



# Resolution of Flood Model Issue

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April 4, 2016



# Agenda

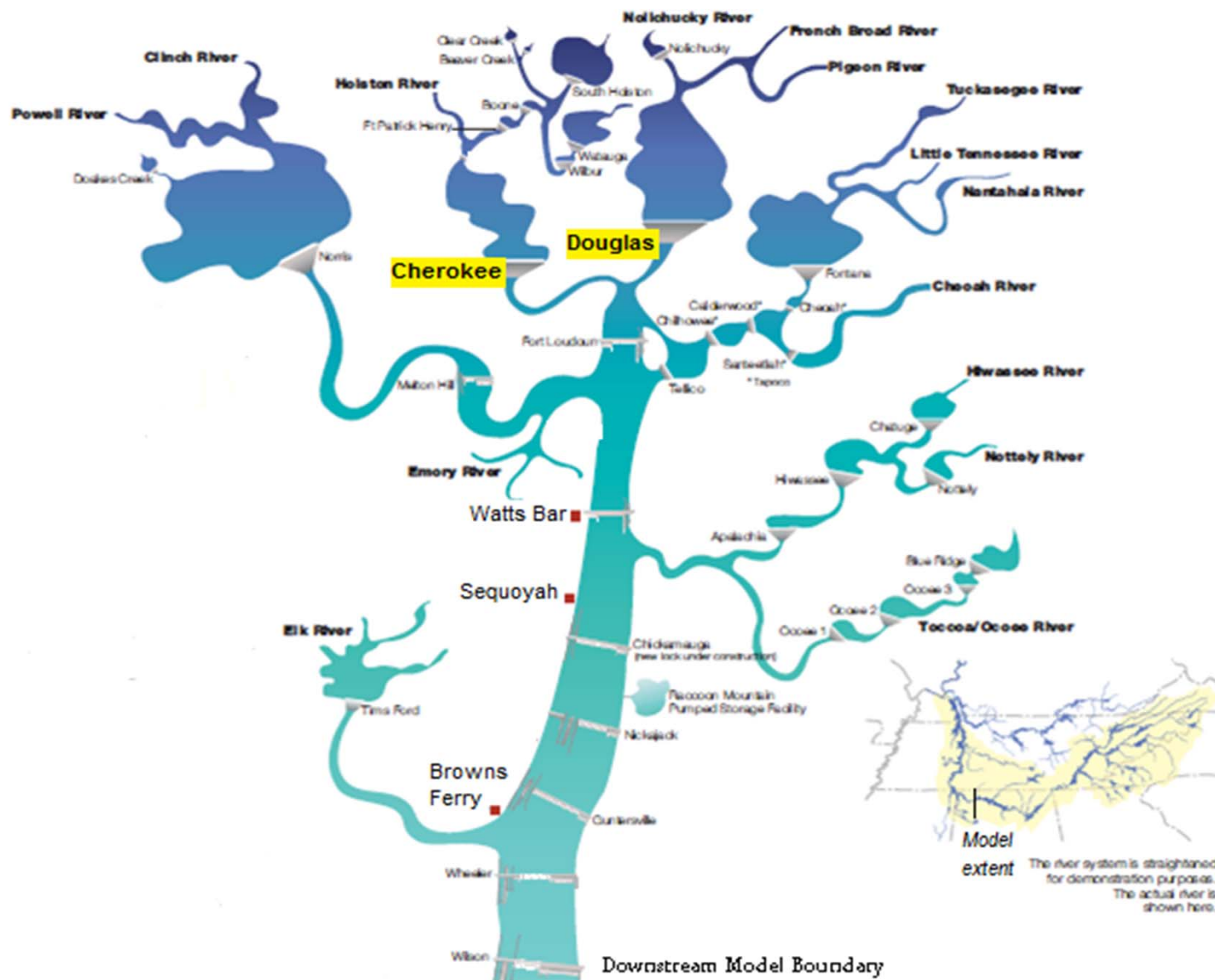
- Purpose
- Background
- Flood Model Issue
- Path Forward/Resolution
- Scope of Work
- Schedule

# Purpose

The purpose of this meeting is to discuss:

- Technical details of the recently discovered external flood model issue using the HEC-RAS code
- Impacts to TVA nuclear sites current licensing basis
- Impacts to NTTF Rec 2.1 Flood Hazard Reevaluation Reports
- Resolution of Issue

# Watershed Model



# Background

- Watts Bar/Sequoyah LAR submittal – July/August 2012
- Watts Bar LAR supplement submittal – September 30, 2014
  - HEC-RAS and updated dam stability criteria adopted for PMF
  - NRC issues Safety Evaluation Report – January 28, 2015

# Background

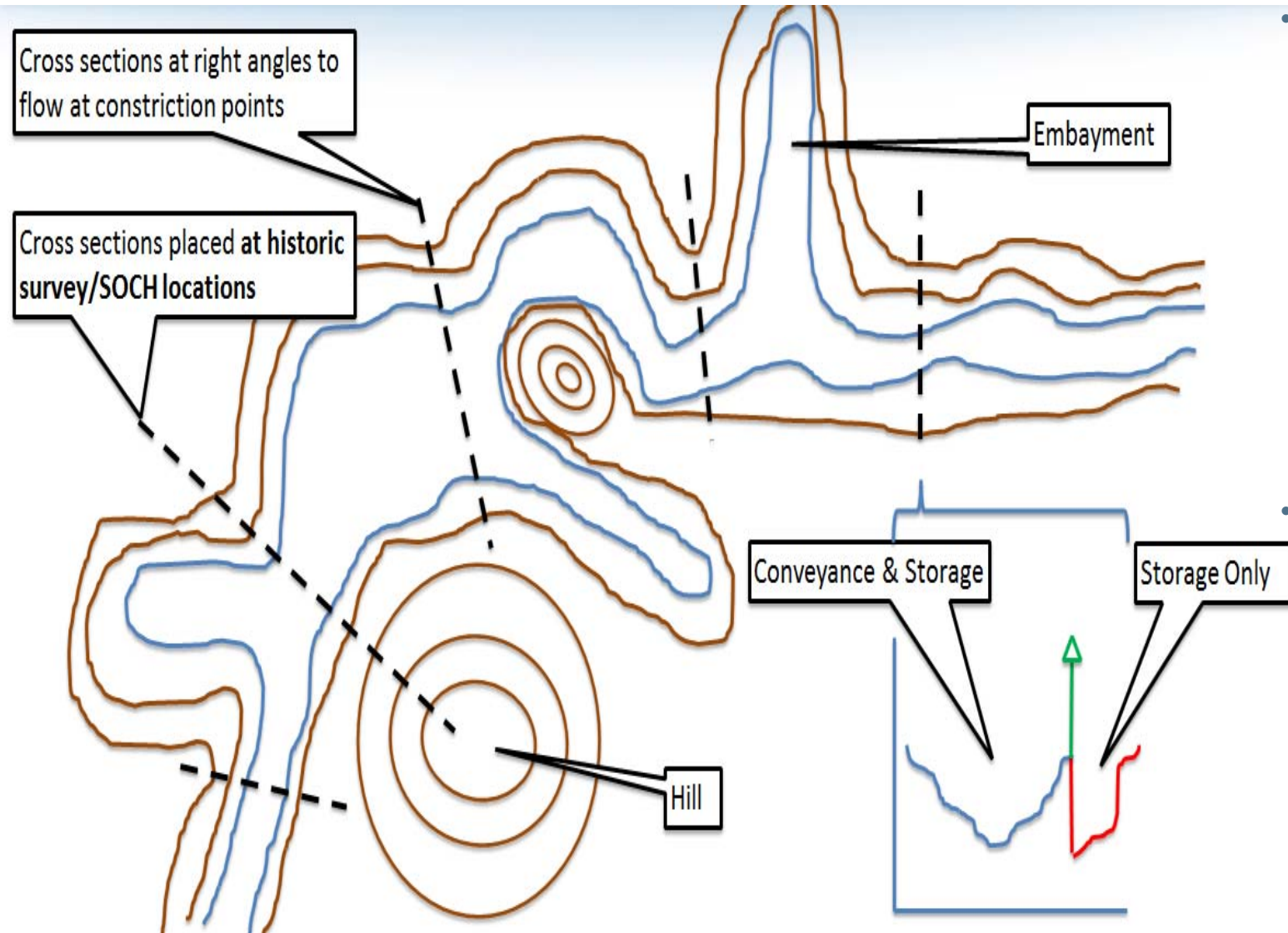
- NTTF Recommendation 2.1 Flood Hazard Reevaluation Reports (FHRRs) submitted for Browns Ferry, Sequoyah and Watts Bar – March 12, 2015
  - NRC issues Interim Staff Response to Reevaluated Flood Hazards for Browns Ferry, Sequoyah and Watts Bar – September 3, 2015
  - NRC issues Staff Assessment of Response to Reevaluated Flood Hazards for Watts Bar – December 1, 2015

# Background

- Model Issue Identified – November 6, 2015
  - Condition Report 1101784
- Model Issue Confirmed – December 16, 2015
  - Condition Reports 1116461 and 1116506



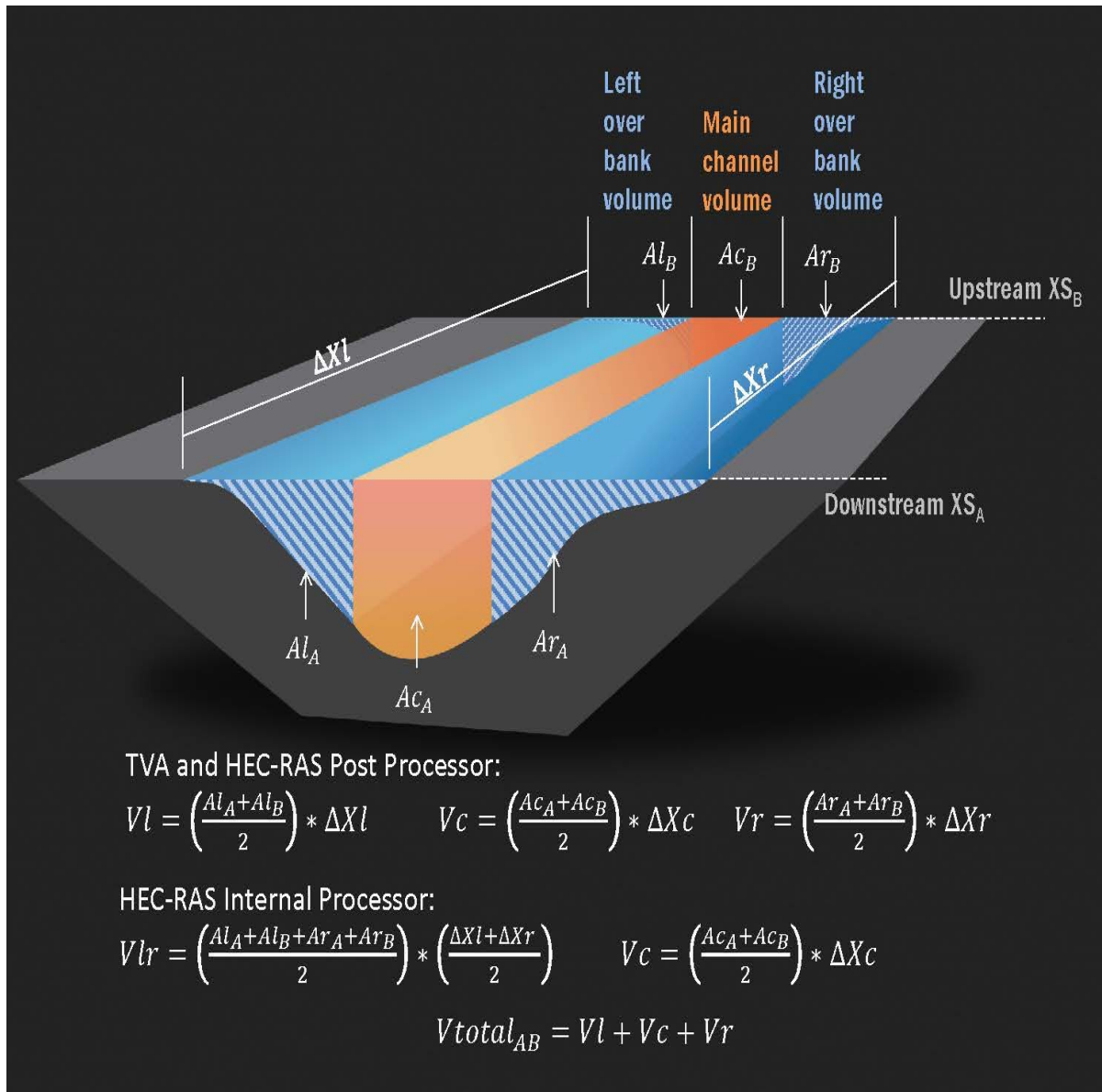
# TVA Current Hydraulic Model



- Traceability of inputs from the SOCH model influenced the decision to maintain historical cross section locations in TVA's current hydraulic model.
- TVA manually augmented ineffective flow areas to account for reach storage between cross sections to match published reservoir storage curves.



# Volume Computation Differences



- TVA Augmented Ineffective Flow Areas & HEC-RAS Post Processor calculates volume for left and right overbanks *separately*.
- HEC-RAS internal computations calculates volume using a simple arithmetic average of the right and left reach lengths.
- Volume differences are compounded as left and right overbank length variance is increased.

# Flood Model Issue

- Difference in volume computations between
  - HEC-RAS internal processor
    - > computes a simple arithmetic average of left and right overbank lengths
  - HEC-RAS post processor
    - > treats each overbank (and overbank length) separately providing a prismatic representation of the volume of each overbank
- Differences exacerbated by TVA approach in accounting for actual reservoir storage by augmenting ineffective flow areas at Cherokee and Douglas where there are significant differences in right and left bank lengths

*Result: TVA's HEC-RAS model overestimates the amount of reservoir storage volume available at Cherokee and Douglas*

# HEC-RAS Bug Report

- After discovering differences in volume checks, TVA submitted a HEC-RAS code Bug Report to USACE Hydrologic Engineering Center
- USACE confirmed HEC-RAS internal and post processors calculate volume differently. However, in typical applications of the HEC-RAS software, this is not expected to significantly change the results
- USACE concludes the issue is “not a bug, but a misunderstanding of the HEC-RAS internal computations”
- USACE expert agreed to revise the user’s manual to provide clarification on the volume equation and is considering a HEC-RAS code revision sometime in the future that would add an alternative solver algorithm which aligns the internal to the post processor
- USACE expert recognized adjustment of augmented ineffective flow areas as a viable approach



# Cherokee Example – Worst Case



Due to TVA's placement of augmented ineffective flow areas on one side of the channel, the HEC-RAS internal averaging of storage volumes in the overbank areas and the biased sinuosity in these reservoirs, TVA's hydraulic model issue has the most pronounced impacts at Cherokee and Douglas.

# Reservoir Extent of Condition Review

Table 1		
Reservoir	*Evaluated Elevation (Feet)	Difference Between Post-Processor and Internal Volumes
Apalachia	1283	0.2%
Boone	1406	0.2%
Calderwood	1100	-0.7%
Cheoah	1282	0.0%
Cherokee	1095	19.5%
Chickamauga	740	-0.3%
Chilhowee	883	-0.2%
Douglas	1023	7.2%
Fontana	1735	-0.4%
Fort Patrick Henry	1310	-0.4%
Fort Loudoun	834	-1.6%
Guntersville	620	0.3%
Hiwassee	1535	0.0%
Melton Hill	812	-0.2%
Nickajack	667	1.0%
Norris	1056	0.1%
Tellico	830	1.0%
Watts Bar	770	0.6%
Wheeler	568	0.9%

\*Approximate PMF elevation

Extent of condition review performed for all reservoirs by comparing internal computed to published reservoir storage curves.

All produced less than 2% difference, except Cherokee and Douglas.

# Impacts

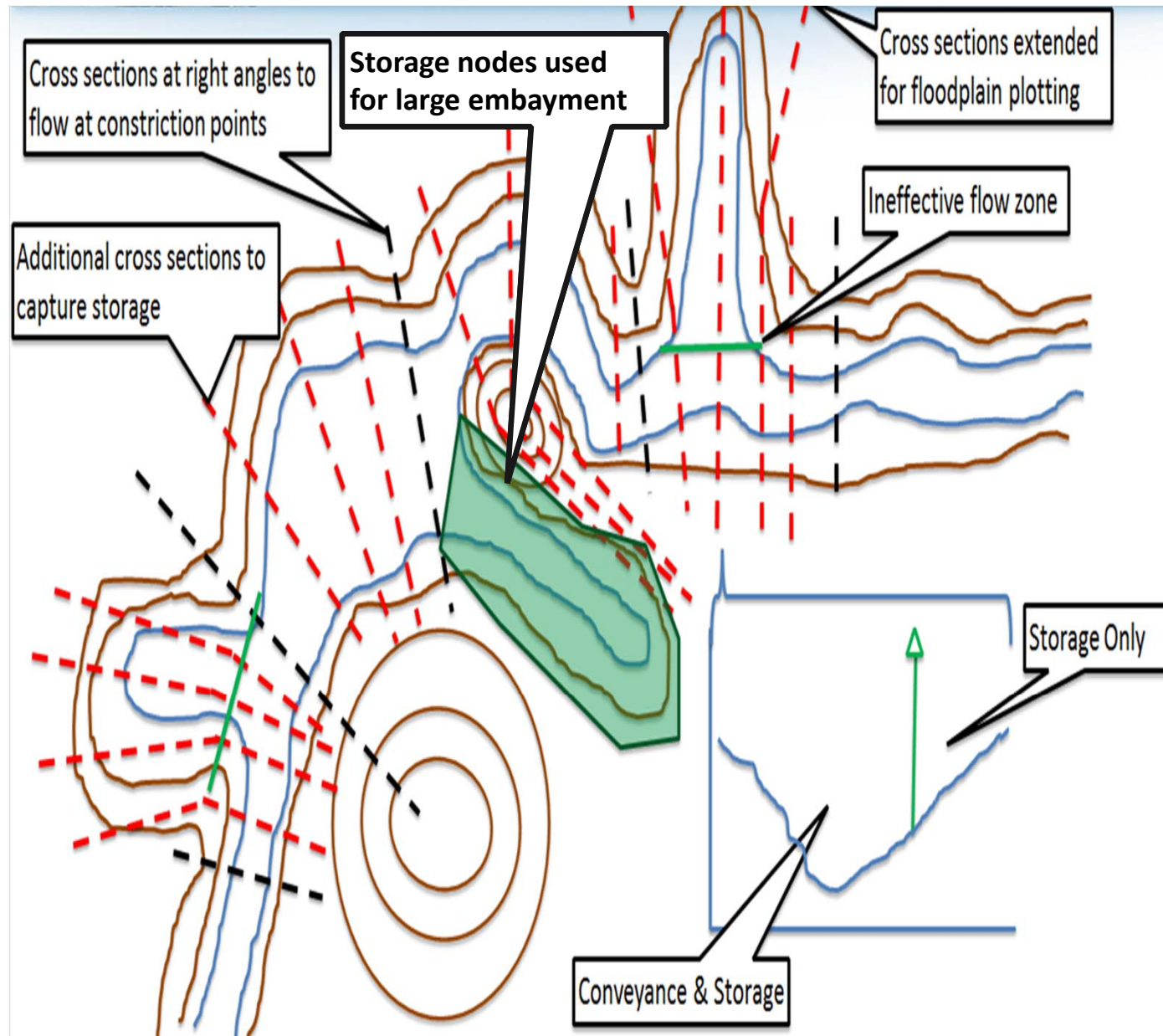
- Watts Bar Current Licensing Basis
- No Impact to Sequoyah and Browns Ferry Current Licensing Basis (SOCH code based)
- Sequoyah HEC-RAS code based LAR Supplement
- Watts Bar, Sequoyah and Browns Ferry FHRRs



# Technical Approach for Resolution

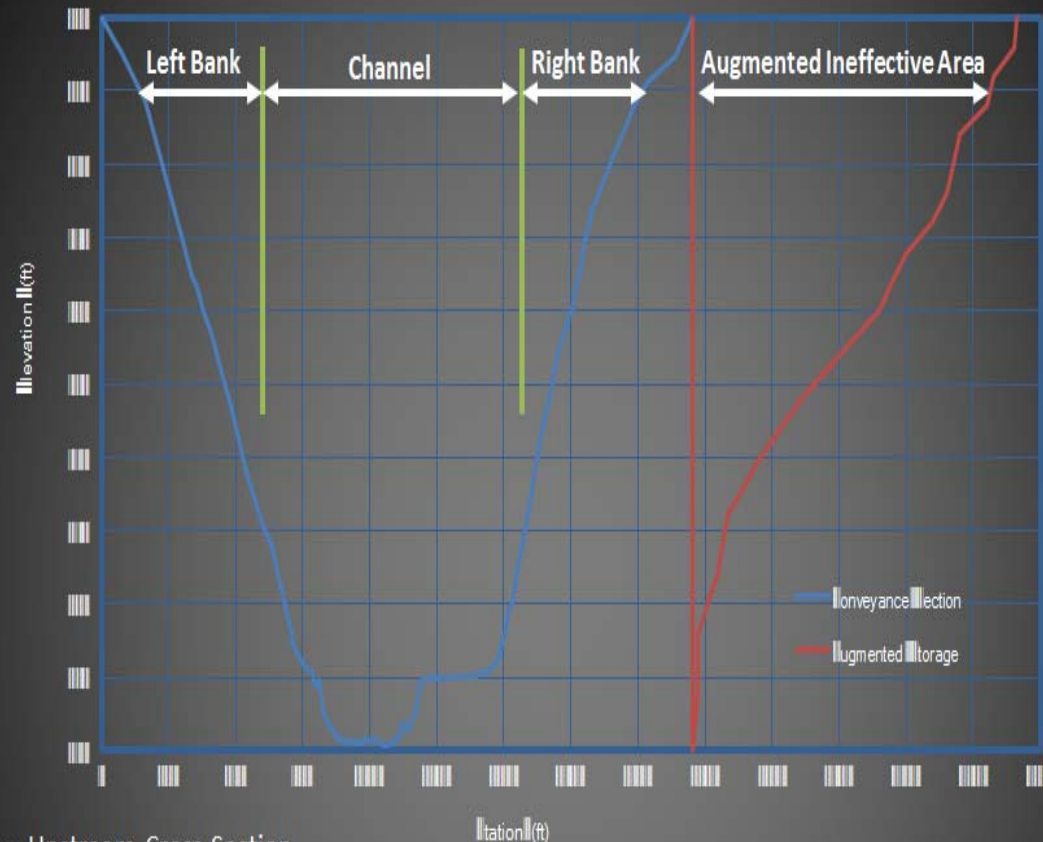
- Updated Precipitation Data
  - Similar methods as HMR with an update to data set and orographic effects along with use of current technology
- Revise Hydraulic Model
  - For the most impacted reservoirs (Cherokee and Douglas) use a more standardized modeling approach, i.e. additional cross sections with storage nodes for large embayments
  - For the remaining reservoirs, adjust the augmented ineffective flow areas using the volume averaging equations consistent with HEC-RAS internal processor

# Hydraulic Model Revision – Cherokee/Douglas



- Add additional cross sections between existing cross-sections and use storage nodes for large embayments
- Provides a more standardized modeling approach utilizing current industry practices
- More realistically represents geography of storage volume in the reservoir

# Hydraulic Model Revision – Other Areas



$XS_A$  = Upstream Cross Section

$XS_B$  = Downstream Cross Section

HEC-RAS Internal Volume:

$$V_{lr} = \left( \frac{A_{lA} + A_{lB} + A_{rA} + A_{rB}}{2} \right) * \left( \frac{\Delta X_l + \Delta X_r}{2} \right) \text{ and } V_c = \left( \frac{A_{cA} + A_{cB}}{2} \right) * \Delta X_c$$

$$V_{total_{AB}} = V_{lr} + V_c$$

$$V_{augmented} = V_{GIS} - V_{total_{AB}}$$

Iteratively Solve For  $A_{augmented}$  such that  $V_{total_{AB}} = V_{GIS}$

- Adjust the augmented ineffective flow areas using the volume averaging equations from HEC-RAS internal processor
- Apply to entire model with the exception of Cherokee and Douglas reservoirs



# Issue Resolution

TVA has confidence in the model issue resolution

- Alternate method produces comparable results
- Calibration shows stage and discharge match well to historic storms
- USACE expert recognized adjustment of augmented ineffective flow areas as a viable approach
- Additional external reviews will be utilized

# Issue Resolution

- Precipitation update
  - Preliminary studies show margin between current HMR 41 and updated data
- TVA has high confidence that:
  - Model issue is corrected with planned resolution
  - Final PMF simulations with use of the updated precipitation and update to the hydraulic model will produce elevations less than those shown in current FHRRs

# Scope of Work

- Mitigating Strategies Assessment
  - TVA plans to use March 12, 2015 FHRR flood model and results to evaluate mitigation strategies
    - > Elevation and flow results are bounding with use of the conservative precipitation data in HMR 41
    - > NRC interim staff review has been completed for Watts Bar, Sequoyah and Browns Ferry with no open issues
  - MSAs will be completed by December 2016



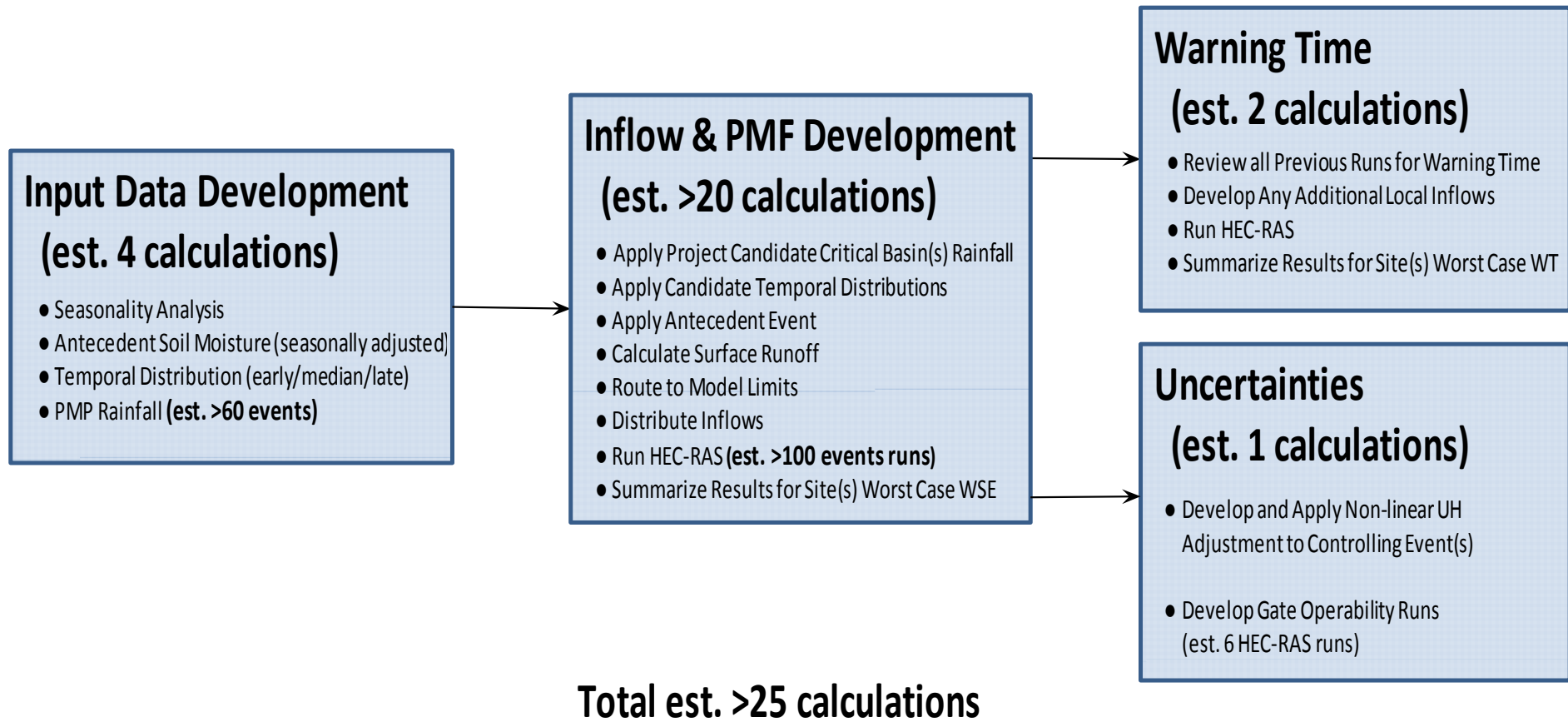
# Scope of Work

- New report/calculations
  - Precipitation data to replace HMR-41
  - PMP development to determine most critical inflows
- Calculation revisions
  - Main Stem and Tributary Geometry
    - > Cherokee and Douglas hydraulic model geometry revised for additional cross-sections with storage nodes
    - > Adjust augmented ineffective flow areas for the balance of the model using HEC-RAS internal processor equations
  - Main Stem and Tributary Calibrations

# Scope of Work, continued

- Calculation revisions, continued
  - Model Setup
  - Probable Maximum Flood Simulations
    - > Significant increase in number of events to review to determine controlling simulation
  - Warning Time
  - Controlling FHRR Seismic Combination Simulation
  - Uncertainties

# Scope of Work, continued





# Scope of Work, continued

- Deliverables:
  - License Amendment Request
    - > Sequoyah
    - > Watts Bar
  - FHRR report revisions
  - Flooding Integrated Assessment

# Additional Licensing Basis Scope

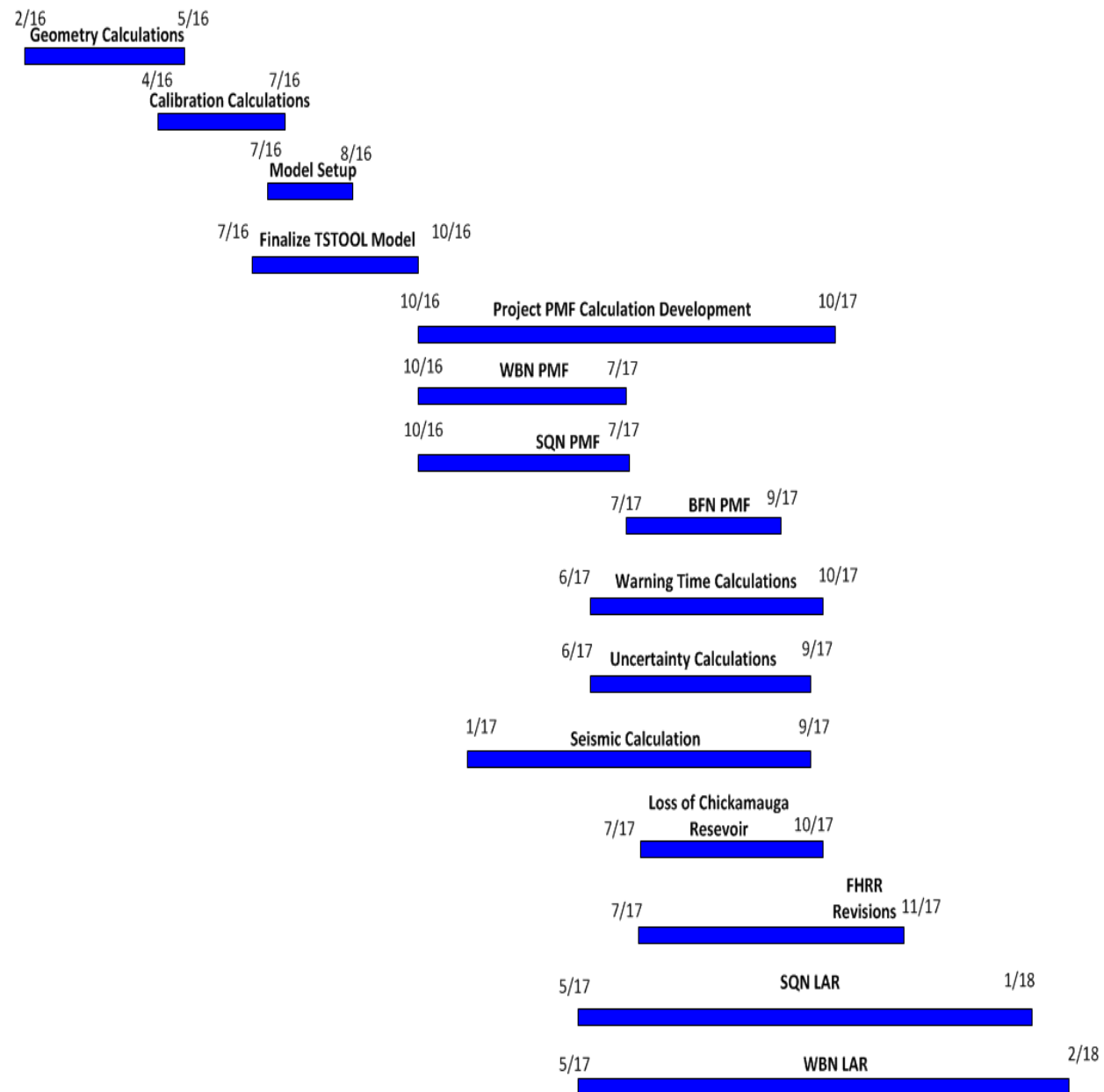
- Update FSAR Section 2.4.4 Potential Dam Failures (Seismically Induced)
  - Simulations in HEC-RAS vs. SOCH
  - Use JLD-ISG-2013-01 guidance
    - > Update seismic dam stability evaluations to current methods
    - > Use dam specific probabilistic earthquake vs. nuclear site deterministic earthquake
      - »  $10^{-4}$  annual exceedance seismic hazard in place of SSE
      - » Half the  $10^{-4}$  ground motion in place of OBE
    - > Use deaggregation to evaluate the potential for multiple dam failures

# Additional Licensing Basis Scope

- Update FSAR Section 2.4.11 Low Water Considerations
  - Simulations in HEC-RAS vs. SOCH
- With this additional change to the licensing basis, legacy SOCH code use will be eliminated for Sequoyah and Watts Bar.



# Draft Schedule



# Questions

