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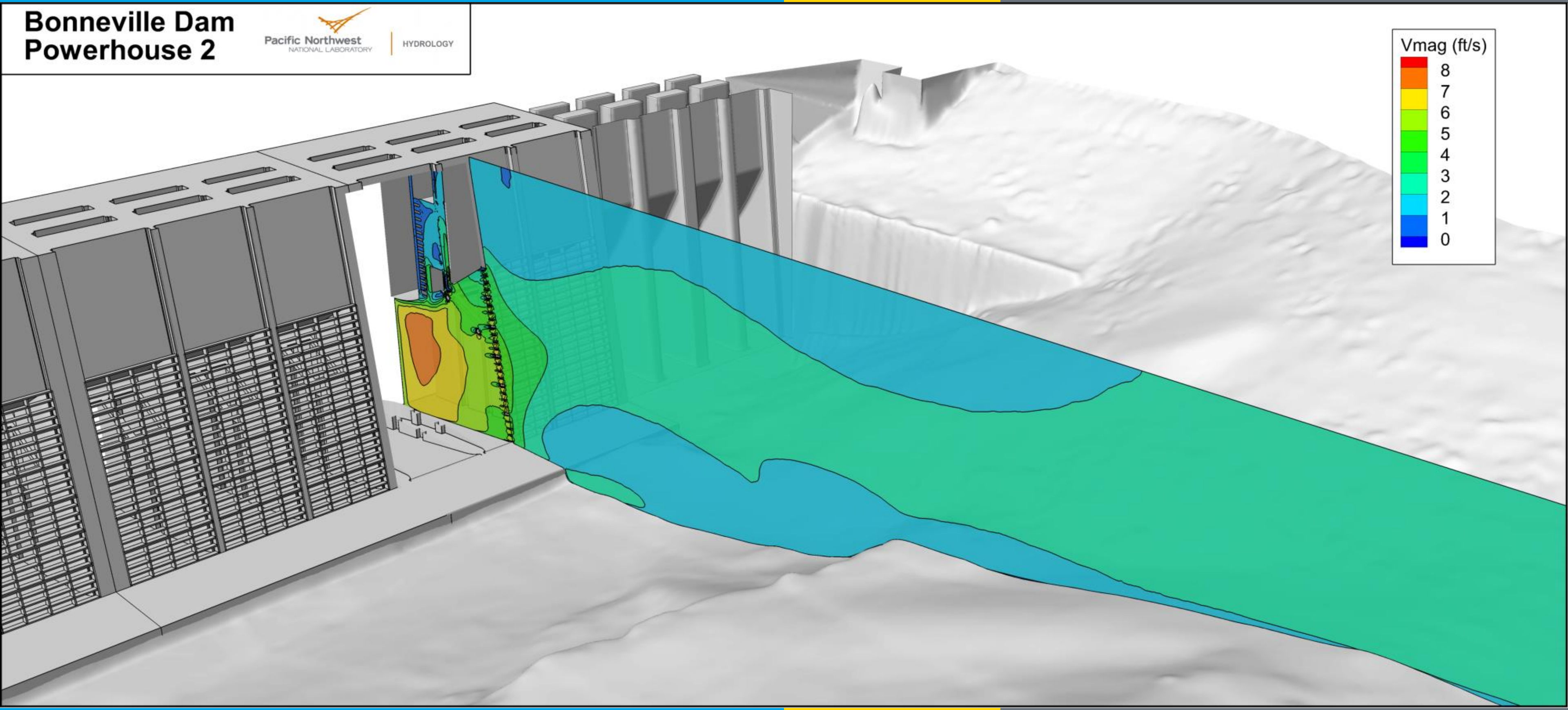

Low-Head, Short-Intake Flow Measurement Research

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Hydropower Flow Measurement:

- Accurate turbine flow rate measurement underpins best practices for hydropower operations, water management, and sustainability. The value of turbine flow rate measurement accuracy is not well-quantified across the U.S. hydropower fleet.

The Challenge:

- Accurate and cost-effective flow measurement in short converging turbine intakes is a long-standing technical challenge not yet overcome by industry or research communities. Innovations in flow sensor systems technology, simulation, and deployment will be required for short converging turbine intakes.

Next Generation Hydropower (HydroNEXT)

Optimization

- **Optimize technical, environmental, and water-use efficiency of existing fleet**
- Collect and disseminate data on new and existing assets
- Facilitate interagency collaboration to increase regulatory process efficiency
- Identify revenue streams for ancillary services

Growth

- Lower costs of hydropower components and civil works
- Increase power train efficiency for low-head, variable flow applications
- Facilitate mechanisms for testing and advancing new hydropower systems and components
- Reduce costs and deployment timelines of new PSH plants
- Prepare the incoming hydropower workforce

Sustainability

- Design new hydropower systems that minimize or avoid environmental impacts
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies to evaluate and address environmental impacts
- Increase resilience to climate change

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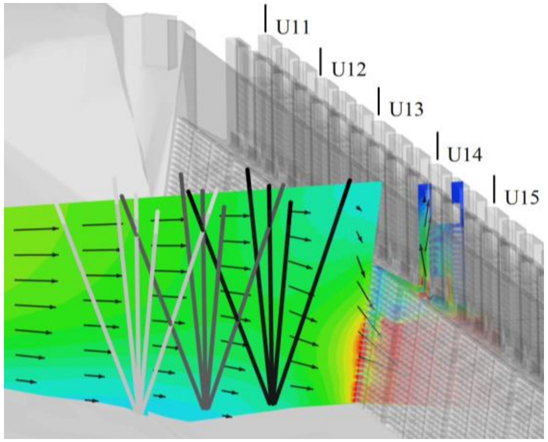
The Impact

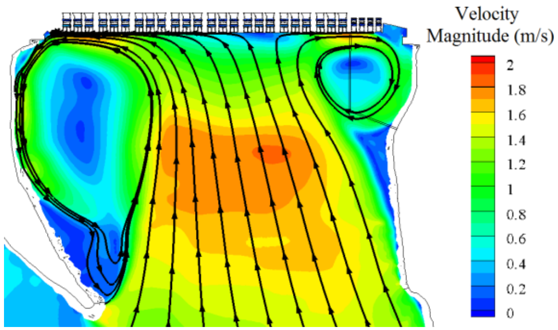
- This project aims to develop absolute flow measurement systems which will allow for turbine unit and powerhouse optimization.
- These new systems and/or components for demonstration or deployment include:
  - Advanced computational tools for engineering design and field test planning
  - New absolute flow measurement technologies for trial in the powerhouse intake and forebay.

To date, the technical approach to this work includes the computational modeling of the flow fields as well as an analysis of how these flow fields would be interpreted using available instrumentation.

Powerhouse Forebay:

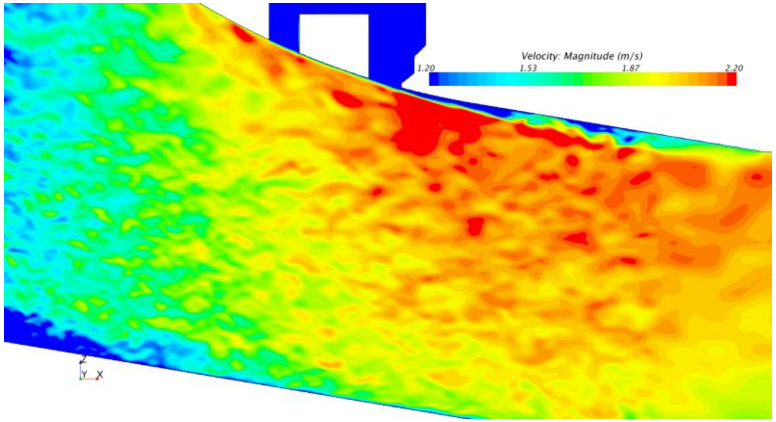
- Acoustic Doppler current profiler (ADCP) were identified as a method of validating the numerical flow solutions, particularly in observed and calculated regions of non-homogeneous flow velocity.
- By using a numerical model of an ADCP operating in a velocity field calculated using CFD, the errors due to the spatial variation of the flow velocity were quantified.

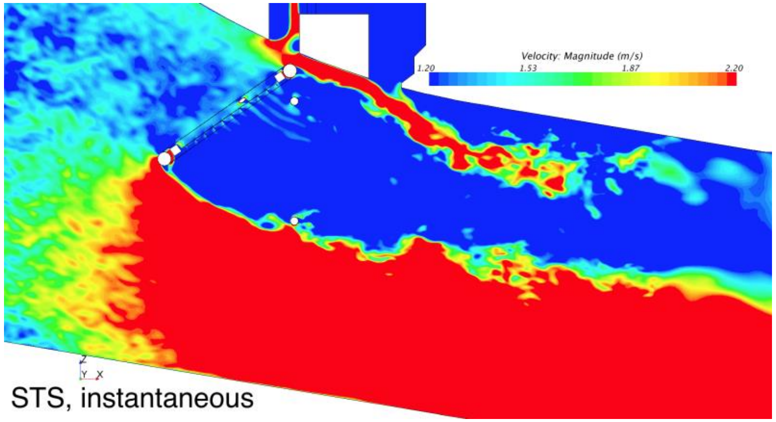




Powerhouse Intake:

- A computational fluid dynamics (CFD) model was developed to model the velocity field of a short converging intake using a detached eddy simulation (DES) turbulence solution.
- An array of virtual point velocity measurements were extracted from the resulting velocity field to simulate an array of virtual current meters (VCMs).
- A sensitivity analysis was performed to observe the effect of the VCM array resolution on the discharge error.





Accomplishments and Progress

Journal Articles

- Harding, S., M. Richmond, P. Romero-Gomez and J. Serkowski. 2016. Effects of non-homogeneous flow on ADCP data processing in a hydroturbine forebay, *Journal of Flow Measurement and Instrumentation*, In Press.
- Romero Gomez P.D.J. ,Harding S.F., Richmond M.C. 2016. The Effects of Sampling Location and Turbulence on Discharge Estimates in Short Converging Turbine Intakes, *Engineering Applications of Computational Fluid Dynamics*, In Review.

Reports

- Harding, S., P.D.J Romero-Gomez and M.C. Richmond. 2016. Performance of Virtual Current Meters in Hydroelectric Turbine Intakes, PNNL-25319, Pacific Northwest National Laboratory, Richland, WA.

Project Plan & Schedule

	FY20014				FY2015				FY2016			
Milestone/Deliverable (selected)	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Coordination meeting with ASME PTC 18 Committee												
Prepared and published: *Effects of non-homogeneous flow on ADCP data processing in a hydroturbine forebay*												
Unsteady CFD Simulation of Ice Harbor Dam Intake												
Prepared technical report: *Performance of Virtual Current Meters in Hydroelectric Turbine Intakes, PNNL-25319*												
Prepared and submitted journal article: *Effects of Sampling Location and Turbulence on Discharge Estimates in Short Converging Turbine Intakes*												

Project Budget

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Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$300K		$0		$350K	

- ~80% of the budget has been expended to date.
- FY14 funds actually arrived in August 2013 for carryover into FY14
- Work at PNNL was on hold for much of FY15 due to a budgeting error at DOE that led to PNNL not being allocated any new FY15 funds. Work continued using FY14 carryover until that was exhausted, and work was placed on hold after completing a high-resolution CFD model for Ice Harbor Dam turbine intake. The project is restarting in FY16 once new funding arrives at PNNL during Q1.
- This project does not have cost share.

Partners, Subcontractors, and Collaborators:

Working with a range of partners to assess measurement needs, current methods, and locations for potential field trials

- Memorandum of Understanding Agency Partners
  - US Army Corps of Engineers
  - Bureau of Reclamation
- Public and Private Utilities
  - Grant County Public Utilities District
- Hydro Industry Flow Measurement Standards Committees
  - ASME PTC-18 (American Society of Mechanical Engineers)
  - IEC TC-4 (International Electrotechnical Commission)

Communications and Technology Transfer

- This work has been disseminated in two journal articles and one technical report.
- Attended meeting of ASME PTC-18 Committee in April 2014, Palm Springs, CA.

Next Steps and Future Research

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FY17/Current research:

PNNL will lead the development and publication of reference powerhouse intake geometries and flow fields for low-head, short-intake facilities with the following milestones:

- Complete the selection and planning for laboratory data collection of refined validation data for CFD and virtual instrument models (FY16-Q1)
- Complete the prototype intake acoustic velocimeter instrument design document (FY16-Q2)
- Complete a refined numerical test bed simulation for an intake reference flow and virtual sensor measurements and compare to refined laboratory test data (FY16-Q3)
- Complete a technical report documenting the results of the prototype testing of the measurement system and field test plans to be undertaken in 2018 (FY16-Q4).

Proposed future research:

In FY18, PNNL will lead the technical support of hydropower flow measurement field demonstration activity (undertaken in collaboration with a project operator, e.g. federal or non-federal).