CENTER HILL MAJOR HYDROPOWER REHABILITATION

AERATION ENHANCEMENT INVESTIGATION

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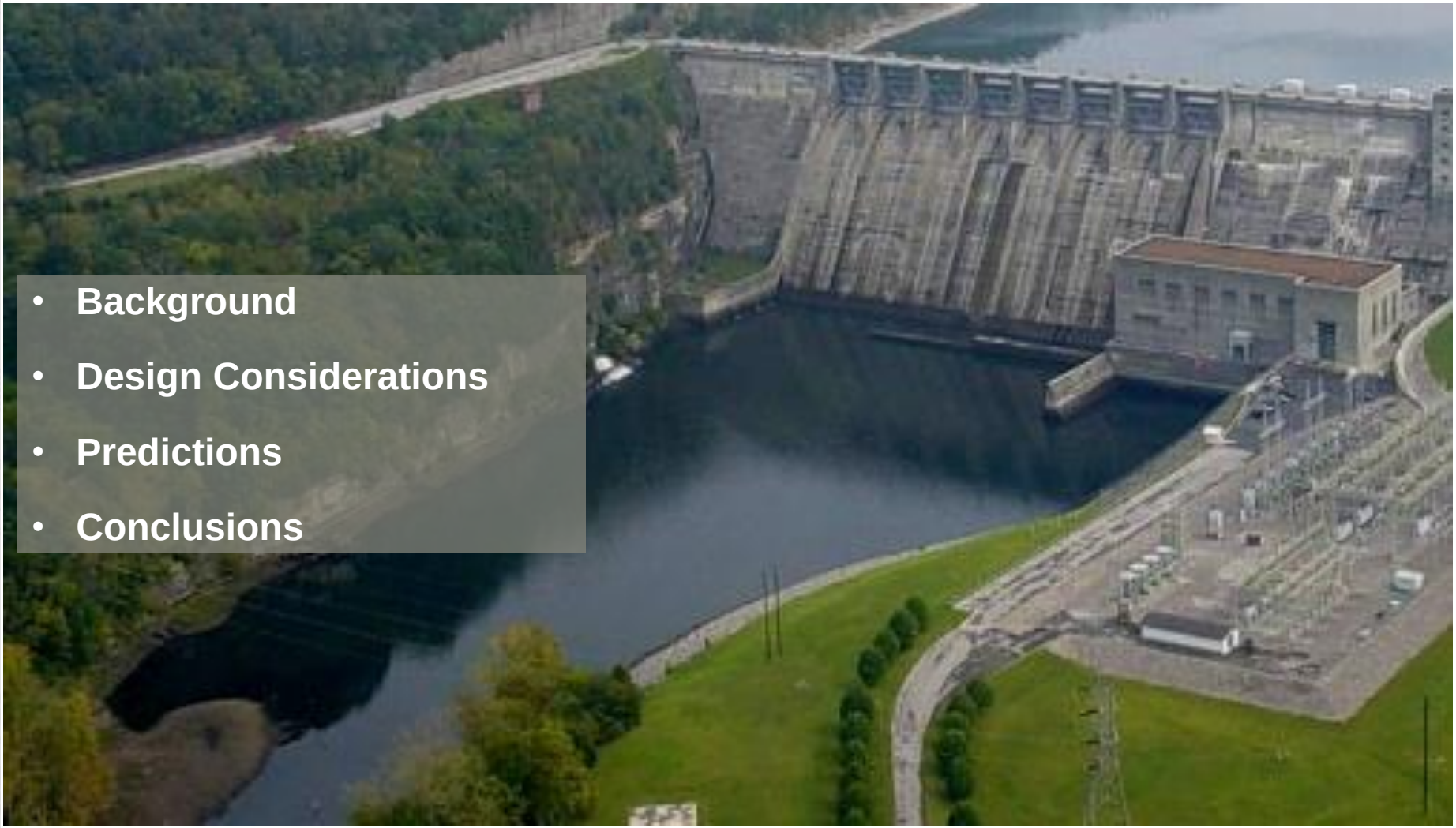
OVERVIEW



- Background
- Design Considerations
- Predictions
- Conclusions

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BACKGROUND

- Center Hill Dam Turbine-Generation Rehabilitation Project consists of complete rehabilitation of 3 generation units
- $47.2M contract awarded to Voith Hydro 25 June 2014
- Replacement runners designed, model tested and are currently being installed
  - 3 Units
  - Rated Net Head = 170 ft
  - Rated Turbine Output = 76,600 hp
  - Runner Diameter = 179.5 inch
- Scheduled for completion in 2020

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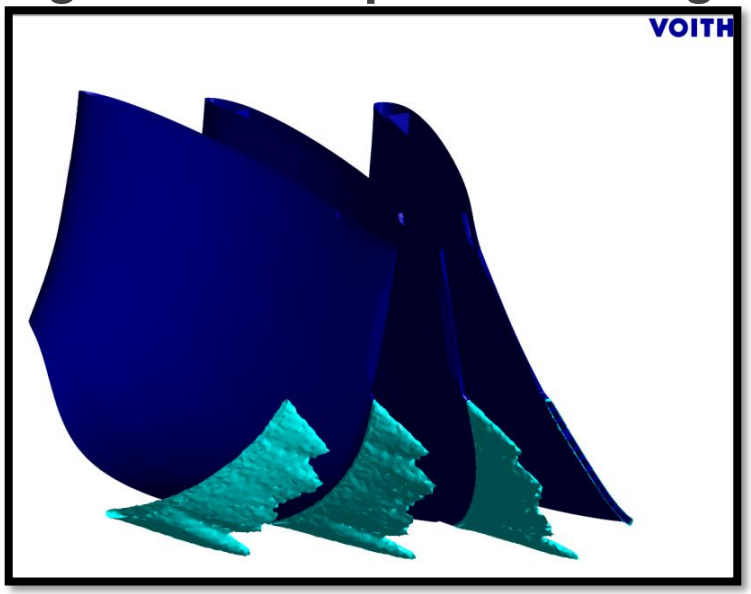
BACKGROUND

- Auto-venting runners naturally draw air into the water passage during operation
- Target tailrace dissolved oxygen (DO) levels of 6.0 mg/L
- 1st Unit (Unit #2) was commissioned in the Fall of 2017
  - Measured tailrace DO levels were below the target due to tailwater being higher than expected during operation



CFD Showing Simulated Air Flow

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SOLUTION FOR IMPROVED AERATION

- In 2018, the USACE commissioned Voith to perform a detailed computational investigation aimed at improving aeration for higher tailwater elevations.
  - Prediction models calibrated with Center Hill aeration measurements.
- Geometry modifications to the runner outlet were defined according to the following criteria:
  - Air flow and resulting tailrace dissolved oxygen
  - Hydraulic impacts, i.e., efficiency, cavitation, vibration (Computation Fluid Dynamics)
  - Structural performance (Finite Element Analysis)
  - Feasible installation both in Voith's manufacturing shop and in-situ
    - Mock-up of proposed modification performed in Voith's shop

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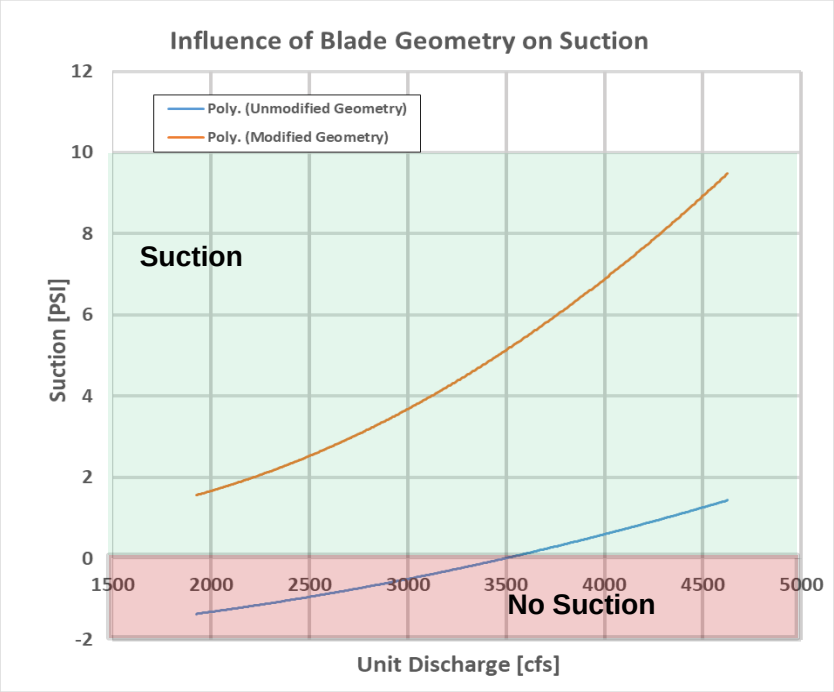
PREDICTED IMPACT ON SUCTION



- Values in chart represent average suction across trailing edge (tailwater elevations for single unit operation)
- Modified geometry results in much larger suction than unmodified geometry for the same operating point
- Larger suction results in larger air flows and corresponding tailrace DO levels

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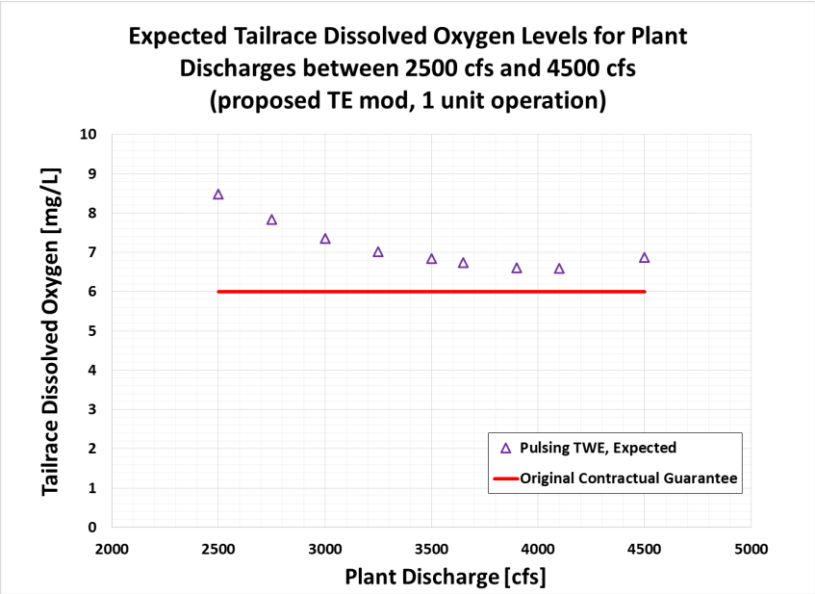
PREDICTED TAILRACE DISSOLVED OXYGEN FOR MODIFIED GEOMETRY

- Tailrace dissolved oxygen model calibrated using Center Hill measurement data
- Tailrace DO during single unit operation > 6 mg/L
  - Expected values incorporate appropriate margin to account for prediction uncertainty



- Tailrace DO during two unit operation ≈ 5 mg/L
- Tailrace DO during three unit operation > 3.5 mg/L

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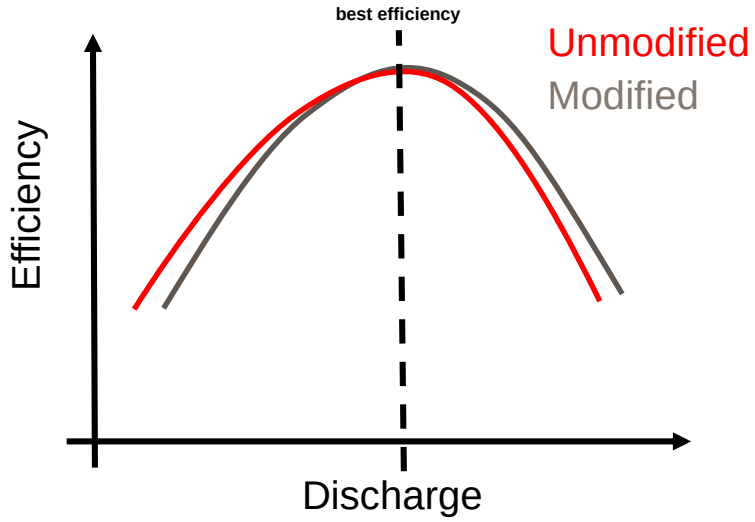
PERFORMANCE IMPACTS DUE TO MODIFICATION

- Efficiency impact dependent on unit discharge
- Small impact on overall weighted efficiency in non-aerating mode
  - Mean Weighted Efficiency ≈ 0.3% lower for modified geometry
- Efficiency corresponding to modified runners are several percent higher than original Center Hill units



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CONCLUSIONS

- USACE and Voith have identified a *cost-effective* modification to the Center Hill runners that will *meet* tailrace dissolved oxygen targets during aeration season
  - Air flow and tailrace dissolved oxygen predictions using computational models are calibrated to Center Hill aeration data for Unit 2
  - The modification meets detailed hydraulic, structural, manufacturing and installation criteria
  - The modification is not expected to impact cavitation or vibration
- Negotiations are underway for modification of 3 runners
  - Unit #3 – Voith's Shop – Installed Feb 2020
  - Unit #1 – Voith's Shop – Installed May 2020
  - Unit #2 – Field Modification
- DO Test – September 2020

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Questions?