Session D1 - Application of CFD Models in Support of Fish Passage Facilities Design

Applications of CFD Modeling in Support of Fish Passage Facilities Design

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Presentation Outline

- Modeling needs and types of models
- How modeling fits into the design process
- Guidelines for model Selection and application
- Project examples, challenges, and lessons learned
- Summary

Passage System Components and Design Questions to be Answered All Tied to Hydraulics

- Site-specific and not easily calculable
  - Where to collect?
  - How to collect?
  - How to bypass?
  - Where to release?
  - How to release?

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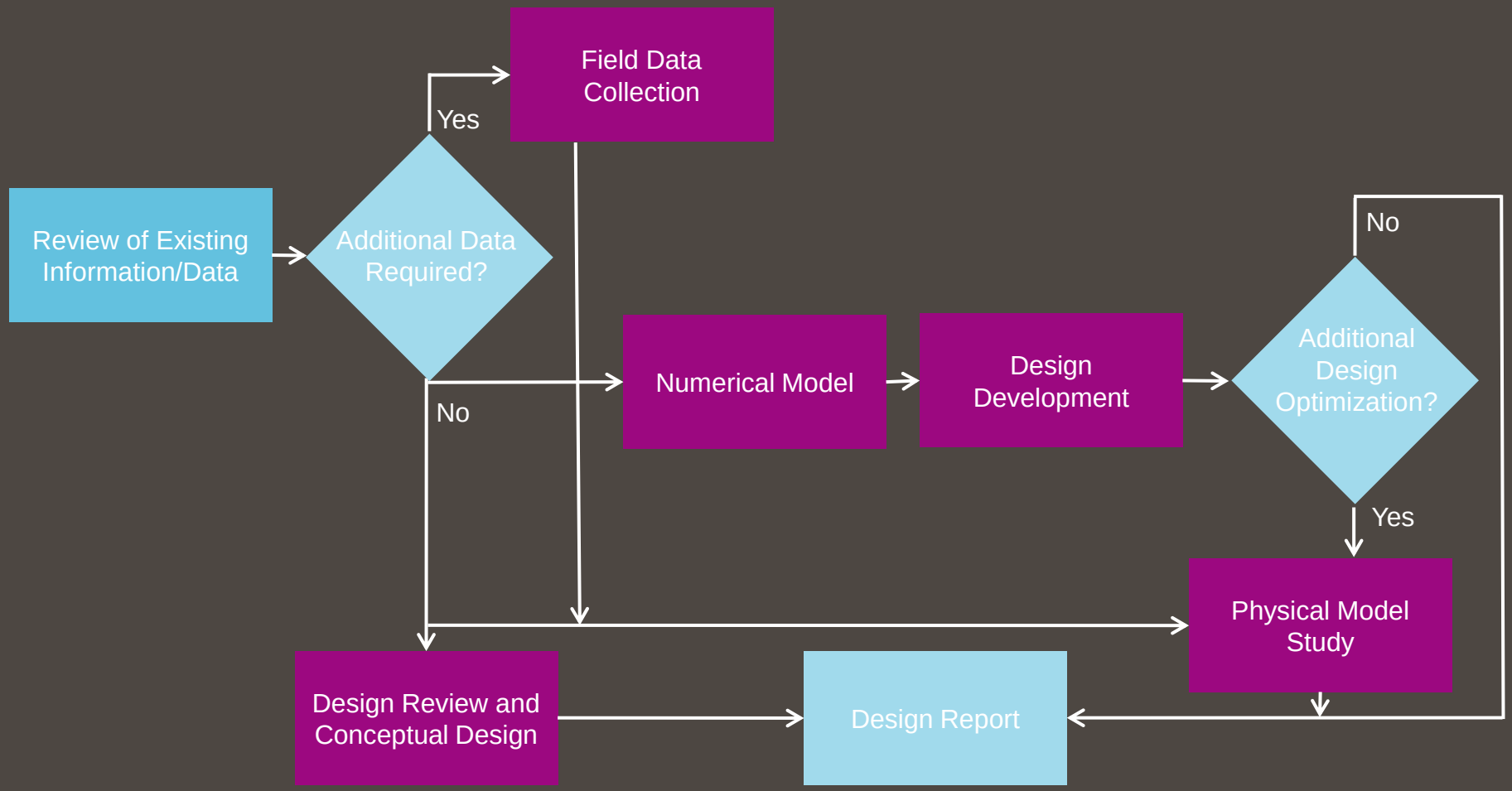
When and Where is Modeling Needed?

- Complex flow conditions and difficult to predict without modeling
- Insurance policy – We know what we need, but just in case!
- Stakeholder buy-in – Let me show you how we are going to do it so you will buy it!
- Voyage of discovery – We know what we don't know, we think!
- Most studies are a combination of all 4 types

Typical Flow Chart-Application of Hydraulic Models



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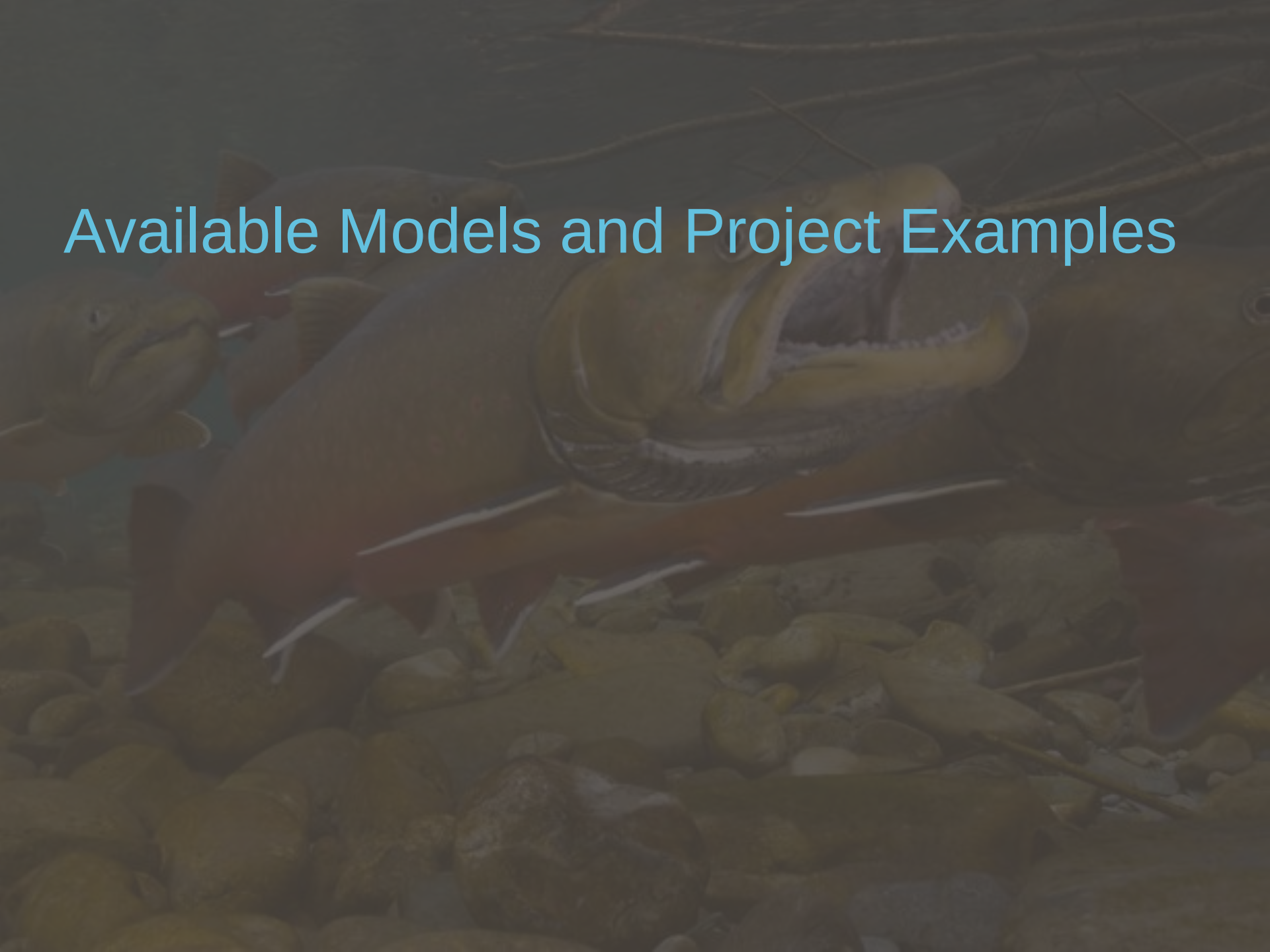
Available Models and Project Examples



Available Modeling Tools

- Numerical Models
  - 1-D
  - 2-D
  - 3-D
- Physical Models
- Hybrid Physical and Numerical Modeling

Computer Models

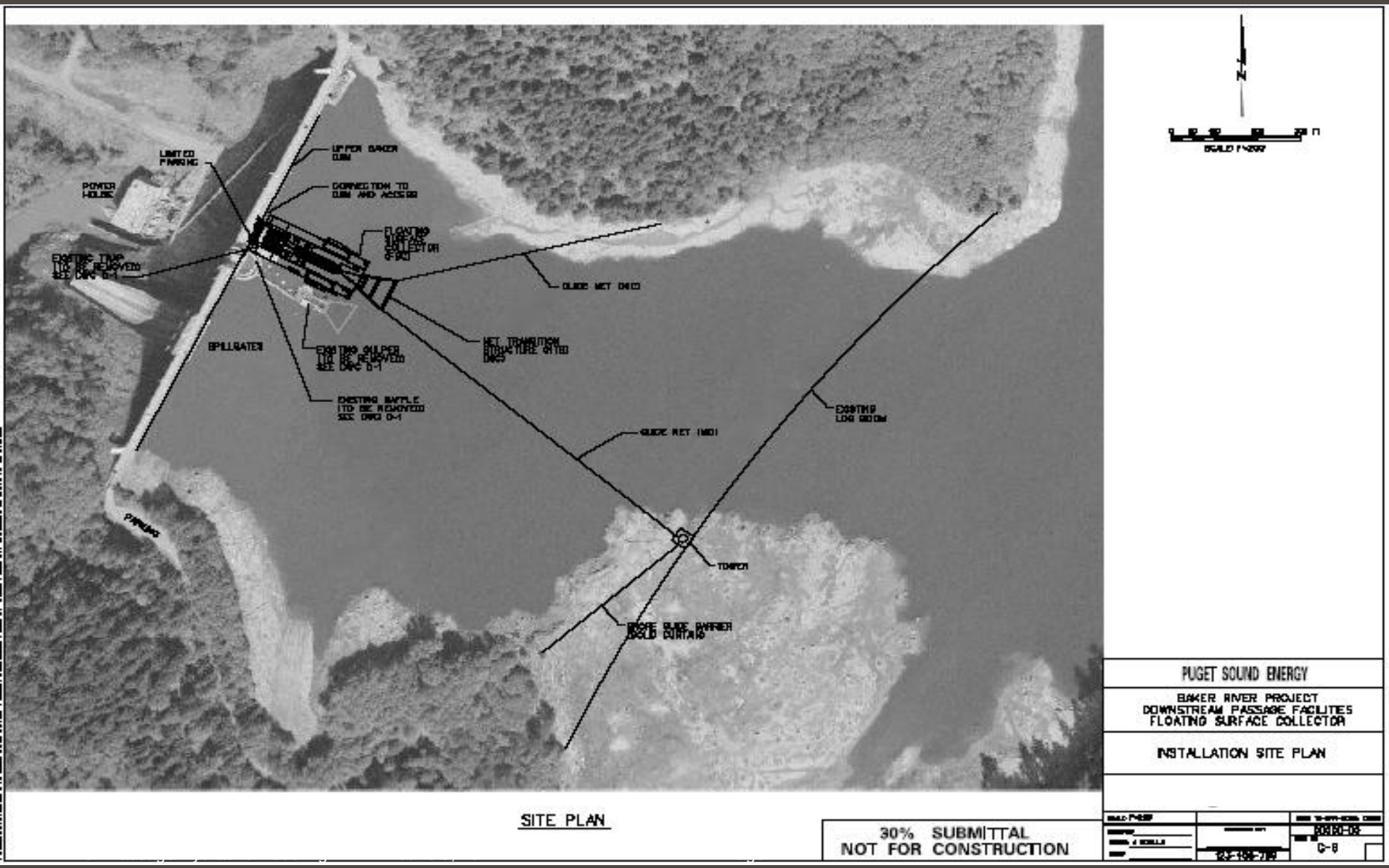
- Hydrologic – HEC-HMS (HEC-1)
- Hydraulic – HEC-RAS, HEC-6, RMA2, HIVEL2D, and SED-2D
- Hydrodynamic – EFDC, and Princeton Ocean Model (POM)
- **Computational Fluid Dynamic (CFD) – STAR CD, FLOW3D, and FLUENT**
- Water Quality – CE-Qual-W2, QUAL2E, and BETTER

CFD Model Studies - Objectives

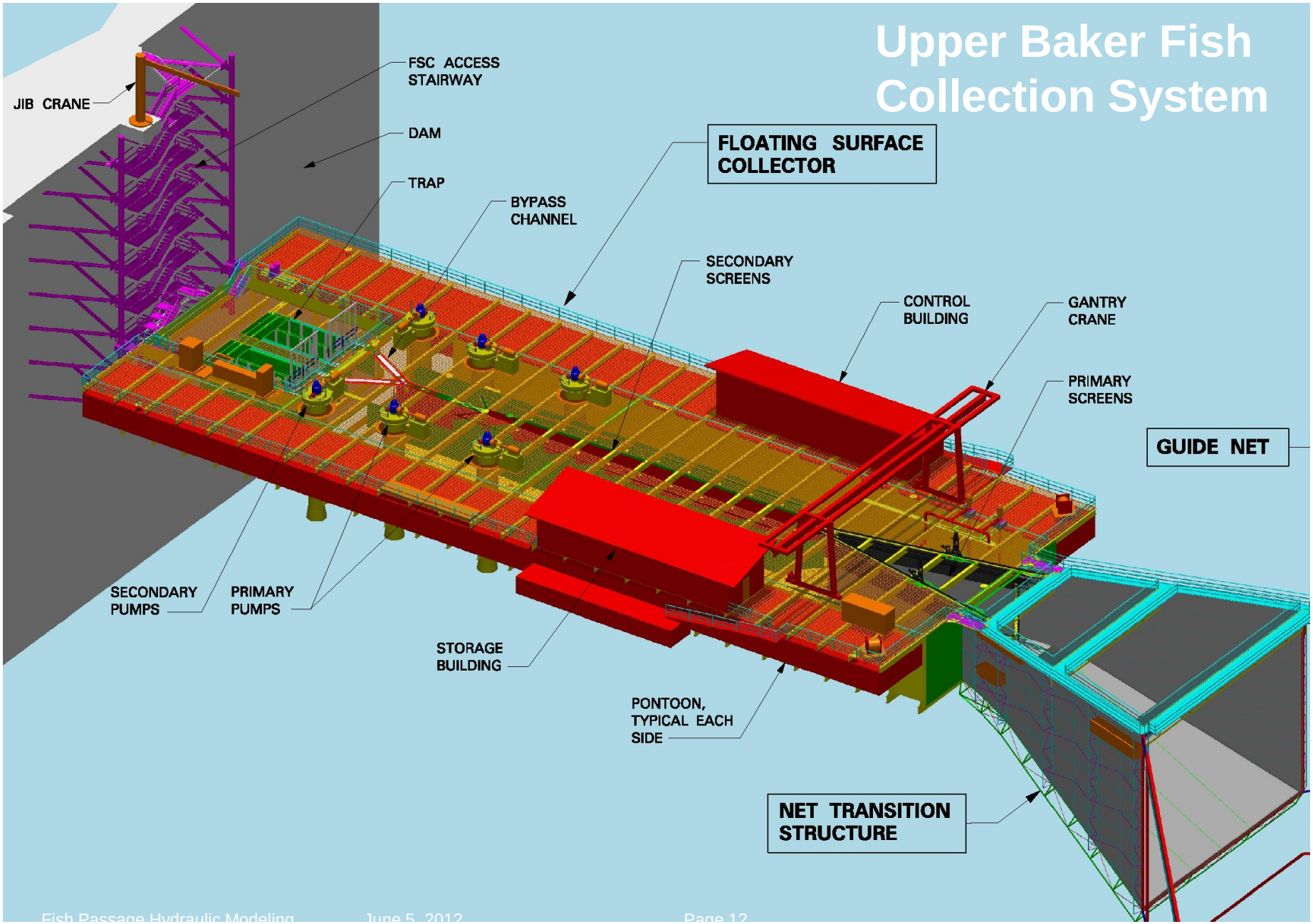
- Hydrologic analysis to determine discharges, velocities, and stages
- Simulation of flow field near and within the fish passage facilities
- Determination of optimum locations for fish passage facilities
- Sediment transport and morphological changes
- Simulation of flushing/sweeping flows

Upper Baker Power Plant Fish Collection and Handling System

Upper Baker Power Plant



Upper Baker Fish Collection System

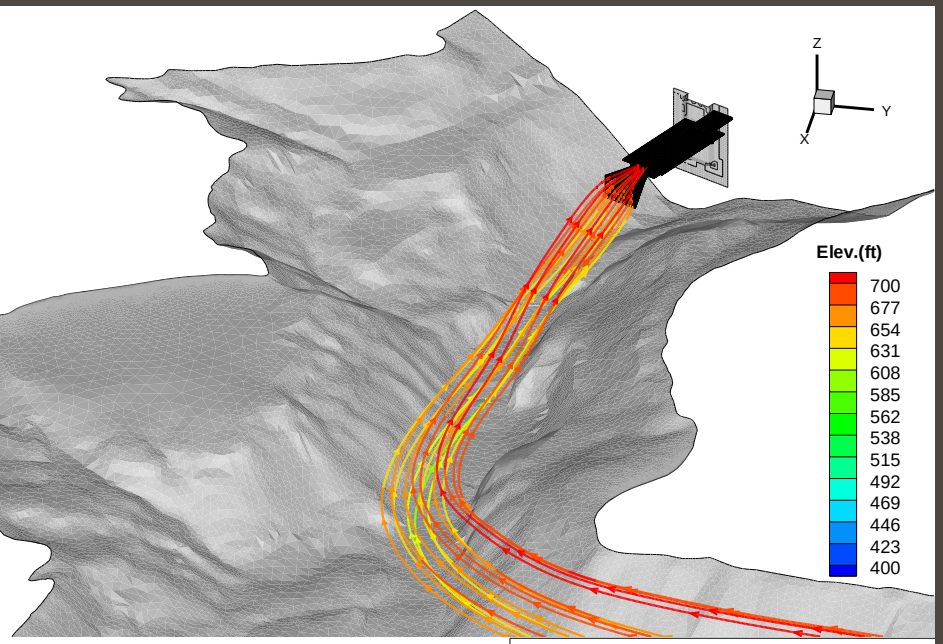


Upper Baker Fish Collection and Handling Facility

- Identify the best location for collection intake and guide net
- Evaluate and develop design modifications to the screens to meet the fisheries design criteria
- Ensure proper approach flow to the flow attraction pumps
- Studies:
  - 3-D CFD model of forebay and fish collection facilities
  - Physical hydraulic model of fish collection facility

Upper Baker - Particle Tracks to Fish Collection Intake

Scenario 1
Units On



DRAWN: L. Khan	DATE: 27 Sep 2004	PROJECT: 08729-060
File: D:\projects\BakerLakeCFD\ModelRuns\Scen01\TPFSC01a.lay		CHECKED: M. Rashid

Figure
Particle Tracks to the FSC for Scenario 1
Upper Baker River CFD Model Study
Puget Sound Energy, WA

Scenario 2
Units Off

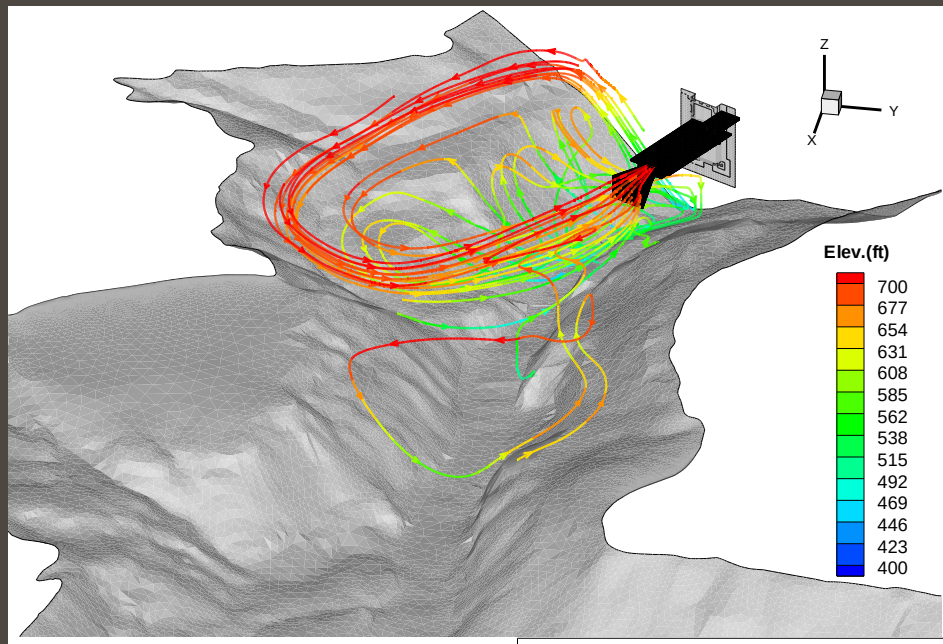


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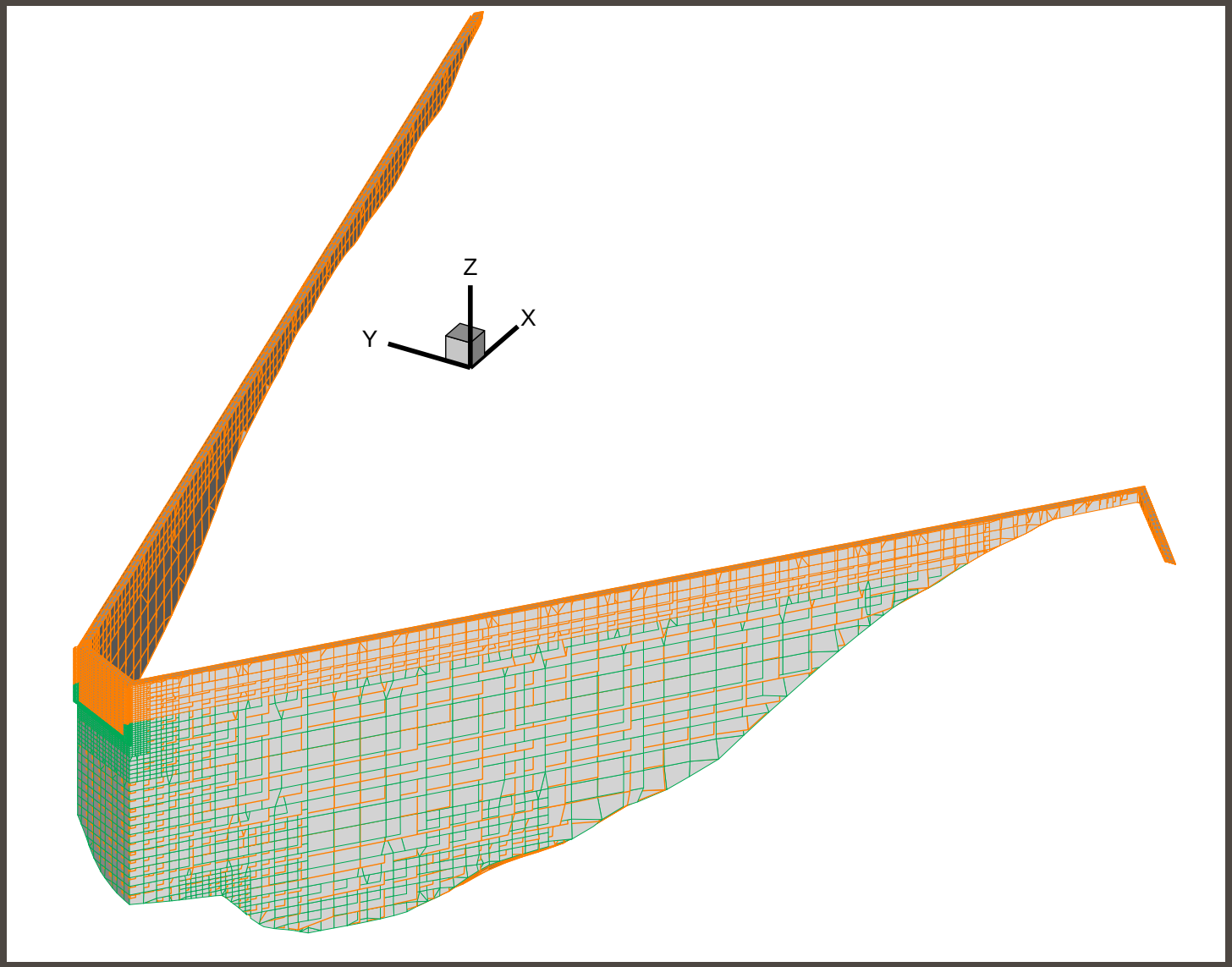
Figure
Particle Tracks to the FSC for Scenario 2
Upper Baker River CFD Model Study
Puget Sound Energy, WA

Upper Baker - 3D View of Model Grid of the Fish Net



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Upper Baker - Physical Hydraulic Model Studies

- Design and optimization of intake including screens

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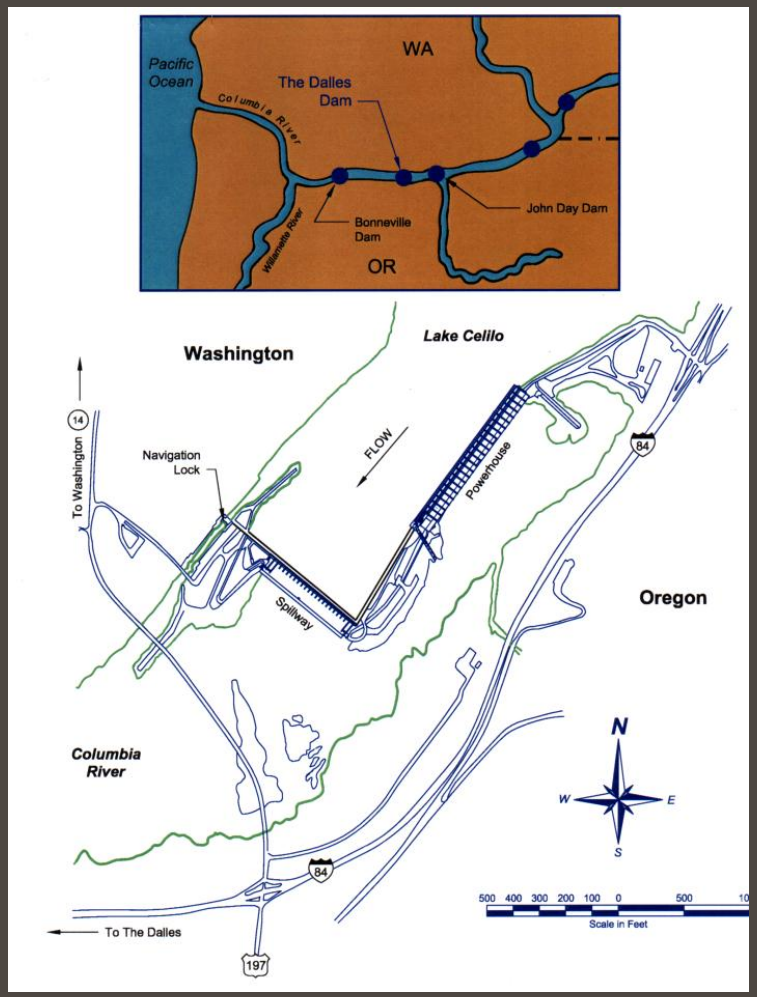
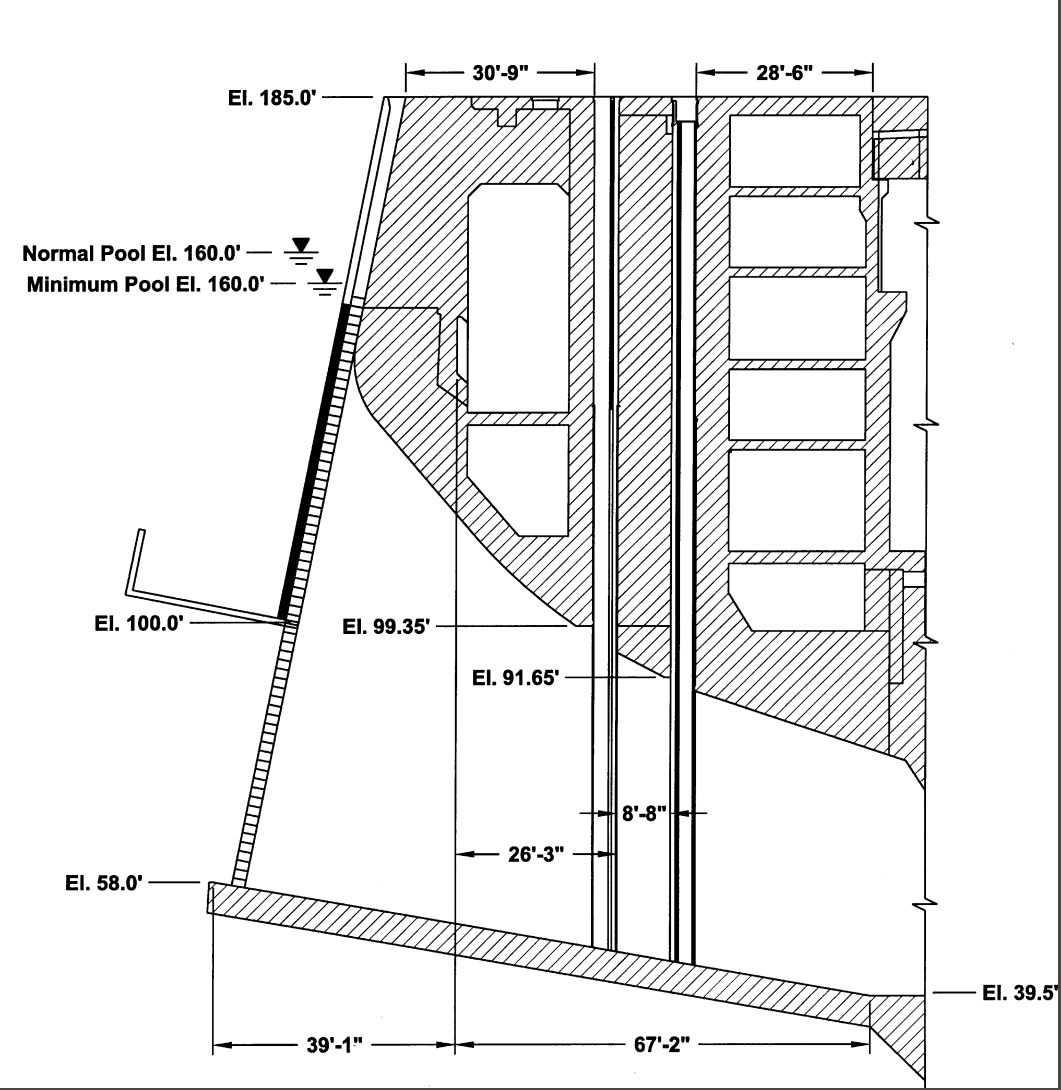
The Dalles Dam

- Numerical model studies of reservoir flow to aid in fish collection design
- 3-D CFD model of project forebay and powerplant developed and calibrated
- Developed trash rack occlusion design



Sectional View of Powerhouse Intake



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The Dalles Dam Turbine Intake J-Block Studies

- Model type: 3-D CFD (STAR-CD)
- Studies:
  - Forebay flow patterns that may influence fish movement
  - Effect of trash rack blockage on flow patterns

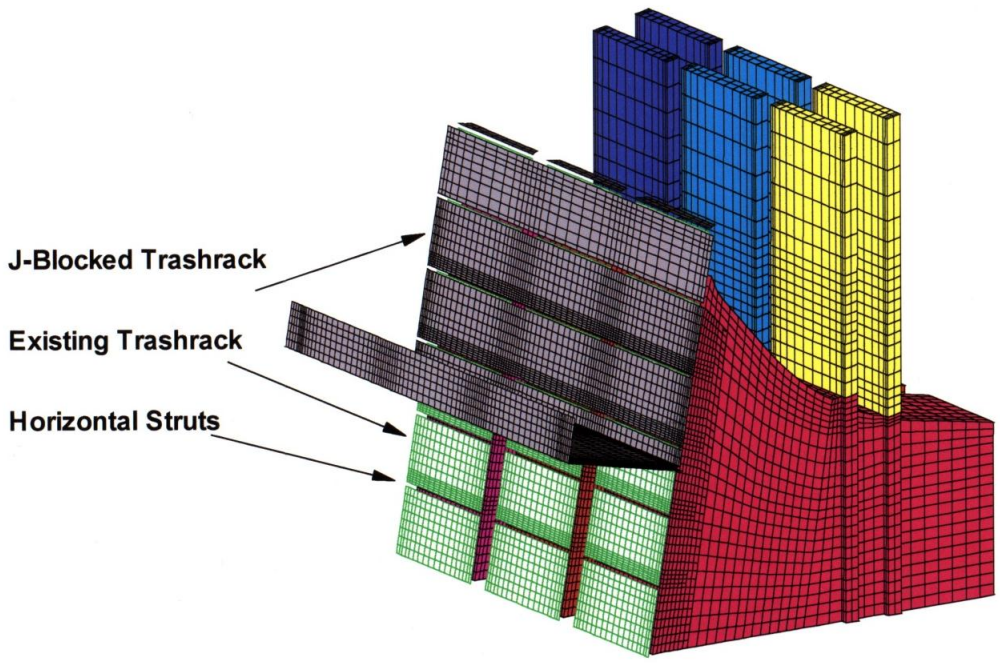
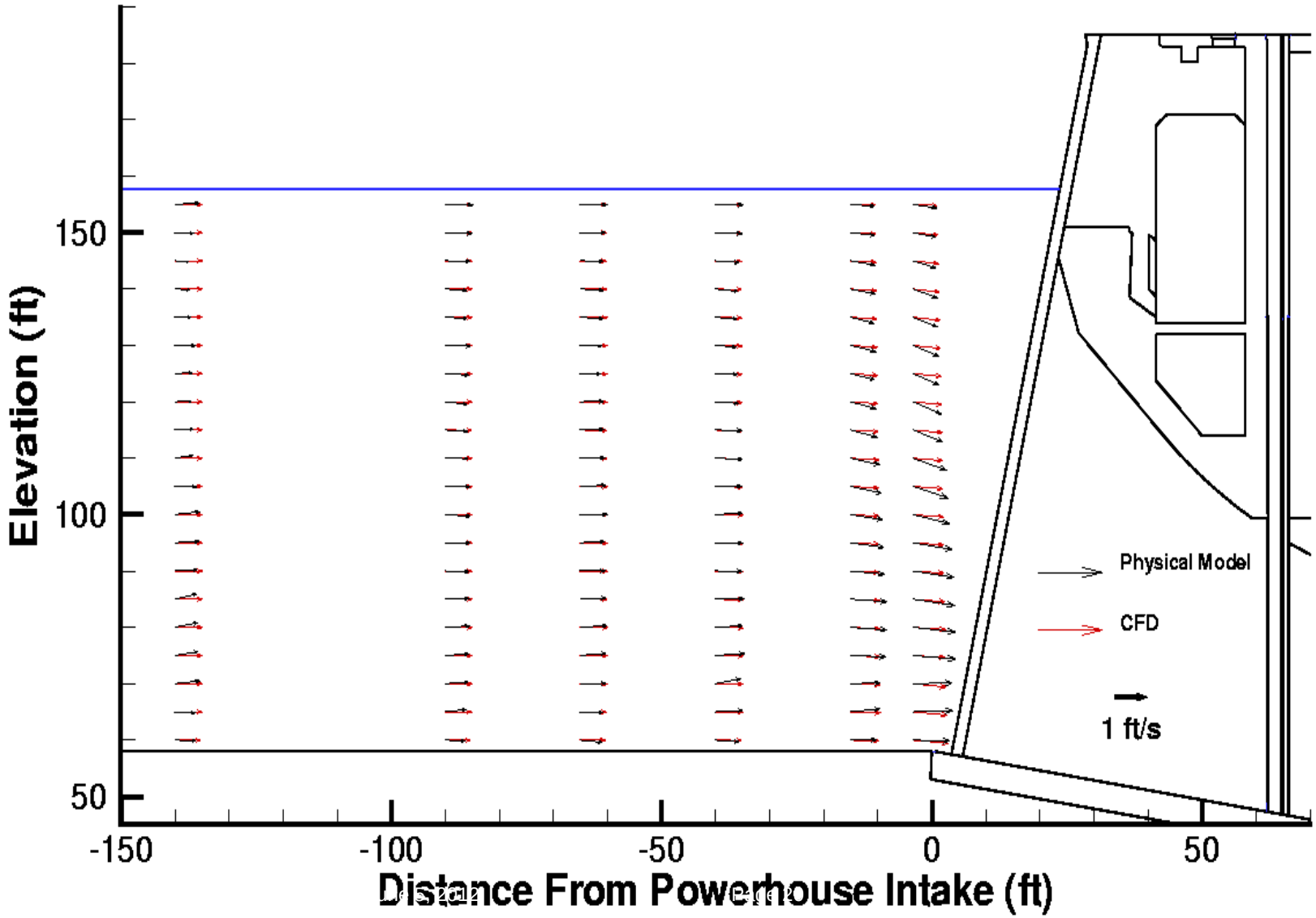
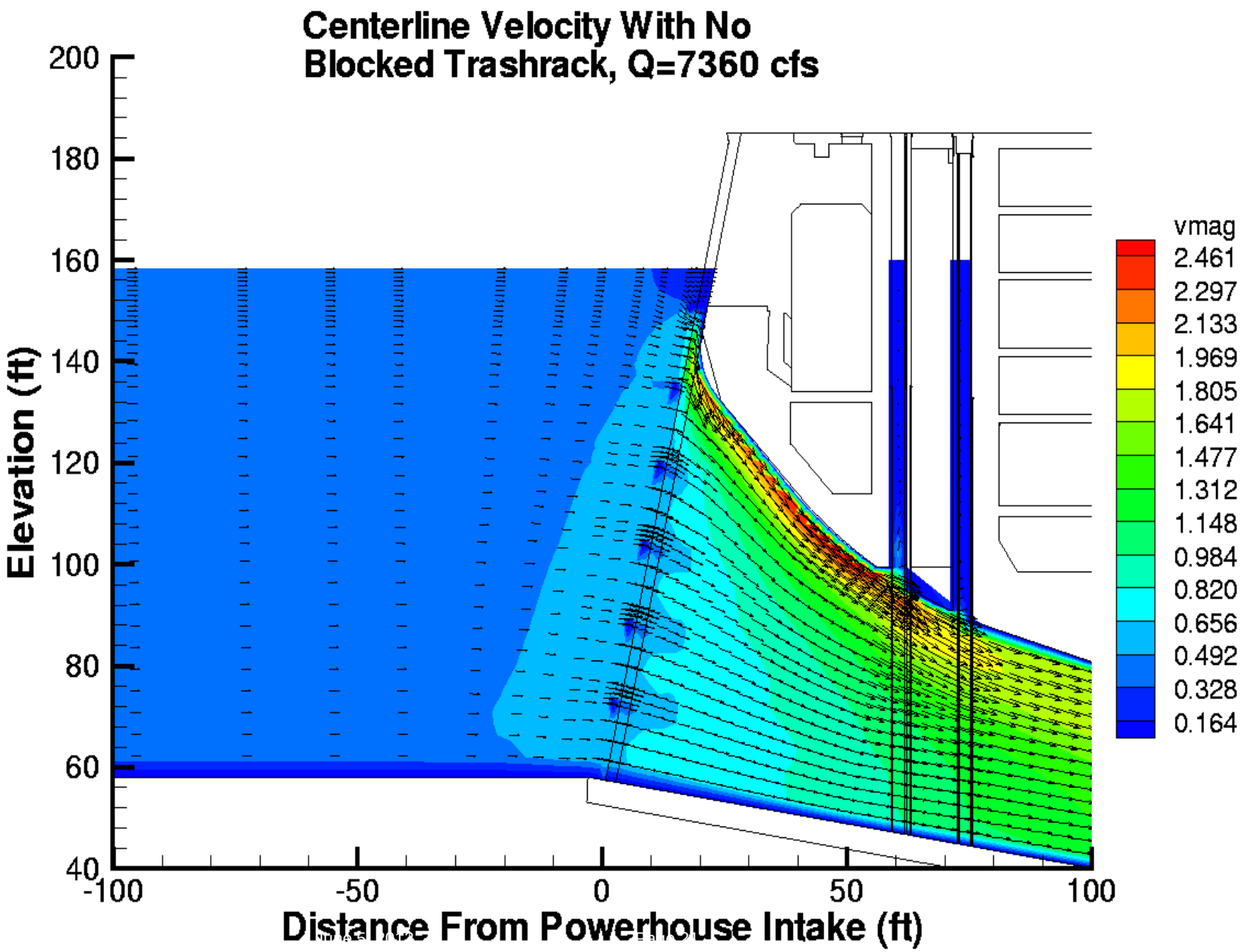
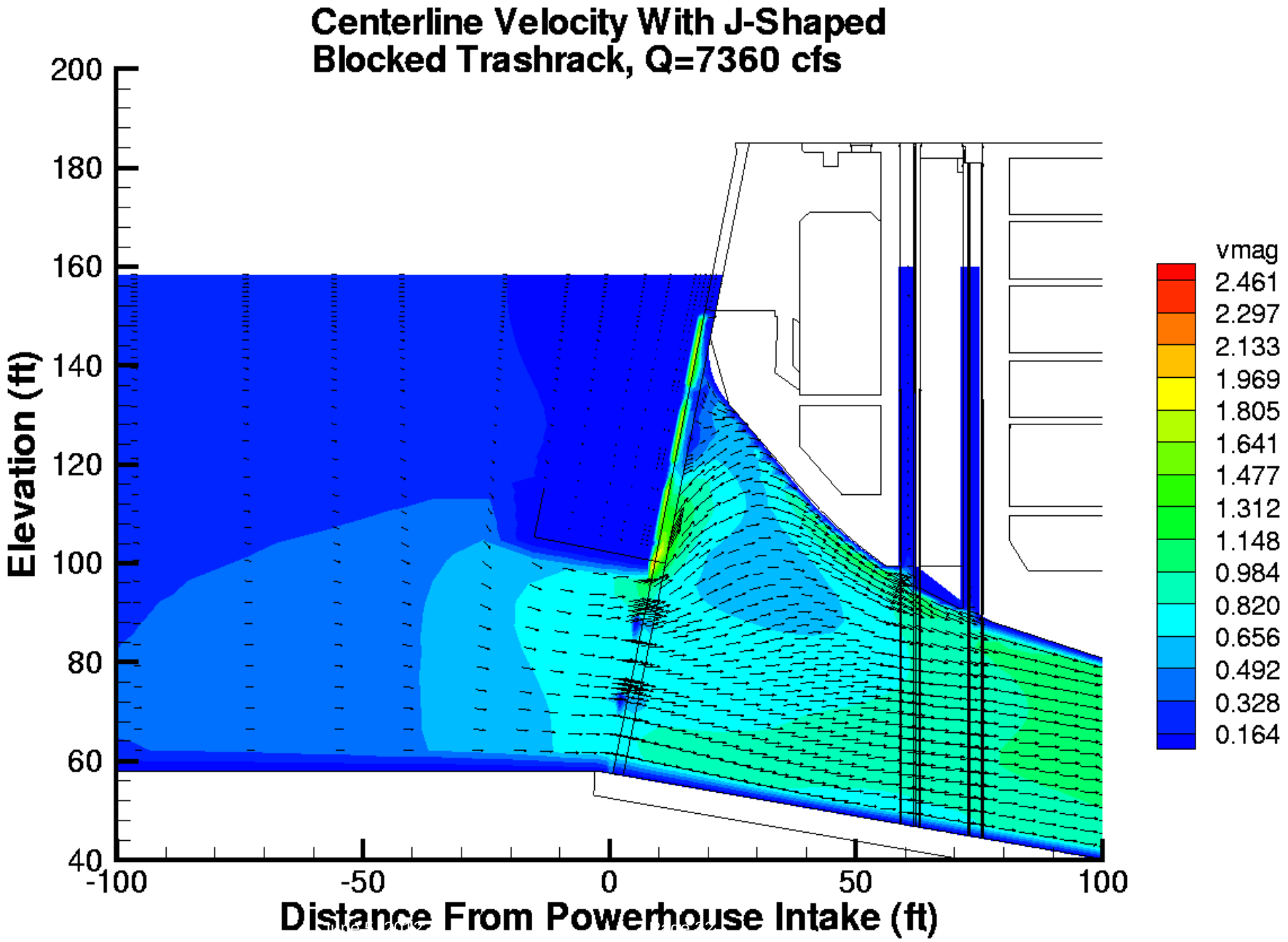


Figure 5-4: Grids for the Existing and J-Shaped Blocked Trashrack

Comparison of CFD Model of The Dalles Dam With Data From 1:25 Scale Physical Model No Blocked Trashrack, Inflow = 7,360 cfs




Centerline Velocity With No
Blocked Trashrack, Q=7360 cfs
Elevation (ft)
200
180
160
140
120
100
80
60
40
-100
-50
0
50
100
Distance From Powerhouse Intake (ft)
vmag
2.461
2.297
2.133
1.969
1.805
1.641
1.477
1.312
1.148
0.984
0.820
0.656
0.492
0.328
0.164


Centerline Velocity With J-Shaped
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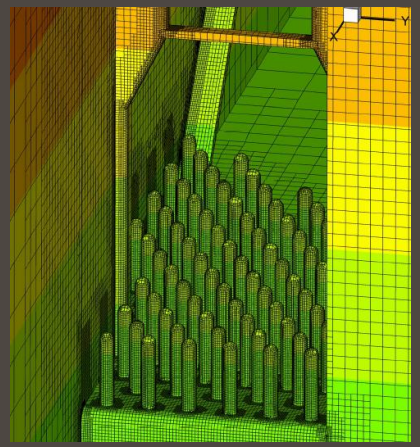
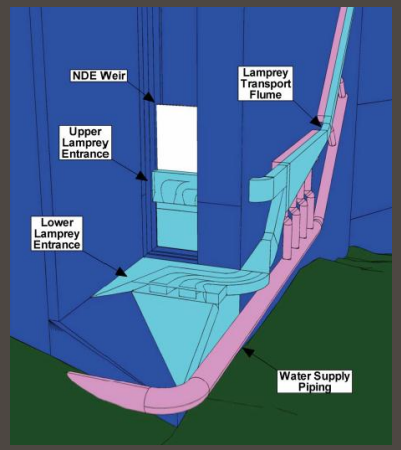
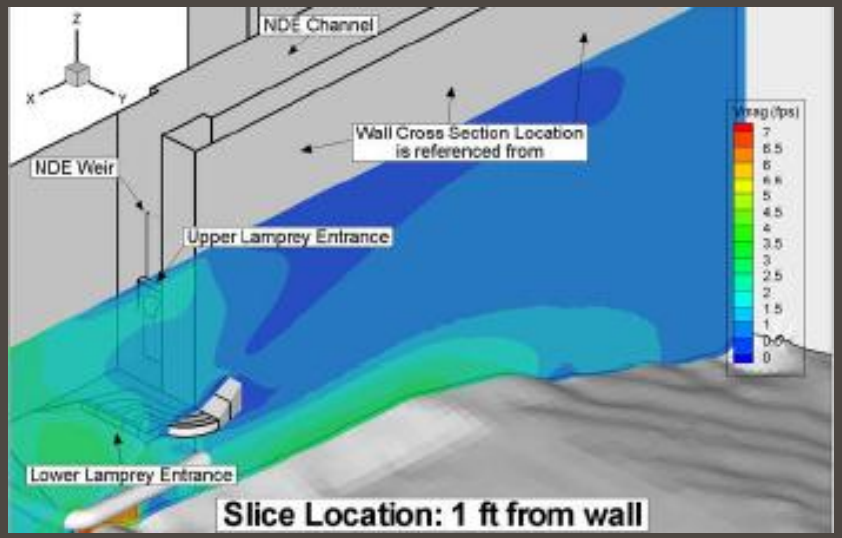
0.656
0.492
0.328
0.164

Bonneville Dam
Cascade Island Fish Ladder

- Model type: 3-D CFD (STAR-CD)
- Studies:
  - Effect of additional structural elements
  - Development of variable-width entrance weir
  - Alternative lamprey entrances







Howard Hanson Fish Passage Facility

- Reservoir provides flood control and water storage for low flow augmentation
- New project purposes include drinking water storage and ecosystem restoration
- Downstream fish passage facility is being designed as part of the project

Howard Hanson Fish Passage Challenges
Existing Passage Conditions

Low-flow outlet:
- Passage delay
- Mortality
- High Velocity
- Pressurized

Outlet Tunnel:
- Passage delay
- Injury potential
- Shallow, high velocity flow

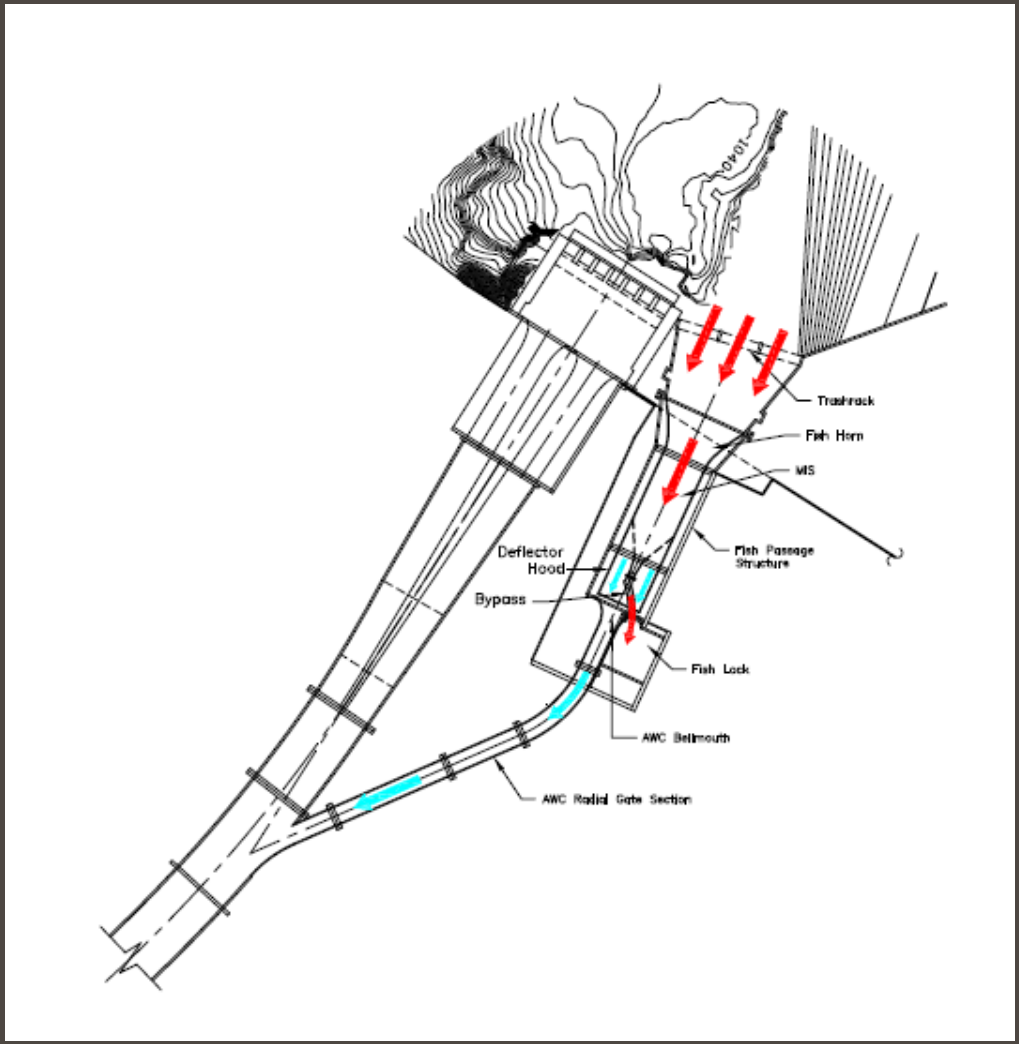
Howard Hanson Fish Passage Facility

Primary Project Goals

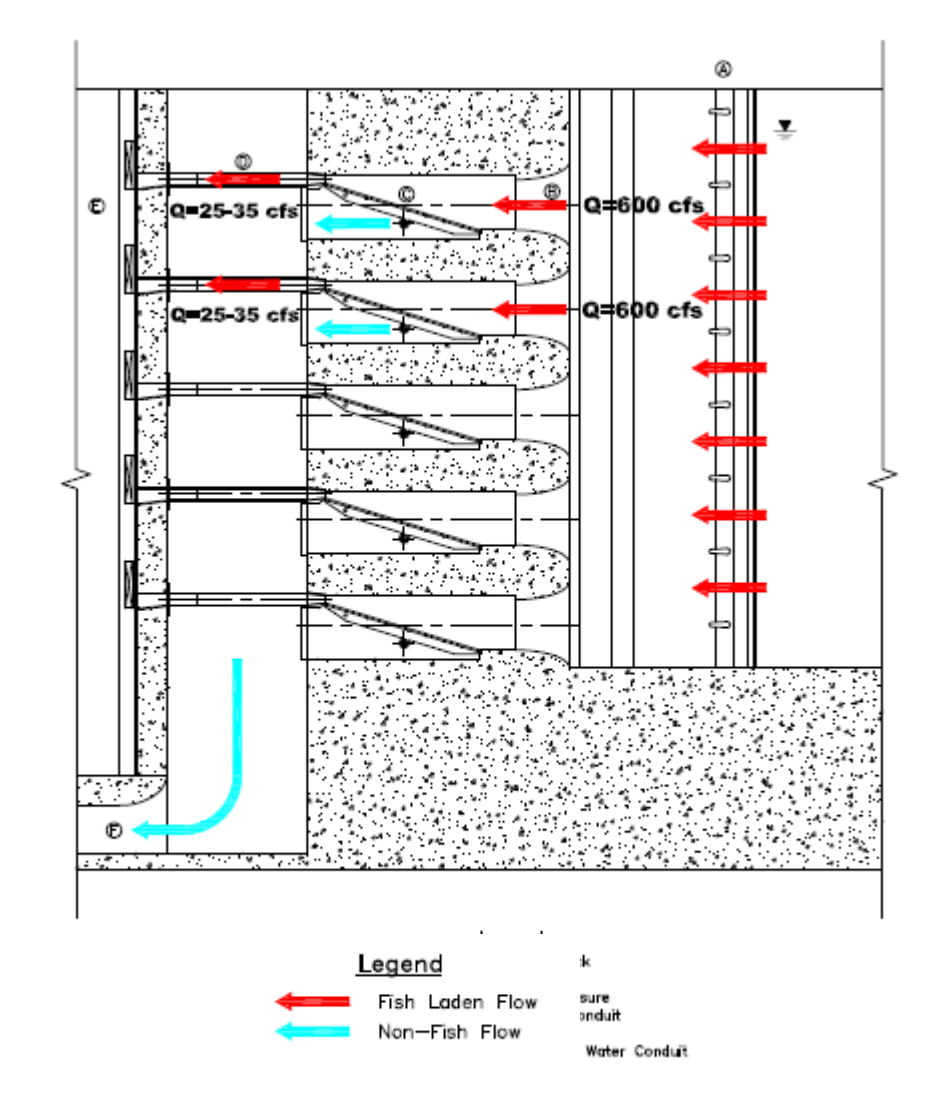
- Minimize juvenile passage delay
- Improve juvenile passage survival
- No impact on existing project function

Howard Hanson Proposed Fish Passage Facility

Fish Passage Features – Plan View

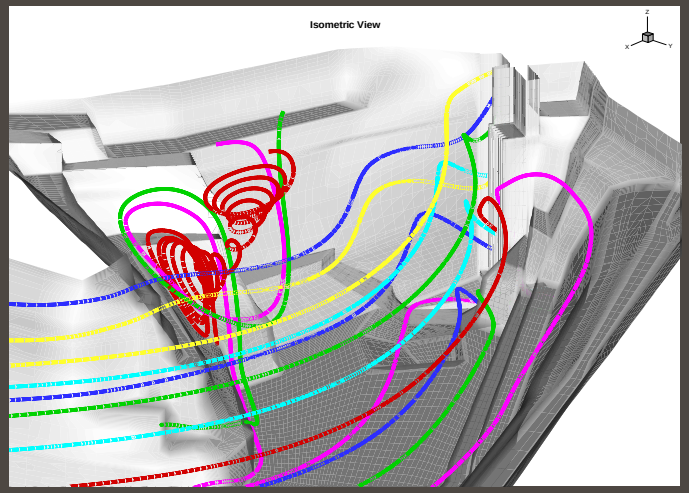


Howard Hanson Proposed Fish Passage- Sectional View



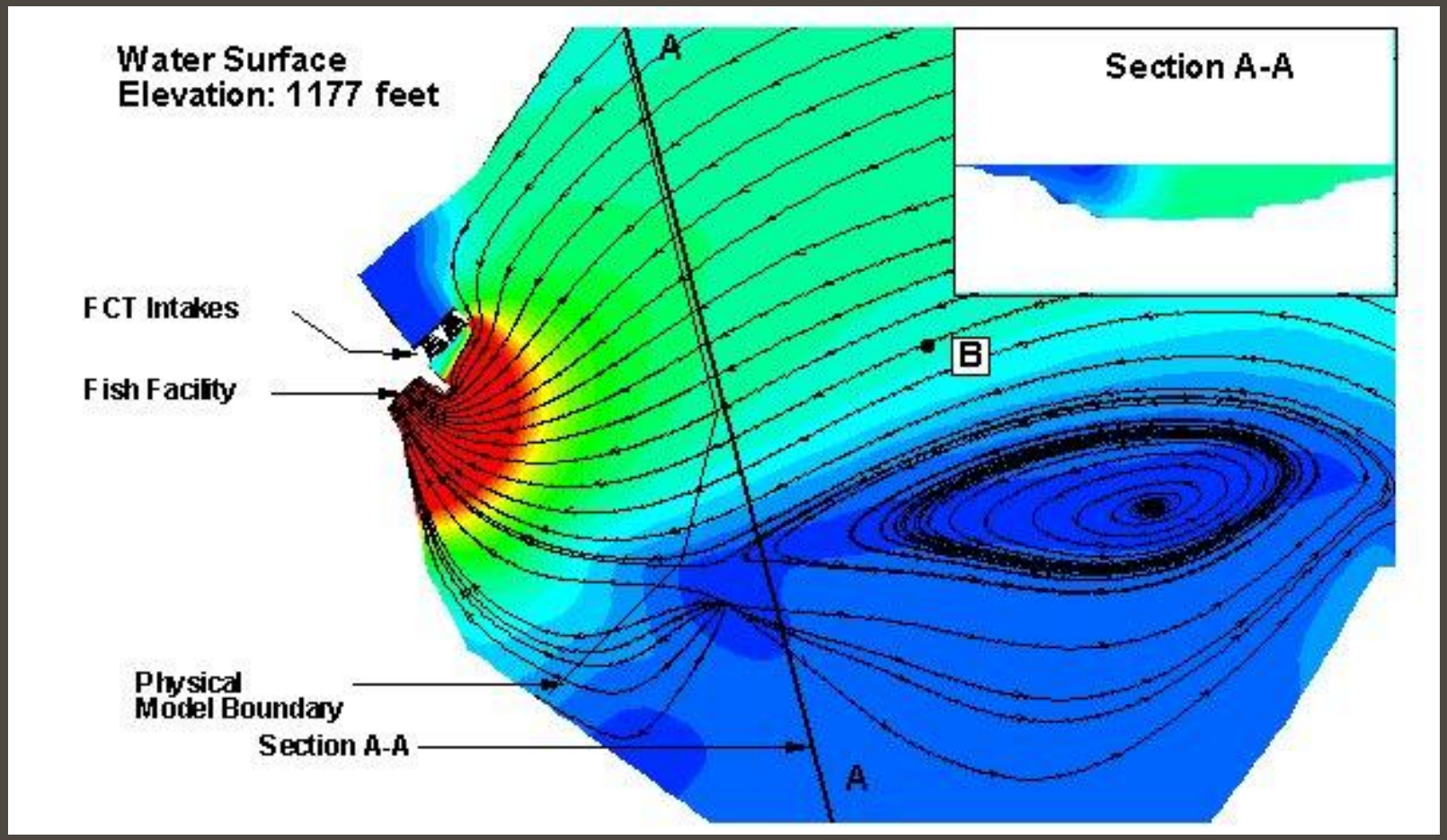
Howard Hanson Fish Passage Facility

- Conduct a physical hydraulic model study
- 1:15 scale model of the overall facility
- 1:8 scale model of screen structure
- CFD model used to define upstream model boundary



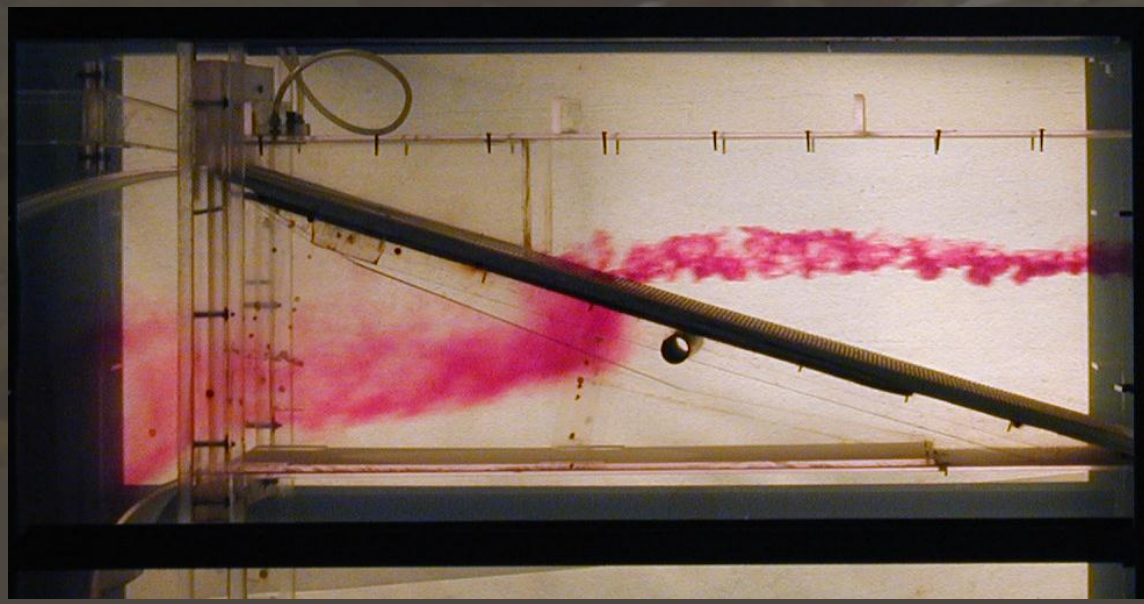
Howard Hanson Fish Passage Facility

Application of CFD Model to determine physical model boundaries



Physical Modeling Results

- Relatively balanced modular inclined screens
- Evaluated debris loading on the screen
- Determined torque of the fish screens under various operating condition
- Rating curve for the AWC gate
- Rating curve for the flood control tunnel



Howard Hanson Fish Passage- Design Challenges Ahead

- **Latest Construction Estimate:** higher than the congressionally authorized budget.

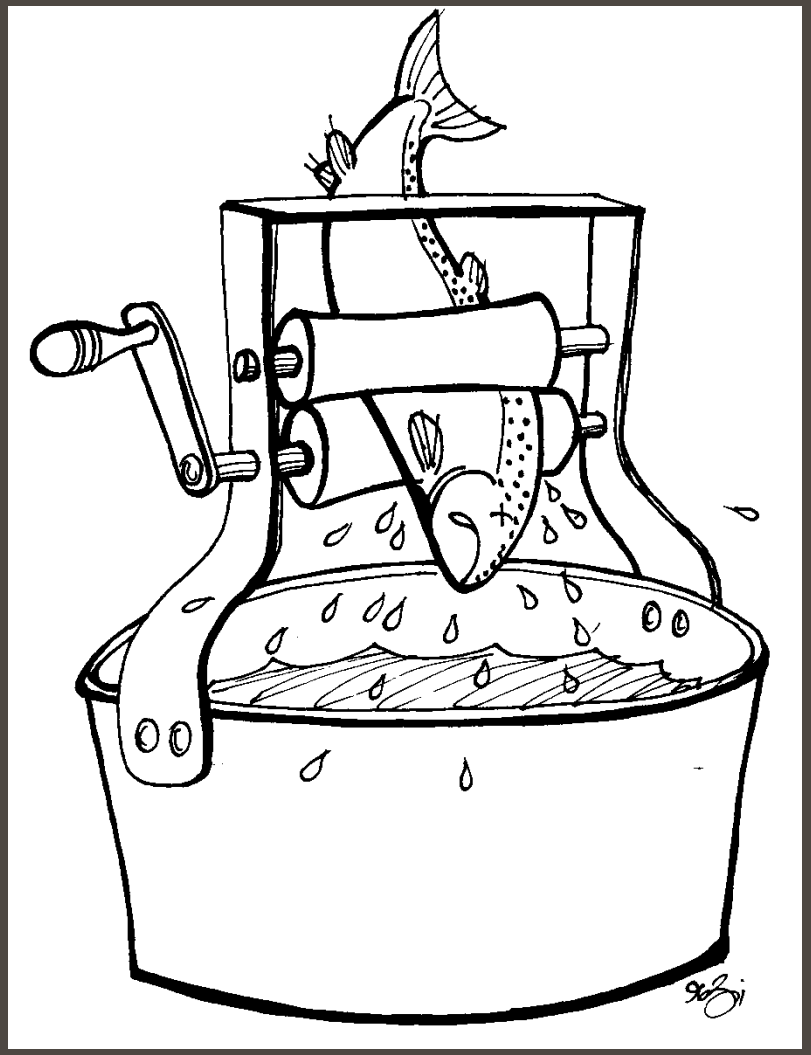
- **O& M Spending.** Design requires high O&M spending, and budget is very limited.

- **Surface Passage.** New concepts emphasizing true surface passage have emerged recently.

Summary

- Hydraulic models can aid fish passage design
  - Many types of facilities may require modeling
    - Ladders, exclusion screens, fish traps
    - Diversion structures, juvenile migrant passage, screens, outfalls
    - Ancillary systems (bypass conduits, pumps)
- Physical & computational tools available
  - Selection of model type depends on problem being addressed
  - Range from simple to complex
- Useful tool for evaluating design performance before construction and stakeholder buy-in
- Part of an iterative process.
  - Design is not necessarily complete when hydraulic criteria are met.

Questions?



What is a fish dewatering facility?

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Thank You

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June 5, 2012

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Presenters

- Mizan Rashid, PhD, PE, D.WRE
  - PhD (Civil Engineering), Washington State University
  - 22 years of experience
  - Specialization:
    - Numerical modeling
    - CFD modeling
    - Sedimentation modeling
    - Physical modeling

Presenters

- Daniel Katz, PE
  - Chief, Hydraulic Engineering Section, Seattle District Corps of Engineers
  - 22 years of experience
  - Specialization:
    - Design and operation of hydraulic structures
    - Application of hydraulic modeling