Operator and Modeler Collaboration on Truckee-Carson River Operations Using Ensembles

River Ware User Group Meeting

Thursday February 1, 2018

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PWRE PRECISION WATER RESOURCES ENGINEERING

TROA Truckee River Operating Agreement

Collaboration

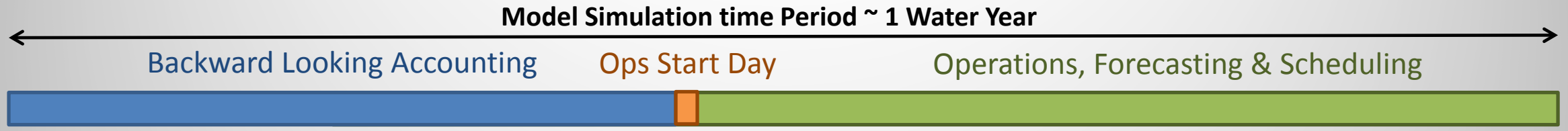
Lahontan Basin Area Office

Federal Water Master Office – Reno, NV

Outline

- Mr. Erkman
  - Model Overview
  - Multiple Run Management - MRM
    - Process
    - Trace scaling
- Mr. Wathen
  - Sample MRM Output
  - Comparison of Deterministic and Probabilistic Results
  - Probabilistic Decision Support

Model Overview: TROA Operations and Accounting

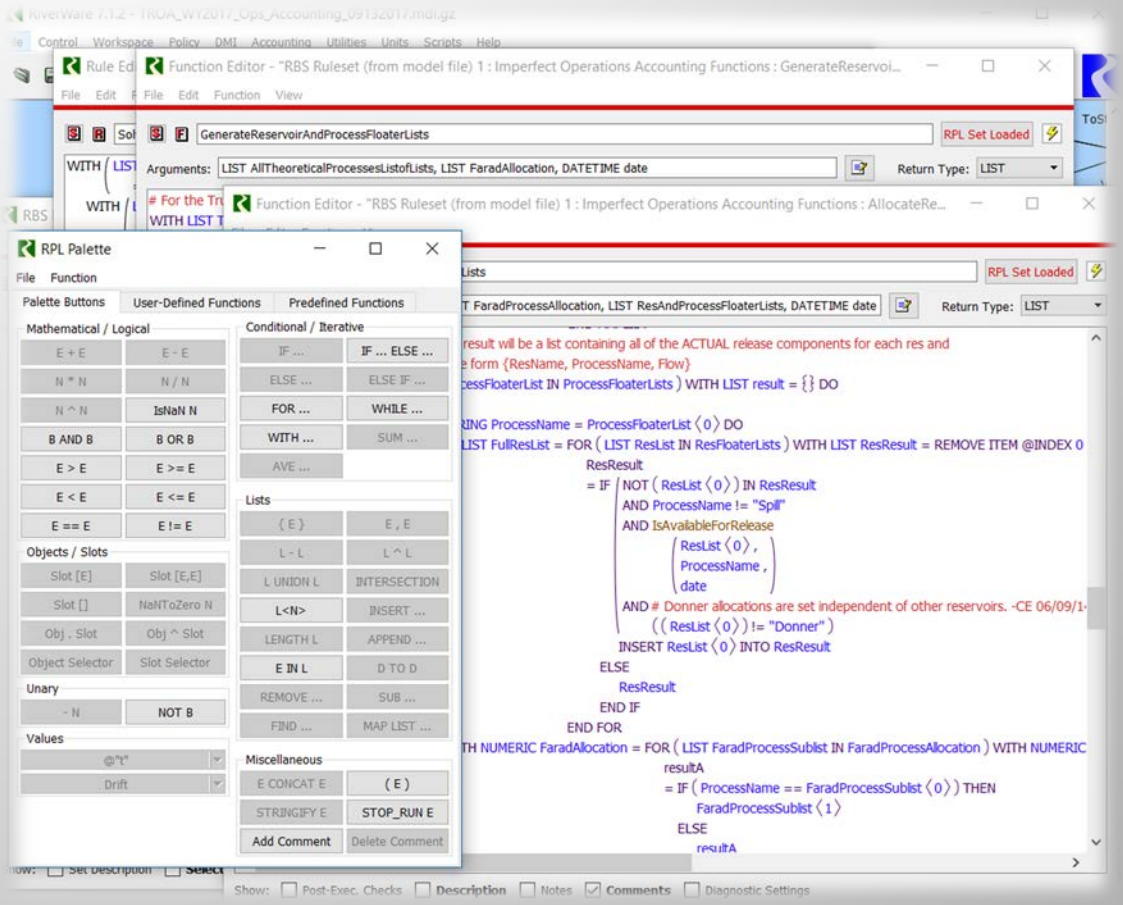


- One model, four purposes
- Specify Ops Start Date
- Seamless transition from *backward looking accounting* to *operational forecasting* in one model run
- Run period stays the same
- RiverWare Accounting, per TROA, done in both modes

- Backward looking accounting mode
  - *Input pool elevation* and *stream gage* measurements
  - Model solves for *inflows to reservoirs* and *reaches*
  - Reconcile imperfect accounting
- Operational forecasting mode
  - *Forecasted inflows*
  - Logic sets releases
  - RiverWare simulates system
  - Informs current operational decisions
  - Used by parties to develop Schedules

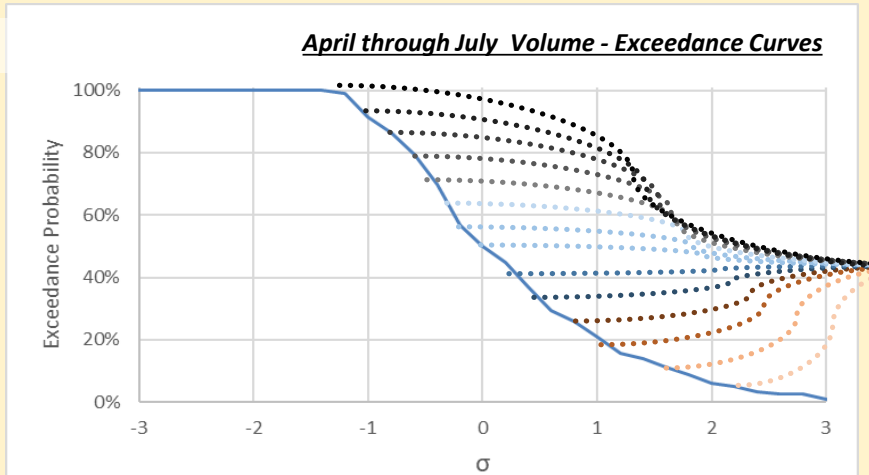
Model Overview: Policy Logic

- TROA prescribes many specific operational and accounting criteria
  - 276 pages long
  - ~9,600 lines
  - ~30 years to compose/negotiate
- Model needs to follow this criteria
  - ~24,000 lines of RPL code
  - ~17 years of work to implement
  - Still working



Multiple Run Management

Input



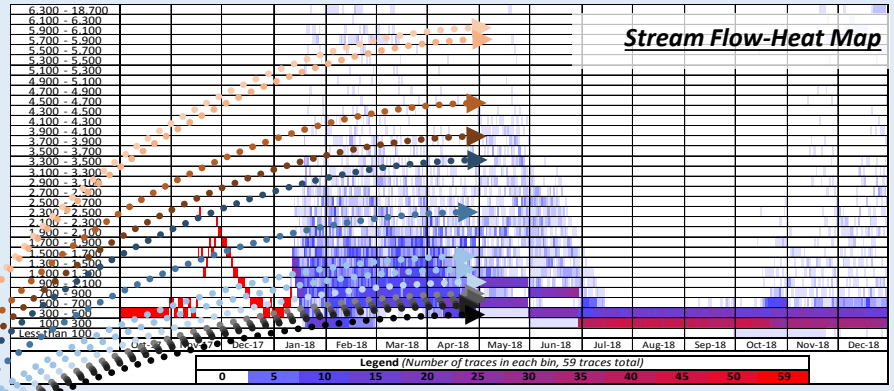
CALIFORNIA NEVADA RIVER FORECAST CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

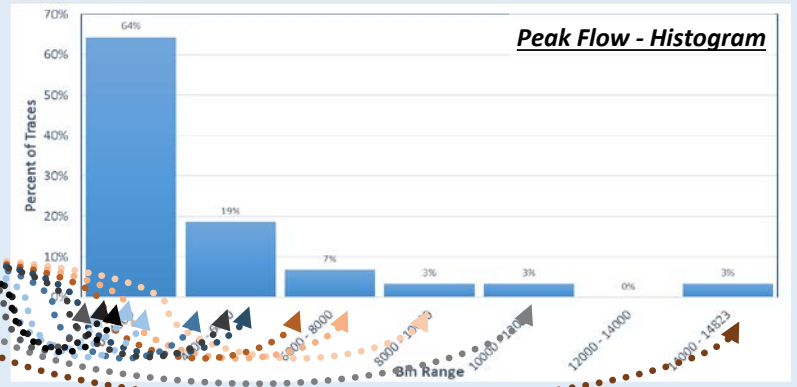
United States Department of Agriculture
NRCS Natural Resources Conservation Service
National Water and Climate Center

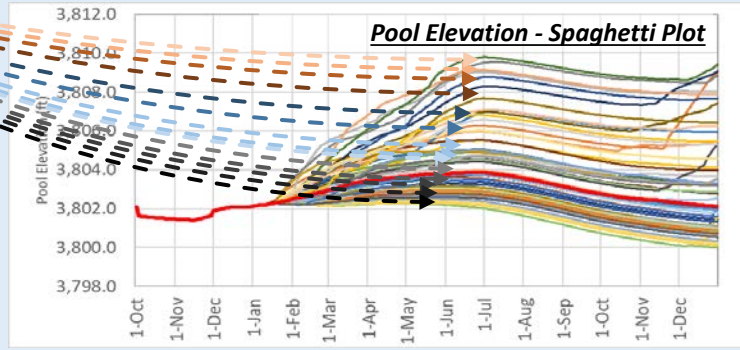
TROA Operations-Accounting Model

RiverWare

Output



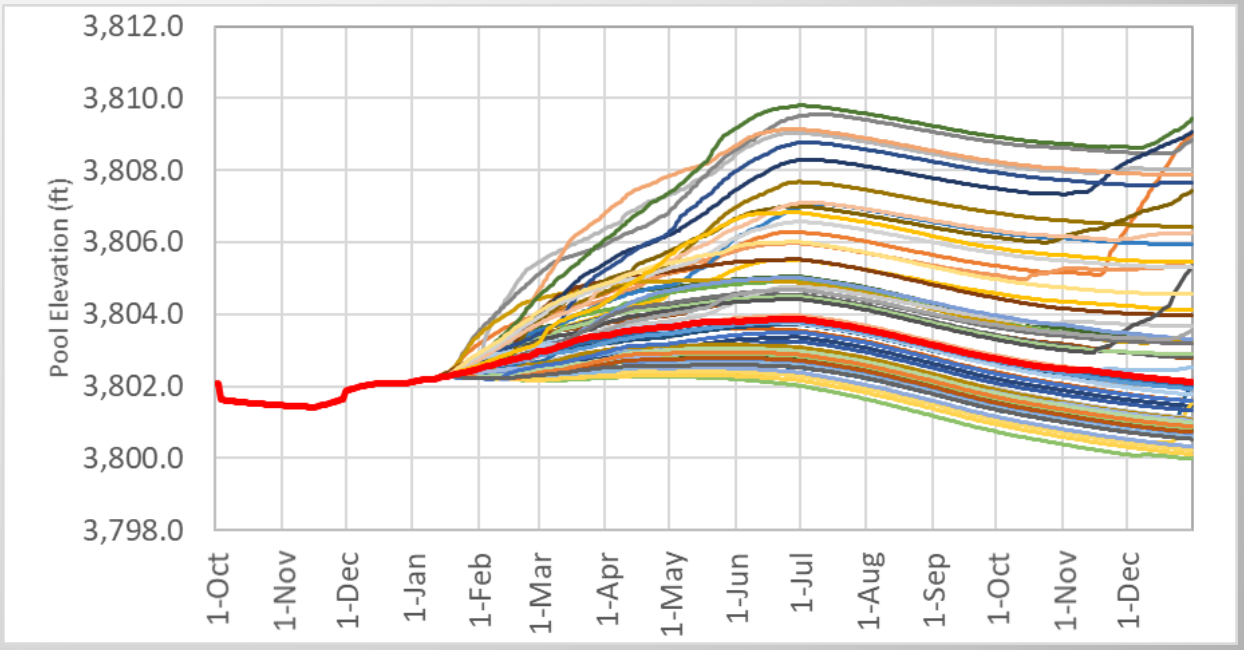




Multiple Run Management (MRM)

- Purpose:
  - Characterize uncertainty in the model outputs
- Method:
  - Configure TROA RiverWare model will stakeholder & decision maker scheduling
  - Run model with a variety of hydrologic conditions
- Provides:
  - Robust decision support
  - Communication of expectations

Pyramid Lake Pool Elevation



Multiple Run Management: Vetting

- Ensemble forecasts introduce the model to a wide variety of conditions.
- QA/QC of results and debugging can be time consuming!
- After continued use, the debugging time requirements diminish.
- The River Forecast Center (RFC) traces are *raw* model output and may contain overly extreme events!
  - Requires QA/QC
  - CNRFC has been very receptive to feedback

MRM: Hydrology

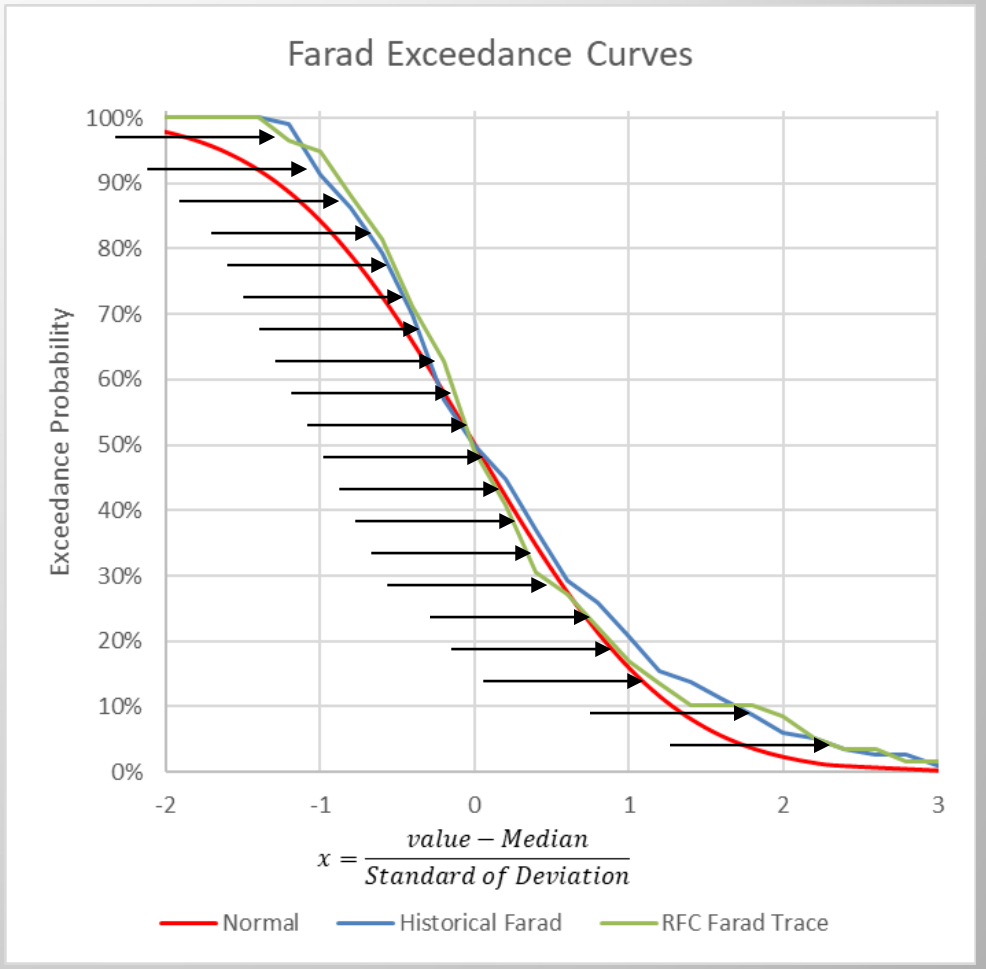
- This method only propagates uncertainty in *hydrology*.
- Historical observations can be used to estimate uncertainty in:
  - Local Inflows
  - Precipitation rates
  - Evaporation rates (if available)
- Additional methods are necessary to propagate uncertainty in other inputs.
  - Diversions
  - Evaporation rates
  - Scheduling

RFC Trace Analysis			
Exceedance	**Farad AJ Vol (KAF)**	**Ft. Churchill AJ Volume (KAF)**	**Tahoe GCR (ft)**
Max	447	484	2.28
10%	353	302	1.75
20%	307	239	1.33
30%	223	187	1.06
40%	195	151	0.86
50%	**164**	**110**	**0.69**
60%	153	87	0.58
70%	140	63	0.49
80%	120	48	0.40
90%	97	31	0.23
Min	45	0	0.00
1901-2017 Average	**269.2**	**184.1**	**1.48**
Percent of Average	**61%**	**60%**	**47%**

MRM: Trace Scaling

- The CNRFC traces are raw model output
  - May not be consistent with official forecast volume distribution
  - May not be consistent with latest observed flows
- Developed Exceedance Distribution Functions based on:
  - Historical hydrology
  - And today's CNRFC traces
- Scale each trace to the volume corresponding to it's exceedance and the desired forecast distribution

Exce (%)				Ref. St. Dev.
5				N/A
10				70.2
30		629	624	45.8
				N/A
		577	570	57.2
90		545	531	53.8
95				N/A
M			KAF	
St				
Av			KAF	
80% CI		151	174	159



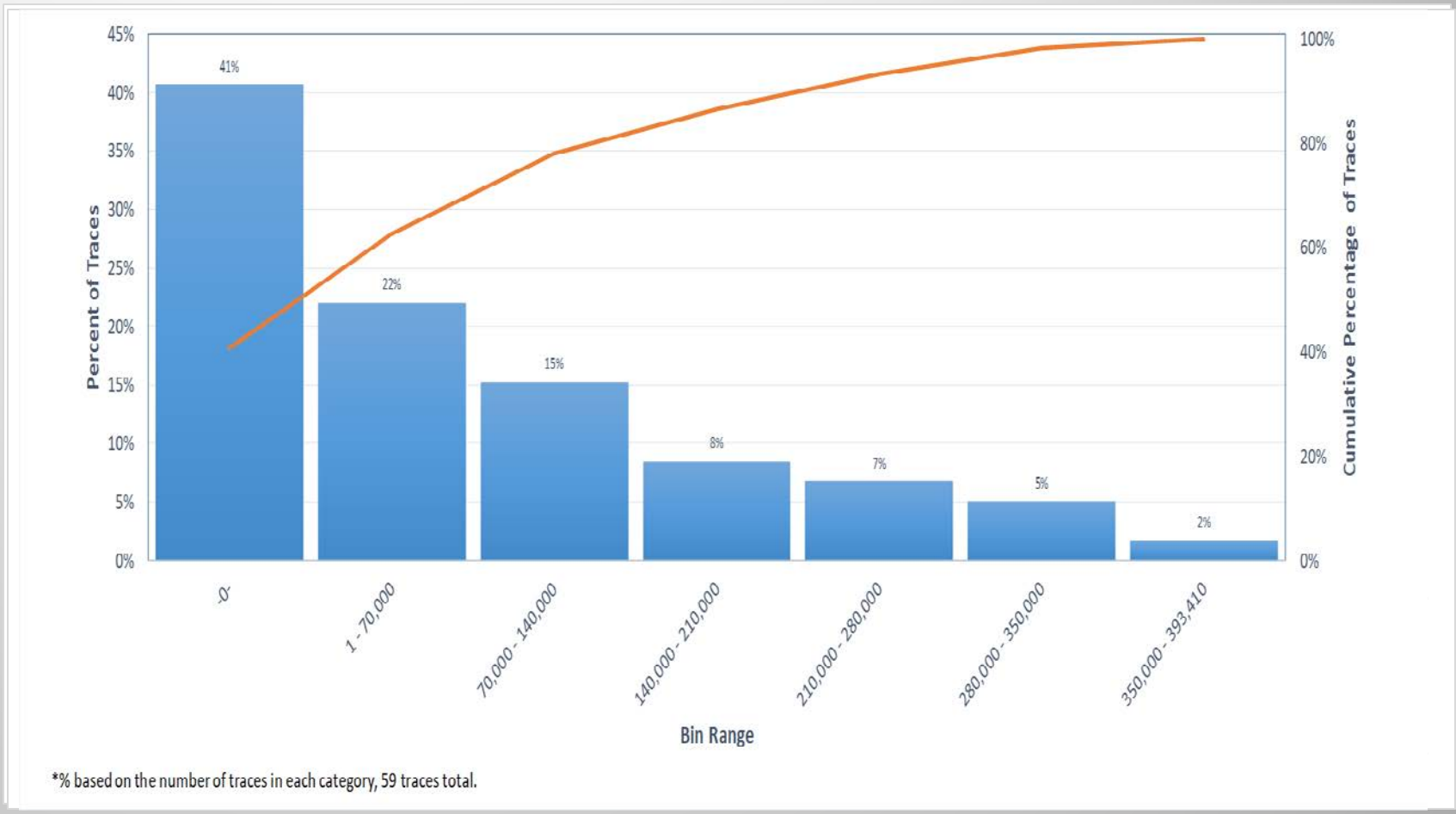
2015 vs 2017 – Extreme Years

- Reliance on the standard 10-50-90 Exceedance volume forecasts can really limit the range of forecasted outcomes…
- Very recent history tells us we must consider the *FULL* range of possible outcomes

111 Years of Hydrologic Record												
Year	Truckee River @ Farad AJ Volume (KAF)	Exceedance	Truckee River @ Farad WY Volume (KAF)	Exceedance	Carson @ Ft Churchill AJ Volume (KAF)	Exceedance	Carson @ Ft Churchill AF Volume (KAF)	Exceedance	Lake Tahoe GCR - April thru High (FT)	Exceedance	Lake Tahoe WY Low to the High GCR (FT)	Exceedance
2015	45.2	99%	138.8	96%	3.9	99%	30.9	99%	0.2	99%	1.2	88%
2017	662.101	3%	1207.612	1%	570.816	1%	946.947	1%	3.73	3%	7.52	1%

Tahoe Outflow – Spill Potential

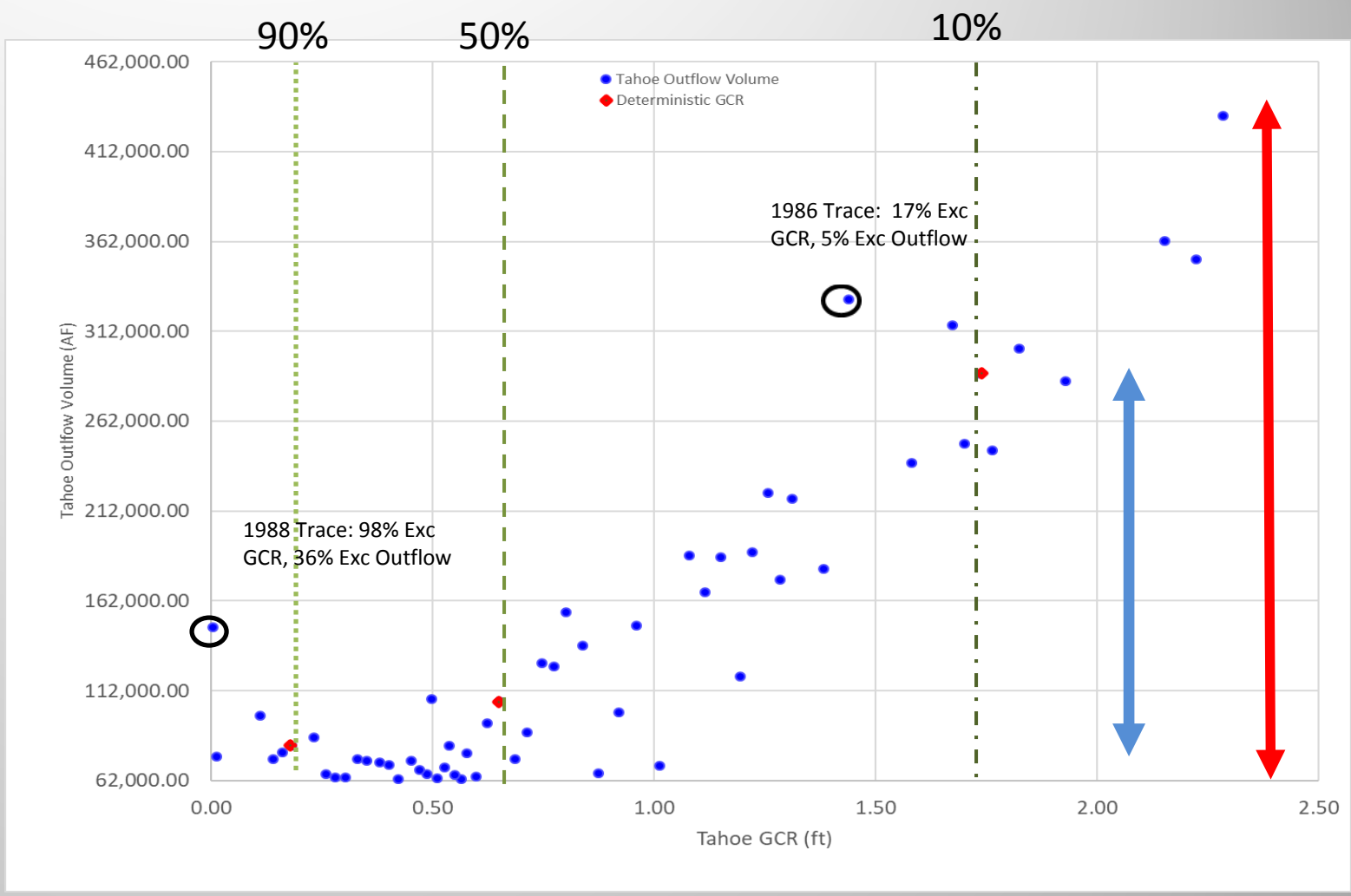
- 50% deterministic indicates approximately 70KAF of spill for the remainder of the WY.
- Comparing the 50% to the full set of MRM output traces…quite a different picture



Lake Tahoe Inflow Volume (GCR) vs. Total Outflow Volume

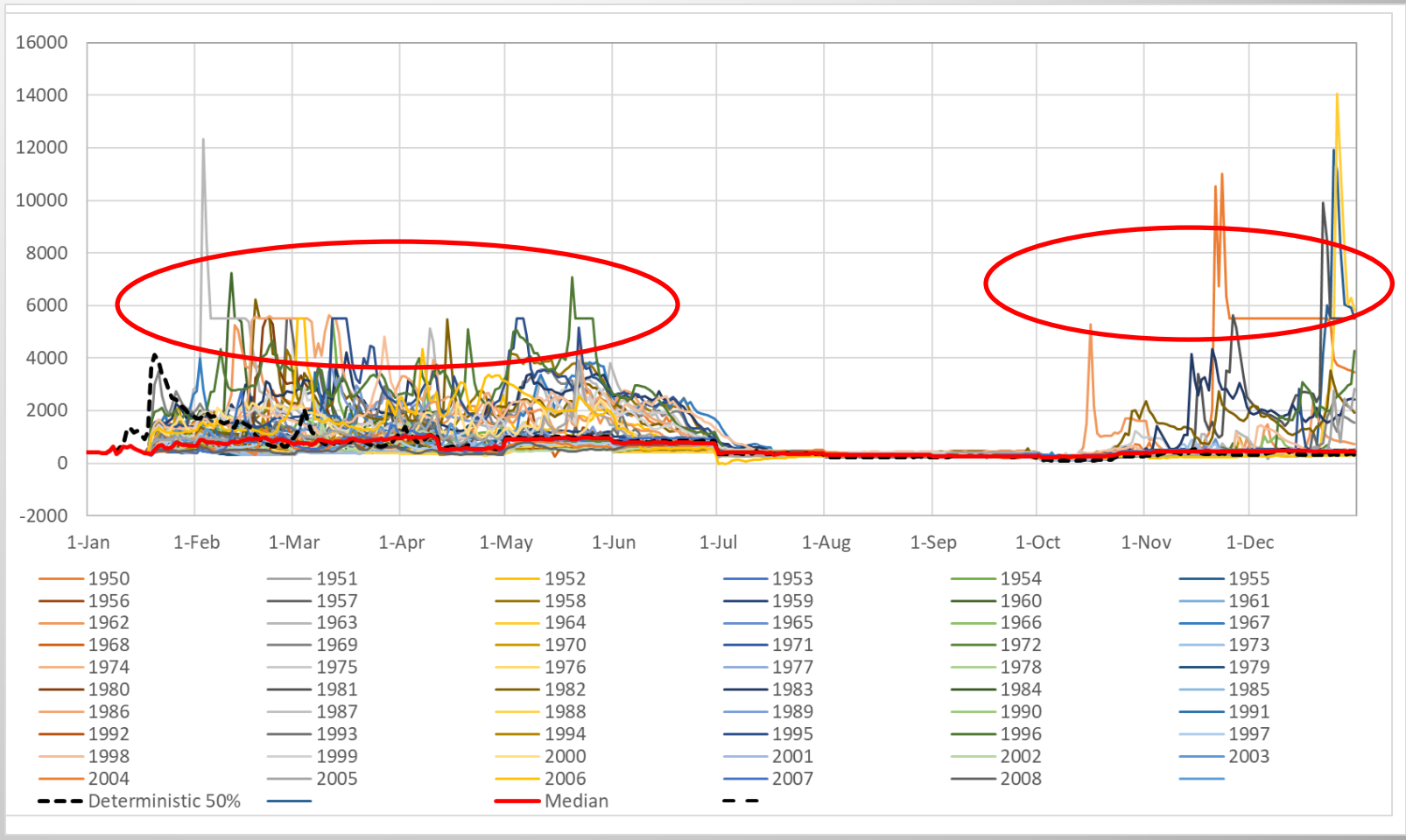
- 10%, 50%, 90% exceedance inflow volumes translate to a range of ~207 KAF in release volume
- Miscommunicates the range of possible release volumes
- Full range of the CNRFC Ensemble inflow show a range of 370KAF in release volume
- The 10-50-90 inflow forecasts don't necessary translate to the 10-50-90 Outflow

❖ GCR: Gates Closed Rise (ft)--- measure of computed inflow as the daily change in reservoir elevation + daily outflow.



Flood Control Operations – Truckee River @ Reno Gage

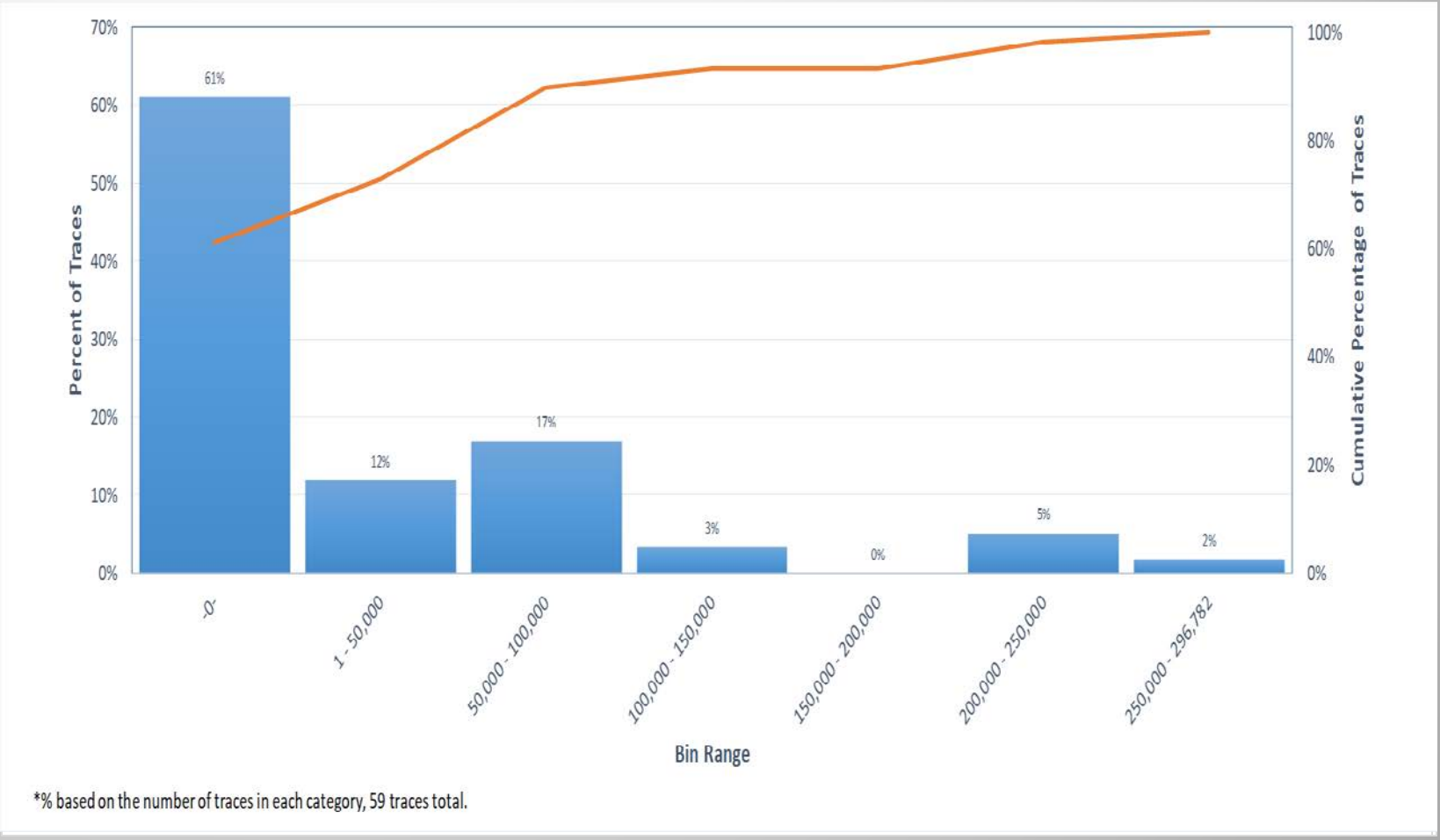
- 50% deterministic output would indicate flows never reaching 6,000 cfs – no flood control issues at any time for the remainder of the WY
- Again, a very different picture when you consider the full set of traces…



Lahontan Precautionary Releases

- 50 % Deterministic output: Approximately 10KAF precautionary releases March 15th thru April 1st.
  - Minimal impacts

- Comparing this result with the full set of MRM output indicates that the 50% deterministic output is fairly unlikely…
  - 61% of the traces show zero level control releases
  - 27% of the traces would require at least 50KAF and up to approx. 297KAF of precautionary release.



Operation with Uncertainty Example

Lake Tahoe Releases - 2017

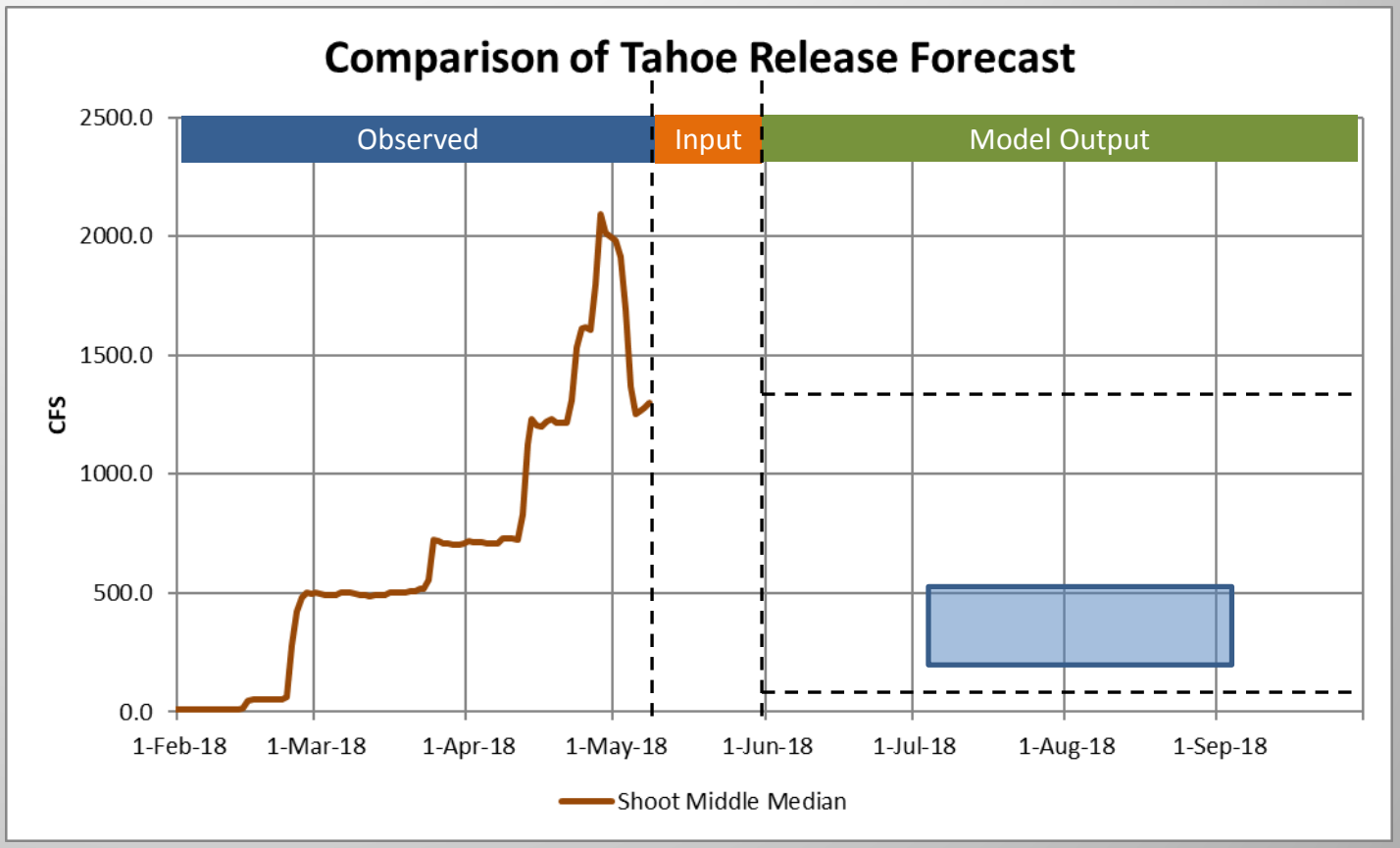
- 2017 was record setting!
- Federal Water Master must spill to prevent the water surface elevation from exceeding elevation 6229.1’
- It is also critical that the lake be filled to the maximum (~6229.1’)
- During runoff, daily inflows can be tens of thousands of cfs
- Maximum release is 2,600 cfs
- Level control releases must be initiated well in advance of the peak inflow
- High degree of uncertainty in future hydrology

Operation with Uncertainty Example

Lake Tahoe Releases - 2017

- Release schedule for May set on May 8th
- Goals:
  - ❑ Guaranteed step down
  - ❑ Low end is above minimum
  - ❑ Maximize chances for rafting
- Run MRM
  - Model determines distribution of remaining releases

Lake Tahoe Outflow (cfs)

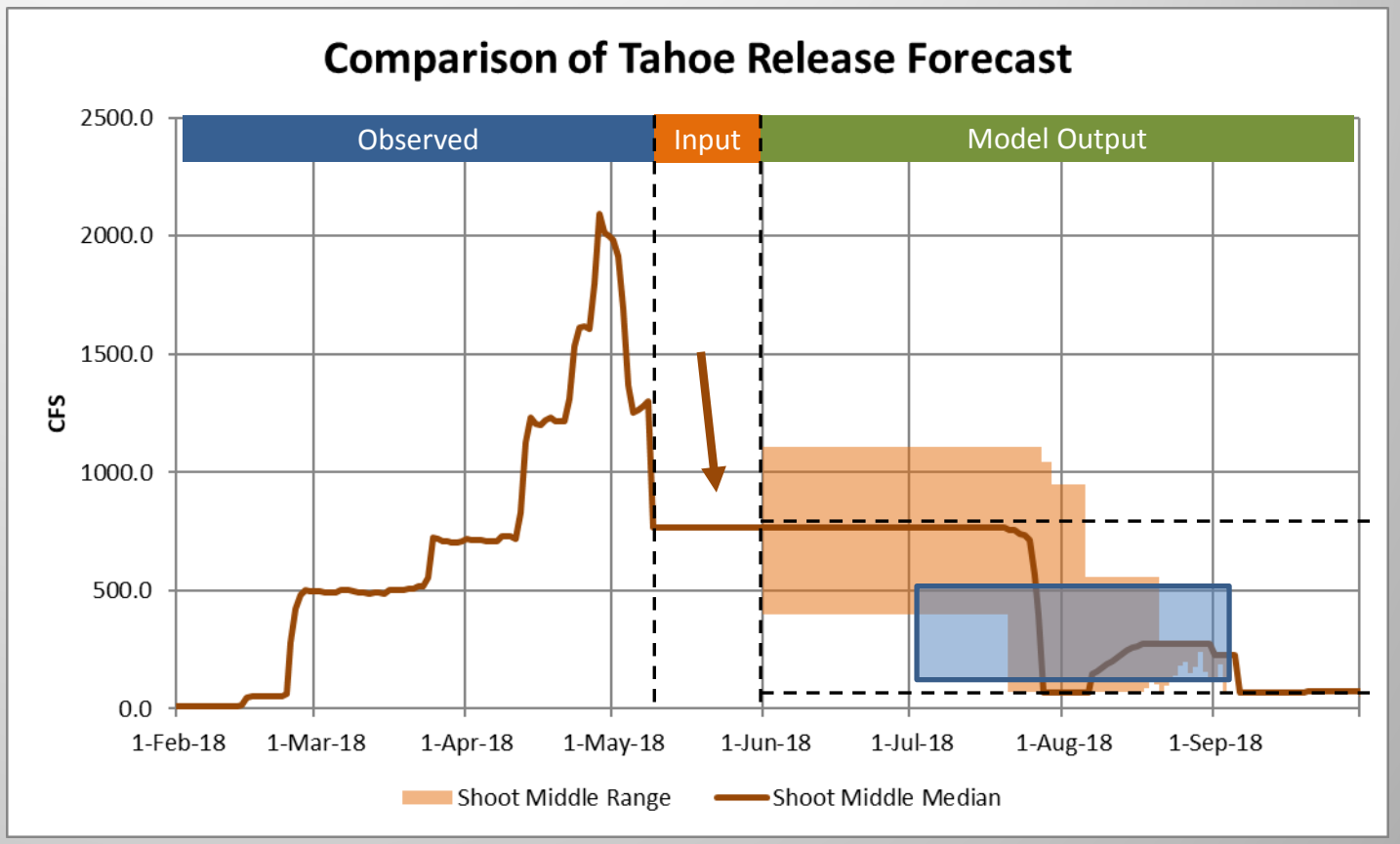


Operation with Uncertainty Example

Lake Tahoe Releases - 2017

- Option #1:
  - Set release to fill the median forecast (750 cfs)
- Run MRM
- Evaluate Goals:
  - ☒ Guaranteed step down
  - ☑ Low end is above minimum
  - ☒ Maximize chances for rafting

Lake Tahoe Outflow (cfs)

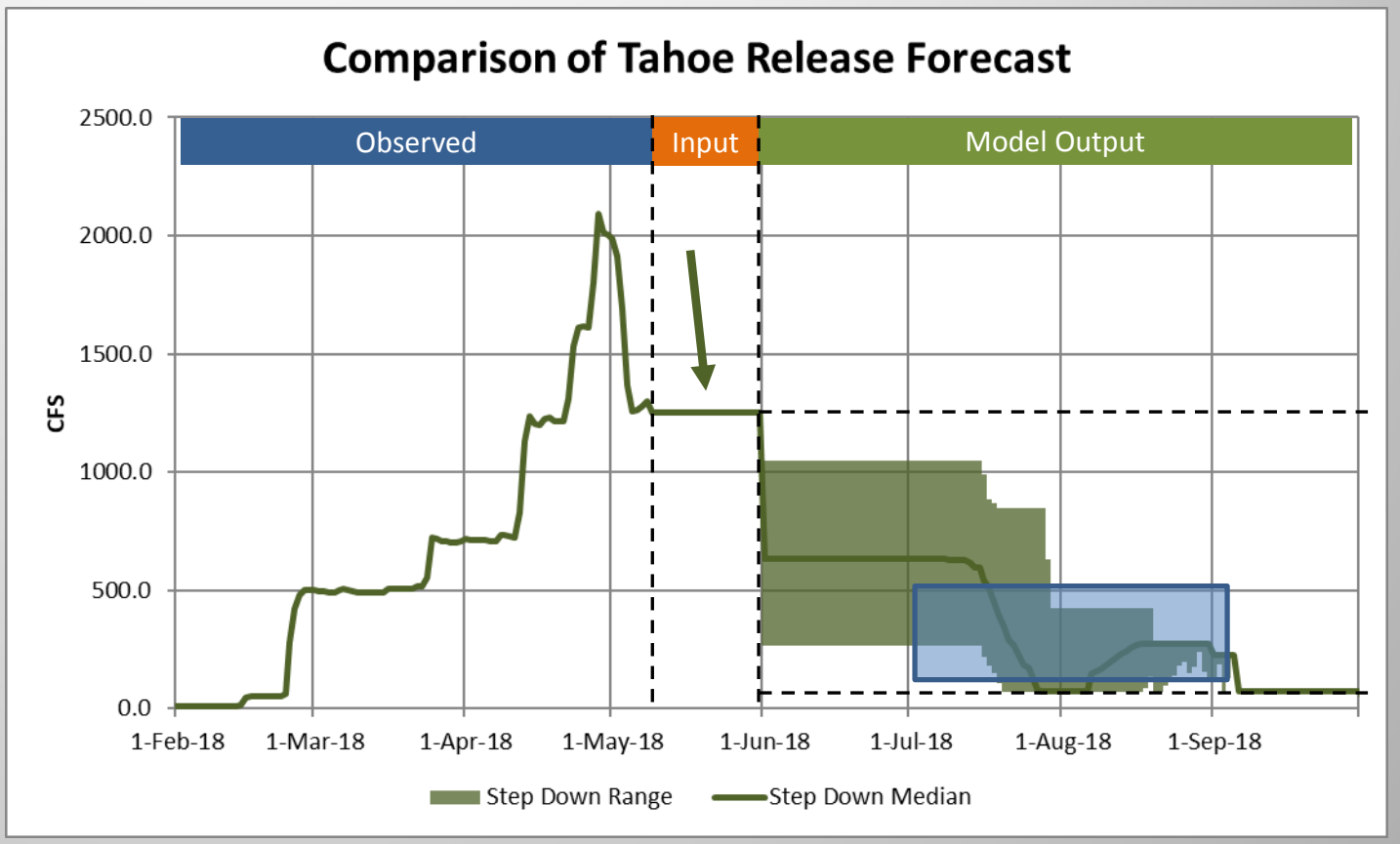


Operation with Uncertainty Example

Lake Tahoe Releases - 2017

- Option #2:
  - Choose a more aggressive release (1250 cfs)
- Run MRM
- Evaluate Goals:
  - ☑ Guaranteed step down
  - ☑ Low end is above minimum
  - ☑ Maximize chances for rafting

Lake Tahoe Outflow (cfs)

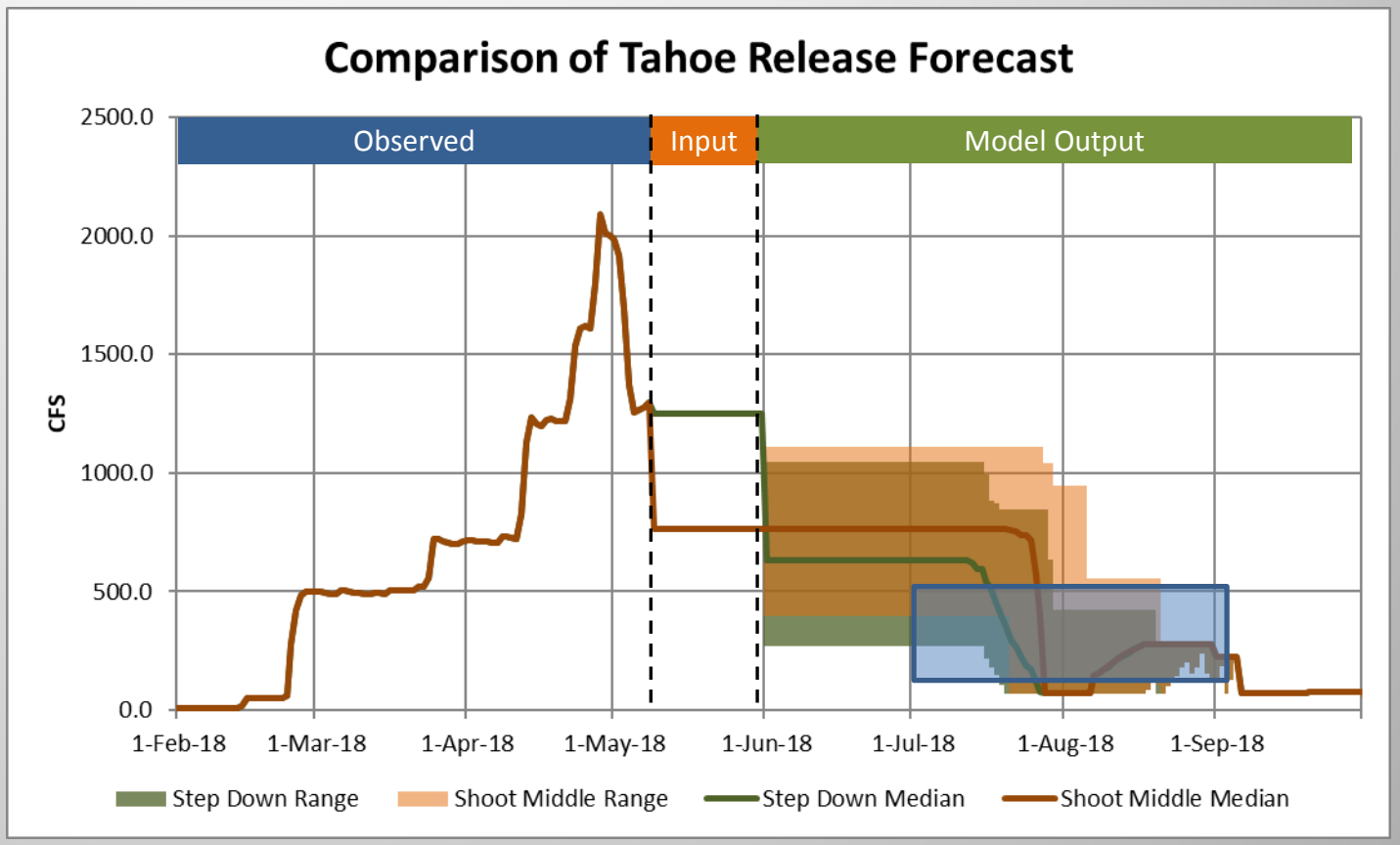


Operation with Uncertainty Example

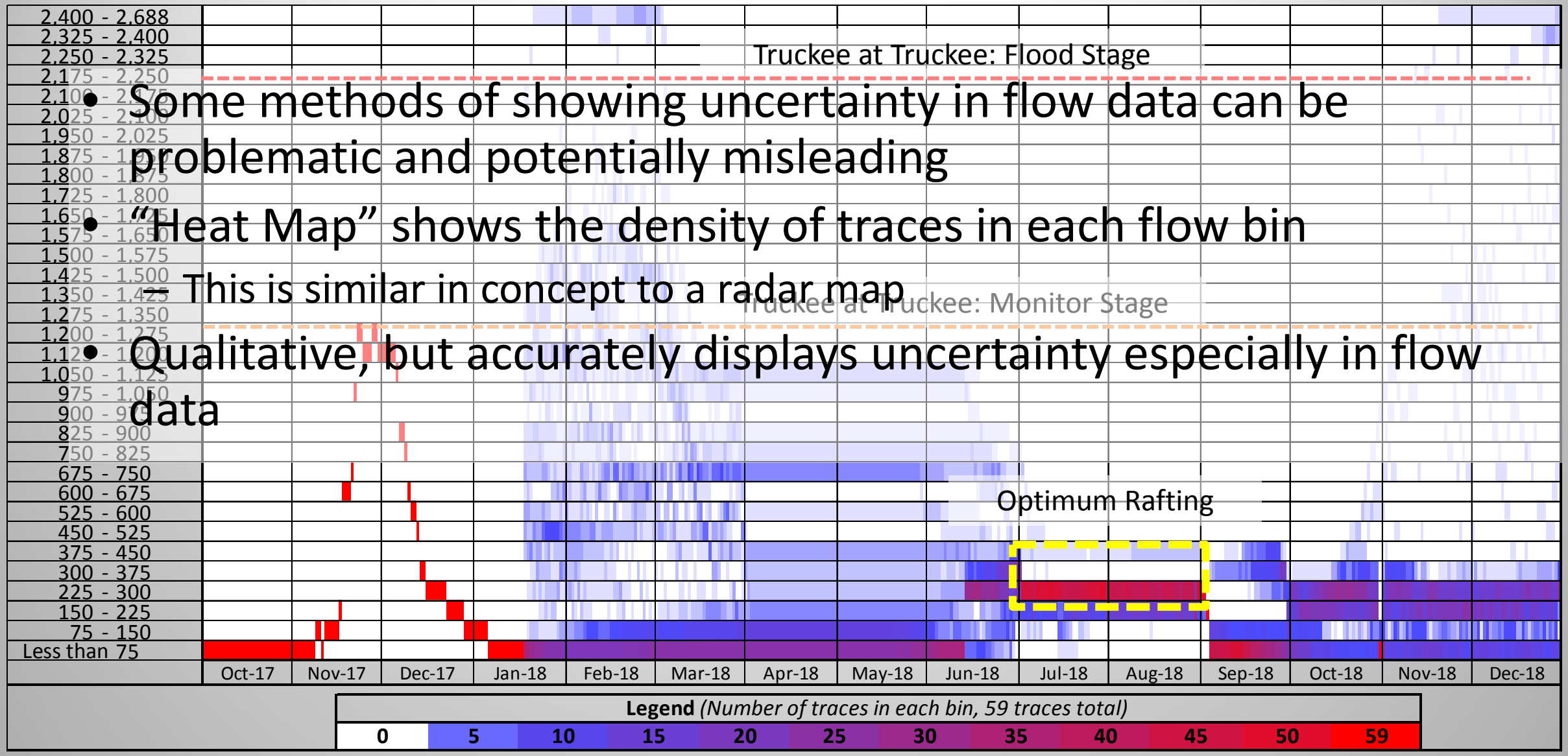
Lake Tahoe Releases - 2017

- Compare Results
  - Option 1: Median (750 cfs)
  - Option 2: Aggressive (1250 cfs)
- Operating to minimize uncertainty improves the probability of success
- Operating to the median may not meet all the objectives

Lake Tahoe Outflow (cfs)



Operations With Uncertainty: Tahoe Outflow 2018 Heat Map



- Some methods of showing uncertainty in flow data can be problematic and potentially misleading
- "Heat Map" shows the density of traces in each flow bin
  - This is similar in concept to a radar map
- Qualitative, but accurately displays uncertainty especially in flow data

In Closing…

- *We must not discard and overlook forecasts that might lie outside of the 10% and 90% exceedance levels*
- *In 2 of the last 3 years on the Truckee and Carson River Basins we have experienced a record dry and a record wet year*
- *Characteristics of hydrology other than volume impact operations*
- *With the right tools…*
  - *RFC ensemble forecasting products*
  - *The RiverWare MRM utility*
  - *Modeling expertise and many additional tools developed by PWRE that further analyzes and assist in interpreting the model output*

…We can effectively manage a very complex river and reservoir system, and feel confident in operational decisions in a very uncertain and highly variable hydrologic climate.

Questions?

Special Thanks to:

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