

Folsom Dam Water Control Manual Update

Joint Federal Project, Folsom Dam

Flood Operations Overview for FIRO

June 28, 2016

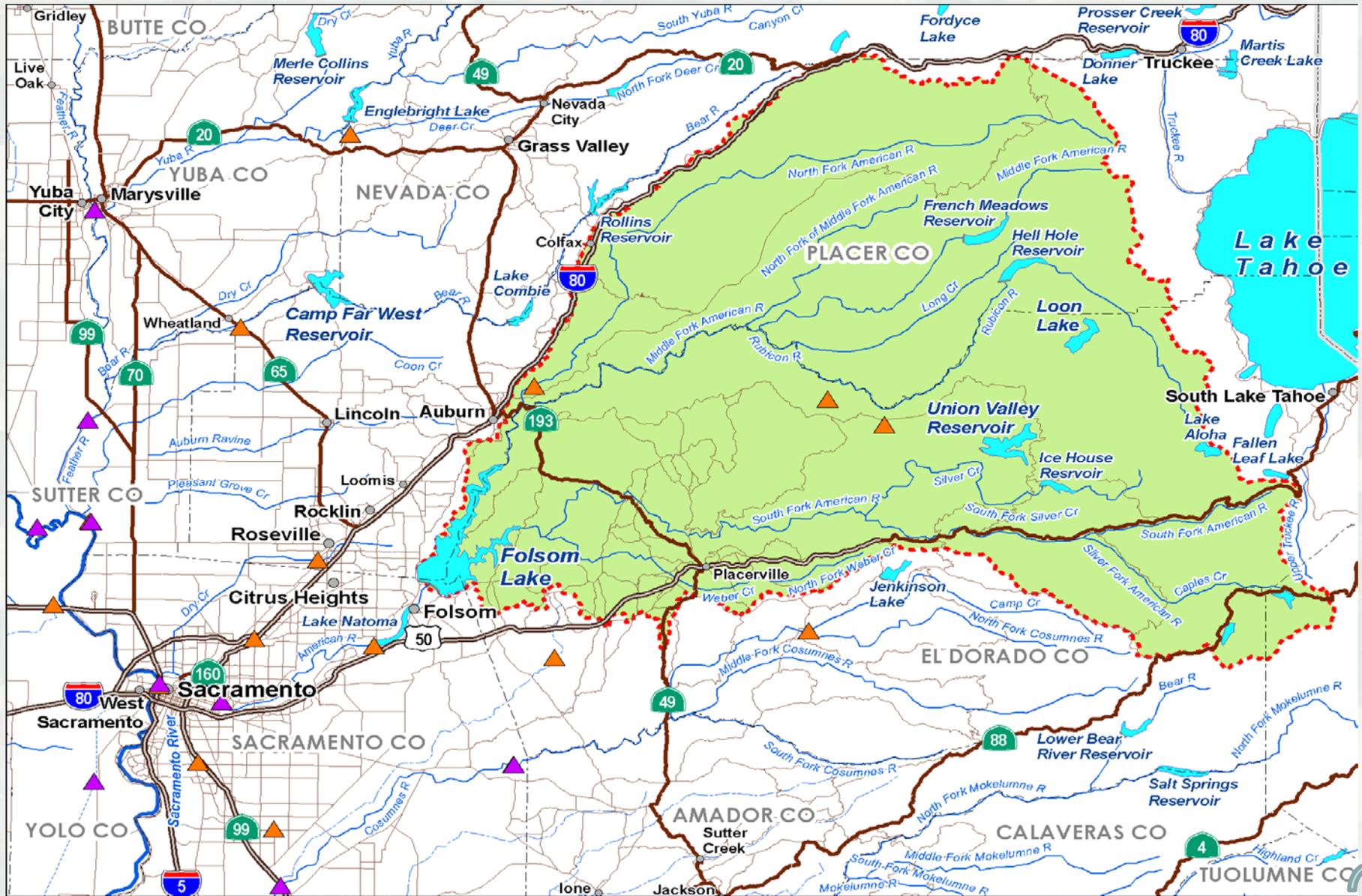
Brad Moore, PE



US Army Corps of Engineers
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American River Basin



Folsom Lake and Dam

- 340 feet tall
- 967 TAF storage (gross pool).
- Objective flood release is 115 kcfs.
Channel capacity ~ 160 kcfs.
- Steep watershed – most water is in reservoir within 8 to 12 hours of hitting ground.
- Winter snow pack – relied upon for Spring refill.
- No downstream control point.
- Headwater reservoirs.
- Gated spillways



Folsom Dam



Main Dam and JFP



JFP Tainter Gate Install

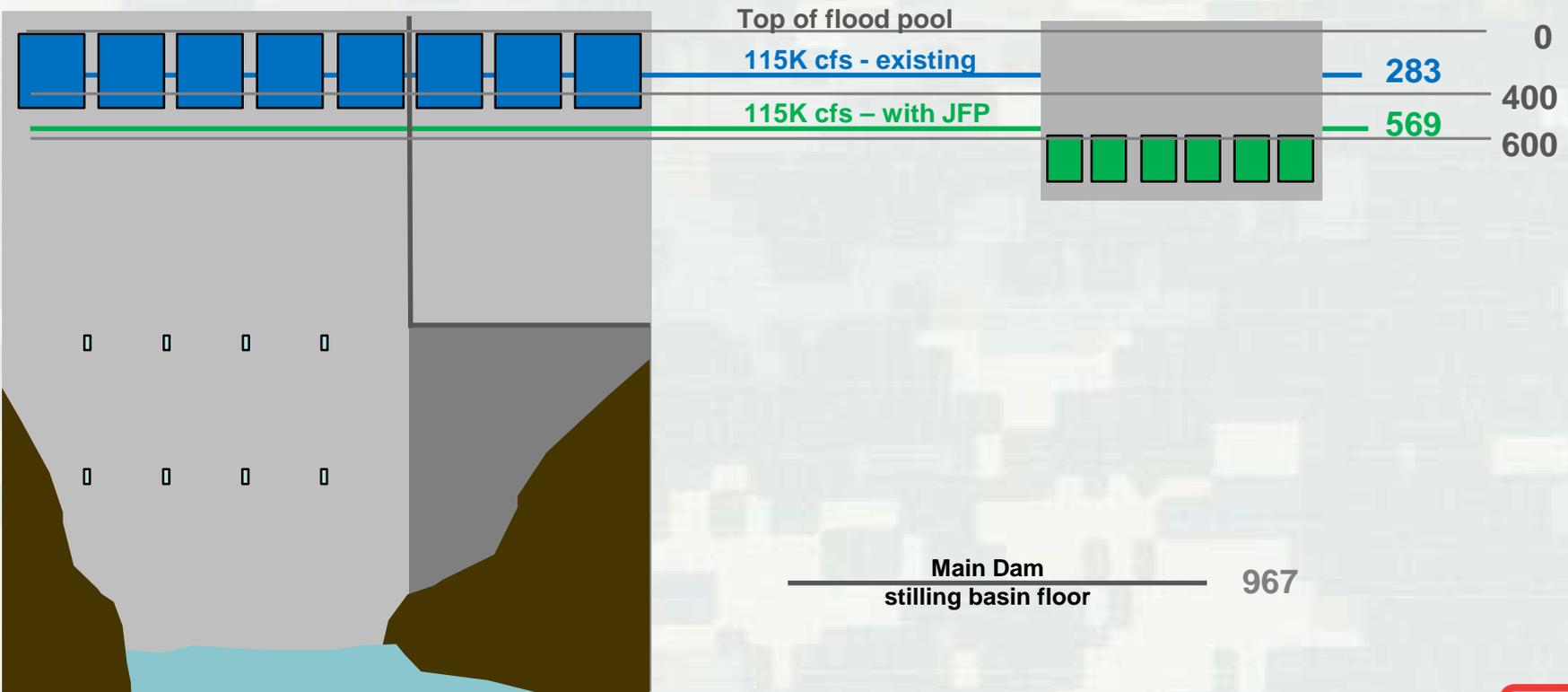


Existing and JFP Outlets

Main Dam

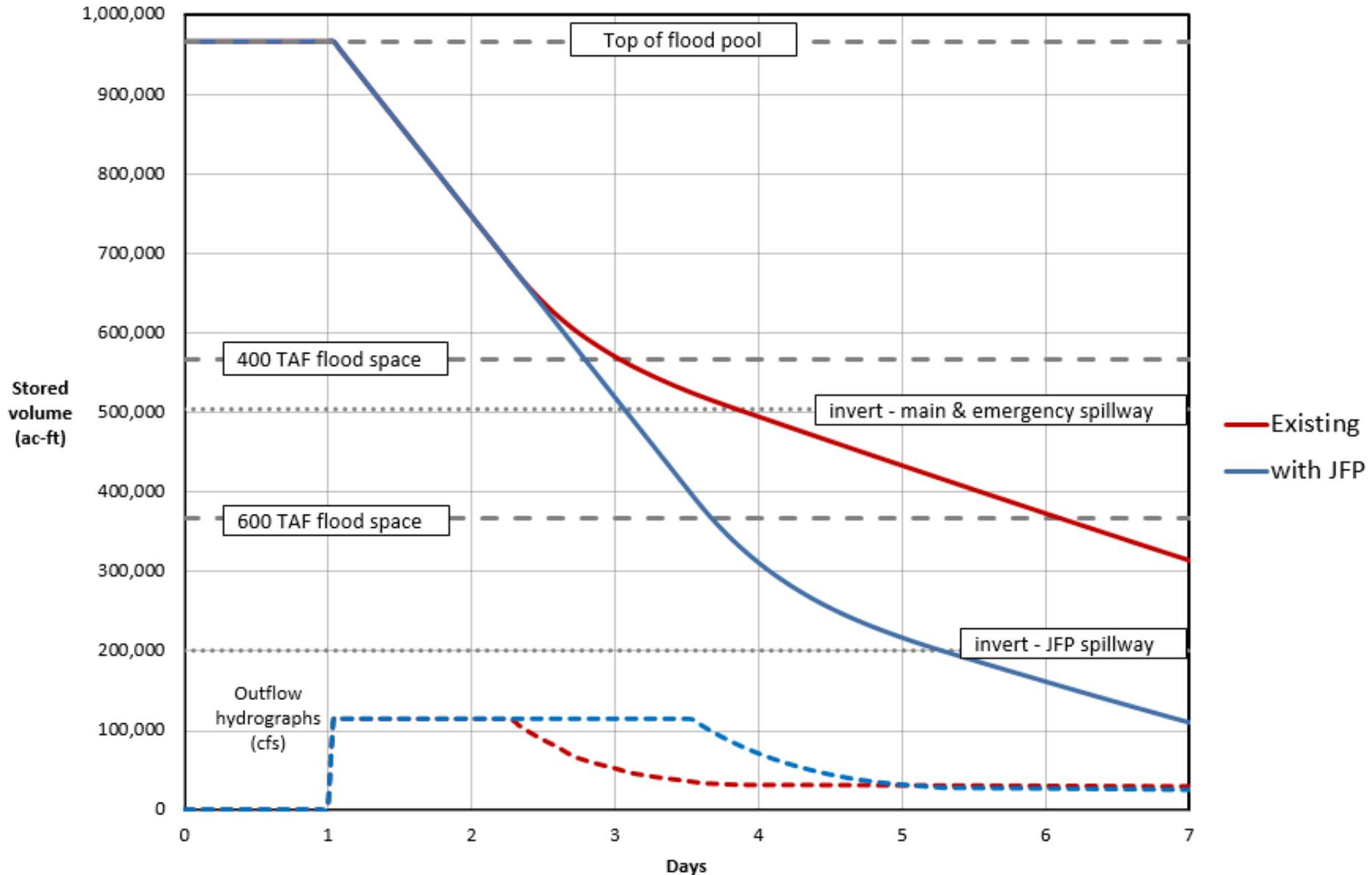
JFP

Flood space
(KAF)

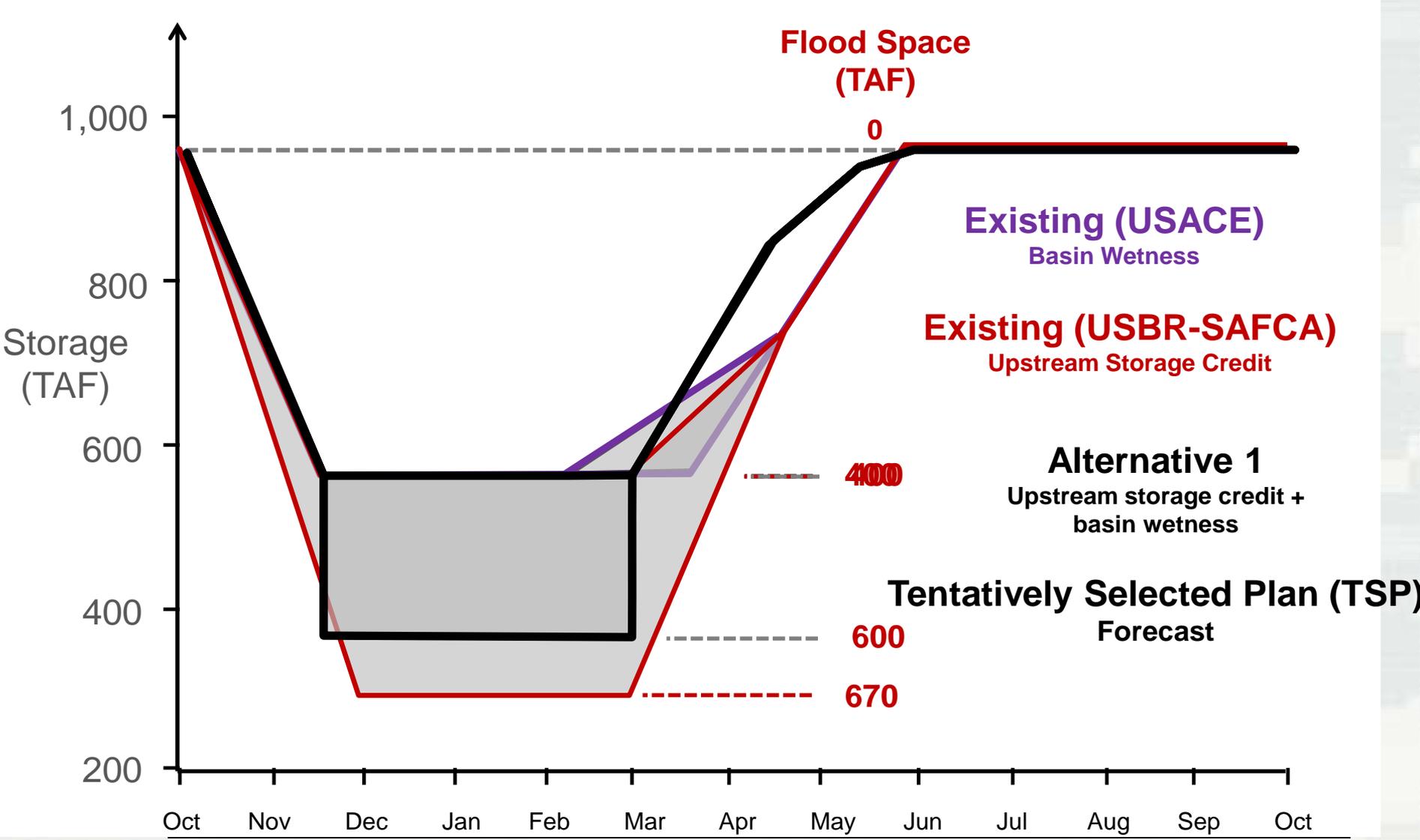


Rapid drawdown capacity (no inflow)

reflects 115k max discharge as only operational restriction, max physical release capacity

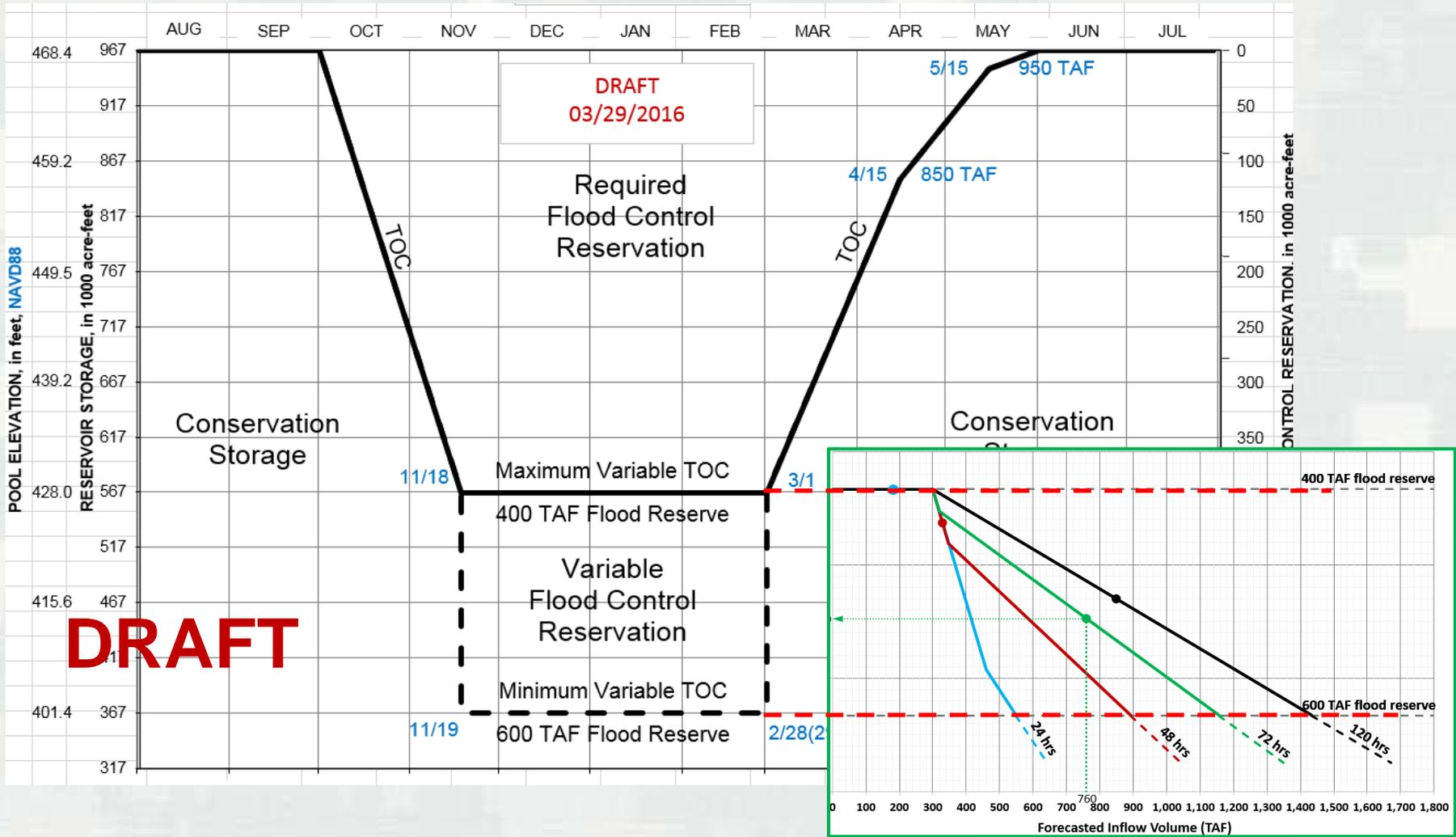


Baselines & Alternatives

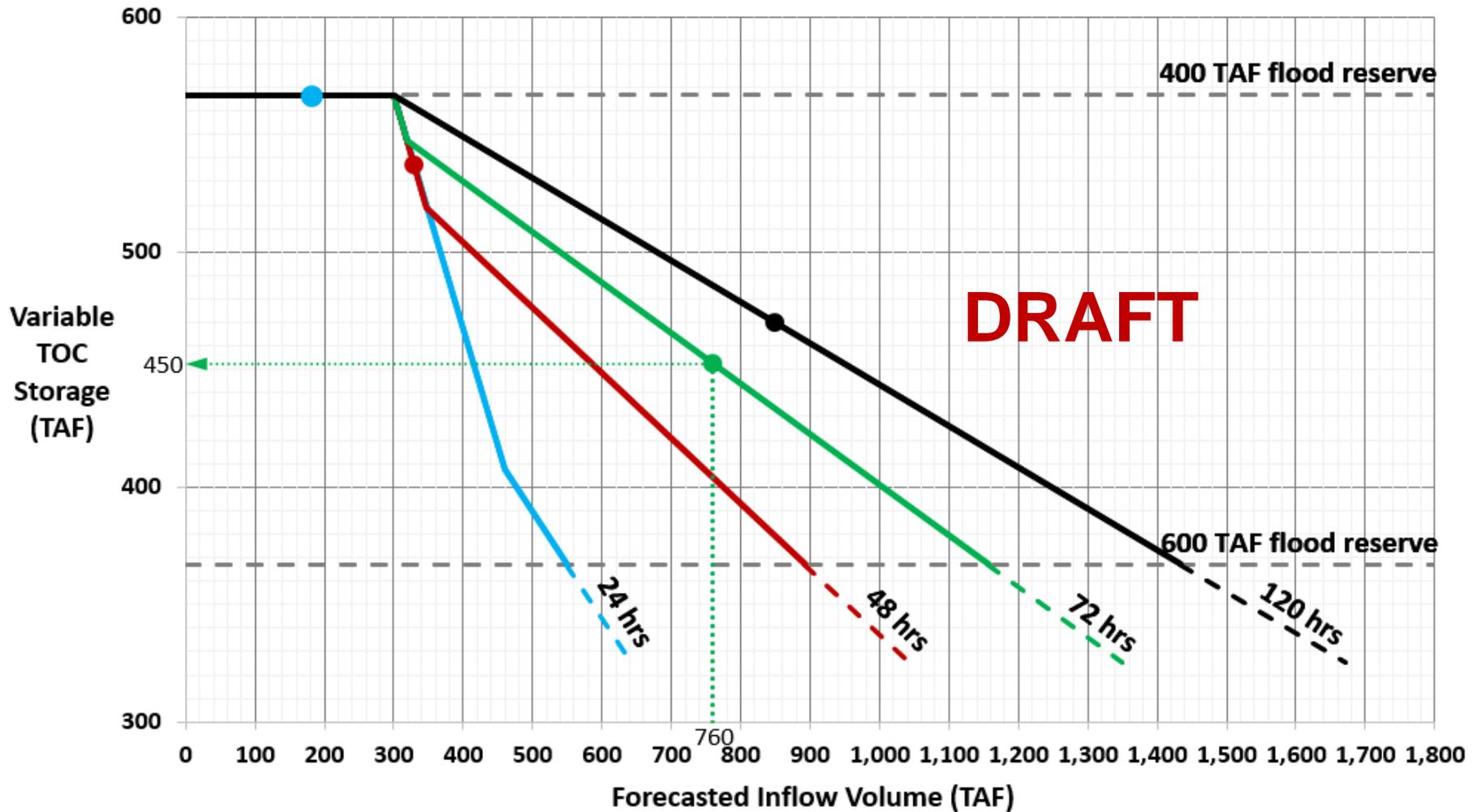


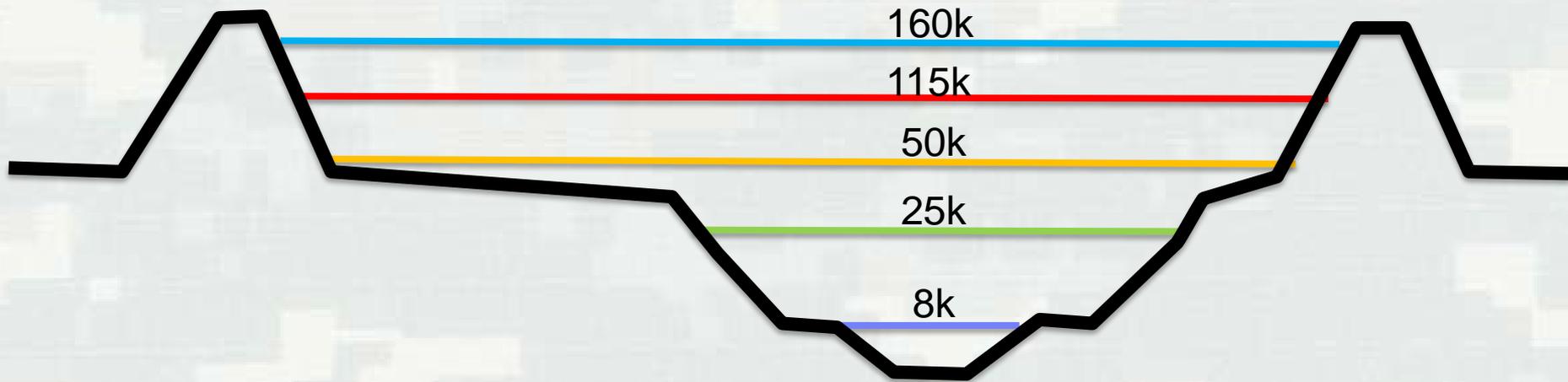
Forecast-based Operation

Forecast-based TOC



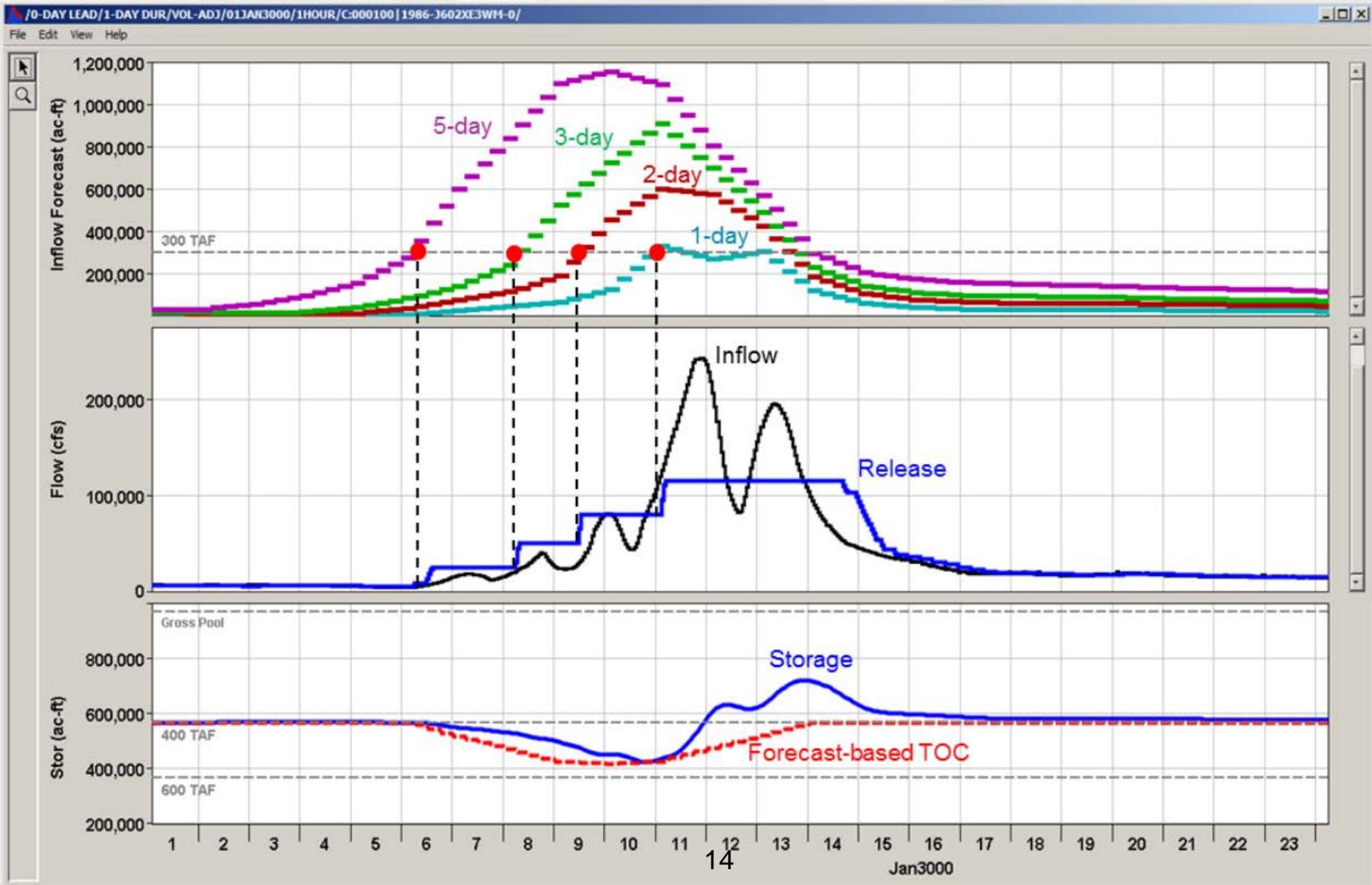
Forecast-based TOC



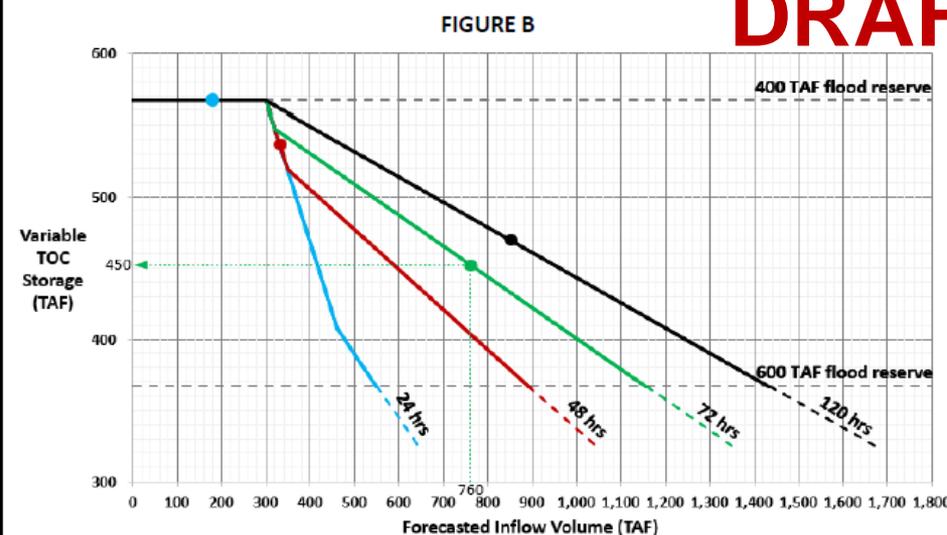
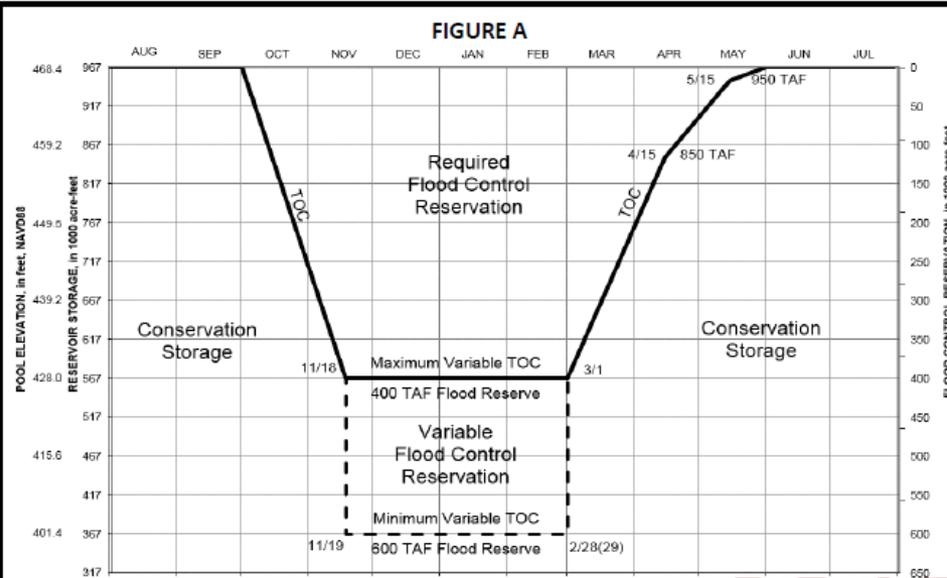


Typical American River Cross Section

Forecast-based Release



Water Control Diagram



USE OF FLOOD CONTROL DIAGRAM

Folsom Dam and Lake shall be operated for flood control in accordance with the Flood Control Diagram (Figure A). The flood control diagram defines the required Flood Control Reservation (FCR). Except when larger releases are required by the accompanying Emergency Spillway Release Diagram (ESRD), water stored within the FCR shall be released as rapidly as possible subject to the Release Schedule (Table A). The Corps of Engineers may direct flood releases to be increased or decreased from the computed release when warranted by existing conditions.

COMPUTATION OF VARIABLE FLOOD CONTROL RESERVATION

Forecasted inflow volumes are obtained from NWS-CNRFCC and are developed for the purpose of supporting Folsom Dam forecast-based operations. Volumes for the following four durations are required: 24, 48, 72, and 120 hours. Figure B provides relationships relating inflow forecast volume to Top of Conservation (TOC) storage for each duration. Each relation is labeled by the duration for which it applies.

FIGURE B - INSTRUCTIONS: Locate each of the four forecast volumes provided on the horizontal axis. For each forecast volume, identify the corresponding candidate TOC storage value on the appropriate curve. Of the four candidate TOC storage values, the lowest value is the adopted TOC storage value. The corresponding FCR value is given by: $FCR = 966.9 \text{ TAF} - \text{TOC}$.

FIGURE B - EXAMPLE: Inflow forecast volumes of 180, 330, 760 and 850 TAF are provided, corresponding to 24, 48, 72, and 120 hours respectively. As shown in Figure A, the volumes are located on the horizontal axis, and candidate TOC values are located on the corresponding curves (indicated by large dots). Of the four candidate TOC values, the 72-hour volume is lowest. This value, 450 TAF, is therefore the adopted TOC storage value. The corresponding FCR value is: $FCR = 966.9 \text{ TAF} - 450 \text{ TAF} = 516.9 \text{ TAF}$.

TABLE A - FOLSOM RELEASE SCHEDULE

Date	Storage Condition	Description
Mar. 1 to Nov. 18	Storage > TOC	Release peak inflow for current event.
Nov. 19 to Feb. 28/29	Storage > TOC	Release greater of Table B indicated release or observed inflow. Do not reduce releases while pool is rising.

RAMPING RATES

- A1) Releases between 8 kcfs and 30 kcfs will not be increased by more than 5 kcfs during any 2-hour period.
- A2) Releases between 30 kcfs and 160 kcfs will not be increased by more than 30 kcfs during any 2-hour period.
- A3) Releases between 8 kcfs and 160 kcfs will not be decreased by more than 10 kcfs during any 2-hour period.

STEPPED RELEASES

- A4) Coordination efforts should be initiated in advance so as to eliminate or minimize the need for release holds.
- A5) Maximum 6-hour release holds, if needed, may be implemented at releases of 8, 25, 50, and 80 kcfs.
- A6) A 6-hour hold at 115 kcfs is required before further increasing releases.

TABLE B - FORECAST-BASED RELEASES

INFLOW FORECAST VOLUMES	Indicated Release
120-hr volume < 300 TAF	8 kcfs
120-hr volume > 300 TAF	25 kcfs
72-hr volume > 300 TAF	50 kcfs
48-hr volume > 300 TAF	80 kcfs
24-hr volume > 300 TAF and inflow >= 115 kcfs	115 kcfs

FOLSOM DAM AND LAKE
American River, California

WATER CONTROL DIAGRAM

APPROVED _____

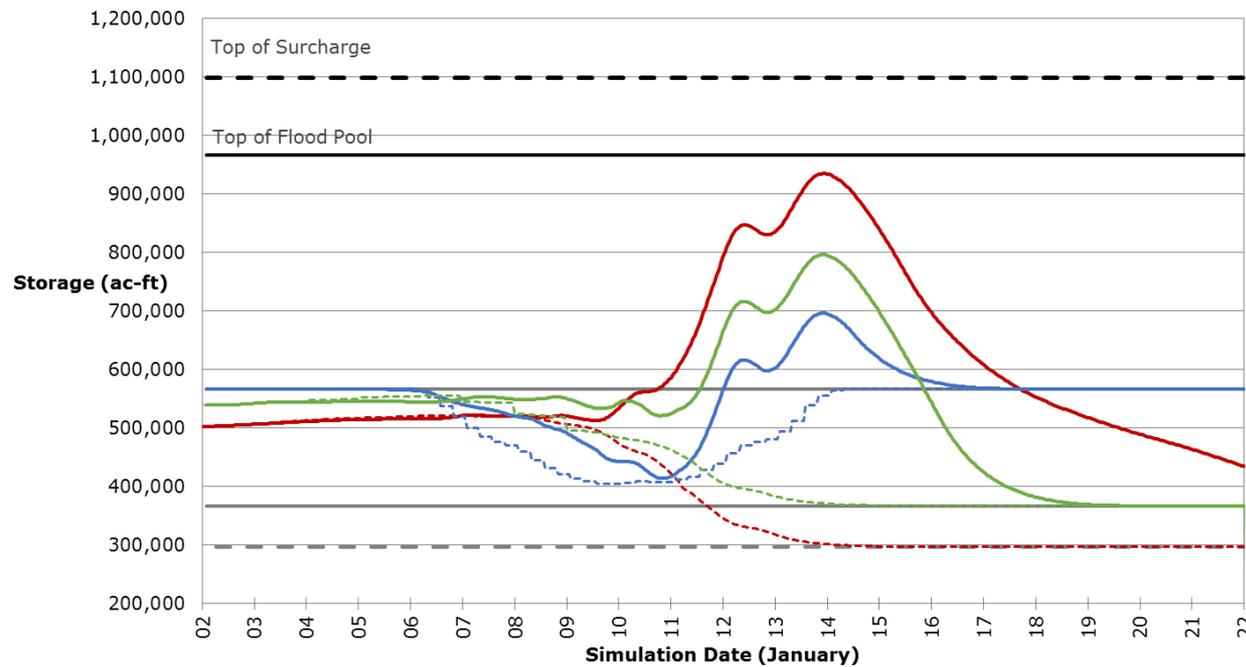
APPROVED _____

Effective Date _____ File No. _____

Routing comparisons

1986 event pattern scaled to 100-yr

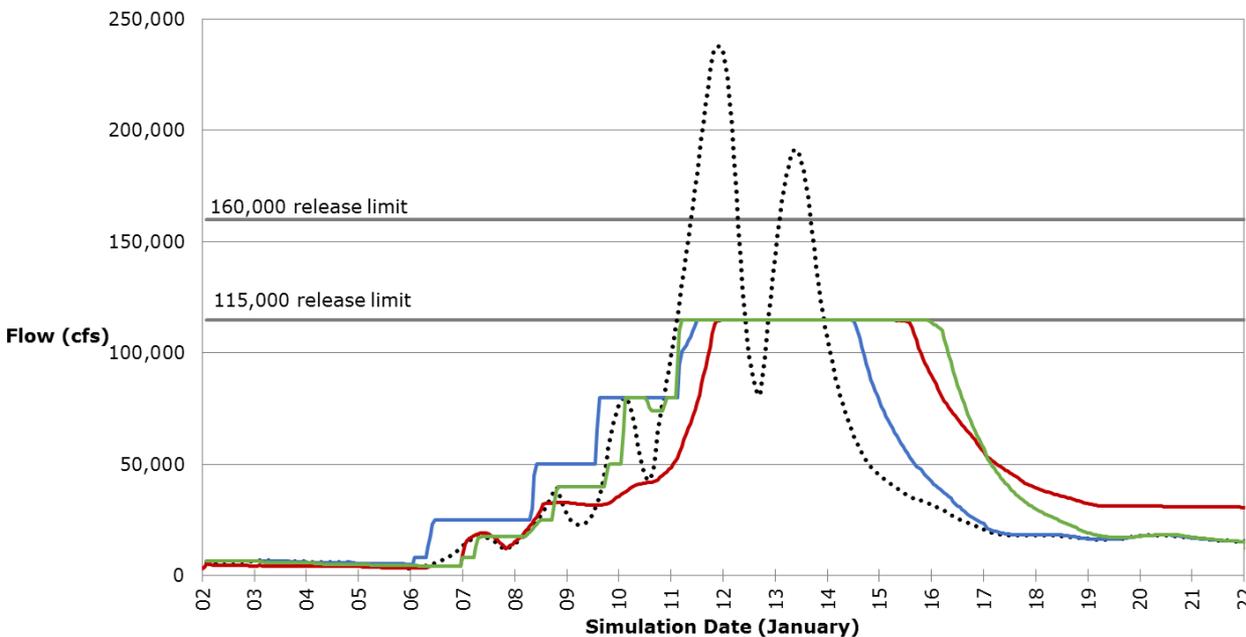
Forecast operation reflects perfect forecast



 USBR/SAFCA – US storage

 Alt. 1 – US storage and basin wetness

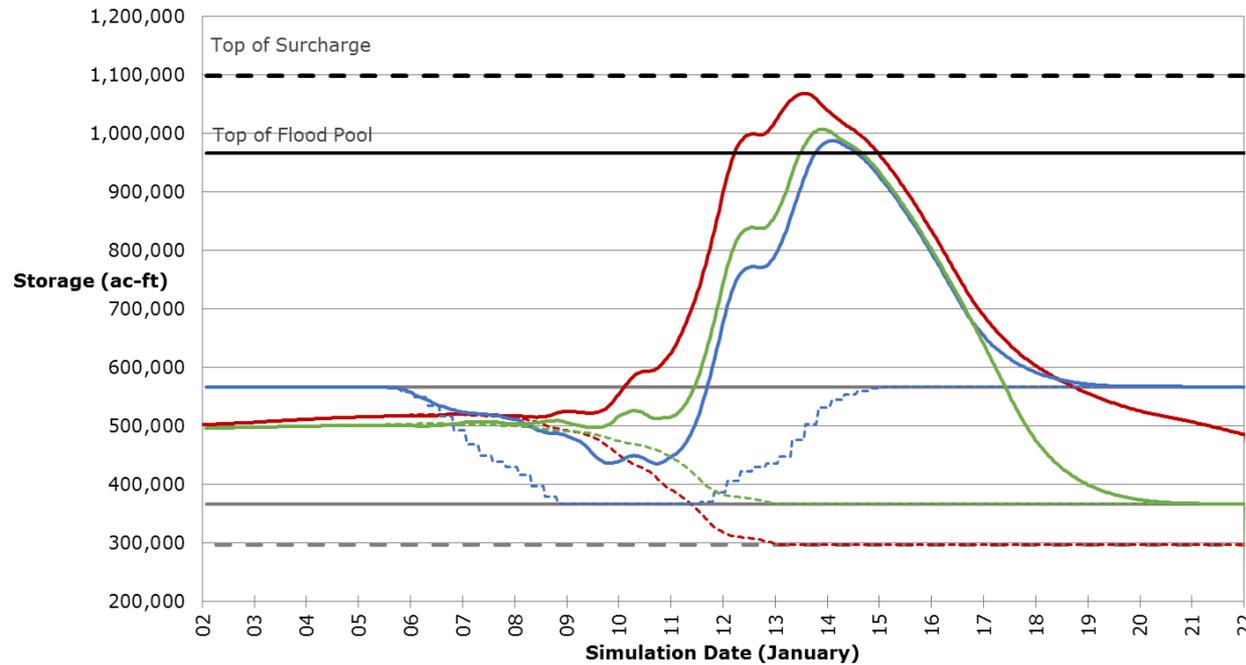
 TSP – Forecast-based



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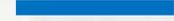
1986 event pattern scaled to 200-yr

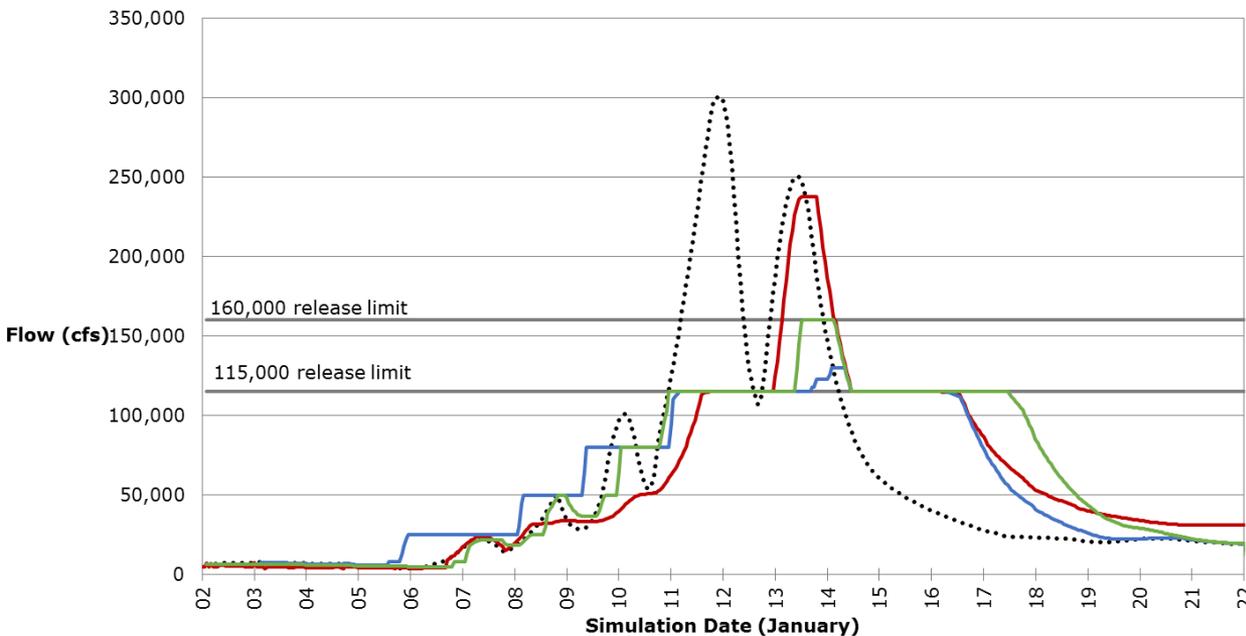
Forecast operation reflects perfect forecast



 USBR/SAFCA – US storage

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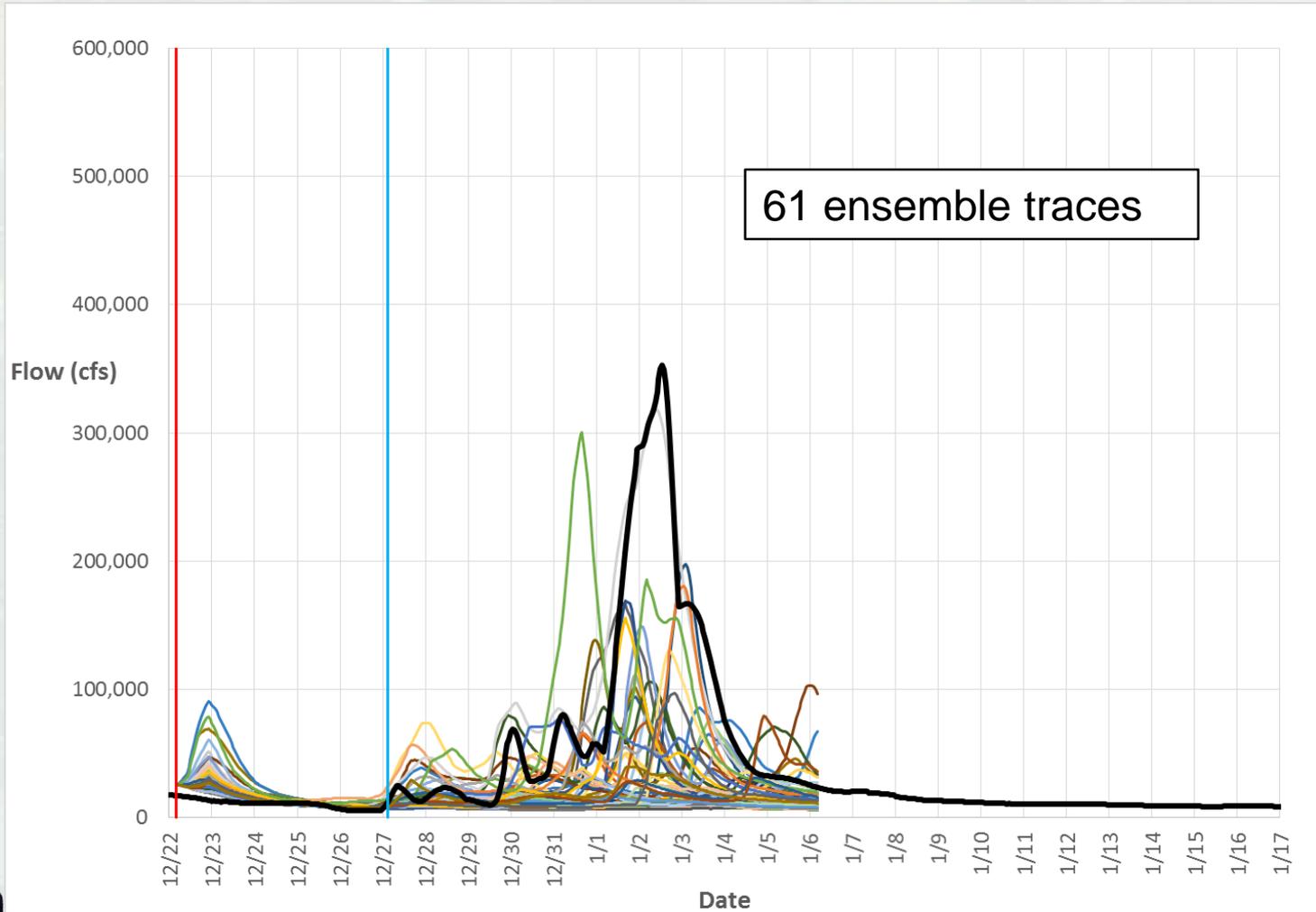
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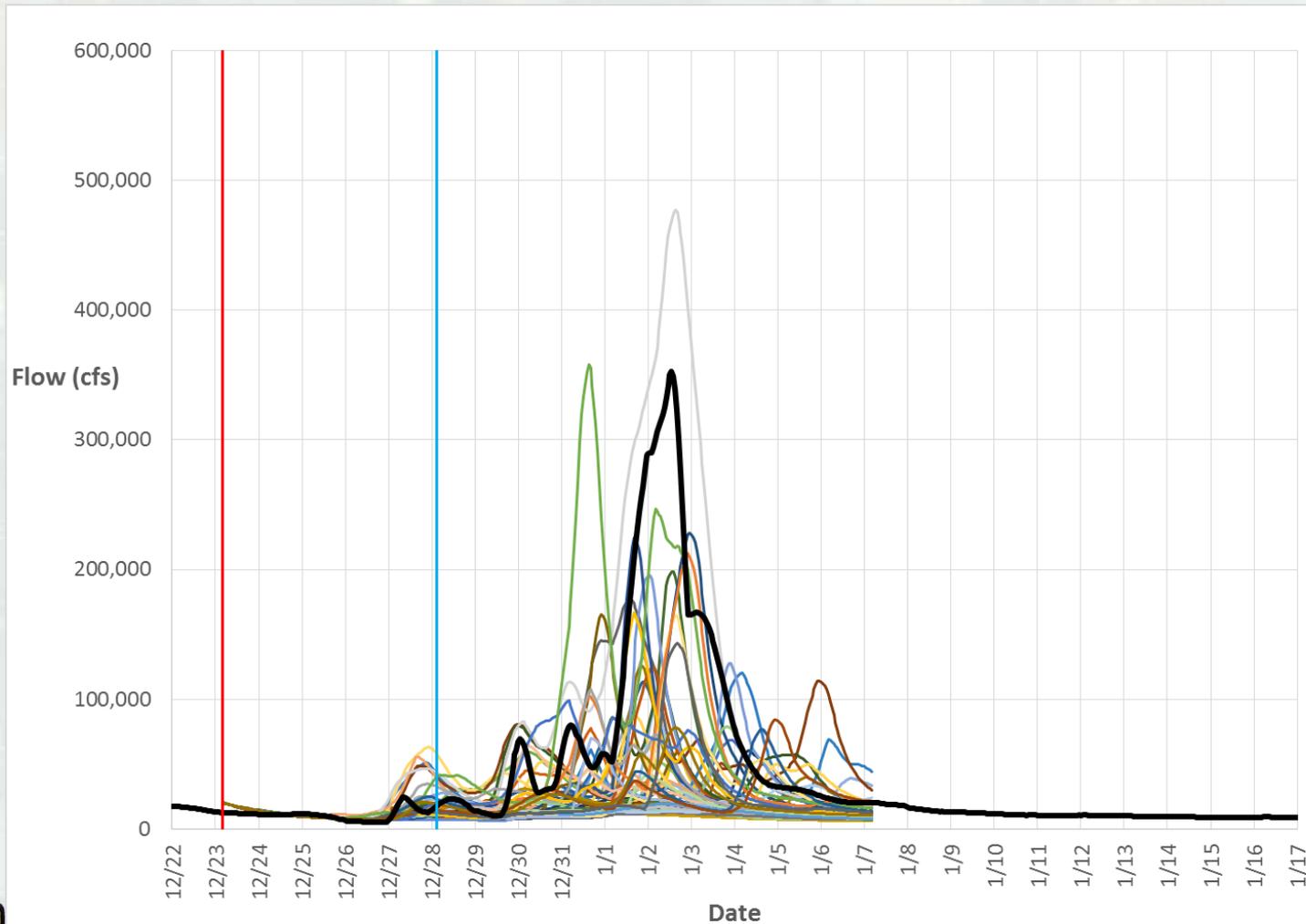
Use of Forecast Ensembles



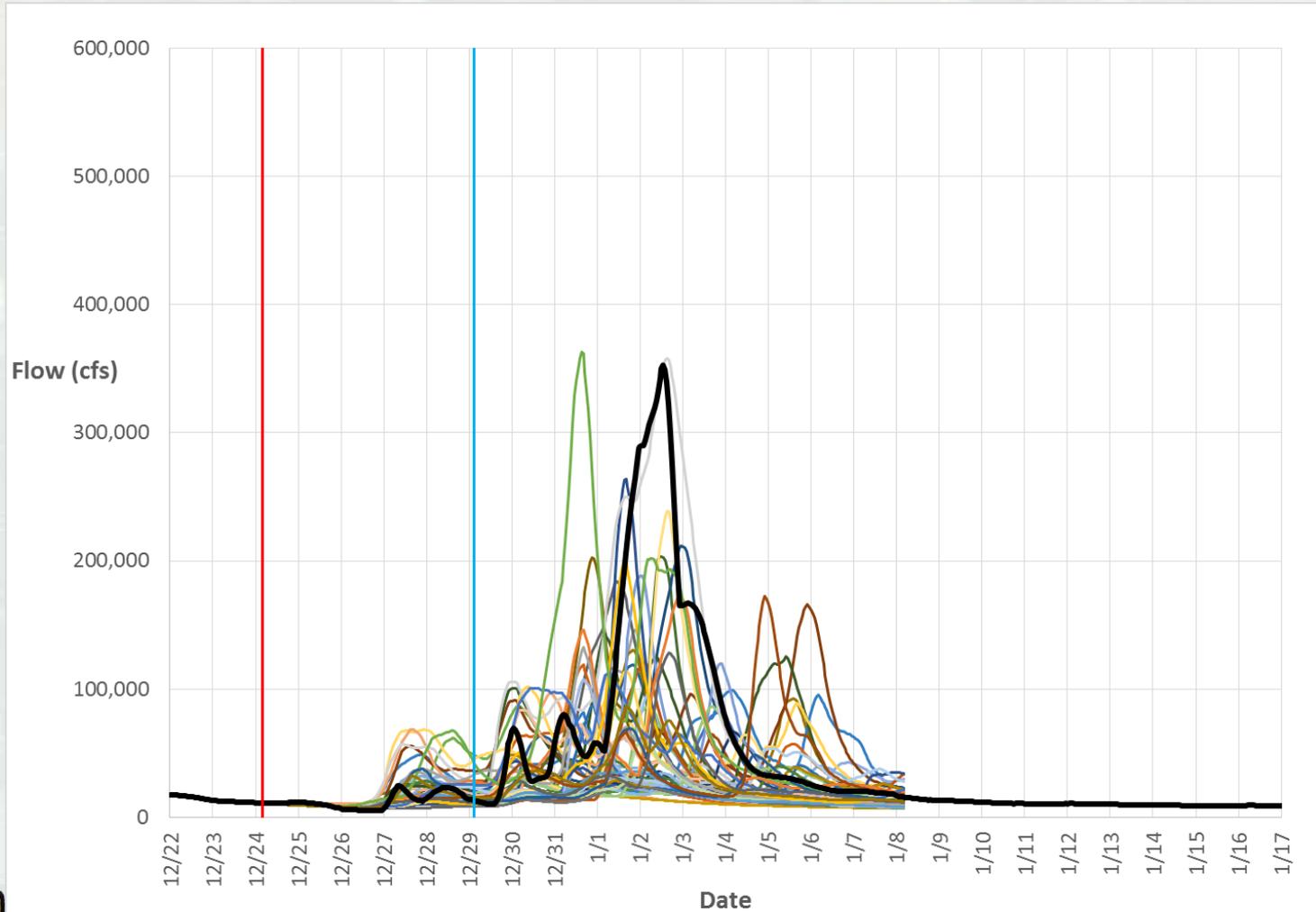
Forecast Ensemble 12/22



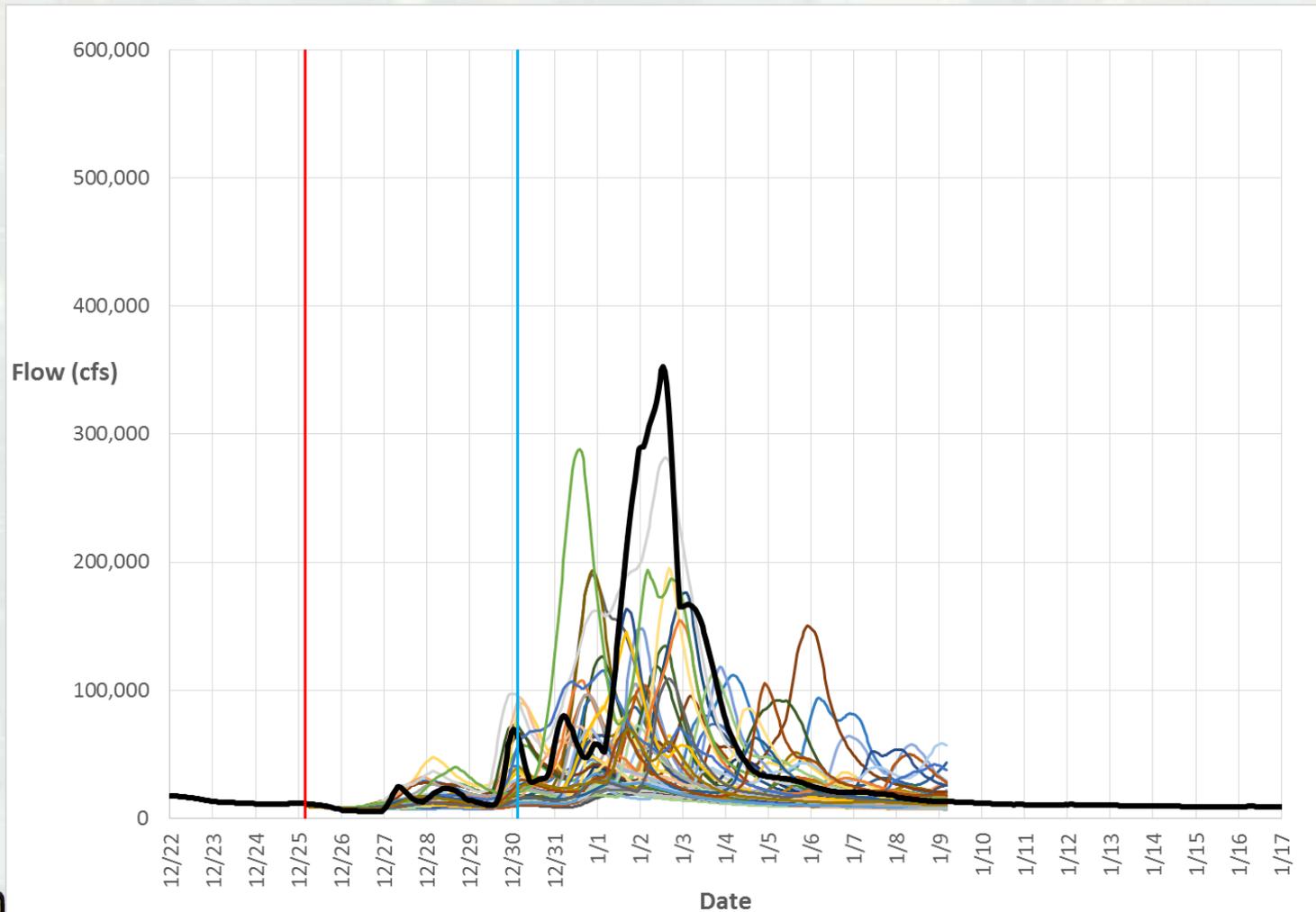
Forecast Ensemble 12/23



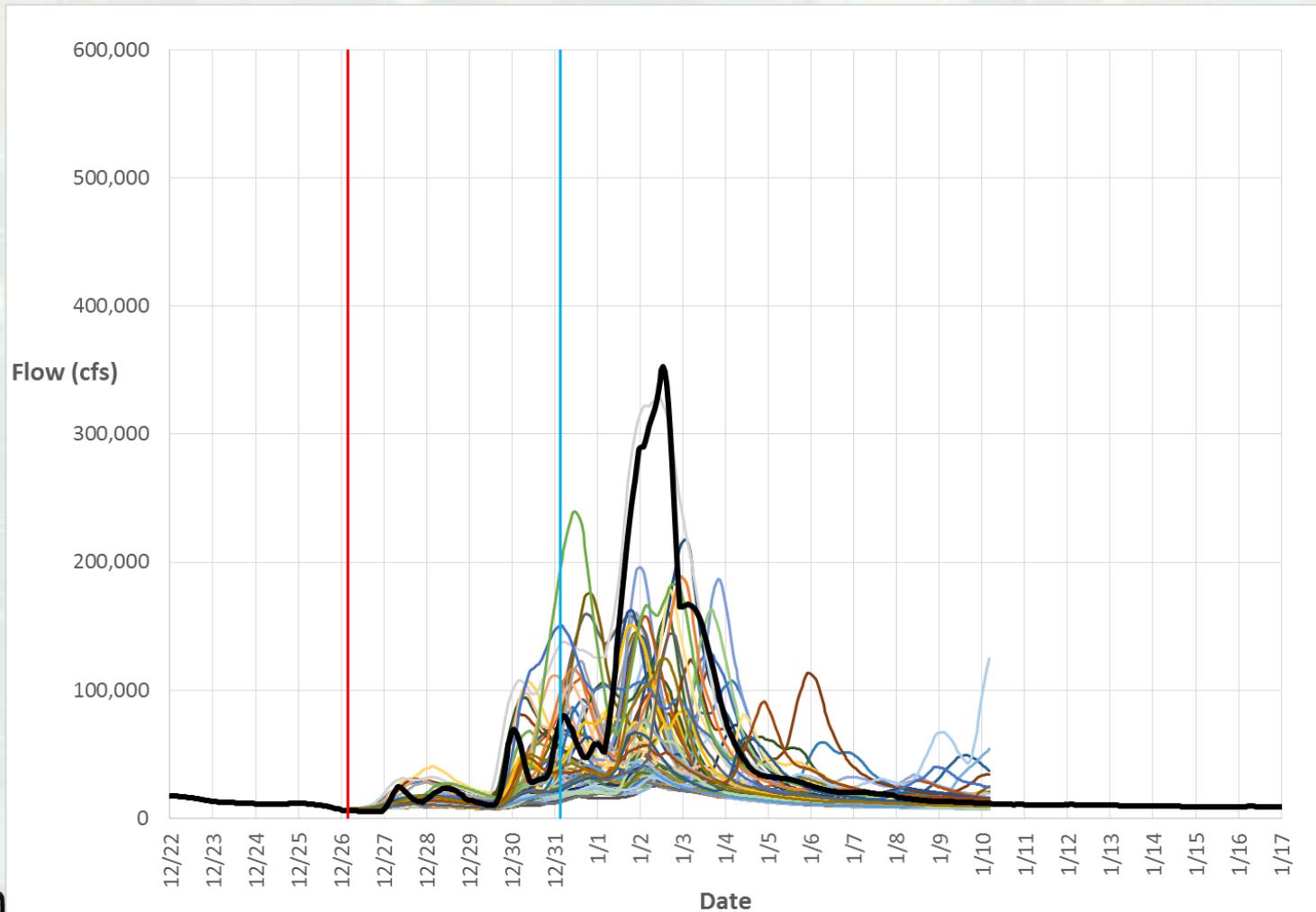
Forecast Ensemble 12/24



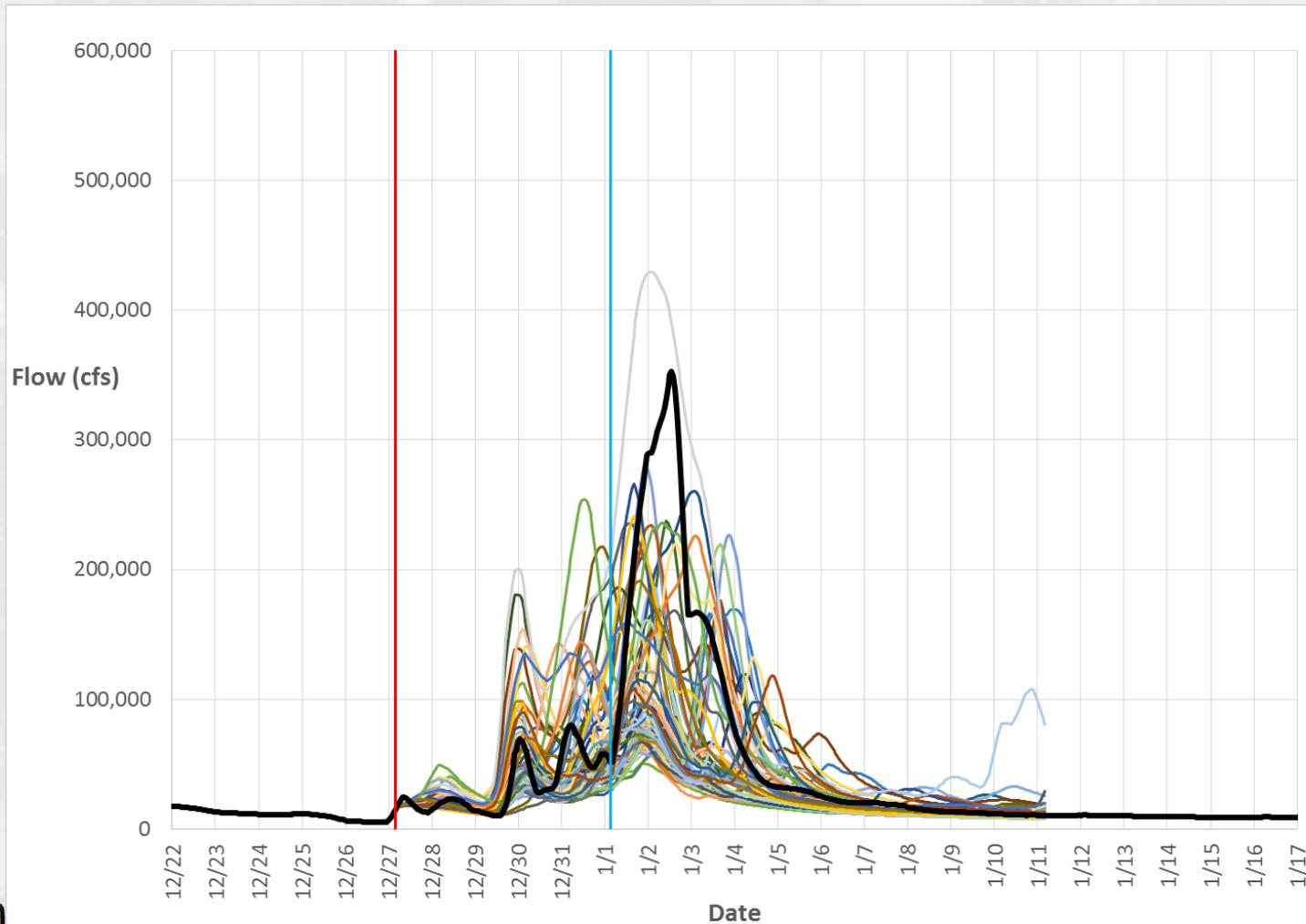
Forecast Ensemble 12/25



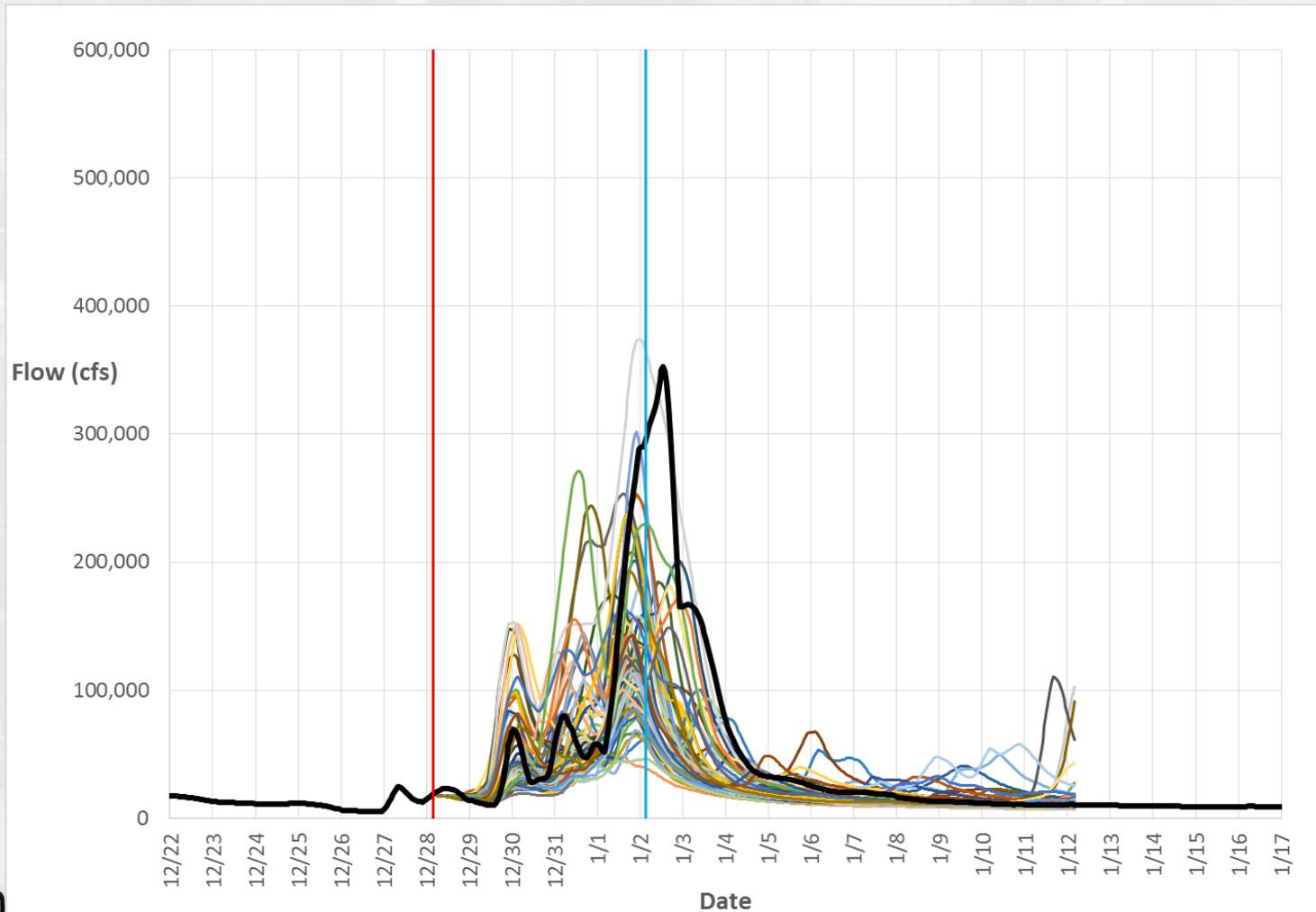
Forecast Ensemble 12/26



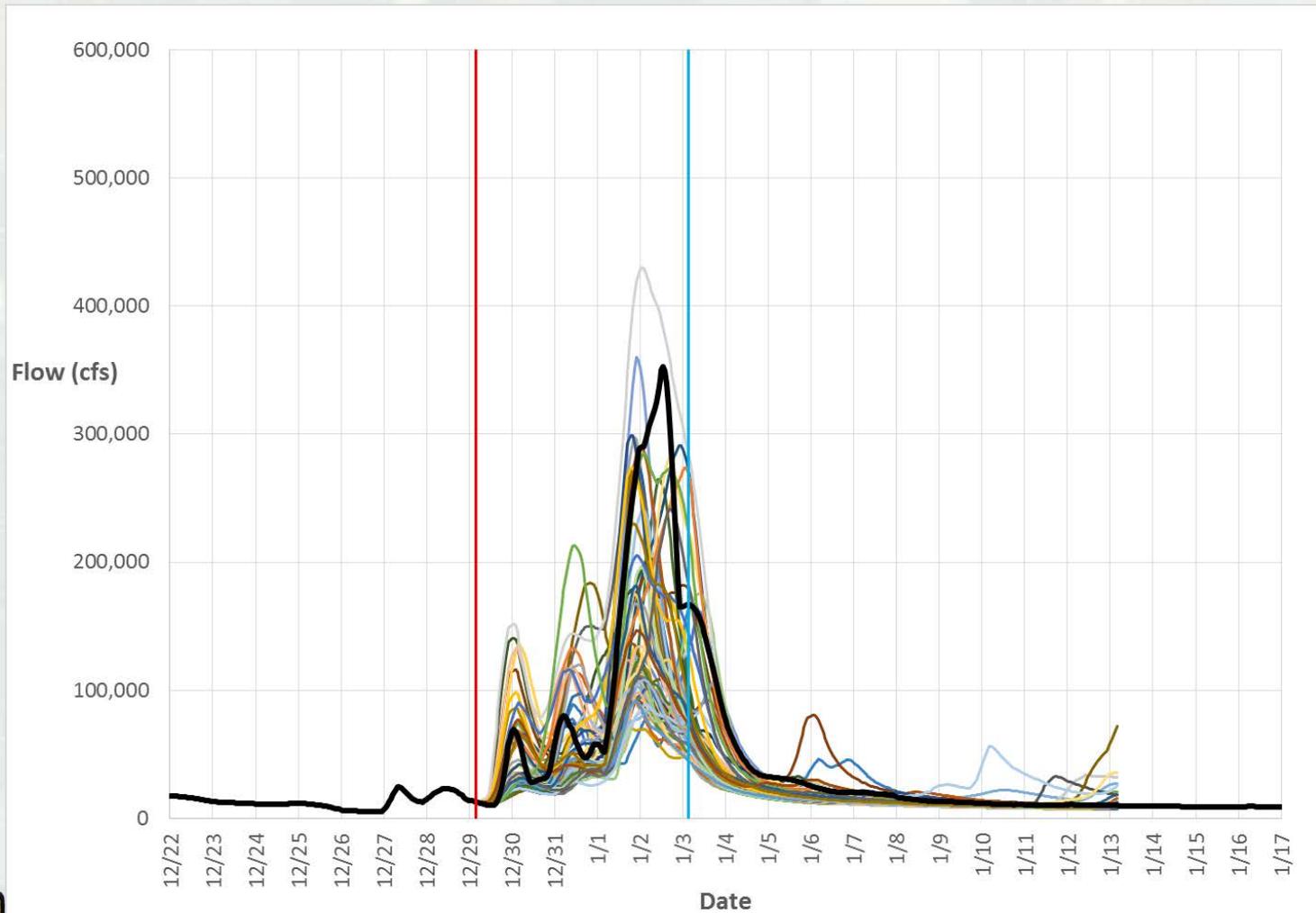
Forecast Ensemble 12/27



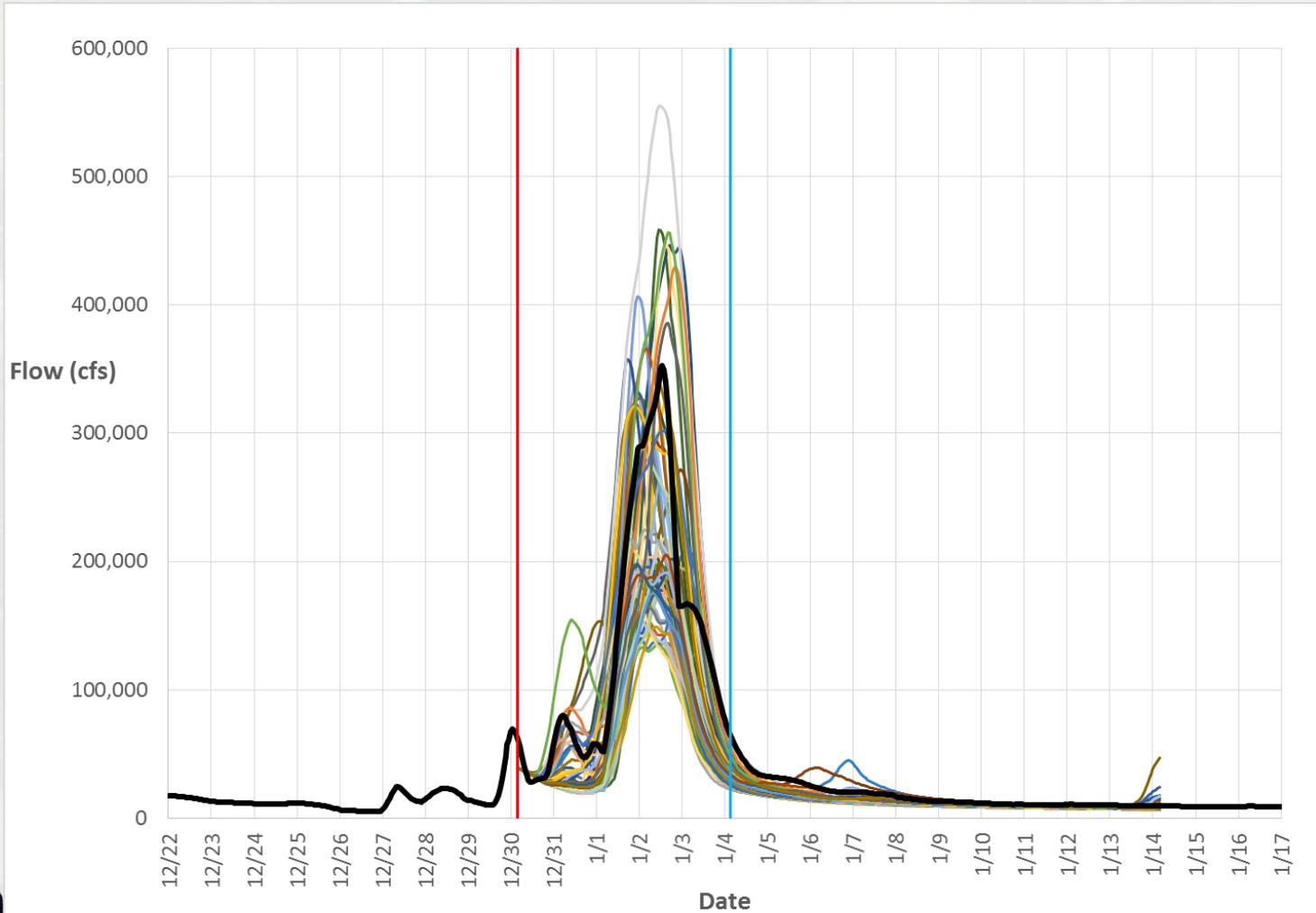
Forecast Ensemble 12/28



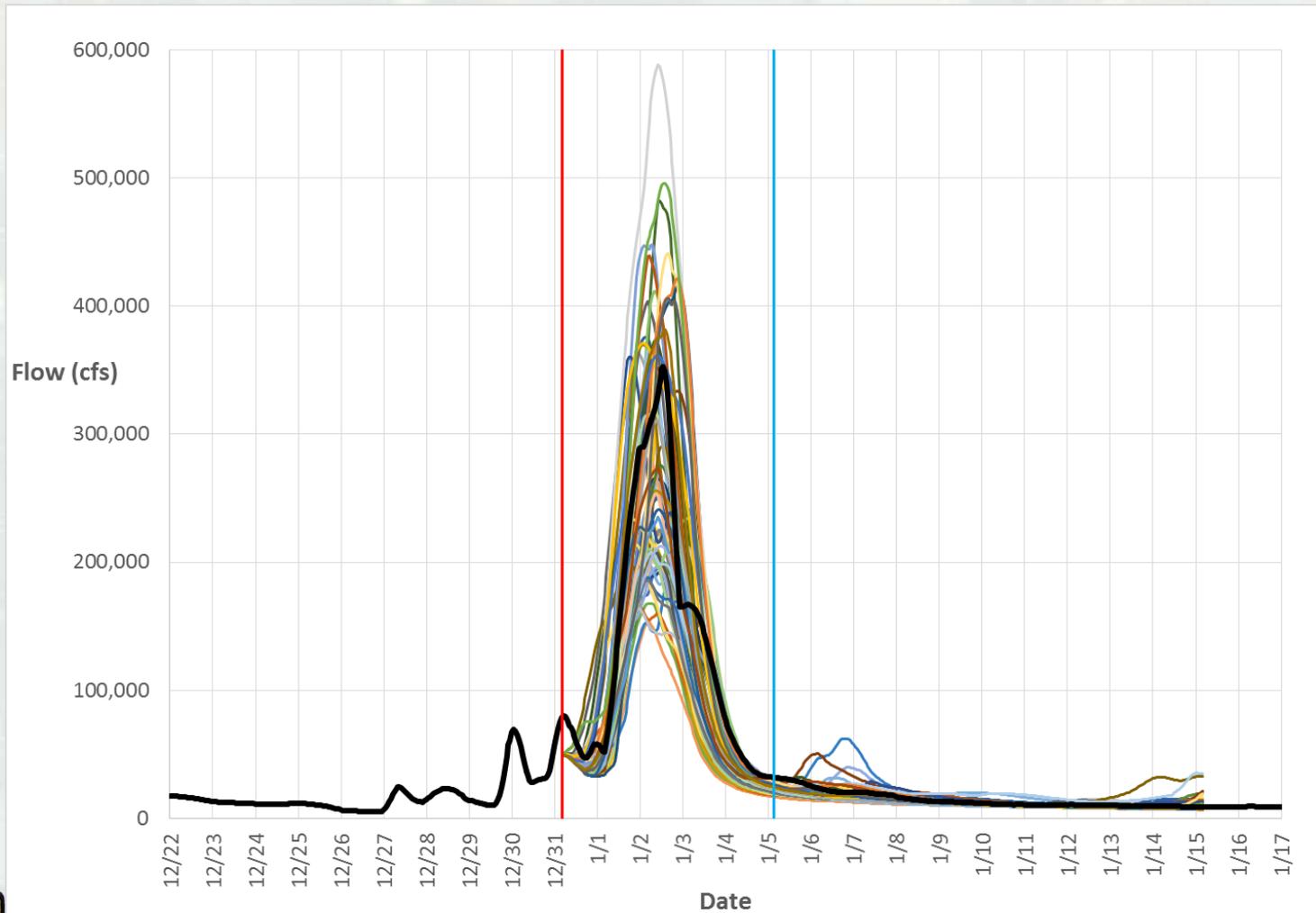
Forecast Ensemble 12/29



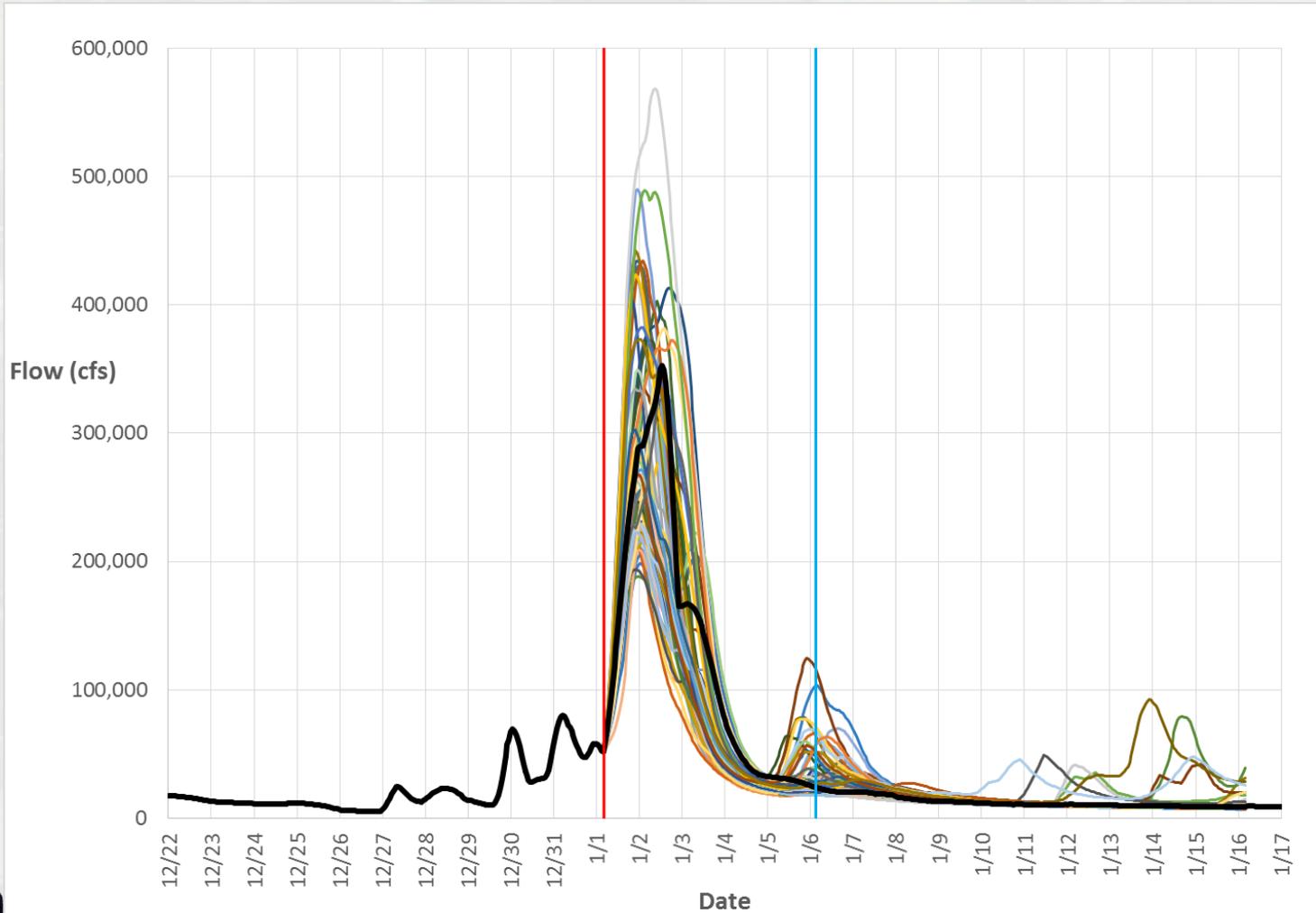
Forecast Ensemble 12/30



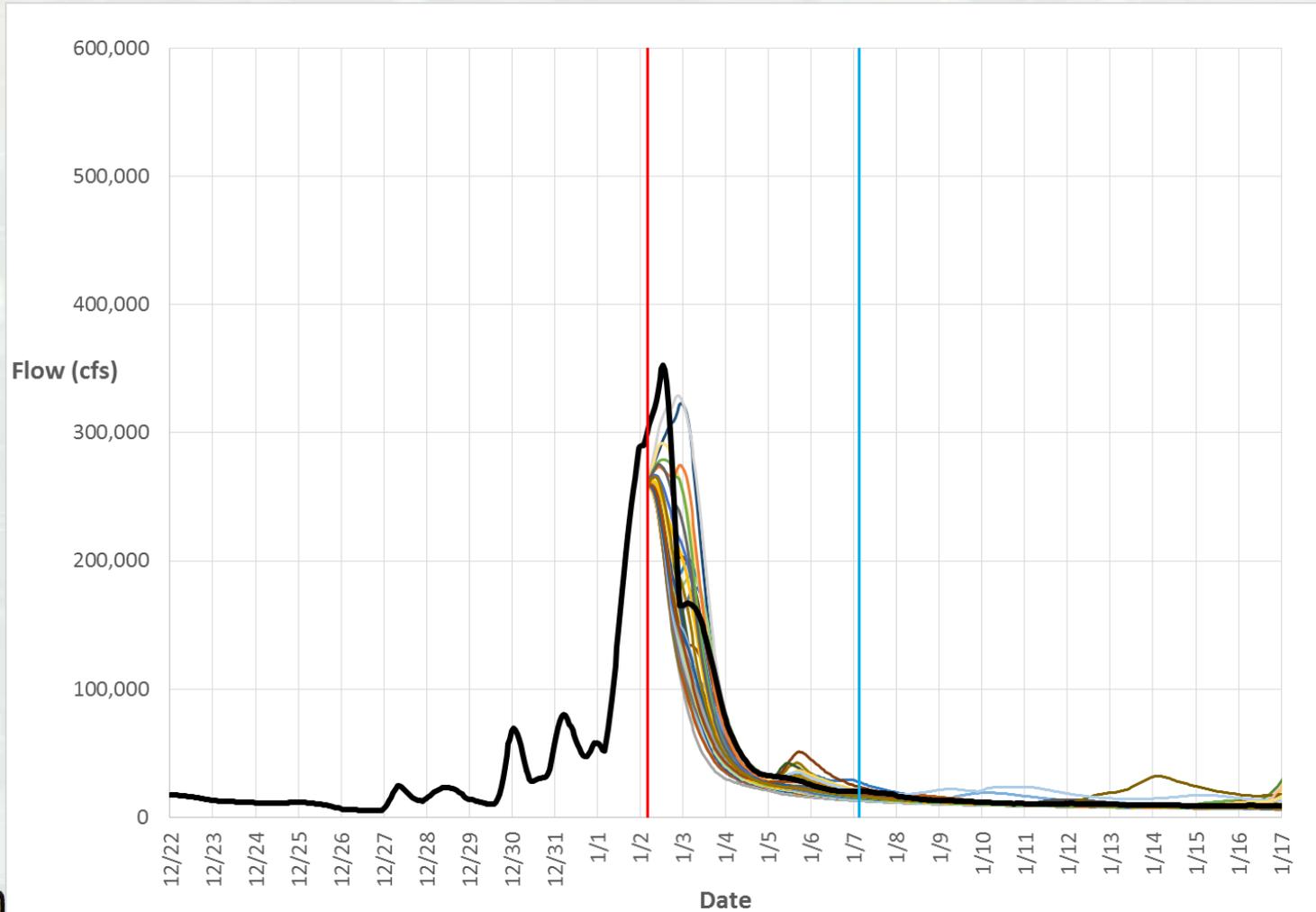
Forecast Ensemble 12/31



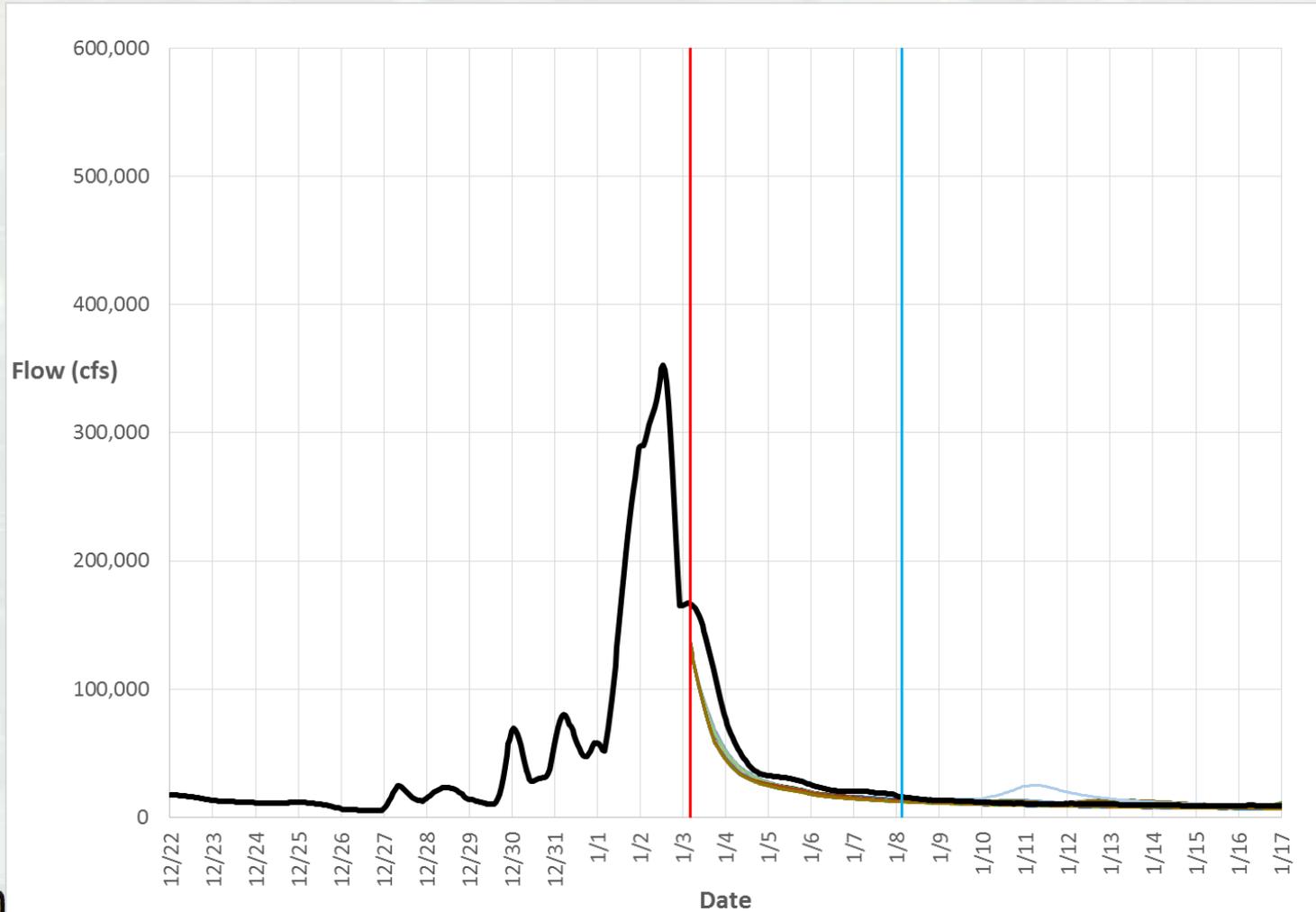
Forecast Ensemble 1/1



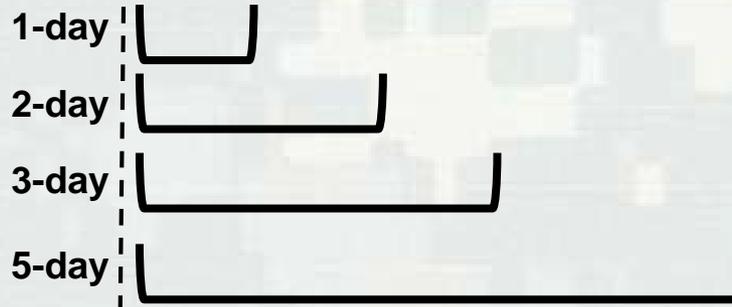
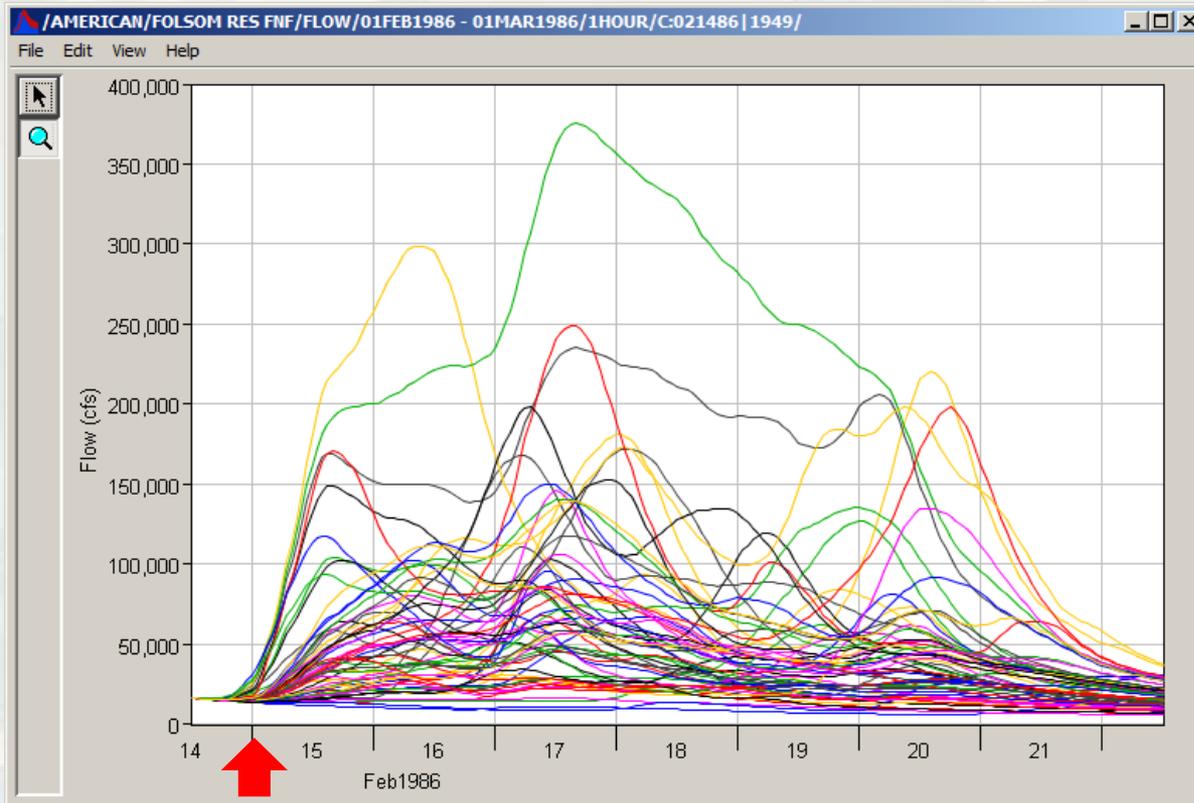
Forecast Ensemble 1/2



Forecast Ensemble 1/3

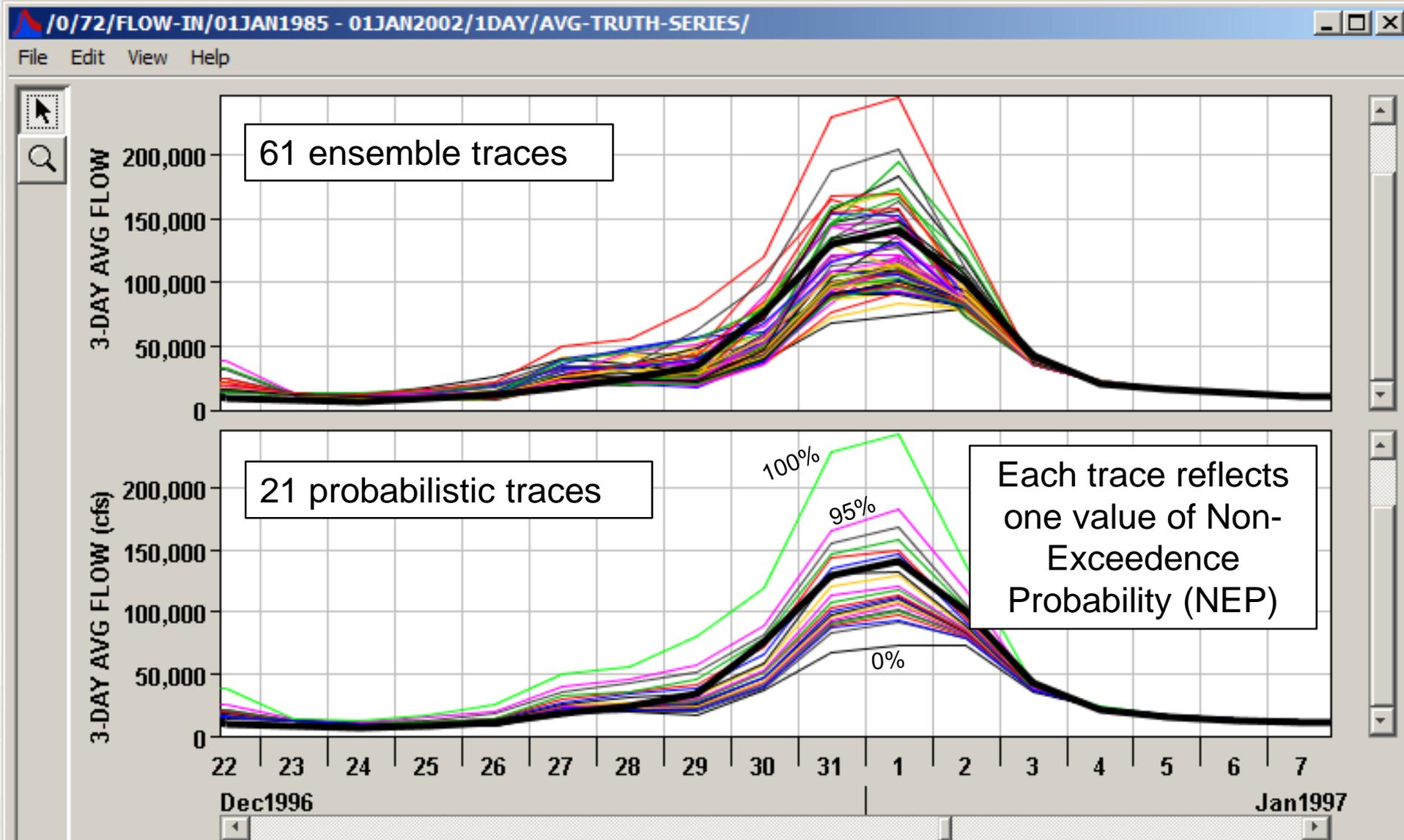


Compute Forecasted Inflow Volumes



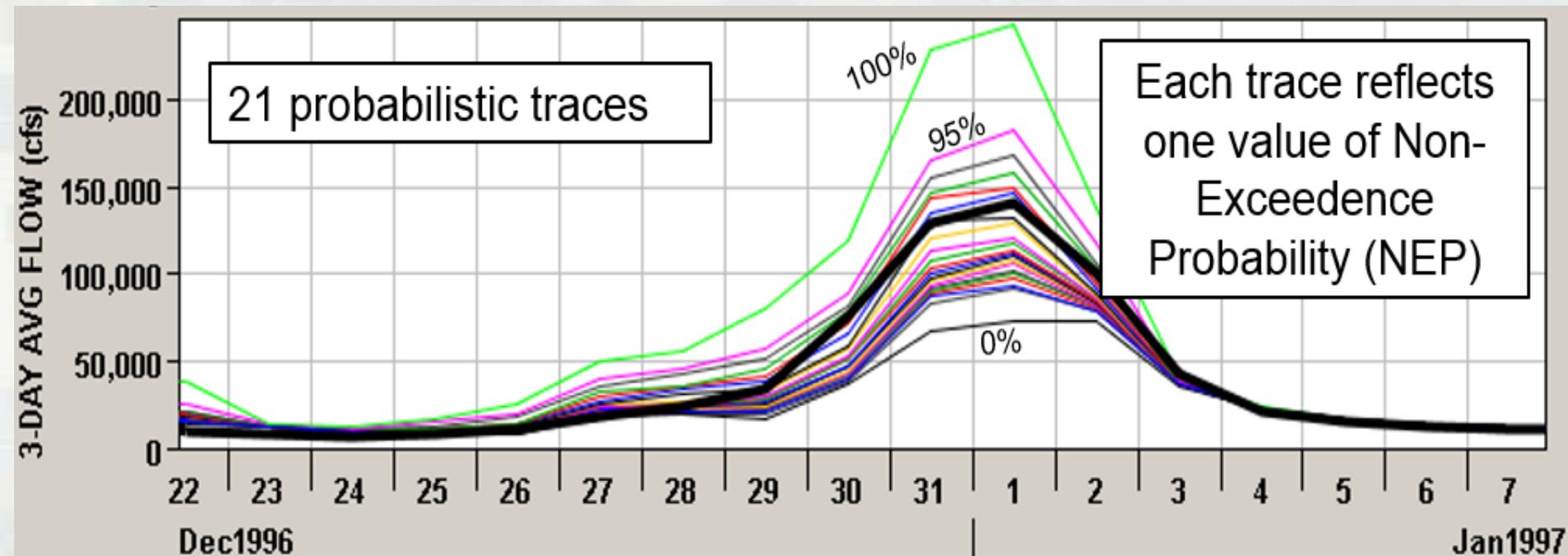
1997 event hindcast series

3-day volume updated daily

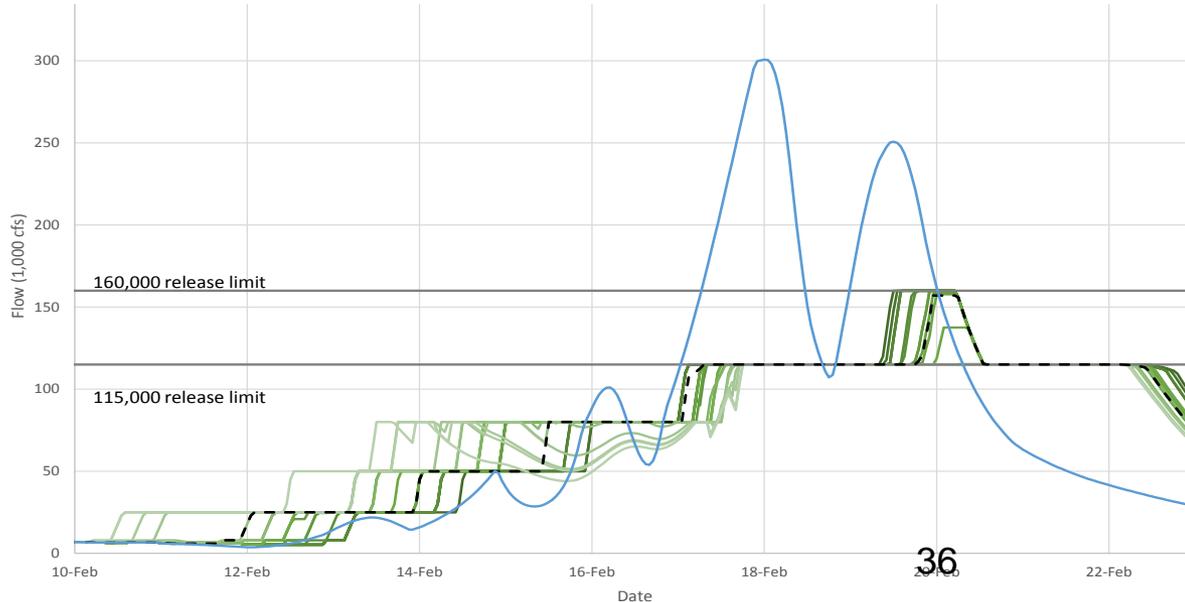
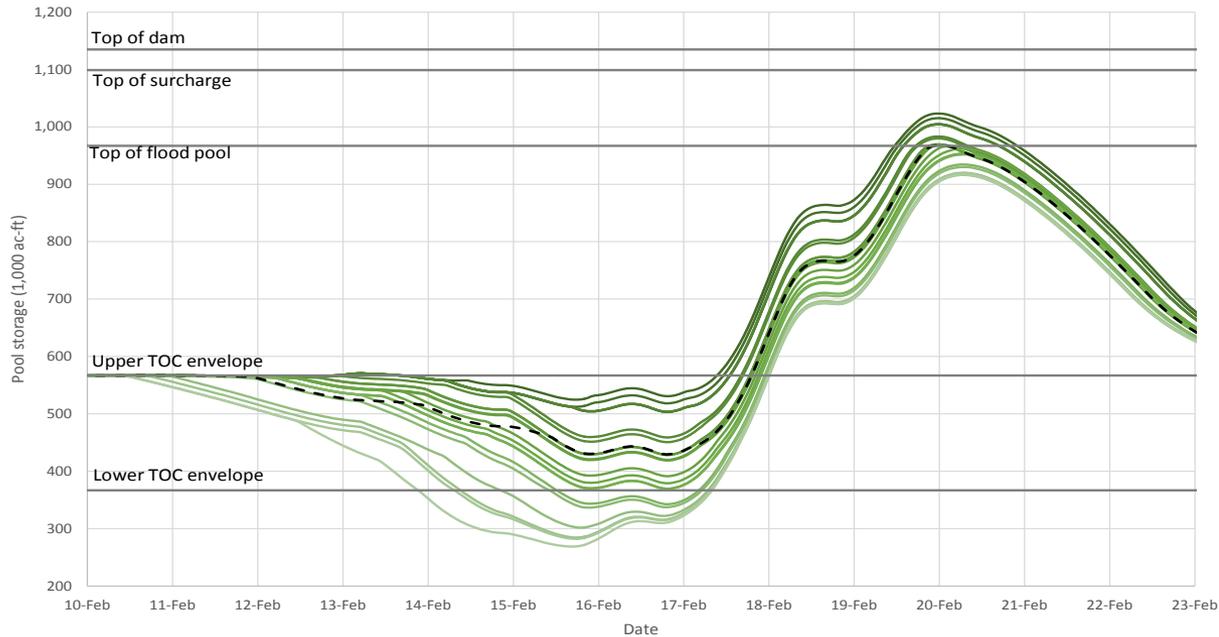


Robustness Testing

- Considers uncertainty in forecast indicated by the forecast ensemble.
- Tests operation using imperfect forecasts.
- Used to identify operational NEP value.



Robustness Test Example



**1986 event pattern
scaled to 200-yr**

21 simulations
corresponding to NEP
values ranging from 0%
to 100% (5%
increments).

Perfect forecast shown
as black dashed line for
reference.



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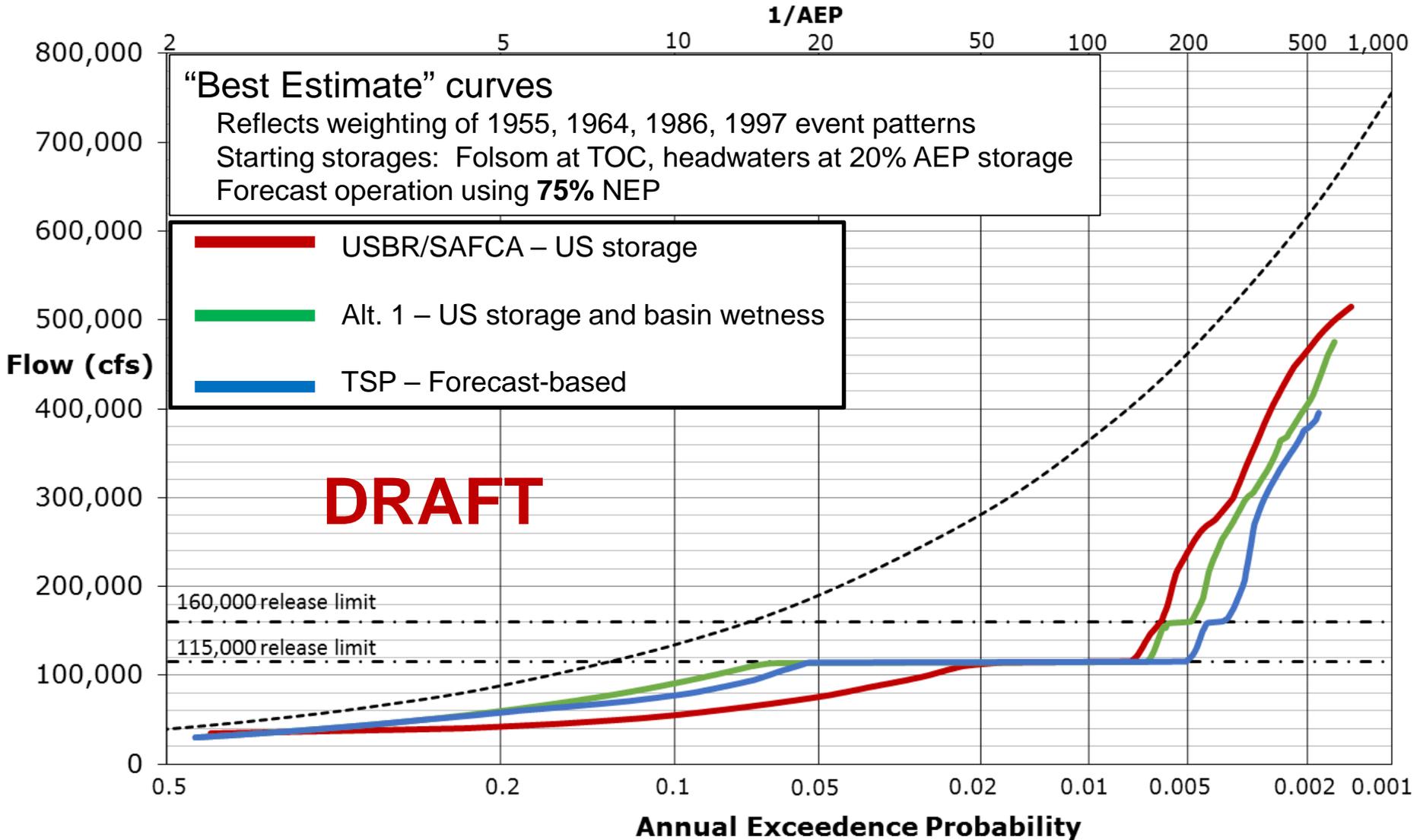
Robustness Summary

Project Goals	Minimum NEP (%) (1986 / 1997 patterns)
Pass 100-yr event at 115 kcfs	0% / 0% (ALL PASS)
Pass 200-yr event at 160 kcfs	0% / 0% (ALL PASS)

Other Metrics of Interest	Minimum NEP (%) (1986 / 1997 patterns)
Pass 200-yr event at 160 kcfs (24-hr late forecast)	55% / 60%
Pass 200-yr event at 115 kcfs	65% / 75%



Regulated Peak Flow-Frequency



Moving Forward

- Tentatively selected plan (TSP).
- 1st draft engineering report complete.
- 8/1/2016 – ATR begins on 2nd draft
- Division / Headquarters / IEPR review
- 4/15/2017 – Final Signatures



Lessons Learned

- Simple vs. Complex
- Corps *seems* more comfortable with:
 - ▶ designated (and limited) variable flood space
 - ▶ work within TOC framework
 - ▶ demonstrate well-behaved releases
- Development of flood control models and their possible use in environmental analyses must be carefully planned.



Discussion

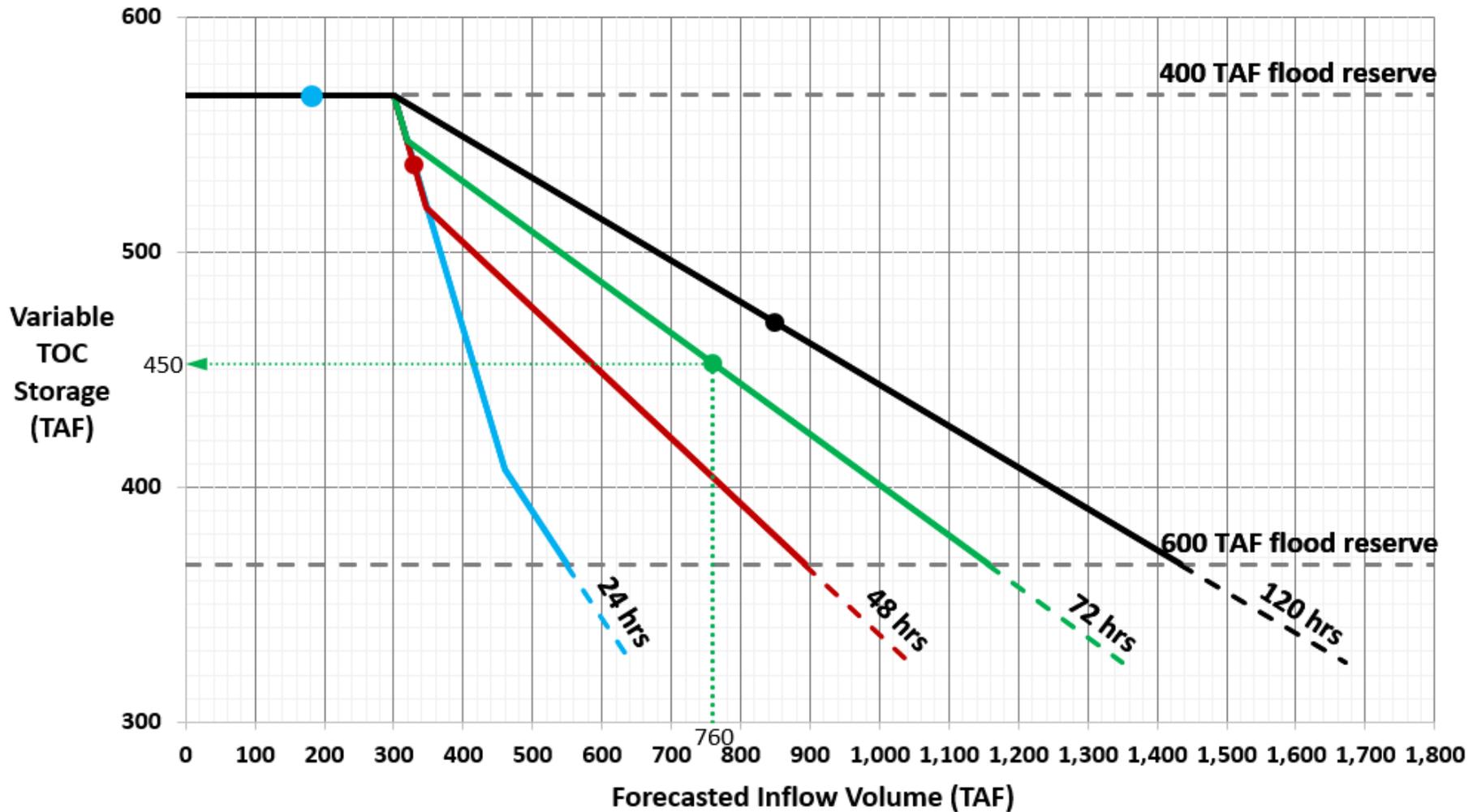


Other notes

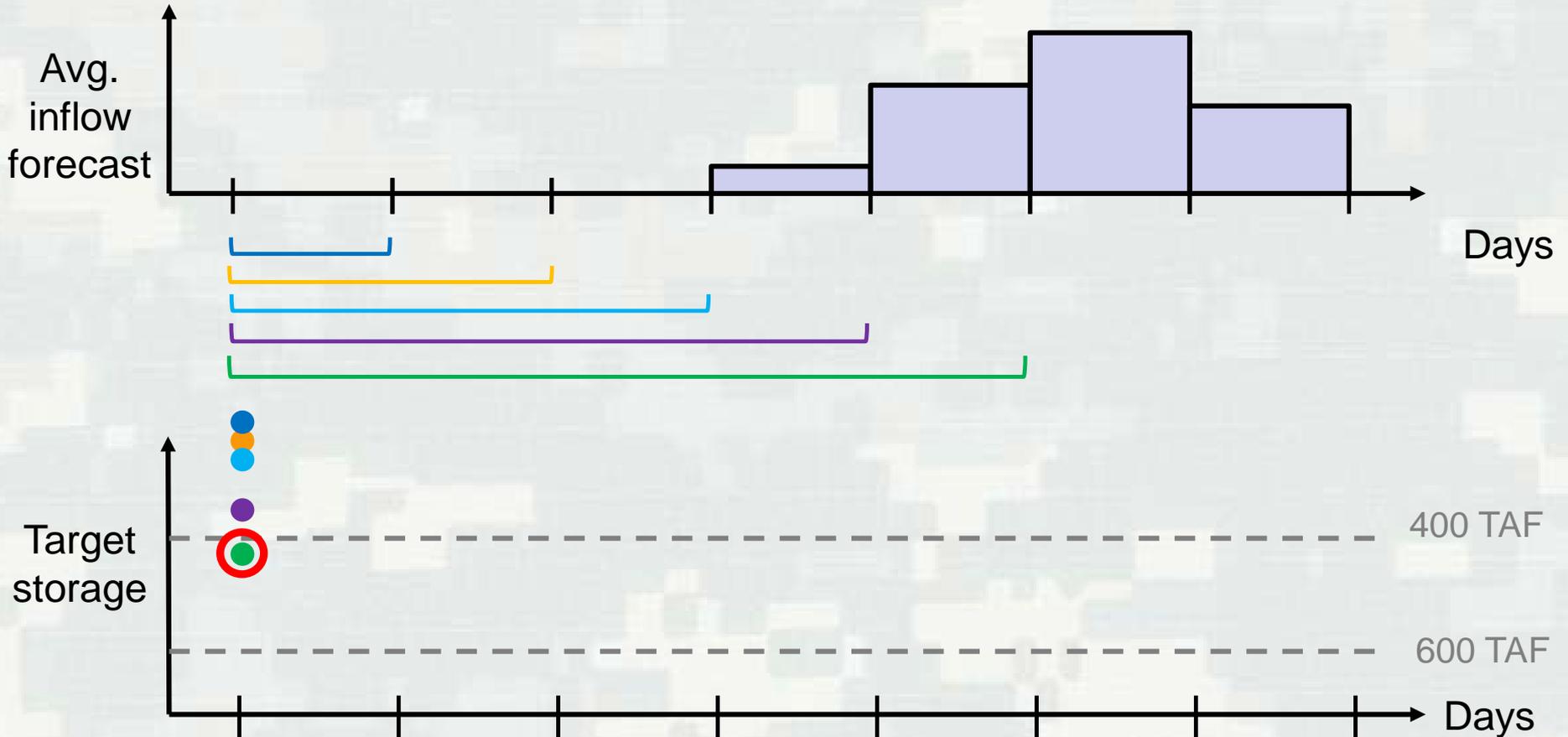
- From analysis of 15-year hindcast period of record:
 - ▶ 2 significant TOC drops (1986 & 1997)
 - ▶ Both refilled



Forecast-based TOC



Forecast-based TOC



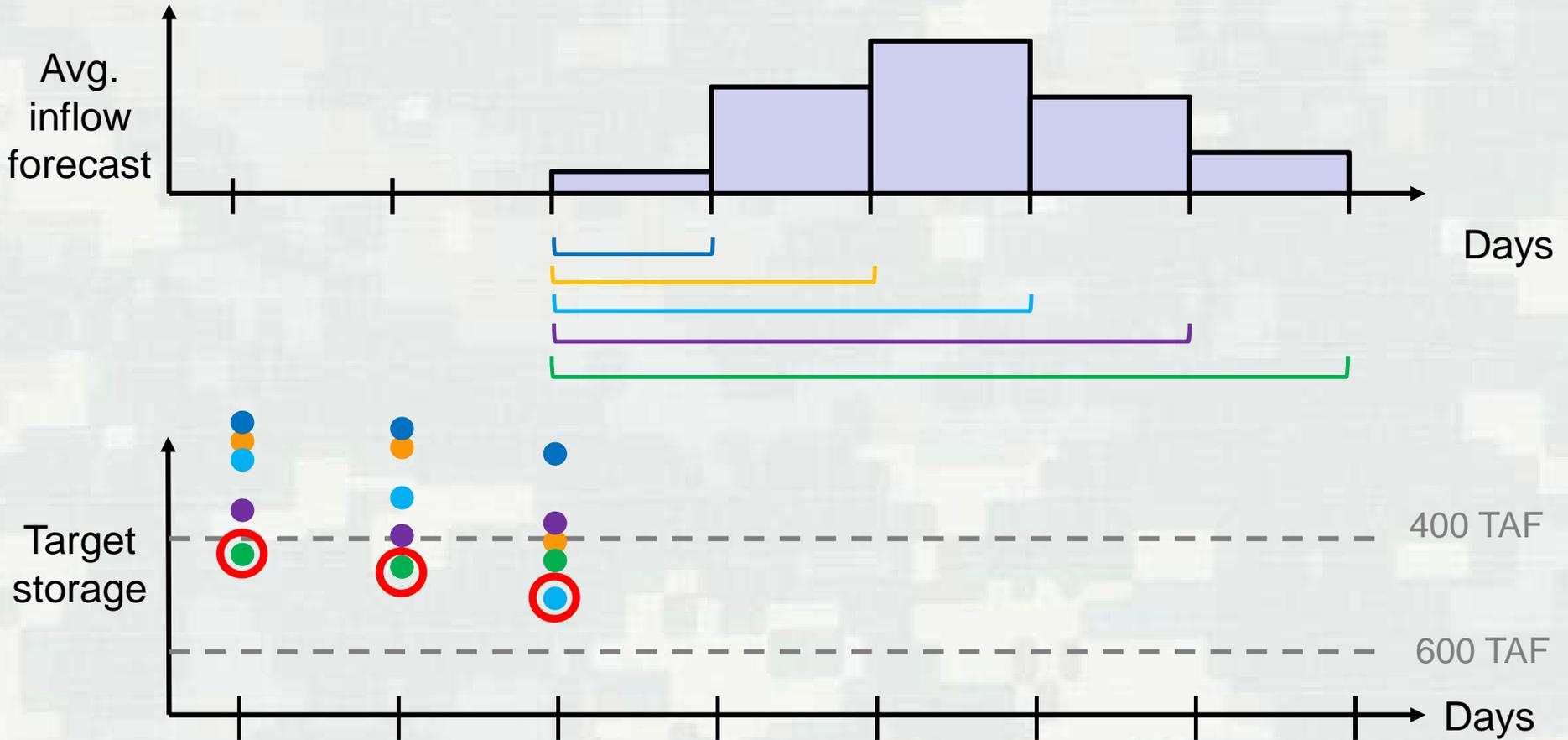
Now



Forecast-based TOC

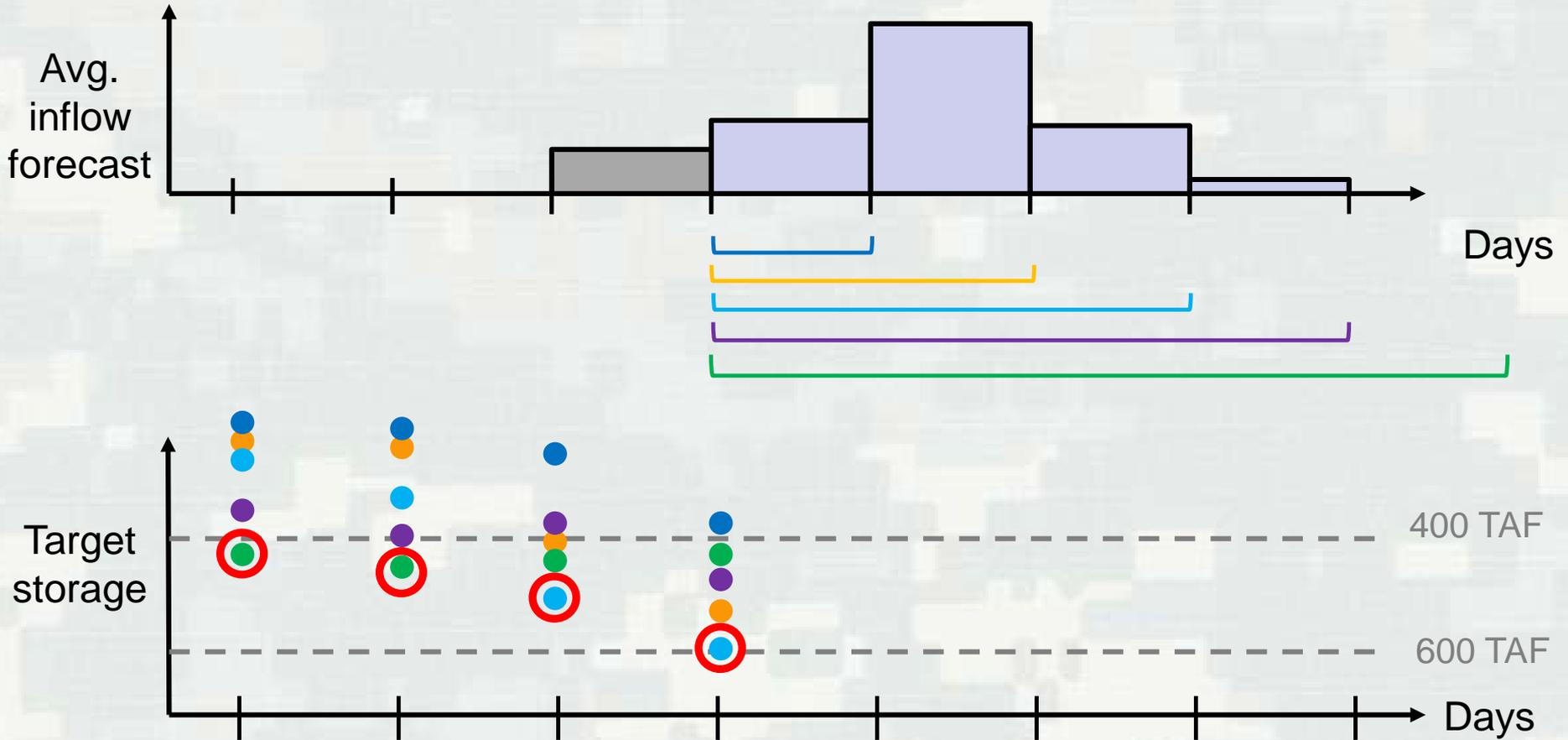


Forecast-based TOC

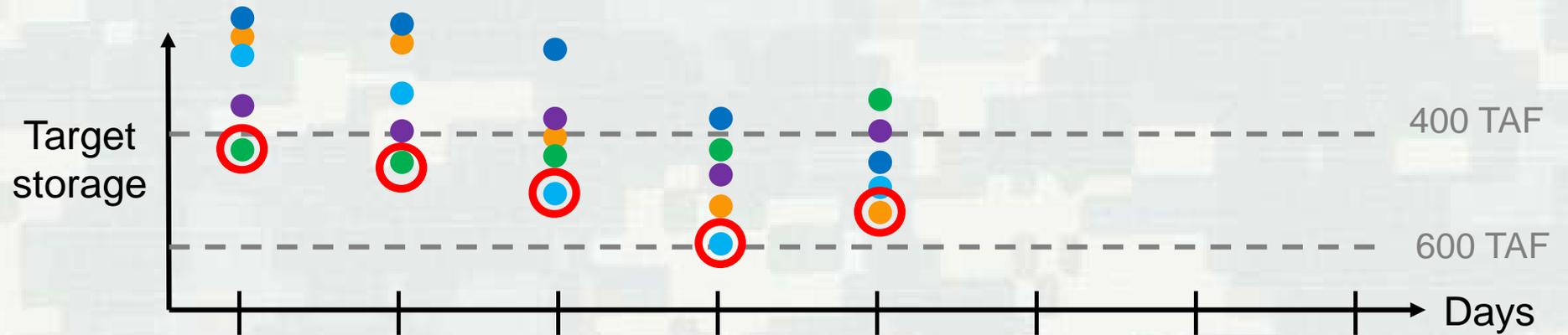
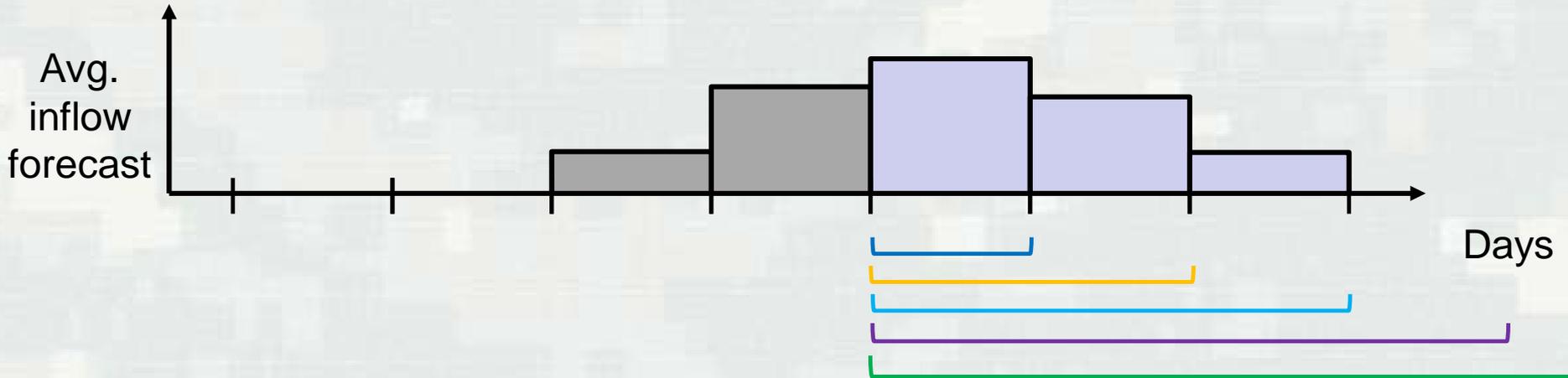


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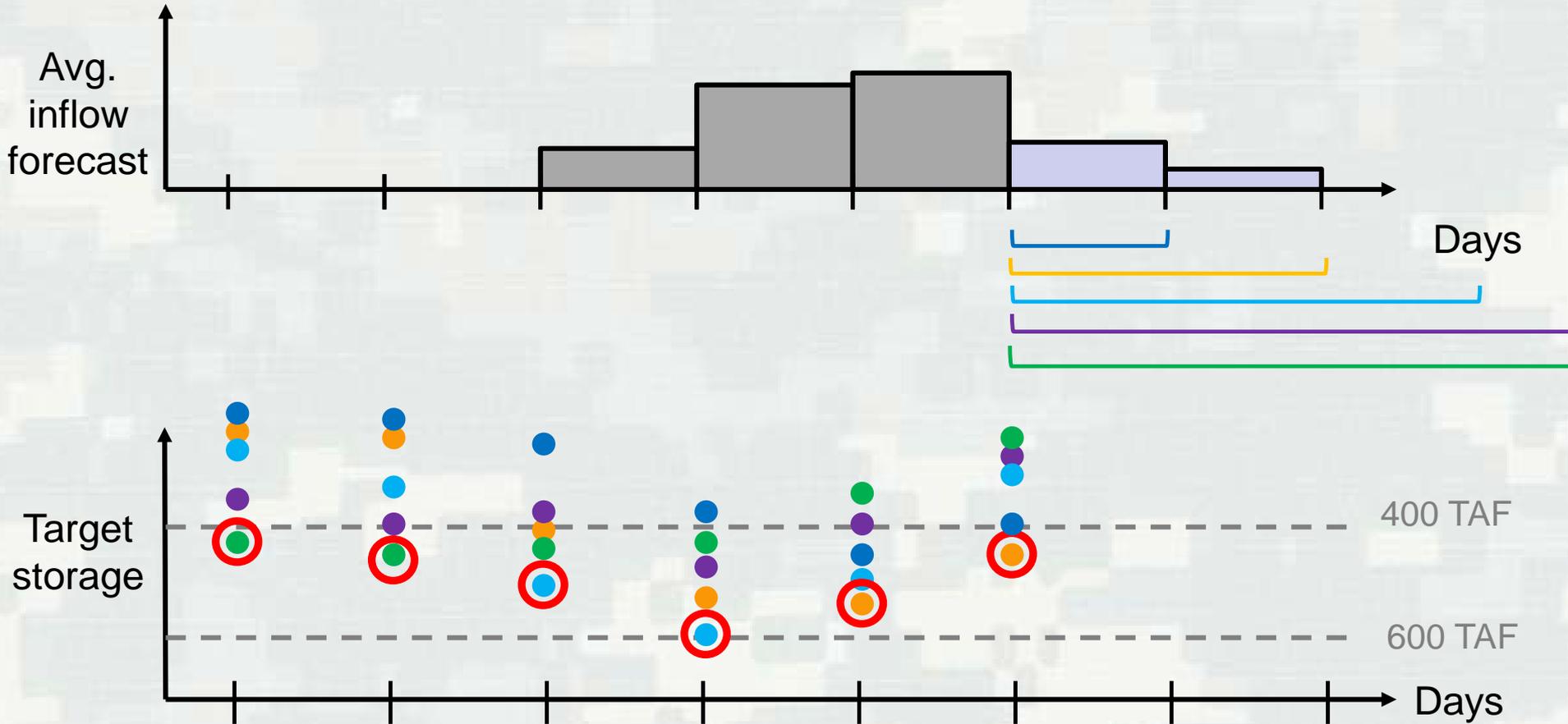
Forecast-based TOC



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Forecast-based TOC



Forecast-based TOC

