

**Cabinet Gorge and Boundary
Hydropower Projects
Total Dissolved Gas (TDG)
Abatement**

Two Projects with Similar Issues

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Keith Moen P.E.

- Project Engineer for Cabinet Gorge Bypass Tunnel Project
- Lead for Total Dissolved Gas Study - Boundary Relicensing Studies
- Manager of Seattle Office of Hatch Acres

The Water Quality Issue

- Both Idaho and Washington States have water quality regulations related to TDG
- TDG limit of 110% saturation with exceptions for situations where forebay TDG is higher than tailrace TDG or for flows greater than 7-day, 10-year (7Q10) flood event

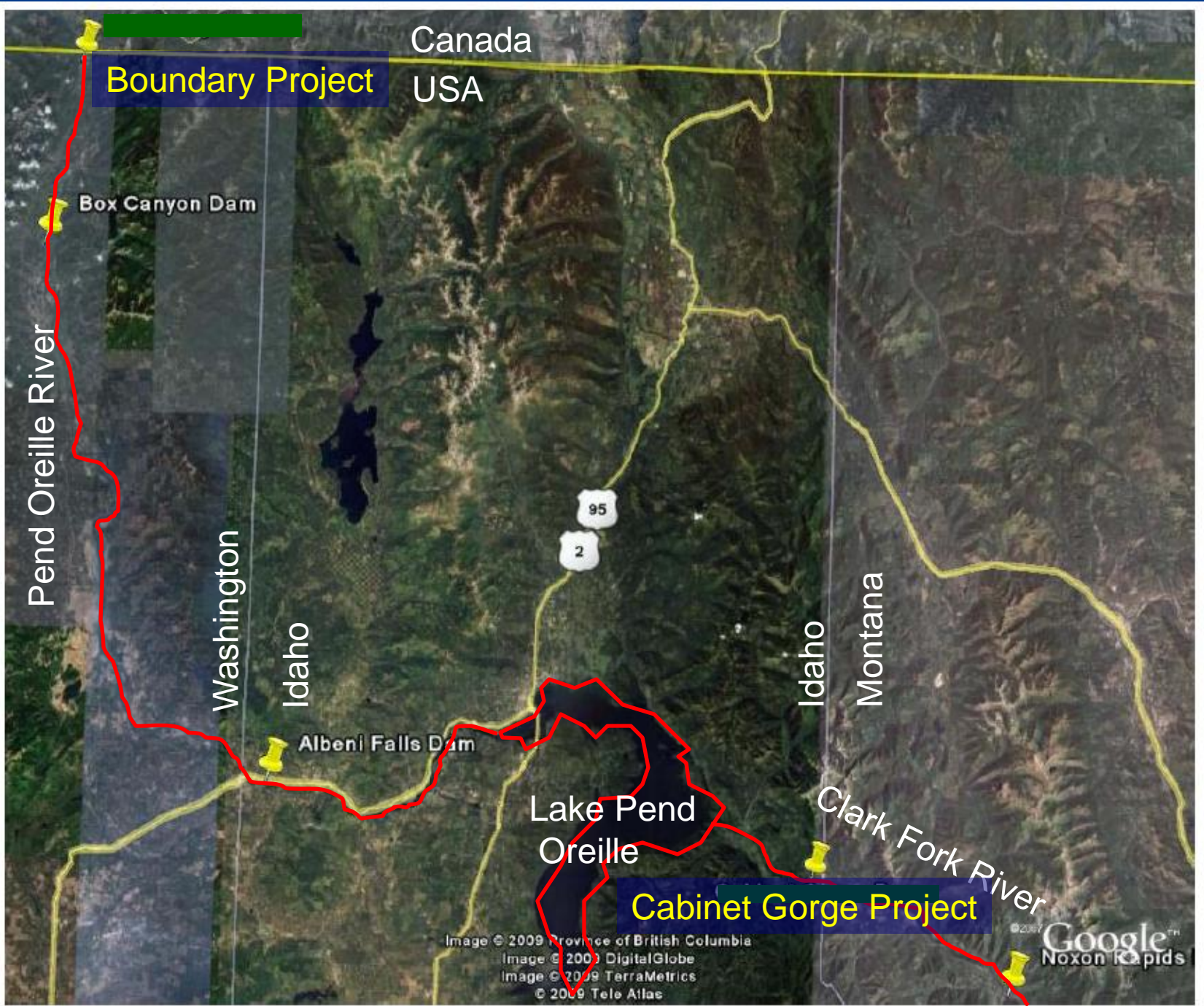
The Projects

Cabinet Gorge

- Avista Utilities
- 263 MW
- PH Cap. = 38,400 cfs
- 7Q10 = 118,400 cfs
- 80,000 cfs flow
between PH capacity
and 7Q10

Boundary

- Seattle City Light
- +1,000 MW
- PH Cap. = 55,000 cfs
- 7Q10 = 108,300 cfs
- 53,300 cfs flow
between PH capacity
and 7Q10



Mechanism that Causes Elevated TDG

- Energetic flow with substantial turbulent energy
- Air entrainment that occurs due to jet falling through air and plunging onto a pool
- Air bubbles are carried to depth within the tailwater

Cabinet Gorge Project



Boundary Project



Cabinet Gorge Bypass Tunnel

- The project water quality certificate as part of the FERC license included development of a spillway bypass using the two existing diversion tunnels to pass flows up to the 7Q10
- Challenges for the project include:
 - High velocity flow in tunnels present challenges at intakes, tunnel lining and changes in flow direction
 - High cost for developing tunnels (rock excavation and concrete lining)
 - Flow exiting tunnel will be energetic, entrain air and carry bubbles to depth

Boundary TDG Abatement Evaluation of Top 7 Alternatives

- Throttle Sluice Gates
- Roughen Sluice Flow
- Spillway Flow Splitter/Aerator
- Right Abutment Tunnel with Submerged Discharge
- Open Existing Diversion Tunnel and Add Control Structure
- Penstock Draft Tube By-pass
- New Left Abutment Tunnel Next to Unit 51 Intake

Boundary - Criteria for Alternative Selection

- Low risk of fish injury
- High likelihood of improving TDG conditions downstream
- Technically feasible for construction and permitting;
- Minimal dam safety concerns
- Lower cost for implementation
- Maintenance and access are not impaired
- Existing Project operations are not impacted
- Ability to prototype concept
- Concept can be phased and adjusted

Boundary

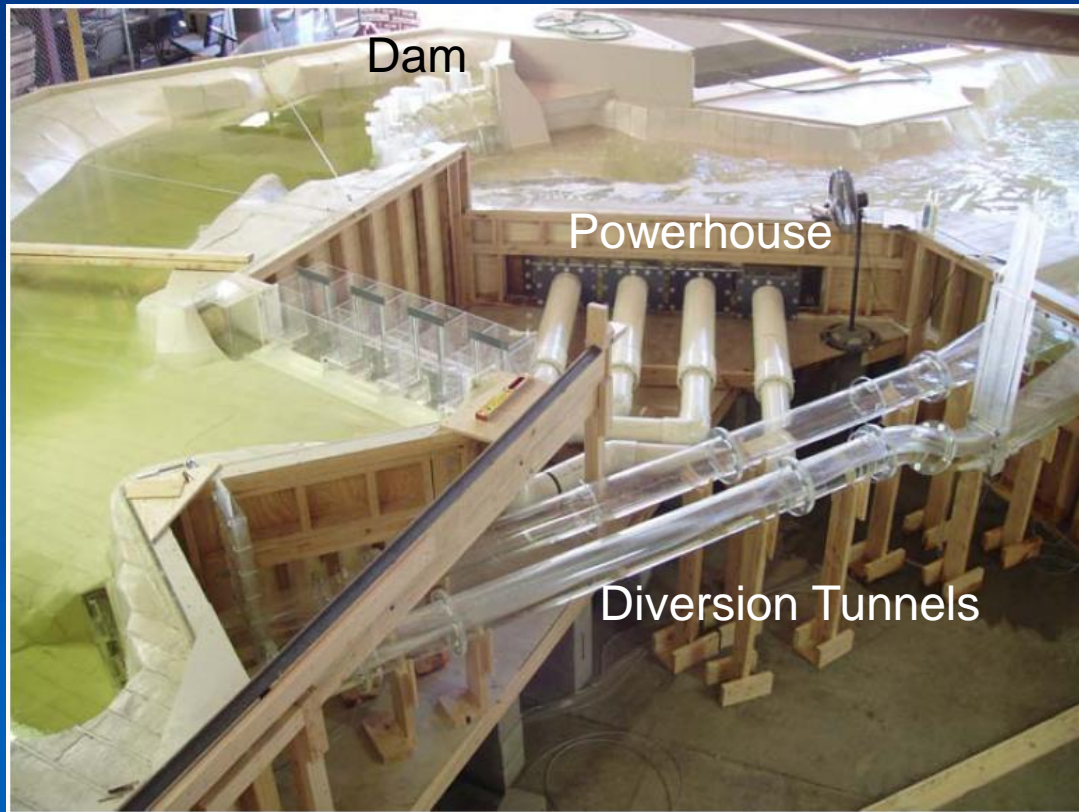
Three TDG alternatives selected for more detailed evaluation

- Throttle Sluice Gates;
- Roughen Sluice Flow; and
- Spillway Flow Splitter/Aerator.

Cabinet Gorge and Boundary Analysis Tools

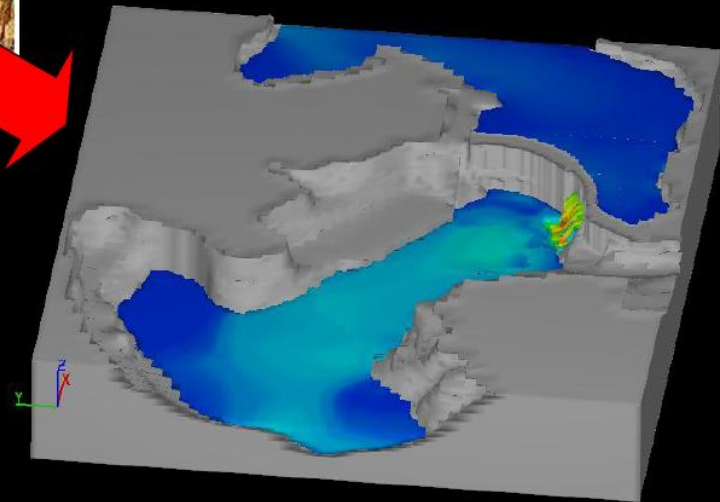
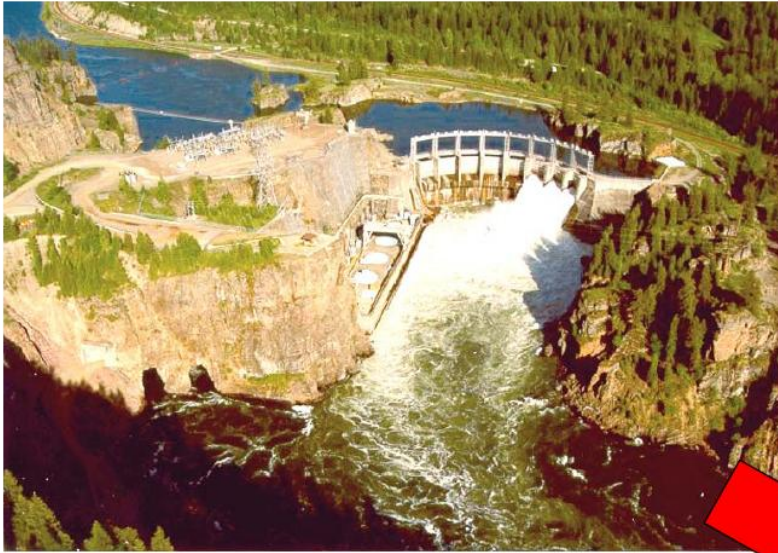
- Physical Model
 - Reliable hydraulic engineering tool
 - Opportunity to test potential options w/o expensive “full scale” structures or forced spill
- Computational fluid dynamics (CFD)
 - Numeric model can be calibrated to physical model and expanded to full scale
 - Ability to examine flow in detail
 - Allows development of TDG predictive tools

1:50 Scale Physical Model of Cabinet Gorge Dam



- Clear Plastic for viewing flow phenomenon
- Tailrace roughness adjusted to water surface profile
- Pressure taps and transducers

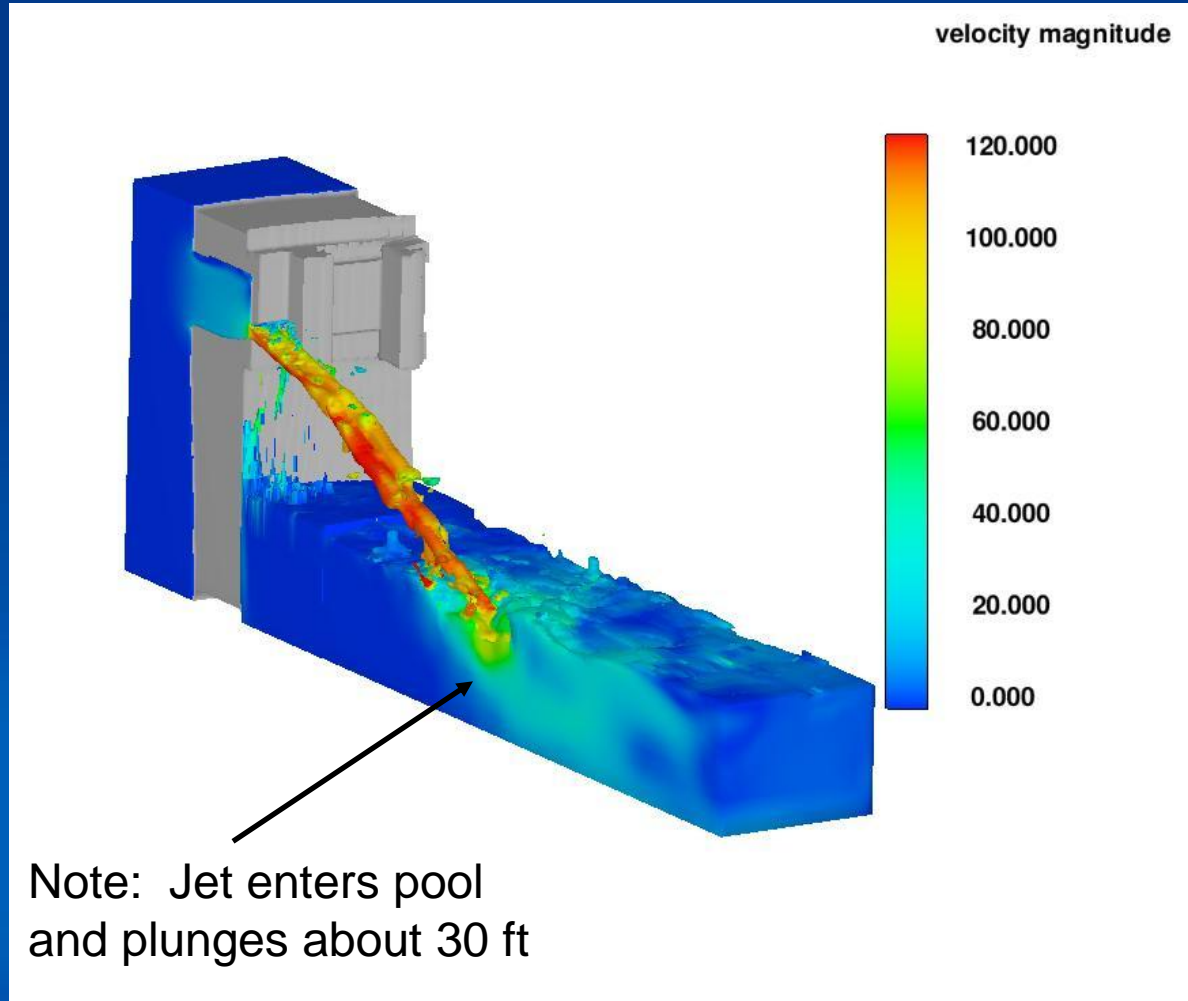
CFD Model of Cabinet Gorge Dam



1:25 Scale Physical Model of Boundary Dam



Boundary CFD Model Tests



Section through jet and plunge pool

Project Status

Cabinet Gorge

- The bypass tunnel would reduce TDG during spill over current configuration
- Much greater cost than originally anticipated
- The bypass project would not meet the TDG standard and the concept is therefore not viable
- Currently Avista is exploring other options to incrementally improve TDG performance

Boundary

- Multiple options were considered
- Top three alternatives selected for further development
- All three alternatives involve modifications of spill gate operations and configuration
- Incremental (adaptive management) approach for operational and structural changes

Compliance w/ TDG Standard

- For both projects it is too early for any conclusions regarding compliance under all flow conditions
- Meeting compliance for TDG becomes more challenging as the flow increases; however the frequency of events decreases as the flow increases

Moving Forward

- Both projects are moving towards combinations of operational modification and structural abatements
- The process favors practical options that can be prototyped and incrementally placed into operation to improve water quality
- Methods to predict TDG performance using computer modeling are part of process