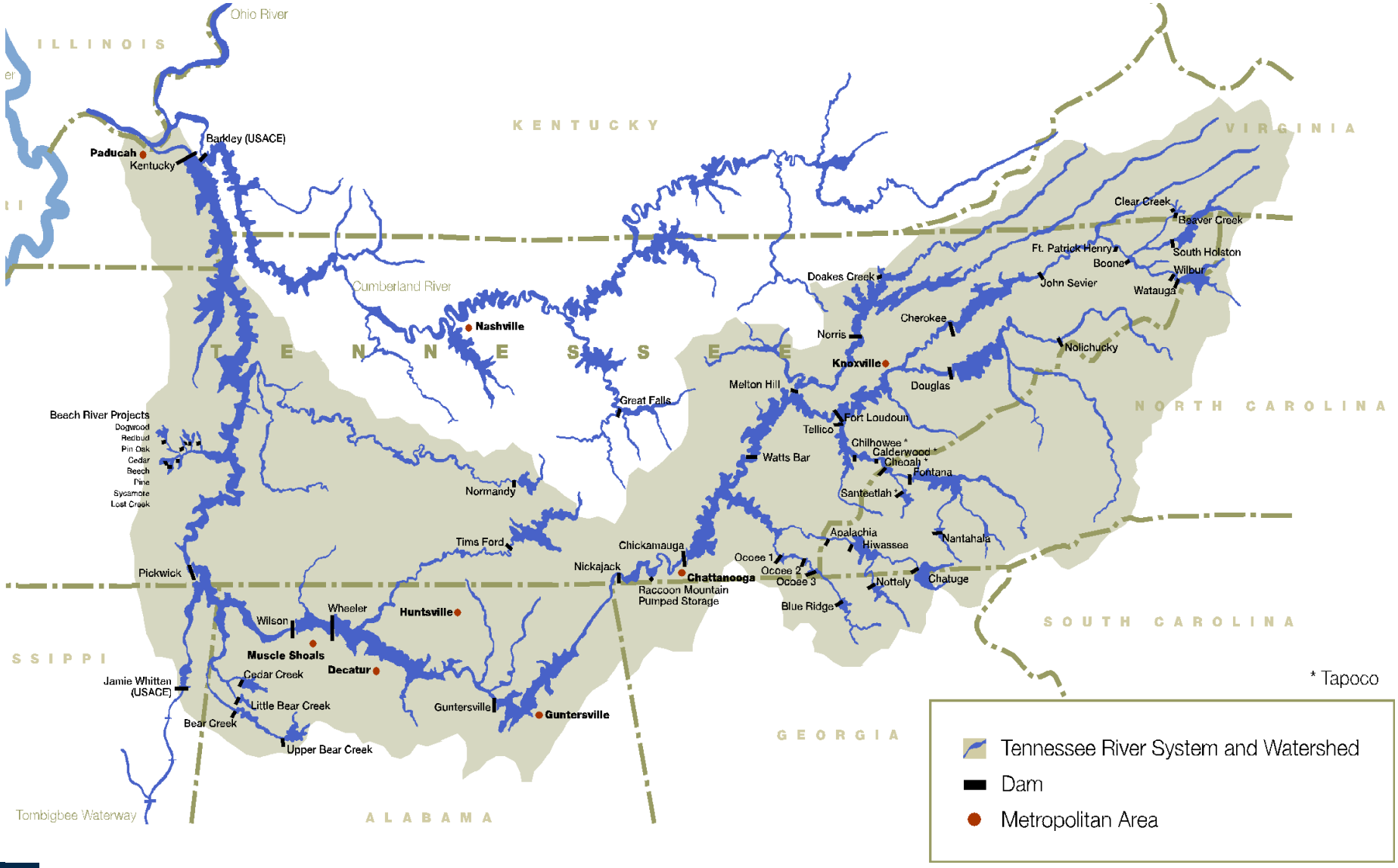
Overview of the TVA PFHA Calculation System

Shaun Carney (RTI International)
Curt Jawdy (TVA)

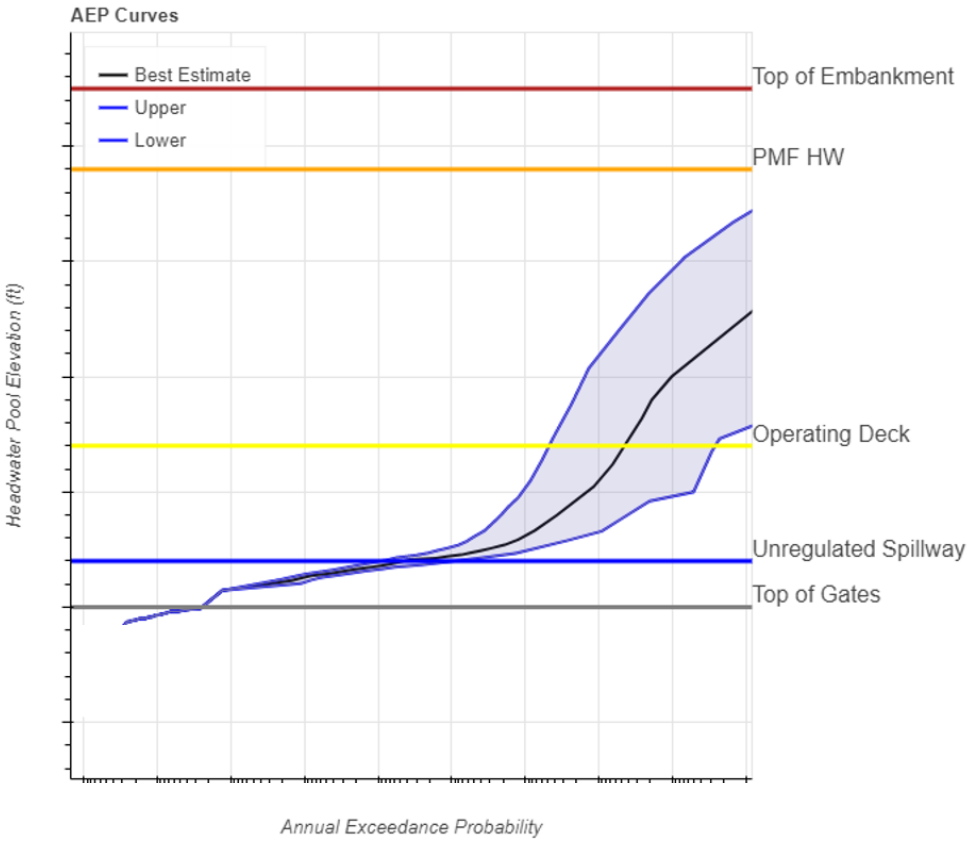
TVA Dams

- 49 dams, of which over 30 are operated as a large system



Probabilistic Flood Hazards Analysis at TVA

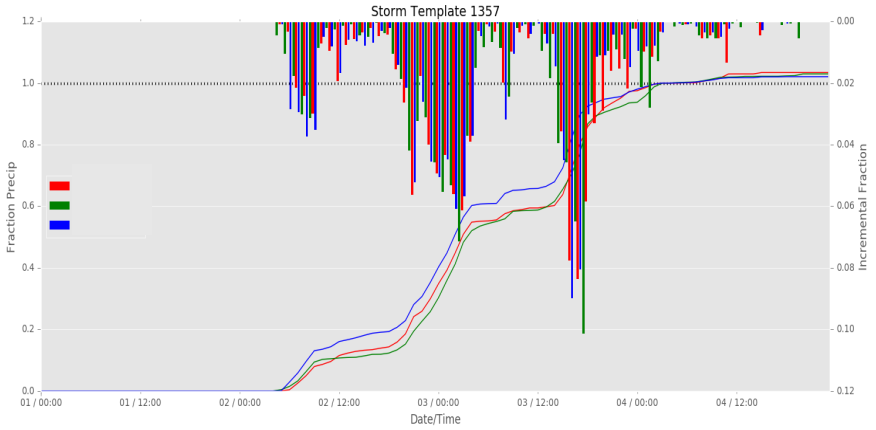
- Began development in 2014
- Application of the Stochastic Event Flood Model (SEFM)
- Applied for 20 unique dams to date
- Supports Risk-Informed Decision Making (RIDM) for dam safety decisions

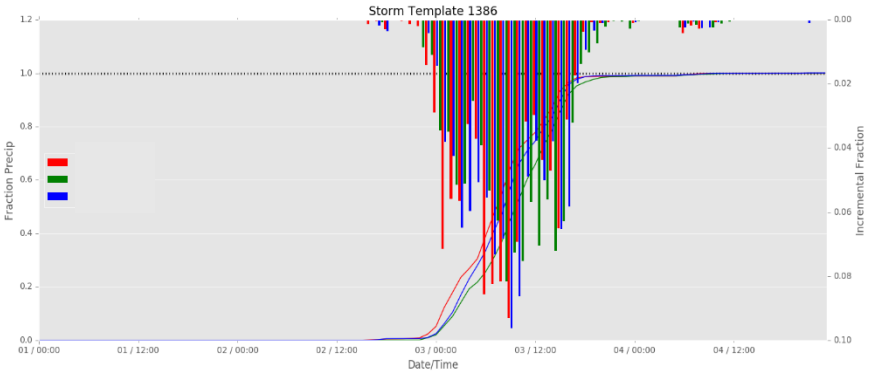


Note axes are intentionally not labeled throughout the presentation to prevent sharing TVA sensitive information

Stochastic Simulations

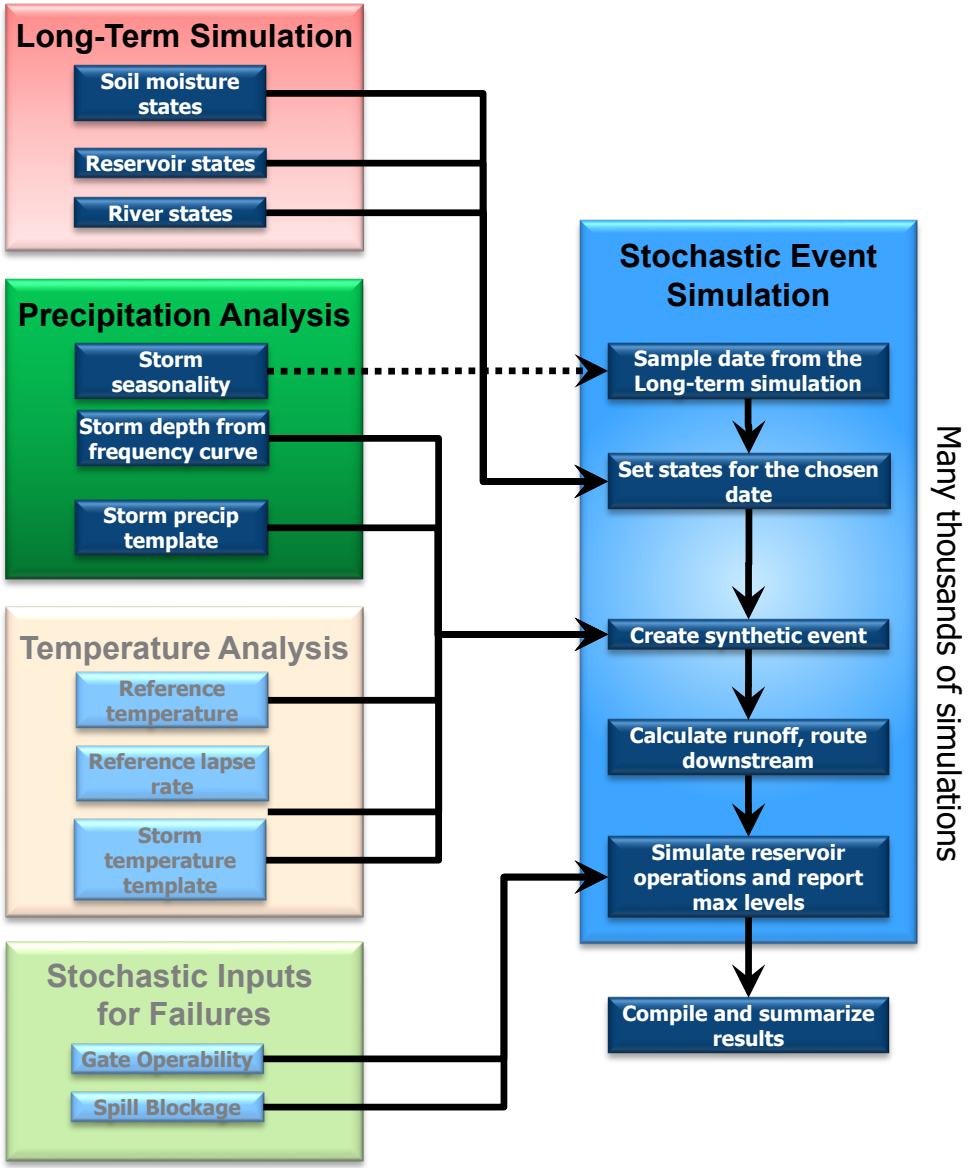
- Generate thousands of realistic storms and starting conditions
- Simulate hydrologic and reservoir operational response to storms
- Aggregate statistics from each storm to make hazard curves





Stochastic Flood Simulation Summary

- Create realistic extreme storms
- Simulate watershed and reservoir system response
- Repeat thousands of times
- Compute statistics from results
- Basins with snow require temperature inputs for snow models
- Next fiscal year will incorporate gate failures for TVA



MGS Engineering Stochastic Event Flood Model Varieties

SEFM Commercial

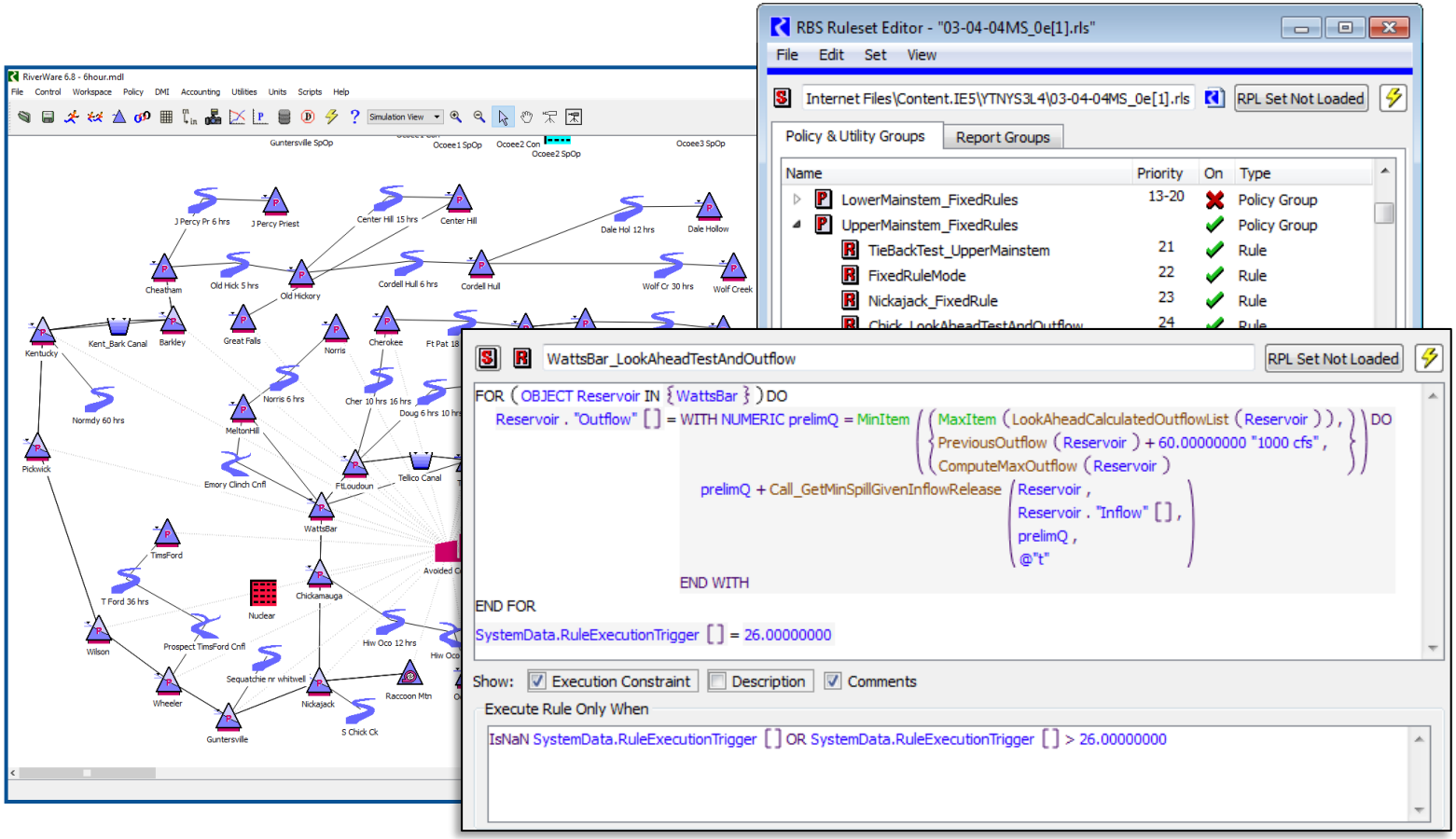
- All-in-one software package
- Multiple hydrologic models
  - UBC model
  - SAC-SMA/modified SAC-SMA
- Custom reservoir model with basic operations

SEFM Sampling Modules

- Standalone process executables
- Intended to embed in more complex applications
- Modules
  - Statistical pre-processor
  - Stochastic input time series generation
  - Statistical post-processor

RiverWare Model

- Rule-based model represents operating policy during extreme events
- Allows complex operating rules
- Includes approximated inflow forecasts
- Capability to modify gate availability, outlet capacity
  - Use a scalar input to control



TVA PFHA System

- Storm Transposition Tool
  - Produce representative storm templates
- Execution framework
  - Long-term, stochastic simulations
- Data management
  - 49 dams, 3 storm types, uncertainty
  - Summary statistics, time series
  - Configuration, inputs
- Analysis Tools
  - Hazards curve comparison
  - Assessment of influences on results
  - Drill-down capabilities

Unique Aspects of the TVA PFHA Calculations

- Precipitation-frequency assessed uniquely per storm type
  - Assess, combine hydrologic hazards from each type
- Statistical methods applied to produce 1000-year synthetic precipitation
  - Preserve spatial/temporal characteristics of events
  - More diverse combinations of events/reservoir conditions for stochastic events
- Intelligent sampling
  - Stratified sampling of precipitation
  - Convergence-based sampling with Neyman's optimal allocation to improve sampling efficiency
- Uncertainty limited to precipitation-frequency
  - Other projects consider additional sources

TVA PFHA System: Current Work

- Improved data storage
  - Scenario input settings
  - Models at time of scenario execution
    - Hydrologic models
    - RiverWare models, rule sets
- Improved run management across multiple servers
- Improved performance for reporting tools
- Goal: better traceability of work

TVA PFHA System Interface

- Model Controllers
  - Set up inputs for scenarios
  - Execute and monitor simulations
- Hazards Curve Explorer
  - Merge results from multiple storm types
  - Compare hydrologic hazard curves (e.g. different operating policies)
- Scenario Explorer
  - Understand drivers of hydrologic hazard curves
- Simulation Explorer
  - Review simulation-specific settings
  - View time series outputs for individual simulations

Model Controller

Long-Term Model Controller | Stochastic Model Controller | Hazards Curve Explorer | Scenario Explorer | Simulation Explorer | Precipitation Explorer | Troubleshooting/Log Files

Stochastic Model Controller

This tab is used to create and execute stochastic scenarios. Once runs are completed, they can be further explored on the following tabs. While models are running, previously completed runs can be viewed and explored.

Make selections in the General Scenario Parameters, Stochastic Simulation Inputs, and Stochastic Sampling Inputs sections. The stochastic simulations may be executed for a fixed number of simulations, or until the hydrologic hazard curves converge (controlled by the Sampling Execution Run Mode).

REFRESH PAGE

Run Selected for Stochastic Model

General Scenario Parameters

Long-term continuous run:
(RW Model Segment~Watershed Model~MAP~WSM Model~RW Model~FailureMode)

Beech~Base~HistoricalMAP_Beech~Base~Base~NoFail

Reservoir

Beech

Storm Type

MEC

Precip-Frequency Parameters

Beech_MEC_10_Percent

Seasonality

MEC_Seasonality

Storm Template Folder

Base

Storm Template Weighting

Base

Database write-mode

Custom

Generate AEP curves for the selected reservoir(s):

Beech
Cedar
Dogwood
LostCreek

Select AEP Parameter

AEP Curves

Annual Exceedance Probability

Check and Re-run Failed RiverWare Simulations

Hazards Curve Explorer

Long-Term Model Controller | Stochastic Model Controller | Hazards Curve Explorer | Scenario Explorer | Simulation Explorer | Precipitation Explorer | Troubleshooting/Log Files

Hazards Curve Explorer

This tab is used to visualize the various AEP curves available from the executed scenarios and generate combined AEP curves.

AEP Scenario Comparison | Merge Storm Types | Produce AEP and Duration Curves

AEP Scenario Comparison

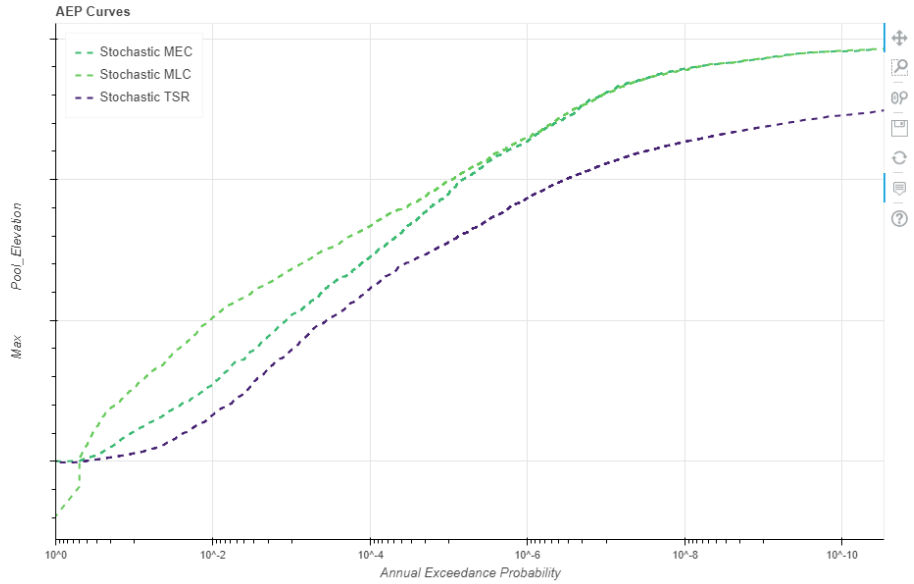
Add lines to plot below by selecting scenarios and AEP lines based on the multi-selects (Ctrl+Click), and clicking *Update AEP Plot* . Hide lines on plot by clicking on an entry in the legend. The plot legend can be updated by typing in the *Plot Legend* column.

Select AEP Line

Stochastic
Long-Term

#	Watershed Model	MAP	Dam	Storm Type	Kappa	Seasonality	Templates	Template Weighting	WSM Model	RW Model	Failure Mode	Plot Legend
0	Base	HistoricalMAP_...	Beech	MEC	Beech_MEC_10_P...	MEC_Sea...	Base	Base	Base	Base	NoFail	Scenario: 0
1	Base	HistoricalMAP_...	Beech	MEC	Beech_MEC_90_P...	MEC_Sea...	Base	Base	Base	Base	NoFail	MEC
2	Base	HistoricalMAP_...	Beech	MEC	Beech_MEC_Best...	MEC_Sea...	Base	Base	Base	Base	NoFail	Scenario: 2
3	Base	HistoricalMAP_...	Beech	MLC	Beech_MLC_10_P...	MLC_Sea...	Base	Base	Base	Base	NoFail	Scenario: 3
4	Base	HistoricalMAP_...	Beech	MLC	Beech_MLC_90_P...	MLC_Sea...	Base	Base	Base	Base	NoFail	MLC
5	Base	HistoricalMAP_...	Beech	MLC	Beech_MLC_Best...	MLC_Sea...	Base	Base	Base	Base	NoFail	Scenario: 5
6	Base	HistoricalMAP_...	Beech	TSR	Beech_TSR_10_P...	TSR_Sea...	Base	Base	Base	Base	NoFail	
7	Base	HistoricalMAP_...	Beech	TSR	Beech_TSR_90_P...	TSR_Sea...	Base	Base	Base	Base	NoFail	TSR
8	Base	HistoricalMAP_...	Beech	TSR	Beech_TSR_Best_...	TSR_Sea...	Base	Base	Base	Base	NoFail	Scenario: 8

Update AEP Plot



Scenario Explorer

Simulation Explorer

Simulation Explorer

Update Selection

Simulation

37129

Export Riverware

Summary | Time Series

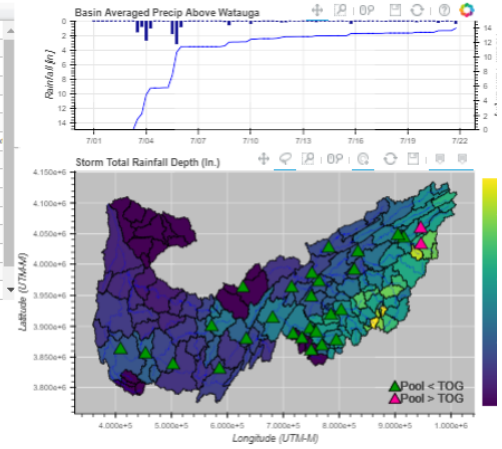
Simulation Explorer

This page allows for the exploration of a single simulation from the currently selected scenario(s). From the previous *Scenario Explorer* tab, select the simulations of interest using the *lasso* tool. Choosing *Update Selection* will change the Simulation drop-down menu to contain only those selected simulations. This tab contains two sub-tabs: Summary, and Time Series.

The *Summary* tab shows a summary table of the selected simulation. The table includes meta-data about the storm dates, precipitation bin, storm template, etc., used during the hazards run for the selected simulation. Two precipitation plots are shown to provide a summary of the spatial and temporal patterns of the storm. Reservoirs are shown on the spatial plot as triangles and are highlighted in red if at some point in the simulation they exceeded Top of Gates.

The *Time Series* tab shows results from the RiverWare simulations. Currently there are 7 plot layouts set up for certain Reservoir systems (i.e. South Holston, Main Stem, etc.). Clicking on the buttons will toggle the different plot layouts (** NOTE: This may take a moment for a new plot layout to load into the interface, please wait). Some plots in the plot layouts may appear empty if those data are missing from a certain scenario run. The plots are linked for zooming and panning and the time-slider can be used to display a vertical line on all of the plots. Changing simulations in the drop-down menu above will automatically update the plots with new data.

#	Attribute	Value
0	SimNumber	37129
1	StormDate	07/01/2004
2	Precip Bin Number	38
3	Incremental Prob of Precip Bin	3.62E-04
4	Kappa Precip AEP	2.54E-03
5	Kappa Precip (Inches)	7.76
6	Storm Temporal Pattern	storm2sefm_watauga TSR_4892_1407.tx
7	Max Watauga Outflow AEP	5.09E-05
8	Max Watauga Outflow	16786.59
9	Max Wilbur Outflow AEP	4.99E-05
10	Max Wilbur Outflow	16915.06
11	Max Watauga Pool_Elevation AEP	5.11E-05
12	Max Watauga Pool_Elevation	1977.45
13	Max Wilbur Pool_Elevation AEP	1.00
14	Max Wilbur Pool_Elevation	1648.00



Simulation Explorer

Update Selection

Simulation

37129

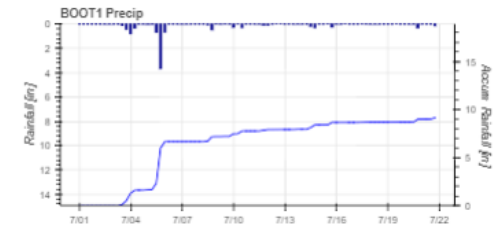
Export Riverware

Summary | Time Series

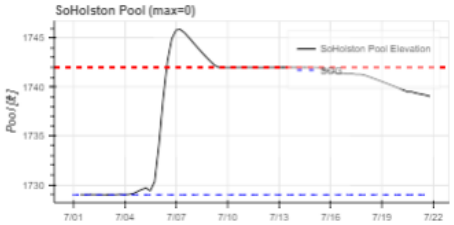
0

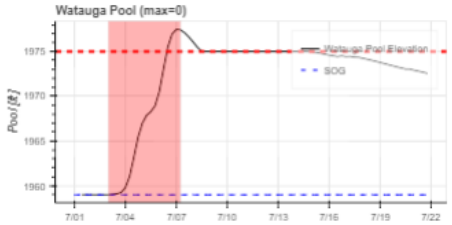
Date:

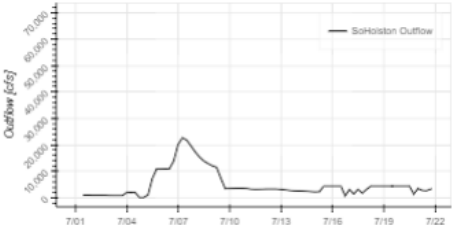
So. Holston | Cherokee & Douglas | Fontana | Norris & Melton Hill | Blue Ridge / Ocoee | Hiwassee | Mainstem

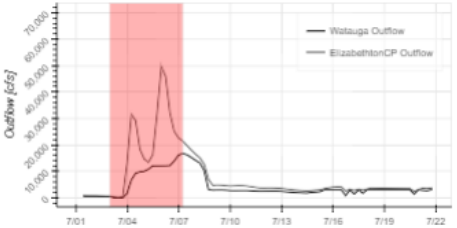


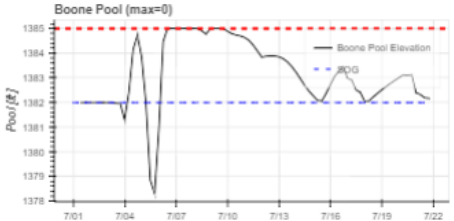
Top of Gates
Flood Trigger
Spillway Crest

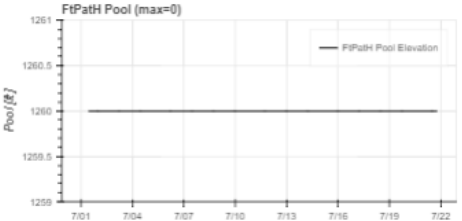






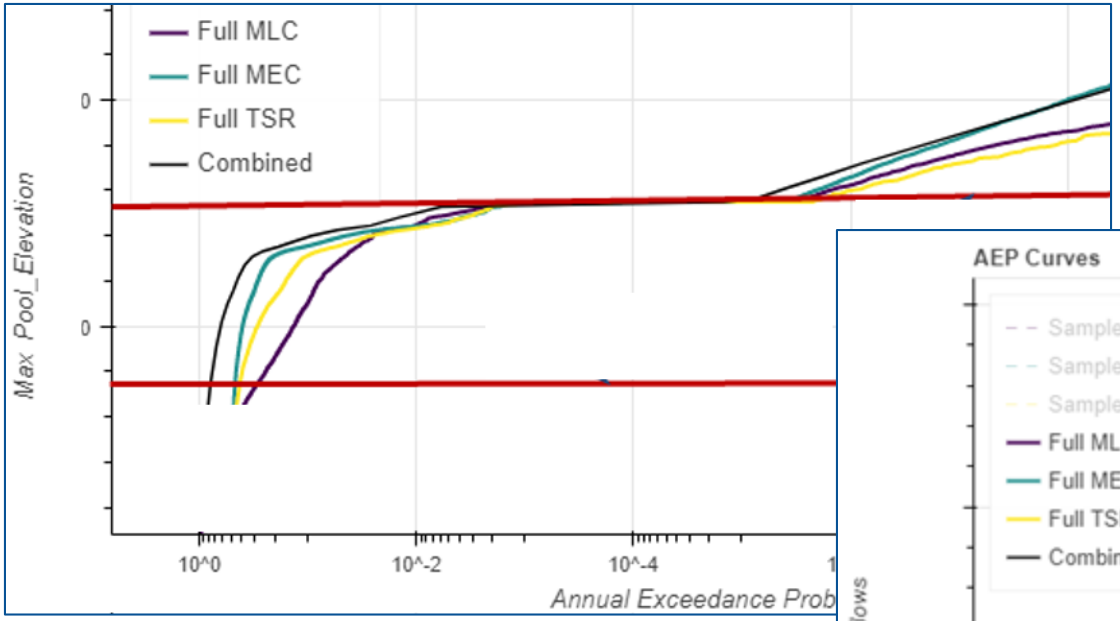


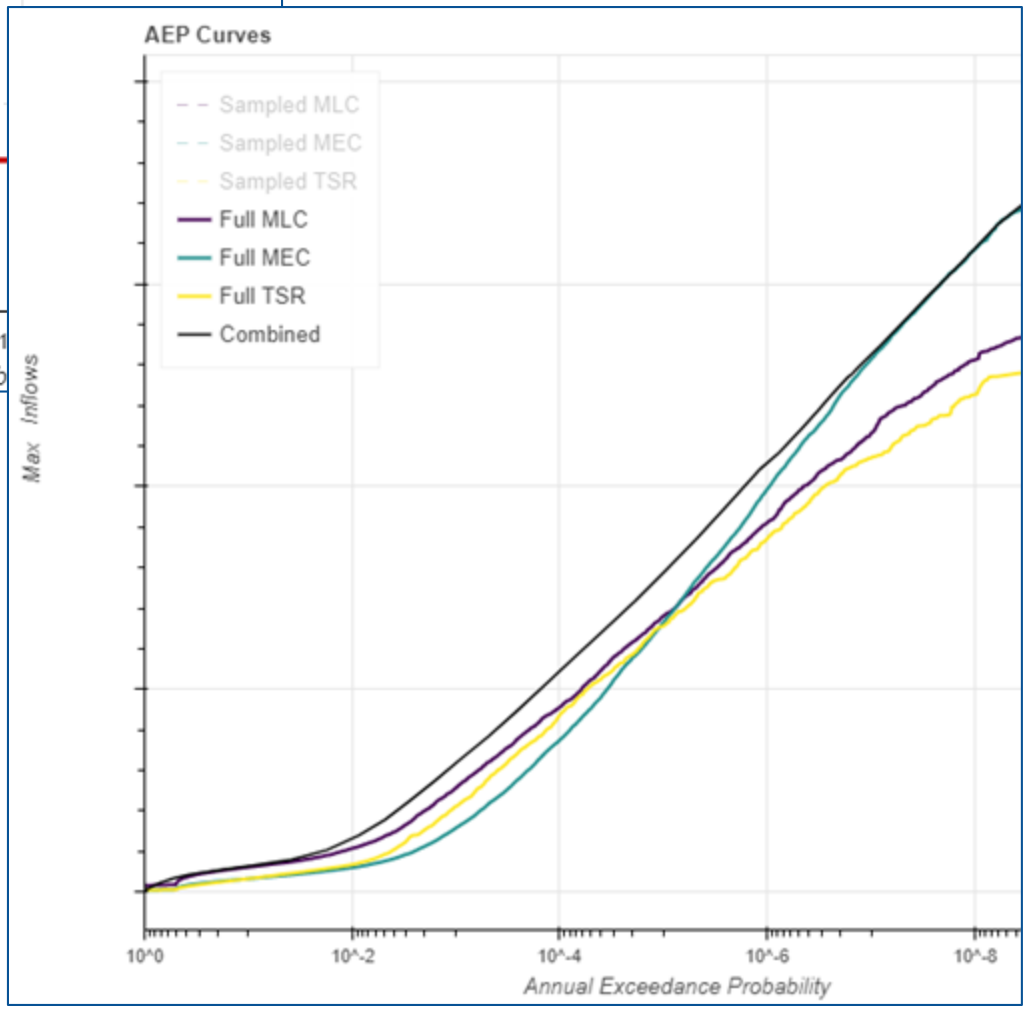




Analysis Applications

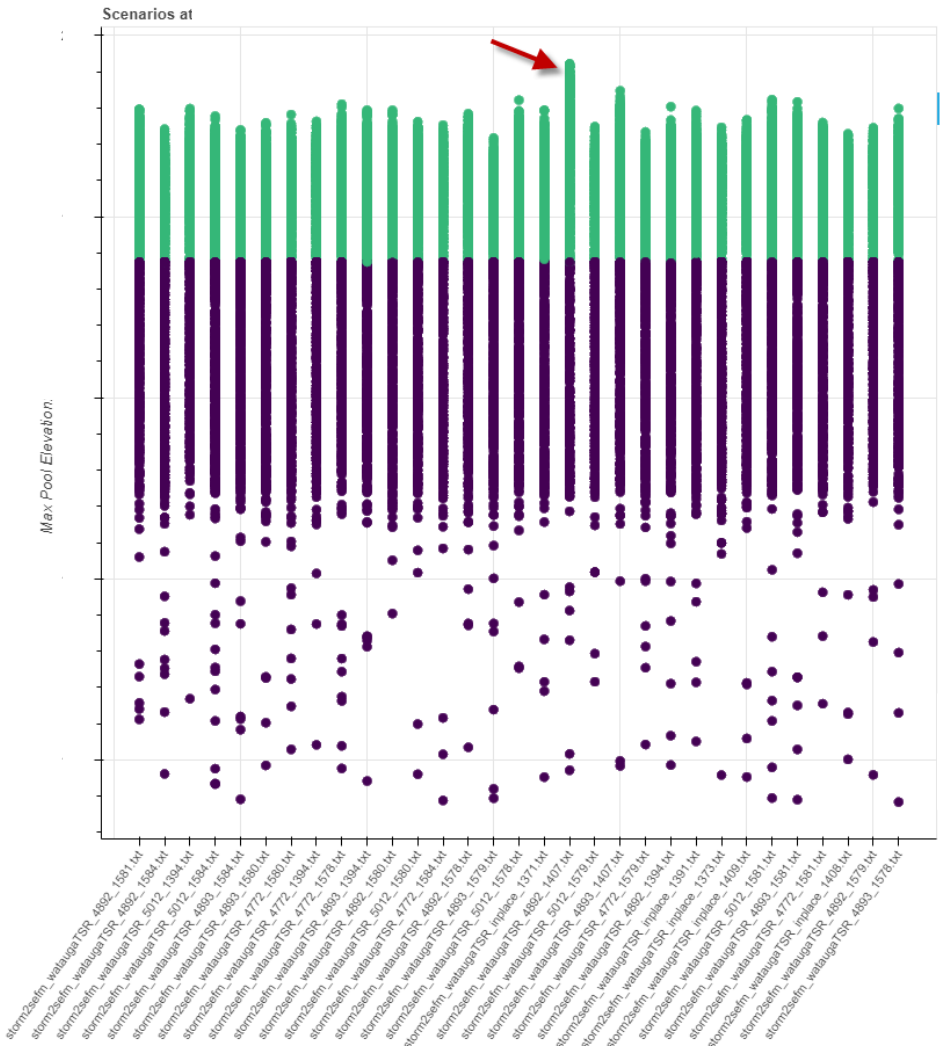
Influence of Different Storm Types



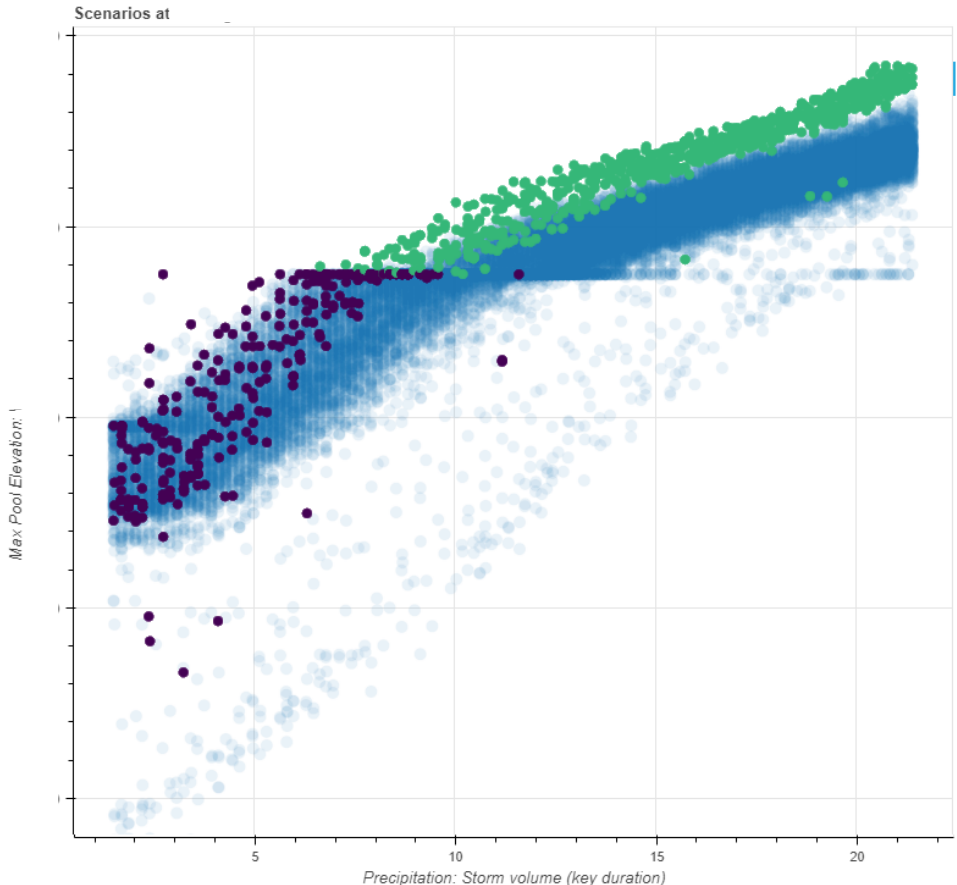


- Different storm types control for different AEP ranges

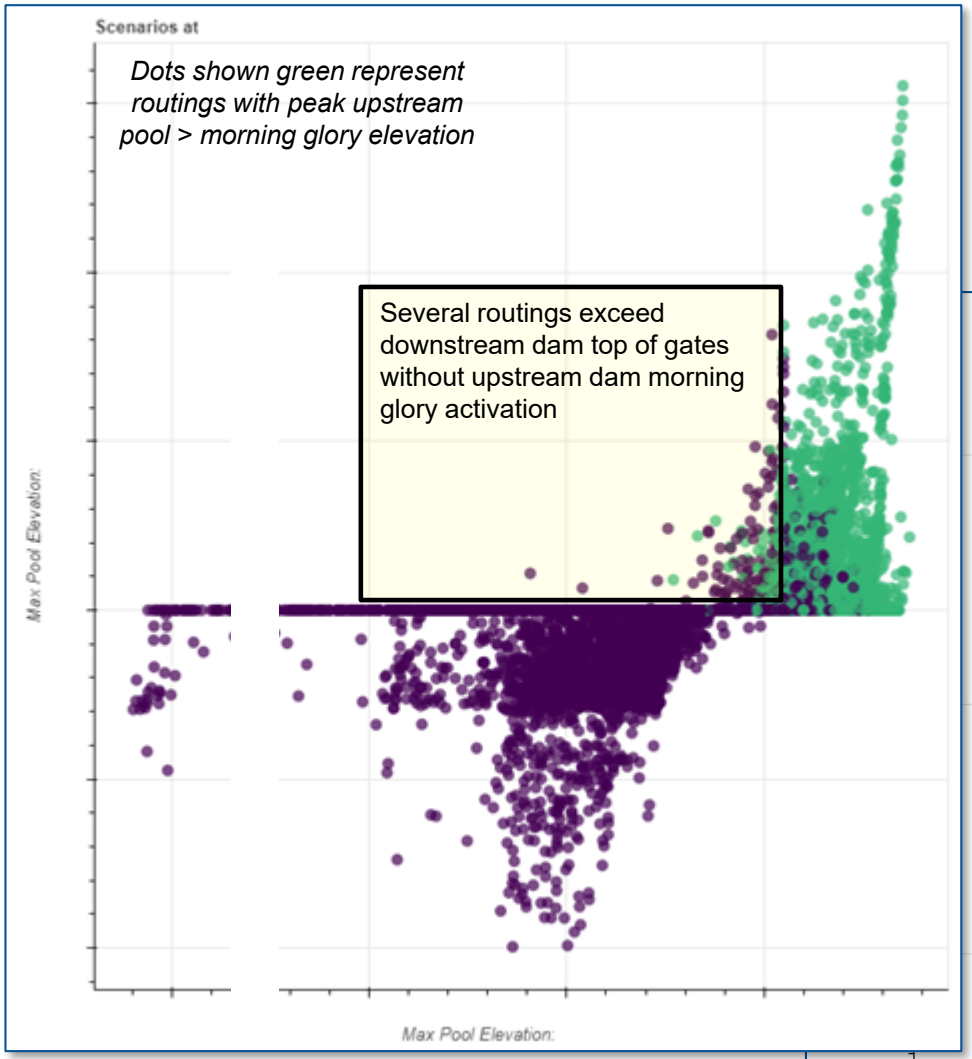
Influence of Storm Patterns

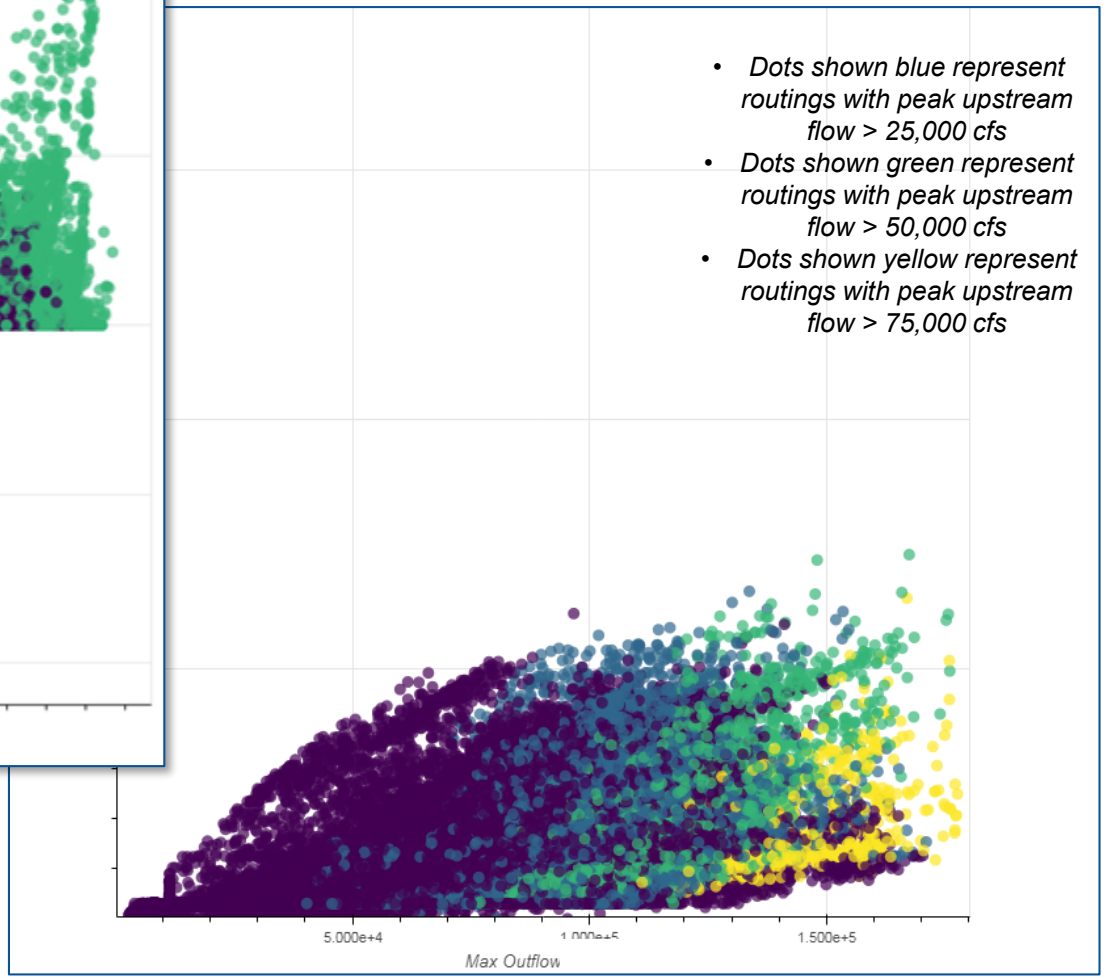


- Storm pattern can have a significant impact



Influence of Other Reservoirs

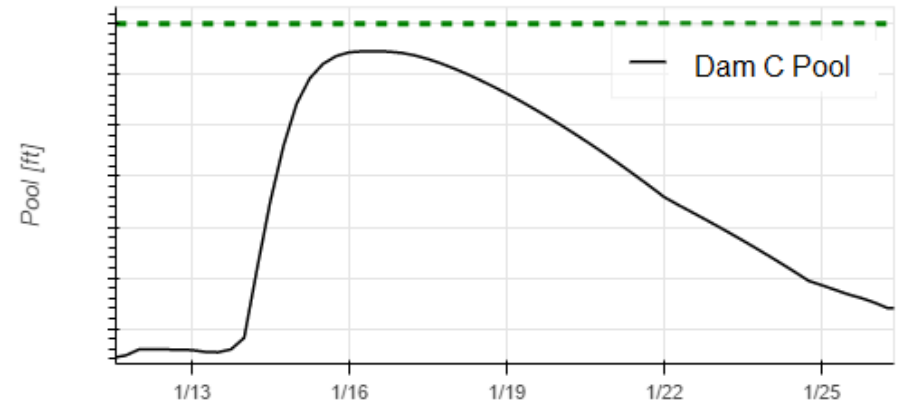


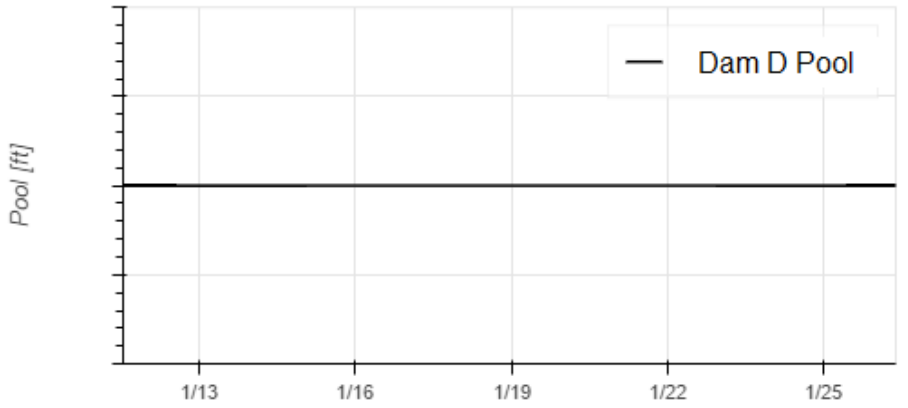


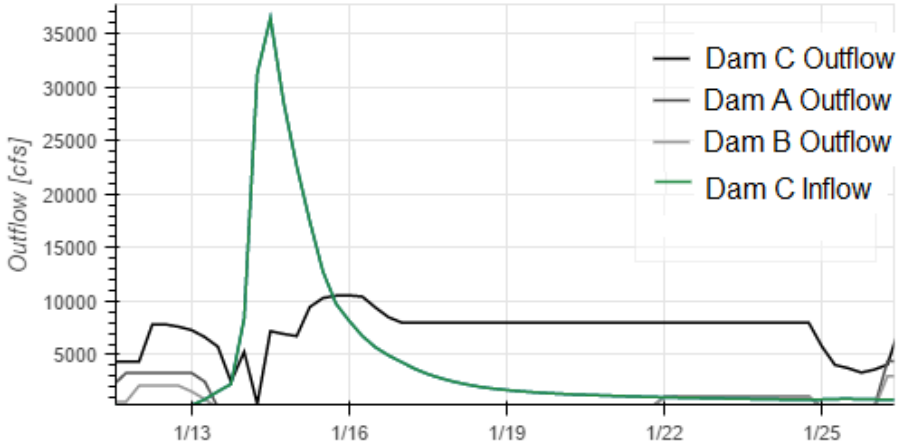
Compare Interim Risk Reduction Operating Policies

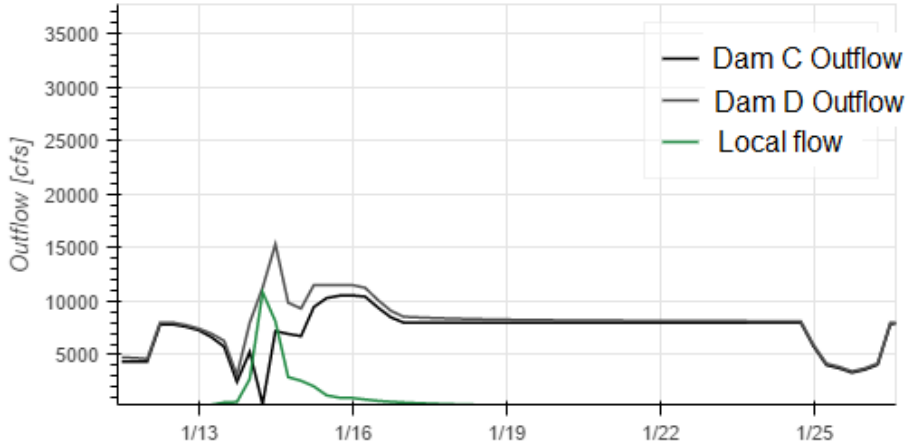
- Two different policy alternatives
  - Protect downstream
  - Keep headwater low

Protect downstream









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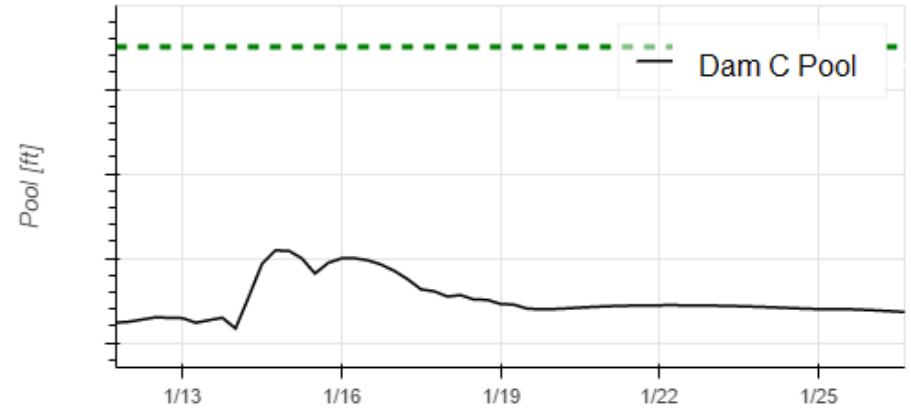
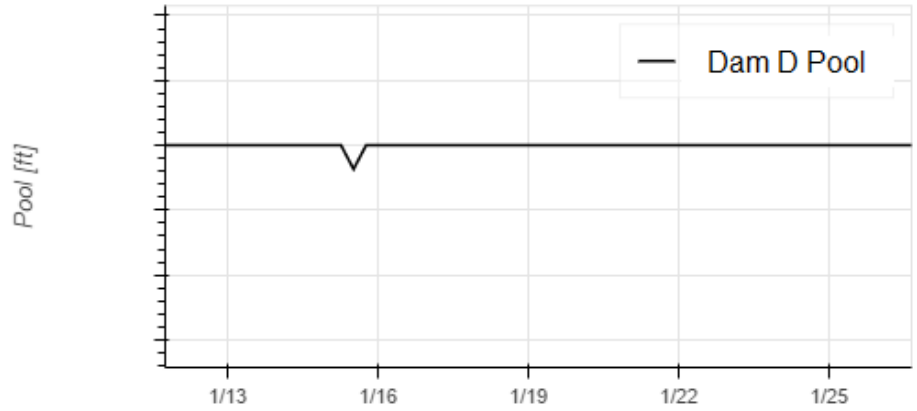
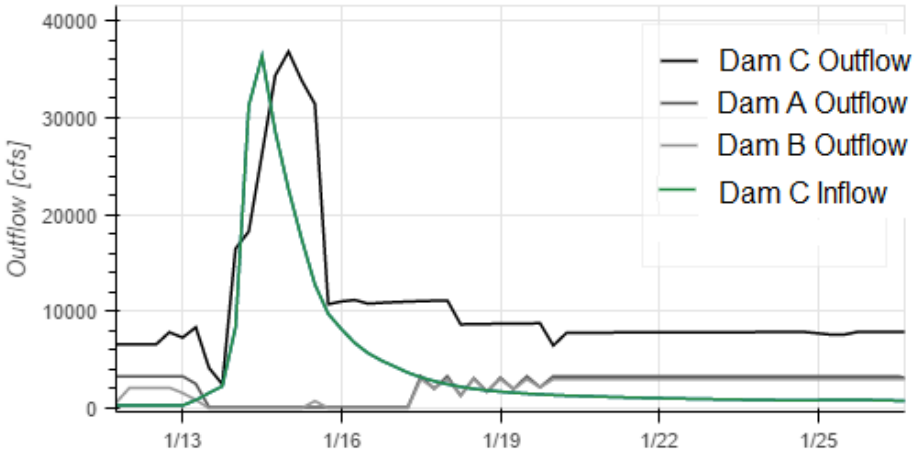
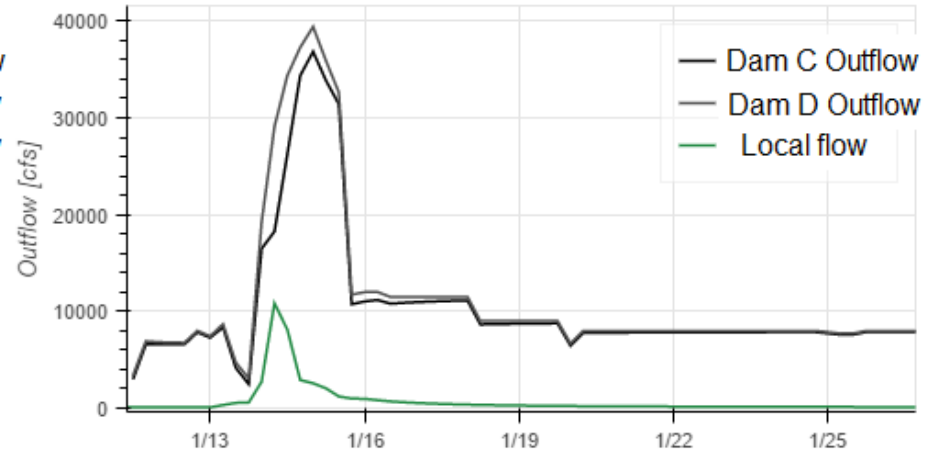
Keep headwater low









Compare Interim Risk Reduction Operating Policies

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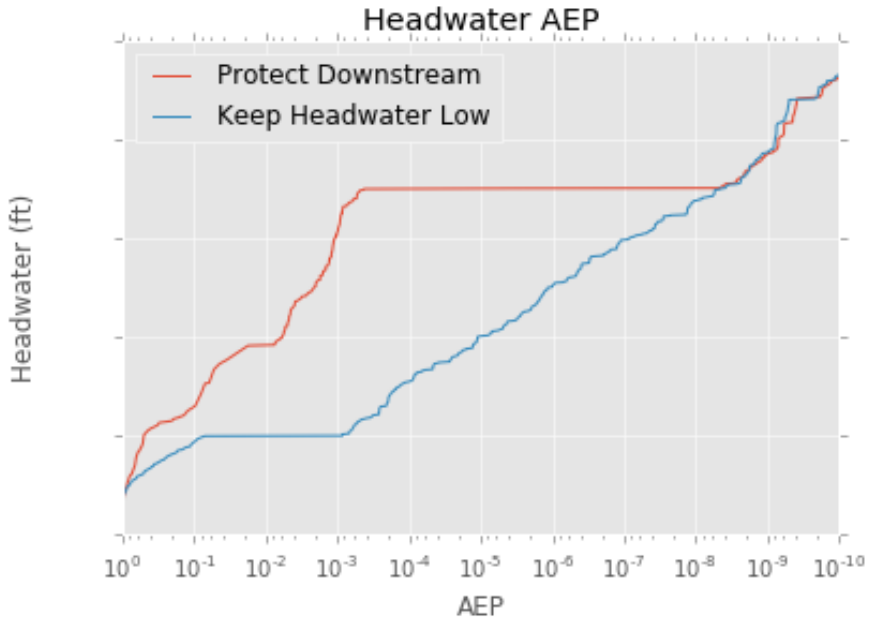
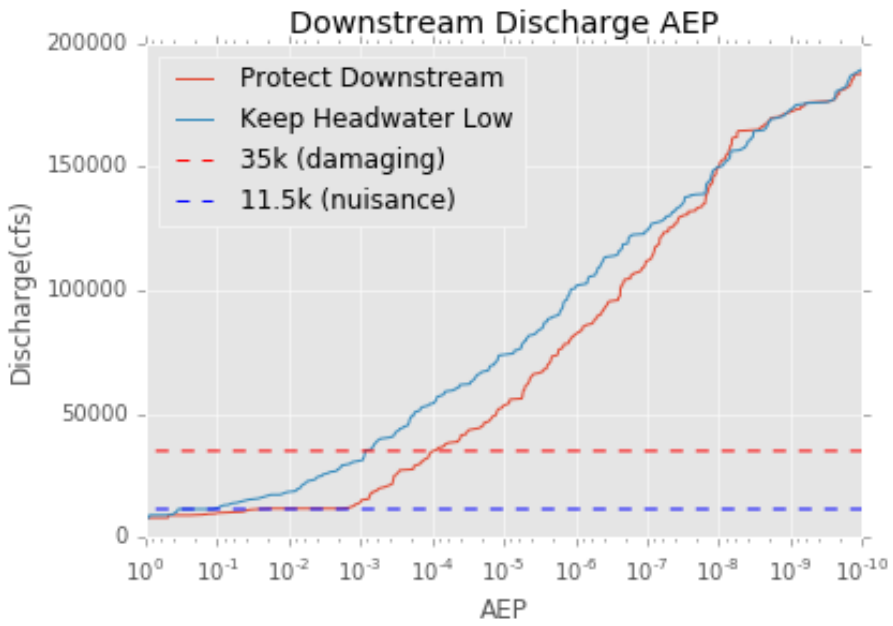
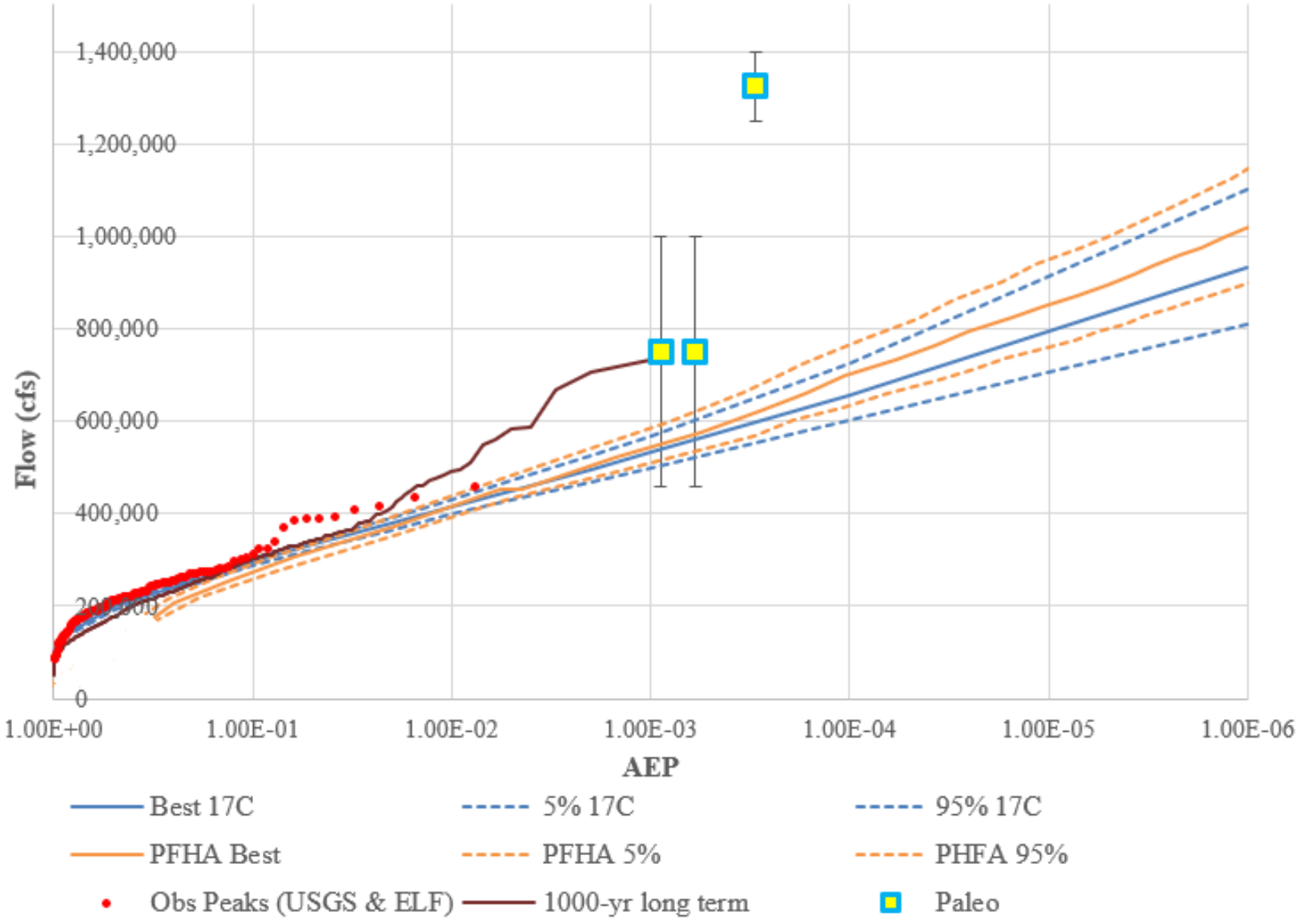
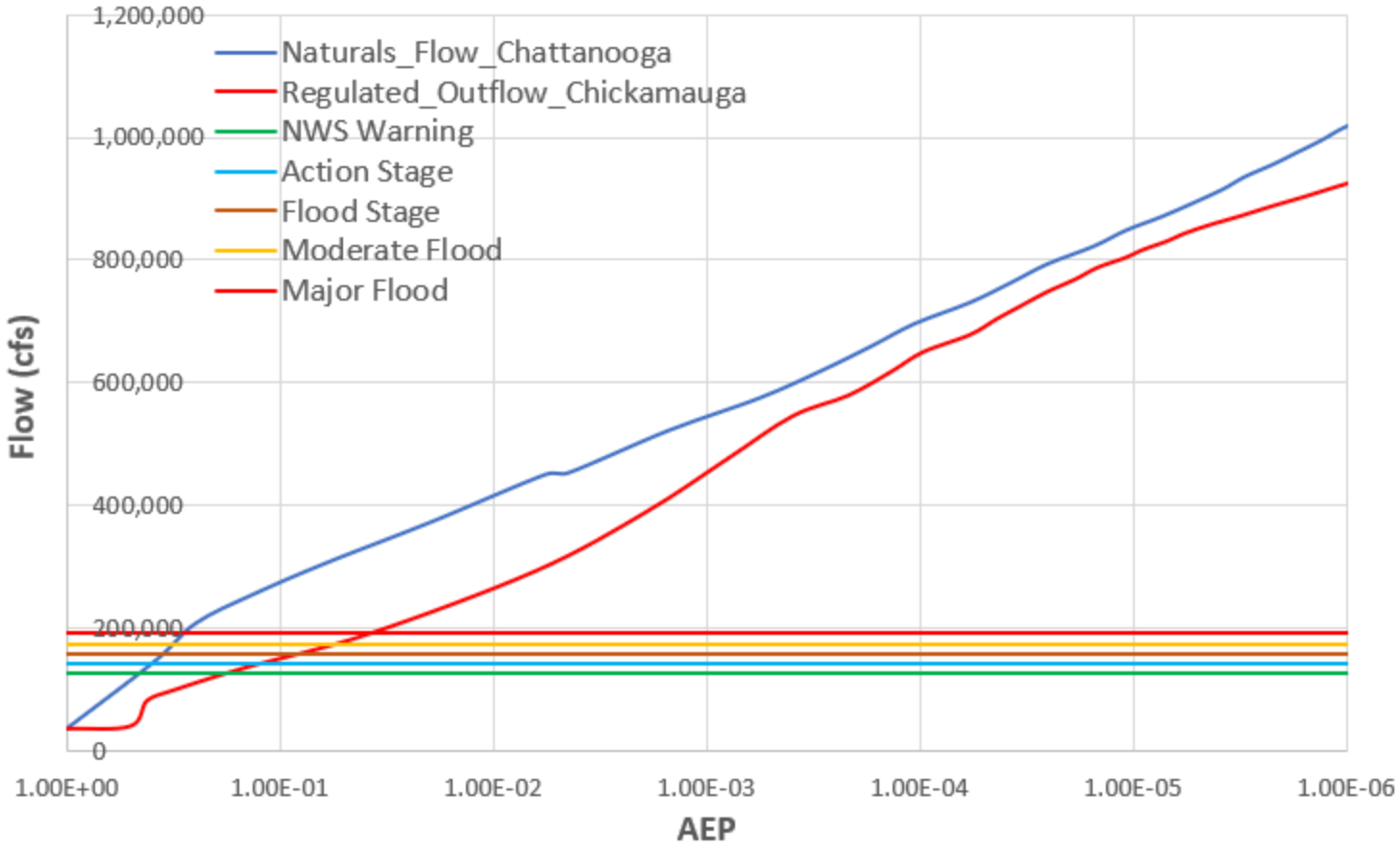




PFHA vs. Flow-Based with Paleo Flow Frequency



Regulated vs. Unregulated Flow Frequency



More Information

Shaun Carney
RTI International
970.498.1845
scarney@rti.org

Curt Jawdy
Tennessee Valley Authority
865.632.4891
cmjawdy@tva.gov

Mel Schaefer
MGS Engineering
360.570.3450
mgschaefer@mgsengr.com