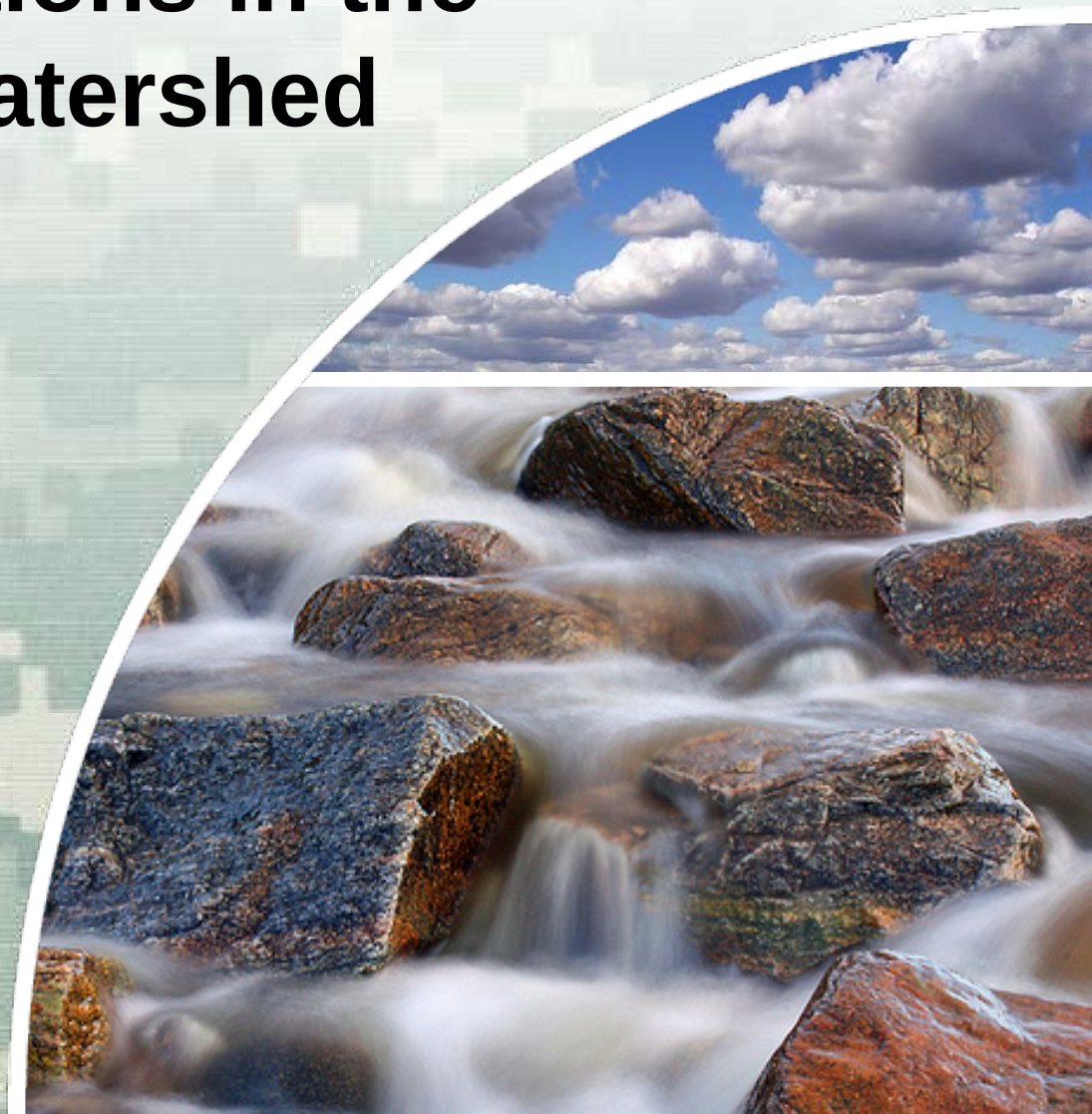
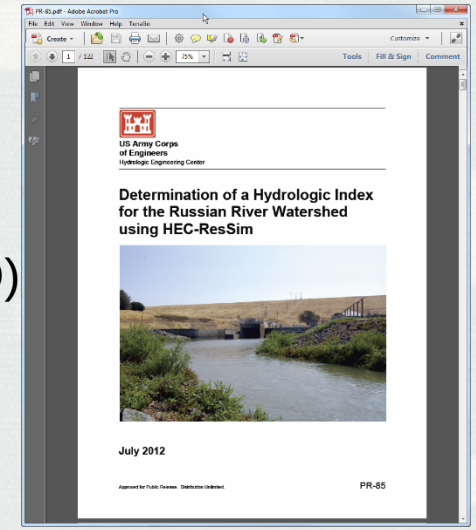
Analyzing Flood Risk for Forecast Informed Reservoir Operations in the Russian River Watershed using HEC-WAT



Matt McPherson
Hydrologic Engineering Center

Goals of HEC Effort

- HEC Project Report: *"Analyzing Flood Risk for Forecast Informed Reservoir Operations in the Russian River Watershed using HEC-WAT"*
  - Demonstrate tools and methods for evaluating the impacts of forecast informed reservoir operation (FIRO) at the Coyote Valley Dam on flood risk downstream.
  - Study approach to be consistent with USACE requirements for system-based risk-informed analysis, and producing models and data suitable for use in potential subsequent formal study process.


US Army Corps of Engineers
Hydrologic Engineering Center

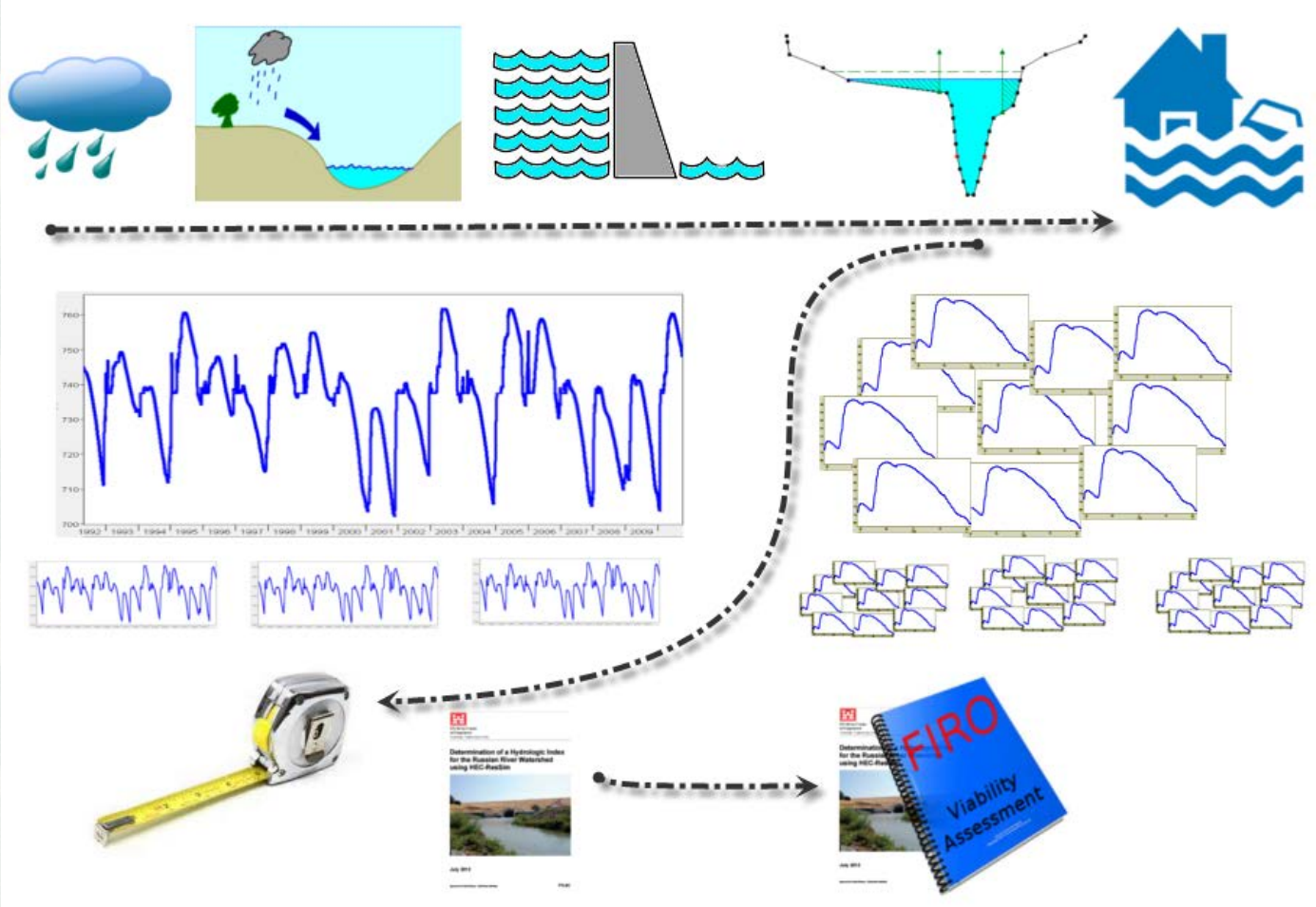
Determination of a Hydrologic Index for the Russian River Watershed using HEC-ResSim

July 2012

PR-85

- Coordinate with Viability Assessment analyses and integrate HEC Project Report into Viability Assessment report.
- Support other Corps elements and FIRO partners as needed.

Analysis Framework



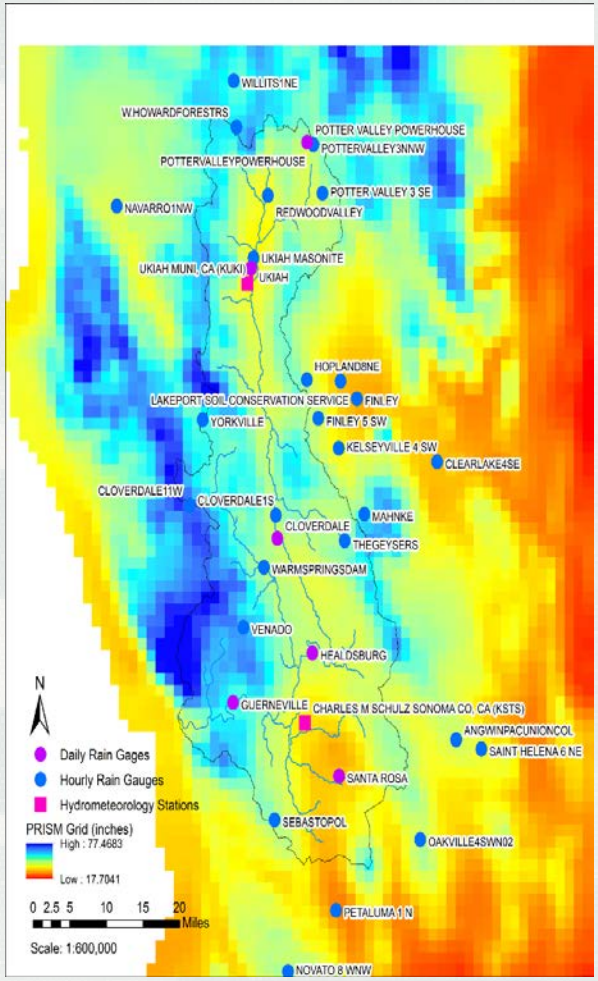
Assumptions

- future=existing
- perfect forecast
- data 1950-2010

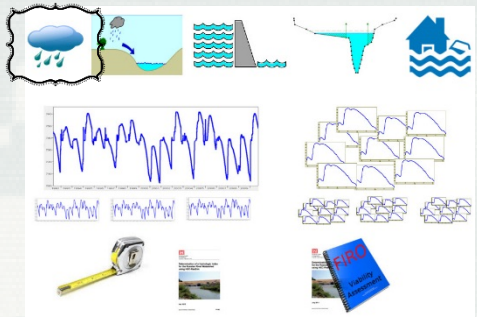
Framework

- model sequence
- PoR vs FRA
- baseline vs 3 alternatives
- metrics: AEP, EAD, available water, happy fish

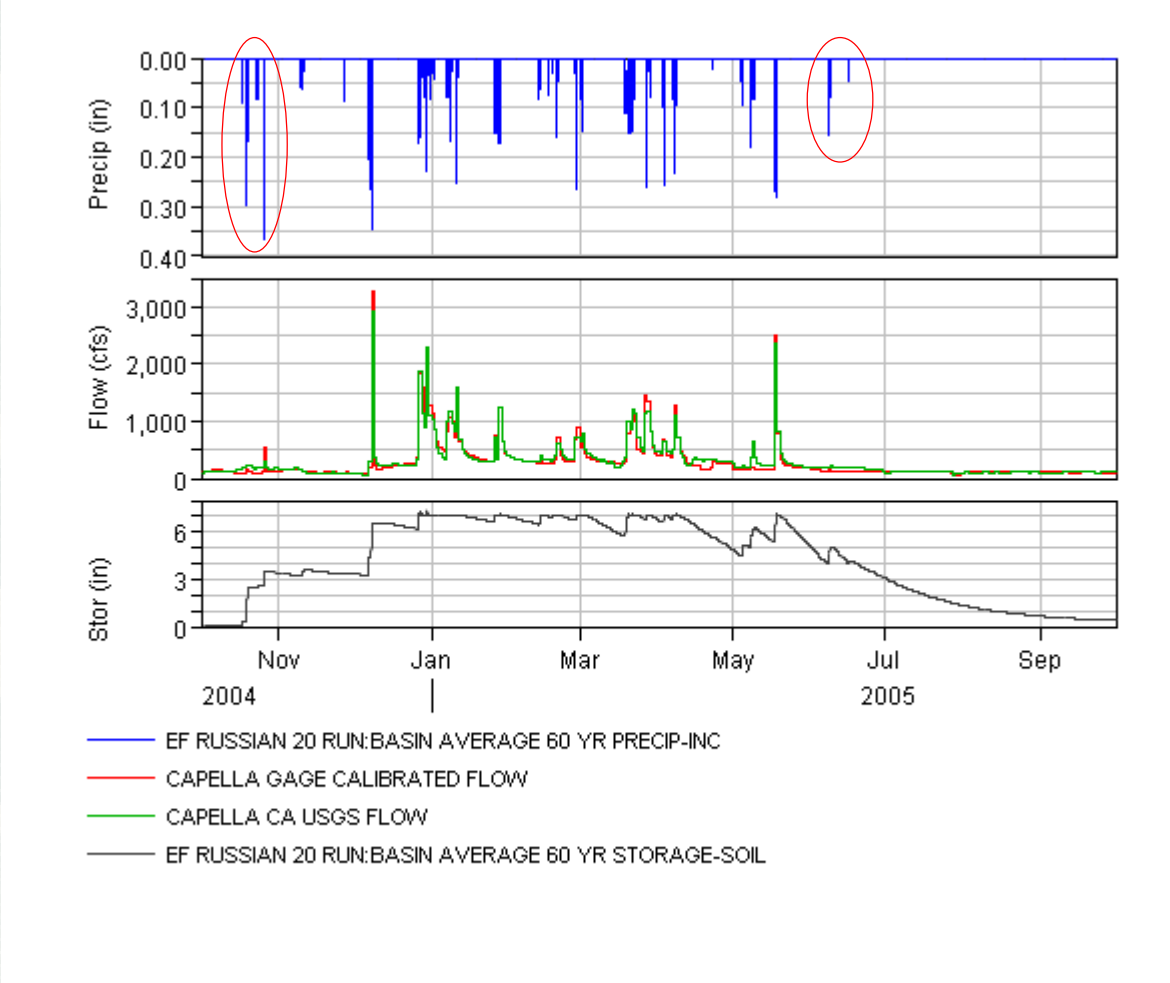
Precipitation Analysis



- 28 NCDC 1951-2010 hourly precipitation gage records
- Gridded using an inverse distance squared
- Biased according to 1981-2010 PRISM grid
- Additional daily data applied to floods of 1964, 1986, and 2005, scaled to hourly using basin average temporal pattern.
- Also used daily data in drought years 1976, 1987, and 1988.

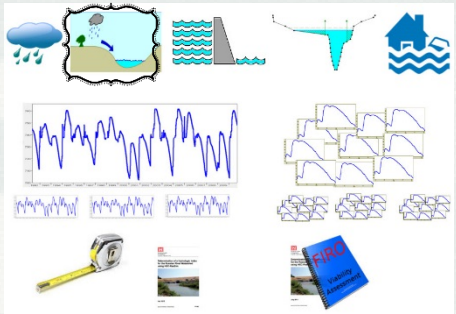


Continuous Simulation Hydrologic Model

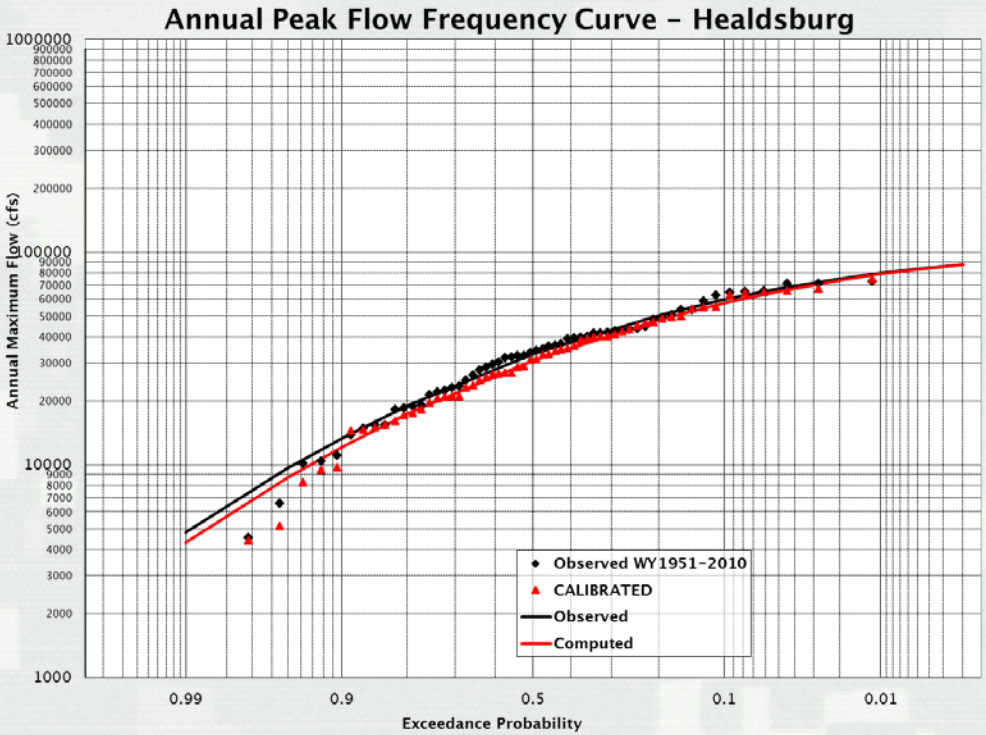


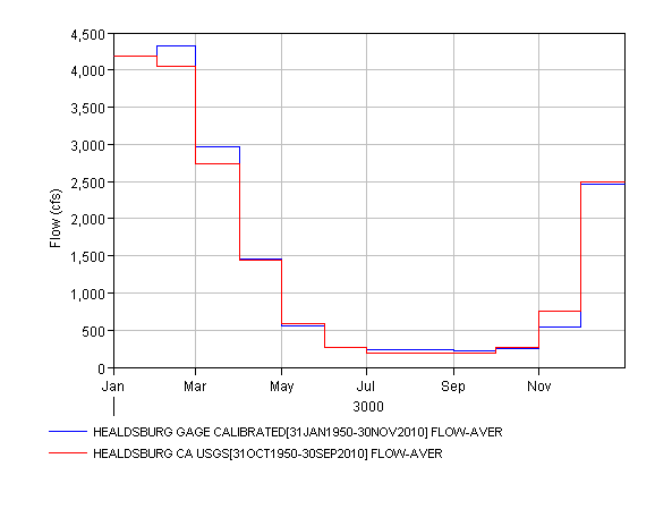
Compute hourly flows from 1950-2010

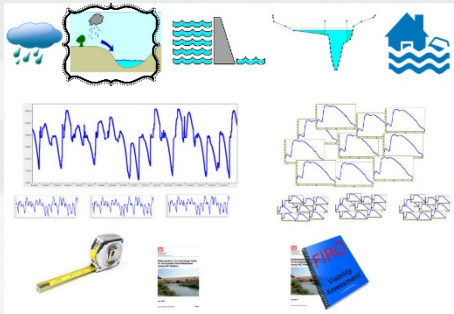
Allows modeling of depletions to establish antecedent reservoir levels for simulation of flood operations



Calibration - Healdsburg

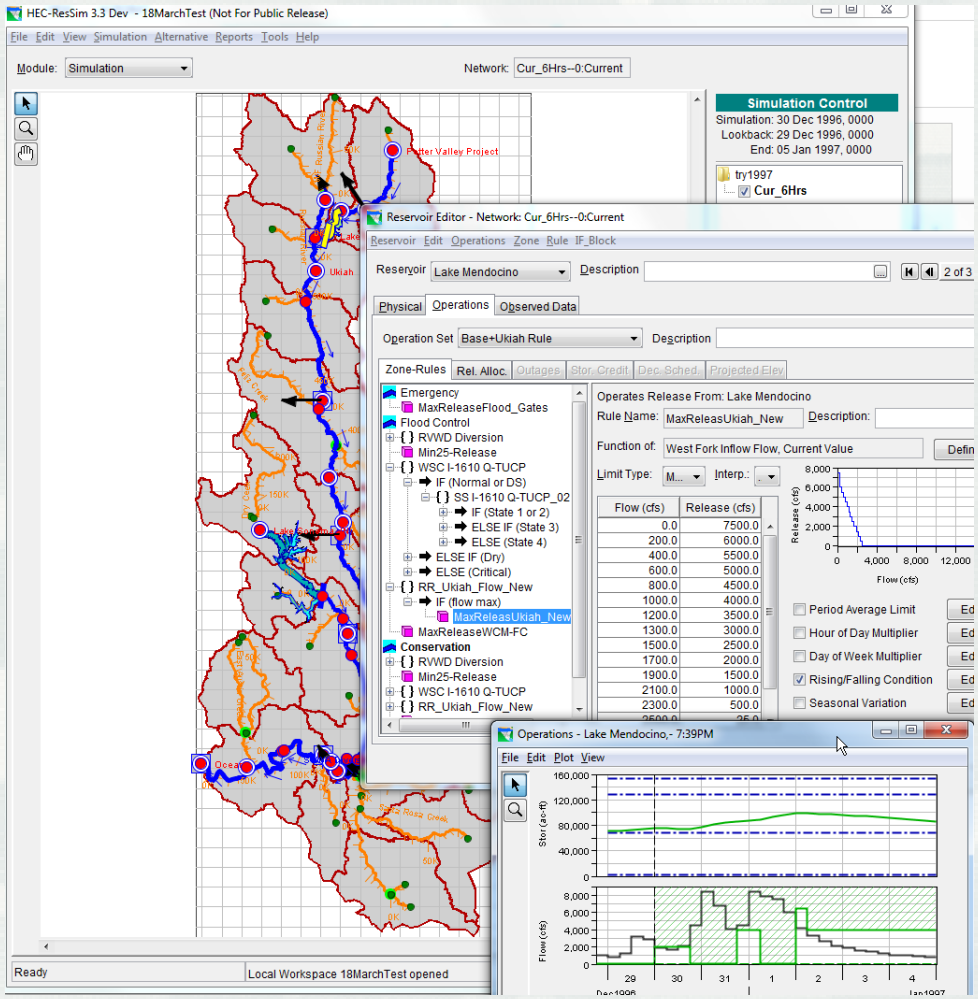




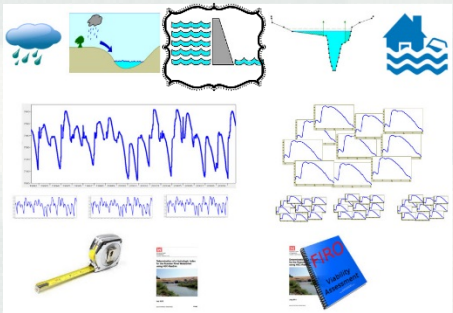


Emphasized calibration of flood flows

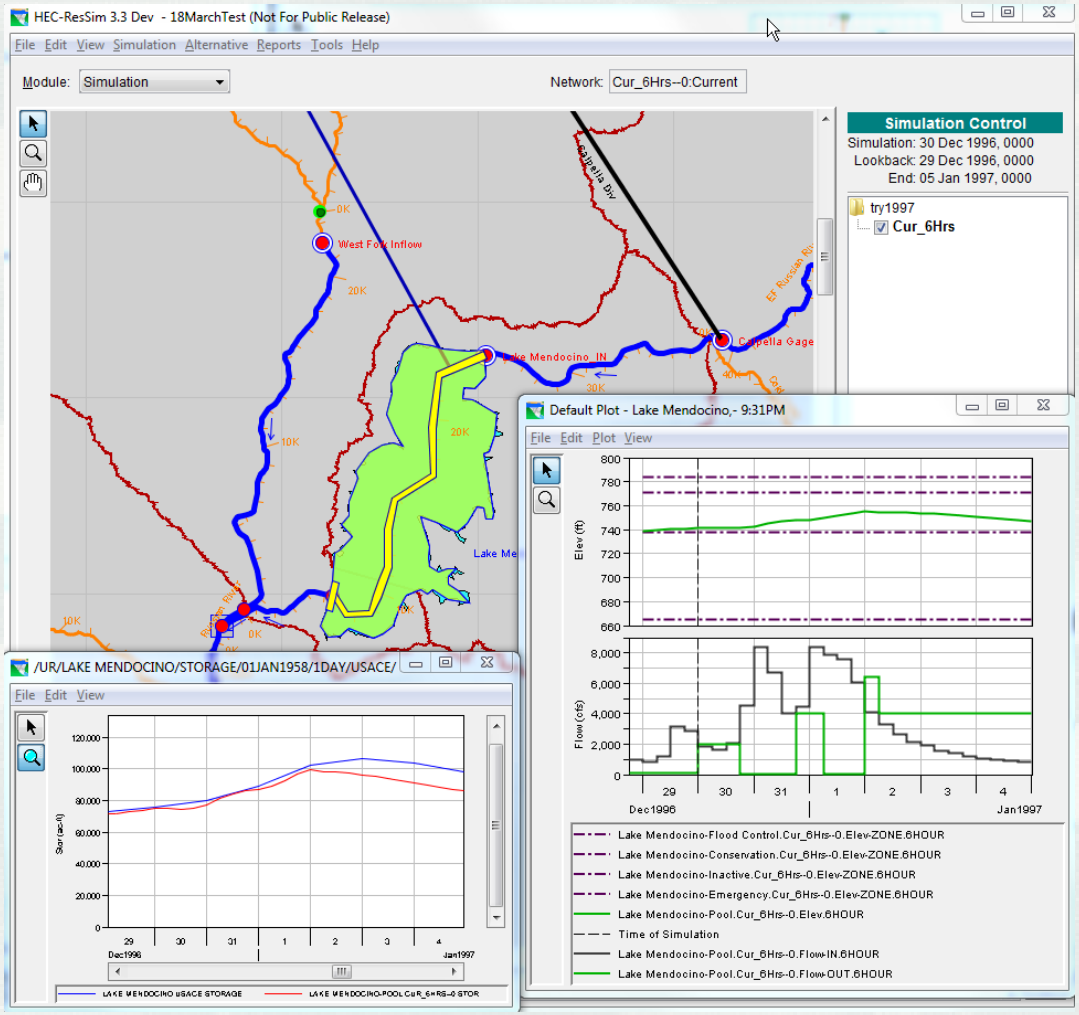
Significant Reservoir Modeling Choices



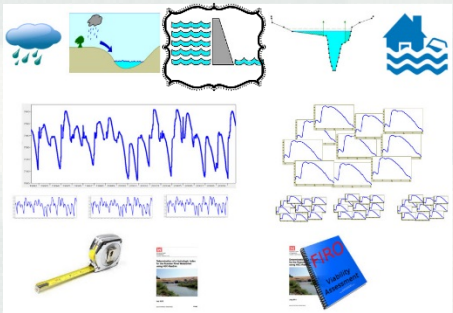
- 6-hour time step
- Demands per SCWA (refinement of Sustainability Report)
- Substitutes for 8000 cfs at Hopland rule
- April 2016 Rate of Change



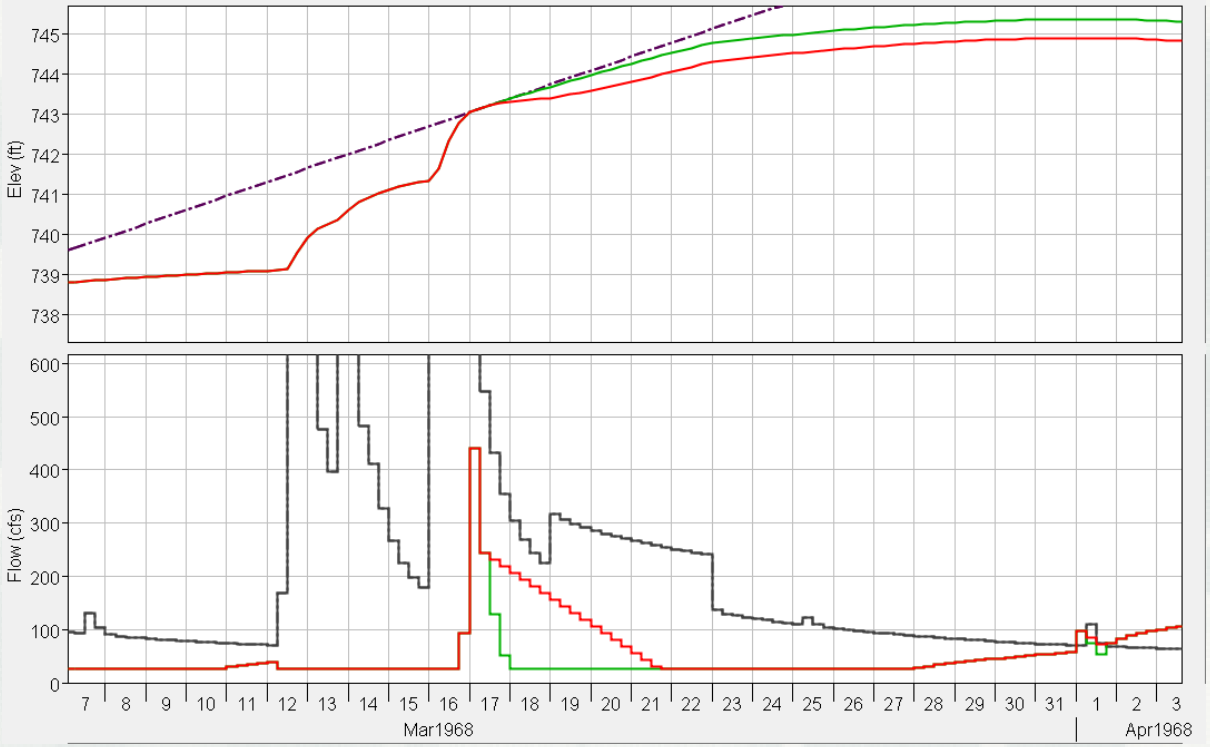
Reservoir Model Validation



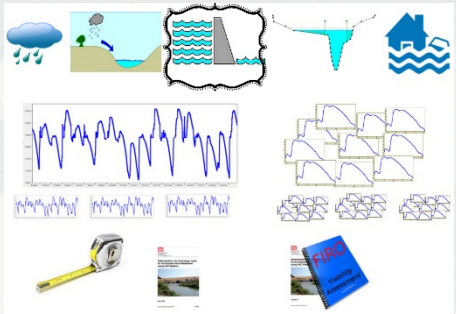
- Nice if simulation results match observations, but different boundary conditions, initial states, or operational assumptions often prevent direct comparison to historical.
- “Validation” is to establish that model did what it was told to do, and to confirm that’s what we want it to do.



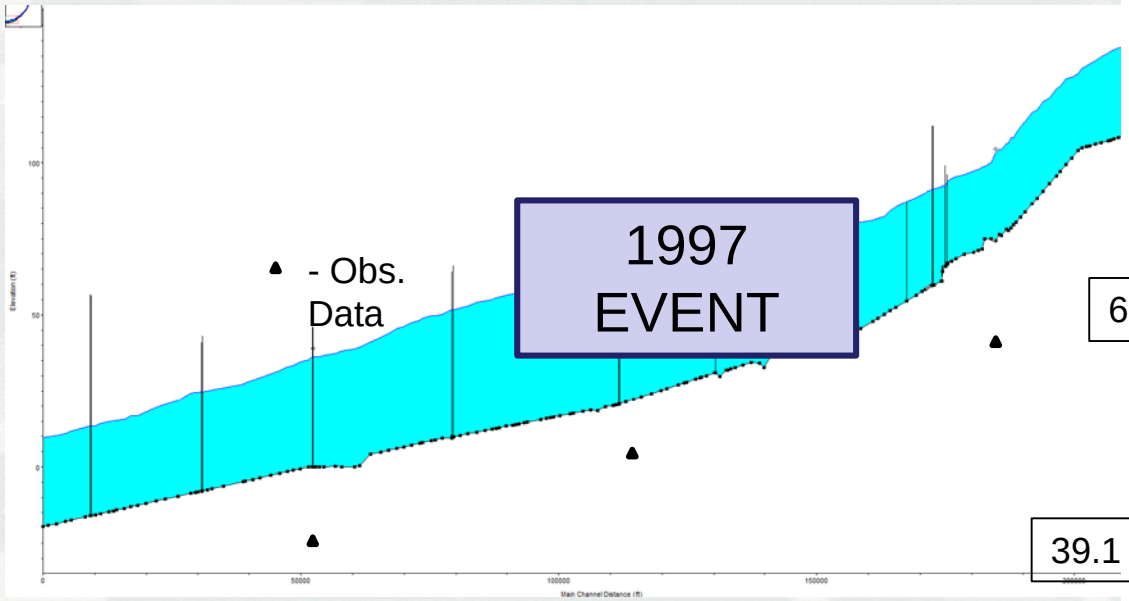
Effect of Apr16 RoC Rule

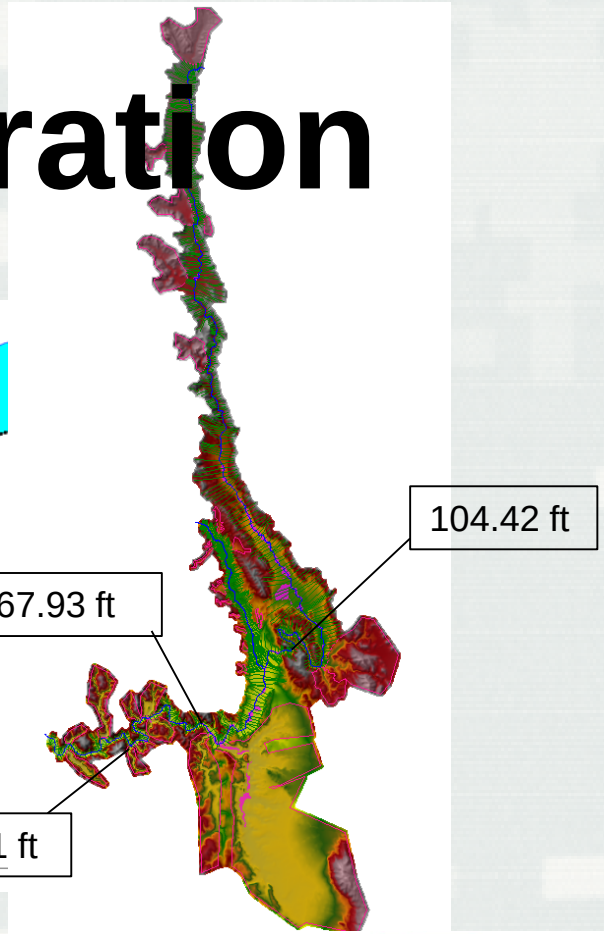


In the spring the new ROC rule often results in a higher outflow than the old rule for a short time after storm. Often this causes a slightly lower lake level for the rest of the summer.

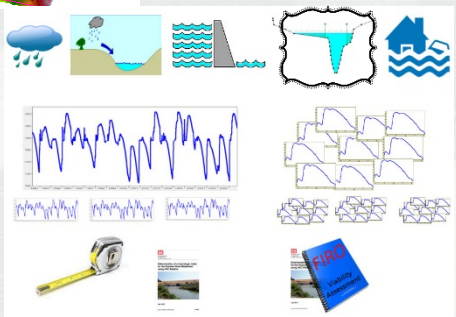


RAS Calibration

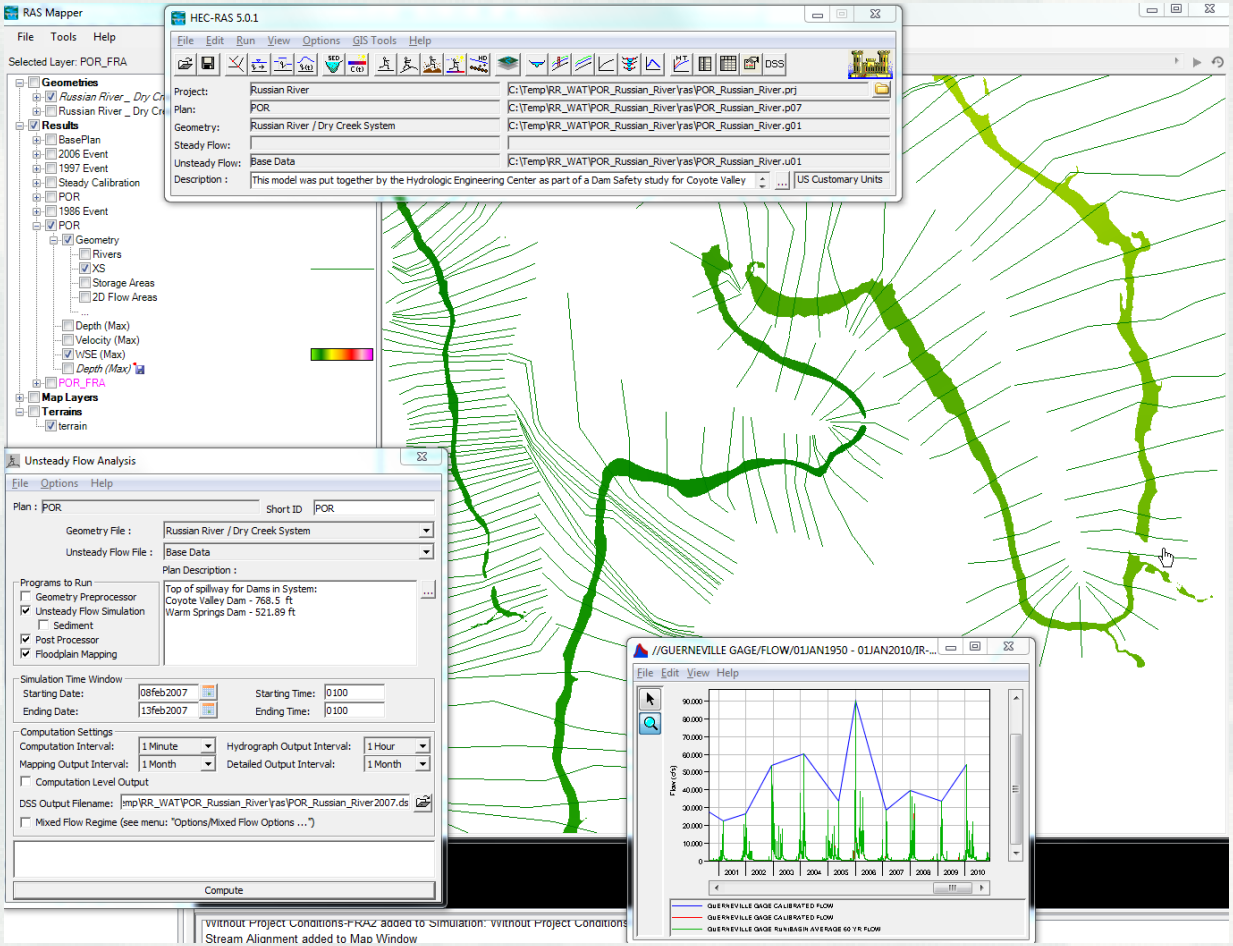


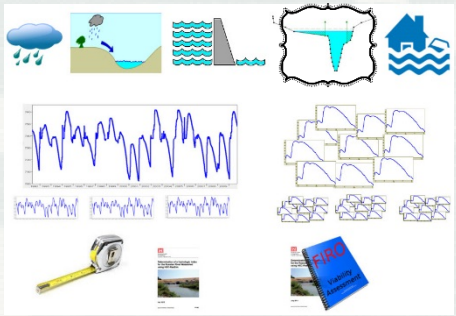


Observed High Water Marks



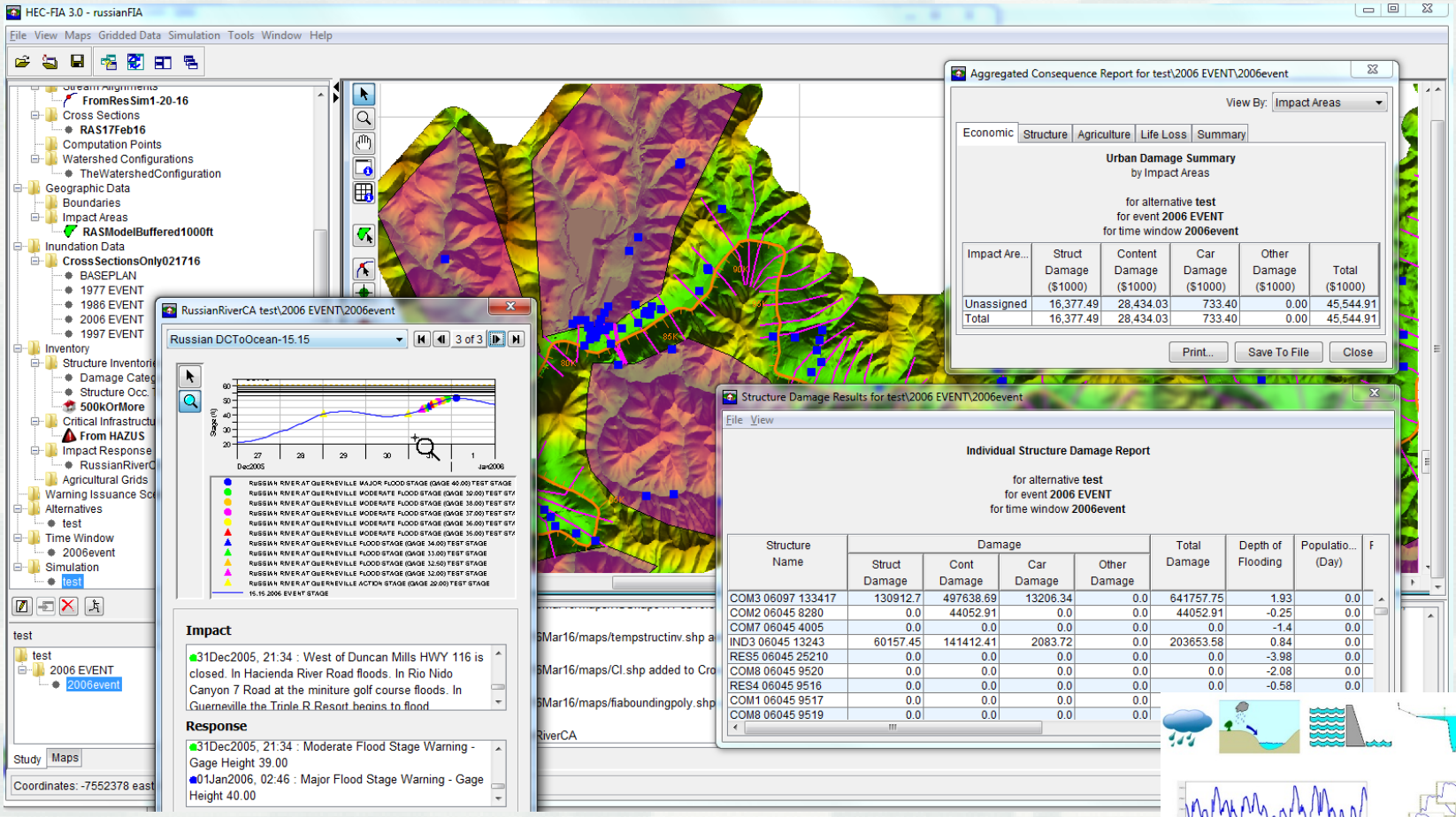
Modeling Non-Damaging Event with HEC-RAS





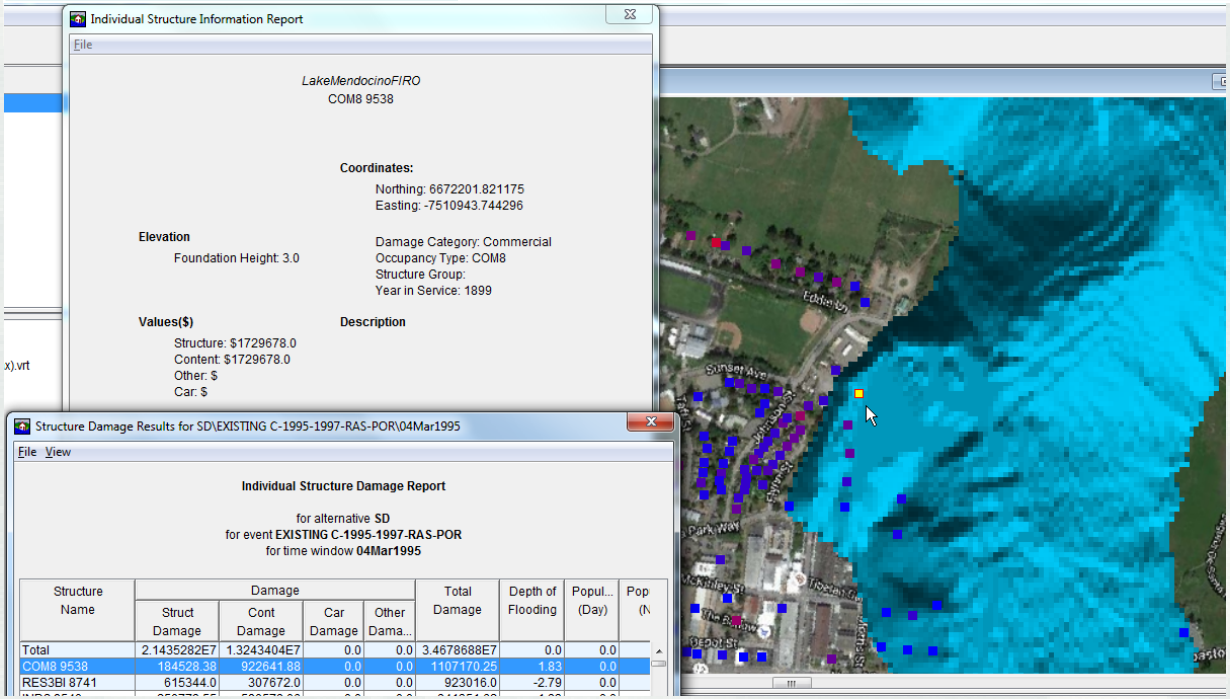
BUILDING STRONG®

Flood Impact Analysis (FIA) Model



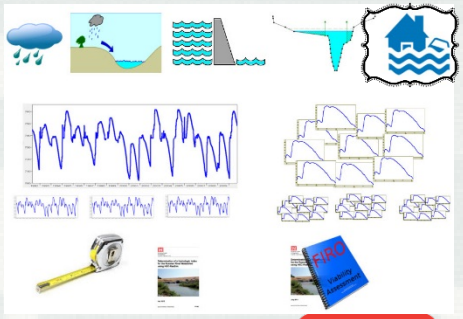
Damage Validation

Date	Loss Estimates*	Damage
January 8-31, 1995	$21 million	Over 50 roads closed. 15,000 residents without power. Total displaced persons exceeded 2,000, of which 456 flood victims were evacuated by air. 13 medical cases were treated and 2 flood-related fatalities occurred.
March 7-15, 1995	$13.3 million	Over 100 roads closed. 45,000 residents without power. At least 3,000 residents displaced. Up to 30 containers of possible toxic materials identified in the flood zone.



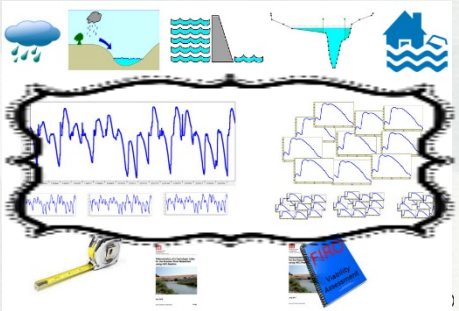
FIA total $35M 1995

See if concentrated in just a few structures

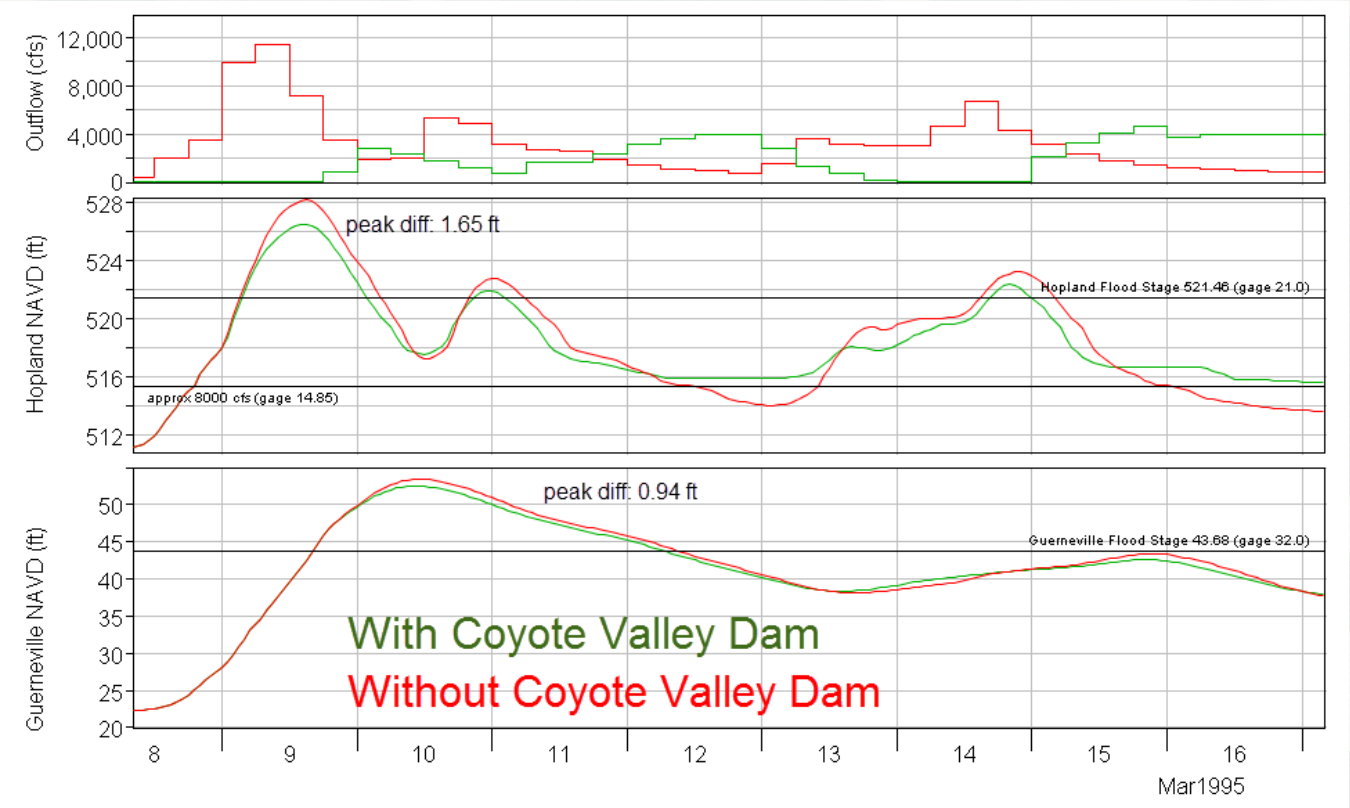


HEC-WAT
Watershed Analysis Tool

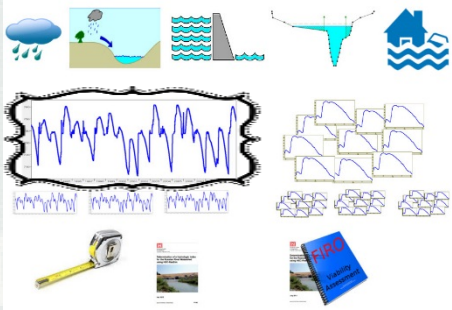
- Provides an interface and a model integration tool that allows a PDT (Project Delivery Team) to perform system-wide benefit analyses assessing risks in complex, interdependent systems and with a life-cycle approach.
- Period-Of-Record Style Simulation for modeling familiar historical events
- Uses the Monte Carlo simulation & allows for a life-cycle type computation of consequences (economic and loss-of-life) and associated performance indices.
- Performs sampling with hydrologic, hydraulic, geotech and economic uncertainties



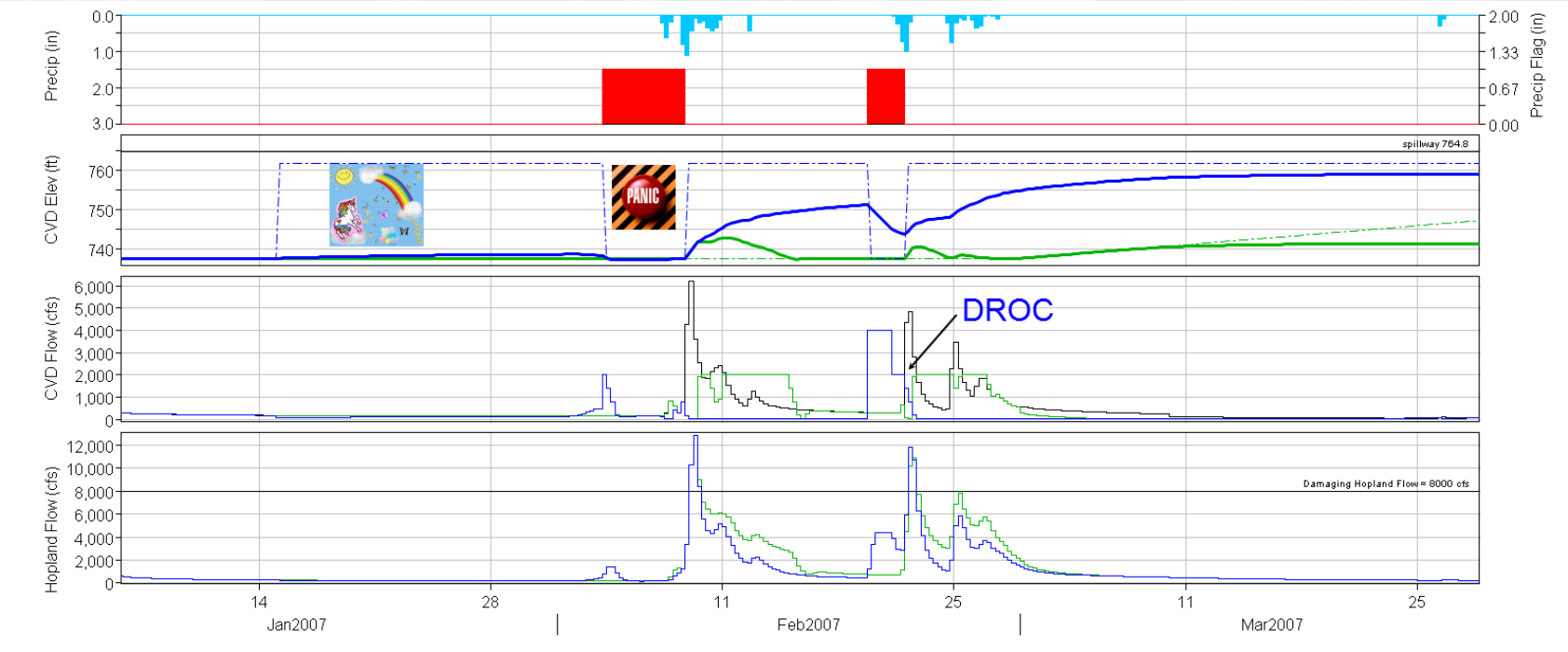
Impact of CVD Downstream



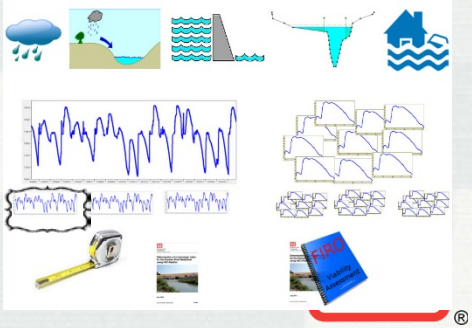
If add to peak at Hopland, usually also increase peaks downstream as well



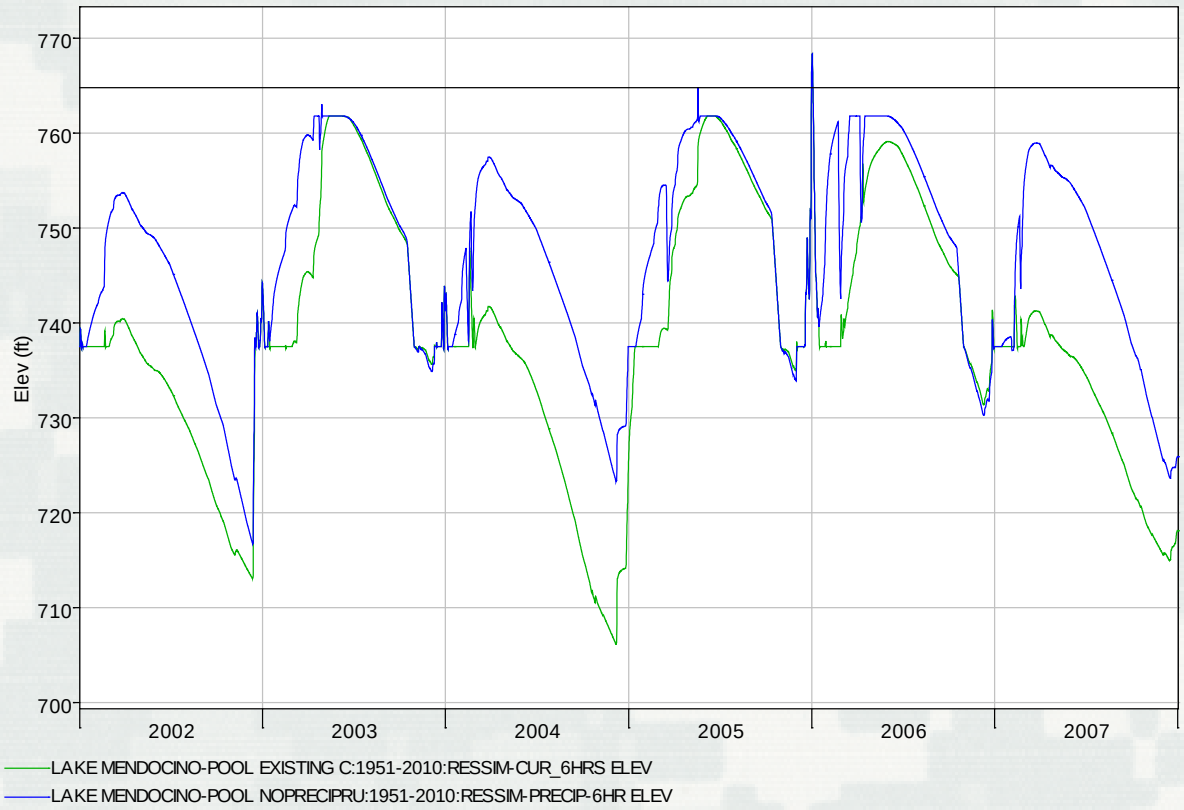
Precip Rule



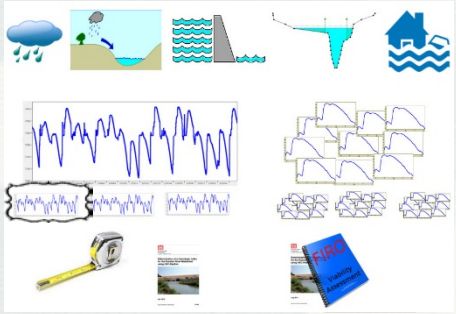
- Simplest type of FIRO rule – hold water after event passes.
- Specific model implementation involved thresholds for forecast duration and cumulative precipitation.
- This analysis assumes perfect forecast, but also usually the forecast with most skill.
- Effective for filling reservoir to summer pool, but may hurt Hopland.



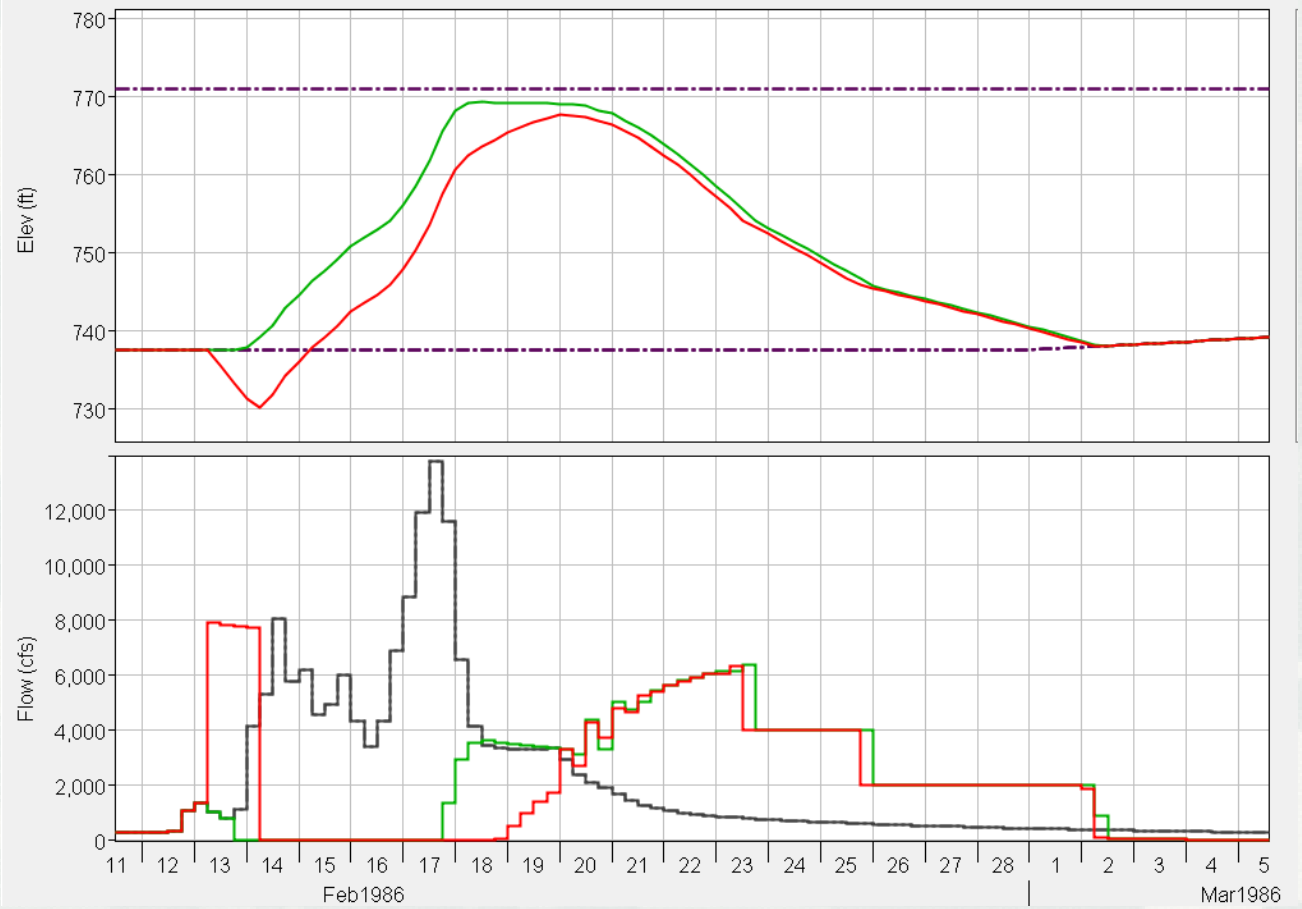
Precip Rule Formulation



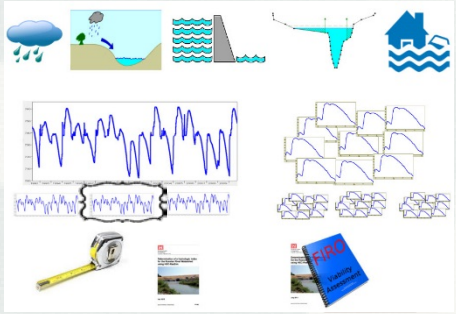
- More fluctuation at Hopland but helps more than hurts (pre-release vs no backfilling)
- Victim of own success in Spring because pool closer to target level
- Set target level higher then dialed back down. Tried lower ceiling Jan-Feb, and special May rule.



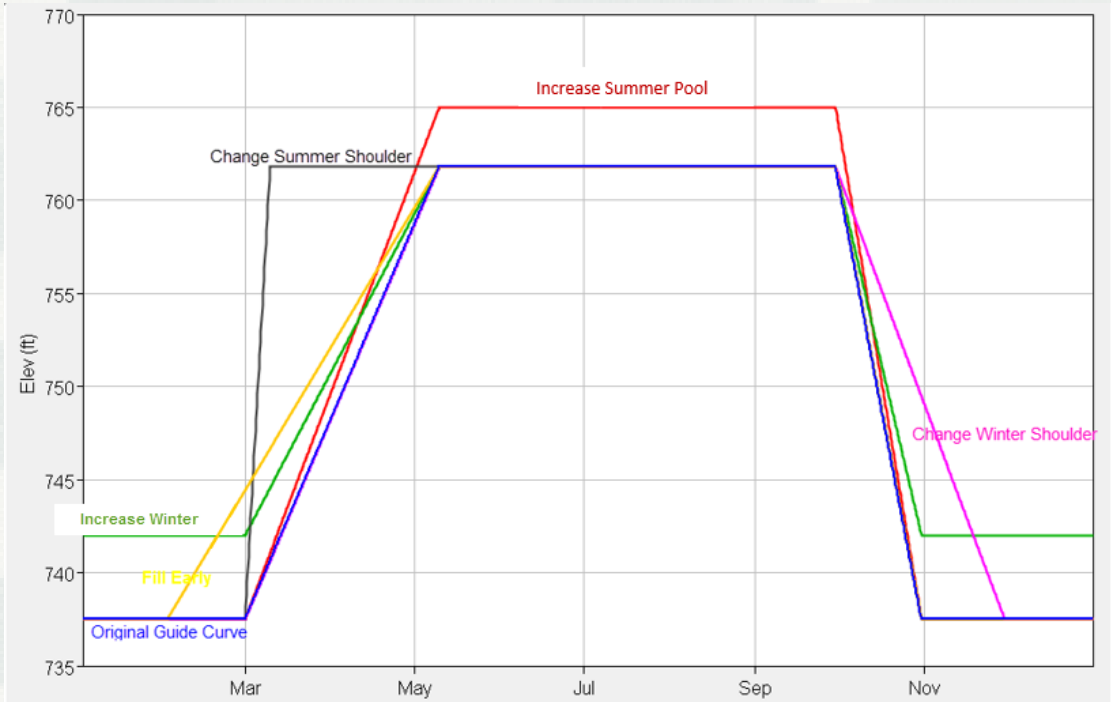
More Complex Alternative



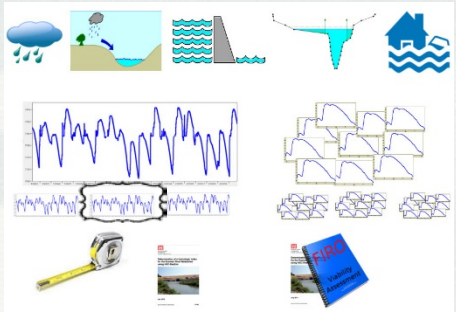
The results in red show the pre-release option as a function for forecasted reservoir inflow.



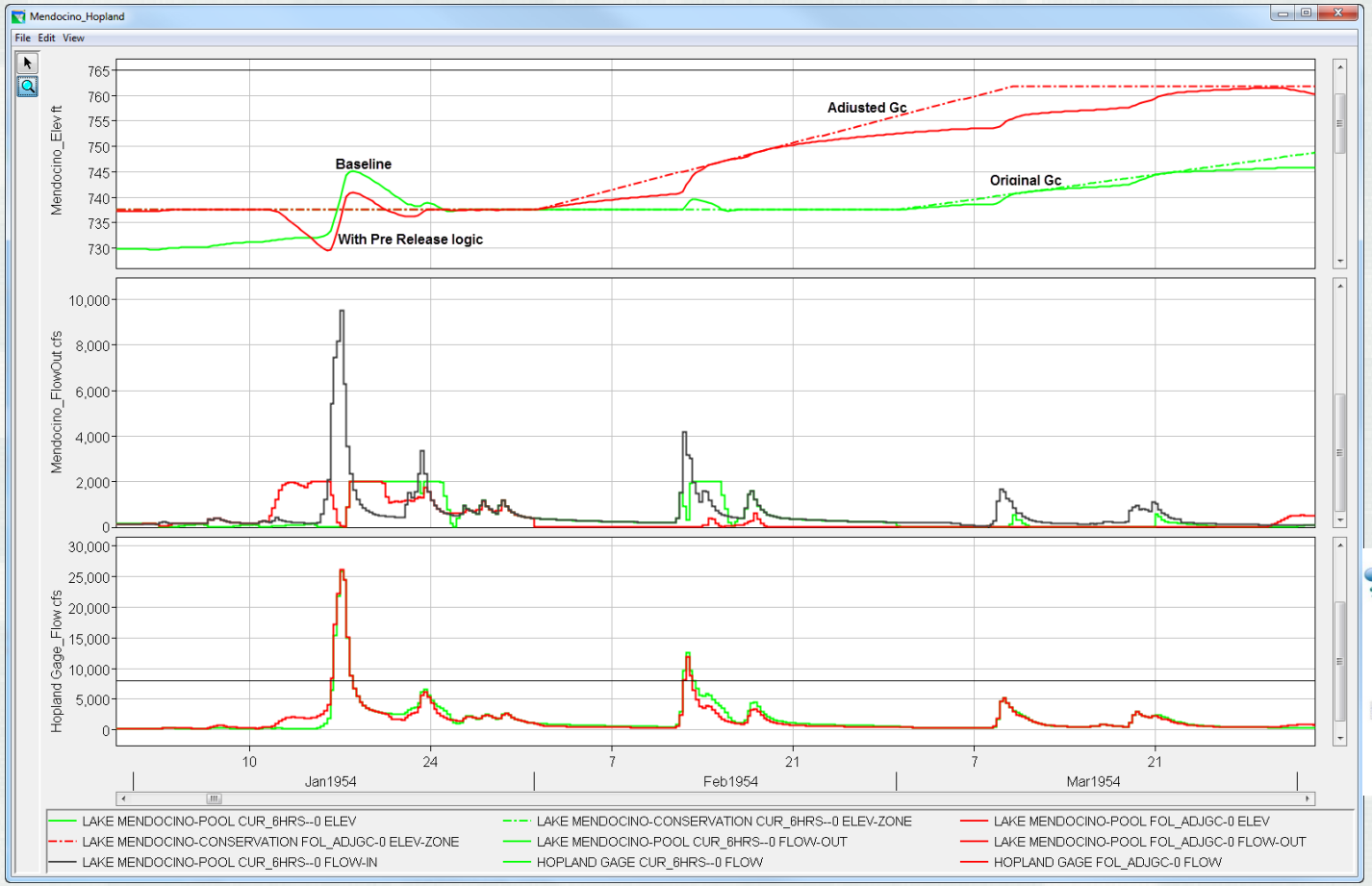
Inflow Forecast Alternative Guide Curve Adjustments

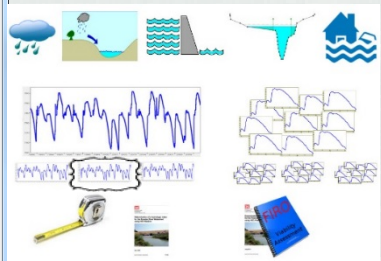


- **Increase Winter Pool**
- **Increase Summer Pool**
- **Change Winter Shoulder**
- **Change Summer Shoulder**
- **Fill Early**

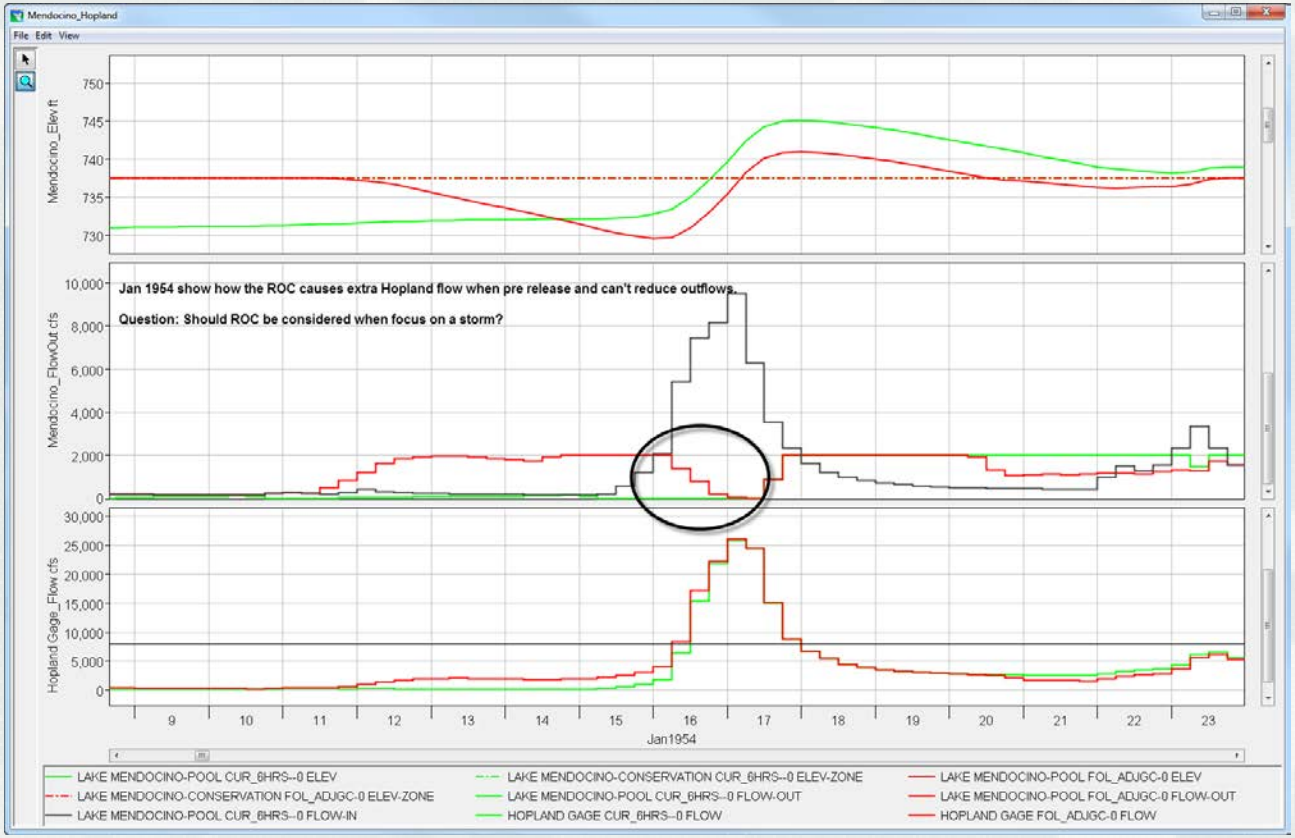


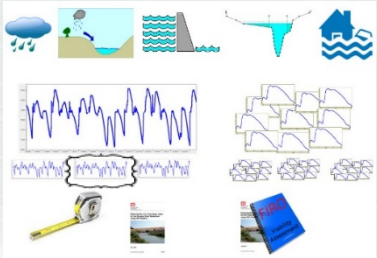
Inflow Forecast Alternative Typical Operations



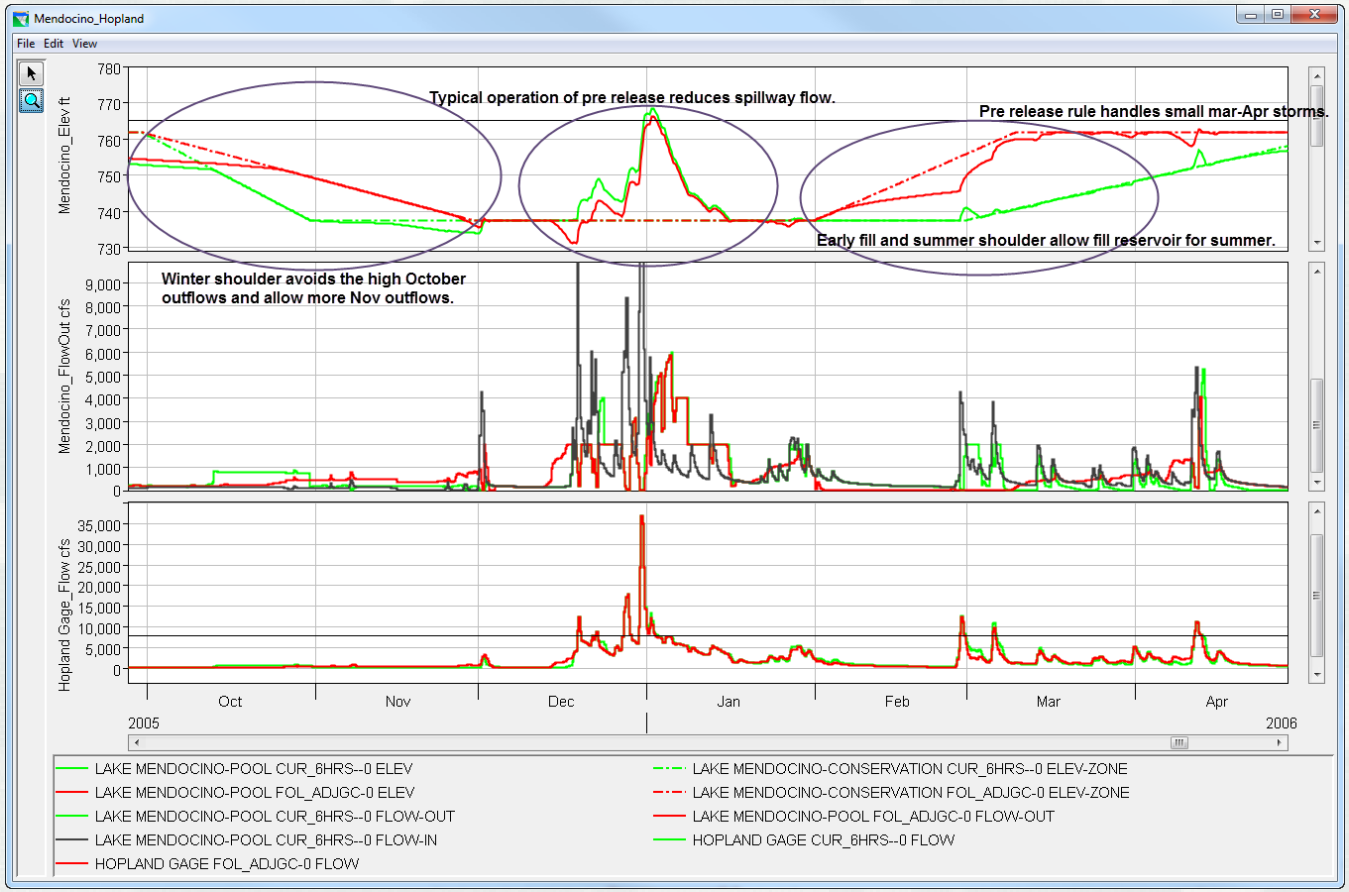


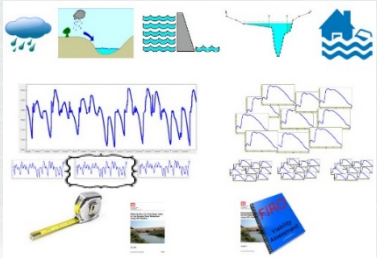
Inflow Forecast Alternative Impact of ROC



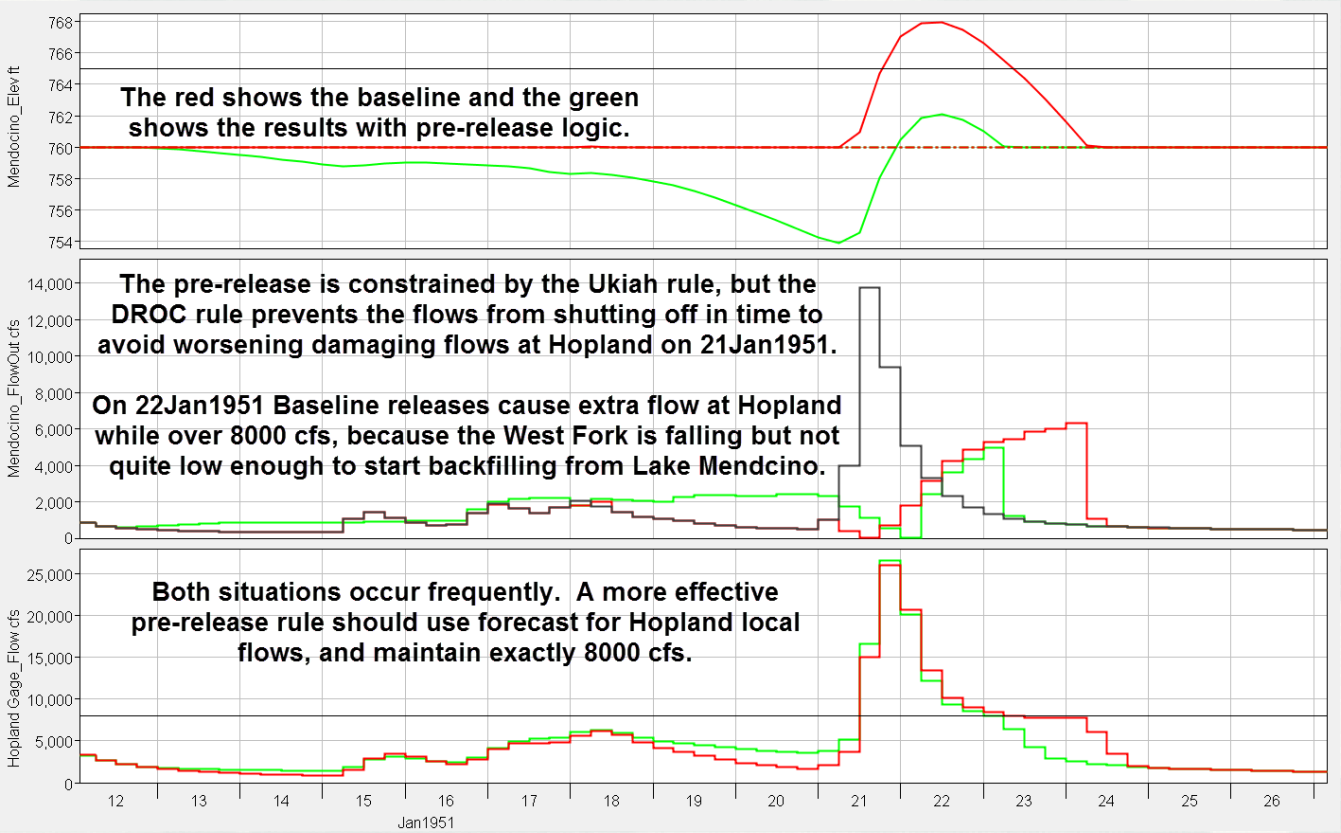


Inflow Forecast Alternative during 2006 Event

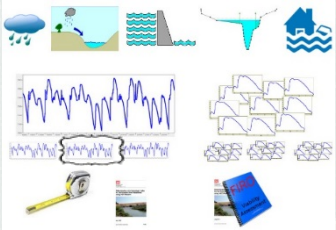




Next Step for Forecast Inflow Rule

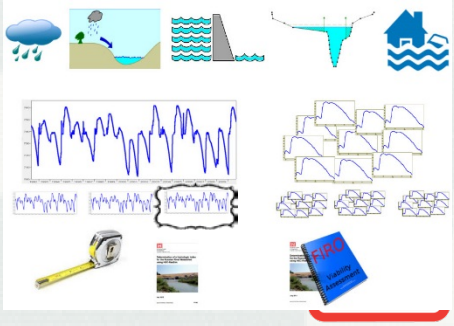


- Forecast-Informed Hopland Rule
- Some type of banding or encroachment, perhaps influenced by soil moisture or climatic parameter



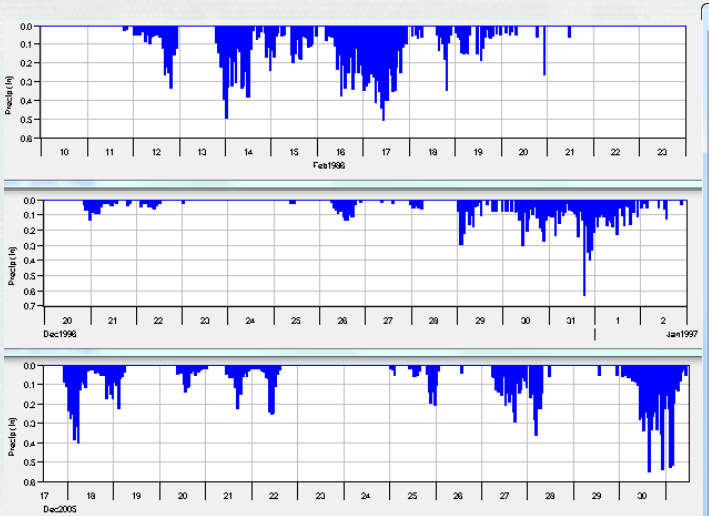
More Realistic Alternative

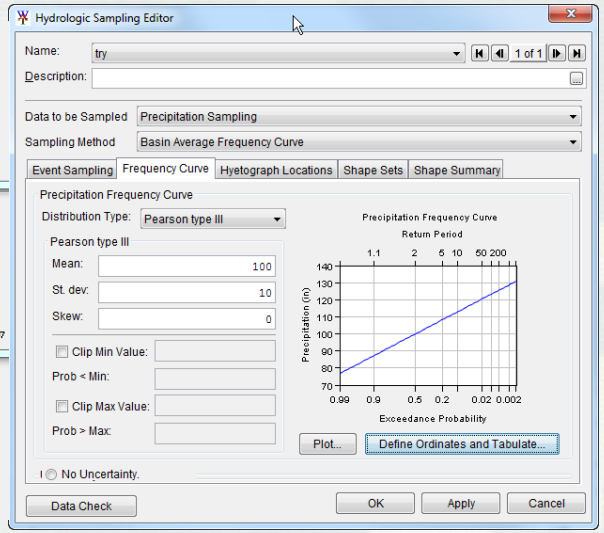
- Original intention to run one of the previous FIRO alternatives but vary (degrade) the forecast information with some type of uncertainty.
- Collaboration with Scripps suggests more useful approach formulating a new alternative based on some representation of forecast skill.

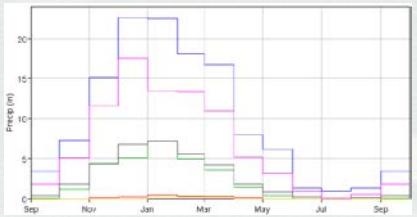


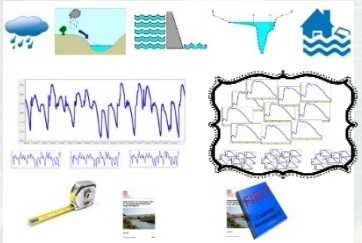
Hydrologic Sampler

- Define historical hyetographs, scaling, and sampling parameters
- Run thousands of synthetic events through the models to get best estimate of uncertainty in results

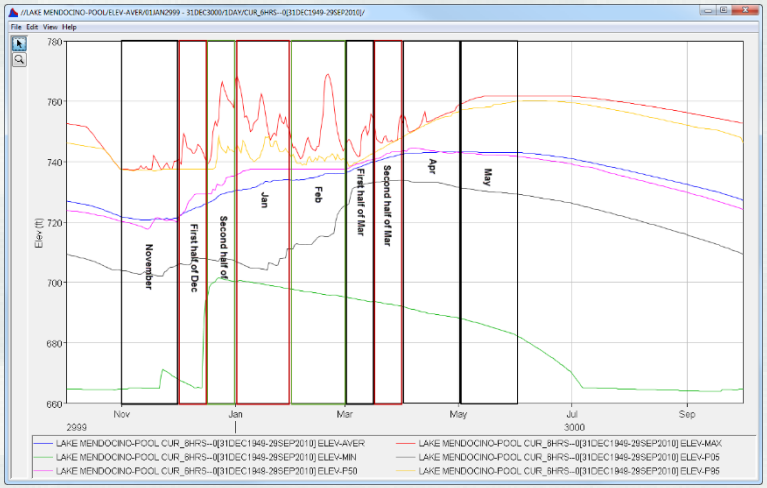




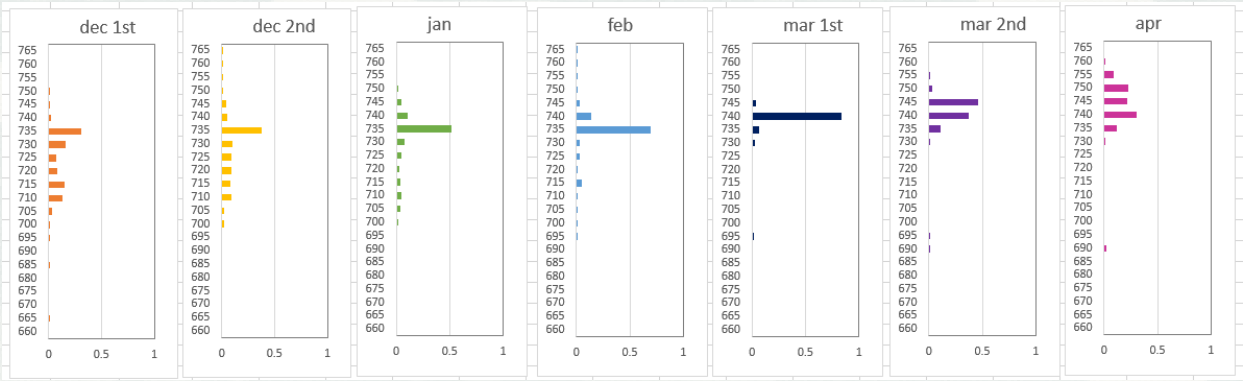


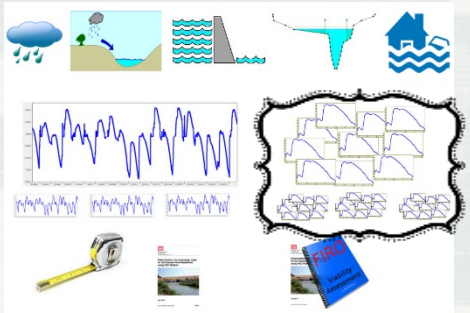


Initial State Sampling



- Choose seasons based on cyclic analysis of baseline
- Determine empirical distribution parameters for each season for pool level
- Repeat for each alternative reservoir plan
- Determine beta distribution parameters for each month for antecedent soil moisture (same all plans)

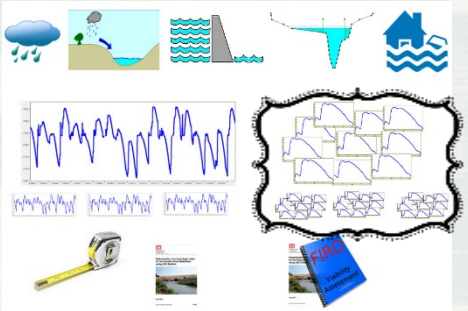




Distributed FRA Compute

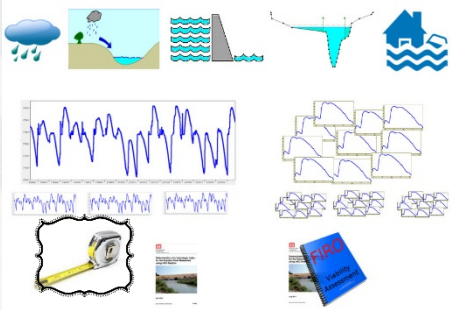
- Run Baseline across the HEC classroom computers
- Refine Skip Flags and Convergence

- Run Alternatives
- Gather and Analyze Results



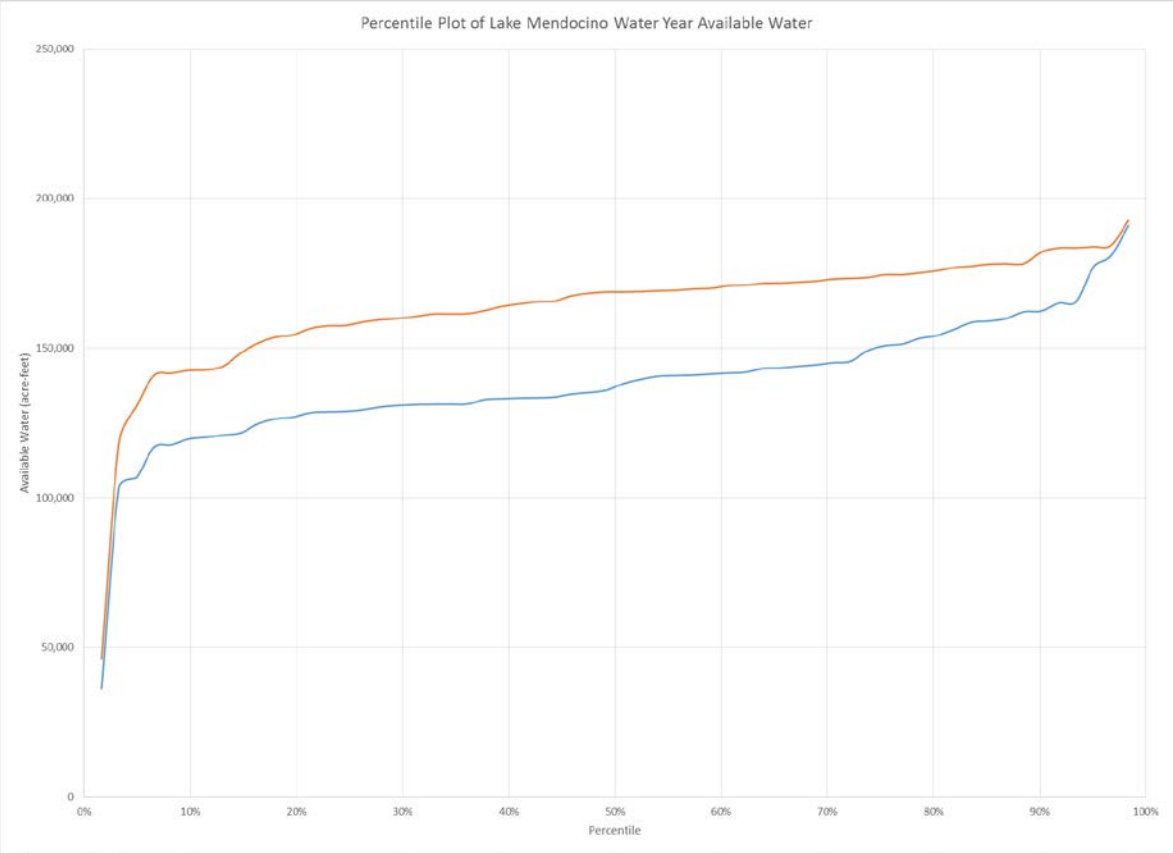
Comparison Metrics

- Annual Exceedance Probability (AEP) –
  - Lake Mendocino pool level
  - Flood stage at Hopland, Healdsburg, Guerneville
- Expected Annual Damage (EAD) – Basin Total
- Available Water
- NMFS Target

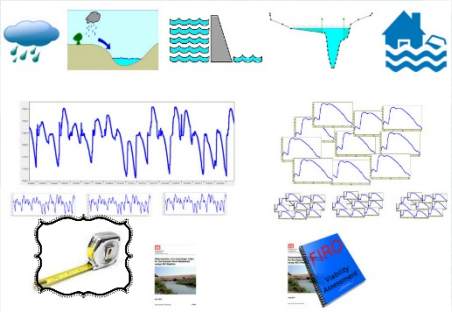


BUILDING STRONG®

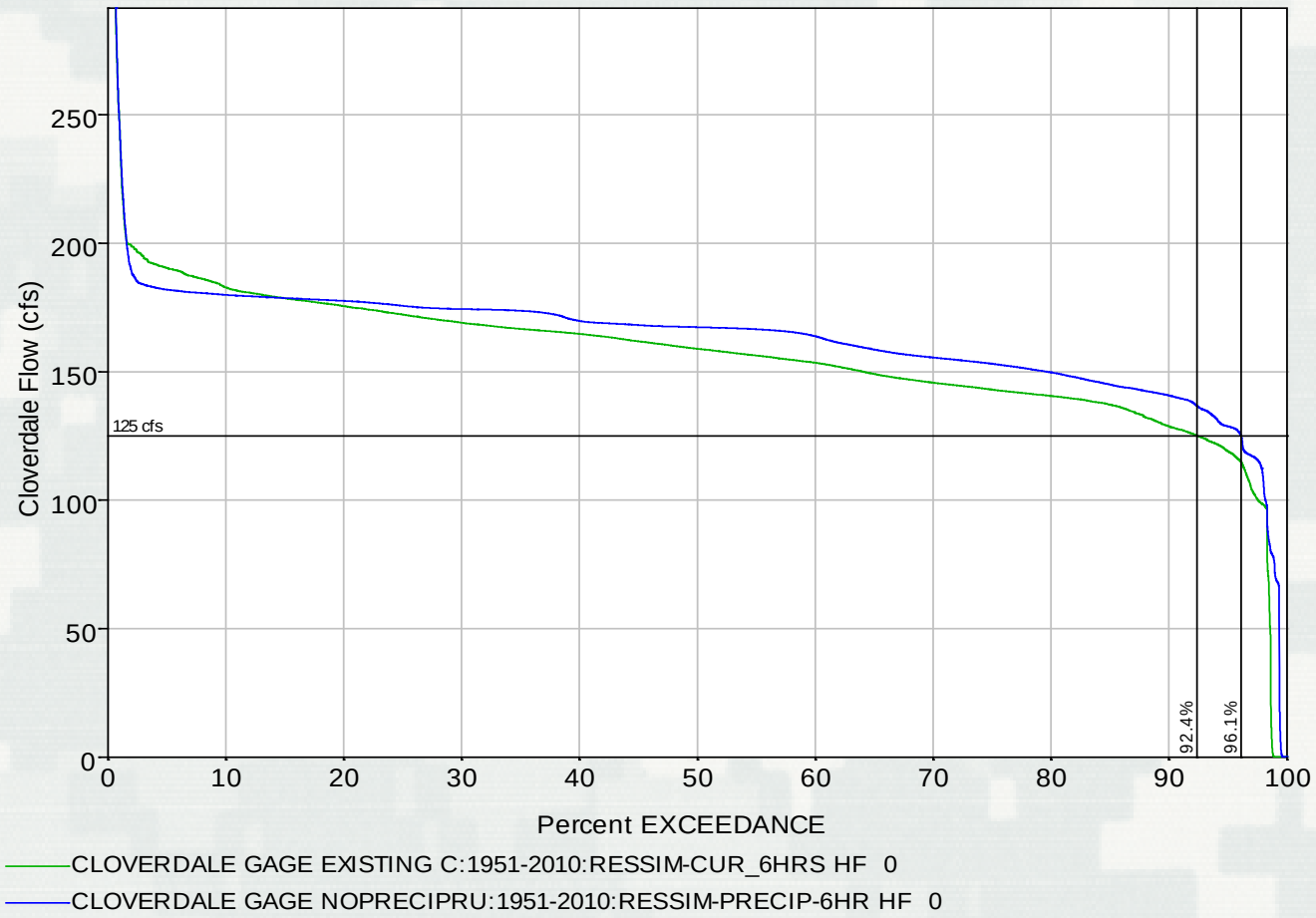
Available Water Metric



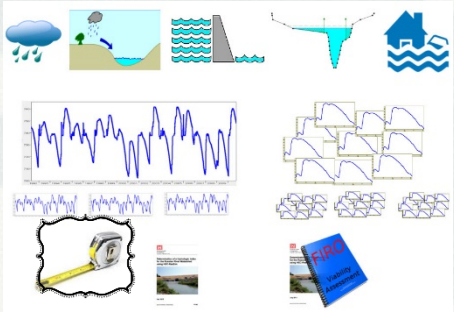
- Considers both EoY storage and minimum flows sustained during March-November
- No Precip Rule 50% likely to have 35 kaf more AW
- No Precip Rule 90% likely to have 25 kaf



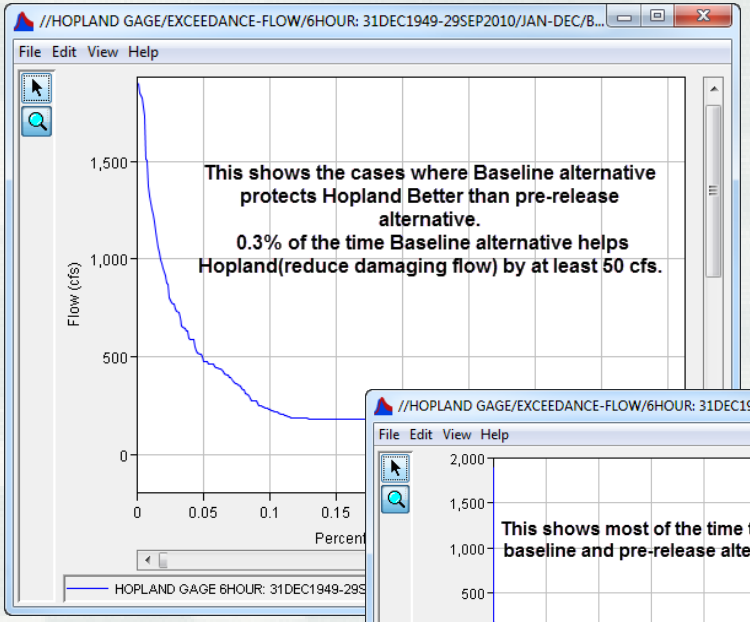
Happy Fish Metric

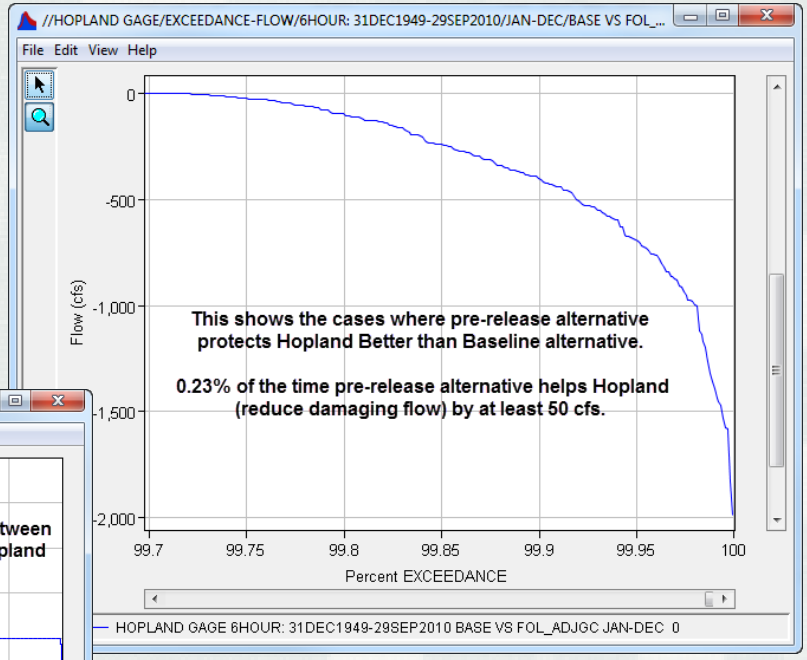


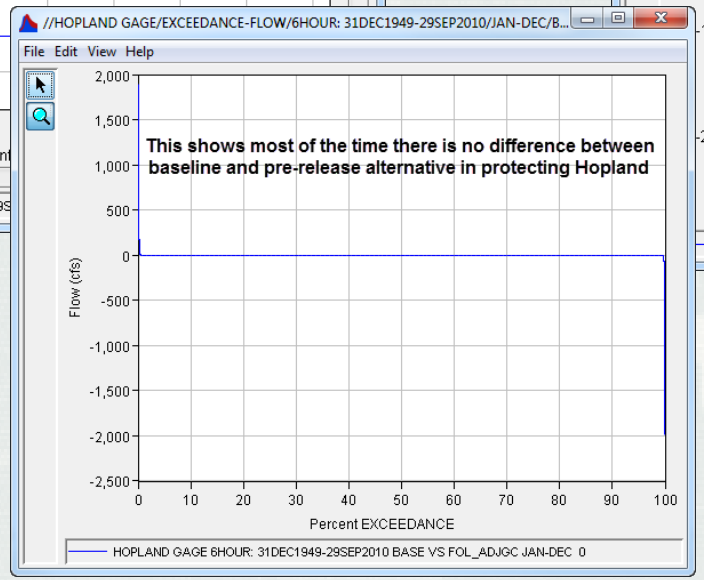
- Duration analysis of June-Sep flows at key location (Cloverdale)
- “Precip” Alternative outperforms for the 125 cfs threshold 96% vs 92%

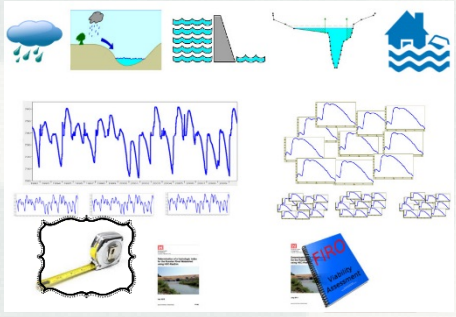


Hopland Damaging Flows

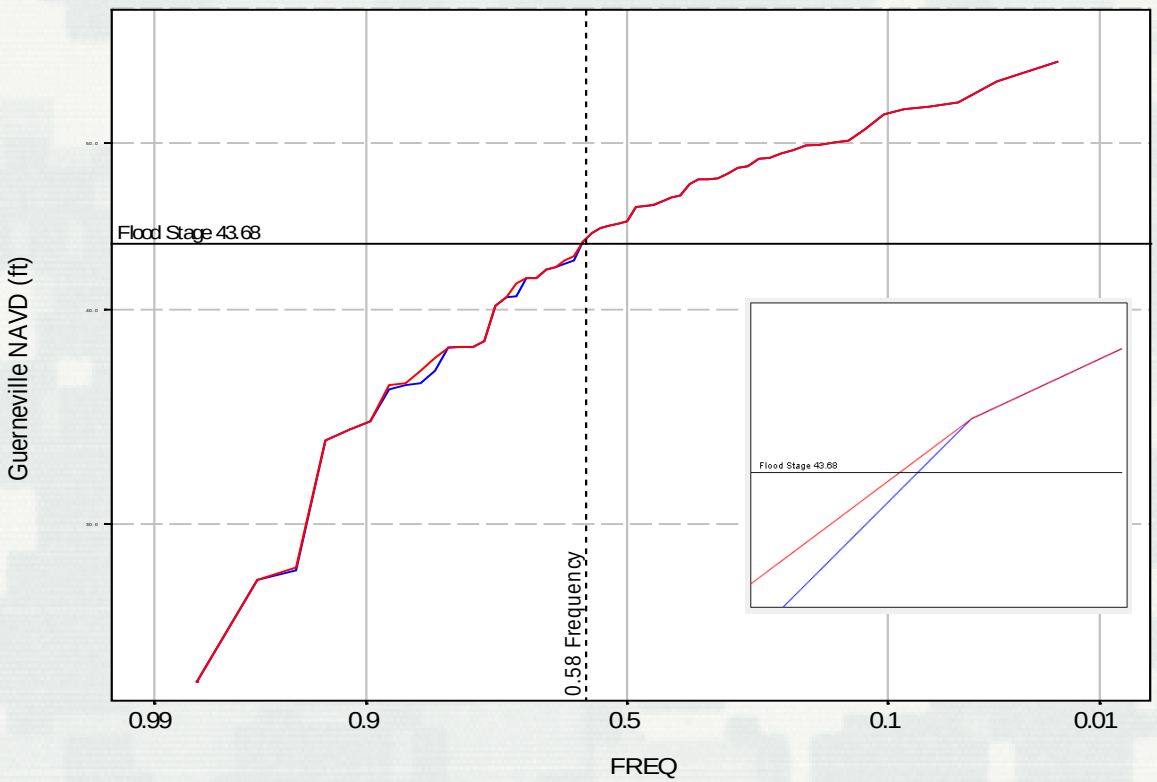




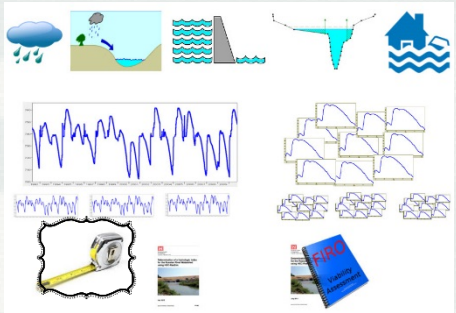




Annual Exceedance Probability



- Show difference in frequency of flood stage or other significant elevation for each alternative
- Show difference for each alternative in stage corresponding to key frequency such as 1% event.
- Plotting positions vs B17B



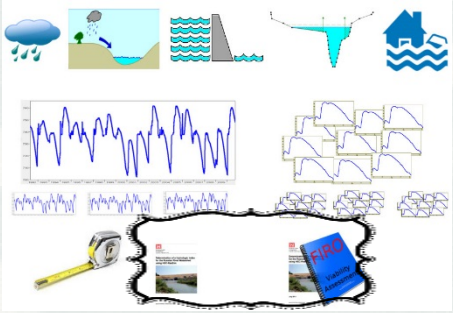
Next Steps

Remaining Work

- Finish formulation of alternatives, finalize PoR results
- Finish Hydrologic Sampler parameters
- Enable distributed computing, perform FRA computes
- Analyze results, prepare Project Report
- Adapt relevant sections to Viability Analysis

Further Opportunities

- Analysis of additional FIRO alternatives
- Other potential uses of tools and data
- Insights regarding most useful forecast information for crafting operating rules



Questions