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# Constructing Nature-Like Fishways- Guiding Downstream Migrants with a Flow Velocity Enhancement System

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**NATURAL SOLUTIONS**  
...A DAM SITE-BETTER! LLC

## **CONSTRUCTING NATURE-LIKE FISHWAYS – GUIDING DOWNSTREAM MIGRANTS WITH A FLOW VELOCITY ENHANCEMENT SYSTEM**

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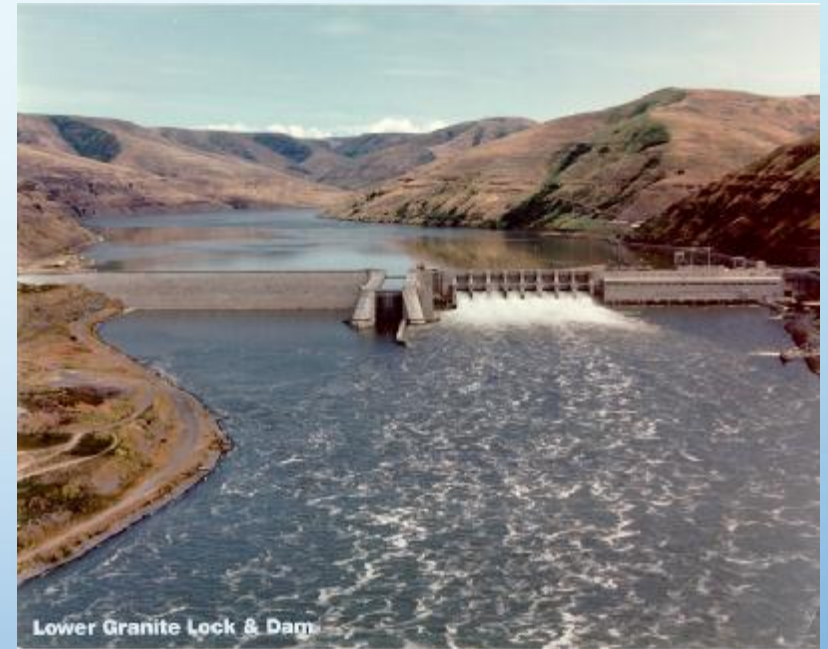
**Fish Passage International**  
**Corvallis, OR – June 19 - 22, 2017**



*A Nature- Like Bypass?*

## ***THE CURRENT SITUATION / PROBLEM:***

- Migrating juvenile salmon and other species of fish 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, especially 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.).



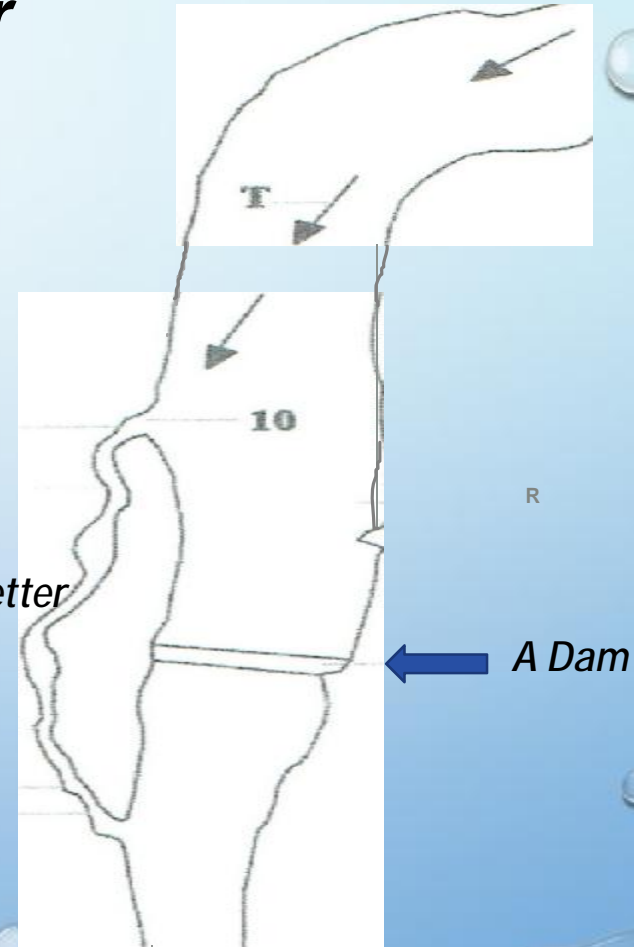
***Lower Granite, one of four dams on the Snake River (Little Goose, Lower Monumental, and Ice Harbor), each one of which has the topography to accommodate a nature-like bypass river – a NATURAL SOLUTIONS river.***

## Nature-like Bypass River

*“In the bypass channel, a silica fume- enhanced shotcrete would be used to replicate the bedrock of a natural river bed. Shotcrete is pneumatically applied and would allow for the formation of rapids, water falls, shelves, and undercut embankments, all in a natural contour.”*



A Dam Site Better



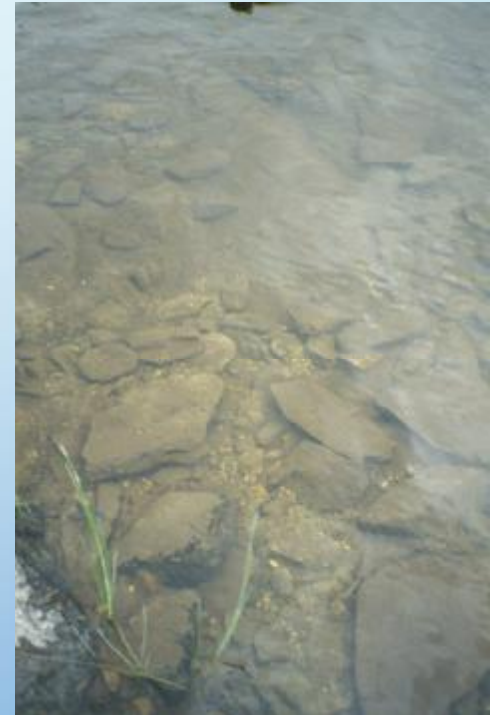
A Dam

## ***Natural Channel Inlet Detail***

Silica fume + shotcrete = compressive strength of > 8,000 psi, significant increase in flexural strengths, and an increase in freeze-thaw durability



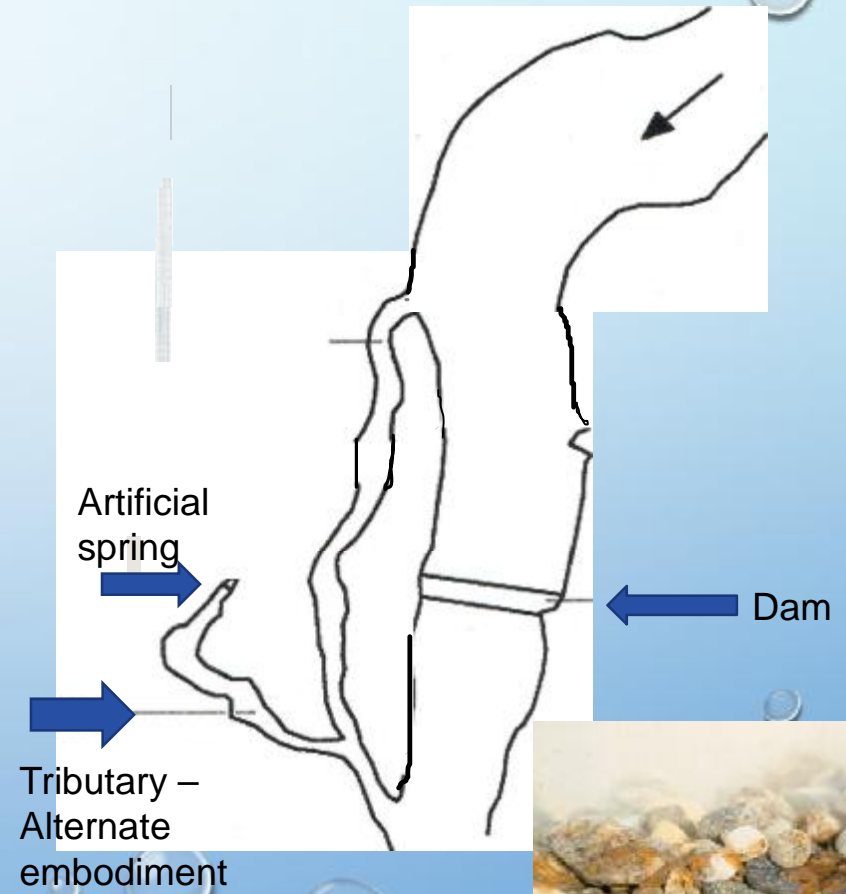
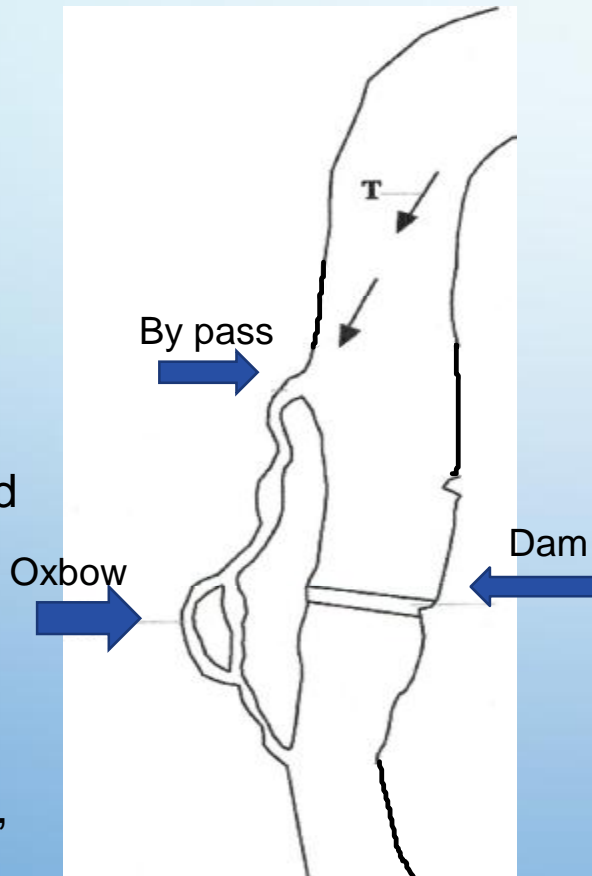
Excavation = remove resident gravel (clean if necessary), stockpile along the route for return to the bypass – add logs, large boulders – all to be “flushed” down stream with water from the reservoir, thus creating a “naturally” sorted river bed.



*Subaquatic species native to the area, such as crawfish minnows, and various native aquatic insects, are then introduced to provide a food source necessary to sustain a year-around fishery. Collection could involve area high school biology students to provide an important field studies component.*

## ***Nature-like Bypass Can be Versatile to Meet Your Needs***

Besides denying upstream fish passage, dams also eliminate spawning sites. Here are two ways in which those areas could be replaced with vary little cost relative to the benefits for fish, power producers, and the public.



## A “NATURAL” FISHERY RECREATION AREA WITH EDUCATIONAL OPPORTUNITIES.....



Primitive Native American fish harvesting methods, such as scaffolding dip netting and fish wheels could be built on site to provide immediate and ongoing educational opportunities and to ensure the survival of these ancient skills.



The recreation area and riparian setting complete with mature trees, native shrubbery and ground cover, would result from the use of a passive, sub-irrigation drain field, just as nature does it.

*Involving tree farms for contributions and high school students to plant trees and other vegetation in the corridors on both sides of the man-made river, a community of support is born. Within a generation, the man-made river becomes a natural river. And native fish stocks are restored for generations to come.*

*Careful siting of the river outlet will take advantage of the juveniles' tendency to travel on the surface and following thalweg.*

How many generations of migrants before this becomes their "natal" stream?



The bypass river would be a natural extension of the migratory path being followed by juveniles through the reservoir.





NATURAL SOLUTIONS can build a nature-like bypass to suit your needs.

But will migrants find the “river”? – here’s the proof they will



# INTRODUCING 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 leading into a “natural” or “nature-like” river bypass. Tests have shown this to be a safe and efficient means of moving water and guiding migrants.

\* *Patented*



- *Other uses:  
Debris mitigation at cold water intakes.  
Preparing to load the 12” FVES with screened submersible pump onto work barge at Dairyland Electric Cooperative, Genoa, WI (Fall, 2012)*

# ***PHYSICAL AND BIOLOGICAL TESTS OF FVES***

## **Biological: (2004 - 2007)**

Net Pen (Astoria, OR) (2004)

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

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

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

## **Physical: (2008 - 2010)**

Bonneville Power Administration-funded guidance test (Cowlitz R., WA) (2008)

Bonneville Power Administration-funded guidance test (Cowlitz R., WA) (2009)

Guidance test (Cowlitz R., WA) (2010)



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

## ***Biological Studies***

- *Research proposal: Determine the efficacy of moving migrating salmonid juveniles through dam reservoirs by creating artificial current and directional turbulence.*
- *Independent Science Review Panel (ISRP) raised the issue: What about potential mortalities of fish entrained by the eductors (FVES) due to dramatic changes of hydraulic pressures within the venturi-driven?*
- *Equipment (FVES) – 40” long, 6” diameter, 2” venturi – Motive water provided by 3” pressure pump at 35 PSI with suction velocities of .27 ft/sec. Discharge velocities ranged from 11.5 to 12 ft/sec.*
- *Experiment: Transfer 50,000 juvenile Coho fingerlings from one net pen to another by operating the FVES to pass the fish non-volitionally.*
- *50,000 Coho fingerling were moved through the FVES at the Young’s Bay net pen complex operated by Clatsop County Economic Development Fisheries Committee Fisheries Project.*

## ***Biological Studies Conclusions***



*Clatsop County Economic Development Fisheries Project Net Pens  
Young's Bay, near Astoria, OR – November 2002 and March 2003*

***“No physical harm has occurred to the fish and no short or medium-term mortalities have resulted from their entrainment... Passing fingerling salmonids or salmonid smolts through the venturi driven eductor does not appear to generate detectable damage.”***

*Tod Jones, (former) Director,  
Clatsop County Economic  
Development Fisheries Project Net  
Pens – Full report available upon  
request.*

## 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
- **FVES is simple, cost-effect, practical**



6" unit deployed at Caspar Hommes,  
Groningen (Netherlands)

## ***BPA Innovative Test Design - 2008***

- 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
- Personnel from the US Geological Survey in Cook, WA designed the test and positioned the acoustic detection array across the reach – about 300’.



## ***Fish Response to FVES***

- 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)
- Trap was not operable during tracking due to high debris loads



*12" FVES ready to deploy in Cowlitz River – 2008*



## *BPA TEST SUMMARY AND CONCLUSIONS*

A barge-mounted FVES created a mildly turbulent plume across the Cowlitz River (~300 ft) during low flows (2008)

Acoustic-tagged chinook salmon smolts oriented to the plume in ways not seen in the river with FVES off (2008)

Fish visualizations suggest a location ~100 ft from the FVES is best for collecting or diverting fish (2008)

Floating debris prevented operation of trap (2008)

***FVES – proven effective in guiding migrants – has the potential to provide natural solutions to challenges of fish guidance!***



# CANAL IN NETHERLANDS - 2011

STUDY TO DIVERT MIGRATING EELS EFFECTIVELY MOVED FLOATING AQUATIC PLANTS



*Caspar Hommes Pumping Station  
near Groningen, Netherlands*



For this test, a large (see pencil), electric submersible pump was suspended in the canal and motive water sent to 6" FVES in a 6" flexible hose (240-250 gpm -- 25 psi) Estimated FVES output = 625-650 gpm

## ***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

## ***OTHER APPLICATIONS FOR THE FVES -DEBRIS***

- Fish tests in 2008 BPA test 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 (EPRI) 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.



*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. BPA Test on Cowlitz River, 2008*

## **VEGETATION GATHERS AT INTAKE AND CAN BE DENSE, PROBLEMATIC & EXPENSIVE**



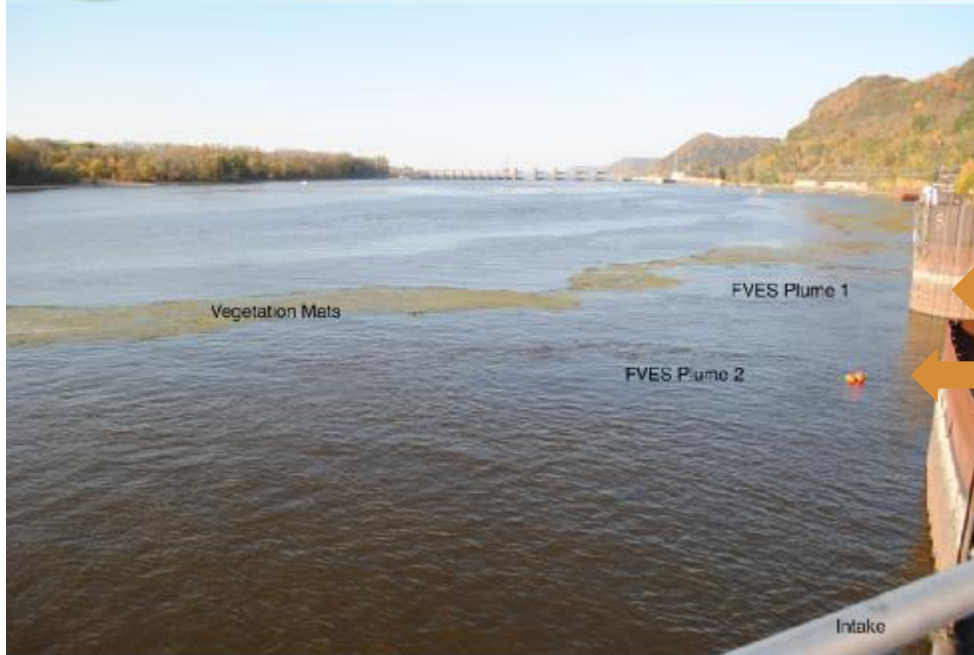
*Energy Power Research Institute –  
funded project at Dairyland's  
Generation Station #3 at Genoa, WI*

Photos represent fairly mild debris season. Two years earlier (2010), the plant lost more than a million dollars managing the debris alone!

The FVES significantly reduced the debris load and, subsequently, blue gill impingement.

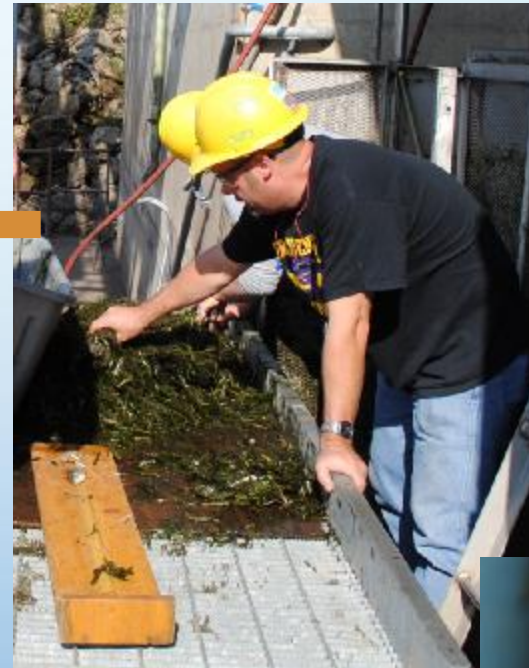


## ***CLOGGED INTAKES, FISH IMPINGEMENT – SERIOUS PROBLEMS***



2 12" FVES units keep grass mats – and Blue Gill – suspended in the Mississippi R.

Biological report available to Energy Power Research Institute (EPRI) members.



Combing through grass mats to remove, measure, count impinged young migrants – costly manpower



## ***OTHER APPLICATIONS*** (continued)

- FVES application may reduce, or help prevent adult fall-back at fish ladders
- 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 [patented] may soon be tested in ballast tanks as a means of rapidly mixing biocides



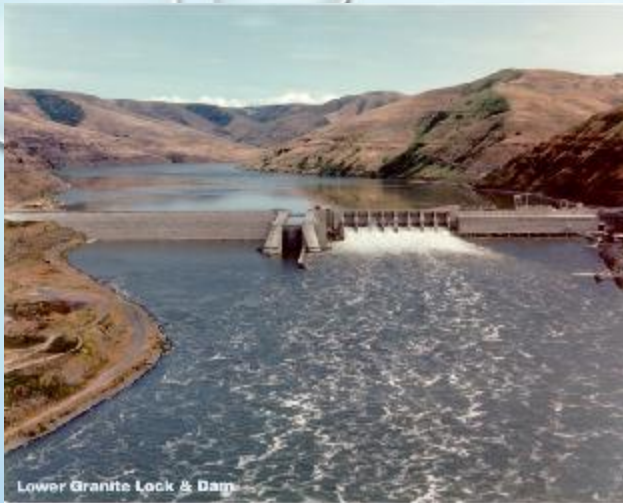
*NS work barge on Cowlitz River*

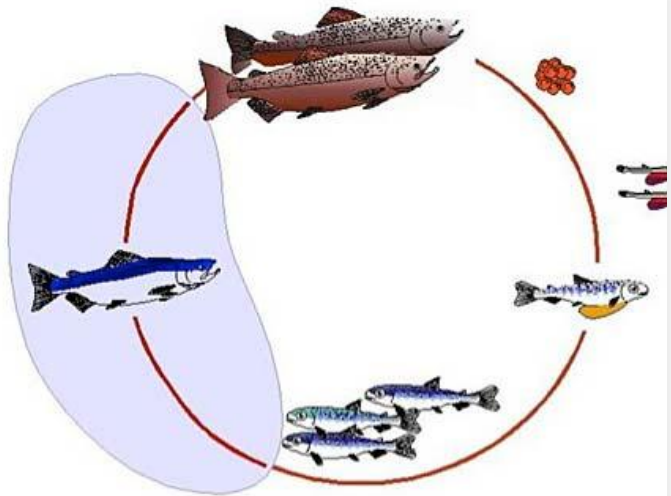
*FVES is suspended from gantry crane and deployed through work well.*

# ***Appreciation***

- NORTHWEST POWER AND CONSERVATION COUNCIL (PORTLAND, OR)
- DR. CHARLES C. COUTANT, COUTANT AQUATICS (OAK RIDGE, TN)
- DOUG DIXON, ELECTRIC POWER RESEARCH INSTITUTE, LENOX, MA
- USGS, COOK, WA - DENNIS RONDORF (RETIRED), NOAH ADAM, RUSSELL PERRY, TERESA LIEDTKE, TOBY KOCK AND STAFF
- TACOMA POWER, TACOMA, WA, MARK LARIVIERE (RETIRED), MARK WICKE, SCOTT GIBSON, JAMIE MURPHY
- BONNEVILLE POWER ADMINISTRATION, PORTLAND, OR – JOHN PICCININNI (RETIRED)
- WASHINGTON DEPT. OF FISH AND WILDLIFE – CHARLES MORRILL, JOHN SERL, STEVE BELL, WADE AND DIANE HEIMBINGNER
- LEWIS COUNTY PUBLIC UTILITY DISTRICT – MIKE KAHN AND JOE FIRST
- CLATSOP COUNTY TERMINAL FISHERIES PROJECT, ASTORIA, OR – TOD JONES, DIRECTOR (FORMER)
- KEITH WARREN, COMMERCIAL DIVER (ASTORIA, OR)
- MARK RELLER, CONSTELLATION SERVICES (HELENA, MT)







**Transportation [barging]**



**Snake River - standard operation to overcome dam mortality**



**Bypass Piping at Lower Granite Dam**

Photo by Steve Pettit

