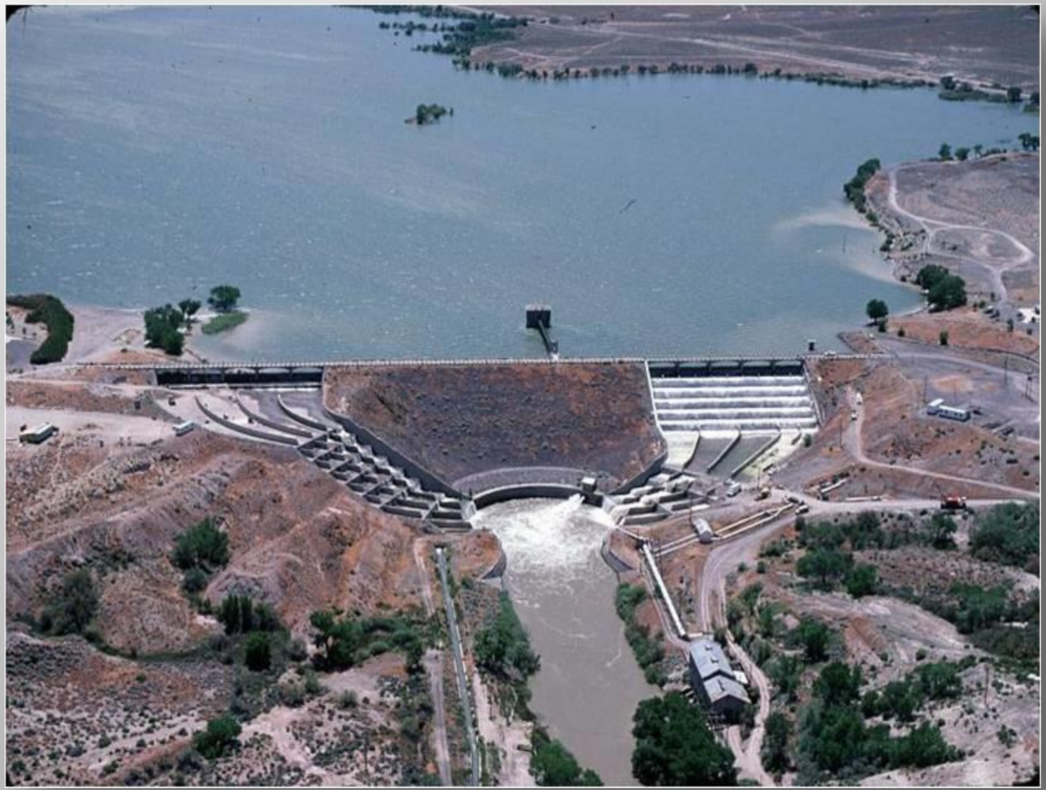
Impacts of Improved S2S Forecasts on Truckee - Carson Basin Operations

Western States Water Conference Workshop
May 19th, 2017



Shane Coors, PE
Precision Water Resources Engineering
www.precisionwre.com

Precision Water Resources Engineering

"Stewardship Through Technology"

- Founded in 2008, headquartered in Loveland, Colorado
- We develop and apply state-of-the-art technological water management tools in close collaboration with water managers of large, complex and contentious water systems
- Industry leader in development and application of RiverWare modeling tools. (www.riverware.org)
- Long-term ongoing projects in :
  - Truckee-Carson River Basin
  - Colorado River Basin
  - Arkansas River Basin
  - Colorado-Big Thompson Project
  - San Juan River Basin
- Clients include:
  - Federal Agencies
  - State Agencies
  - Municipalities
  - Research Institutions

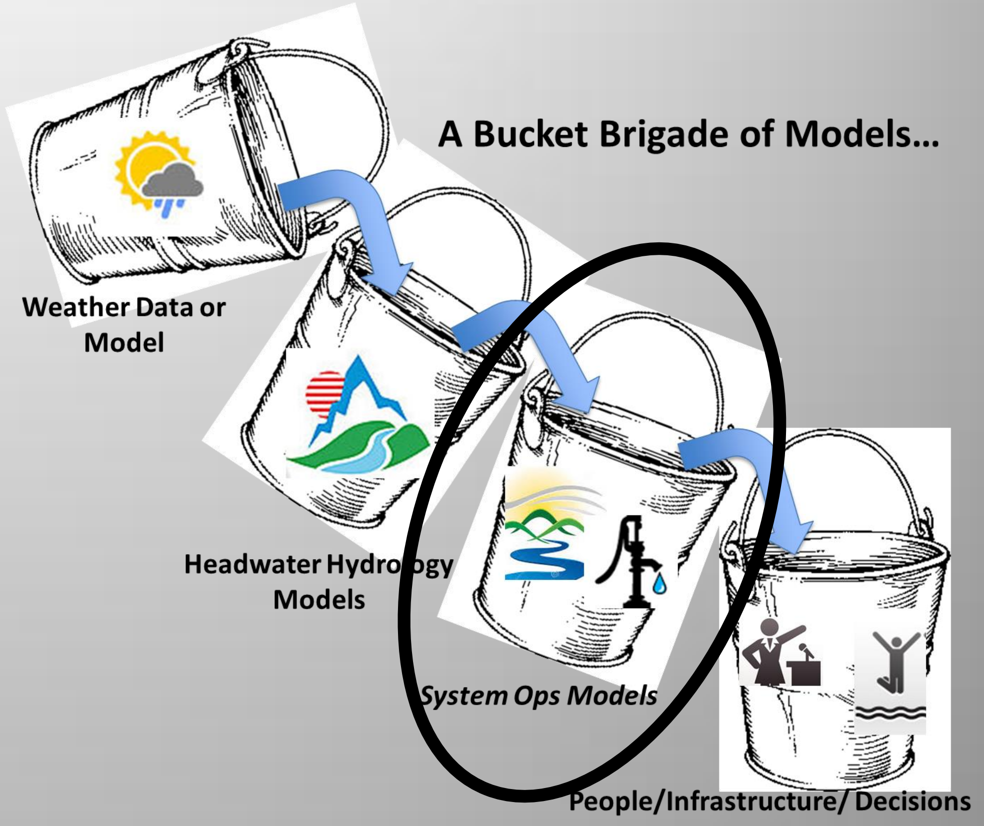
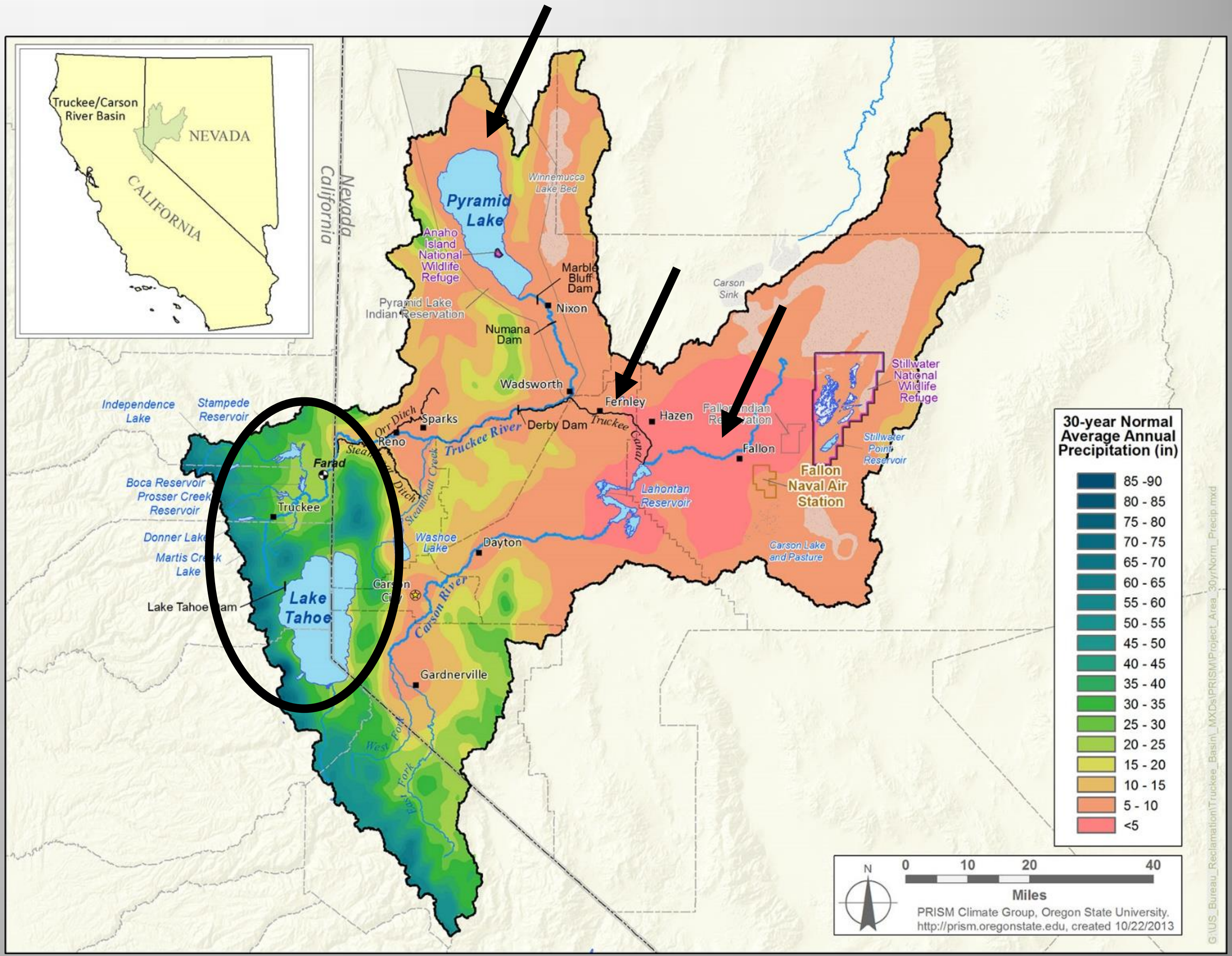


Figure courtesy of Mike Dettinger, USGS

Truckee–Carson Basin Introduction

- Truckee River is ~100 miles long, flowing from Lake Tahoe to Pyramid Lake
- Seven upstream storage reservoirs that regulate ~70% of the basin water supply
- Majority of the water originates in California (Sierra Nevada Mountains)
- Majority of the water usage is in Nevada
- The river ends in a desert terminal lake, Pyramid Lake in the Great Basin
- Water is diverted from the Truckee Basin to the Carson basin via the Truckee Canal at Derby Dam
- The Newlands Project is served by the combined Truckee and Carson River in the lower Carson River basin



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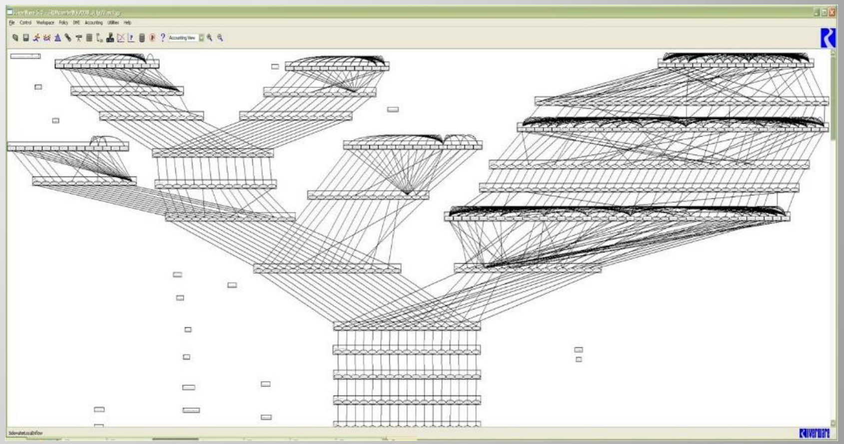
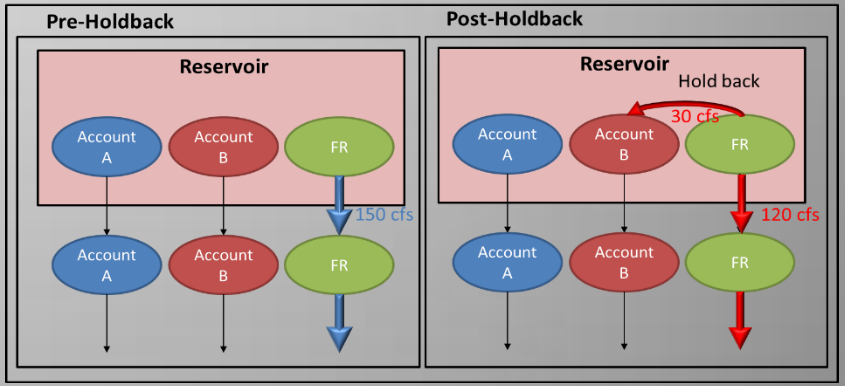
TROA Introduction

- Origin – Public Law 101-618 - Under the 1990 Settlement Act, Secretary of the Interior is directed to negotiate an operating agreement for the Truckee River Reservoirs
- Purpose – To improve operational flexibility and efficiency of Truckee River reservoirs while satisfying water rights in conformance with existing decrees
- Signatory Parties
  - Secretary of the Interior (United States)
  - State of California
  - State of Nevada
  - Pyramid Lake Paiute Tribe
  - Truckee Meadows Water Authority
- Signed into law in 2008. Implementation began on December 1st, 2015
- The primary tool for implementation of the agreement is a RiverWare operations/accounting model run by the TROA Administrator/Federal Watermaster

TROA Characteristics

- TROA establishes mechanisms (credit water establishment, exchanges, etc.) by which stakeholders can utilize their water resources more flexibly and efficiently
- Stakeholders can propose and schedule mutually beneficial transactions (exchanges and trades) whereby diverse objectives can be achieved
  - Environmental benefits (enhanced instream flows, habitat maintenance)
  - Hydropower generation
  - Drought resiliency
  - Recreational flows and reservoir levels
- These transactions require much more precise and demanding water accounting and operation of the reservoirs
- Parties are less inclined to enter into these potentially beneficial, but voluntary transactions when outcomes are highly uncertain
- Hydrologic uncertainty is the greatest source of uncertainty in future conditions

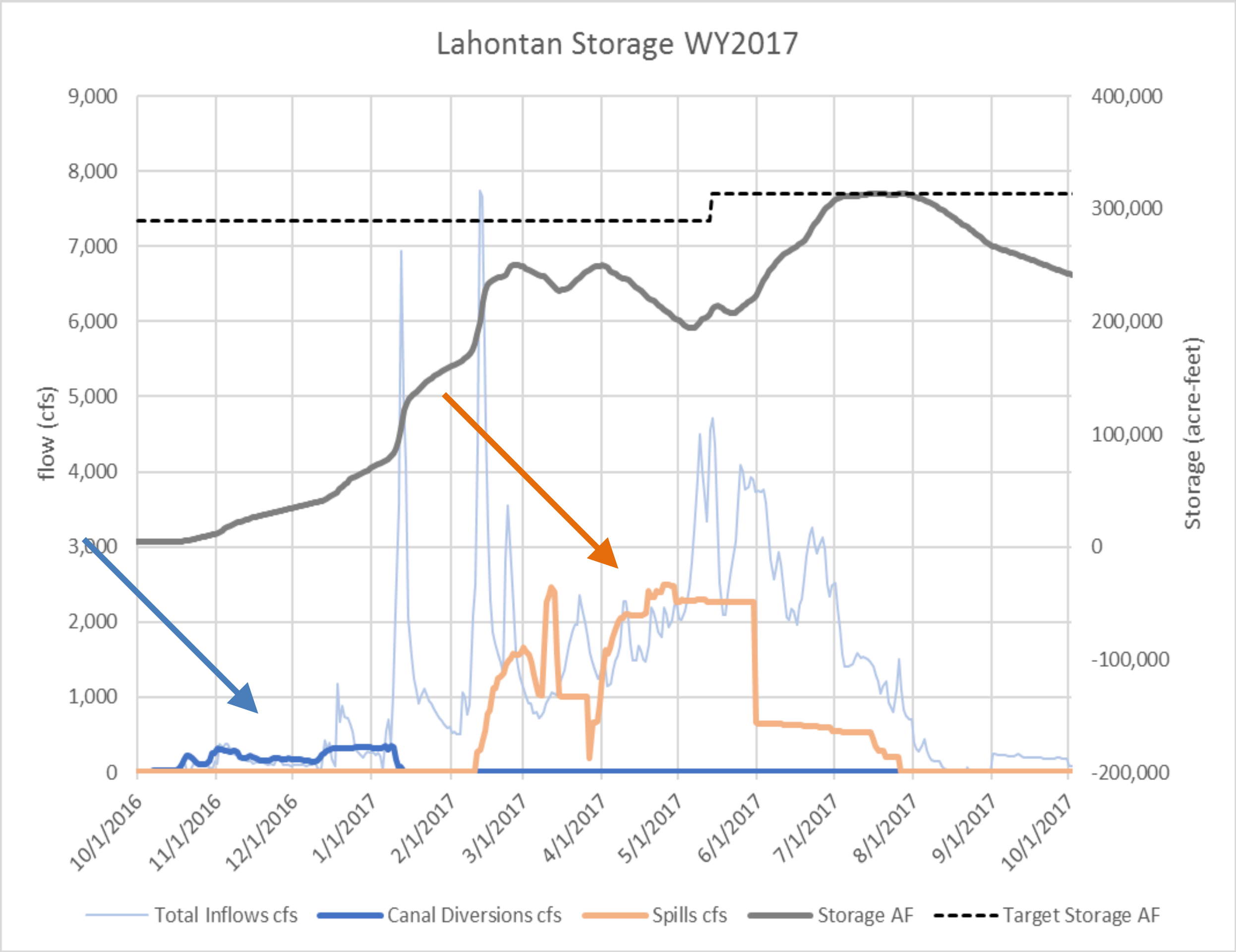




Lahontan-Truckee Canal Diversions

Example #1

- Lahontan reservoir stores inflow from the Carson River, supplemented by diversions from the Truckee River through the Truckee Canal
- In late 2016 per OCAP, 40 KAF was diverted through the Truckee Canal to Lahontan Reservoir because of very low storage
- Record inflows to Lahontan Reservoir from the Carson river occurred during early 2017
- Current projection is 440 KAF will be spilled this water year, requiring significant investments to facilitate this release.
- Had record high January and February inflows been foreseen in November, diversions could have been avoided, reducing the required spill.



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Fish Water Operations

Example #2

- Pyramid Lake is home to one endangered fish species, the Cui-ui, and one threatened species, the Lahontan Cutthroat Trout
- 2015 was the 4th consecutive dry year in the Truckee System, and the driest April-July runoff volume on record
- Storage in Stampede reservoir, which is designated for the Pyramid Lake fishes, was retained in Fall of 2015 despite very low flows in the lower river
- If it had been known that 2016 would return to average, minimum flow targets could have been achieved, significantly reducing stress on the fish

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From Improved Climate Forecasting to Improved Water Operations

- Operations and planning in the Truckee-Carson basin will certainly benefit from improved skill in S2S forecasting
- BUT… water managers have an important role to play in propagating forecasting improvements to actual realized benefits to the basin and its stakeholders
- Improvements in S2S forecasting should be more appropriately thought of as reduced uncertainty in future climate
- To realize these benefits, tools and techniques must be in place that enable robust operational decision making across the entire forecast range (even at current levels of uncertainty in S2S climate forecasting)
- With these tools and techniques in place, even small incremental reductions of uncertainty in forecasts can translate to improved operational precision and efficiency
- Water managers must develop tools and techniques that propagate uncertainty in climate forecasts to uncertainty in operations forecasts of water systems

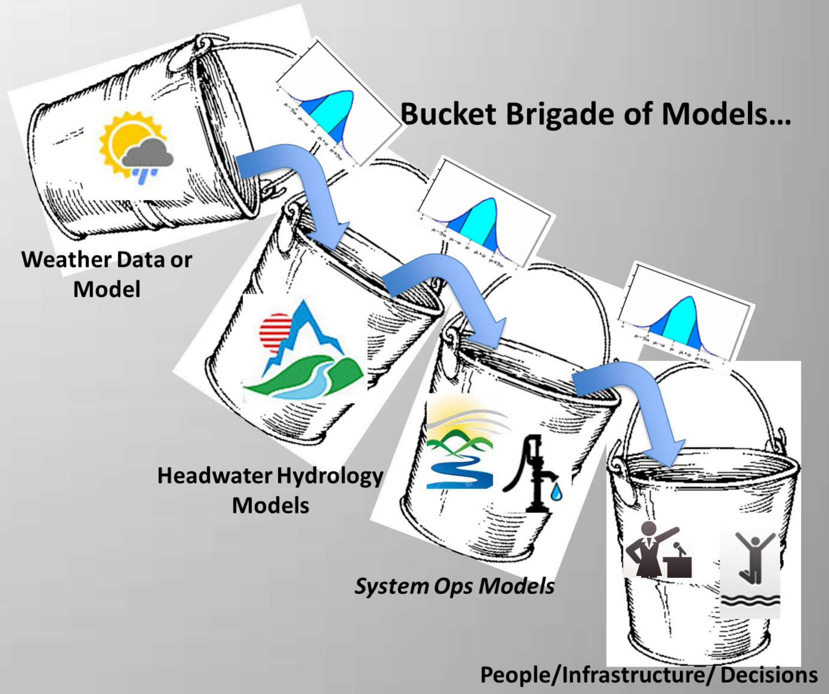


Figure courtesy of Mike Dettinger, USGS

Uncertainty Propagation Technique

“The Problem”

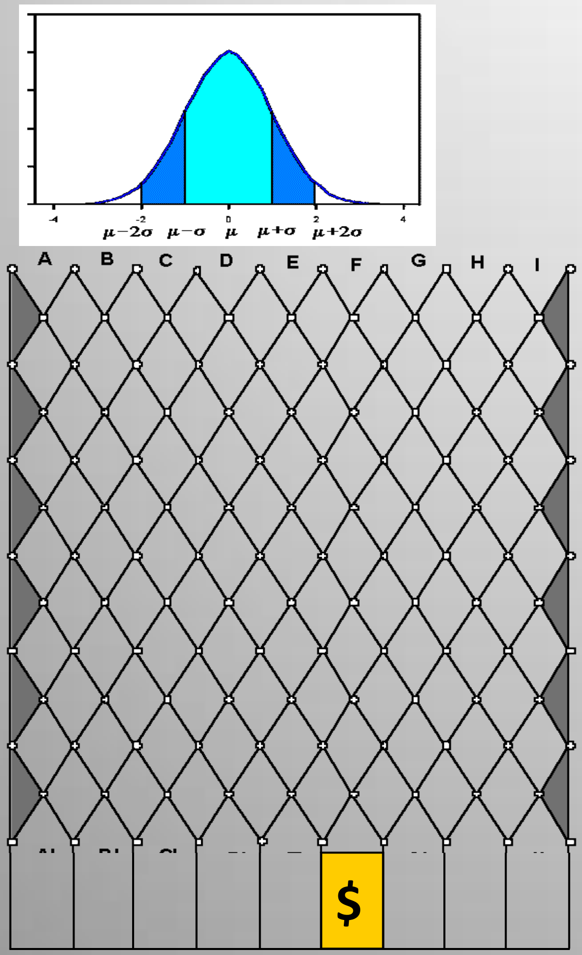
• Water resources system models do a good job of accurately simulating physical processes and operational policy in a river system.

• There is uncertainty in model inputs such as demands, losses, return flows, and many others. But the largest source of uncertainty is the hydrologic forecast uncertainty, which is driven primarily by uncertainty in climate

•A “model run” assumes a single value for each of these quantities. It is almost certain, however, that the selected values are not accurate.

• Output from a model run gives no information about the level of uncertainty in its results.

Uncertainty Propagation Technique



The Game

1. One ball is dropped
2. Cost to buy output slot - $1000
3. Payoff for correct forecast - $5000
4. Input location is unknown
5. Probability distribution of input location is known

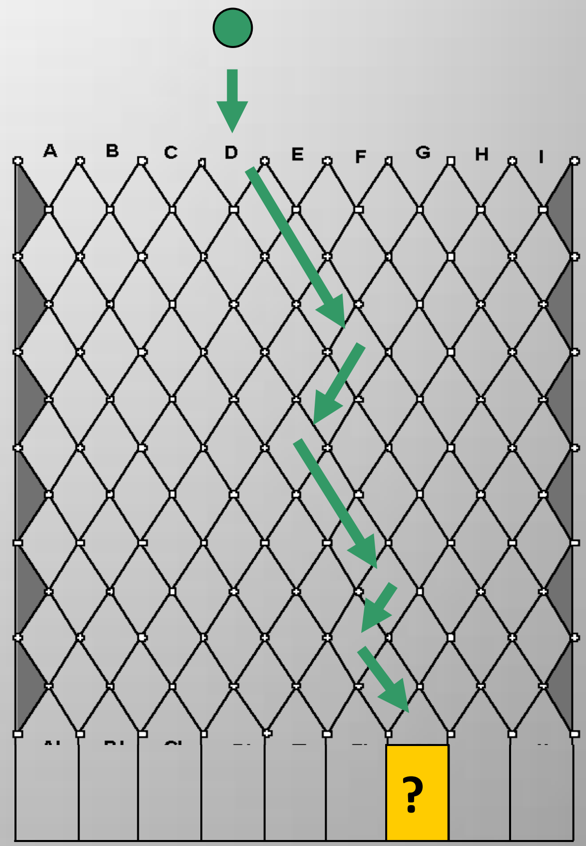
Assessment: 1 in 9 chance of winning 5X the entry cost. Playing this game is a gamble, and a losing proposition over time. Need some help to make playing worthwhile.

Uncertainty Propagation Technique

Player #1 - Strategy

1. Develop model for decision support
2. Assume highest probability input location
3. Run the model to simulate path of ball
4. Note modeled outlet location
5. Question: Given the result of the model run, should Player #1 spend $1000 to play for real???

Assessment: Even after running simulation model, playing the game is still a gamble. Though Player #1's chances of winning are improved, there is no basis for deciding whether it is worth the cost to play. There is no assurance that Player #1 will be ahead playing the game over time. The uncertainty in the model result is unknown

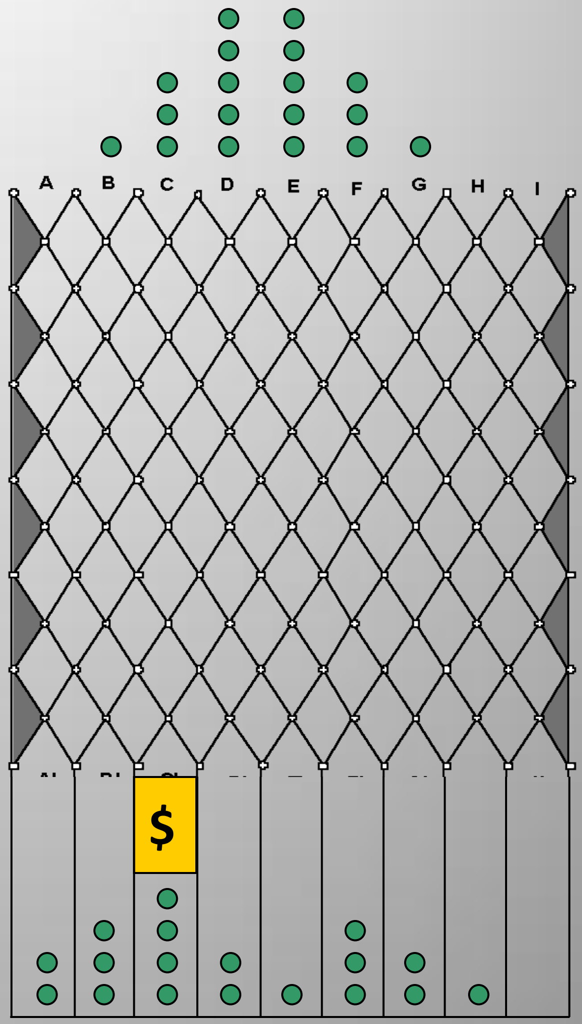


Uncertainty Propagation Technique

Player #2 - Strategy

1. Develop model for decision support
2. Assemble many inputs conforming to known input distribution
3. Use model to simulate path of each ball one at a time
4. Collect all output and generate output probability distribution
5. Question: After the ensemble of model simulations, should Player #2 spend $1,000 to play???

Assessment: Still don’t know where the ball will enter or exit on any given game. However after the many simulations and developing an output distribution, the player can quantify the likelihood of any outcome. This strategy provides a basis for deciding whether it is worth it to play, and can assure winning over time.



Uncertainty Propagation Technique

Implementation

- Current available hydrologic forecasting products characterize uncertainty in forecasted hydrology. River Forecast Center's ESP traces and NRCS statistical volume forecast are both utilized

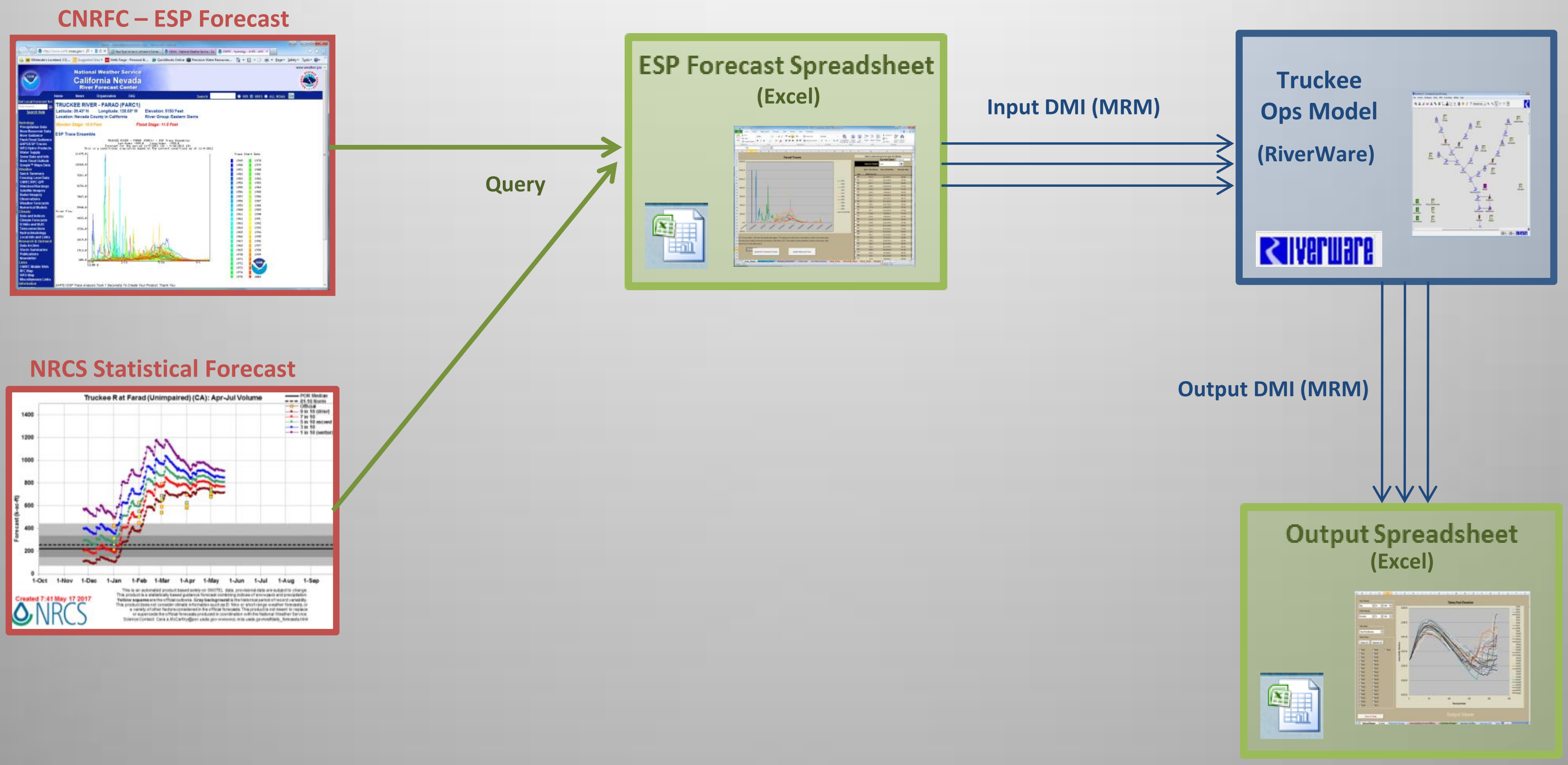
- Use each trace in the ensemble to drive a run of the system operations model (RiverWare TROA Operations Model) to simulate basin operations across a range of possible input hydrology

- Analyze the output from the model runs collectively to produce distributions for any key output quantities or conditions

- This system transforms the RiverWare model from a simulation model to a tool which propagates distributions (hydrologic uncertainty) from inputs to the outputs

- Decision-makers can make far better-informed decisions when provided with accurate uncertainties associated with critical future conditions in the system

Truckee Operations Modeling System



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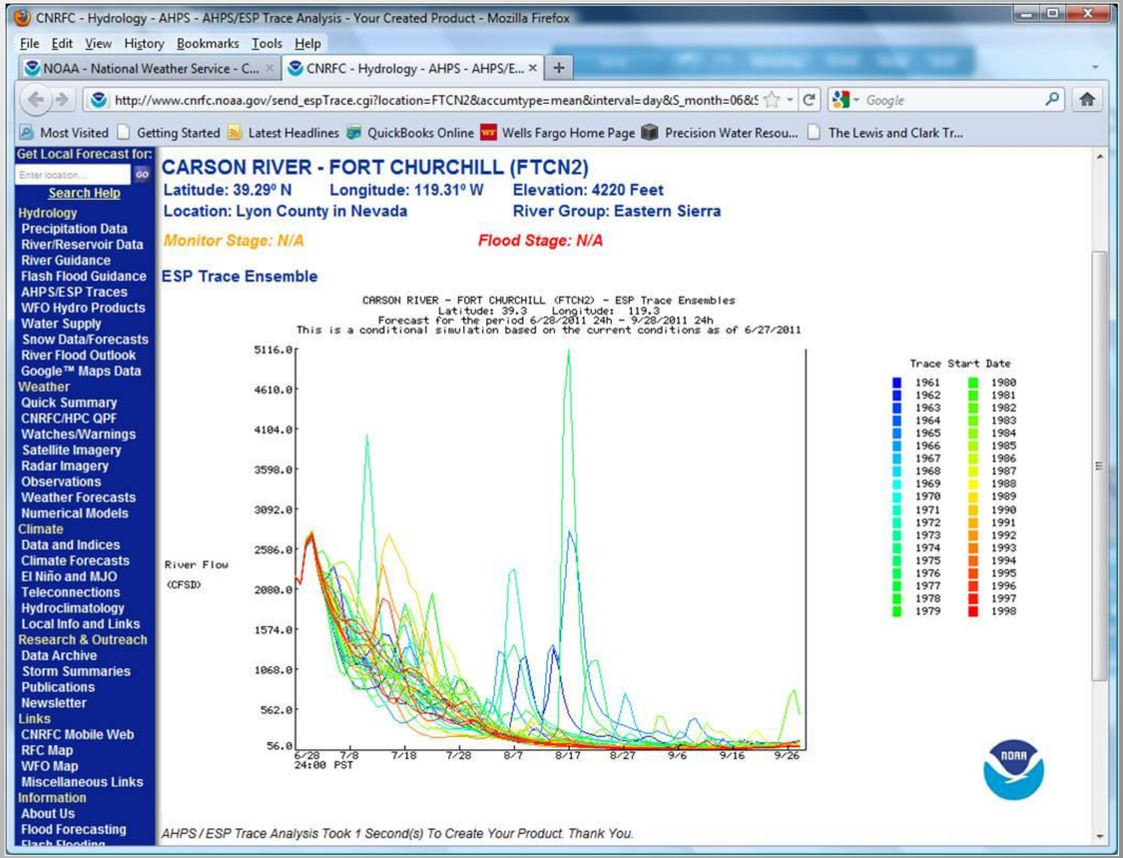
Hydrologic Forecast

Ensemble Streamflow Prediction (ESP) Forecast

- National Weather Service product (http://www.cnrfc.noaa.gov/ahps.php)
- Currently Truckee - Carson forecast nodes include 59 forecast traces corresponding to historic years 1950 - 2008
- Each trace represents streamflows that would occur if each historic year's temperature and precipitation acted on current hydrologic conditions in the basin
- Collectively the ensemble represents an estimate of the uncertainty in future inflows



Operation with Uncertainty Example

Lake Tahoe Releases - 2017

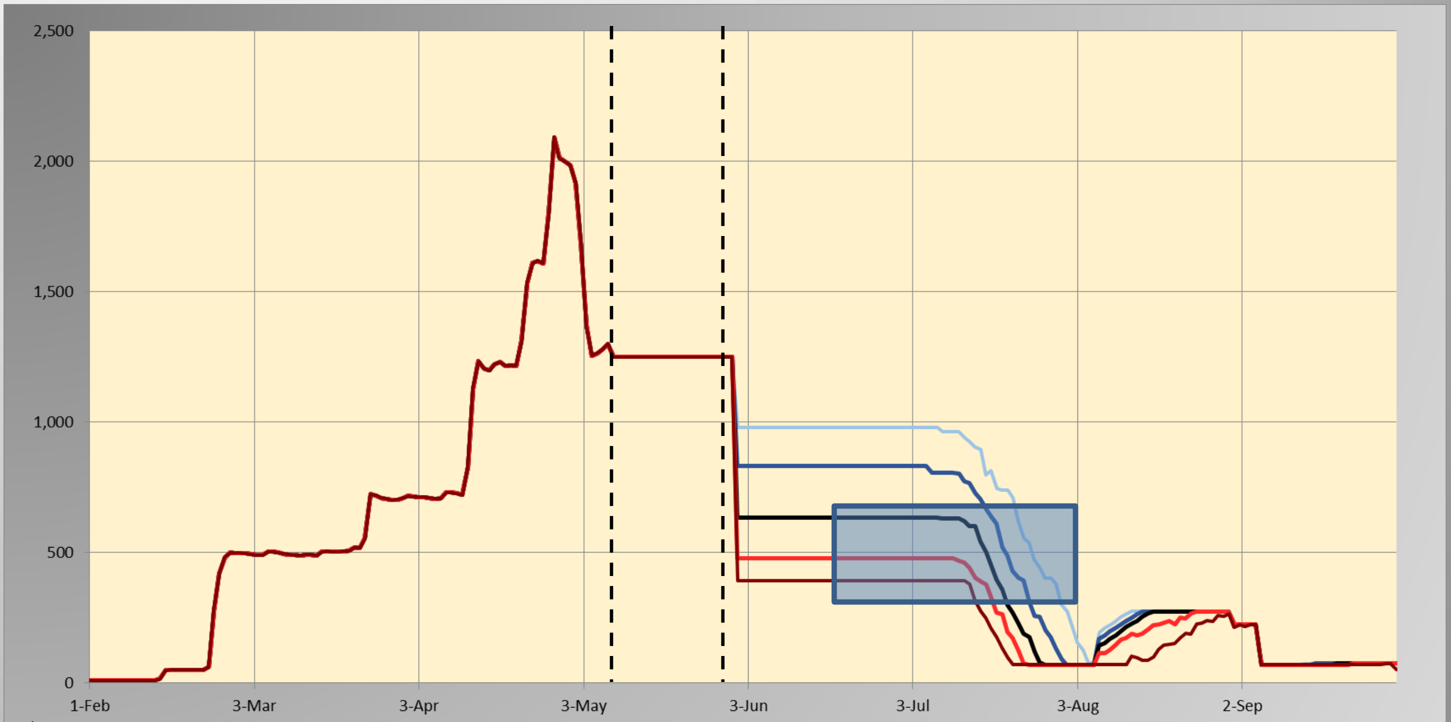
- 2017 has set the record for the most precip, deepest snowpack, and largest lake level rise to date in 116 years of record
- Federal Watermaster must spill to prevent the water surface elevation from exceeding its legal maximum (6229.1’)
- For water supply purposes it is also critical that the lake be filled up to the maximum
- During runoff, daily inflows can be more than 15,000 cfs.
- Maximum release is 2600 cfs
- Level control releases must be initiated well in advance of the peak inflow
- High degree of uncertainty in future hydrology exists when critical release decisions are made

Operation with Uncertainty Example

Lake Tahoe Releases - 2017

- Release schedule set on May 8th : Release 1,250 cfs until June 1st
- RiverWare Model run 59 times holding this schedule until June 1st , then operating each trace individually to achieve perfect fill
- Resulting range in flows post-June 1st is the current range of uncertainty in future operations given the current range of uncertainty in inflows
- Traces are counted to generate exceedance bands of the output ensemble
- The 1,250 cfs was chosen after multiple ensemble runs as the optimal release based on the range of post-June 1 flows
- Release schedule was designed by taking into account the entire spread of future conditions
  - Guaranteed step down
  - Low end is above minimum
  - Maximize chances for rafting

Lake Tahoe Outflow (cfs)



*Exceedance percentages display percentage of the 59 traces that exceed the specified value day-by-day

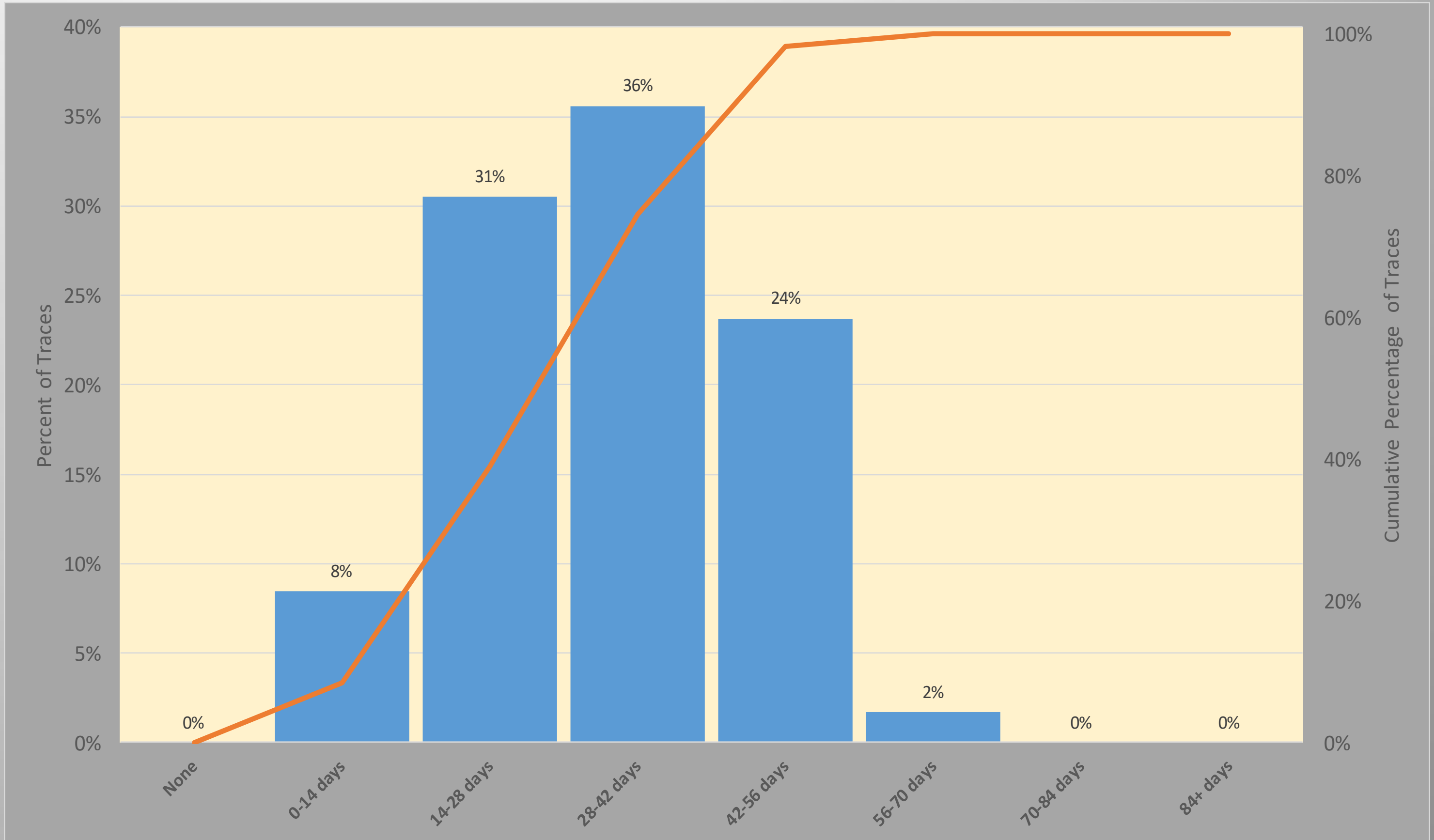
Operation with Uncertainty Example

Lake Tahoe Releases - 2017

So…will there be rafting in 2017?
What is the right answer?

- It's not "No"
- It's not "Yes"
- It is definitely "Maybe"
- Probability distribution that characterizes the uncertainty in future operational condition is the most correct and complete answer
- Decreased uncertainty in future precipitation will propagate through the model to decrease uncertainty in operational conditions and facilitate better answers

Number of days between July and Labor day of 200 cfs to 500 cfs



*% based on the number of traces in each category, 59 traces total.

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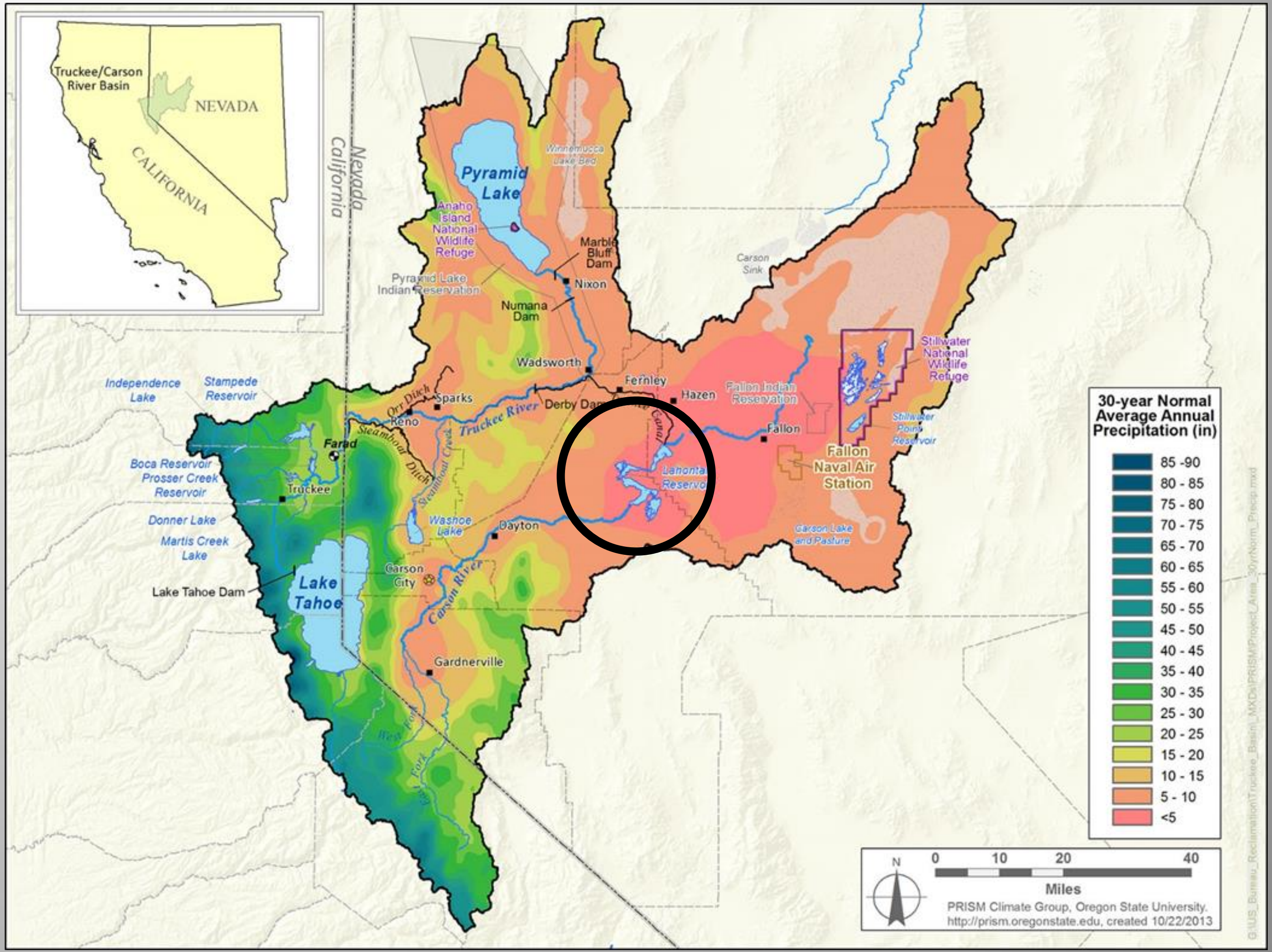
Operation with Uncertainty Example

Lahontan Releases - 2017

- Lahontan Reservoir is near the bottom of the Carson River with a capacity of 313,000 af
- Primarily a water supply reservoir for the Newlands Project, a ~55,000 acre irrigation project in the Nevada desert
- Provides flood protection to Fallon, NV but has no official flood criteria
- 2017 snowpack and expected runoff presented unprecedented challenges to operators
- Available storage space on April 1st was 63,000 af.
- April 1st median April-July runoff forecast was 530 kaf
- Going into the winter the stated maximum allowable release was 1,200 cfs



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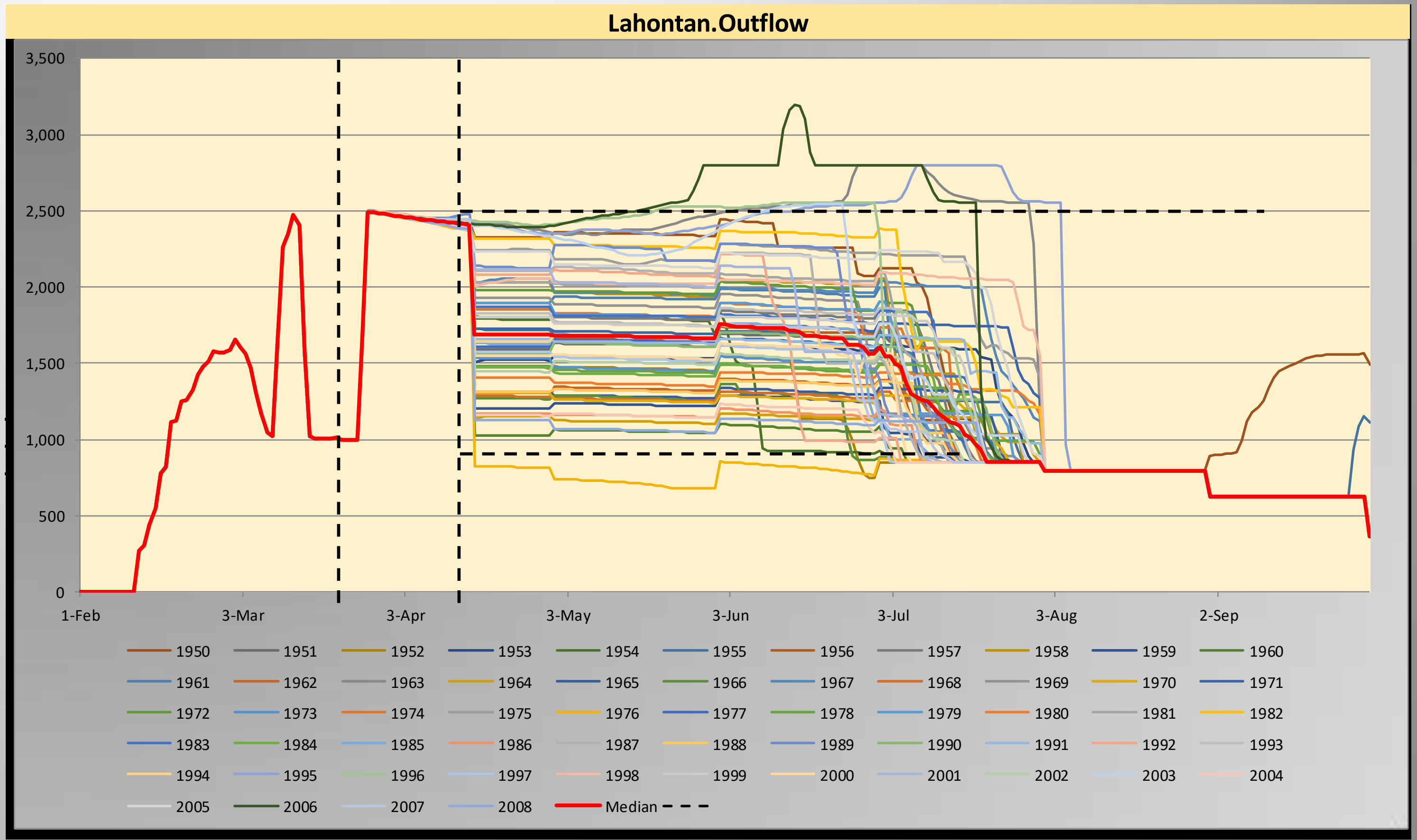
Operation with Uncertainty Example

Lahontan Releases - 2017

- In mid-March a problem with the outlet works of the dam necessitated reducing release to 1000 cfs
- Ensemble run of the RiverWare Model was made on March 23rd with a release schedule of max release through April 15th, then let model operate each trace to fill the reservoir
- Max controlled release ~2,500 cfs
- Min release (demands) ~800 cfs
- Traces outside of "operable" range on both sides
- Uncertainty in hydrology exceeded operable range. Now operators are crossing their fingers
- This illustrates operational decision-making that considers the entire range of operational forecast uncertainty



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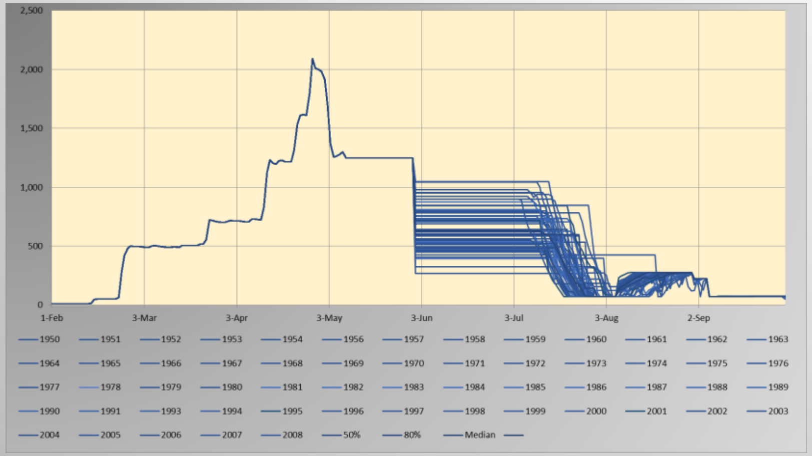
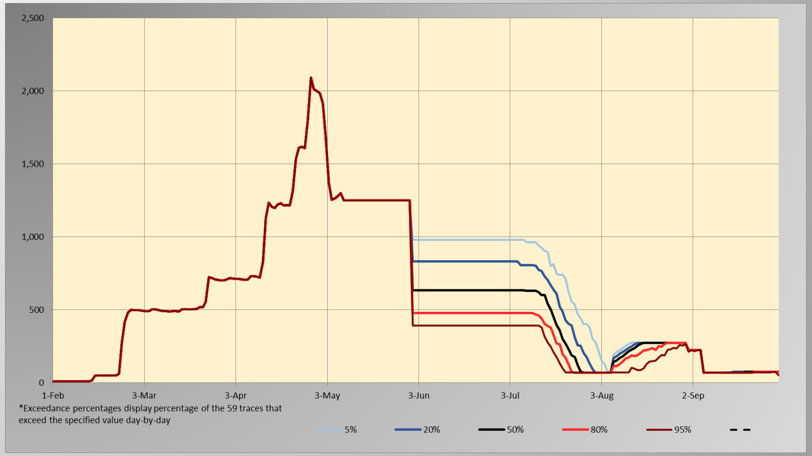
Taking a Look Ahead

How might better S2S predictability translate to reduced uncertainty in future operational conditions?

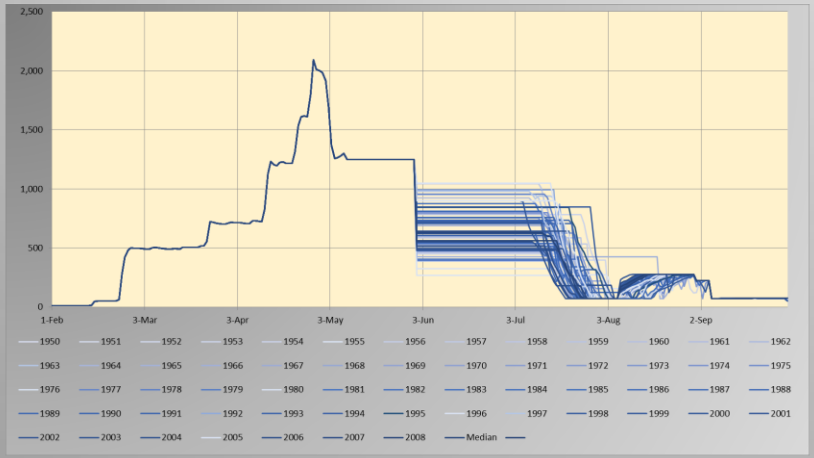
Un-weighted traces



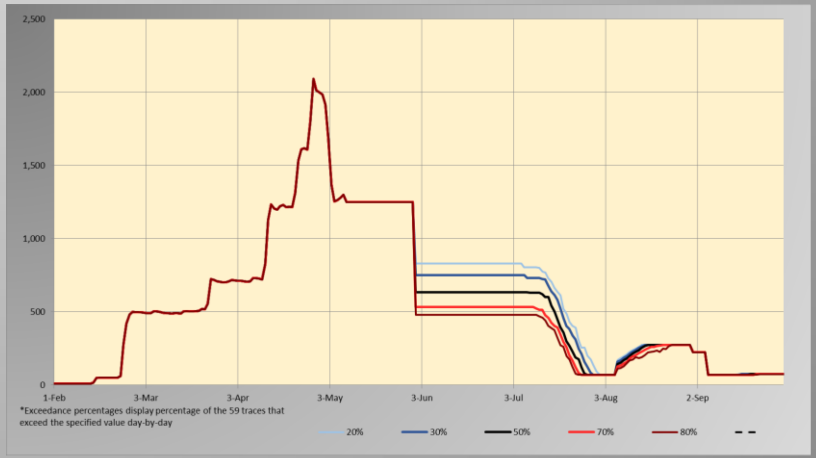
Σ traces



Weighted traces



Σ traces * weight



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Summary and Conclusions

- Supporting water operations involves a series of modeling tools. Climate models are at the front, and water system models are at the end
- The best and most accurate information to support water ops decisions is an operational forecast with well defined uncertainty (even if its ugly)
- In addition to making the deterministic S2S forecasts better, it is equally critical to put effort toward characterizing the uncertainty in the forecasts accurately.
- It is incumbent on water operators to not simply wait for improved S2S forecasting. Development of tools and techniques for assimilating incremental reduction in the uncertainty of S2S forecasts must take place in order for the benefits to propagate all the way down to the users of the water