Probabilistic Flood Hazard Analysis using RiverWare

Some Lessons Learned

Noah Friesen, RTI International

RTI at a Glance

- Incorporated as the Research Triangle Institute in 1958
- Formed by major universities in central North Carolina
  - Duke University
  - University of North Carolina (Chapel Hill)
  - North Carolina State University
- Independent, non-profit
- ~5,000 employees
- Global operations
- Mission: “*Improve the human condition by turning knowledge into practice.*”

Presentation Outline

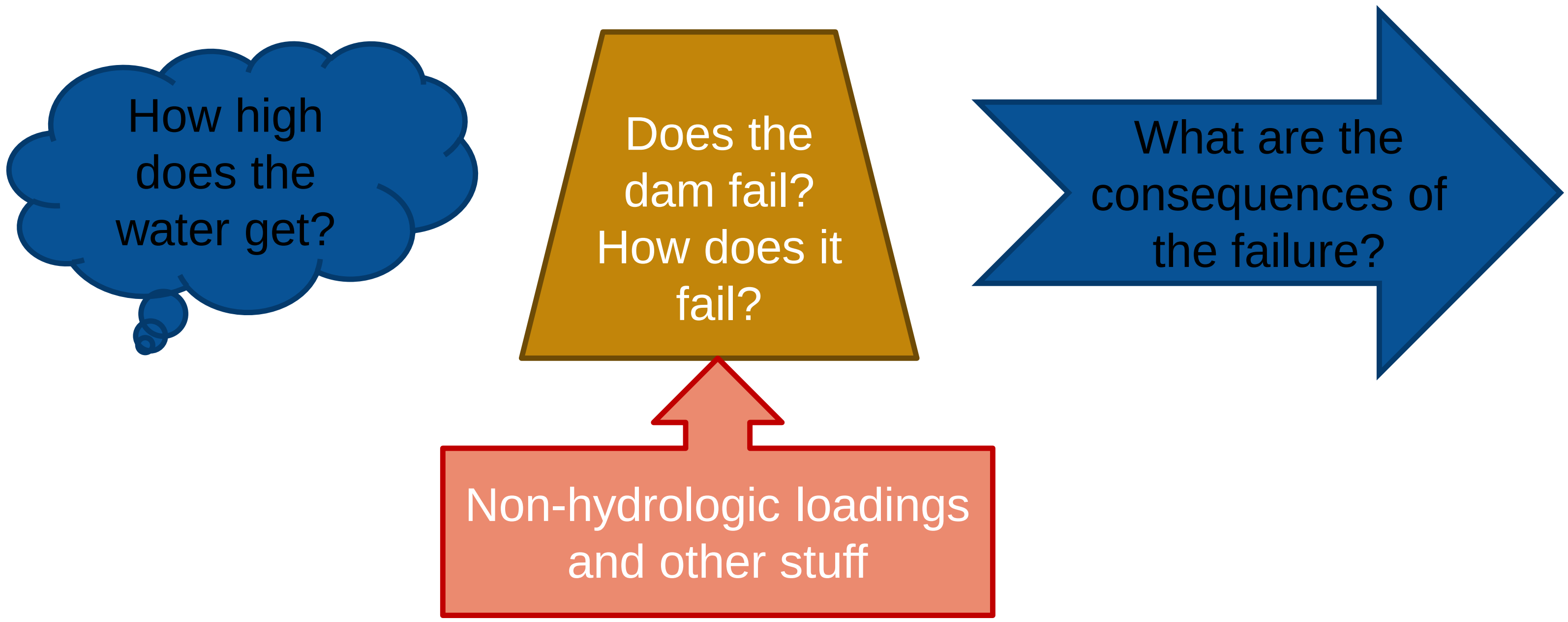
Hydrologic Hazards Analysis Overview

TVA Hazards Analysis

New Brunswick Power Hazards Analysis

Hydrologic Hazards Analysis Overview

- Hydrology plays a significant role in risk-informed decision-making because:
  - Headwater elevations are the primary loading mechanism for many potential dam failure modes

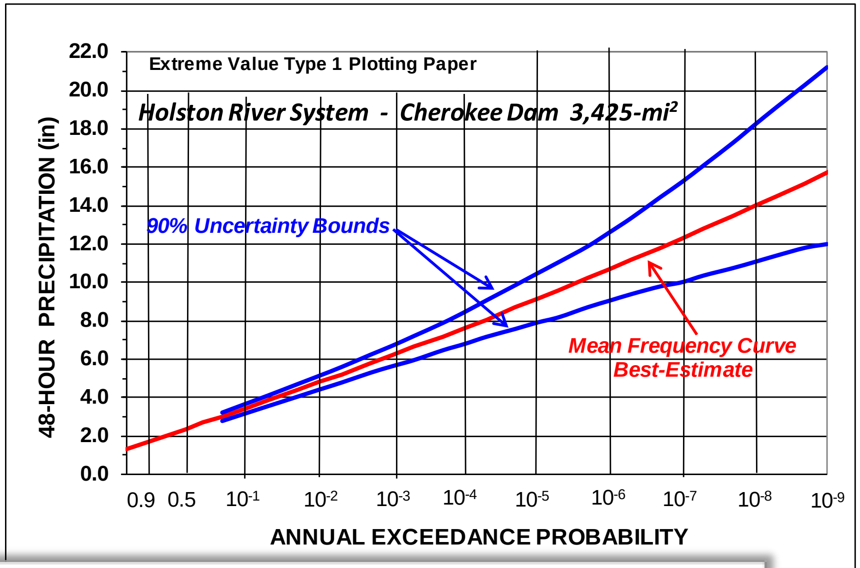


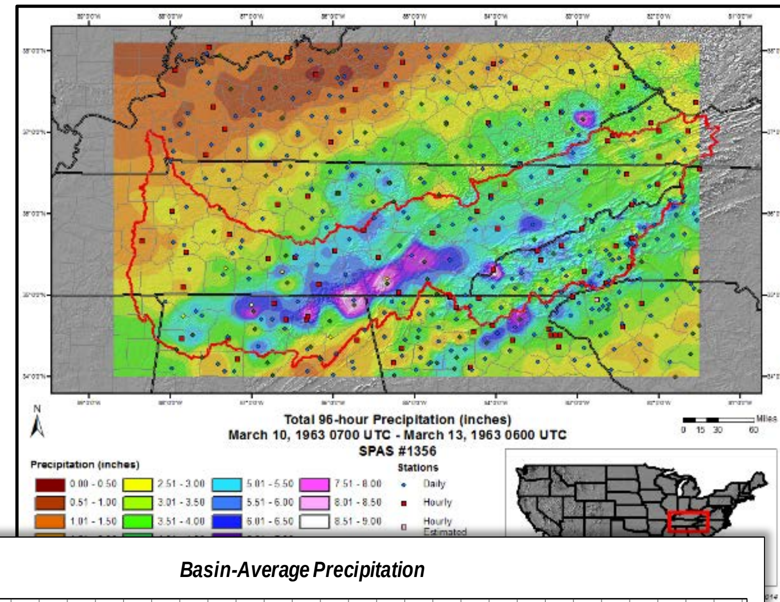
Hydrologic Hazards Analysis Overview

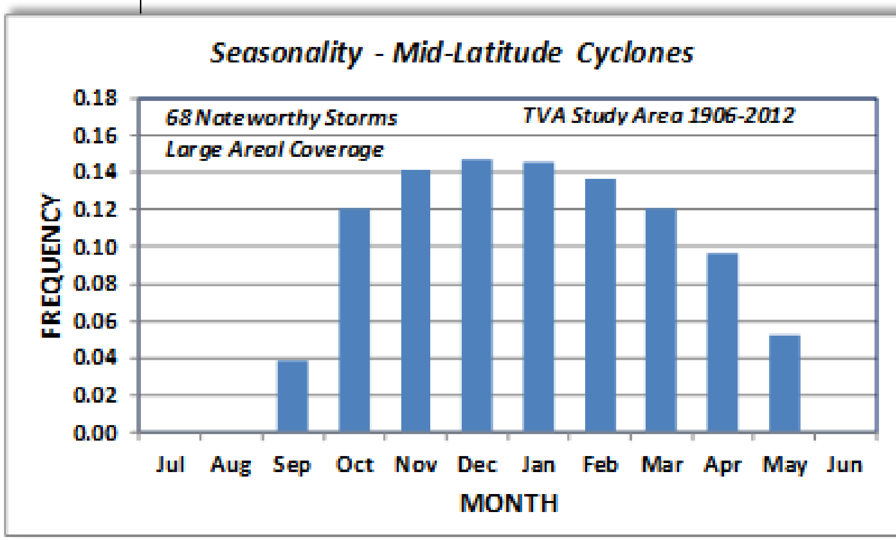
- Stochastic Flood Simulation
  - Natural hydrologic processes
  - Reservoir operation
  - Simulation process is easy to understand and validate – mimics reality
  - A natural platform to add dam safety risk analysis:
    - Failure modes, gate reliability, breach modeling and consequences
  - Inputs to Risk Informed Decision Making

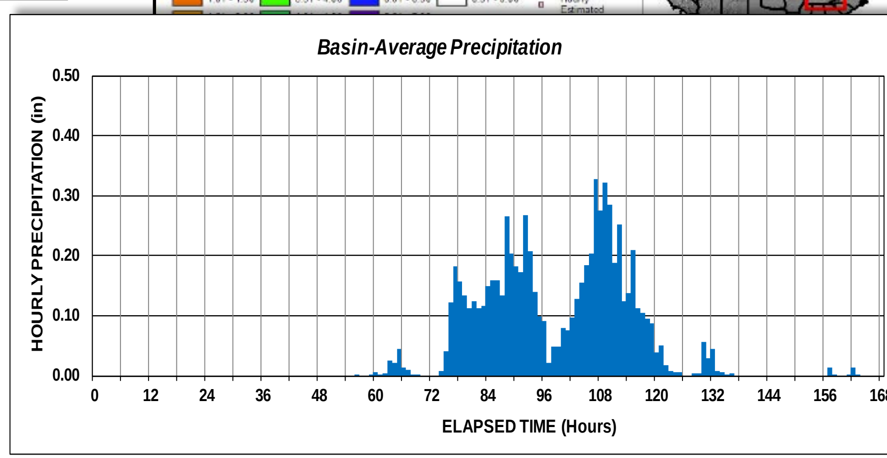
Hydrologic Hazards Analysis Overview: Precipitation

- Precipitation sampling per simulation



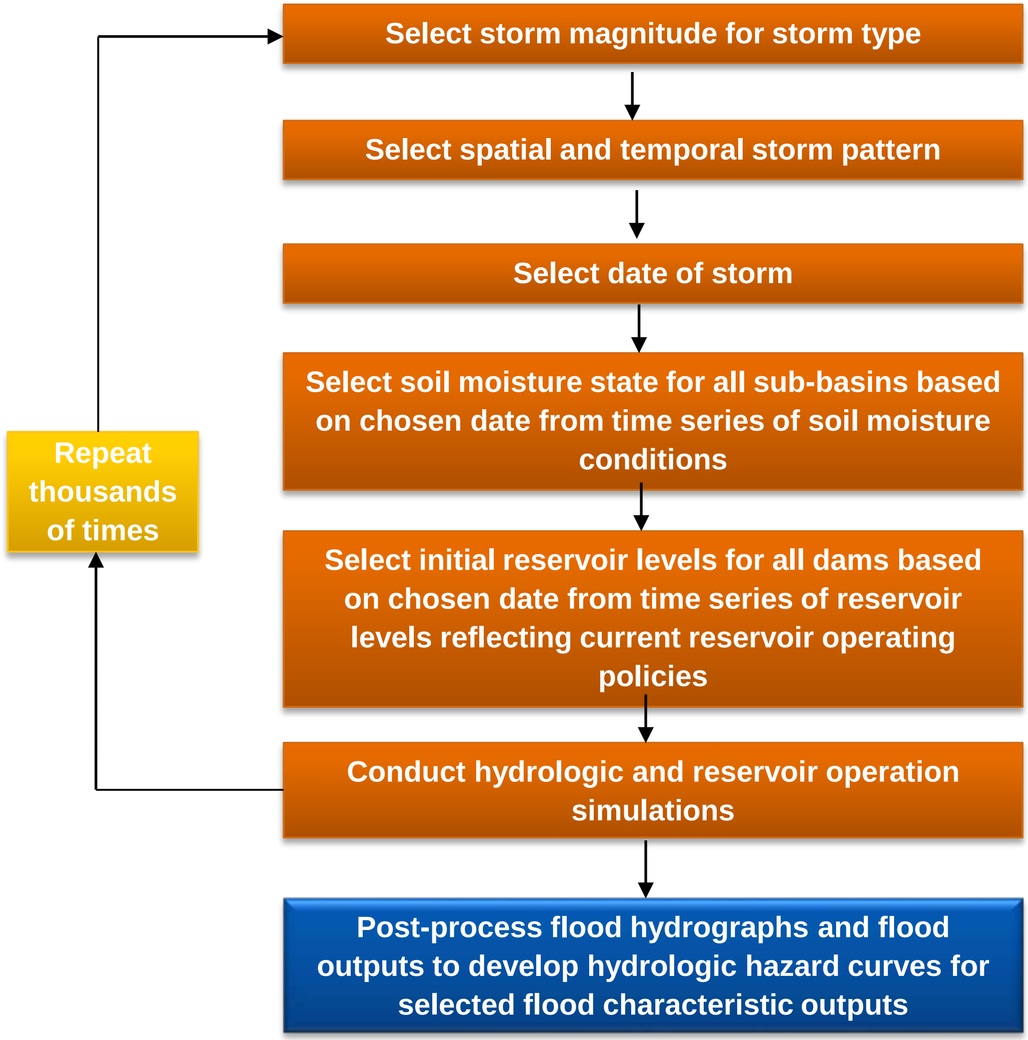






Hydrologic Hazards Analysis Overview: Process

- Simulate real storms, watershed response, and reservoir system response
- Repeat ten of thousand times, compute statistics from results
- Each simulation mimics response to real events



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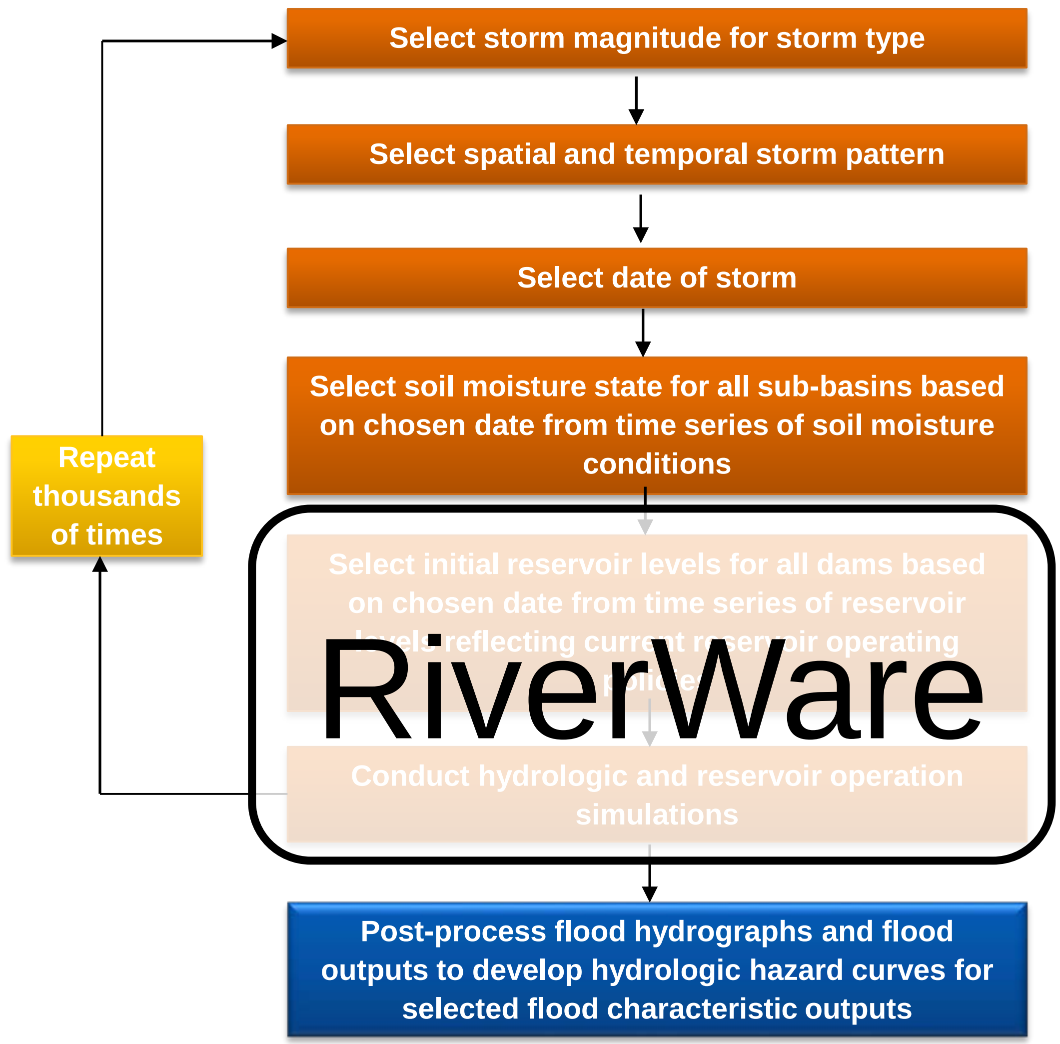
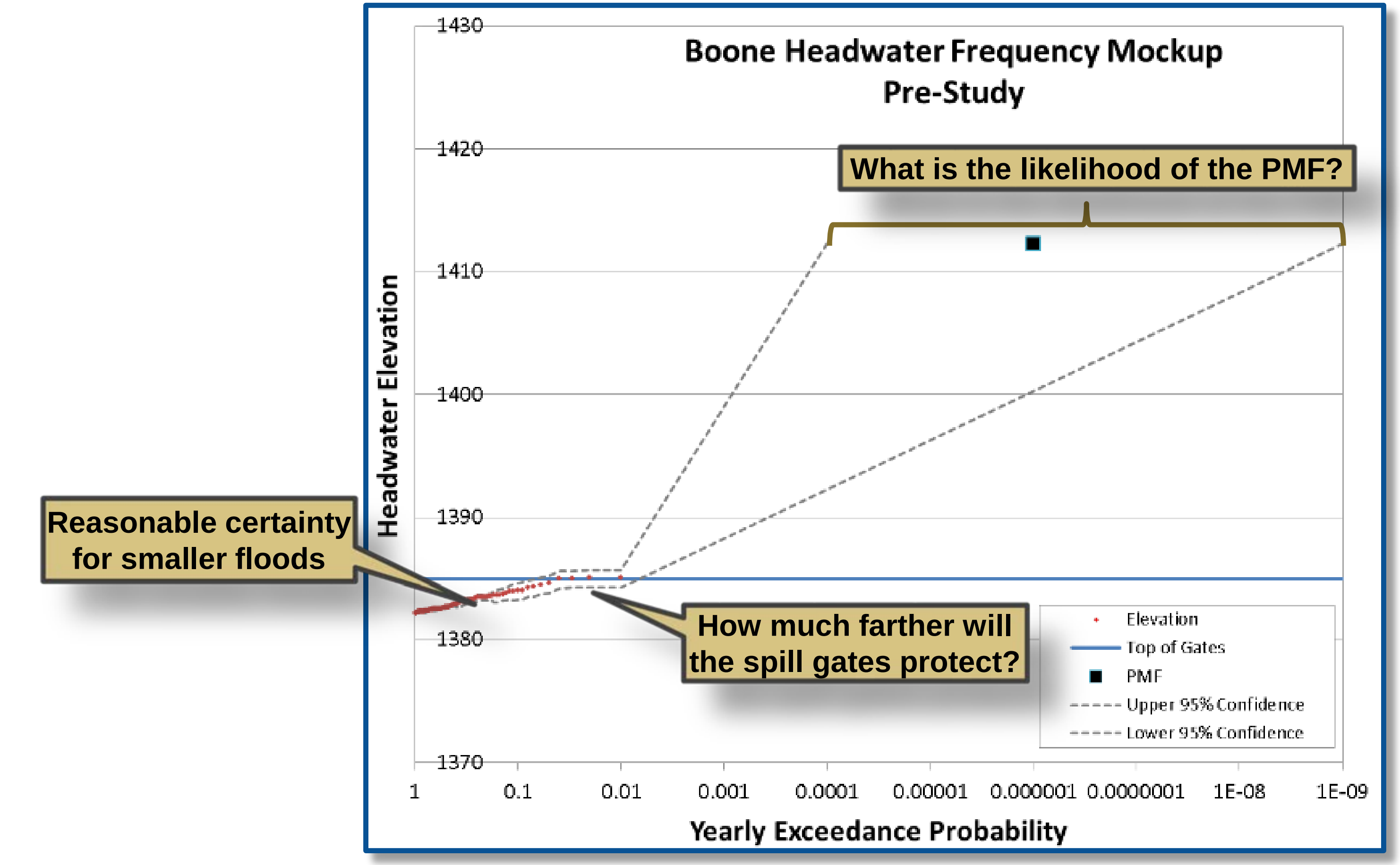


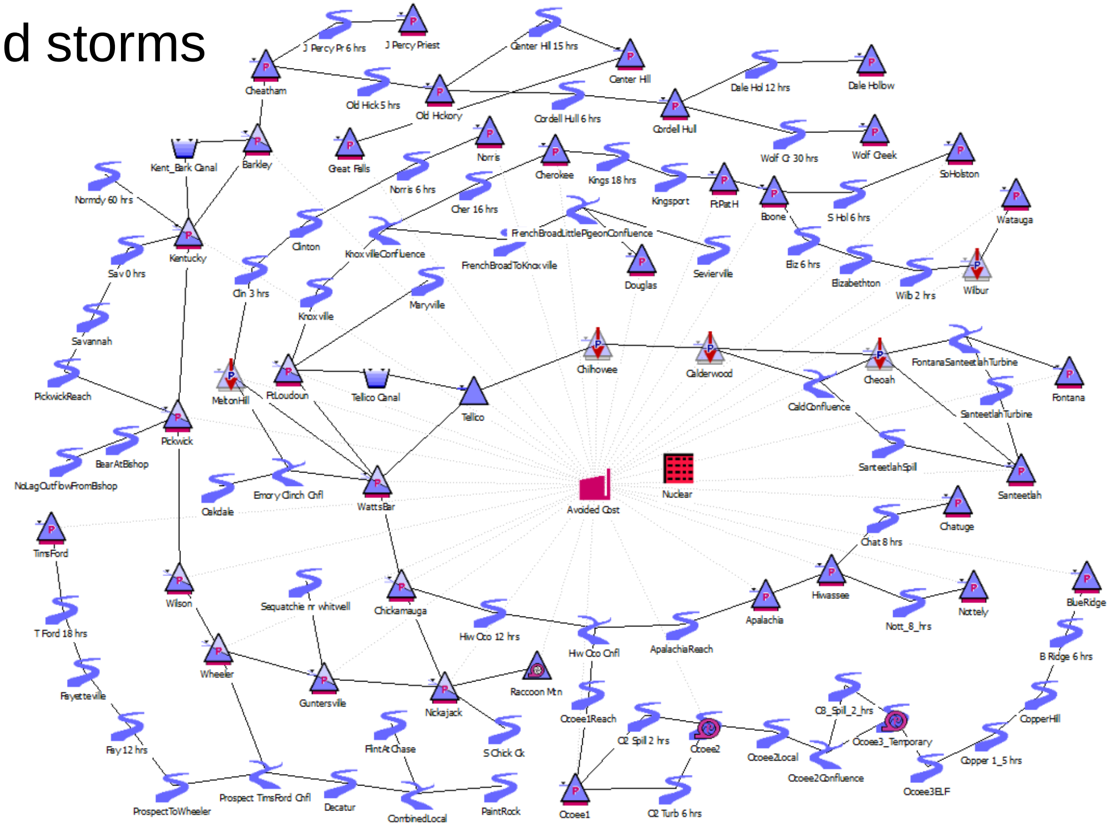
Hydrologic Hazards Analysis Overview: Goal

- Determine probabilities for events between historical record and PMF
- Prioritize risk reduction efforts effectively



TVA Hazards Analysis

- Perform this analysis for dozens of dams with varying storage capacities and operations
  - Main RiverWare model covers ~30 major reservoirs
  - Non-power and minor dams covered in separate models
- Long-term run (60-1000 years) for initial conditions
- Stochastic runs for imposed storms



TVA Hazards Analysis - Issues

Long Term Modeling

- Long-term run needs to provide good simulation of current operations
  - Even for flows/situations that have not been seen historically
- Can be difficult to verify that model is performing accurately
- Coordination between multiple modelers can be tricky

Stochastic Modeling

- Flows are much larger than historical
  - Reservoir parameters do not cover full range
  - Rules do not consider some high-flow situations
- Need to initialize model to match long-term results

Long Term Modeling

- Collaboration with reservoir operators/schedulers is crucial
  - Inspect operations for adherence to policy/typical ops
  - Iterative improvement

- Coordination among modelers is important, but technical solutions also help
  - Source Control (Git, etc.) can help keep track of changes and makes reverting to old versions simple
    - Can also help merge rulesets, if differences are not too big
  - Merging models not recommended
  - Model comparison tool would have solved many problems!

Stochastic Modeling

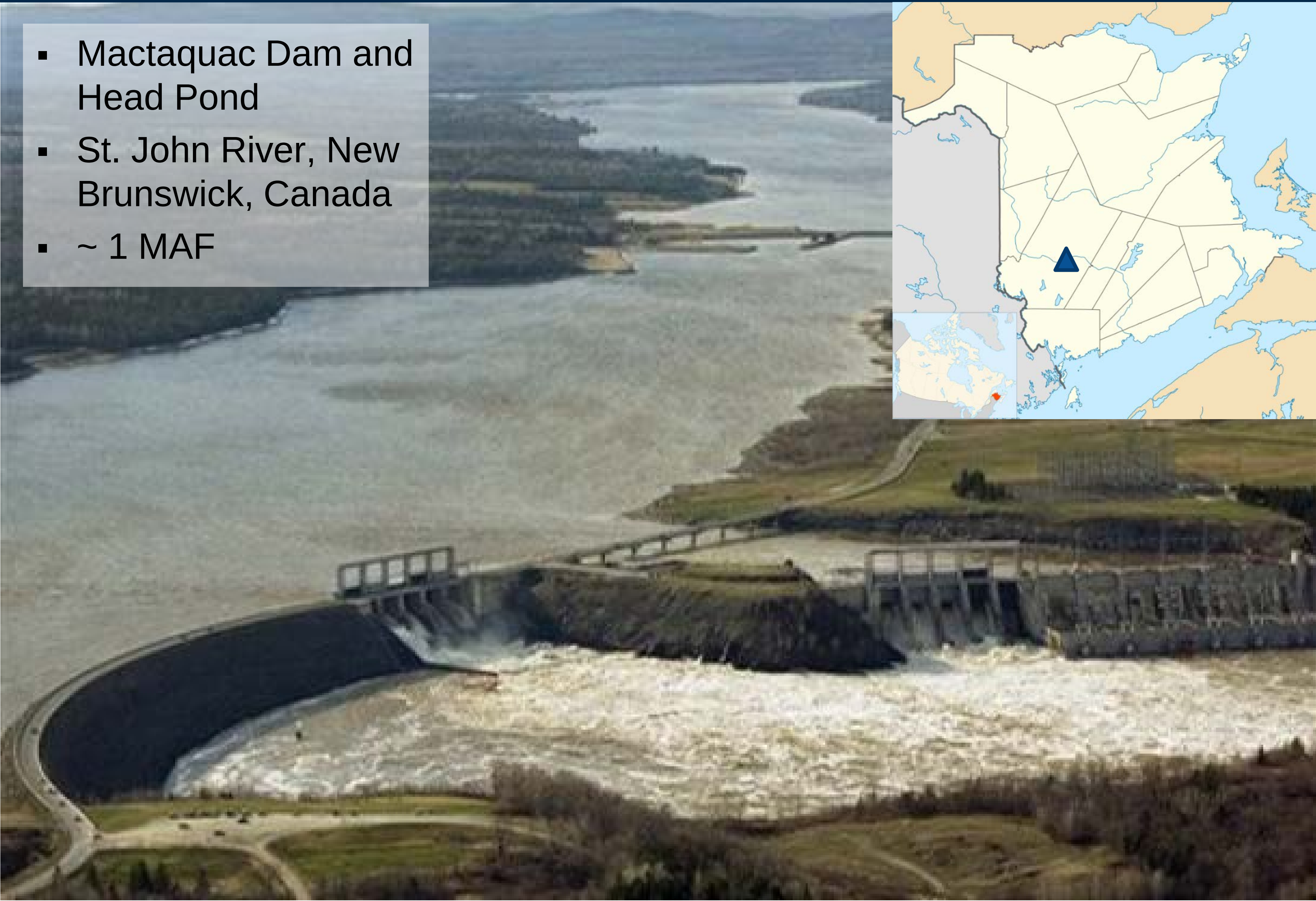
- Expand tables well beyond what you think you should
  - Internal iteration can require values outside the actual solution range
  - Make sure slope/curve shape is appropriate
  - 3-D tables can be unpleasant to expand

- Test rules with good variety of flow configurations
  - There will always be another run that breaks the model
  - Make sure results are reasonable – collaboration again key

- Tool to repeatably pull initial values from long-term model
  - Lookback period for each time series
  - Too little causes problems, too much probably doesn’t

New Brunswick Power Hazards Analysis

- Mactaquac Dam and Head Pond
- St. John River, New Brunswick, Canada
- ~ 1 MAF

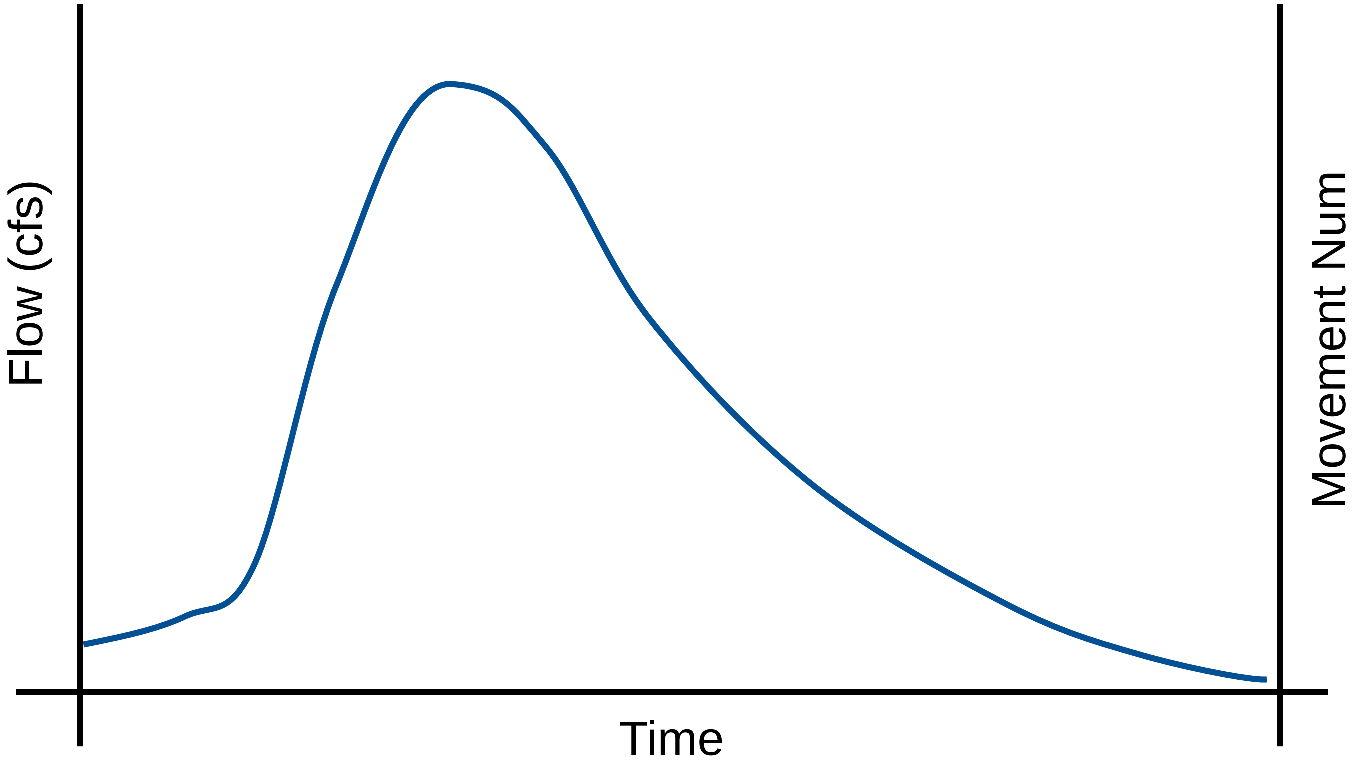


New Brunswick Power Hazards Analysis

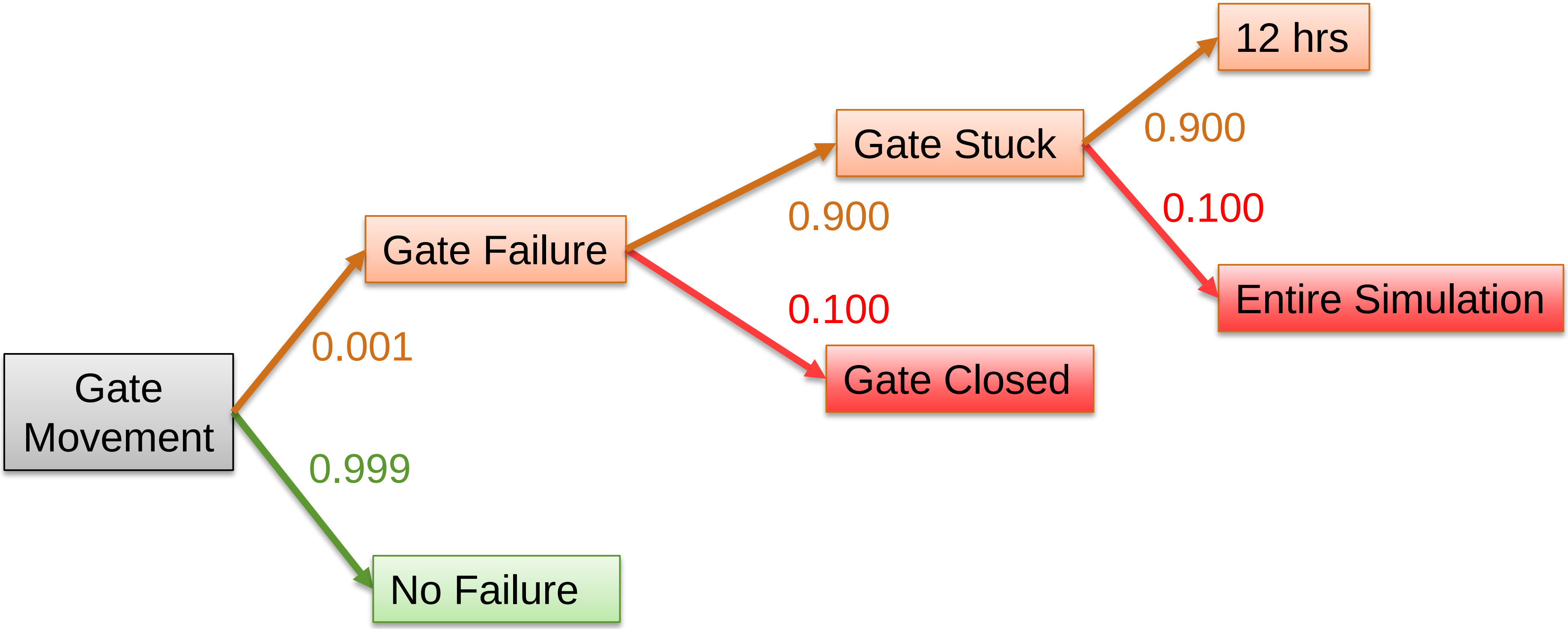
- Similar process to TVA, with much simpler RiverWare model
- Addition of gate malfunction and failure risks

New Brunswick Power Hazards Analysis: Gate Failure

- 10 gates, 10 movements each to fully open
  - 100 movements from no spill to full spill
- Failure Movement Number
  - May or may not matter

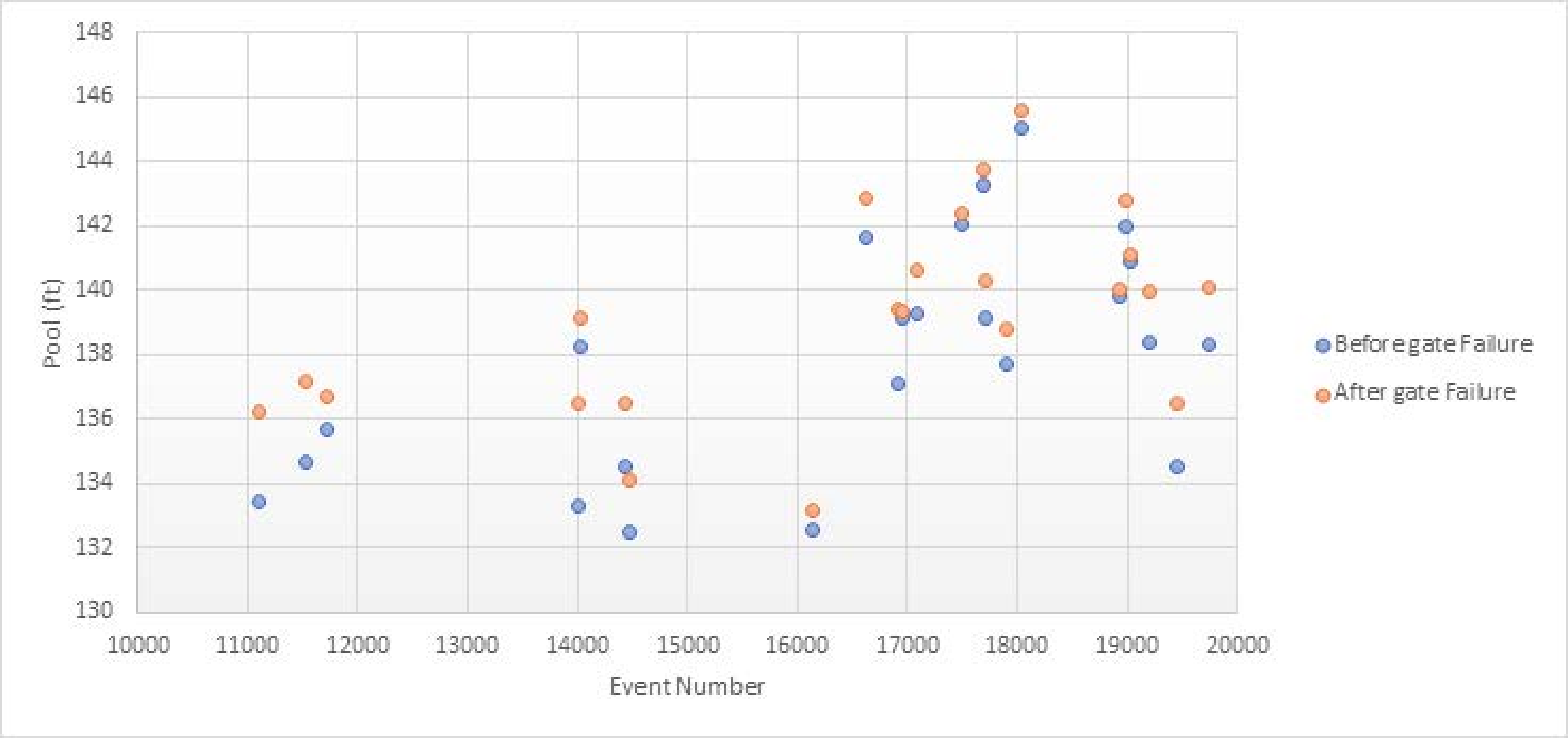


New Brunswick Power Hazards Analysis: Gate Failure



Failure Condition	Probability
Gate stuck for 12 hrs	0.081%
Gate stuck for entire simulation	0.009%
Gate closed	0.010%

New Brunswick Power Hazards Analysis: Results



New Brunswick Power Hazards Analysis: Lessons

- With a strong framework, addition of risk scenarios is simple
- Impact of gate failures on dam safety depends on # of gates, probability of failure, and available storage

Thank You

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Questions?