

Ice Harbor Turbine Replacement Designed for Improved Fish Passage Survival

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- Hydroelectric Design Center (HDC)
- Engineering, Research, and Design Center (ERDC)
- Bonneville Power Administration (BPA)
- National Marine Fisheries Service (NMFS)
- Voith-Hydro (Design and Supply Contractor)



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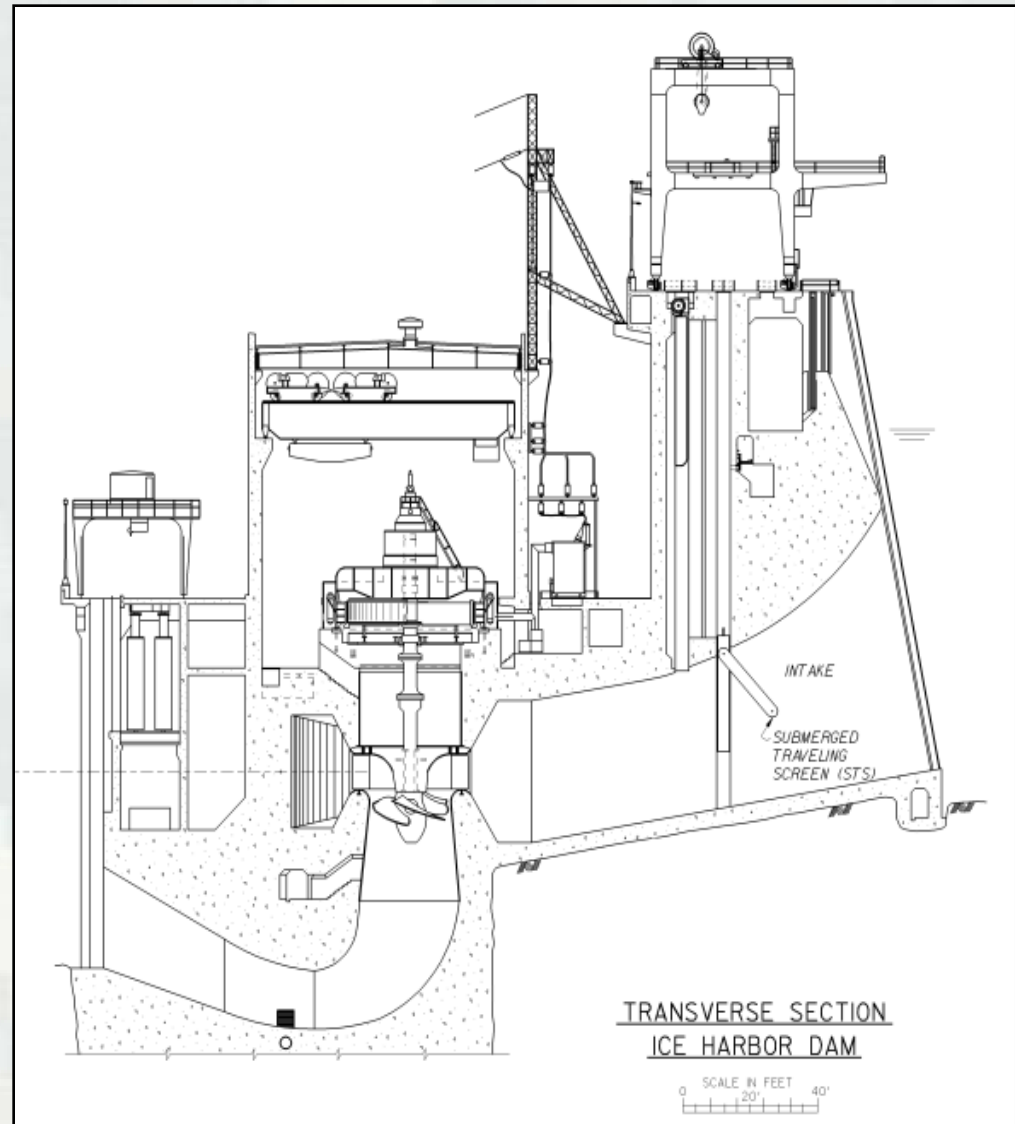
Background

- USACE Operates 8 Major Hydropower dams on the Lower Snake and Columbia Rivers
- Management focused on improving passage and survival for ESA-listed juvenile salmonids
- Majority of juveniles are passed via spillways and powerhouse by-pass systems.
- Approximately 5 % to 25 % pass through turbines.
- Turbine passage survival ranges from approximately 75 % to 95 %.



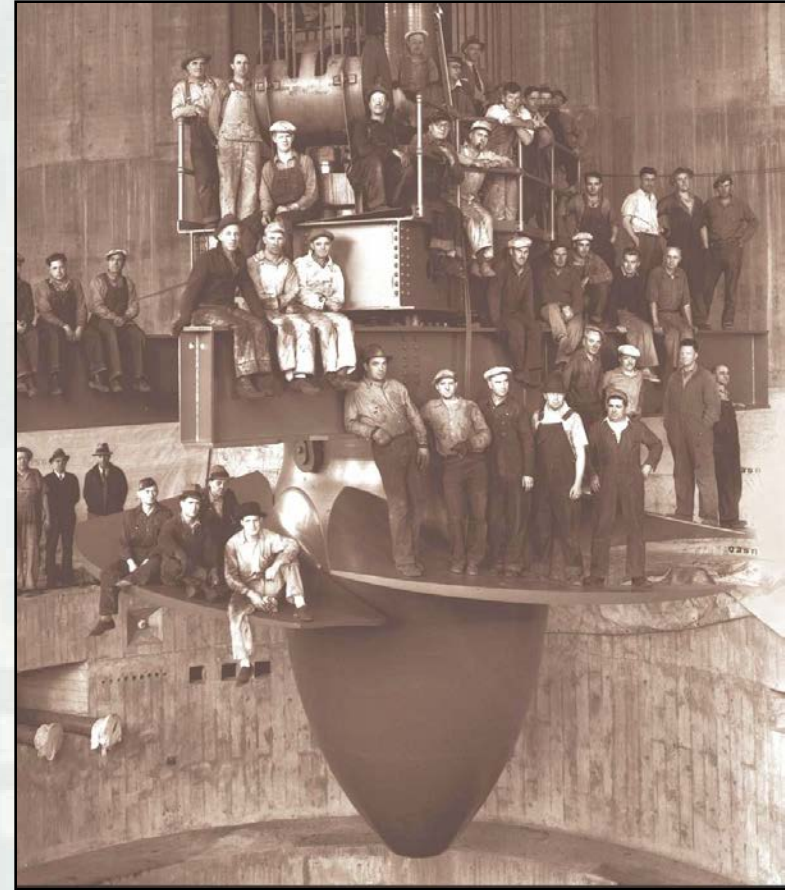
Typical Kaplan Turbine Cross-Section

Ice Harbor turbine intake with fish
screens installed



General Information

- Turbines within the FCRPS
 - ▶ Total System Capacity - 10,394 MW
 - ▶ Original installations - **1938 to 1979**
 - ▶ Turbines are near end of design life; major rehabilitations are being required.
- Major Species of Concern
 - ▶ Chinook, Steelhead, Sockeye Salmon
 - ▶ Lamprey
- Concern for endangered fish species and reliable generation led to development of the Turbine Survival Program (TSP) and the **Ice Harbor Test Turbine Project**



Turbine Survival Program

- Established in mid 1995
- TSP Goals and Objectives
 - ▶ Improve our understanding of the turbine passage environment
 - ▶ Determine the effects of that environment on juvenile salmonids
 - ▶ Develop design criteria/guidelines to improve fish passage.



Turbine Survival Program

- Model Investigations
 - ▶ Physical hydraulic model investigations
 - ▶ Computational model investigations
- Focus on large propeller (Kaplan) style turbines
- Major components

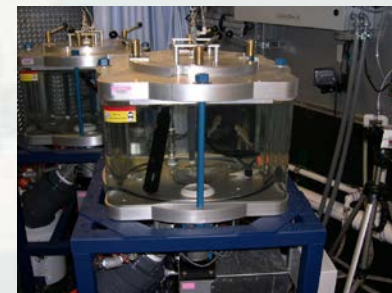


1:25 Scale Ice Harbor Physical Model



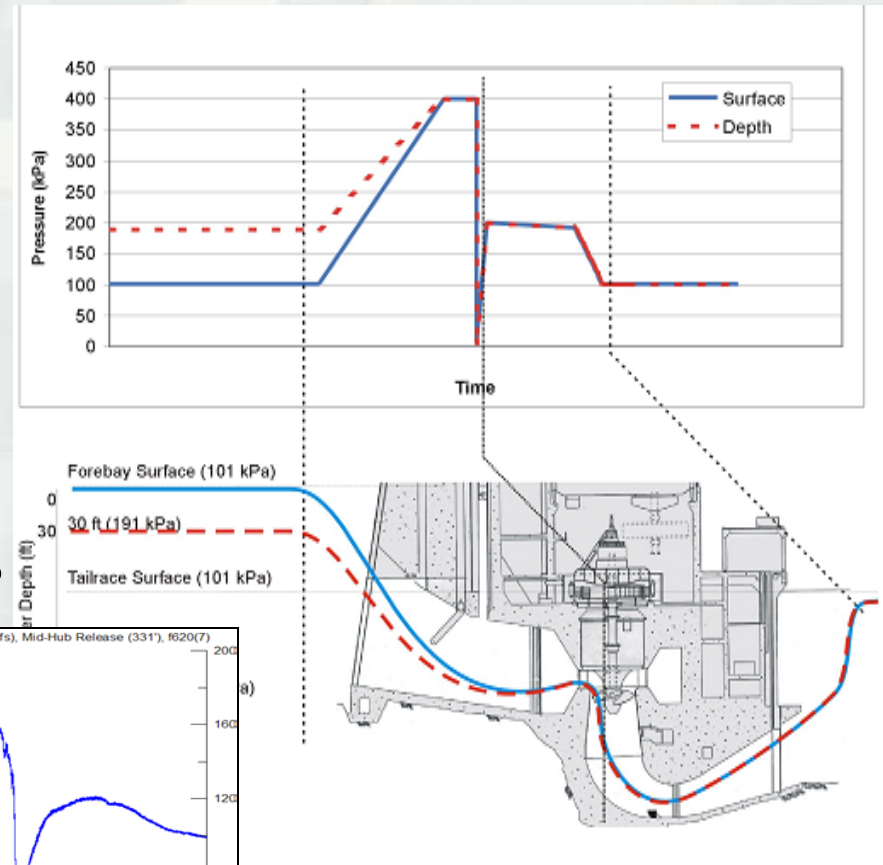
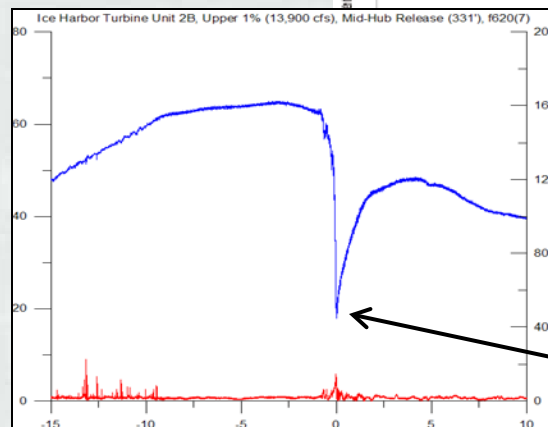
Turbine Survival Program

- Field Investigations
 - ▶ Fish survival studies
 - ▶ Sensor fish
- Laboratory Investigations
 - ▶ Pressure effects study
 - ▶ Shear exposure study



“Sensor Fish” Measurements

- Pressure and Acceleration
 - ▶ Indication of strike and shear
 - ▶ Pressure rates of change
 - ▶ Maximum pressure drop
- Confirmation of CFD models

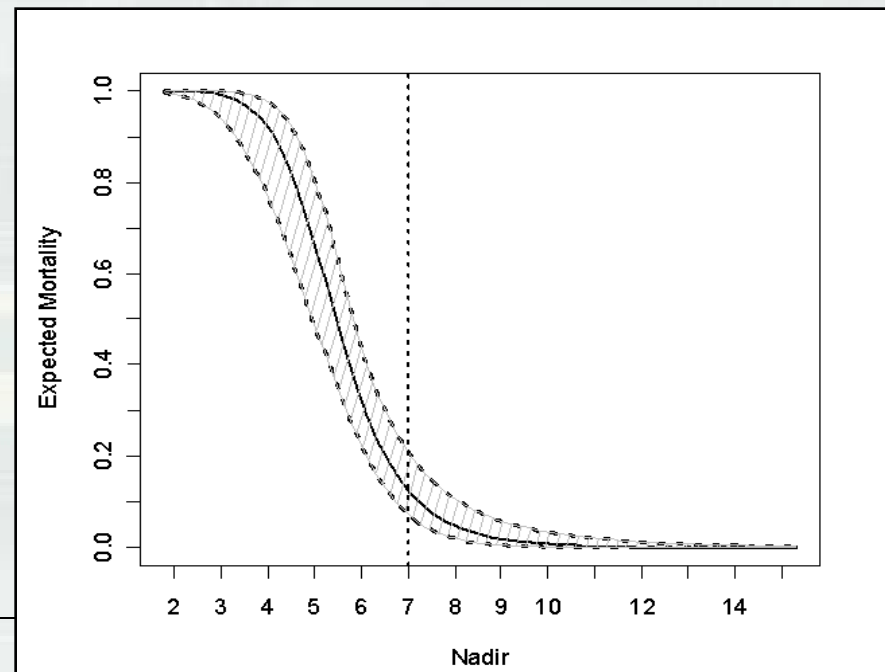
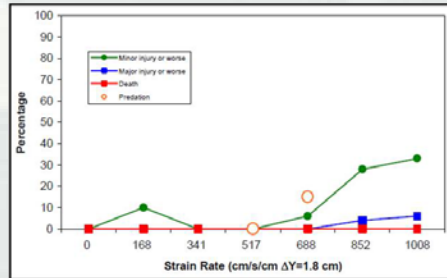
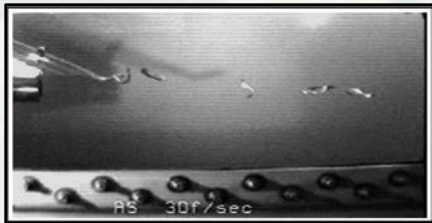
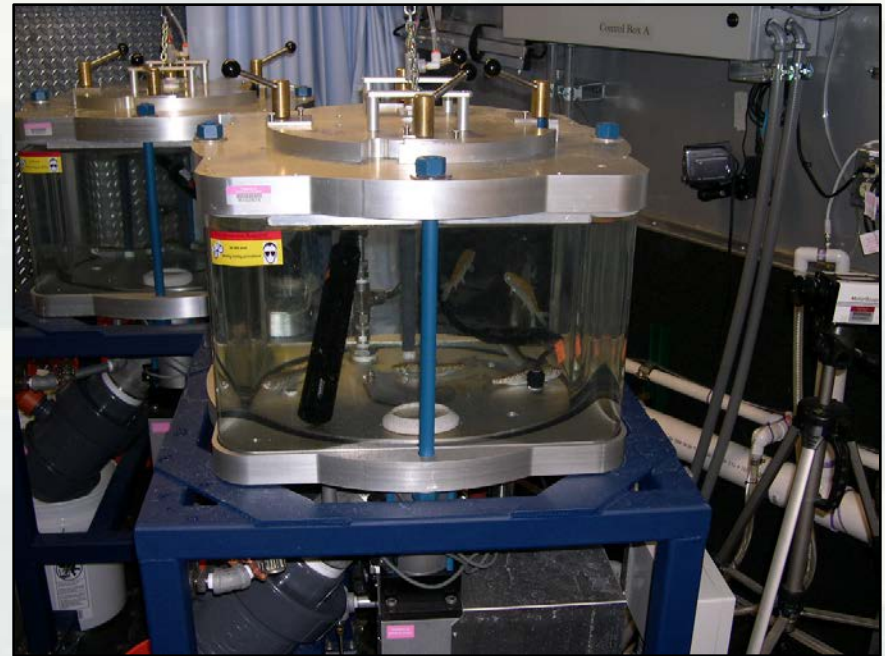


Nadir
Pressure



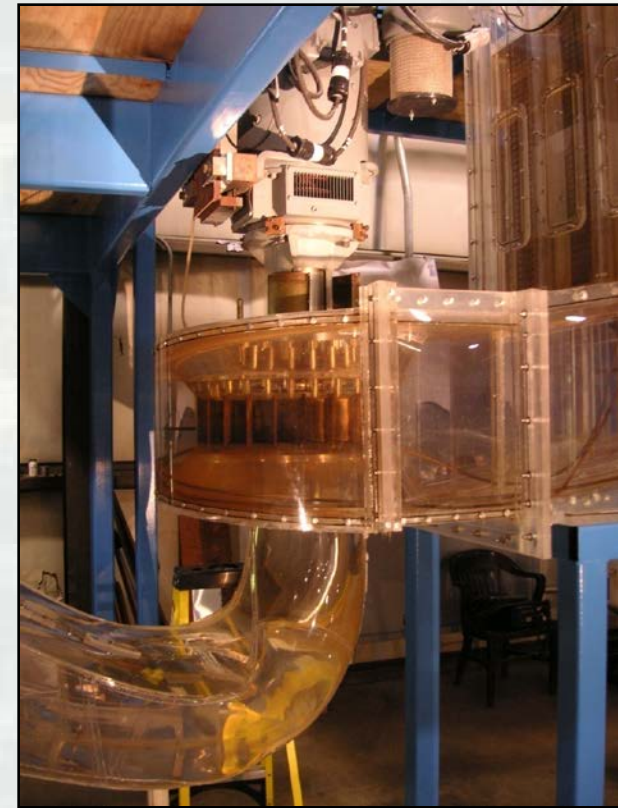
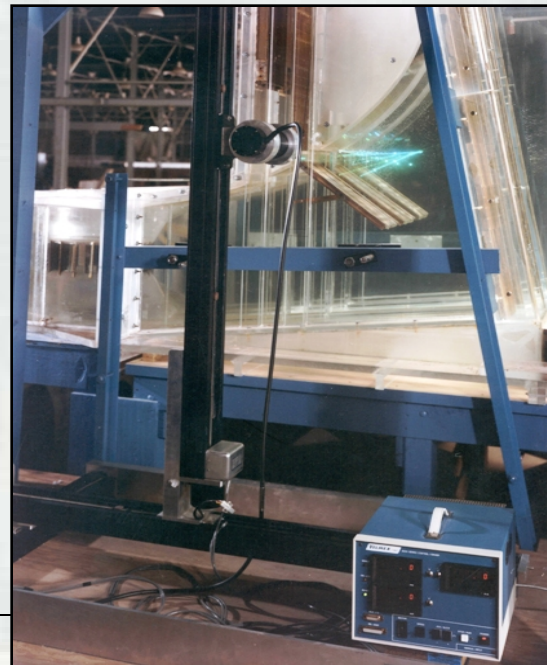
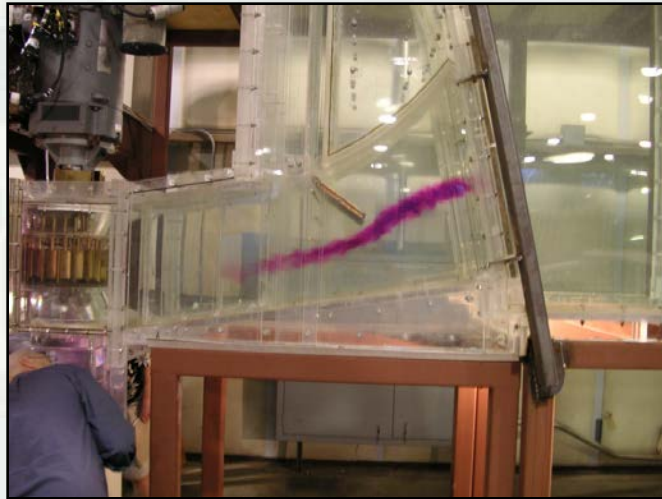
Laboratory Investigations

- Pressure studies
 - ▶ Simulated turbine pressures on juvenile Chinook salmon
 - ▶ Primary variables:
 - Acclimation depth
 - Nadir pressure
- Shear Studies
- Criteria for new designs



Ice Harbor Turbine Physical Model

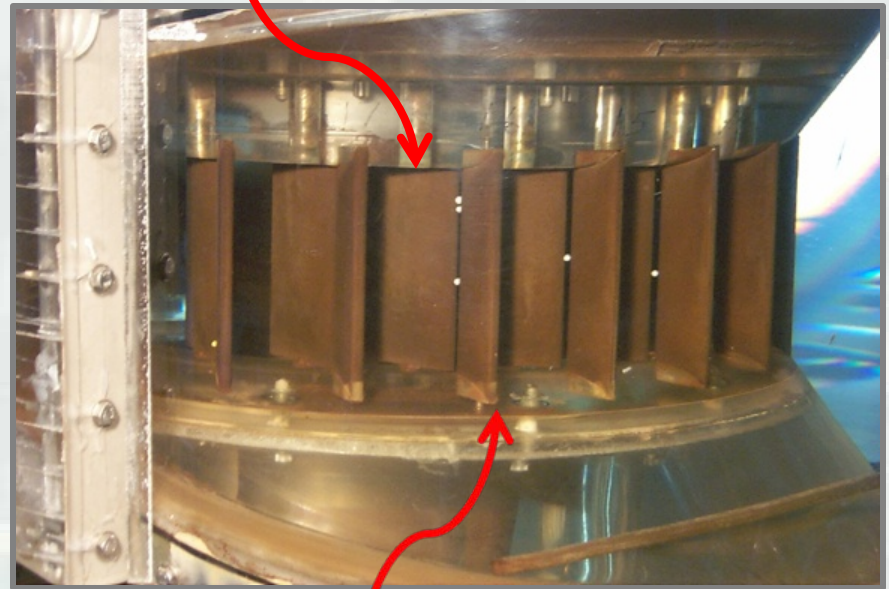
- 1:25 Froude Scale
- Visual observation of dye release
- High speed digital imaging of neutrally buoyant beads
- Velocity measurements using laser (LDV)



Stay Vane and Wicket Gate Analysis

- Uses high-speed digital video 250 to 500 fps
- Approximately 1000 beads graded for changes in direction
- Approximately 1000 beads graded for surface contact
- Number of gap passages obtained (between stay vanes and wicket gates)

Wicket Gate



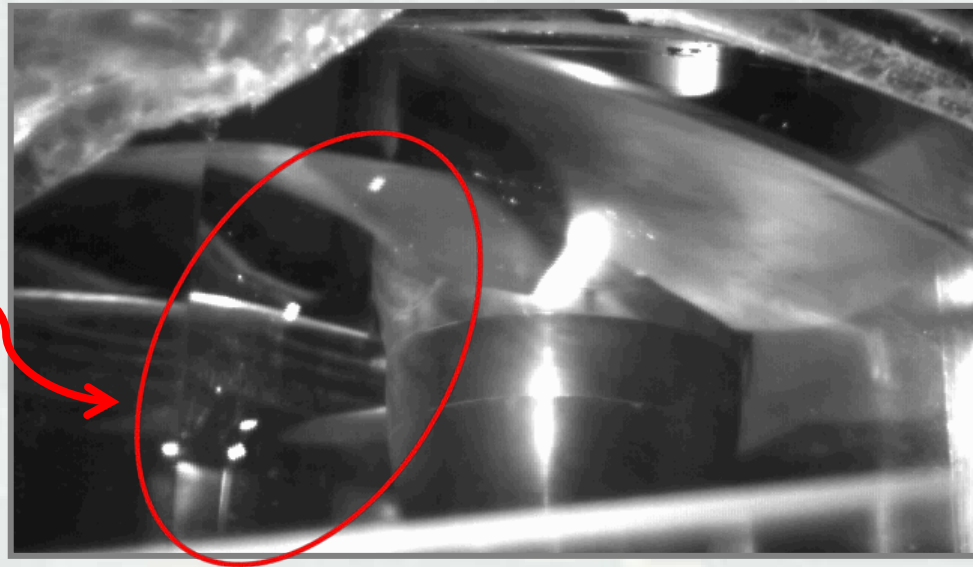
Stay Vane



Runner Region Analysis

- Uses high-speed digital video 1000 fps
- Approximately 2000 beads graded for changes in direction (blade tip, mid-blade and hub regions)
- Approximately 2000 beads graded for surface contact (blade tip, mid-blade and hub regions)

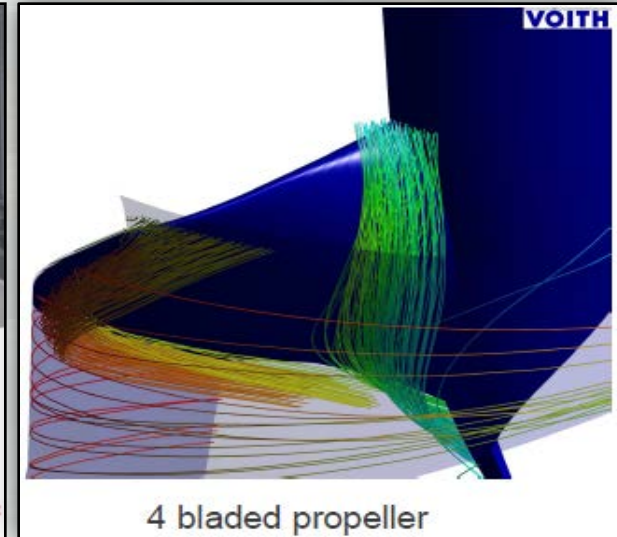
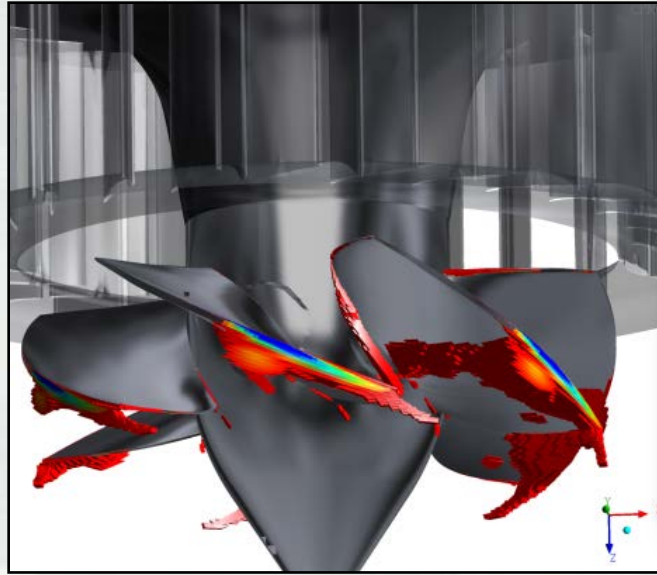
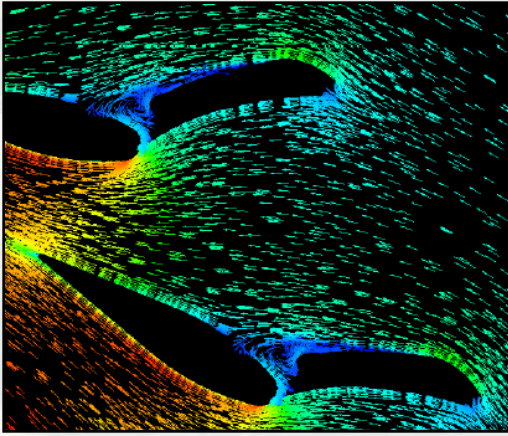
Beads following
runner passage



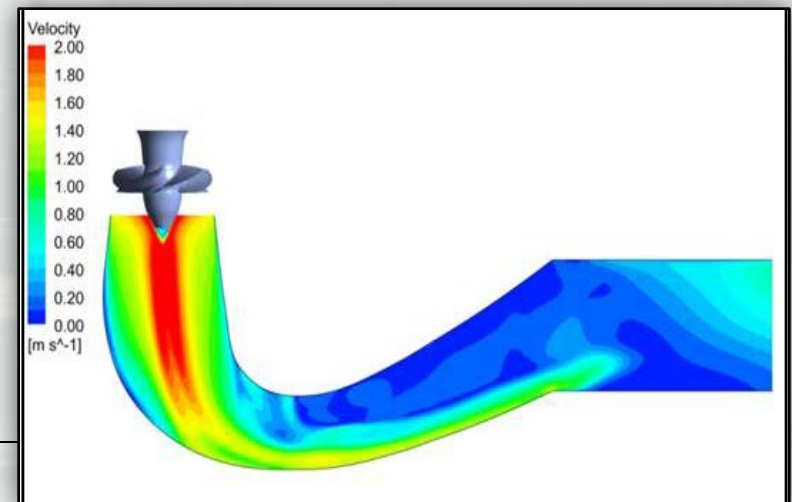
Ice Harbor – Tip Release



Computational Fluid Dynamics



- Streamlines
- Velocity
- Pressure
- Turbulent Kinetic Energy
- Efficiency Estimates



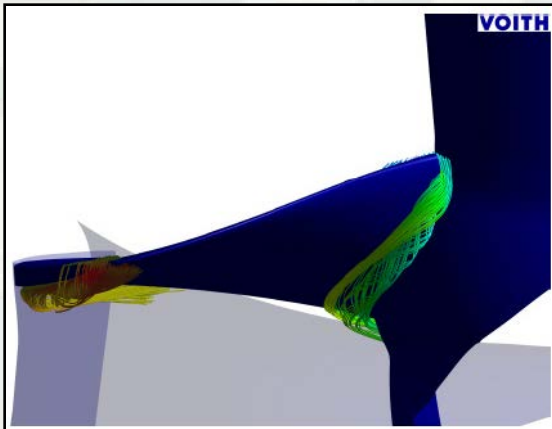
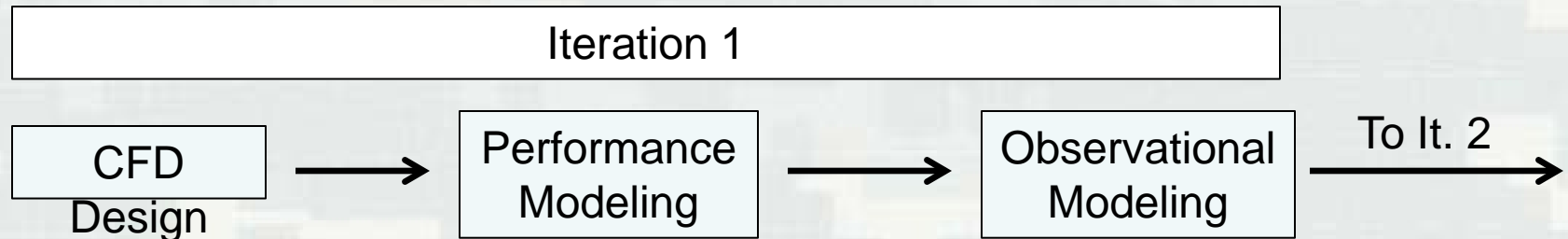
Project Goals

- Replace Ice Harbor Unit 2 & 3
 - ▶ Original Installation in 1962
- Design a turbine that provides safer passage for juvenile salmonids
 - ▶ Design Fixed Blade Runner
 - ▶ Design an Adjustable Blade Runner
- Develop and Test turbine design process
 - ▶ Collaborative design effort
 - ▶ Apply new design criteria for safer fish passage
- Demonstrate COE and BPA commitment to invest in long term sustainability



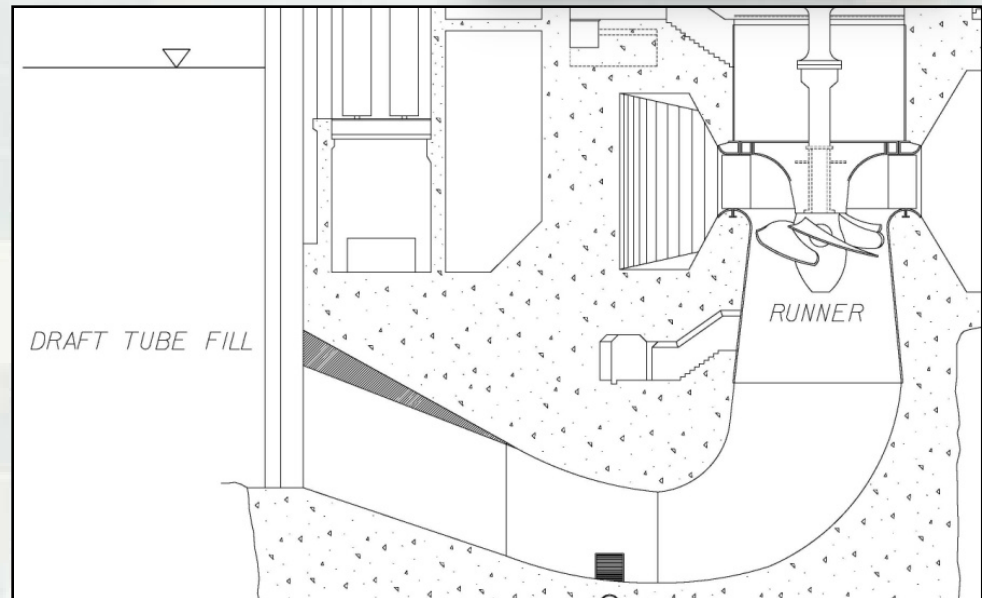
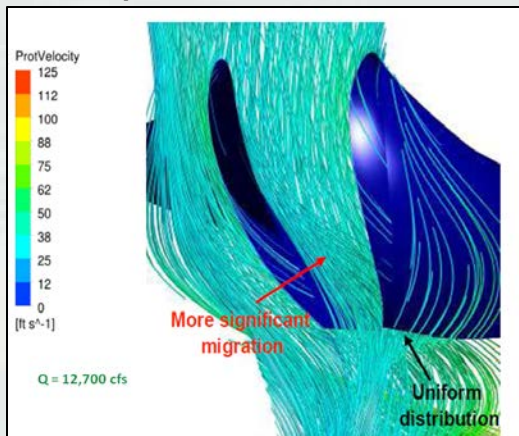
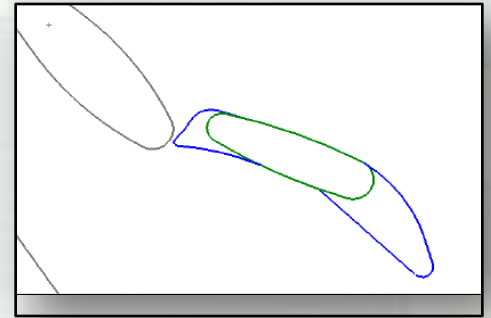
Design Team and Approach

- Design team – NWW, HDC, ERDC, NMFS, BPA and Voith Hydro
- Iterative design and evaluation process includes baseline model testing, CFD development and analyses, performance model testing and observational model testing



Design features and criteria

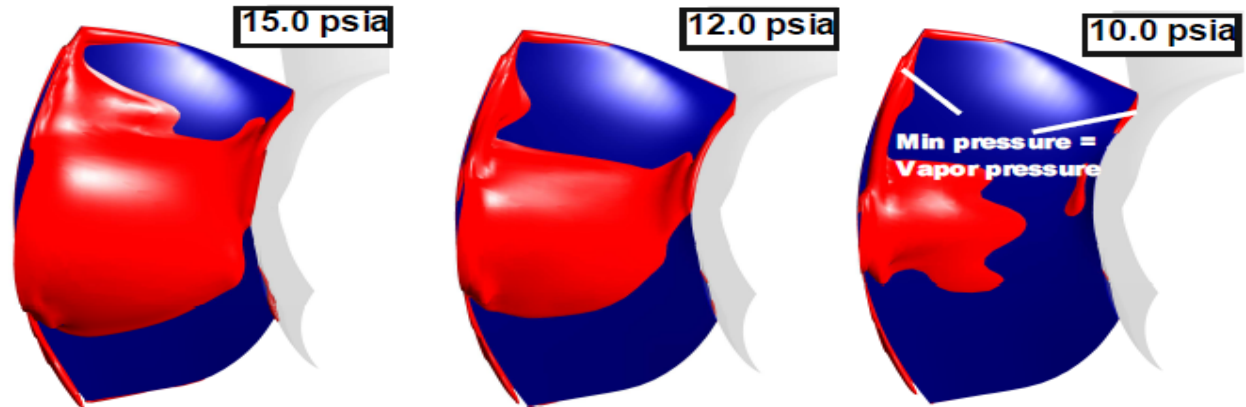
- New adjustable blade and fixed blade runner
 - Minimum blade gaps near hub and periphery (MGR for adjustable)
 - Blade shape to reduce blade strike
 - Minimize pressure differential (increase minimum pressure) to above 12 psia or 1-atm (14.7 psia) if possible
- Stay vane leading and trailing edge extensions
 - Improve alignment with flow
 - Minimize gaps between stay vane and wicket gate
- Draft tube modifications (roof and floor fills)
 - Reduce turbulence
 - Streamline flow
 - Improve exit conditions



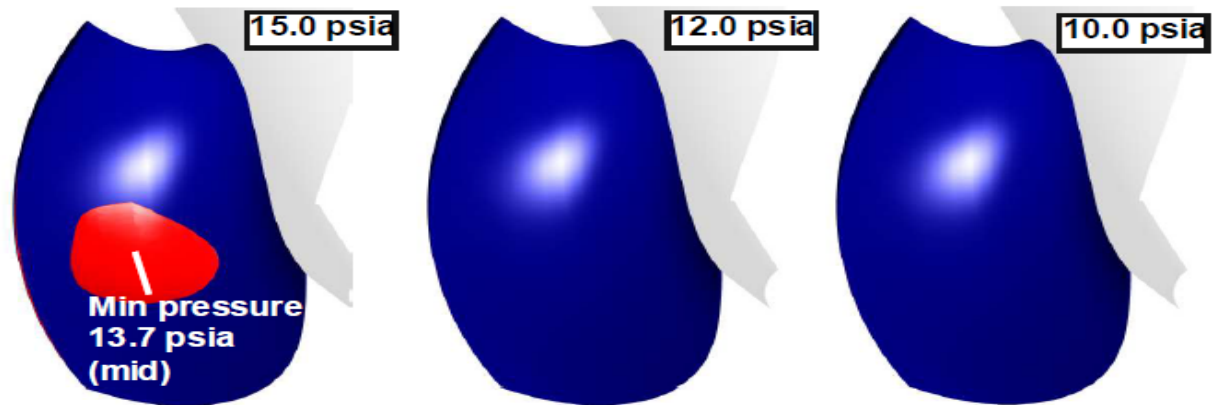
Nadir Pressure Comparisons

Nadir Pressures for 99 ft at 13,737 cfs

(Existing)
Kaplan

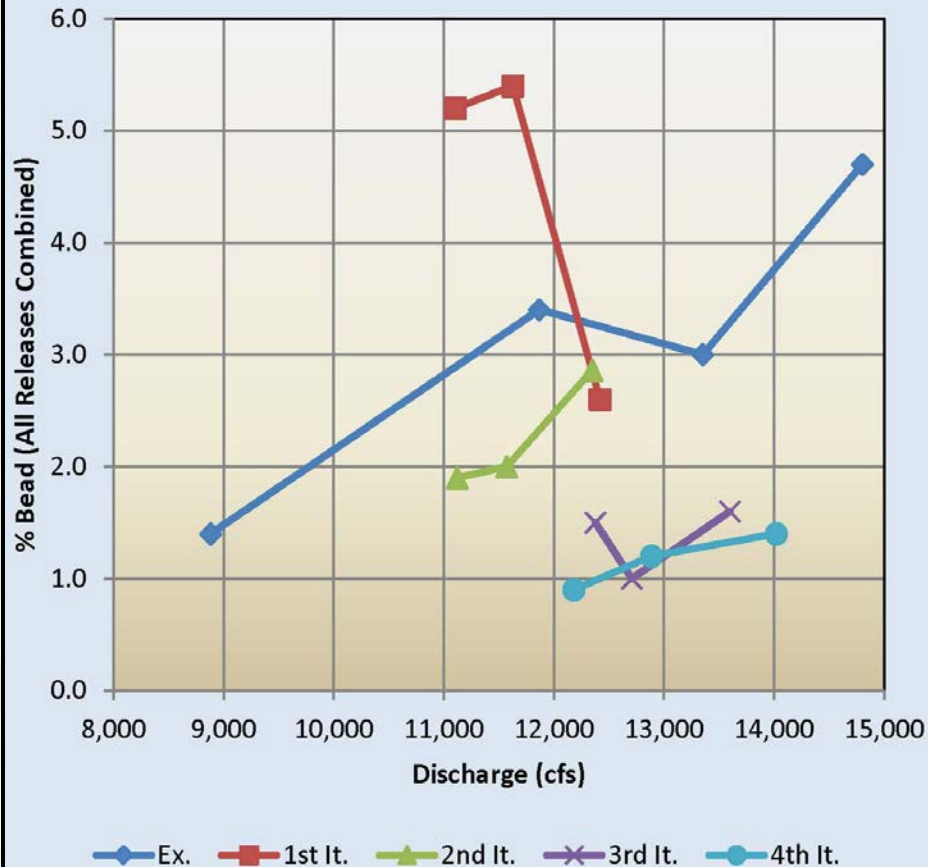


Final Fixed

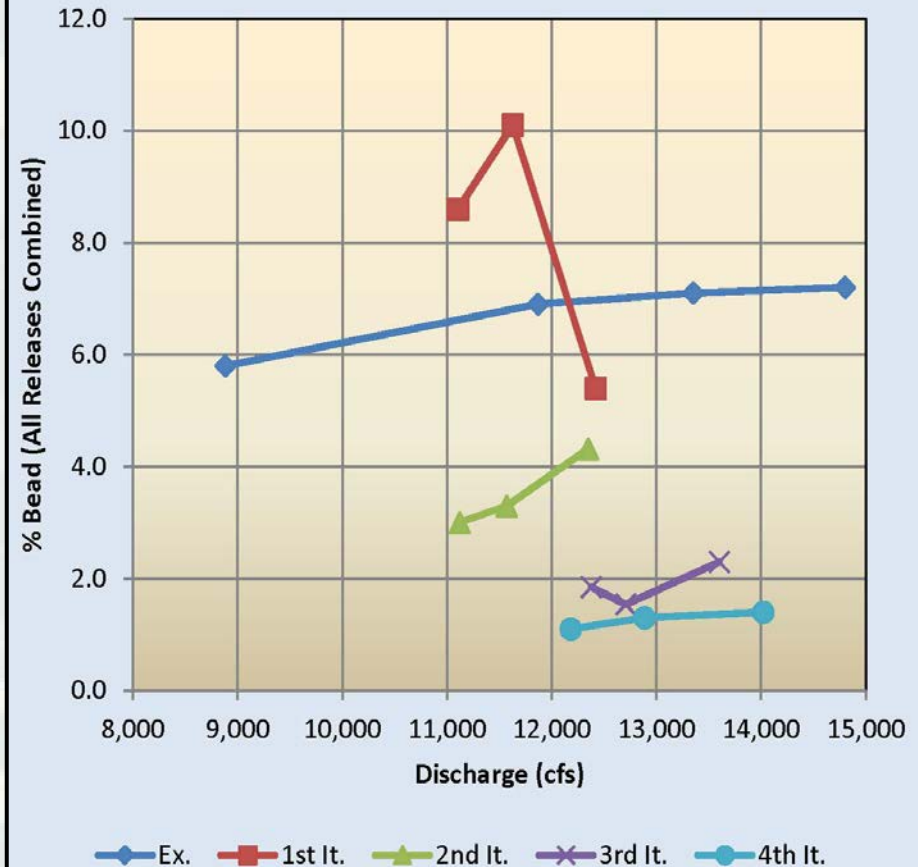


Ice Harbor Fixed Blade Model Results

Runner Bead Strikes



Runner Bead Direction Change



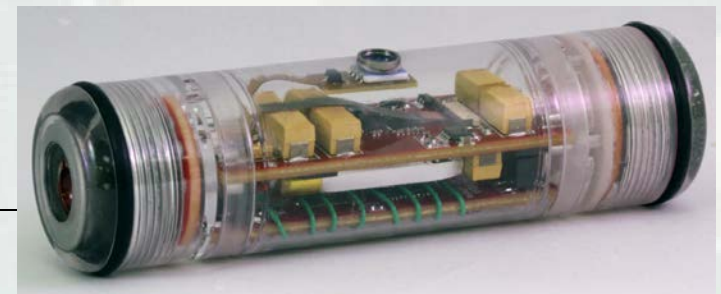
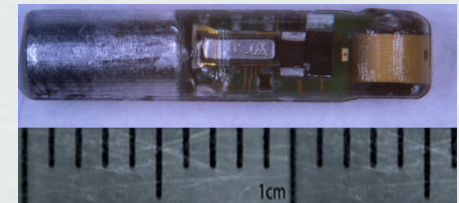
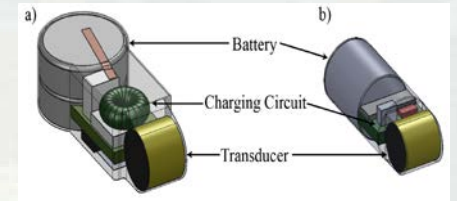
Path Forward

- Complete analysis of adjustable blade runner
- Award contract for installation of the fixed blade and the 2 adjustable blade runners
- Test for Fish Passage Survival
 - ▶ Fixed blade testing in 2017
 - ▶ Adjustable blade testing in 2018
- Incorporate new design process in future turbine replacement efforts



Bio-Testing the New Turbines

- 2017 through 2019
- Acoustic Telemetry Tag Method
 - ▶ **Total Turbine Passage Survival** including Immediate Tailrace
- Balloon Tag Methods (Hi-Z)
 - ▶ **Direct Turbine Effects** - injury and mortality of the immediate turbine passage
- Sensor Fish data collection
 - ▶ **Pressure and Acceleration** data
 - Estimates probabilities of exposure to low pressure
 - Estimates probabilities of strike and exposure to shear
 - ▶ Will compare to Baseline (Existing Turbine) data



Questions ?



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