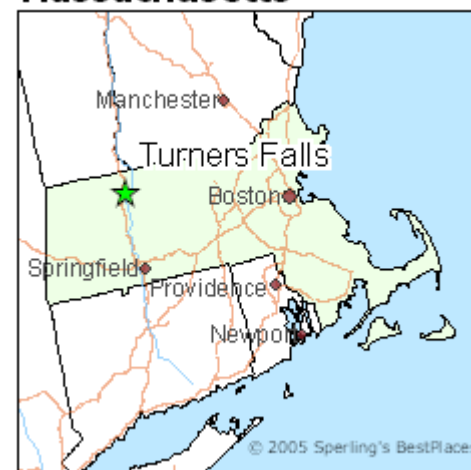
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## USGS-LSC Conte Flume Facility



### Massachusetts



### Flume Facility Details

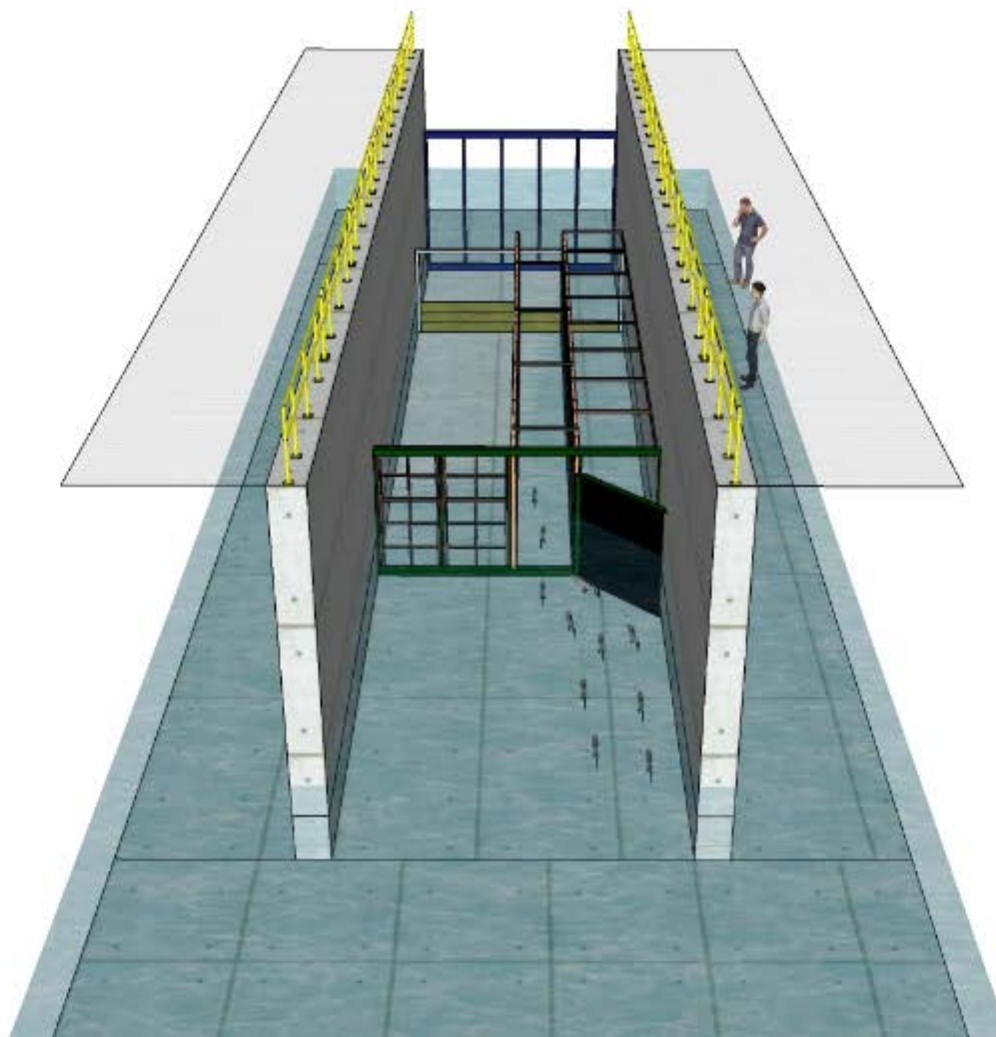
- Multiple large flumes, largest is 6 m. wide
- Flow capacity of 10 cms

Build → Collect Fish → Experiment

# Management and Technical Approach

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy





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## Project Objective & Impact

The Entrance Palisade is an innovative fish passage structure that helps fish move upstream efficiently while reducing the costs of maintenance and construction. The design is being evaluated with American shad in the Northeast USA, but will likely be applicable to a wider variety of migratory fish and at locations throughout the USA.

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## Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

Technology R&D for  
Low-Impact  
Hydropower Growth

R&D to Support  
Modernization,  
Upgrades and Security  
for Existing Hydropower  
Fleet

Understand, Enable,  
and Improve  
Hydropower's  
Contributions to Grid  
Reliability, Resilience,  
and Integration

## Environmental R&D and Hydrologic Systems Science

Develop technologies  
and strategies that  
avoid, minimize, or  
mitigate ecological  
impacts

This project was awarded through DOE Funding Opportunity Announcement 1662: Innovative Solutions for Fish Passage at Hydropower Dams, Topic Area 1 which focused on gathering information and data on the effects innovative fish passage technologies have on fish. The Entrance Palisade design aids in reducing the impact of dams on river connectivity for fish through improving the efficiency of fishway entrances. Additionally, this new technology holds potential to be a more cost-effective choice as compared to standard systems in practice.



## Total Project Budget – Award Information

DOE	Cost-share	Total
\$353K	\$35K	\$388K

**FY17**

**FY18**

**FY19  
(Q1 & Q2 Only)**

**Total Actual Costs  
FY17–FY19 Q1 &  
Q2 (October 2016  
– March 2019)**

**Costed**

**Costed**

**Costed**

**Total**

**\$0K**

**\$0K**

**\$46K**

**\$46K**

- **Challenges**

- 35-day federal government shutdown
- Unknowns of fish behavior
- State and federal regulatory requirements are the only significant barriers to market penetration.

- **Success Factors**

- The resource agencies (e.g. NOAA, USFWS) are science-based, requiring experimental verification of effectiveness of the Entrance Palisade concept.
- Must prove equally protective and less costly than conventional floor/wall diffusers. The Energy Policy Act (2005) would allow hydro owners (FERC licensees) to advocate for this technology.

- **Management Approach**
  - Multiple project milestones and “go-no go” decision points
  - Established project team that consists of UMass, USGS, USFWS, and NOAA.
  - Regular project team meetings
  - Weekly PI, co-PI, and graduate student meetings
  - Established an Industrial Advisory Board to provide project feedback and aid in technology transfer
  - Several project deliverables

- **Target market for the Entrance Palisade**
  - Private, FERC jurisdictional hydroelectric facilities subject to statutory requirements of the Federal Power Act and Endangered Species Act.
  - Among those locations, the target market primarily includes run-of-river (or quasi run-of-river) hydroelectric facilities on rivers with threatened, endangered and trust species.

- **Cost savings to the hydropower industry in both construction and maintenance.**
  - Reduced diffuser size
  - Reduced sub-grade excavation
  - Elimination or mitigation of contingencies attributable to the additional duration of sub-grade, in-river work and the associated flood risks.
  - Avoidance of possible dam safety issues
  - Simpler and less costly inspections, cleaning, and repairs



- **The Industrial Advisory Board consist of several hydroelectric company representatives that will aid in the development of the Entrance Palisade.**
- **Primary Objectives:**
  - Engage industry and communicate the product potential to development partners,
  - Ensure technology transfer occurs,
  - Balance design goals of overall EP performance with economic costs,
  - Evaluate the product market place, and
  - Identify and implement a field test following completion of the laboratory project
- **Board to meet periodically between August 2019 and the end of the project.**

## INDUSTRIAL ADVISORY BOARD MEMBERS

**Shana Bernall**, Research Biologist, Avista, (406) 847-1293,  
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**Richard Dill**, Compliance Specialist, Brookfield Renewable, 207-852-299,  
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**Paul T. Jacobson**, Ph.D., Senior Technical Leader, Electric Power Research Institute, 410-489-3675, [pjacobson@epri.com](mailto:pjacobson@epri.com)

**Shane Scott**, Owner, S. Scott & Associates LLC, 360-601-2391,  
[shane@sscottandassociates.com](mailto:shane@sscottandassociates.com)

**Ralph D. Nelson, Jr.**, P.E., M.ASCE, Senior Civil Engineer, HDR, 207.239.3837,  
[Ralph.Nelson@HDRinc.com](mailto:Ralph.Nelson@HDRinc.com)

**Alan W. Stuart**, Senior Project Manager, Duke Energy Carolinas, LLC, Water Strategy, Hydro Licensing and Lake Services, 980-373-2079,  
[Alan.Stuart@duke-energy.com](mailto:Alan.Stuart@duke-energy.com)

- Conference presentations (e.g., American Fisheries Society)
- Journal publications
- Potential resource agency (e.g. USFWS, NOAA) fish passage criteria
- Social Media

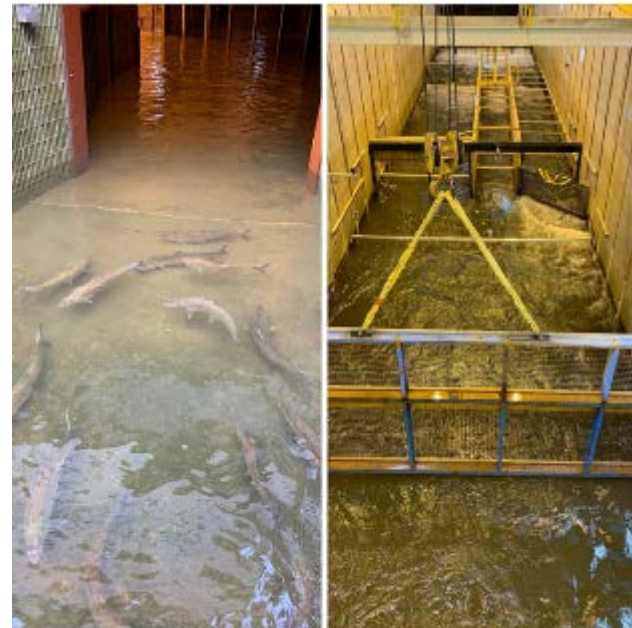


**USGS Leetown Science Center**

Yesterday at 3:24 PM • 🌐

## Researching American Shad Passage at the USGS-Conte Lab

This past spring, the USGS-Conte Lab studied passage of American shad through a new type of fishway entrance, called the Entrance Palisade. We brought in 1400 shad over a seven-week period from a fish lift on the Connecticut River to



👍 You,

and 20 others

4 Shares

- Auxiliary water system database
- First generation prototype design that utilizes an angled louver as the diffuser. These include vertical slats angled parallel to the auxiliary channel flow set at a spacing of  $\frac{3}{4}$ ".
- A hydraulic evaluation of the Entrance Palisade and wall diffuser treatments in a 1:8 scale model was performed.
  - The data collected was used to inform the experimental design in the biological evaluation.
- The behavioral evaluation of the Entrance Palisade was performed in May and June of 2019. Approximately 25 trials were conducted with 30 American shad per trial that evaluated the effect of several treatments.



# Flume Facility Set-Up

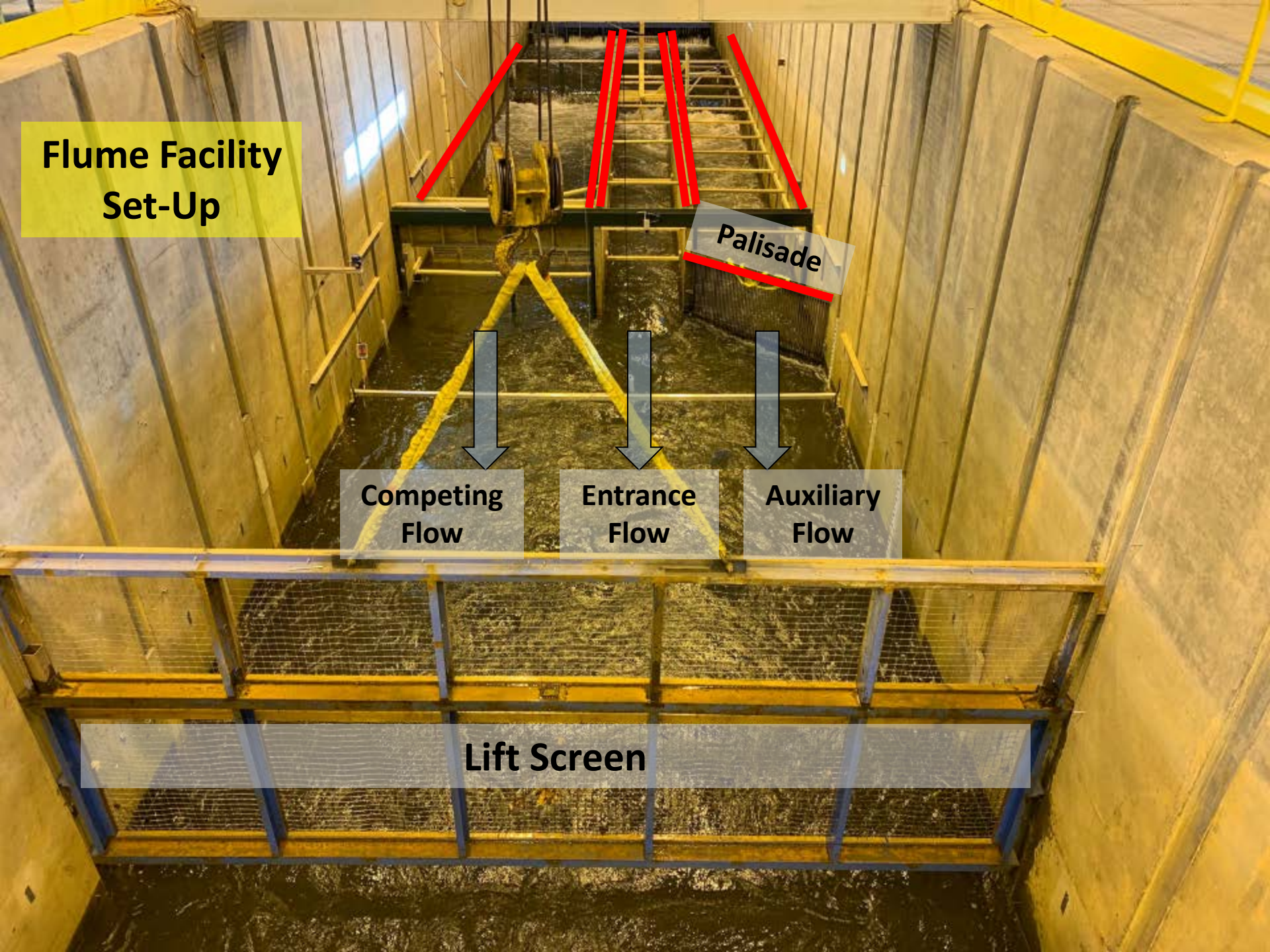
Palisade

Competing Flow

Entrance Flow

Auxiliary Flow

Lift Screen







The image shows a large, rectangular concrete tank filled with water. A yellow crane with a pulley system is suspended over the tank. A yellow rope is attached to the crane and extends into the water. A red horizontal line is drawn across the water surface. Several blue squares are placed along the red line and near the crane. The tank is surrounded by concrete walls and has a metal grate floor. The text 'PIT Antennas for Tracking Fish' is overlaid on the left side, and 'Video Cameras' is overlaid on the right side.

**PIT Antennas for  
Tracking Fish**

**Video Cameras**



# Treatments

Competing  
Flow

Fixed @  
1 fps

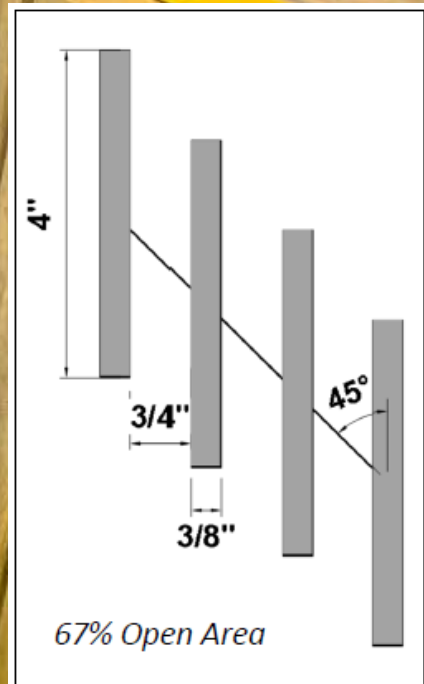
Entrance  
Flow

Fixed @  
4 fps

Auxiliary  
Flow

T1: 3 fps  
T2: 4 fps  
T3: 5 fps

Total of 18 trials  
(6 per treatment)





Competing Flow

1 fps

Entrance Channel

4 fps

Auxiliary Channel

3 fps

2019-06-04 07:53:43



**Treatment 1: Palisade Velocity < Entrance Channel Velocity**



Competing Flow

1 fps

Entrance Channel

4 fps

Auxiliary Channel

4 fps

2019-06-05 07:58:17



**Treatment 2: Palisade Velocity = Entrance Channel Velocity**



Competing Flow

1 fps

Entrance Channel

4 fps

Auxiliary Channel

5 fps

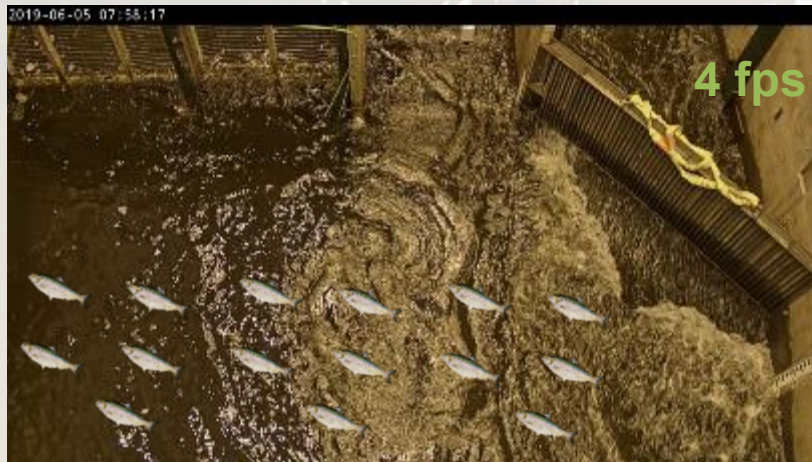
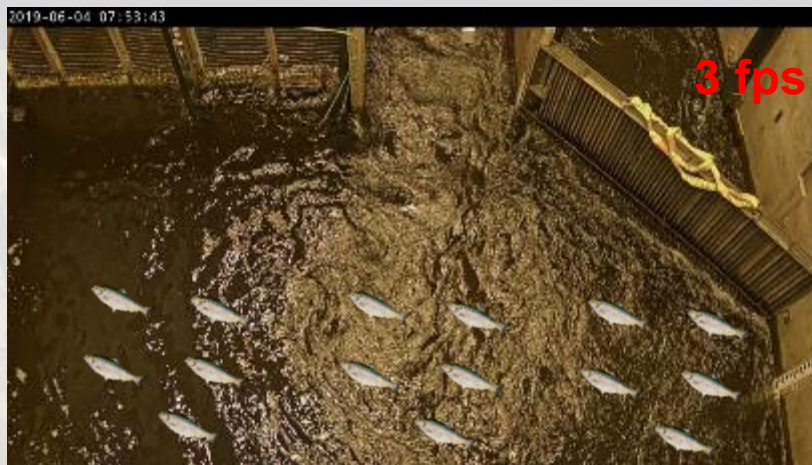
2019-06-04 13:11:07



**Treatment 3: Palisade Velocity > Entrance Channel Velocity**



# PRELIMINARY RESULTS



**Entrance Efficiency = 70 %**

Minimum = 35 % @ 14.4 °C

Maximum = 90 % @ 18.5 °C

**Entrance Efficiency = 62 %**

Minimum = 23 % @ 14.6 °C

Maximum = 93 % @ 18.6 °C

**Entrance Efficiency = 59 %**

Minimum = 20 % @ 14.4 °C

Maximum = 78 % @ 18.5 °C

- Velocity & turbulence data collection throughout the flume for each of the treatments (ongoing)
- Data analysis of spring 2019 trials (ongoing)
- **Six month project extension appears likely**
  - End date would change from March 31 2020 to Sept 30 2020
  - Would allow for more trials with migratory fish
    - American shad, river herring, lamprey, white sucker)
  - Modifications to the palisade diffuser (e.g. angle, slat design)





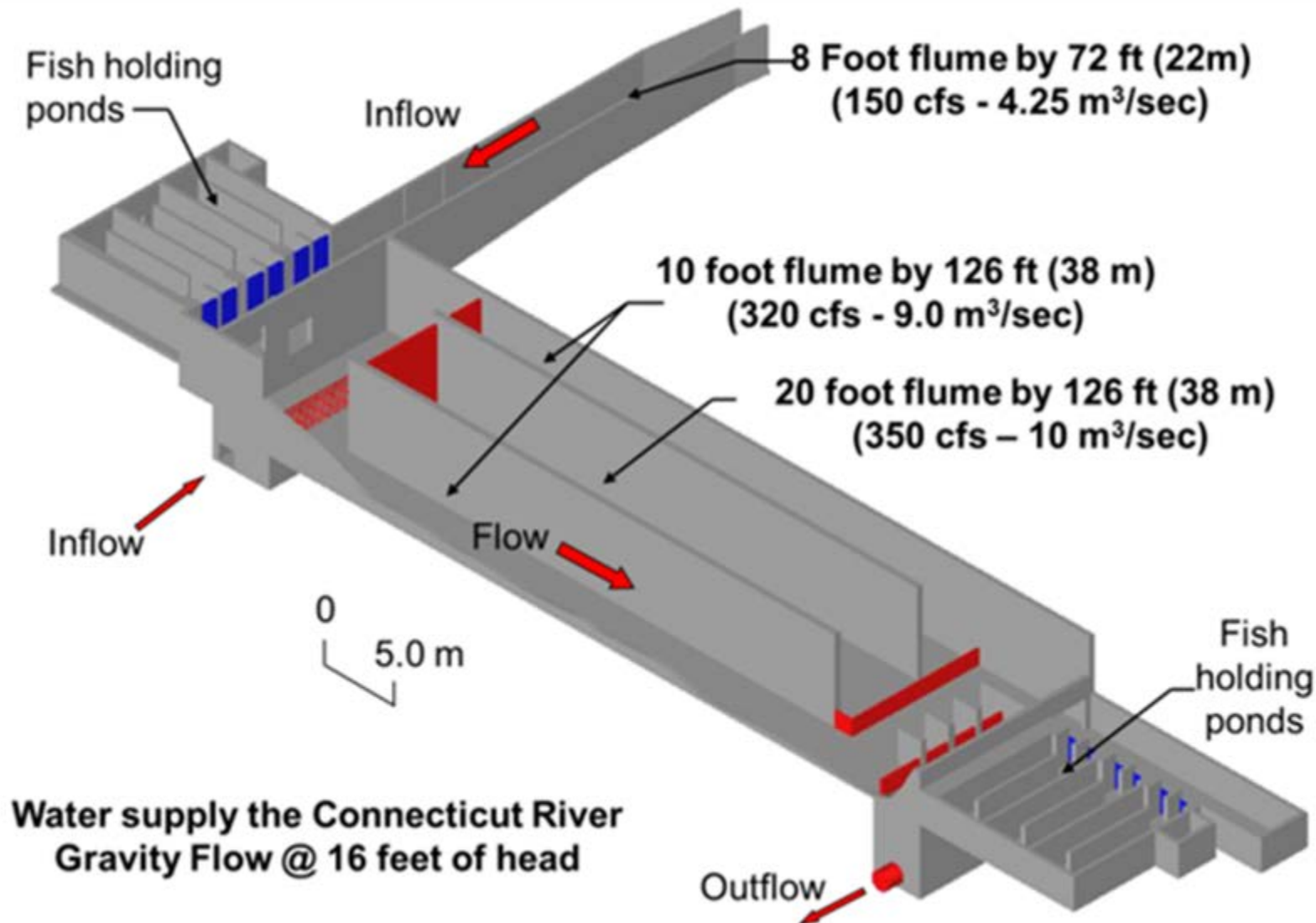
Questions?

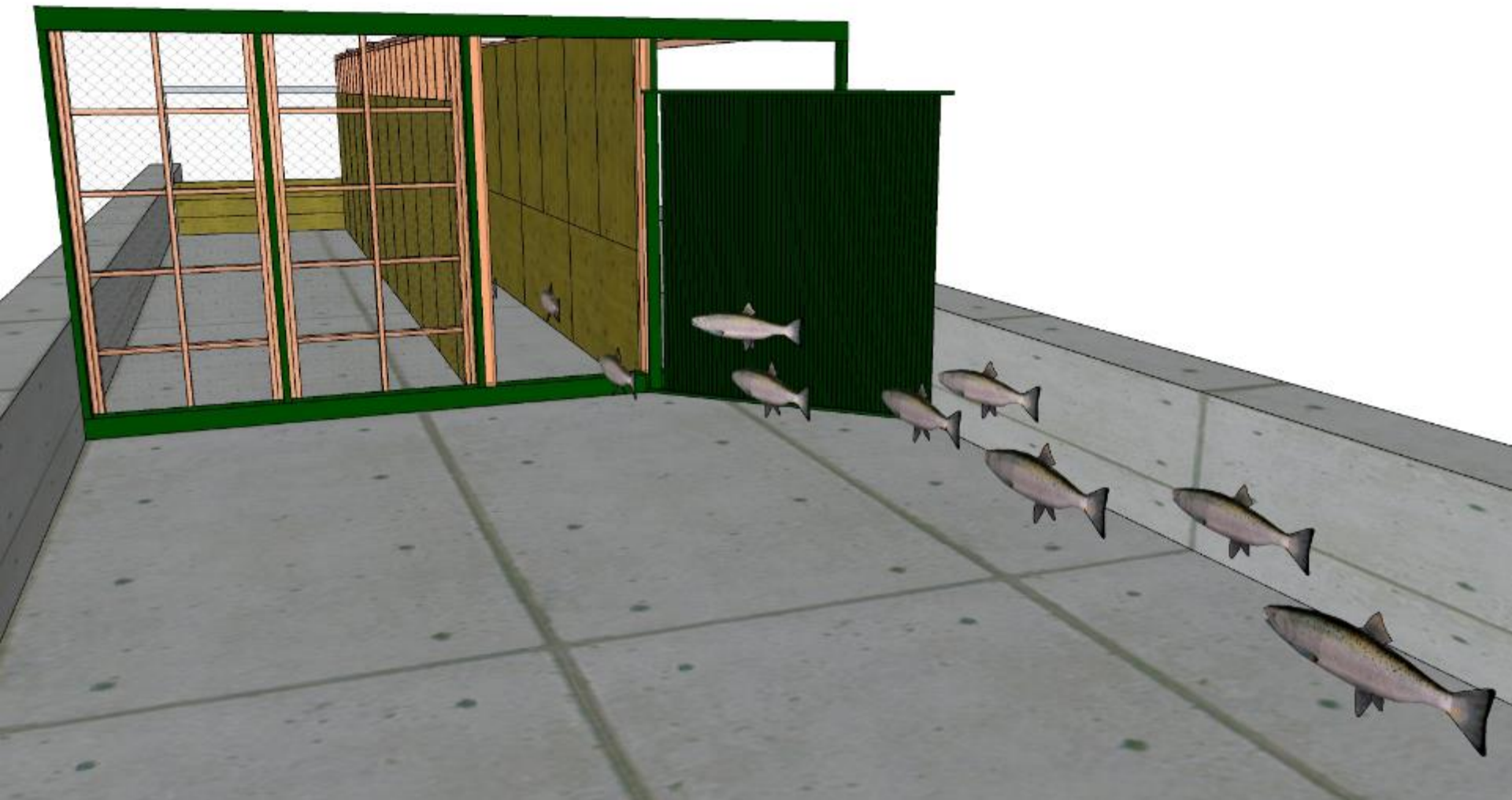


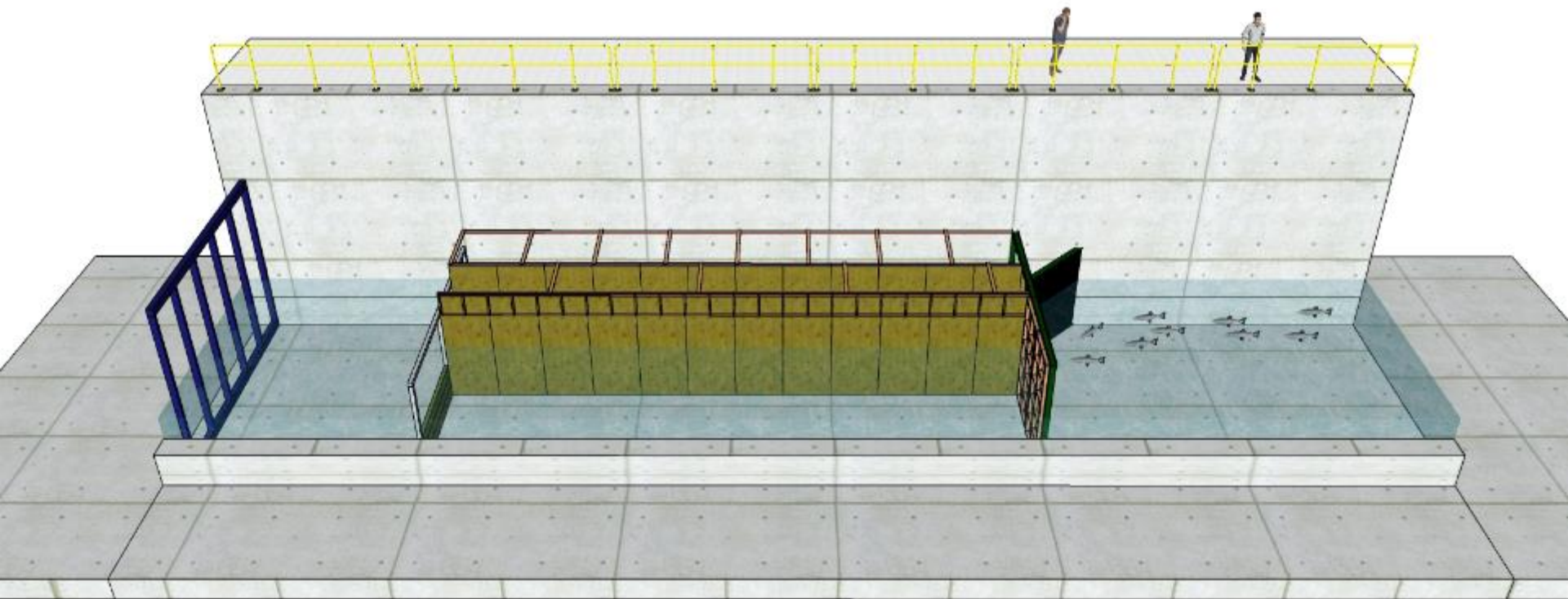
# EXTRAS



# Management and Technical Approach



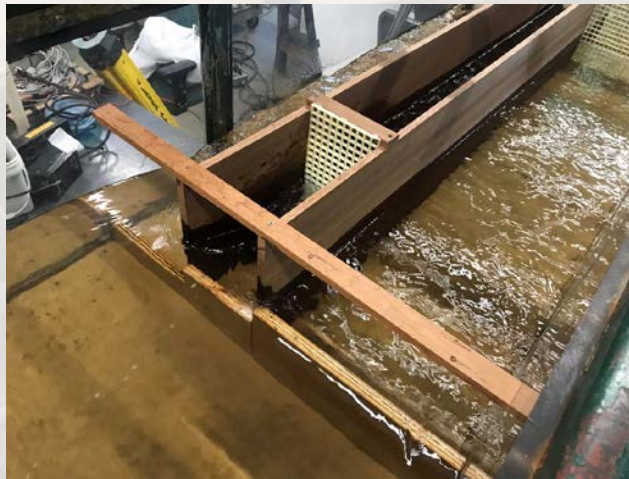






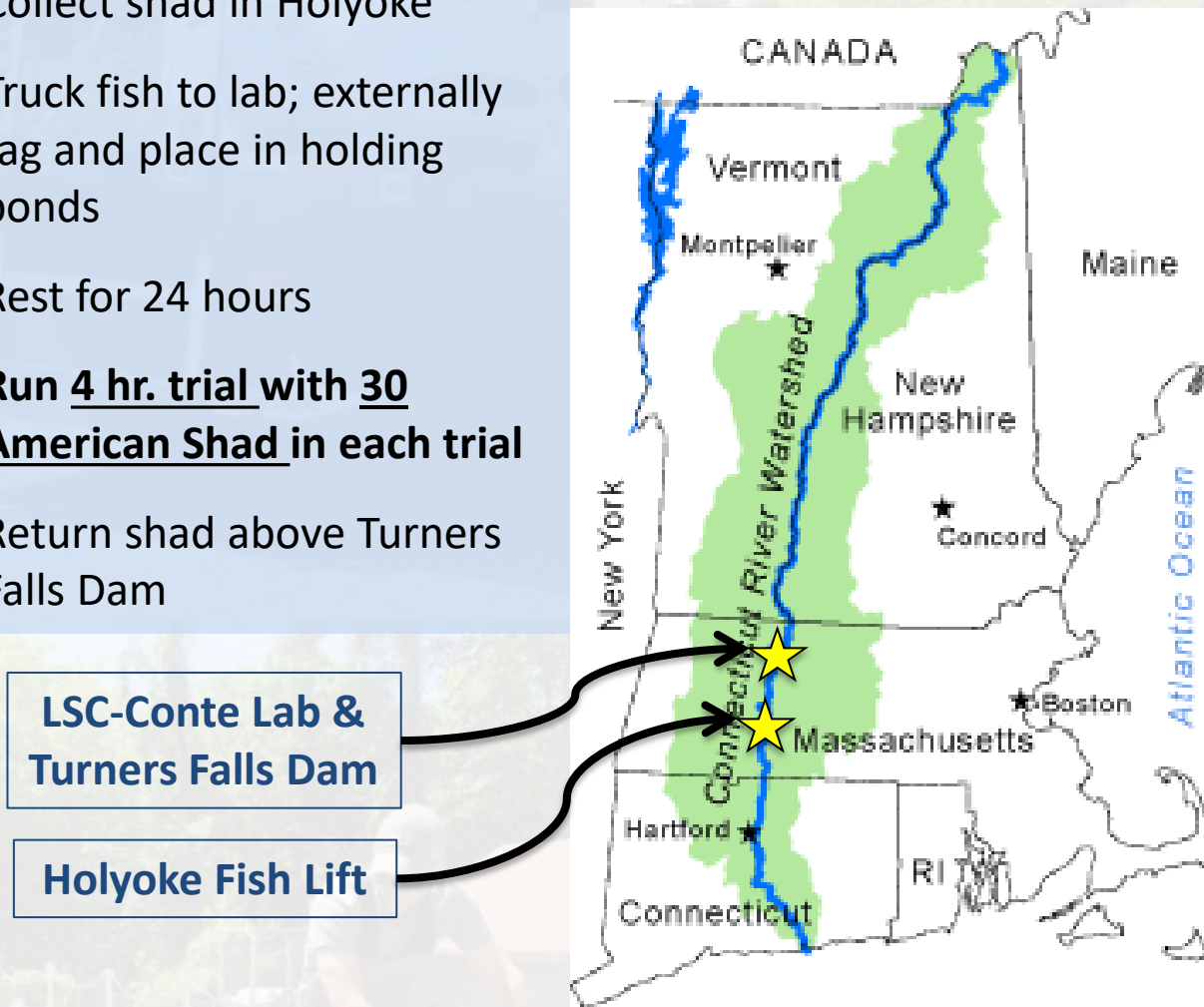
# Hydraulics Laboratory

## 1:8 Scale Model



# American Shad Collection

- Collect shad in Holyoke
- Truck fish to lab; externally tag and place in holding ponds
- Rest for 24 hours
- **Run 4 hr. trial with 30 American Shad in each trial**
- Return shad above Turners Falls Dam



**Approximately 1,350 shad were collected for this study**





Holyoke Fish Lift Sampler





**Tank #2**

rectangular  
connection  
between tanks  
for counting

**Release into truck's tank**

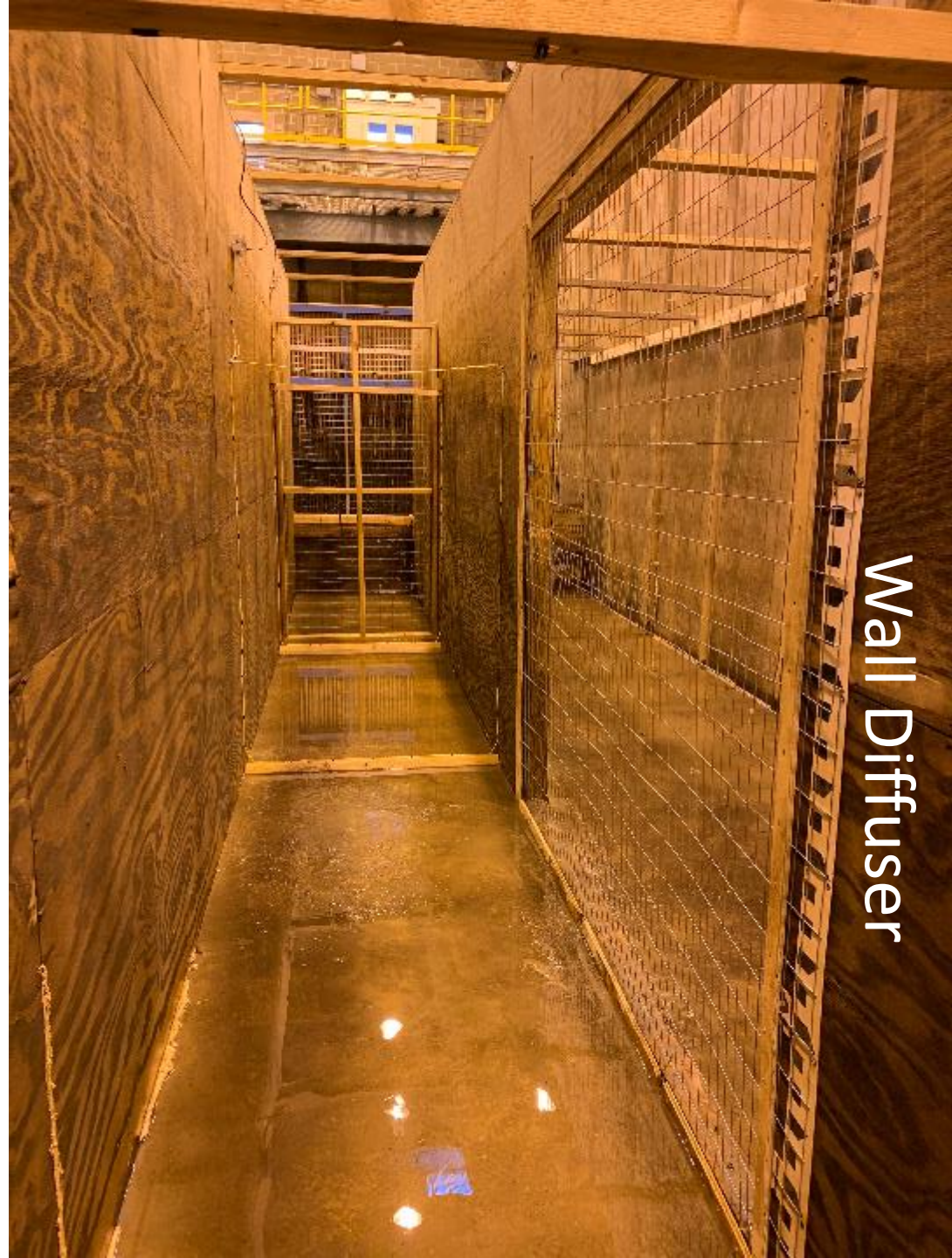
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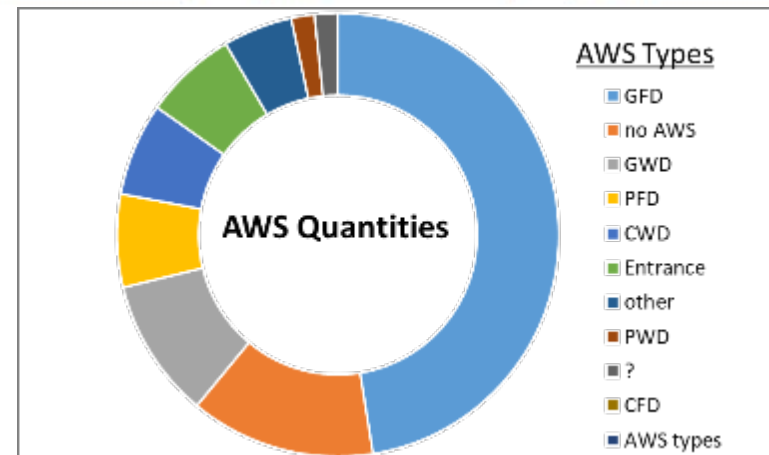
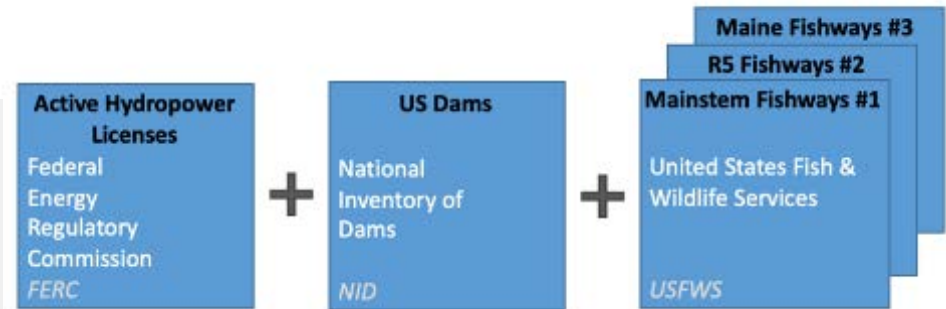
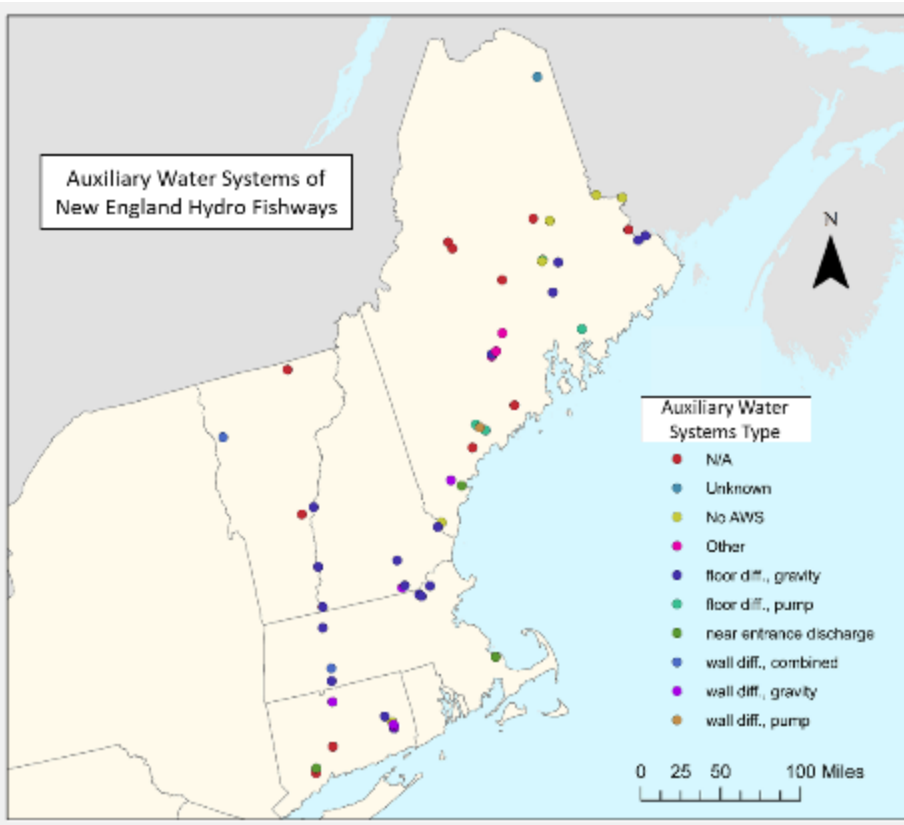
## Two Treatments

- Wall Diffuser Velocities of 0.5 and 1.0 fps

6 Trials, 30 Shad Per Trial



# Auxiliary Water System Database



AWS types:

GFD – Gravity Floor Diffuser;  
GWD – Gravity Wall Diffuser;  
PFD – Pumped Floor Diffuser;  
CWD – Combined Wall Diffuser;

## Marketplace Assessment