This electronic document contains a set of Powerpoint slides presented by Leslie Hanna at the 2013 International Conference on Engineering and Ecohydrology for Fish Passage, held June 25 - 27, 2013 at Oregon State University in Corvallis, Oregon.

The title of the presentation was:

Physical Modeling of Drop-Pool and Upwelling Intake Structures for Downstream Fish Passage at Cle Elum Dam

This presentation is designated as document PAP-1123 in the files of the Bureau of Reclamation Hydraulics Laboratory, Denver, Colorado.

Despite extensive efforts, no completely satisfactory method could be found for achieving compliance with Section 508 of the ADA. In order to provide the maximum possible access to this document, it is being provided here in several different forms provided sequentially in one file. Each different manner of presentation makes different parts of the document accessible.

- “Notes” pages printed from Powerpoint. These slides include printed speaker’s notes, but screen readers may fail to actually read the notes and the text content of the slides.
- Slides pages printed from Powerpoint. The text content of these slides will be read, along with alternate text for graphic elements. Speaker’s notes are not included.
- Presentation outline. This provides the text content of the slides in a readable form. Graphic elements and speaker’s notes are not included.

NOTES PAGES

RECLAMATION

Managing Water in the West

Cle Elum Dam Downstream Fish Passage

(a progression of studies and lessons learned)

Leslie Hanna
Hydraulic Investigations & Research Laboratory

U.S. Department of the Interior
Bureau of Reclamation

Background

- 1983 -- Need for fish passage at Yakima Project Dams identified by the Northwest Power Planning Council.
- 2003 -- Reclamation completed an appraisal level assessment of alternatives for providing fish passage at the five large storage dams
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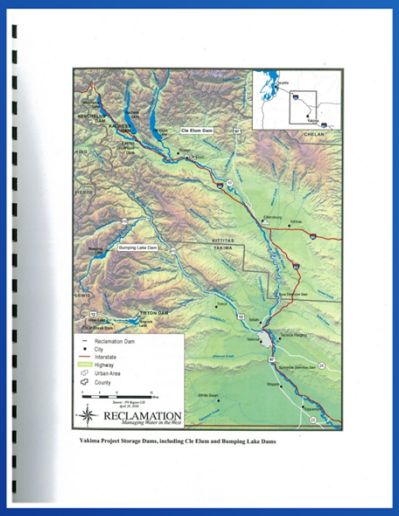
Yakima Project Dams



RECLAMATION

Background (cont)

- 2005- The U.S. Bureau of Reclamation (Reclamation) and the Yakama Nation entered into an agreement to collaborate to prepare technical plans & a planning report for fish passage at Cle Elum and Bumping lake dams. Reclamation also agreed to provide interim downstream fish passage at Cle Elum until a permanent facility was implemented.

- The Interim Flume proves to be a success in passing fish.

Large Storage Reservoir Challenges

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- Dam Height
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RECLAMATION

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- Increase sockeye salmon, coho salmon, spring chinook salmon, and Pacific Lamprey populations to self-sustaining levels
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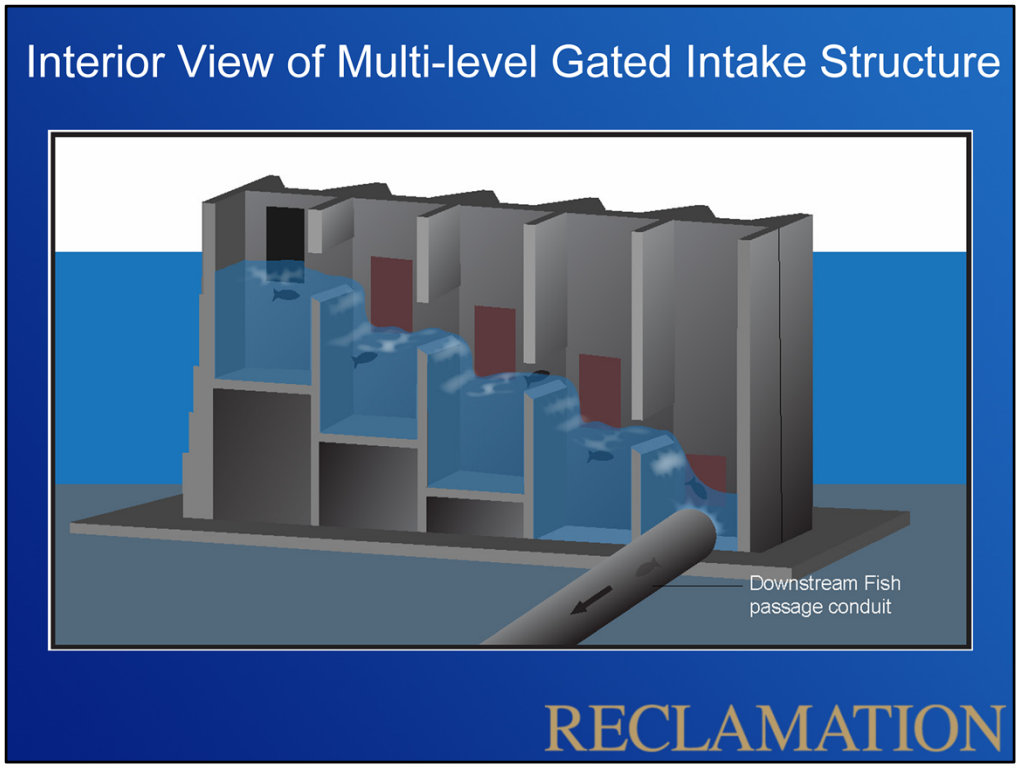
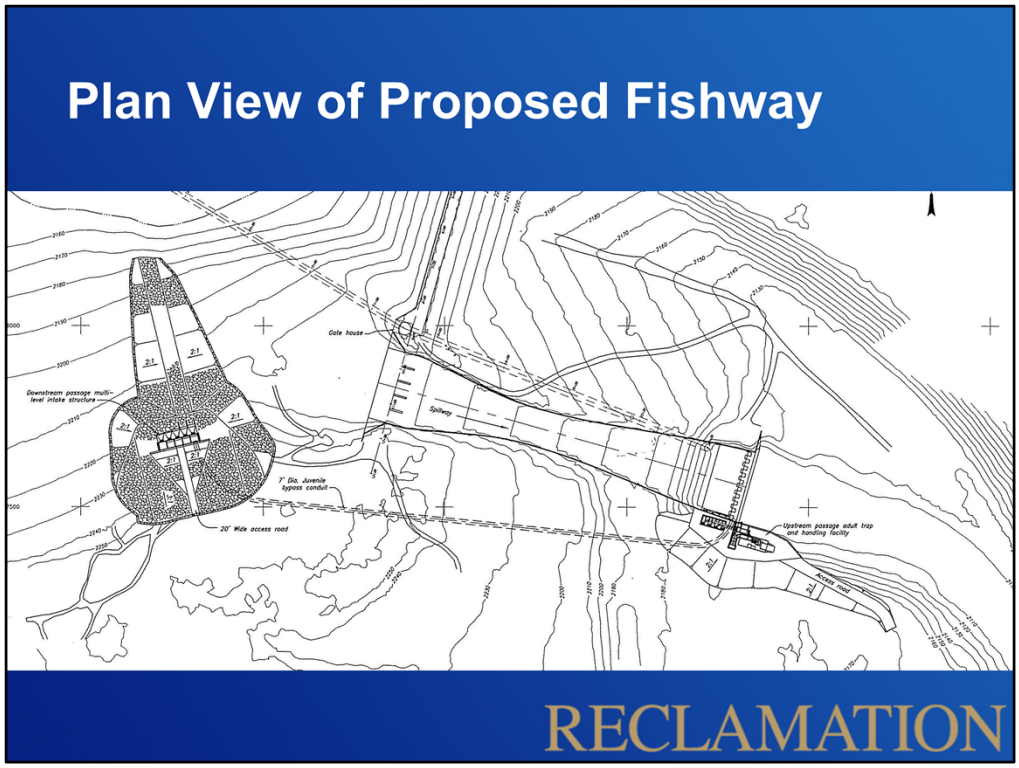


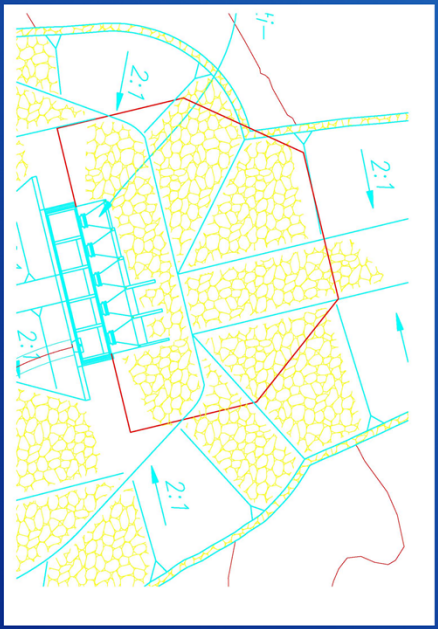
To try and accomplish these goals, in 2012, a design concept provided by Reclamation's Pacific Northwest (PN) Region, was tested in Reclamation's Hydraulic Investigations and Research Laboratory in Denver Colorado. This multi level gated intake structure design was based on following NOAA's standard criteria for downstream fish passage with a maximum water surface drop of 10 ft or maximum velocity of 25 ft/s into any bay. Flow coming into the structure, would cascade over a series of weirs (10 ft drop height) discharging into a free flow conduit (pipe) passing under the right abutment of the spillway. The intake structure would provide surface withdrawal over a range of reservoir pool elevations to cover water surface fluctuations in the reservoir any time the reservoir water surface is within 50 feet of full pool. Downward opening weir gates would be used to select withdrawal conditions favoring juvenile fish attraction. The gates would provide fish passage flows in the range of 100 ft^3/s to 400 ft^3/s. Only the uppermost one or two gates beneath the reservoir water surface would be operated at any given time, while the other gates remain closed.

The series of drop-pools was also a means for maximizing energy dissipation to provide a smooth, low velocity, transition into the downstream passage conduit.



The proposed fish passage conduit was a 7 to 8-foot diameter reinforced concrete structure 1,520 feet long. Fish carried through the conduit would be released into the river at the downstream end of the spillway stilling basin. The proposed downstream fish passage facilities were designed to maximize passage for the majority of the season when smolts are migrating in early March to June, even in drier years. The height of the intake structure and gate elevations were selected to optimize the fish passage window without an excessive increase in costs.

1:10 Geometric Scale - Model Extents (red line)



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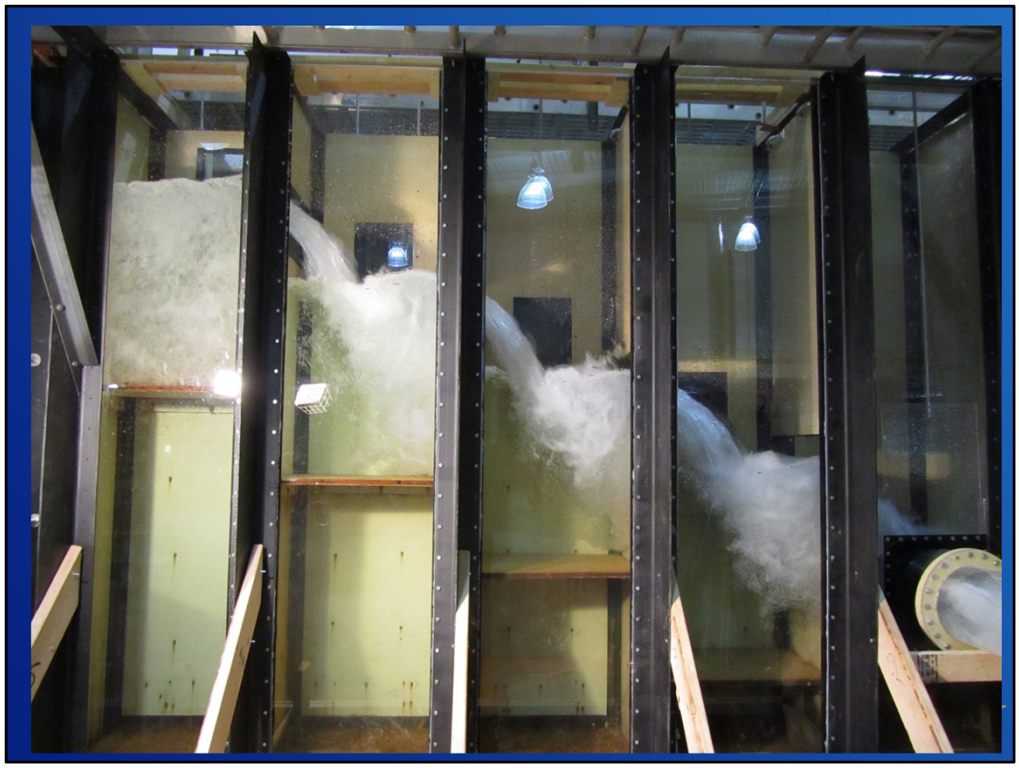


The intake tower consists of 5 drop bays each 20 ft long by 20 ft wide by 20 ft deep with inflow controlled by four adjustable 8 ft wide by 16 ft high entrance gates (prototype) and one adjustable 8 ft by 8 ft entrance gate, each with ramped and converging entrances. The structure can be operated when the reservoir is in the range of 2190 ft to 2240 ft. The front wall of the intake structure was made of Plexiglas to provide for full viewing and evaluation of flow conditions in each drop bay.

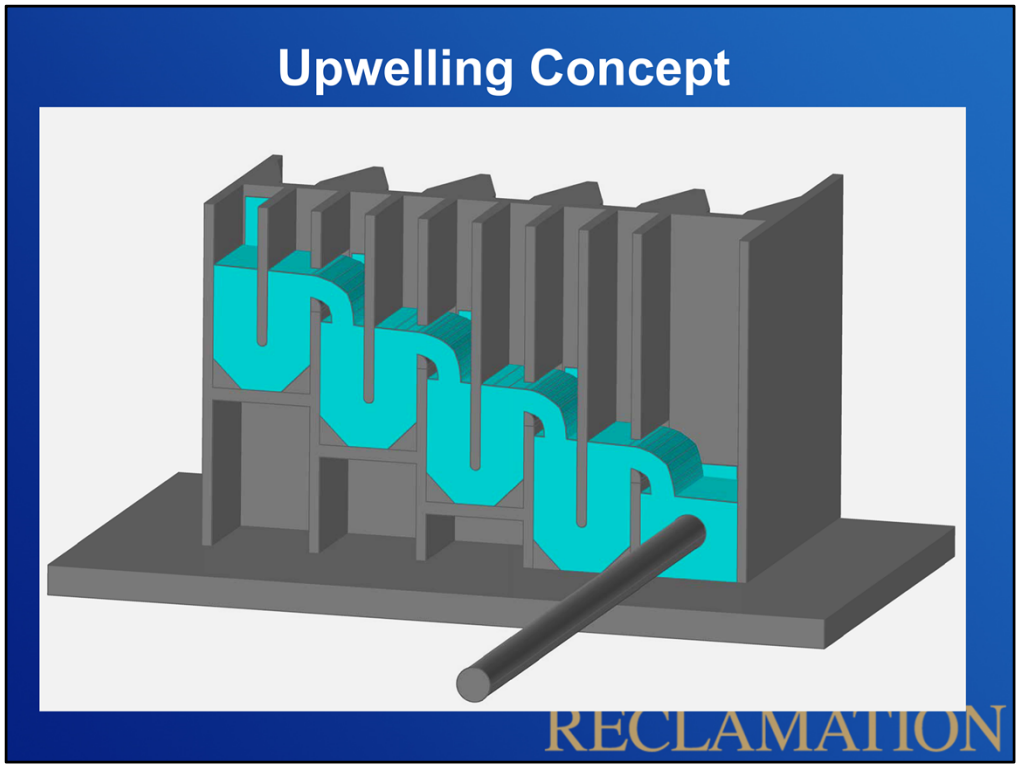
In addition, a 100 ft section of the free-flowing outlet conduit was modeled to evaluate conduit entrance conditions. Due to the scale of the model required to investigate flow within the bypass structure, the reservoir outlet works and the spillway were not included in the model.

The laboratory investigations demonstrated there were significant issues with the design.

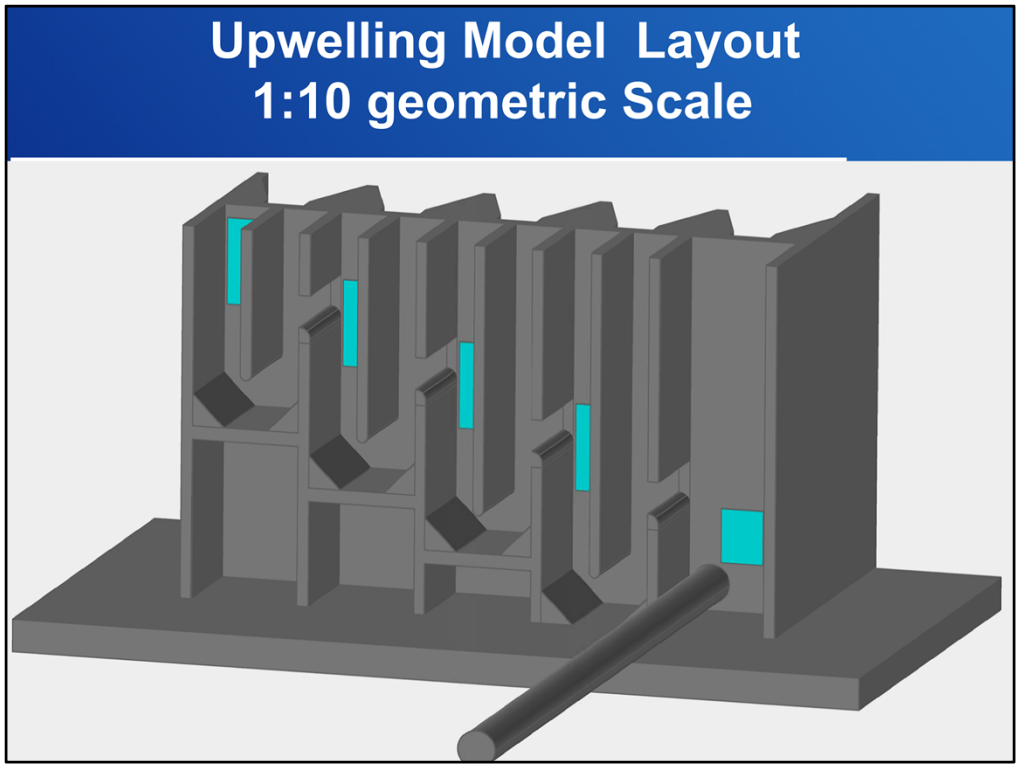
This shows the model operating at the prototype design flow (Q) of 400 cfs. Gel-beads were injected into the flow to better observe and demonstrate flow patterns within each bay. Flow coming into the 1st bay from the reservoir is extremely turbulent and significantly impacts the floor and sidewalls. Thus, it is not very fish friendly. Then observing the following bays, flow recirculation provides large areas for fish to seek refuge, potentially leading to long holding times and increased stress levels, which can lead to high mortality rates in fish.

Next, to try and improve flow conditions and keep fish moving downstream, two rectangular orifice slots were added to each of the four divider walls in each bay. These were added to provide a means for the fish to continue moving downstream should they congregate near the bottom of a bay. Each slot was 1 foot wide by 2 ft high. About 30% of the total flow, that was moving past the weir divider wall into the adjacent downstream bay, was pulled through the orifice slots. One problem with this configuration was that the range of influence of flow through the orifice only extended a short distance (about 2.5 ft) upstream from the slot, where it actually turned flow toward the opening. The video demonstrates that beads are occasionally pulled into the an orifice. However, beyond the distance of about 2.5 feet upstream from each downstream wall, flow recirculates much as it did before the orifices were added. Not only that, this flow pattern has the potential to carry fish directly into the shear zone coming from an adjacent upstream orifice.
As a result of these investigations, the Yakima Storage Dams Fish Passage Core Team (CORE team) decided this intake structure design was unacceptable.

Once this design was abandoned, CORE team members and representatives from Reclamation's Denver office collaborated in a brainstorming session to come up with new design concepts. One of those concepts, was a modified version of the drop-pool concept and was labeled as the "upwelling concept".



The basis for this design was that flow and fish were being pushed through the system very quickly, so although there would be a lot of turbulence associated with this configuration; there was evidence to support the idea that if fish can be passed through a system very quickly, survival may be high (despite that turbulence). The other advantage with this concept is that although more energy is being carried through the system, a fair amount of energy is dissipated so velocities entering the transition into the downstream conduit are relatively low compared with other concepts that had been discussed. Velocities would be reduced to the range of about 12 ft/s to 14 ft/s before entering the downstream conduit.



The physical model was modified to represent the upwelling concept while maintaining a 1:10 scale. To accomplish this, each bay was shifted downstream and centerline walls were added. The location of the centerline walls and the geometry of corner chamfers, were designed so that a consistent cross sectional area was maintained along the flow path. In addition, the crest shape of each weir was modified into an ogee shape (with high discharge coefficient) designed to pull the flow downward close to the wall so that it didn't impact the center wall and helped to drive flow through the system more efficiently. The entrance weirs for each bay remained unchanged.

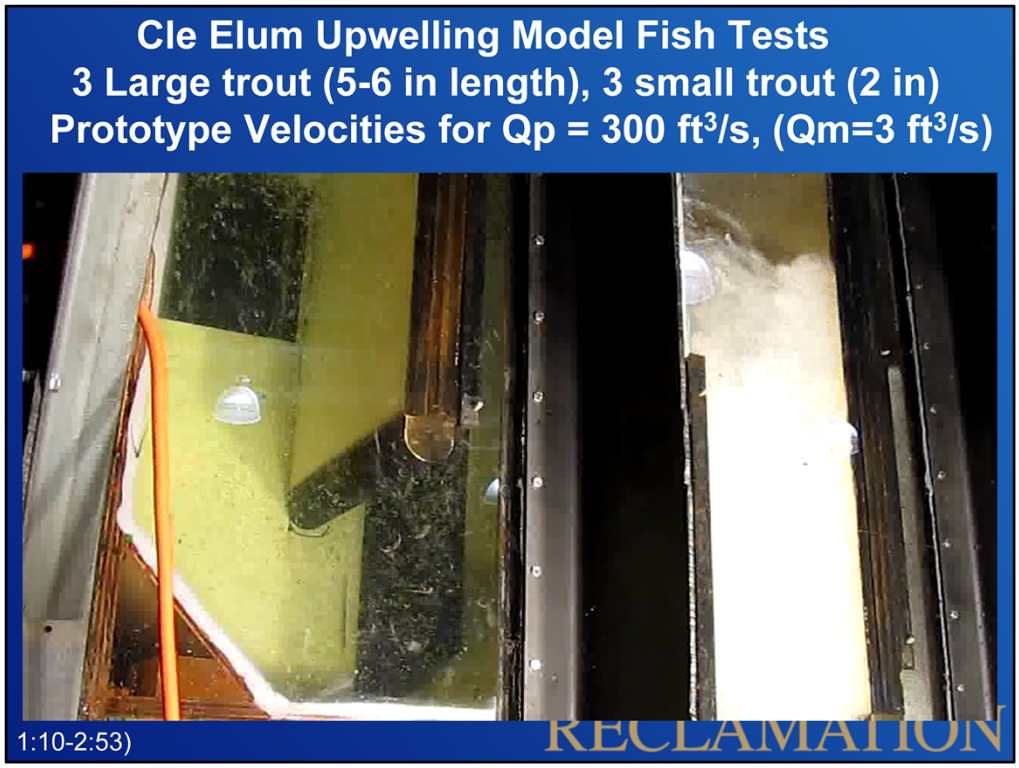
This video shows the model operating at a prototype flow of 400 cfs and reservoir elevation of 2236.6ft. (3.5 feet below maximum pool). Gel beads were injected into the flow to help in observing flow patterns. The beads moved through the system very quickly. As expected, turbulence within the system was considerable, but it showed good potential for getting fish through the system quickly. At this point it appeared to be worthwhile to inject a few fish to see how they would react to the hydraulic conditions. Although these tests did not represent true biological testing, they provided valuable information to the designers by observing how the fish react to the flow conditions. In this case trout were used for the fish tests, since they were readily available.

Model discharge to produce average prototype velocity in model

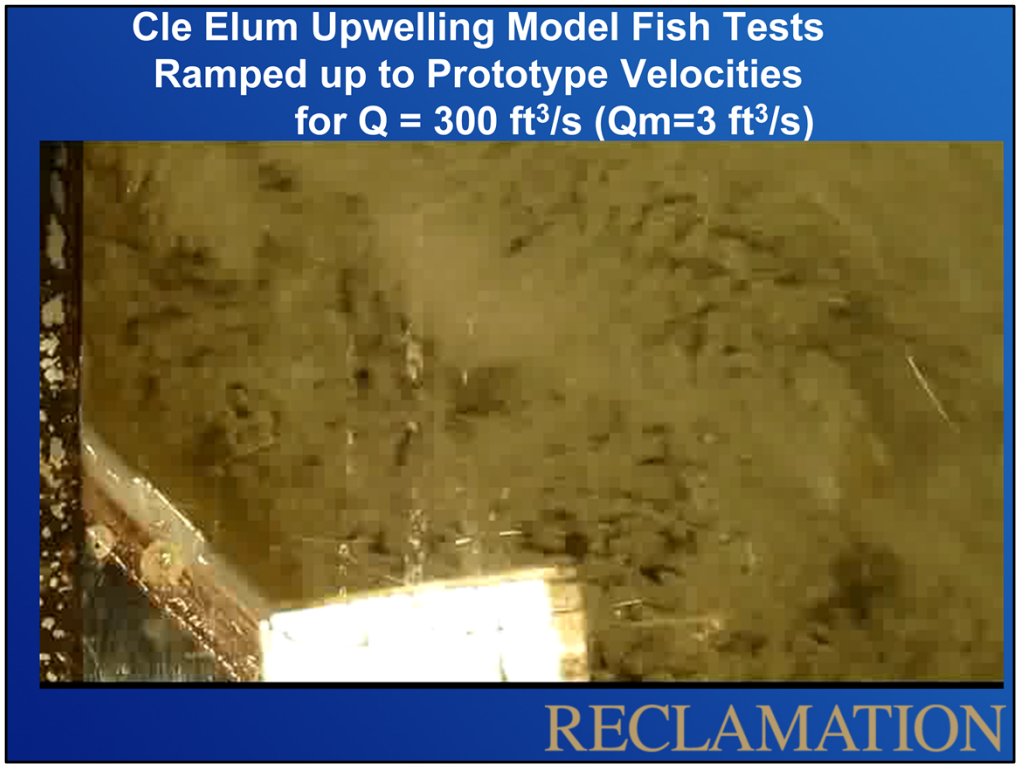
Prototype Discharge	Prototype Cross Section Area below Center Wall	Prototype Average Velocity	Model Cross Section Area below Center Wall	Model Discharge to achieve V_p	Model Scaled Discharge
Q_p (ft^3/s)	A_p (ft^2)	V_p (ft/s)	A_m (ft^2)	$Q_m = Vp * A$ (ft^3/s)	(ft^3/s)
400	180	2.23	1.8	4.0	1.26
300	180	1.67	1.8	3.0	0.95

RECLAMATION

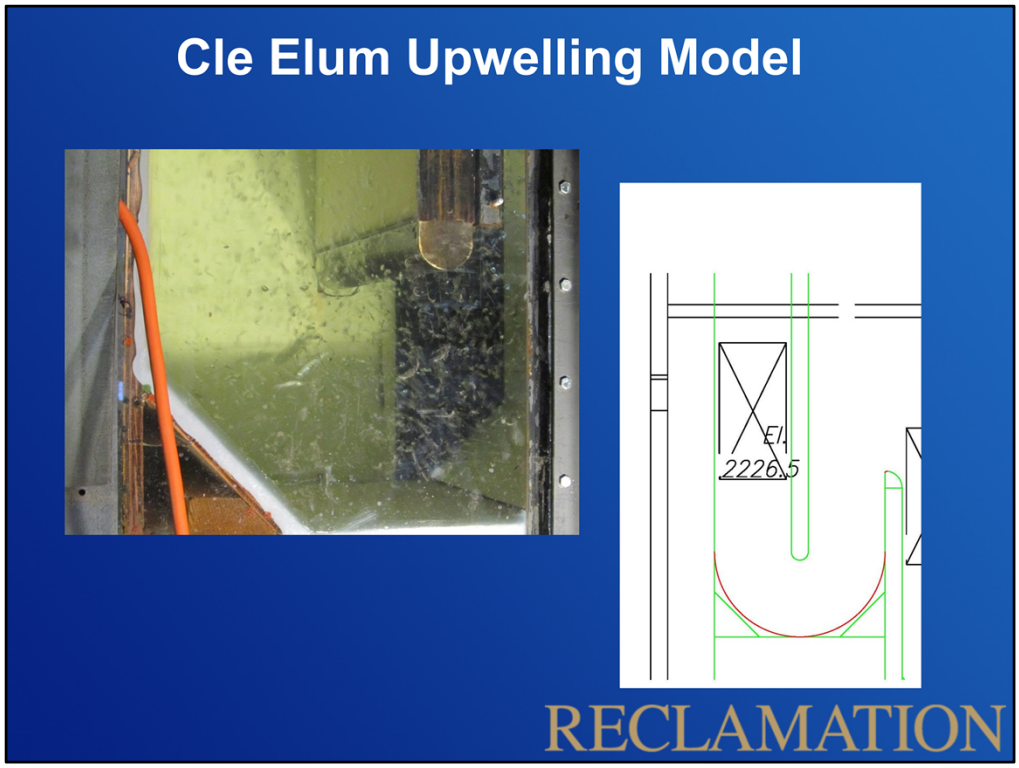
Several different fish tests were conducted. For this test case three small trout, each about 2 inches in length, and 3 large trout (in the range of 5-6 inches in length) were deposited into a screened area upstream from the highest bay (shown). They were allowed to acclimate to the flow for about 10 min before being crowded downstream into the 1st bay



This video shows the model operating with an average prototype velocity close to what it should be for a prototype flow of 300 cfs. Nearly all of the test fish were swept quickly through all bays without delay and into the tail box where they appeared to be ok; however no biological testing was conducted to ensure there was no immediate or long term injury.



In this next video some of the smaller fish (about 2 inches in length) were deposited into the first bay at a very low flow rate. The flow was gradually increased over a 15 minute period until prototype velocities corresponding to a flow rate of 300 cfs were reached. Most of the fish passed through the system well before the target velocity was reached. This portion of the video was taken near the end of that 15 minute period and shows a few of the stronger fish struggling to maintain control, however they also pass through the system before a prototype velocity at 300 cfs is reached.



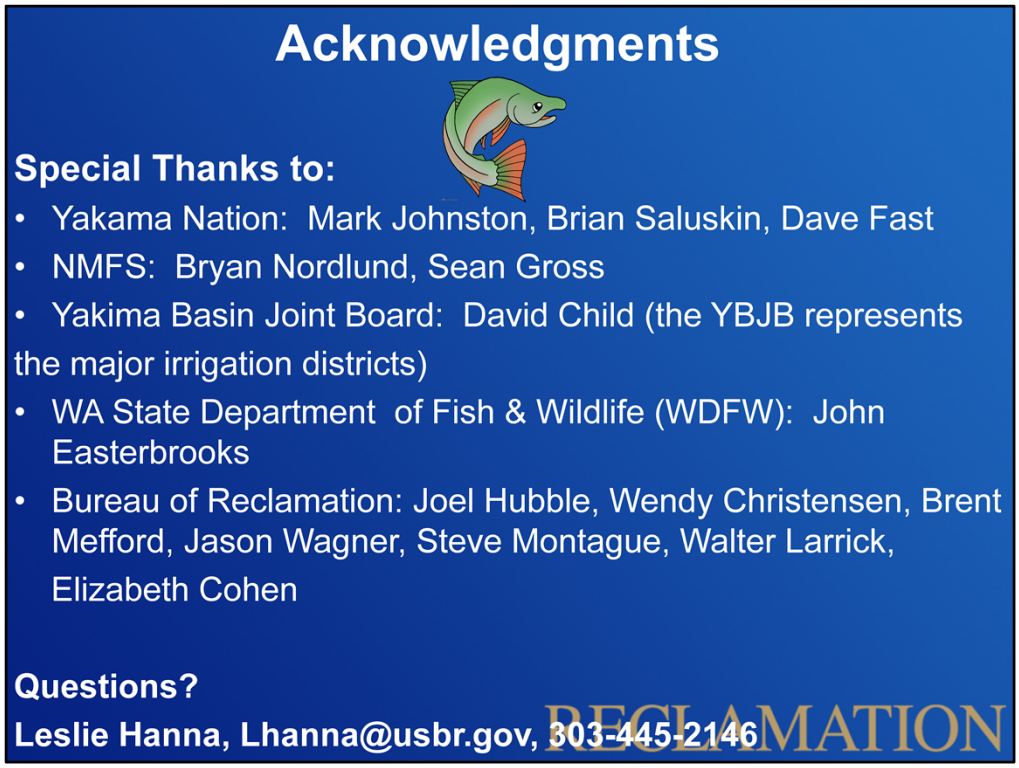
This video shows one of the tests where we found that several fish had managed to seek refuge in the 2nd bay where a small area of recirculation (eddy) had formed at the location where the corner chamfer meets the side wall. This is a case where testing with fish helped identify a problem area within the design. As a result, it was determined that if this design were to be carried forward, the corner chamfers would be replaced with a corner radius similar to what is illustrated here. In addition the corner radius could be reduced further to accelerate the flow through this area so fish have no chance of holding in this area.

Upwelling Concept Conclusions

- Improved design over drop –pool concept
- Fish should pass through system quickly although within a very turbulent environment
- Sinusoidal design is not considered optimal by fisheries biologists
- Further evaluation with biological testing is recommended if this concept were carried forward

RECLAMATION

The conclusions from this study are presented here, however after further evaluation it was decided by Core team members and Denver staff to abandon this concept in favor of a helical type design.



Special thanks to all these people that contributed their expertise to this project and to the brainstorming effort in coming up with the final concept for testing.

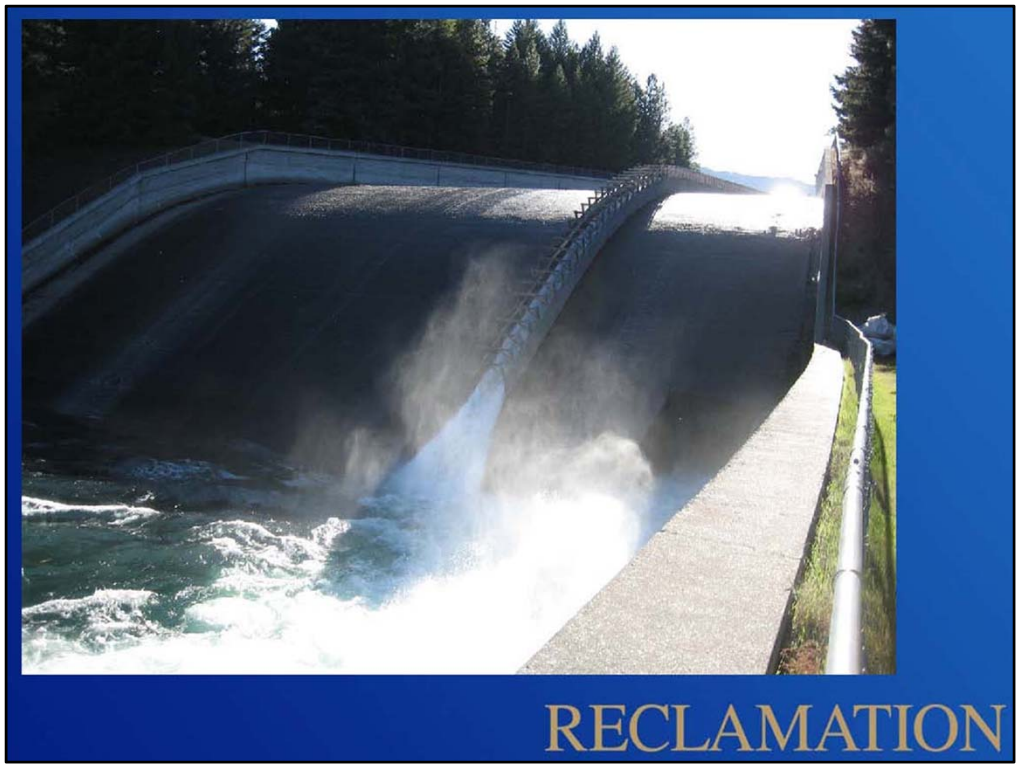
End
RECLAMATION

Additional Slides

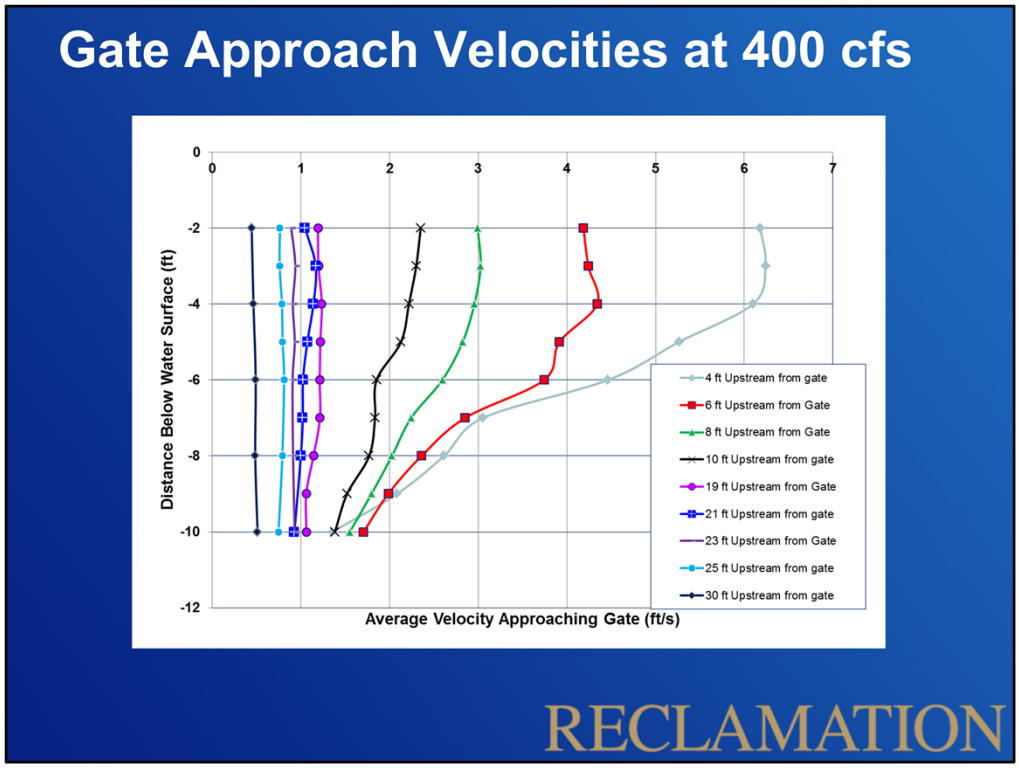
RECLAMATION

Interim Fish Passage at Cle Elum Dam

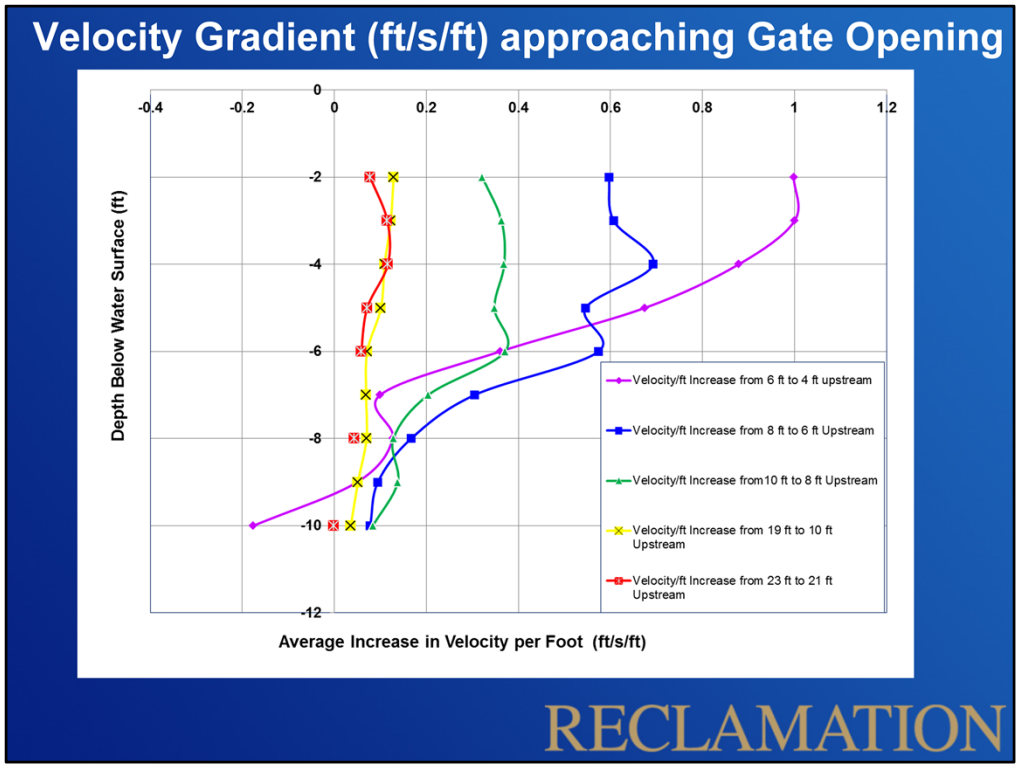
- Reclamation agreed to provide interim downstream fish passage at Cle Elum dam until a permanent facility was implemented, as a part of an agreement with the Yakama Nation.


RECLAMATION

The converging side walls and ramp on the upstream face of the structure were designed to provide a smooth transition into the gates to meet a maximum recommended velocity gradient criteria (at the time of this study) of 1 ft/s/ft until capture velocity (7.8 ft/s) was reached.



This shows velocity profiles measured in the model beginning 4 ft upstream from the gate.



This shows the velocity gradient for the consecutive profiles shown on the previous slide. Velocity gradients remained below the 1.0 ft/s/ft criteria, demonstrating that the converging walls and ramp performed as they were designed to do.

SLIDES

RECLAMATION

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(a progression of studies and lessons learned)

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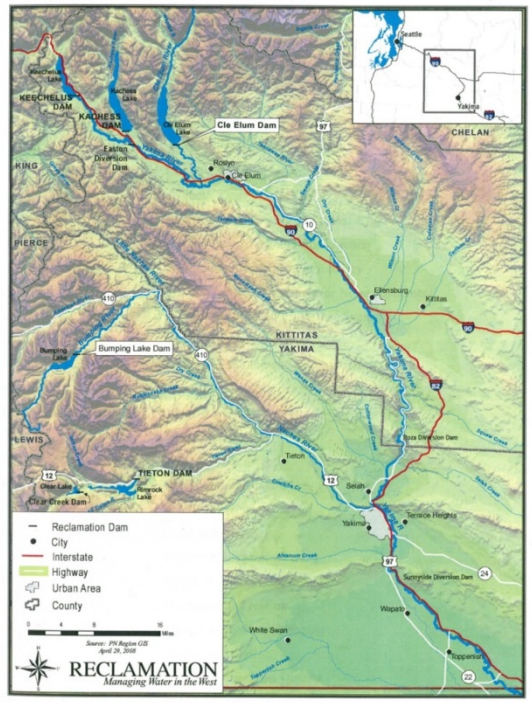
Yakima Project Dams



Yakima Project Storage Dams, including Cle Elum and Bumping Lake Dams

RECLAMATION

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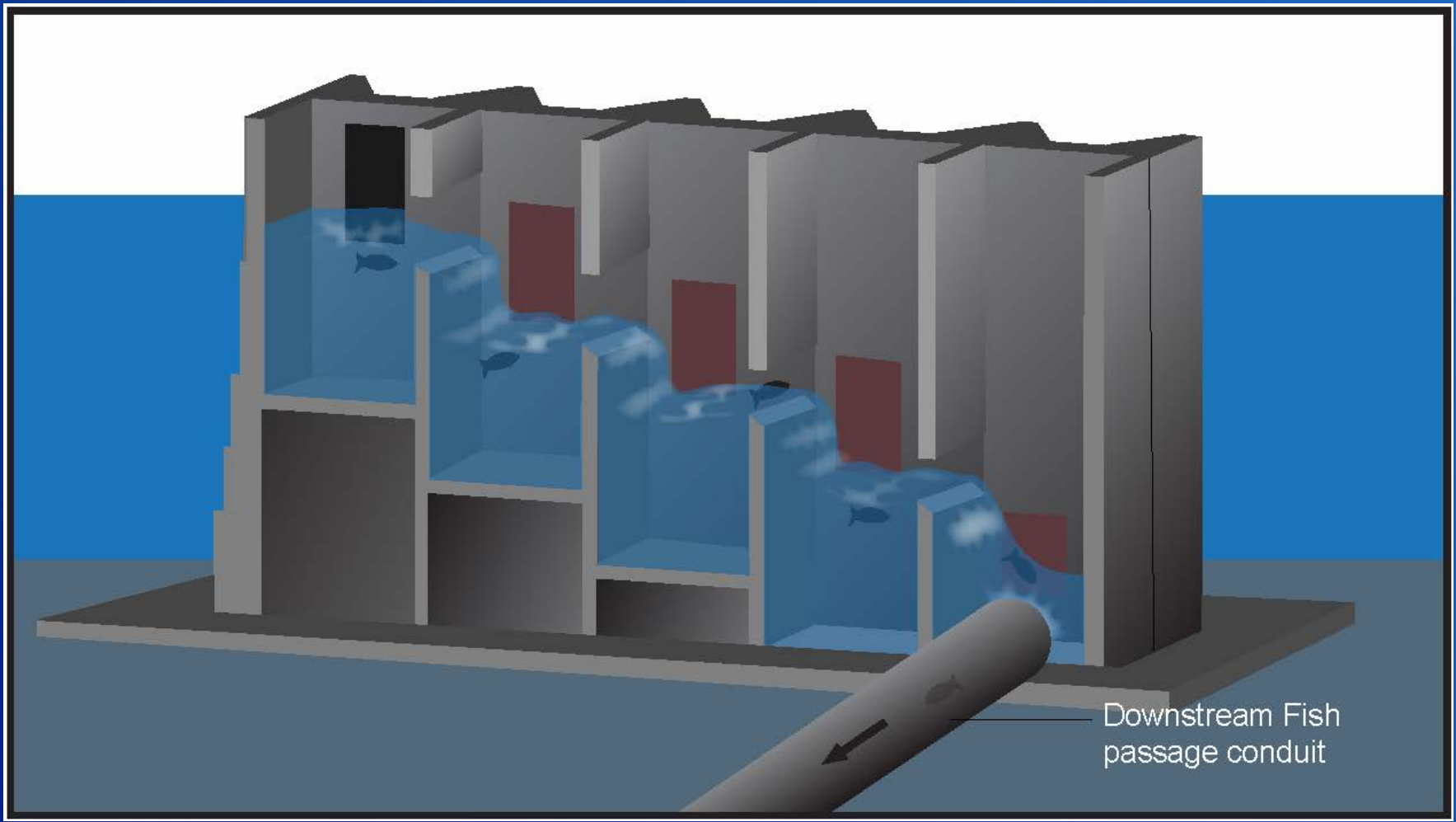
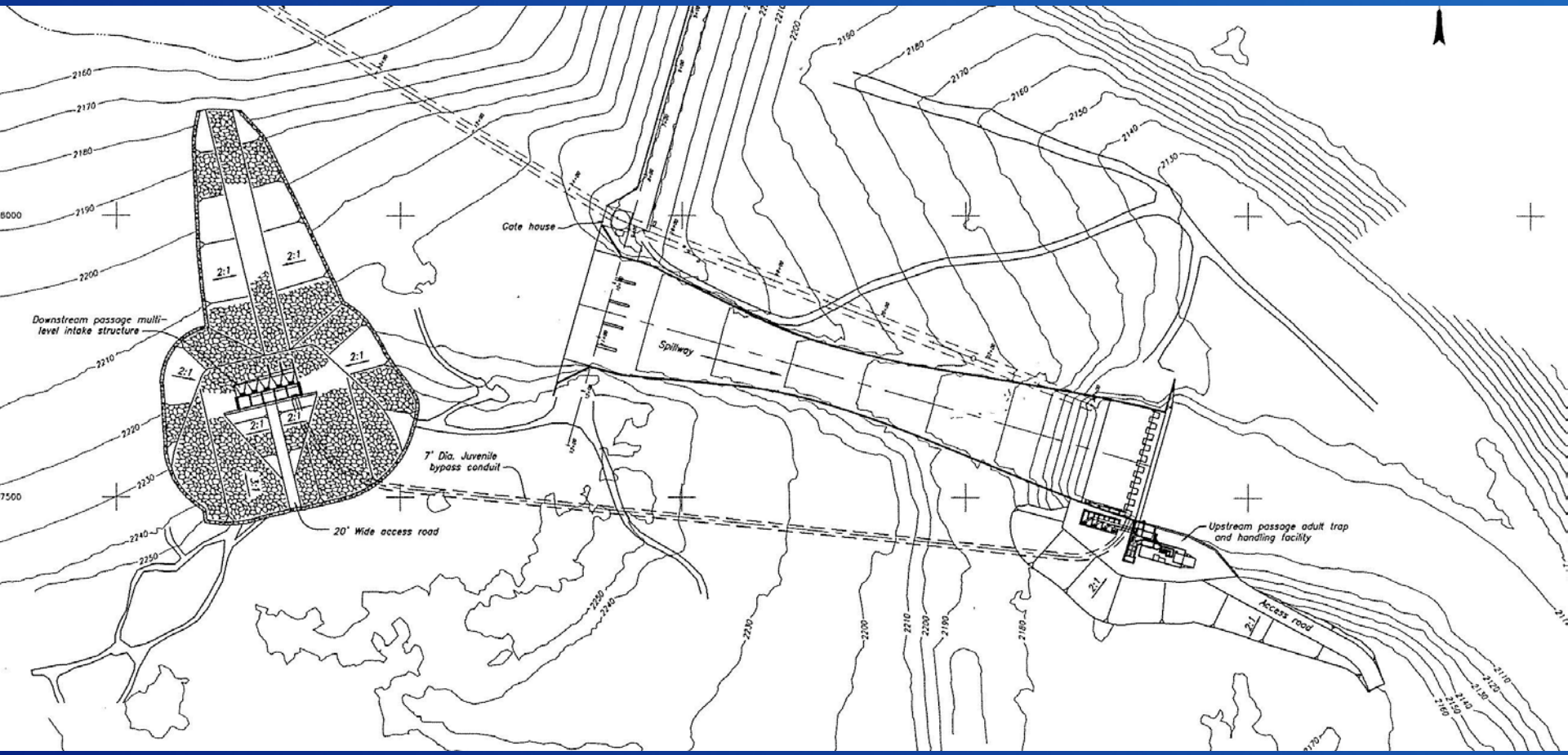
RECLAMATION

Interior View of Multi-level Gated Intake Structure



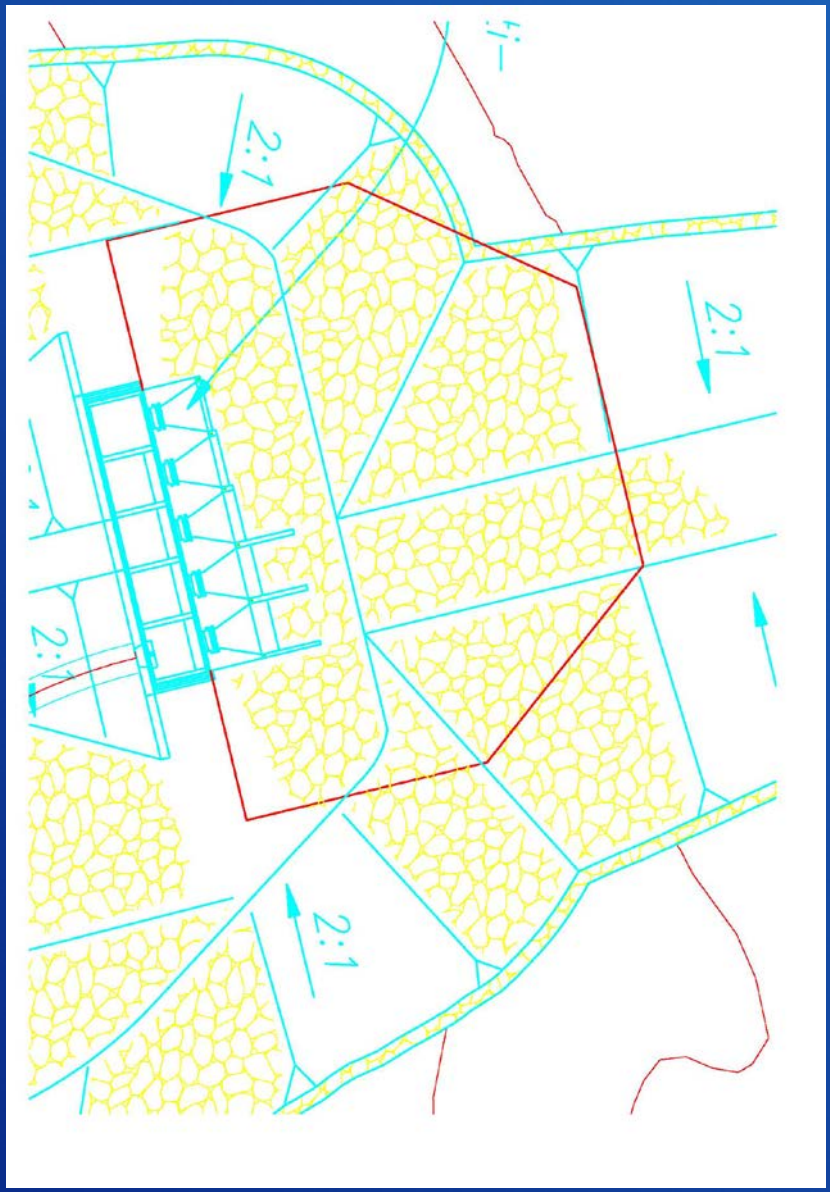
RECLAMATION

Plan View of Proposed Fishway



RECLAMATION

1:10 Geometric Scale - Model Extents (red line)



RECLAMATION

RECLAMATION

Cle Elum Intake Tower , Q = 400 cfs

RECLAMATION

Cle Elum Intake Tower with Orifices
Q = 200 cfs

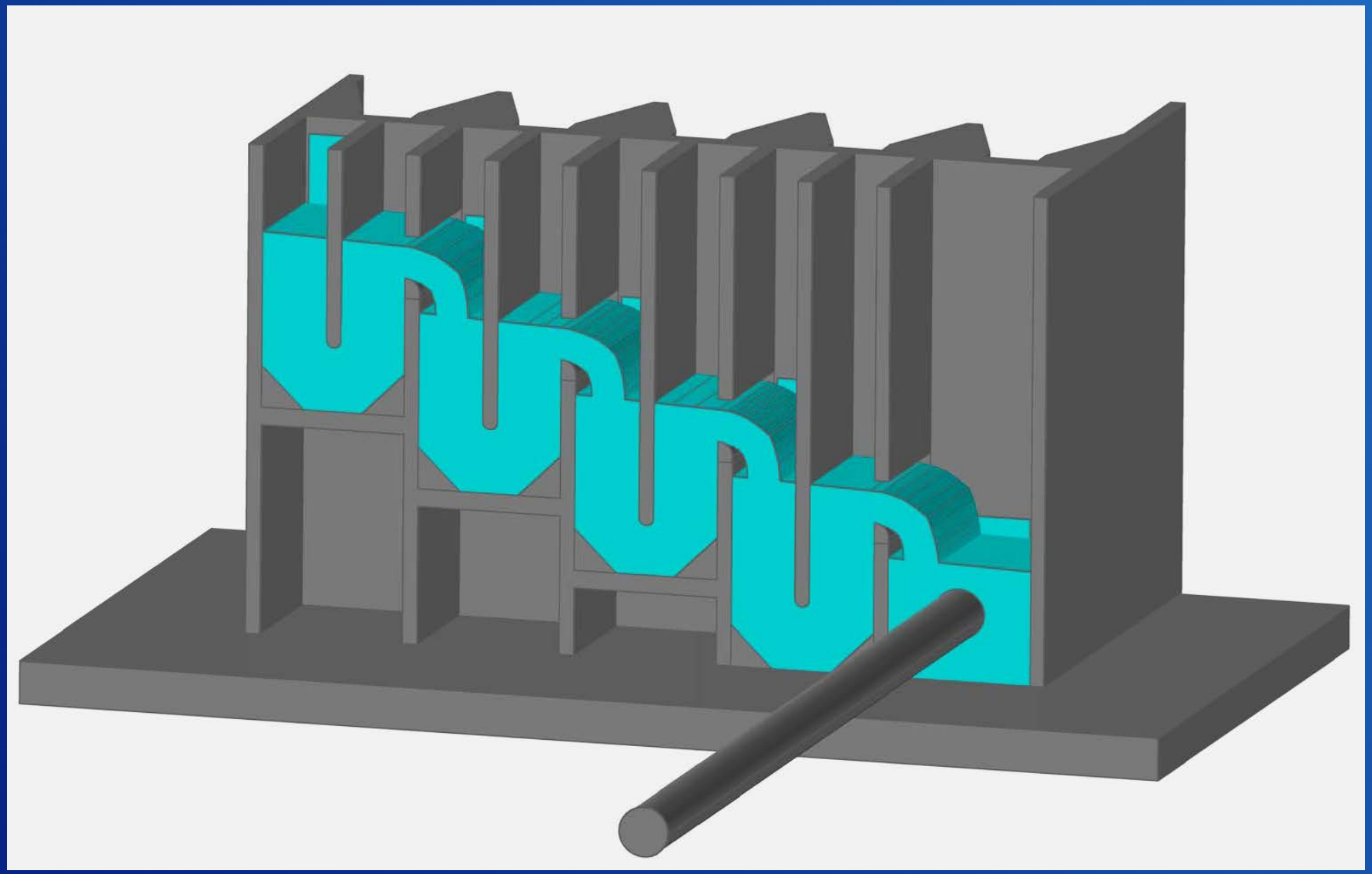
RECLAMATION

Back to the drawing board!!!

Brain storming new concepts

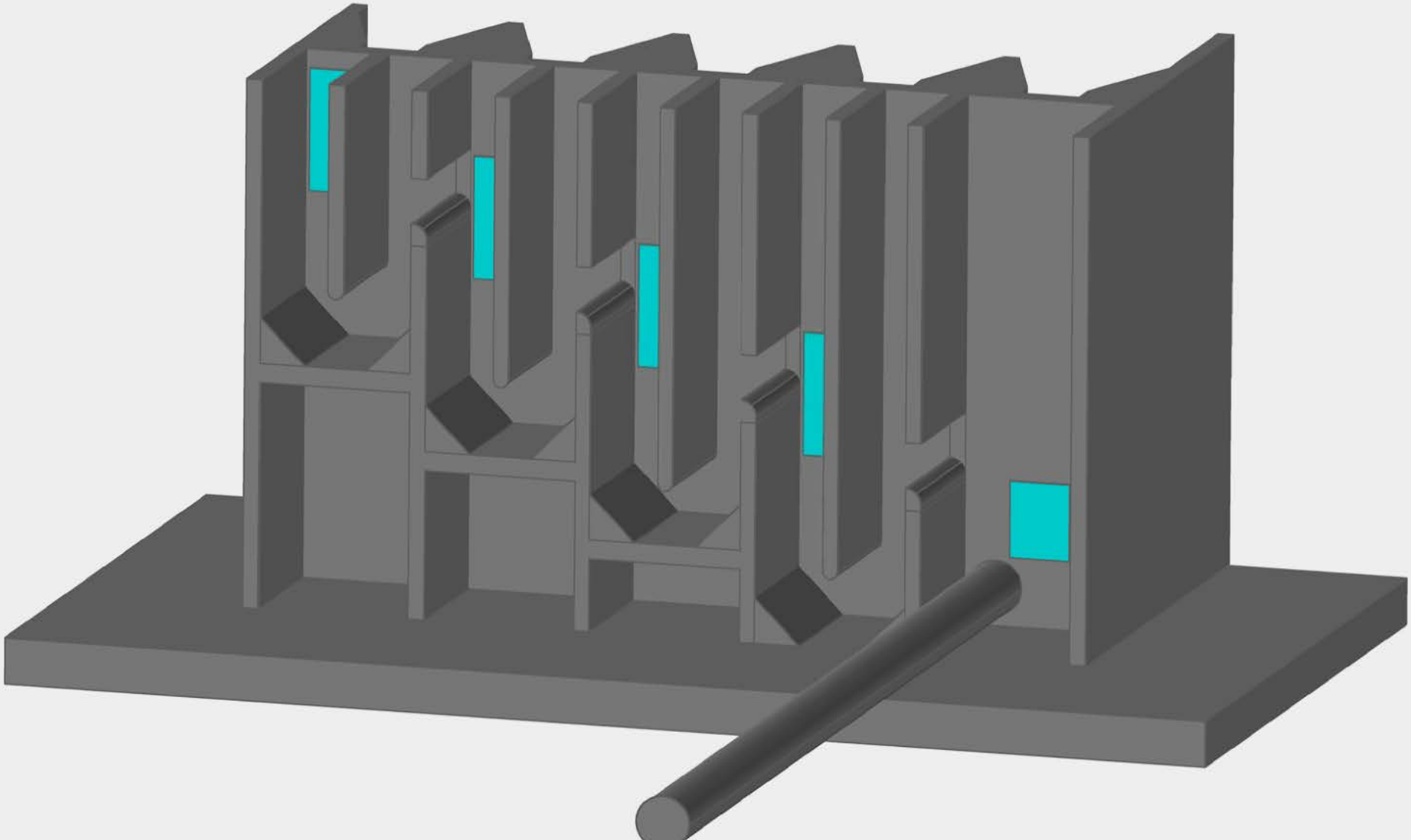
RECLAMATION

Upwelling Concept

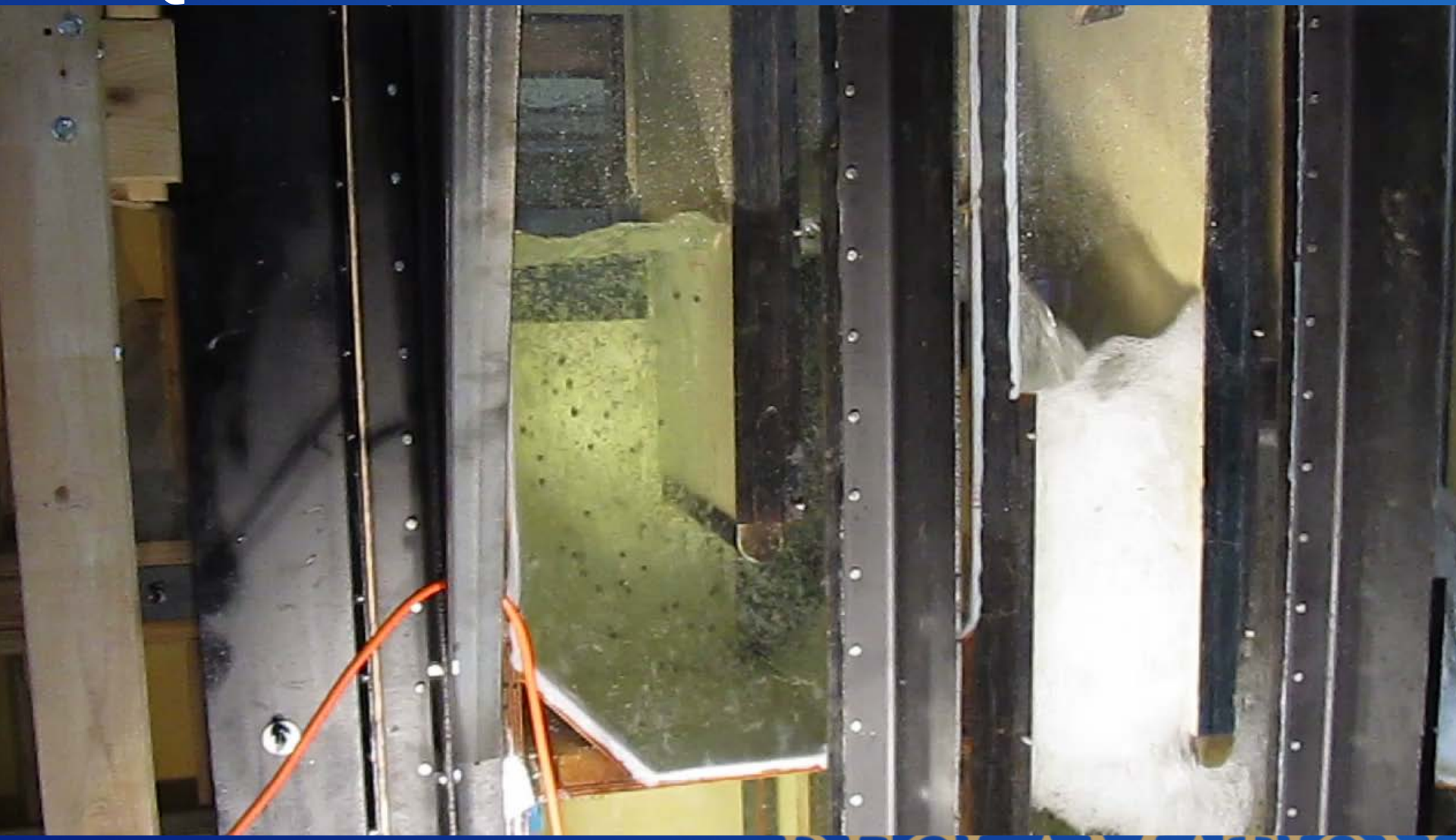


RECLAMATION

Upwelling Model Layout
1:10 geometric Scale



Cle Elum Upwelling Model
Q = 400 cfs Reservoir El 2236.6 ft



RECLAMATION

Model Discharge to produce average prototype velocity in model

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RECLAMATION

RECLAMATION

Cle Elum Upwelling Model Fish Tests
3 Large trout (5-6 in length), 3 small trout (2 in)
Prototype Velocities for Qp = 300 ft^3/s, (Qm=3 ft^3/s)

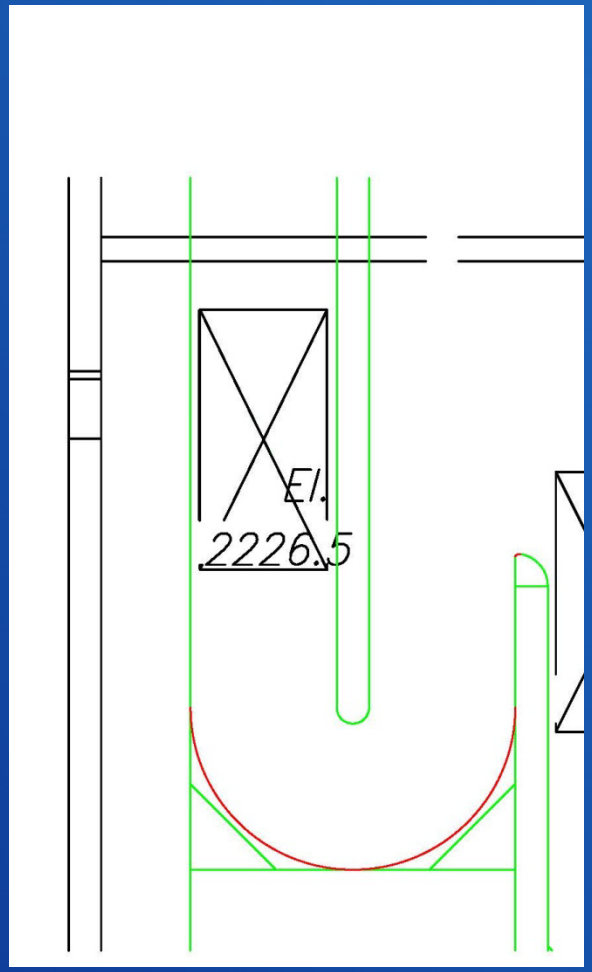
1:10-2:53)

RECLAMATION

Cle Elum Upwelling Model Fish Tests Ramped up to Prototype Velocities for Q = 300 ft^3/s (Qm=3 ft^3/s)

RECLAMATION

Cle Elum Upwelling Model



RECLAMATION

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RECLAMATION

Acknowledgments

Special Thanks to:

- Yakama Nation: Mark Johnston, Brian Saluskin, Dave Fast
- NMFS: Bryan Nordlund, Sean Gross
- Yakima Basin Joint Board: David Child (the YBJB represents the major irrigation districts)
- WA State Department of Fish & Wildlife (WDFW): John Easterbrooks
- Bureau of Reclamation: Joel Hubble, Wendy Christensen, Brent Mefford, Jason Wagner, Steve Montague, Walter Larrick, Elizabeth Cohen

Questions?

Leslie Hanna, Lhanna@usbr.gov, 303-445-2146

RECLAMATION

End

RECLAMATION

Additional Slides

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Interim Fish Passage at Cle Elum Dam

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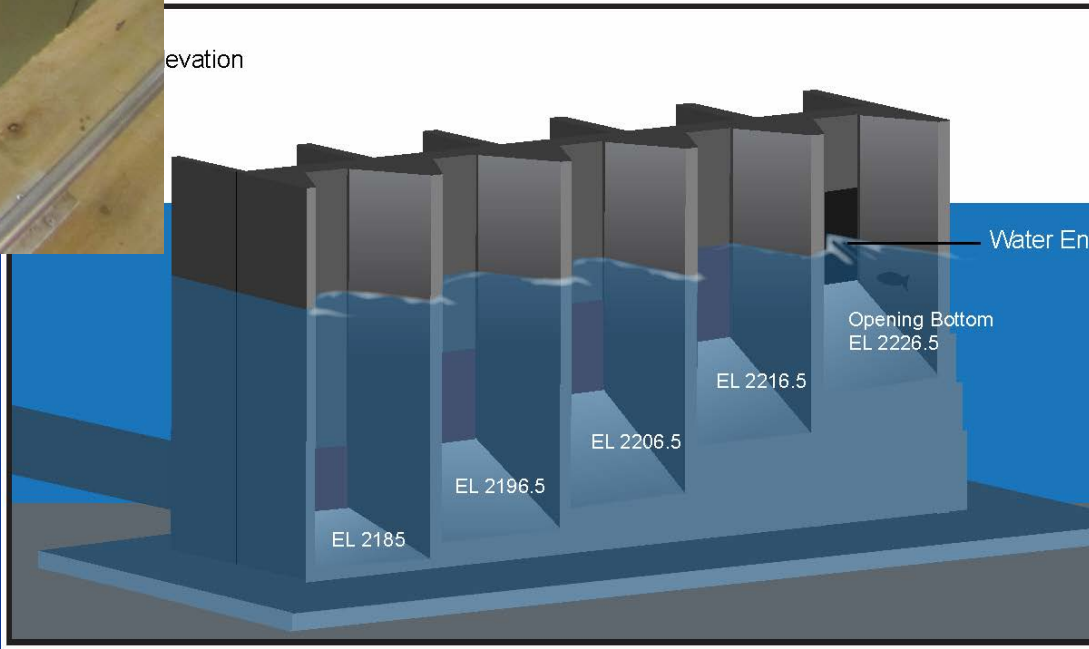
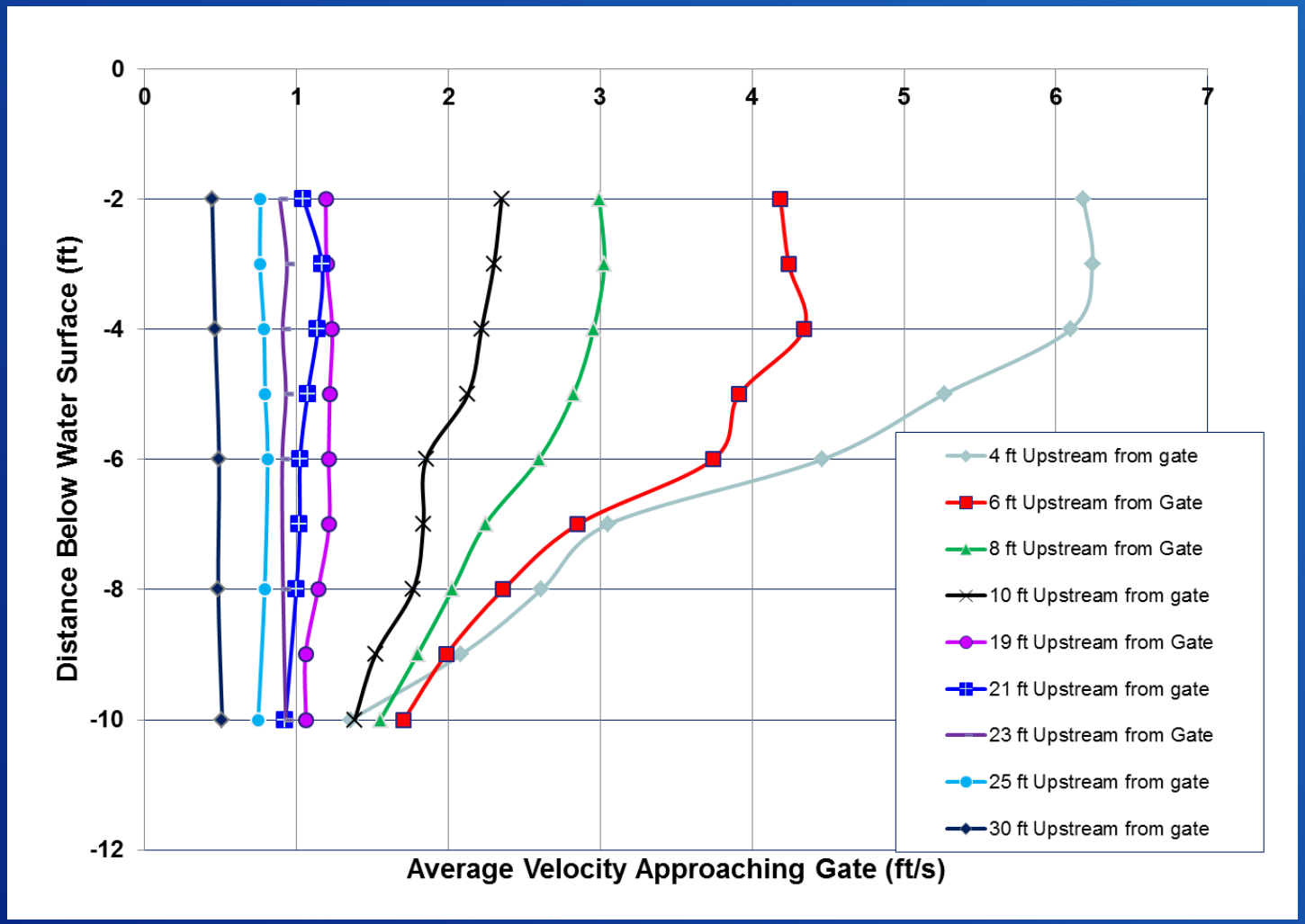
RECLAMATION

Upstream View (trashrack not shown)

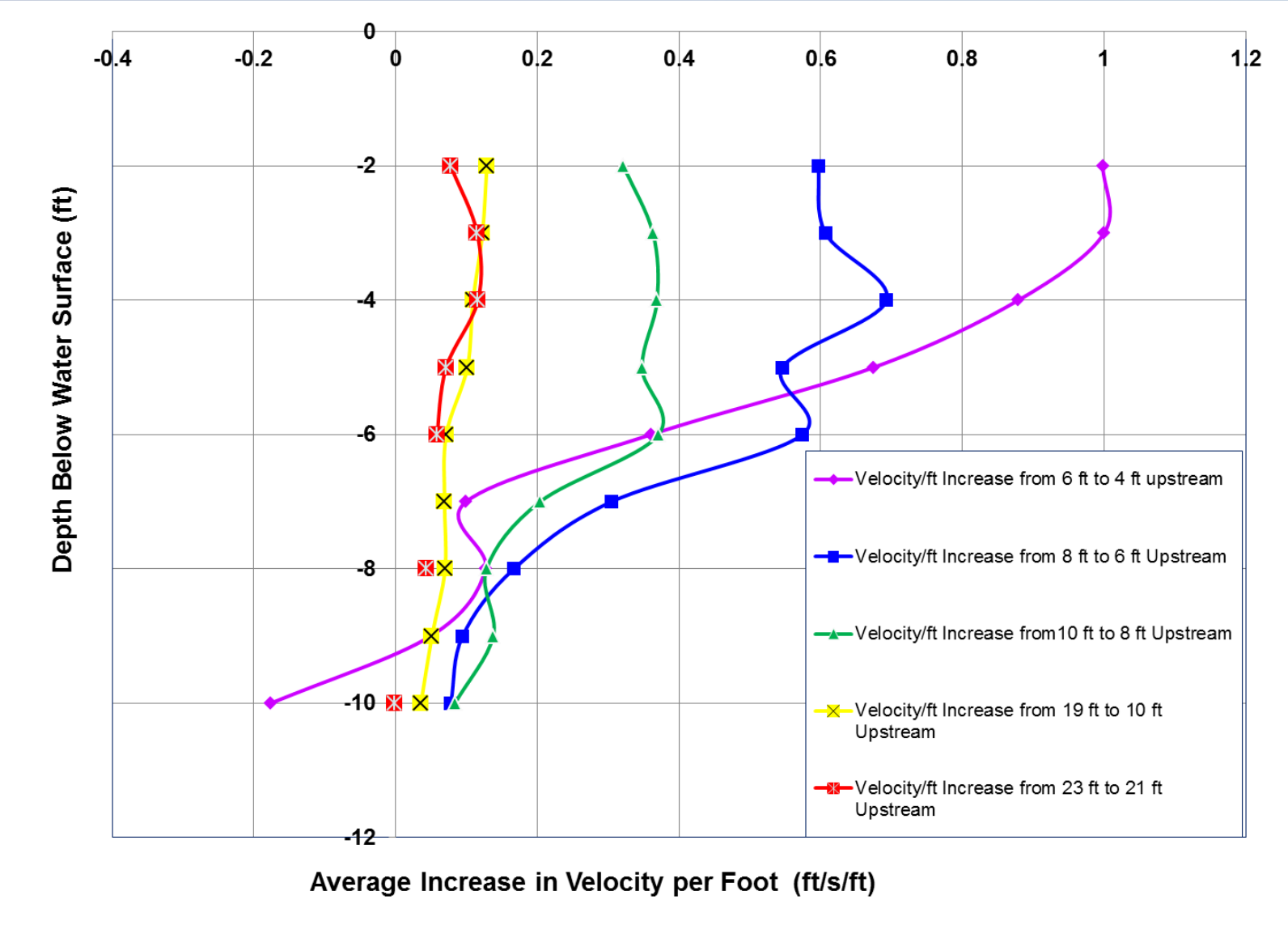


Gate Approach Velocities at 400 cfs



RECLAMATION

Velocity Gradient (ft/s/ft) approaching Gate Opening



RECLAMATION

PRESENTATION OUTLINE

1 **Cle Elum Dam Downstream Fish Passage**
(a progression of studies and lessons learned)

Leslie Hanna
Hydraulic Investigations & Research Laboratory

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- Large water surface fluctuations due to seasonal releases
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6 **Interior View of Multi-level Gated Intake Structure**

7 **Plan View of Proposed Fishway**

8 **1:10 Geometric Scale - Model Extents (red line)**

9

10

11

12

13 **Back to the drawing board!!!**

Brain storming new concepts

14 **Upwelling Concept**

15 **Upwelling Model Layout**
1:10 geometric Scale

16 **Cle Elum Upwelling Model**
Q = 400 cfs Reservoir El 2236.6 ft

17 **Model discharge to produce**
average prototype velocity in model

18

19 **Cle Elum Upwelling Model Fish Tests**
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26

27

28 **Upstream View (trashrack not shown)**

29 **Gate Approach Velocities at 400 cfs**

30 **Velocity Gradient (ft/s/ft) approaching Gate Opening**