American Water Works Association
Pacific Northwest Section

CFD Modeling to Optimize Hydraulic Design of River Intake Pump Station, LOTWP

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LAKE OSWEGO · TIGARD WATER PARTNERSHIP

BLACK & VEATCH

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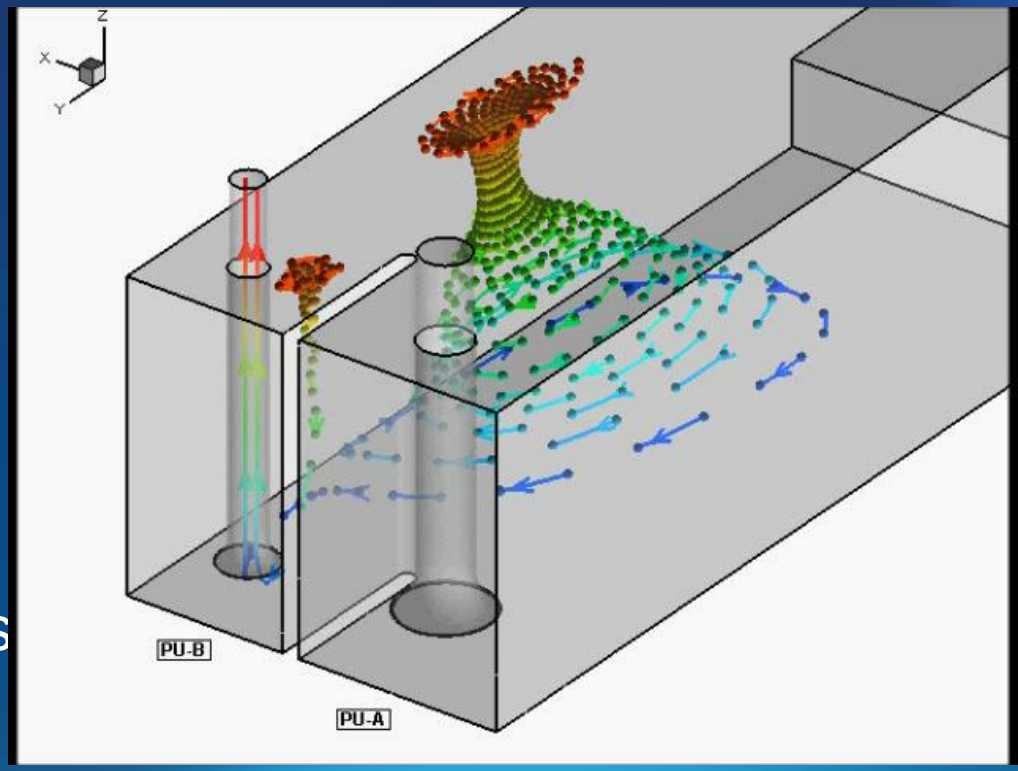
Presentation Outline

- Project Background
- Study Objectives
- CFD Modeling Overview
- Design Guidelines
- Initially Proposed Design
- Design Modifications
- Summary and Conclusions

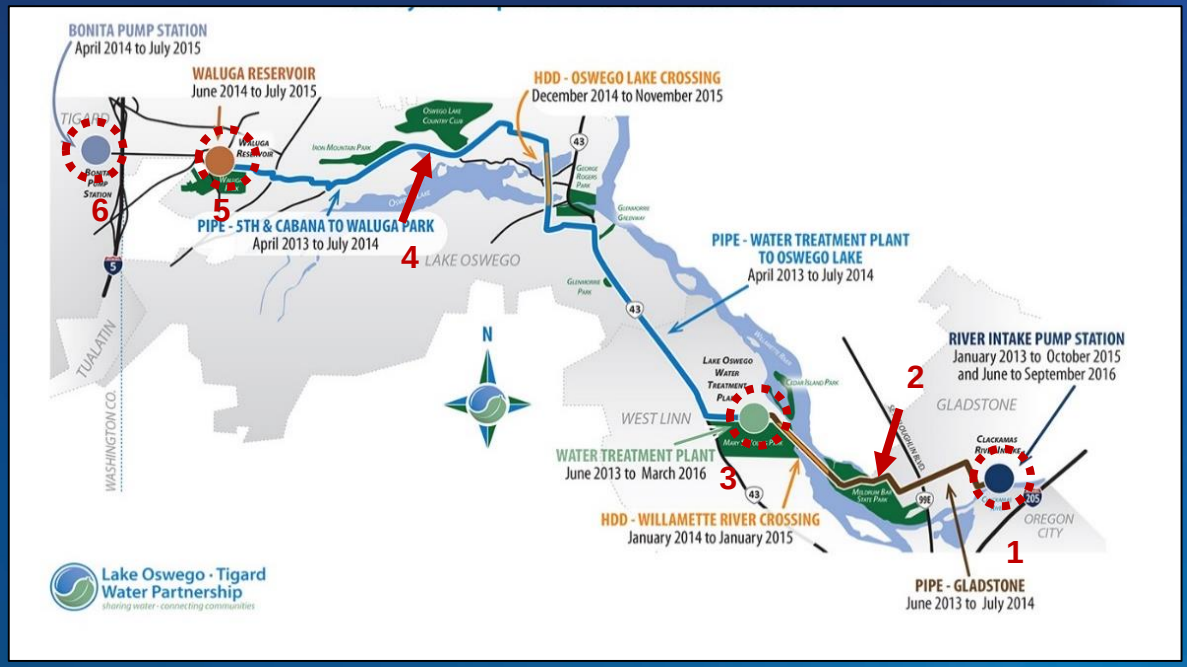
Two Surface Vortices Entering a Pump



Project Background

- LOTWP is a partnership between Cities of Lake Oswego and Tigard
- LOTWP program will upgrade to 38 mgd
- Key elements are
  1) River Intake Pump Station (RIPS)
  2) Raw Water Pipeline (RWP) to transport water to the WTP
  3) WTP in West Linn
  4) Finish Water Pipeline (FWP) to distribution
  5) Waluga Reservoir 2 (WR2) to store water
  6) Bonita Pump Station (BPS) to Tigard service zones

Six Key Elements



River Intake Pump Station withdraws water from the Clackamas River

Hydraulic Design Considerations

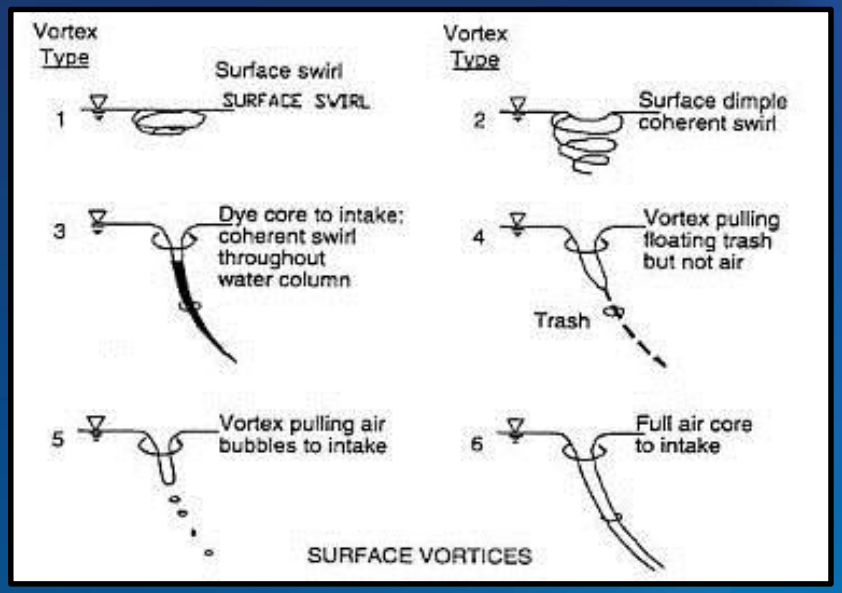
- Operational problems
  - Excessive noise
  - Reduced performance
  - Air binding
  - Loss of prime
  - Component failure
  - Cavitation damage
- Causes of problems
  - Non-uniform velocity
  - Excessive turbulence
  - Vortices
  - Pre-swirl

Damaged Pumps

Hydraulic Design Guidelines

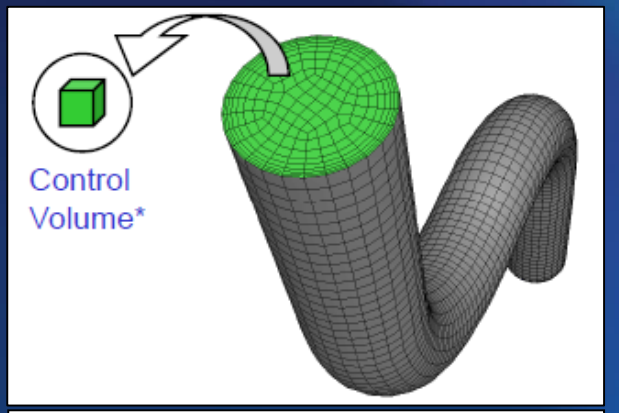
- HI(2012) guidelines
  - Mean pre-swirl less than 5^{o}
  - Velocity uniform to 10% of the mean
  - No strong surface and subsurface vortices

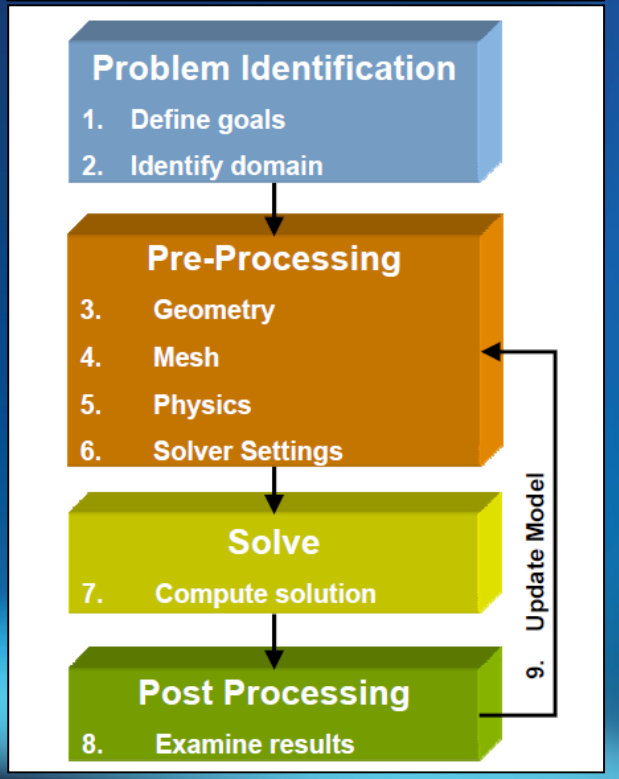
Vortex Classification



CFD Modeling

- Solves fundamental equations of fluid flow by numerical algorithms
  - Navier-Stokes equations
  - Turbulence closure equations
- Divides the computational domain into a large number of small cells
- Simultaneous solution at each node provides a complete picture of the hydraulic regime
- CFD software package: STAR-CCM+

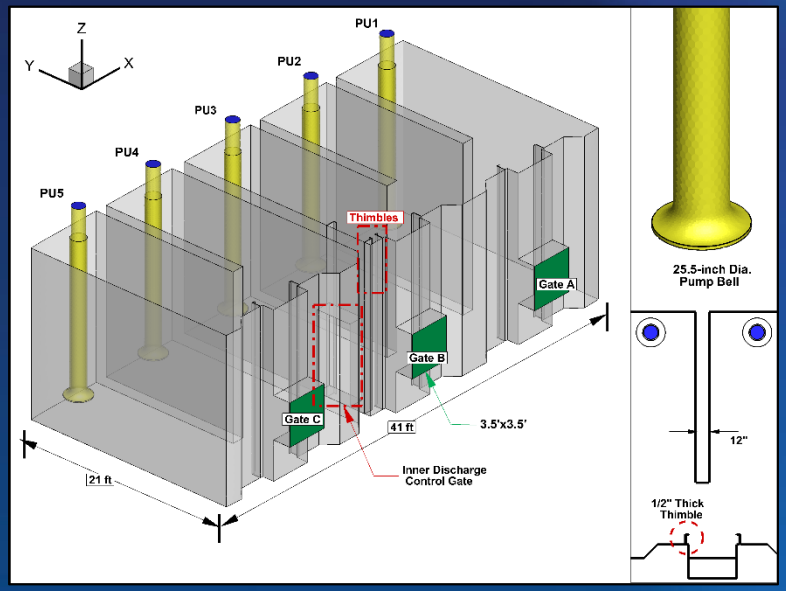




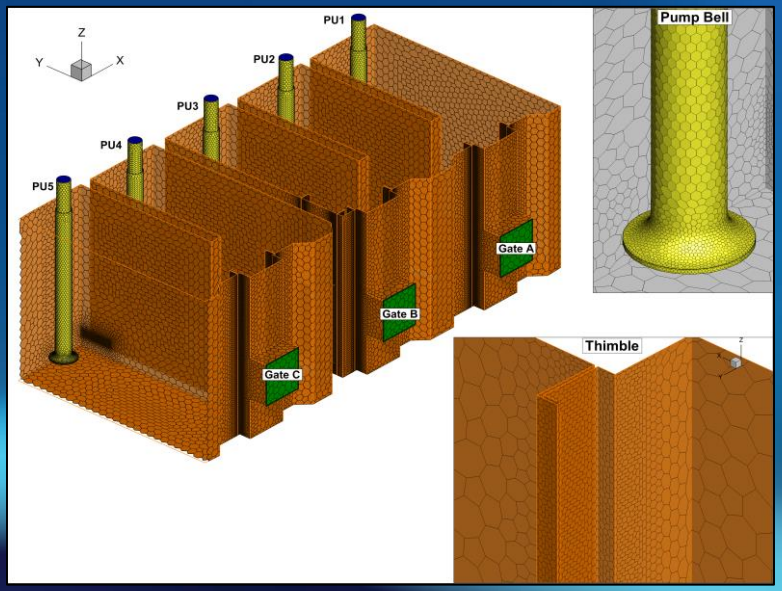
Initial Design

- Project features
  - 38-mgd capacity
  - 41-foot long and 21-foot wide
  - 4 operating and 1 standby pumps
  - Three screened inlet with T-screens
- CFD model
  - Mesh consists of 2.5 million polyhedral cells
  - High resolution mesh around
    - pump bells and gates
  - 38 mgd flow equally divided among three gates

Model Domain

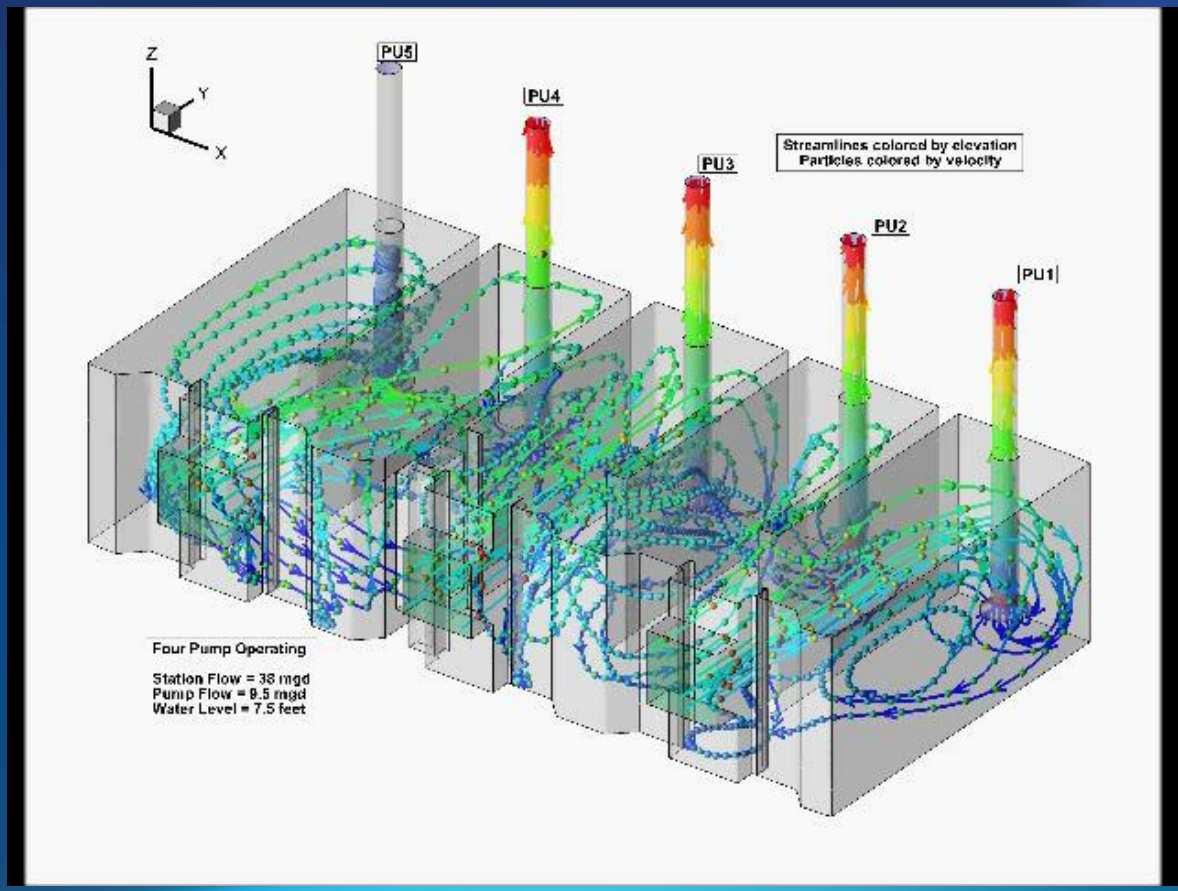


Computational Mesh



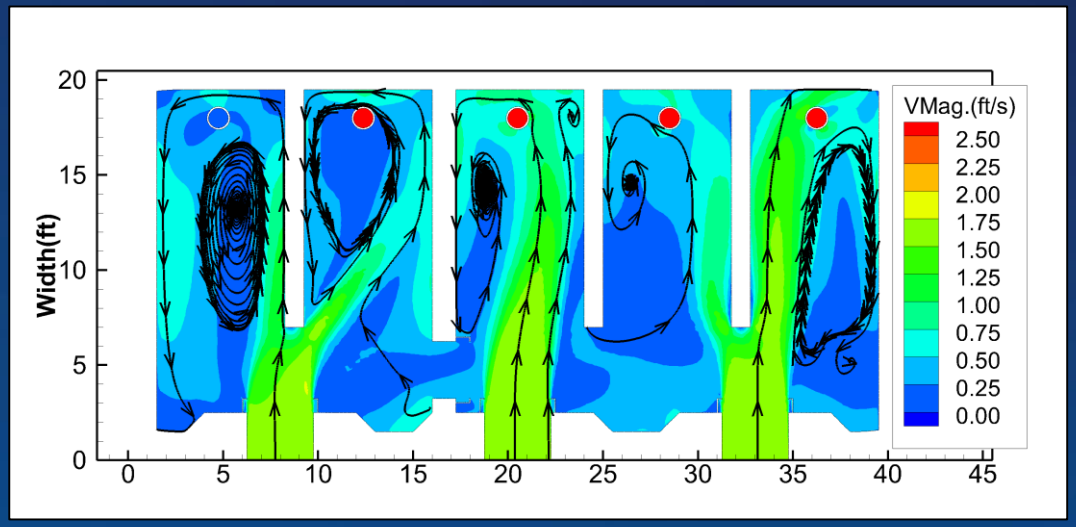
Initial Design: 3-D Circulation

- Higher velocity near
  - Gates
  - Pumps
- Several eddies are visible
- No strong surface vortices

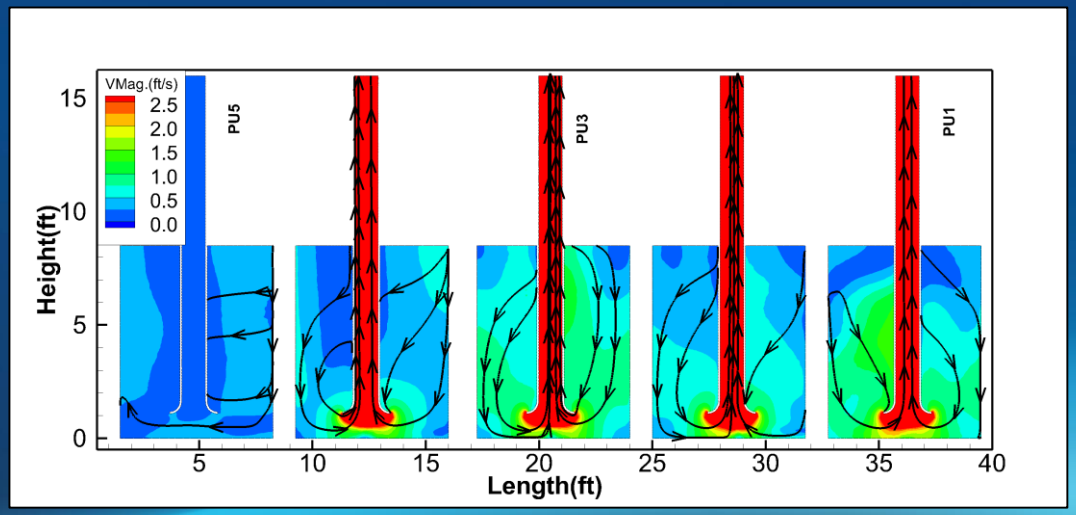


Initial Design: Velocity Distributions

Horizontal Section



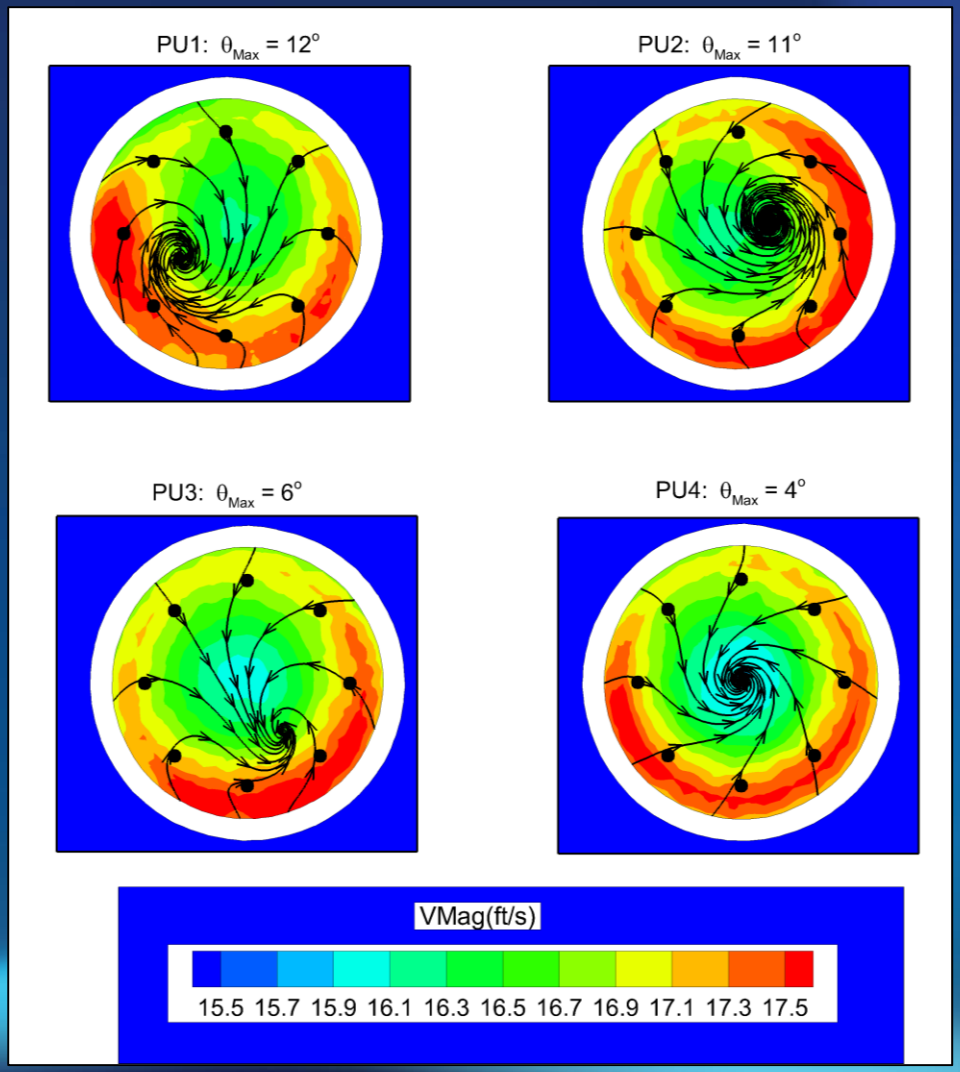
Vertical Section



Initial Design: Pump Bell Hydraulics

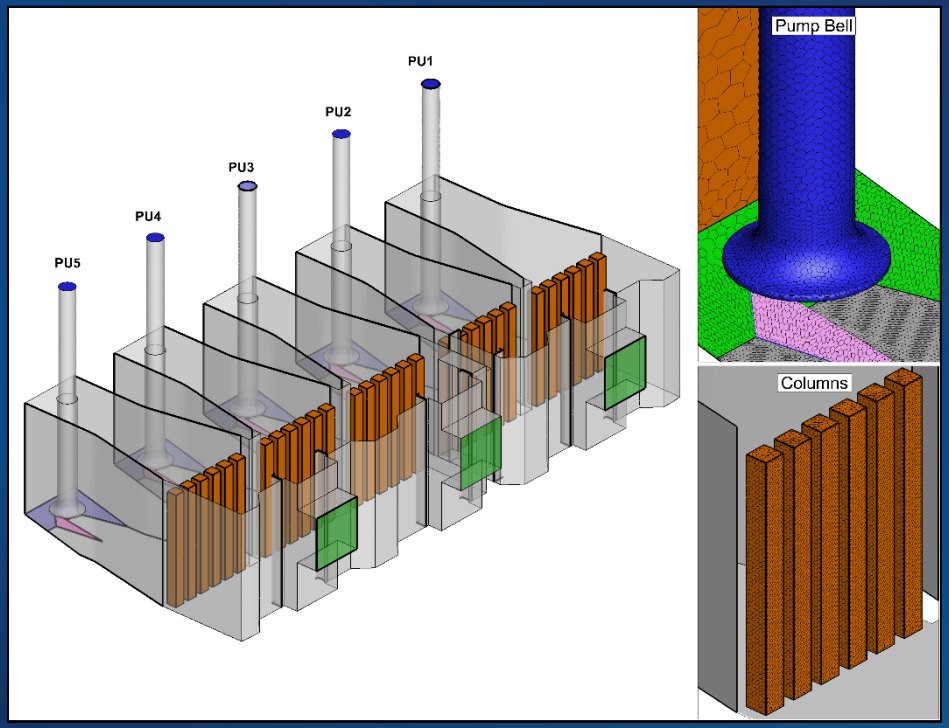
- Eight points in each pump bell throat
- Streamlines indicate flow rotation or pre-swirl
- Pre-swirl varies from 4 to 12º
- Pre-swirl exceeds HI criterion (5º) at thee pumps
- Velocities at eight points are within with 10% of the average

Pump station hydraulics do not comply with the HI guidelines

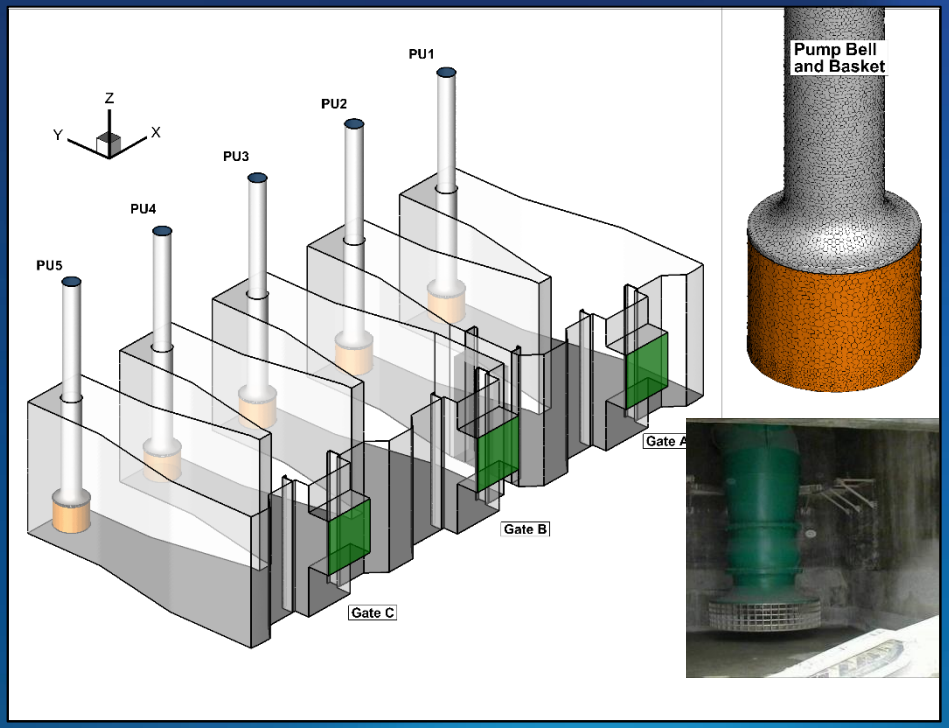


Design Alternatives: Options 1 & 2

Option 1: Columns, Splitters & Fillets



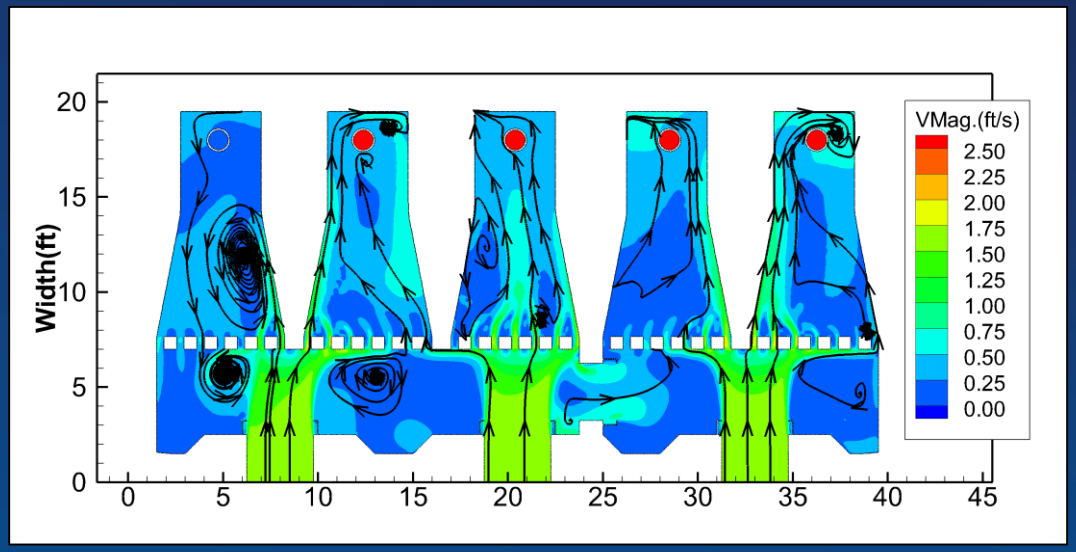
Option 2: Vane/Grating Basket



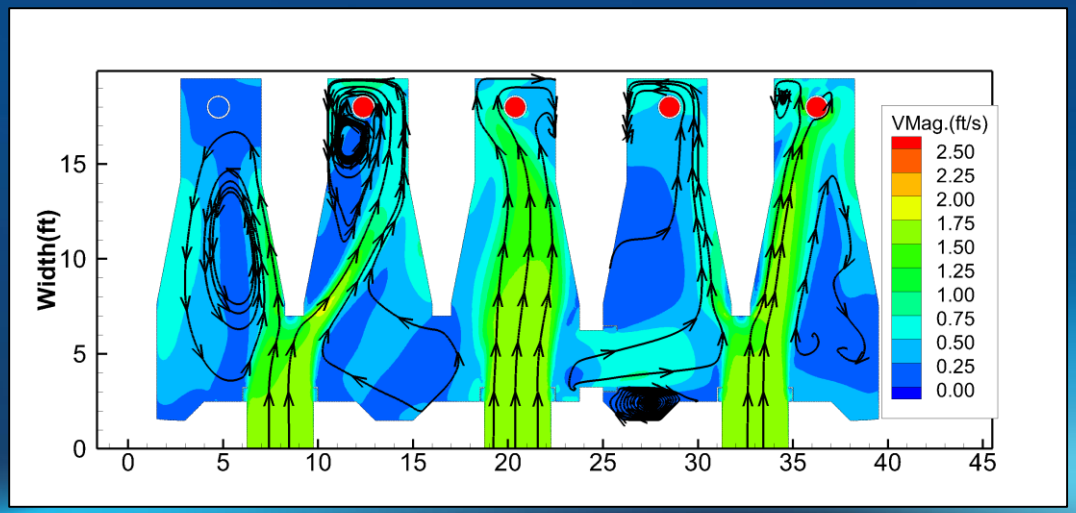
Pump bay width reduced to twice the bell inlet diameter

Options 1 & 2: Velocity Distributions

Option1: Columns, Splitters & Fillets



Option 2: Vane/ Grating Basket

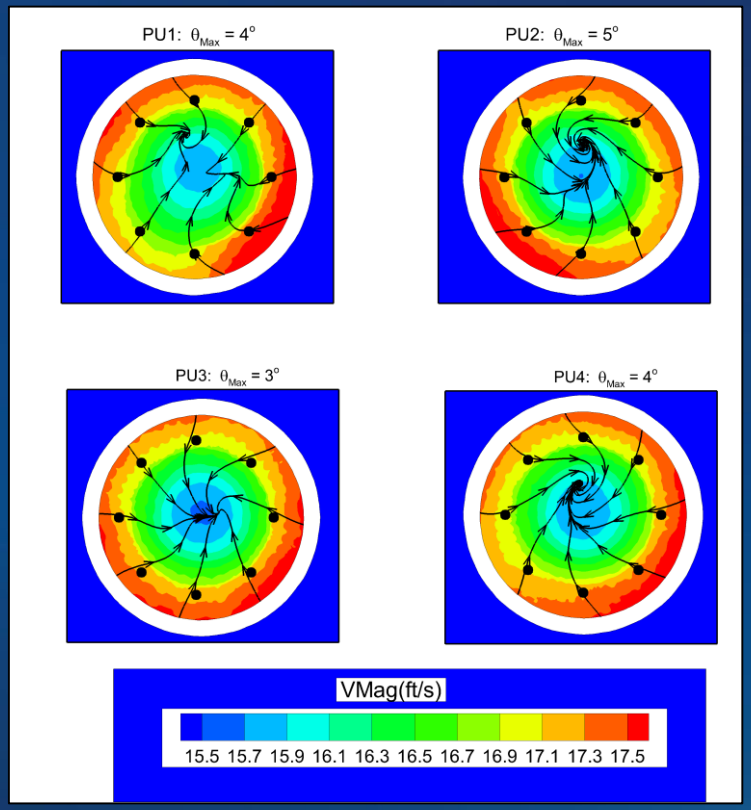


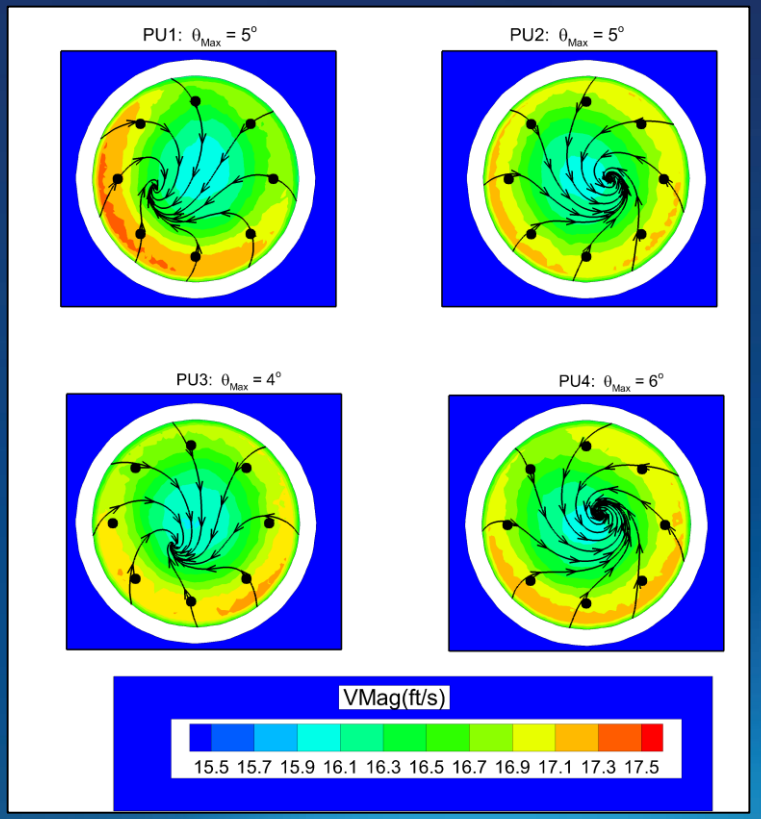
Options 1 & 2: Velocity Distributions

Option 1: Columns, Splitters & Fillets

Option 2: Vane/Grating Basket

Maximum pre-swirl = 5°



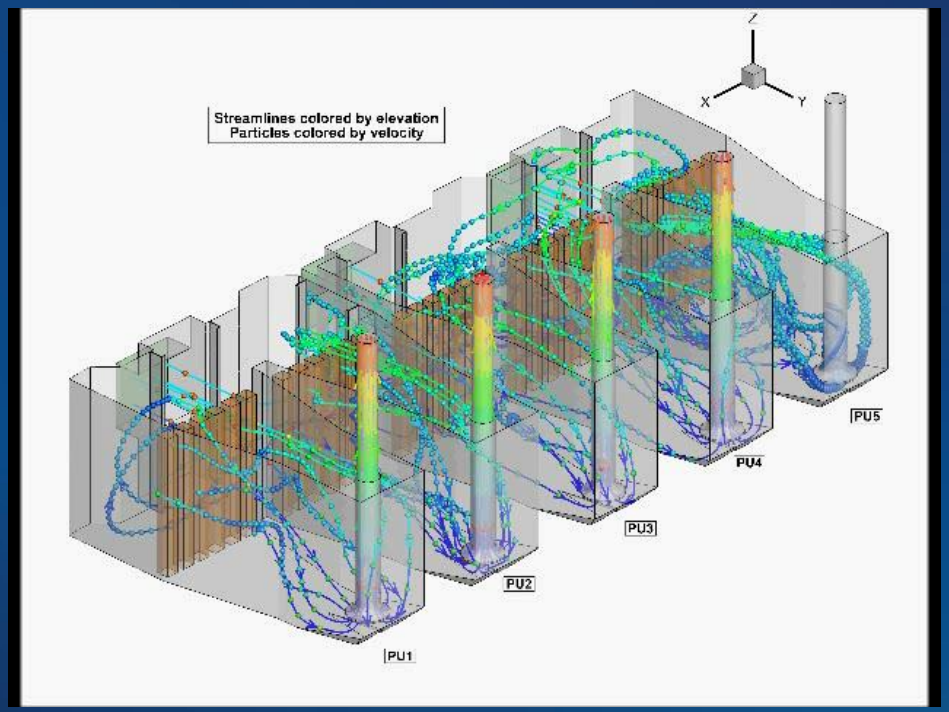


Maximum pre-swirl = 6°

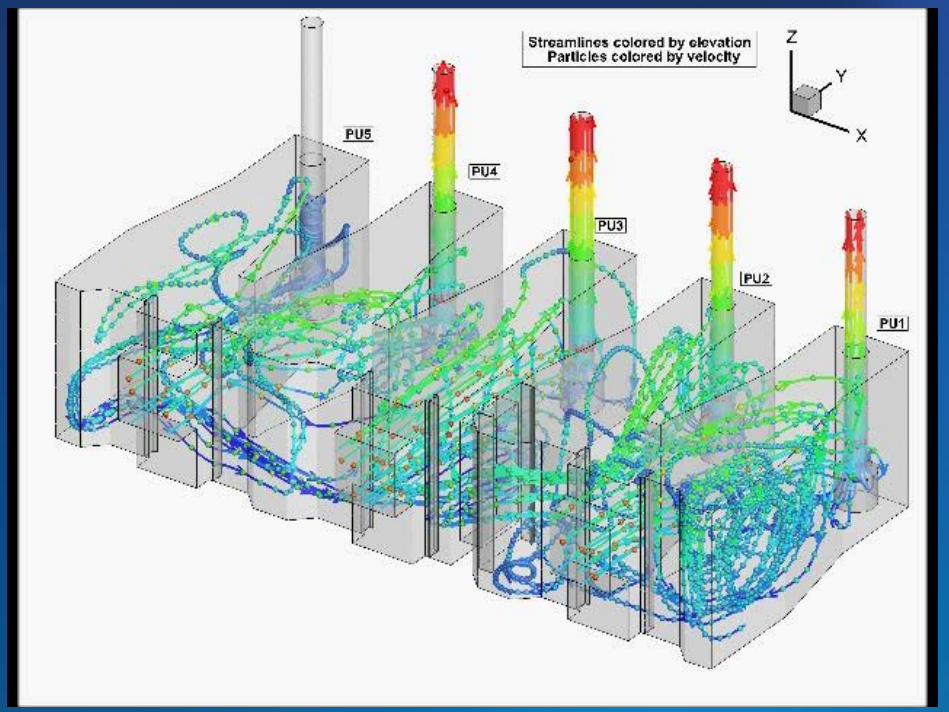
CFD model did not consider basket structural details. Actual pre-swirl reduction is likely to be considerably more.

Options 1 & 2: 3-D Circulation

Option 1



Option 2



Summary and Conclusions

- Described a CFD model analysis of River Intake Pump Station withdrawing 38 mgd from the Clackamas River
- The initial design did not satisfy the Hydraulic Institute (2012) guidelines
- Two design approaches were developed to improve pump station hydraulics
  - Six-columns at each pump bay entrance along with floor splitter and wall fillets
  - A vane/grating basket attached to each pump bell
- For raw water pump station, the six-column option may result in sediment deposition
- LOTWP decided to use the vane/grating option, after confirming results with a physical model

Q&A

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