Pacific Northwest NATIONAL LABORATORY

PNNL-33017

PNNL CRADA No. 488, Amendment 2 with Natel Energy, Inc.

The Center Sender

June 2022

Natel Energy, Inc.
Abe Schneider
Sterling Watson
Pacific Northwest National Laboratory
Brett Pflugrath
Alison Colotelo
Brian Bellgraph

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Cooperative Research and Development Agreement (CRADA) Final Report

Report Date: June 2022

In accordance with Requirements set forth in the terms of the CRADA, this document is the CRADA Final Report, including a list of Subject Inventions, to be provided to PNNL Information Release who will forward to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Natel Energy, Inc.

Pacific Northwest National Laboratory

CRADA number: 488 Amendment No. 2

CRADA Title: Natel Energy, Inc. - Fish Protection Prize

Responsible Technical Contact at DOE Lab: Brian Bellgraph

Name and Email Address of POC at Company: Sterling Watson

sterling@natelenergy.com

DOE Program Office: Water Power Technologies Office

Joint Work Statement Funding Table showing DOE funding commitment:

Estimated Costs	PNNL Shared Resources	Natel Energy, Inc. Shared Resources	Totals
Phase I	$11,000	$4,300	$15,300
Phase II	$100,000	$66,000	$166,000
	$111,000	$70,300	$181,000

Summary of Research Results

Under the Cooperative Research and Development Agreement (CRADA) No. 488, awarded to Natel Energy, Inc. (Natel) for third place in the Fish Protection Prize 2020 initiative, research was conducted on the Center Sender concept, a simple physical or combined physical and electrical device intended to guide fish to the safest path through a hydropower intake or water diversion. Applying this to a hydropower turbine, the Center Sender can be designed to divert fish to the center of the turbine, where blade velocities are slower and the risk of severe injuries due blade strike, pinching, and grinding are reduced.

The Natel team, collaborating with Markus Aufleger and Jonas Haug of the University of Innsbruck (UIBK) and Brett Pflugrath, Alison Colotelo, and Brian Bellgraph of PNNL examined the Center Sender concept within a flume. Natel, with recommendations from UIBK and PNNL designed and constructed a specialized flume and UIBK designed and constructed the Center Sender unit to be installed into the flume. Once the flume and Center Sender were constructed and installed, all three partners conducted the live fish examination at Natel's Almeda facility to determine the functionality of the device.

A total of 48 trials were conducted with 10 fish each. Various combinations of design and operational variables were examined during testing (Table 1): water velocity, bar angle, voltage, and number of bars. Additionally, control trials were conducted at both water velocities and no bars were installed or voltage applied. Diversion success for the Center Sender was assessed by examining video collected during the trials to determine the portion of fish that approached the bars and were diverted to the desired region of the flume (Figure 1).

Table 1. Design and operational variables combinations for examining the Center Sender device. Bars were installed in two different configurations: all 6 bars evenly spaced (All) and top and bottom bars only (T&B). Controls were conducted with no bars installed.

Velocity (m s^{-1})	Bar Angle	Bar Configuration	Voltage (v)
0.4	20°	All	0
0.4	40°	All	0
0.4	20°	T&B	0
0.4	40°	T&B	0
0.4	20°	All	80
0.4	40°	All	80
0.4	20°	T&B	80
0.4	40°	T&B	80
0.4	N/A	N/A	N/A
1.1	20°	All	0
1.1	40°	All	0
1.1	20°	T&B	0
1.1	40°	T&B	0
1.1	20°	All	80
1.1	40°	All	80
1.1	20°	T&B	80
1.1	40°	T&B	80
1.1	N/A	N/A	N/A

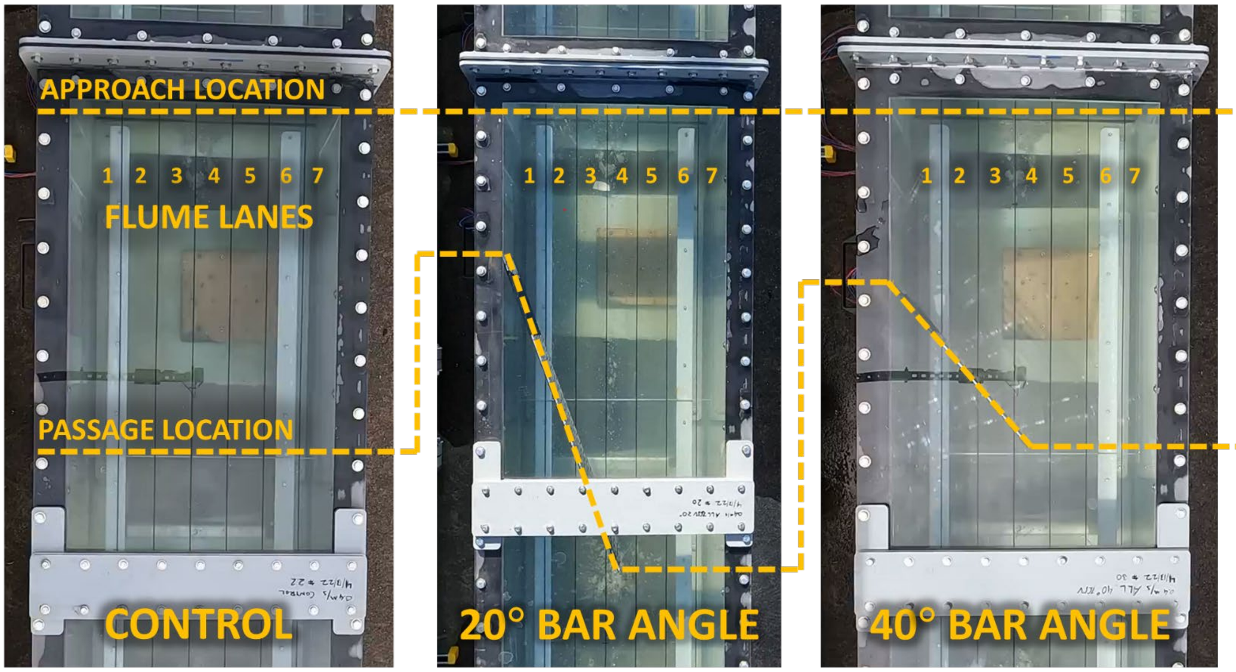

Figure 1. Video analysis was based on the locations outlined in the image. Flume lane and threshold encounter (approach and passage locations) designations were based on the midpoint of the fish (intersection of sagittal and transverse planes of the fish).

Throughout testing, a total of 800 approaches were detected in the downstream direction, 425 of which fish passed the Center Sender device. Approach distribution was more evenly distributed across the flume lanes for testing conducted at 0.4 m s^{-1} compared to 1.1 m s^{-1}. Additionally, aborted passage (fish that encounter the bars or electric field and go back upstream rather than pass the device) was more common for the slower velocity, particularly for tests conducted with electrified bars and especially for the treatment with all bars set at the 20° inclination. Under these testing settings fish approached the Center Sender a total of 128 times while only three passage events were observed (Figure 2).

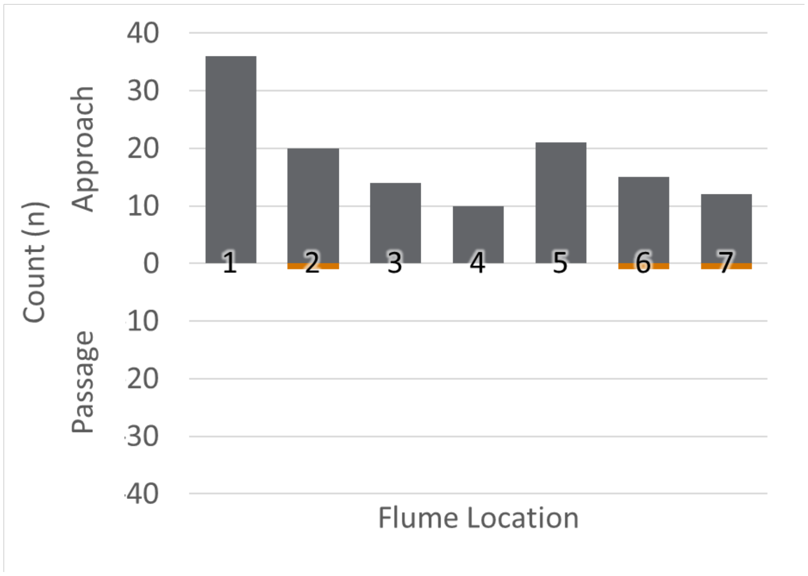

Figure 2. The number of approach (gray bars) and passage (orange bars) events per flume location (lanes 1-7) that occurred for fish encountering the Center Sender while operated at 0.4 m s^{-1}, all bars installed at 20°, and 80 v.

A logistic regression analysis was conducted, and three variables were found to be significant predictors of passage success: water velocity, bar angle, and approach lane. Passage success for this study is defined as fish that pass the Center Sender device in lanes 5 or greater (open portion of the flume adjacent to the Center Sender). The probability of passage success, increased as water velocity increased, as bar angle increased, and as approach lane increased. The probability that fish would pass the Center Sender at a flume lane of 5 or greater is represented by:

$$P = \frac{e^{-3.394+2.483v+0.0561A+0.458\angle}}{1+e^{-3.394+2.483v+0.0561A+0.458\angle}} \quad \text{Equation 1}$$

where v is the water velocity, A is the approach lane, and $\angle$ is the bar angle. Based on this analysis, the most effective test condition examined is a bar inclination set to 40° and a water velocity of 1.1 m s^{-1} (Figure 3). For example, under these conditions, fish approaching from lane 1 of the flume would have an 88% likelihood of passing the Center Sender at lane 5 or greater and fish approaching from lane 7 would have a greater than 99% likelihood of successful passage (Figure 4).

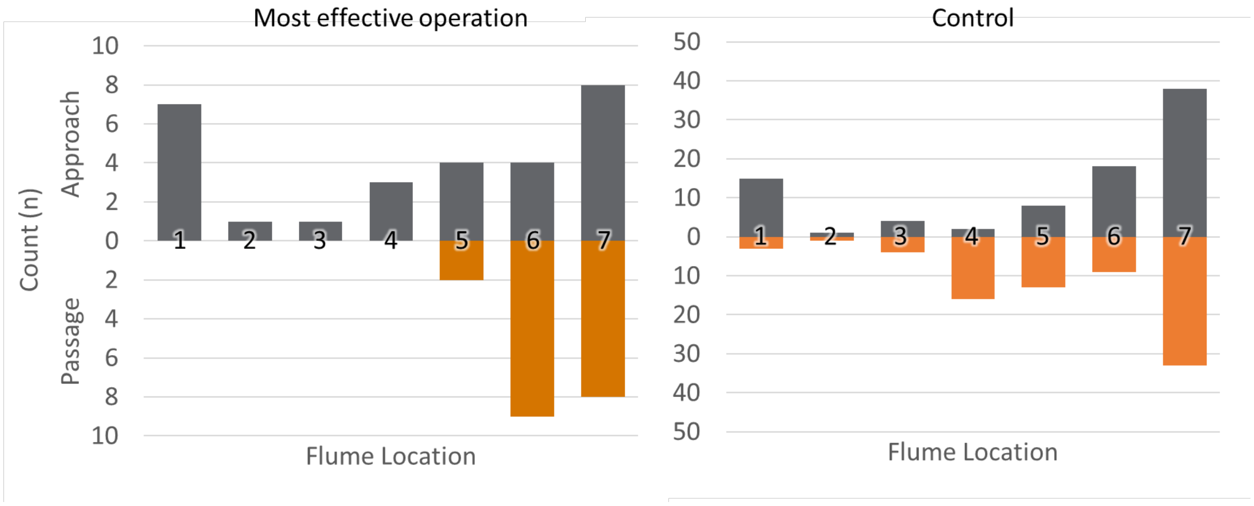

Figure 3. Comparison between the most effective operation examined (1.1 m s^{-1}, all bars, 40°, 80v; represented by the solid black line in Figure 4) and the 1.1 m s^{-1} control group. Approach events are indicated in gray and passage events are in orange. Successful passage was observed for all fish under the most effective operation.

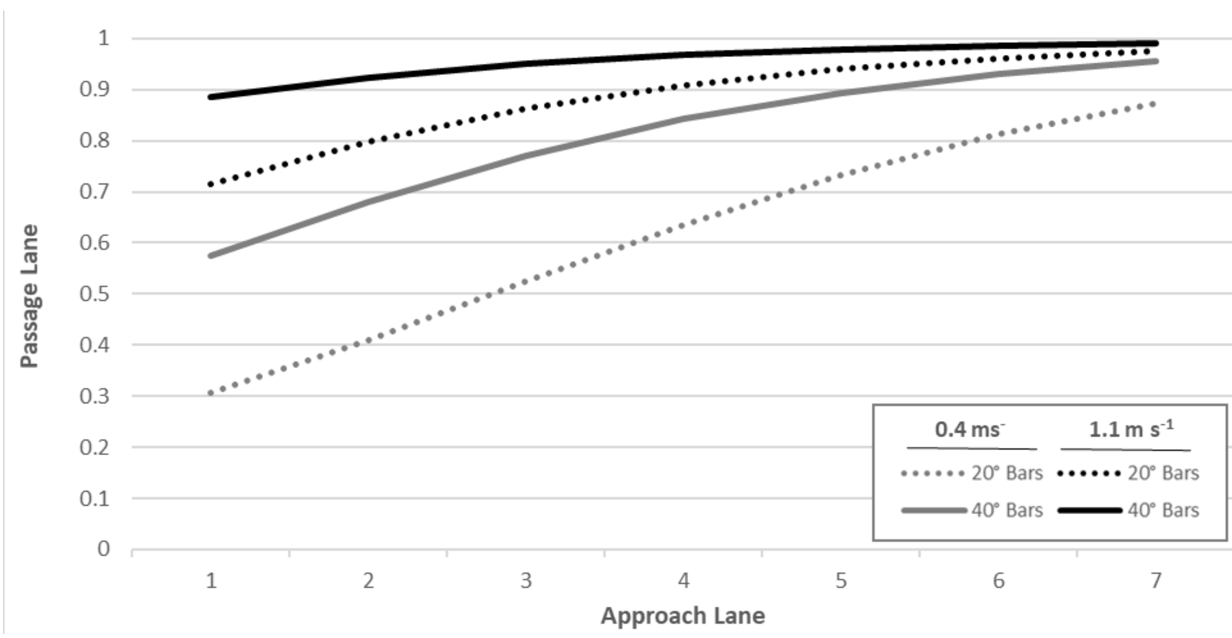

Figure 4. Graphical representation of equation 1, predicting the probability of passage success dependent upon water velocity, bar configuration, and approach lane.

Further optimization of the Center Sender is needed; however, this initial study displays the potential for diverting fish to safer passage regions within high flow water infrastructure. The presence of the electrical field was not a significant variable for predicting passage success, however it did appear to have an influence whether or not fish passed the center or aborted passage and went back upstream. Additional examination of this variable may provide further indications on how the electrical field can be optimized to provided further fish guidance efficiency.

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

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