Concurrent Sessions A: Nature Like Fishways - Guiding Downstream Migrants Into Fish Bypasses or Nature-Like Fishways With A Flow Velocity Enhancement System

Guiding Downstream Migrants into Fish Bypasses or Nature-Like Fishways With A Flow Velocity Enhancement System

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Engineering & Ecohydrology for Fish Passage
Oregon State University
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The Current Situation/Problem:

- Migrating juvenile salmon follow river currents downstream
- Regulated rivers and dams result in lost migrational cues, causing confusion, delay, and often mortality
- How to use normal behavior of migrating fish, esp. downstream migrants, to enhance guidance away from hazardous water intakes
- How to “work smart” with biology to avoid brute force diversion (screens, nets, bar racks, etc.)

Inducing Turbulent Flow: Flow Velocity Enhancement System*

- NATURAL SOLUTIONS developed the FVES as a means of providing a guiding current in the quiescent waters of a forebay. Tests have shown this to be a safe and efficient means of moving water.

Preparing to load the 12" FVES with submersible pump onto work bare at Dairyland Electric Cooperative, Genoa Plant #3, Genoa, Wisconsin

***Patented**

Physical and Biological Tests of FVES

<u>Physical</u>: (2002-3)

- Swimming pool
- York Bridge (Hauser Reservoir, MT)
- Goose Bay Marina (Canyon Ferry, MT)
- Canyon Ferry Dam (Canyon Ferry, MT)

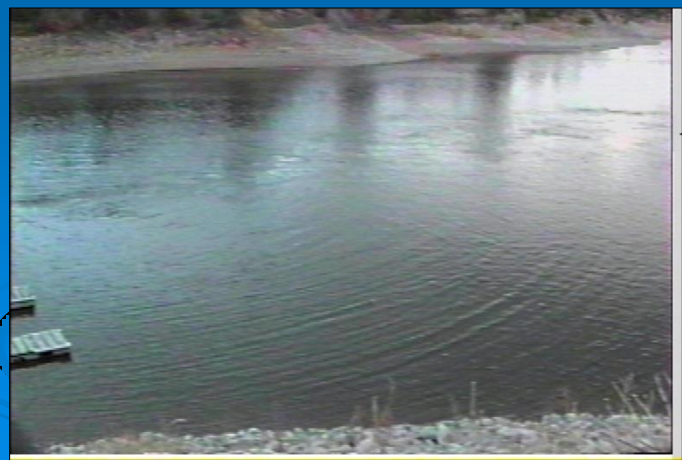
<u>Biological</u>: (2004-07)

Net Pen (Astoria, OR) (2004)

Lake Scanewa (Cowlitz R., WA) (2005)

Riffe Lake (Cowlitz R., WA) (2006)

Riffe Lake (Cowlitz R., WA) (2007)



Goose Bay 2003. 8" eductor created measurable current for 210' (Marsh-McBirney FLO-MATE 2000).

Physical Studies Conclusions

- Eductor efficiently produces a mildly turbulent plume
- Turbulent boils and eddies typical of a natural river (not spiraling as with propellers)
- Turbulence = 20-30% variation about average velocity
- Higher pressure motive water and/or larger diameter eductors create larger plumes (wider, longer) (can tailor plume size)
- 16” eductor generates current at full potential in less than ½ hour

Net Pen Study

Clatsop Co. Fisheries Project Net Pens
Near Astoria, OR April 2004

Net Pen Test: 4,000 Coho Smolts Respond to Eductors (FVES)

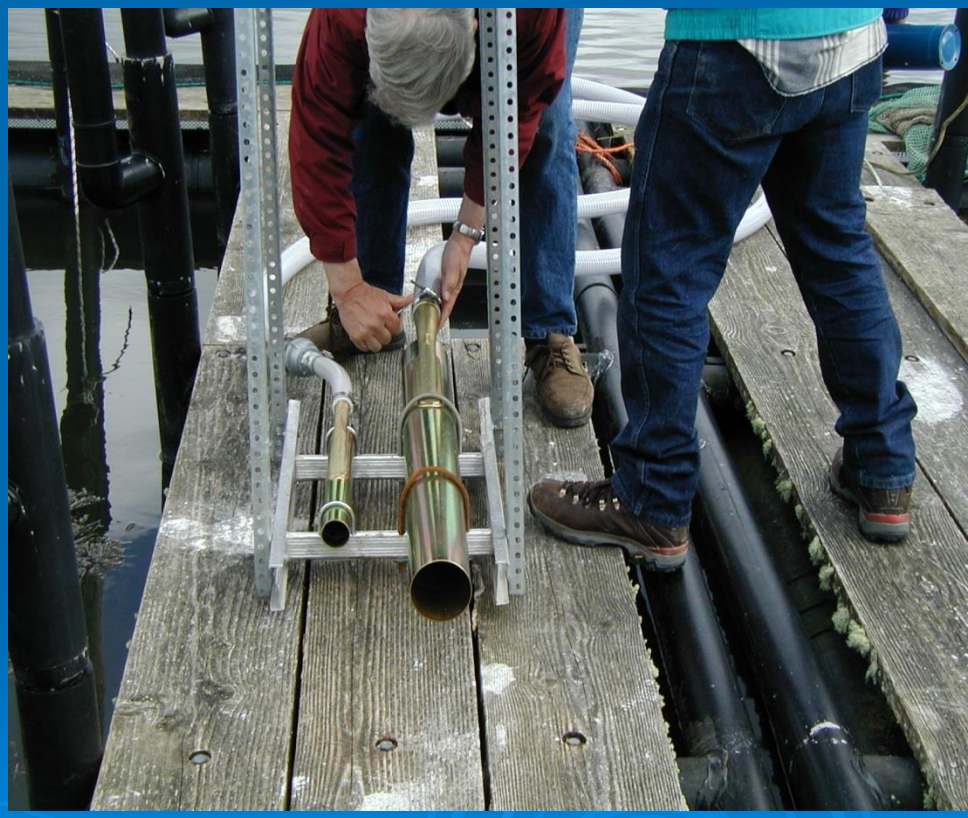
<u>With eductors off:</u>

- quiet water
- random school swimming

<u>With eductors on:</u>

- Mildly turbulent plume with surface boils, vortices, and visible current
- Patterned, systematic fish behavior riding the plume to end of pen, swimming back along sides, and re-entering the plume

(Didson camera images ~ USGS)



Tod Jones and Gordon Burns prepare 2" and 4" eductors for positioning in net pens.

The Real World: Riffe Lake/Cowlitz River (2006)

- Upper Riffe Lake below Cowlitz Falls Dam (350’ wide, 22-26’ deep at full pool)
- Radio tracking Chinook salmon smolts
- FVES on bottom angled 45° downstream, 6° up
- 16-inch eductor
- Plume length ~ 350 ft

River was 22-24’ deep during this study.

2008 Two-Dimensional Acoustic Telemetry Test ~ Objectives

- Quantify guidance of tagged smolts with FVES using 2-D telemetry
- Test ability to guide smolts into a trap for capture and transport

FVES current/plume develops quickly. Shown from end of work barge.

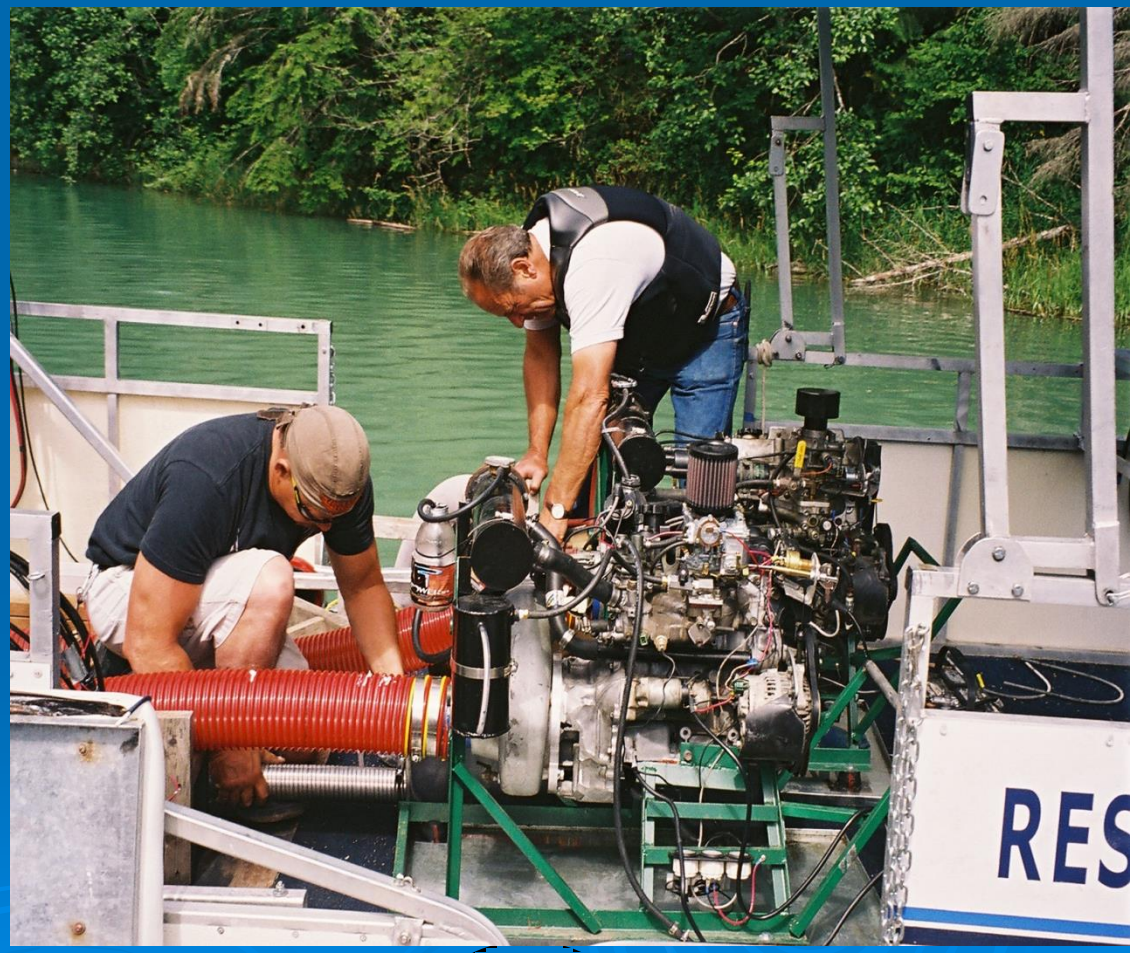
2008 Two-Dimensional Acoustic Telemetry Test ~ Site

Mainstem river at upper end of Riffe Lake between Cowlitz Falls Dam and Taidnapam Park. Actual 2-D test period: Aug. 7 – 18, 2008.

Google Earth photo of above stretch of test reach.

Eductor and Motive Power
Riffe Lake

16" eductor ready to deploy.



Sprint motors on work barge power pumps, activates FVES on river bottom. Motive water hoses are screened.

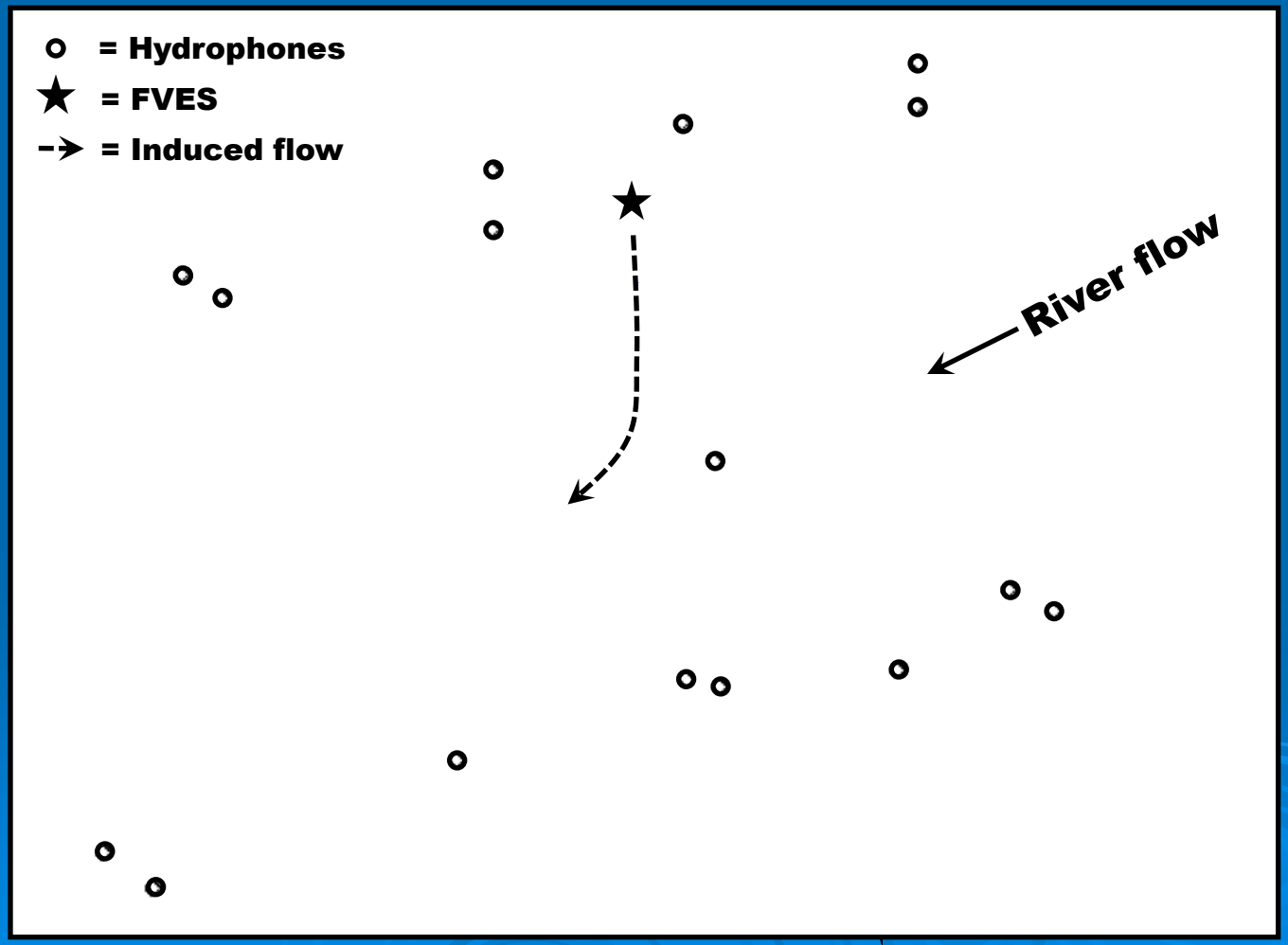
The Test Design

- 90 smolts were implanted with acoustic transmitters at the Cowlitz Falls Fish Facility
- Smolts were held for 24 hours and released: 9 per day during 10-day period in August
- FVES was operated on a rotating "on" – "off" schedule to compare natural and guided migration trajectories
- Acoustic detection array (16 hydro-phones) was positioned by USGS personnel

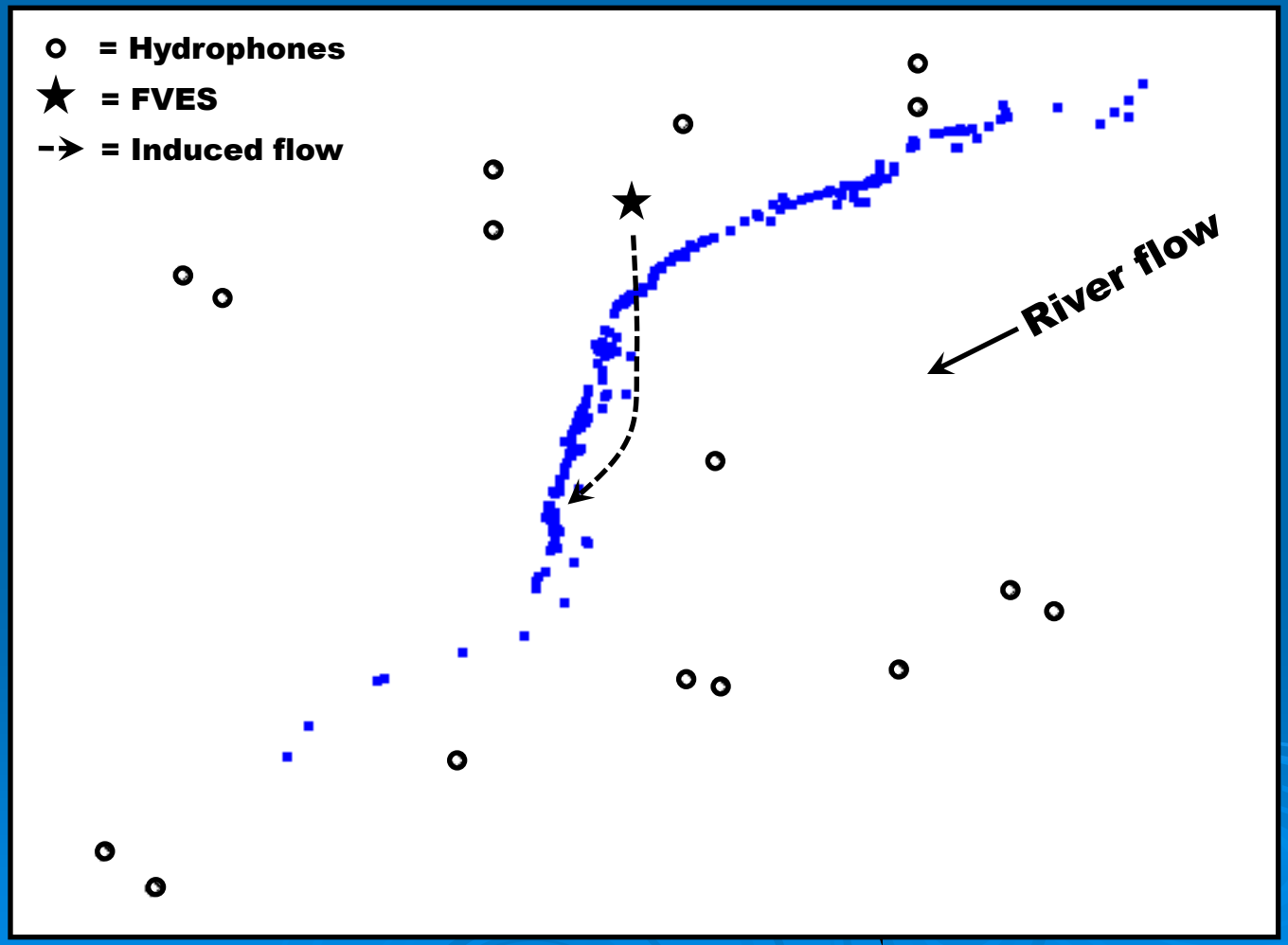
Unusual Debris Challenges USGS, Test Design

Debris crowds the work barge downstream. Note the motive water hoses and motor. Once the FVES is activated, debris mass begins to move and remains in constant motion while FVES runs

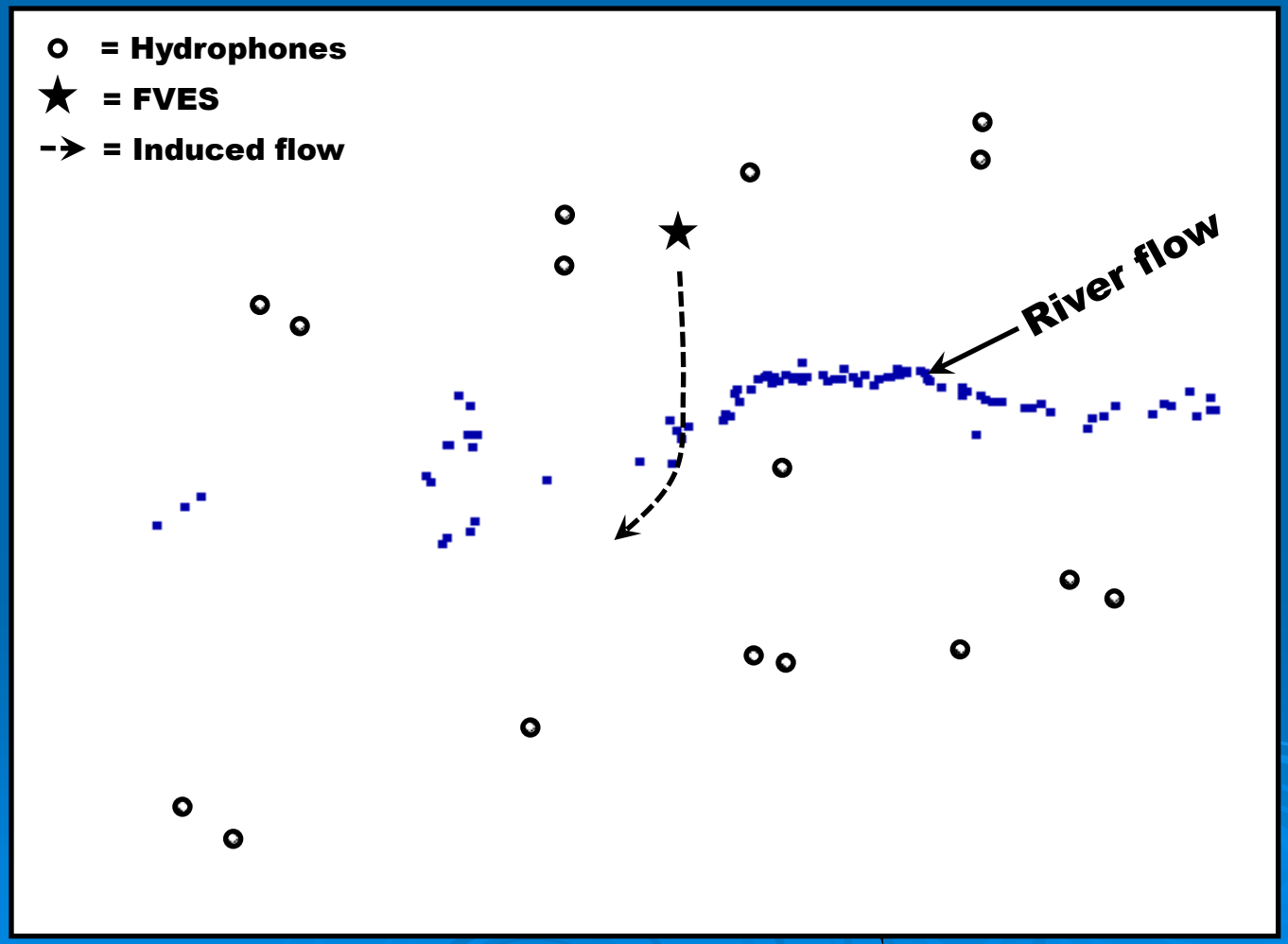
Acoustic Array



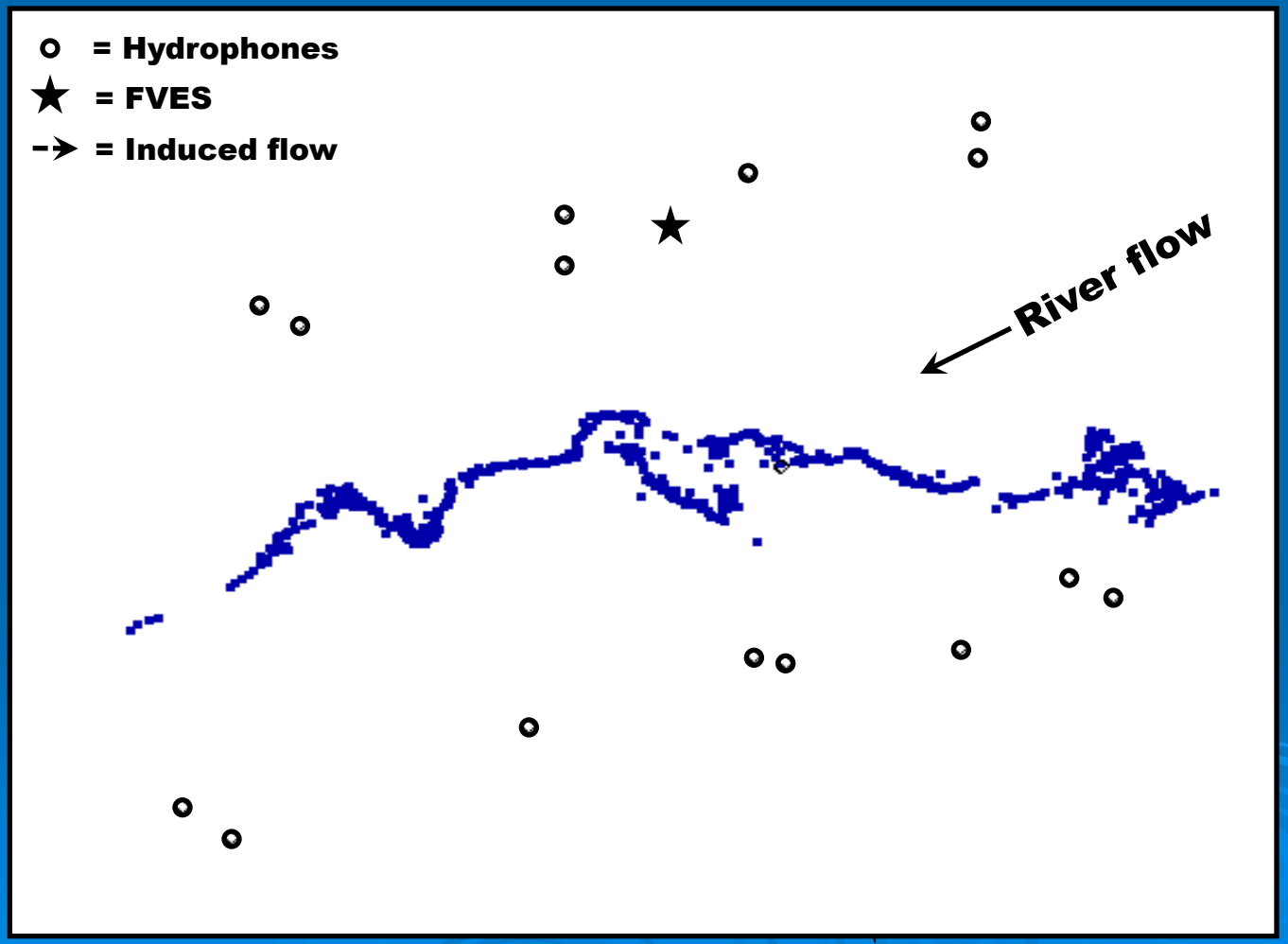
"Guided" Fish Response



“Unguided” Fish Response



Fish Behavior With FVES Off



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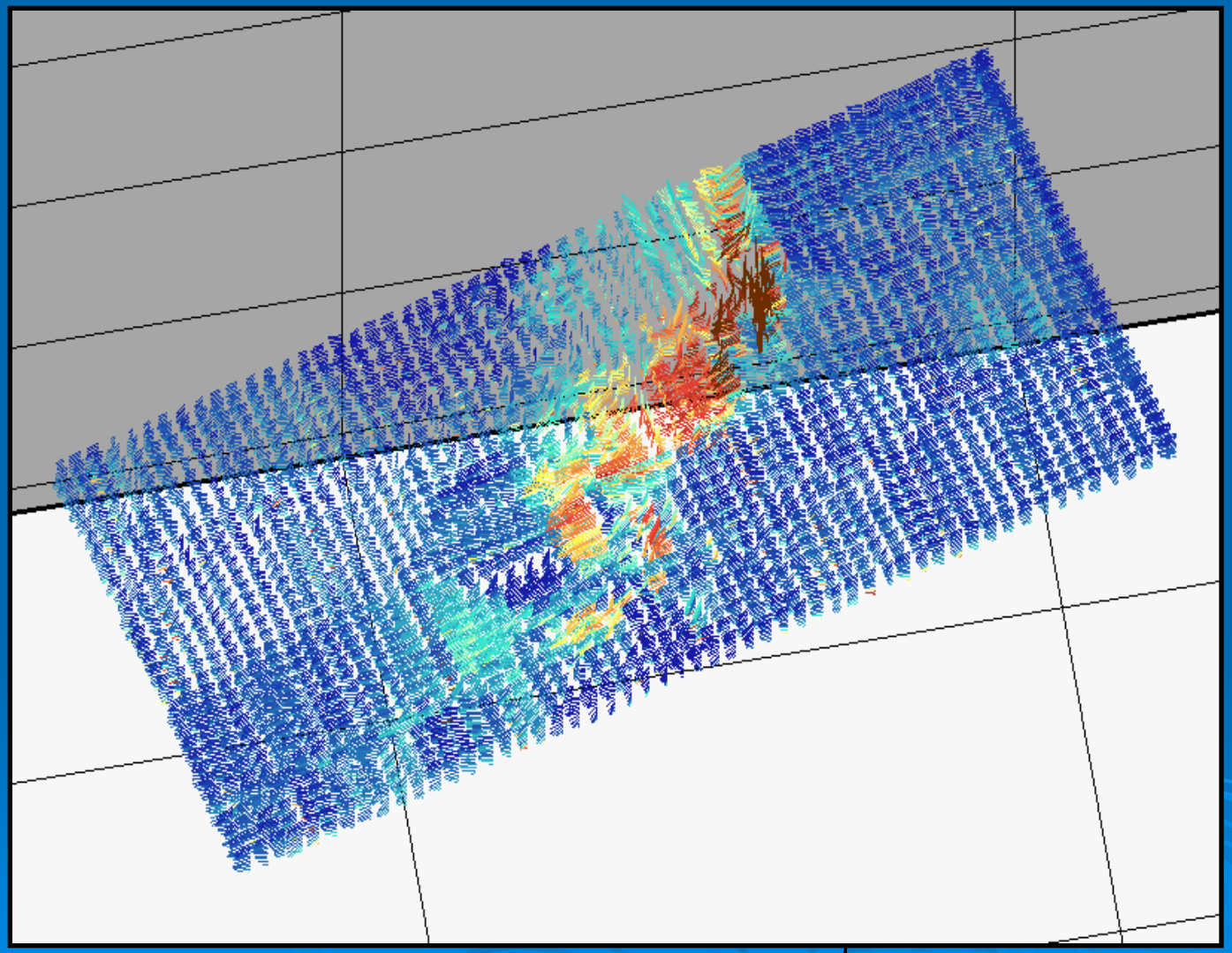
Velocity Data, FVES On



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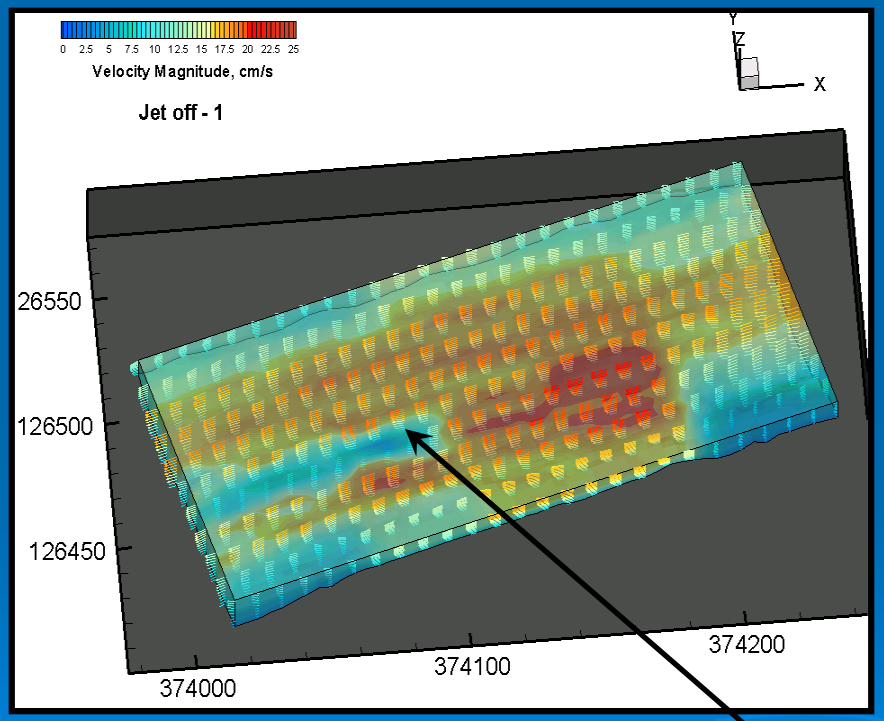
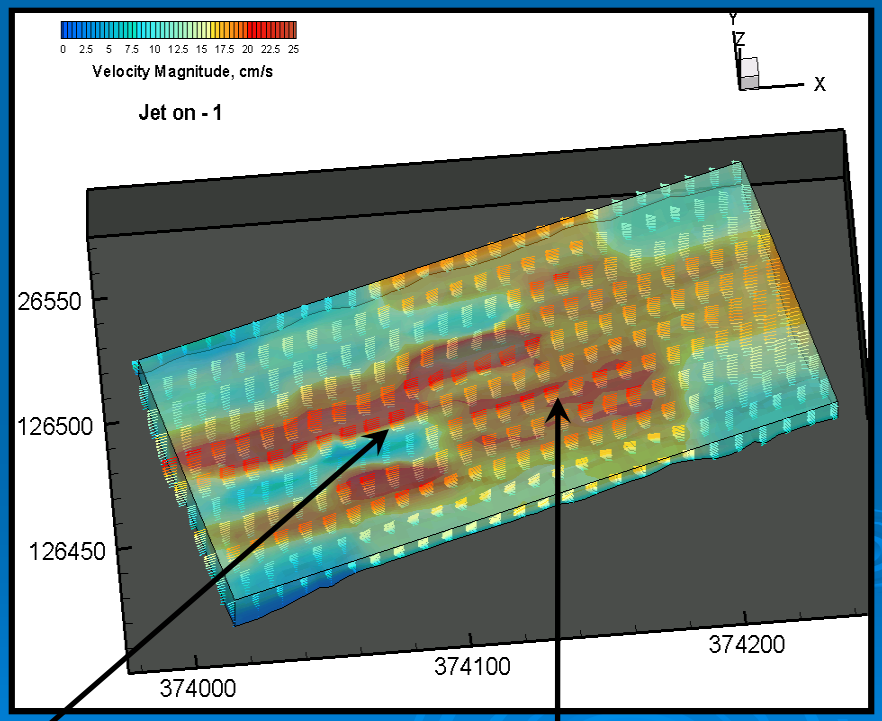
Contours of Surface Velocities

FVES Off



FVES On



Decreased flow caused by trap presence

Elevated flow from FVES

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Site Conditions Recorded

- Daily Cowlitz River flows ranged from 5,028 on July 16 when the work barge was launched to 1,733 on Sept. 6 when the trap was removed
- Flows averaged 1,943 fps during test period (8/7-8/18)
- Riffe Lake elevations: from 776.55 – 772.28 during test period
- Flows and elevations were unusually high
- Debris mass was unusually large and constant

Analyses

Track visualizations of FVES ON and OFF by USGS, showing:

- Different numbers of detections per fish
- Different lengths of time for all tracks
- (Useful for visualizing individual fish behavior)

Statistical analysis of number of fish locations in specified areas on a grid (Useful for quantitatively comparing locations of fish occurrence)

Analysis Grid

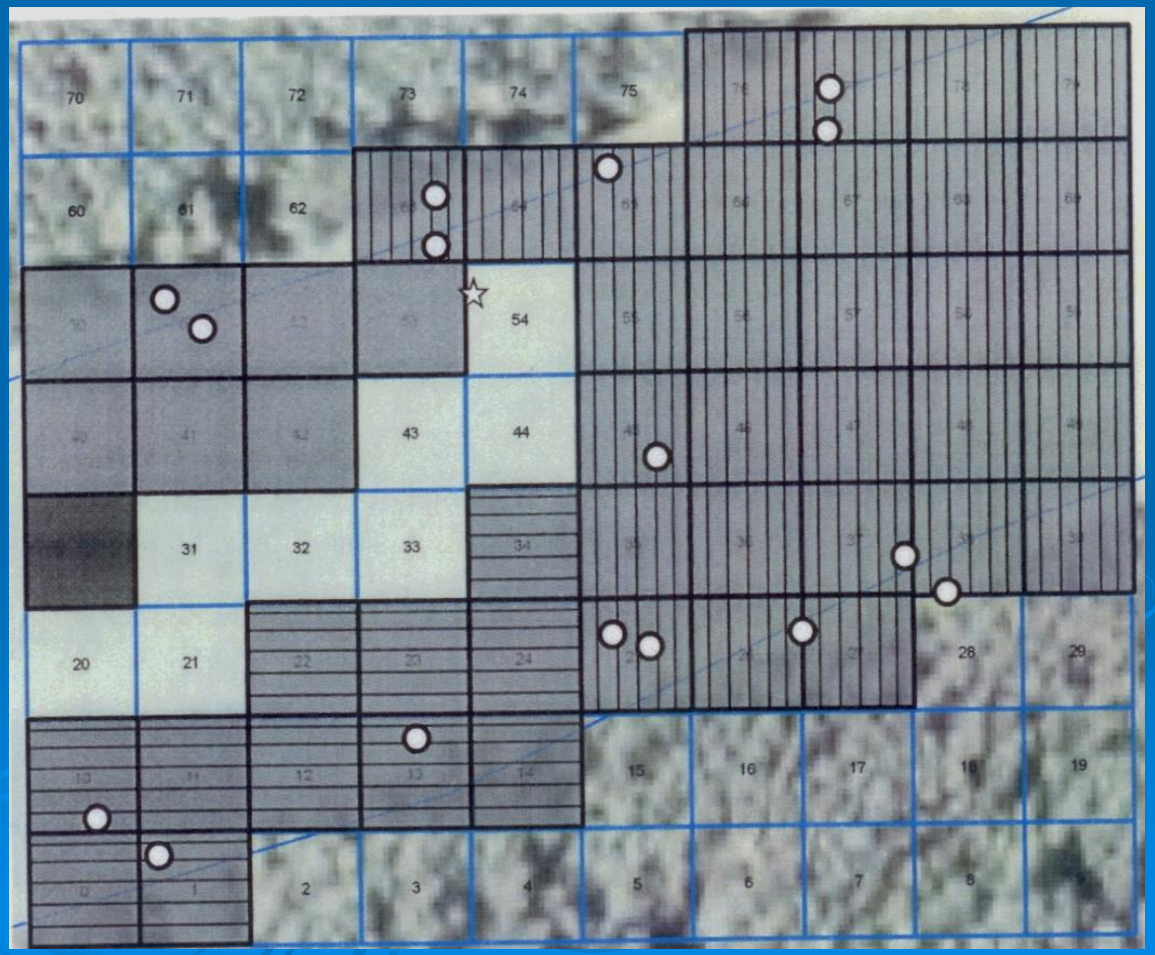
20 m by 20 m cells overlaying study area for tallying number of individual fish detections

Center plume (unshaded)

North periphery (solid shaded)

South periphery (shaded, horizontal bars)

Upstream (shaded, vertical bars)



Results

- Aggregate of tagged fish stayed in the study area longer when FVES ON than OFF (but residence times variable; medians of 12.3 h vs. 8.6 h, respectively, NS; P=0.632)
- Much milling behavior in and around FVES and plume when ON but less in area when OFF
- Same fish entered plume multiple times when ON (recirculated, like in net pens)
- FVES motor and pump did not repel fish when ON (fish seemed attracted to the currents near equipment)
- The trap was not operable during tracking due to high debris loads

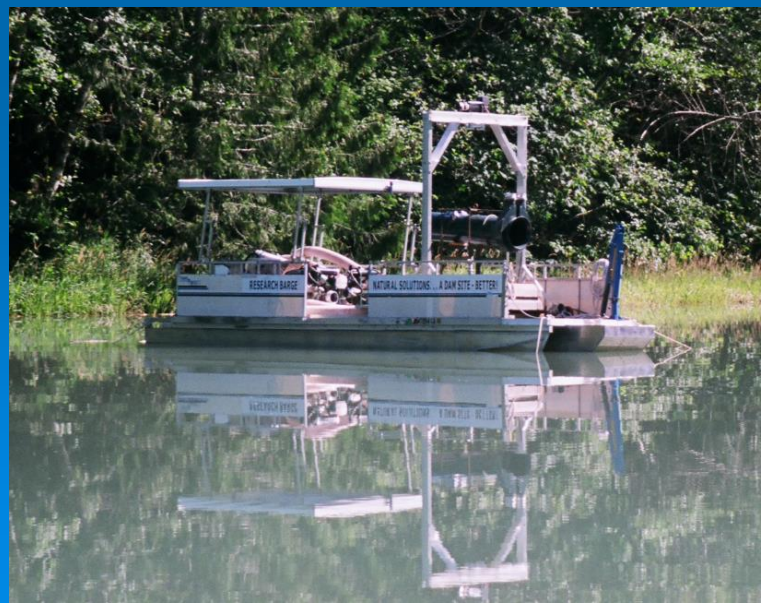
Results (continued)

- More fish occupied the center plume and north periphery zones when ON than when OFF ($P<0.0001$); More lingered upstream when OFF
- Many fish lingered along shorelines in both ON and OFF, likely using cover of abundant debris
- A center-line plume location about 100 ft from FVES (~1/3 river width) had high occurrence of smolts when ON (but not when OFF) suggesting a good location for capturing or diverting smolts using FVES
- Visualizations are still being analyzed for behavior of specific fish in relation to river flow, dates, etc. and attractiveness of specific locations

Summary and Conclusions

- A barge-mounted FVES created a mildly turbulent plume across the Cowlitz River (~300 ft) during low flows
- Acoustic-tagged Chinook salmon smolts oriented to the plume in ways not seen in the river with FVES OFF
- Fish visualizations suggest a location ~100 ft from the FVES is best for collecting or diverting fish
- Floating debris prevented operation of trap

FVES has good potential for fish guidance/diversion; more analyses are underway



2009 - 2010 Study

- Practical application: Guide fish to a new river trap, designed by NATURAL SOLUTIONS
- Trap design (heart) inadvertently resulted in a hydraulic block

- Fewer fish were captured then expected
- Trap redesign in 2010 test resulted in increased catch, but hydraulic barrier remains. Trap is being redesigned for future tests.

Tacoma Power biologists, Jamie Murphy and Scott Gibson, prepare to help deploy Natural Solutions' in-river net trap

Other Applications for the FVES

- Fish tests in 2008 showed dramatic displacement of debris and suggested new use.
- Blockage of cooling-water intakes by debris occurs frequently at nuclear and fossil power.
- An FVES may be useful for debris management by “guiding” debris away from hazardous water intakes.
- A presentation to Energy Power Research Institute in Feb. 2009, resulted in an expression of interest from Allegheny Power (leaf debris) and Oyster Creek (algae).
- A test using the FVES as a means of guiding eel in the Netherlands was conducted in the fall of 2011.

Other Applications (continued)

- FVES application may reduce, or help prevent adult fall-back
- FVES may enhance movement to forebay fish bypass
- FVES may increase attraction to fish ladders
- FVES may “break up” conflicting currents at dam face
- FVES may enhance egress and reduce predation at SBC outfalls
- A redesigned FVES [patent pending] will soon be tested in ballast tanks as a means of rapidly mixing biocides

NS work barge on Cowlitz River

Canal in Netherlands

Study to divert migrating eels effectively moved floating aquatic plants

Caspar Hommes Pumping Station near Groningen, Netherlands

FVES Installation

Two FVES sizes (4”, 6”) on one block for testing
On shore (left) and in water (right)

Motive water was supplied by submersible pump

For this test, a large (see pencil), electric submersible pump was suspended in the canal and motive water sent to FVES in a 6” flexible hose

240-250 gpm
25 psi
Estimated FVES output = 625-650 gpm

(50-75 psi pump preferred, but not available)

FVES Plume deflected flow and aquatic plants

A clear plume developed with 6” eductor (center of photo)

Flow and floating mats of aquatic plants were deflected to left in photo

Fish and mats could be collected at left shore

Appreciation

- Northwest Power and Conservation Council (Portland, OR)
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- Mark Reller, Constellation Services (Helena, MT)
- Brian Marotz, Montana Dept. of Fish, Wildlife and Parks (Kalispell, MT)