

Evaluation of Forecast-Based Advance Release Strategies at Folsom Dam

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BIOGRAPHICAL SKETCH

Beth Faber received her Bachelor of Science degree in Civil Engineering from the University of Colorado at Boulder in May 1991. From June 1991 to July 1995, she was employed by Denver Water in Denver, Colorado, performing analysis and operation of the city's reservoir system. During that period she also completed a Master's degree in Civil Engineering at the University of Colorado at Boulder.

Between 1995 and 2000, she completed the doctoral program at Cornell University, interspersed with brief periods of employment with Pacific Gas & Electric in San Francisco and Denver Water. She is currently employed at the US Army Corps of Engineers' Hydrologic Engineering Center in Davis, California.

Forecast-based Advance Release Operation at Folsom

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Information for Decision-making

1. More information allows better decision-making
2. Forecasts are valuable real-time information, although with some uncertainty
3. To use this information effectively, we must take the uncertainty into account
 - What decisions will this information aid?
 - What is the form of the uncertainty?

Decisions Made with Forecasts

Forecast-based Advance Release

When forecasts predict a flood event, begin additional release to reduce reservoir storage

- Allows a portion of the Conservation Pool for flood event storage - *increased flood protection*

OR

- Allows conservation storage in the Flood Pool, which can be evacuated before a flood event - *increased water supply*

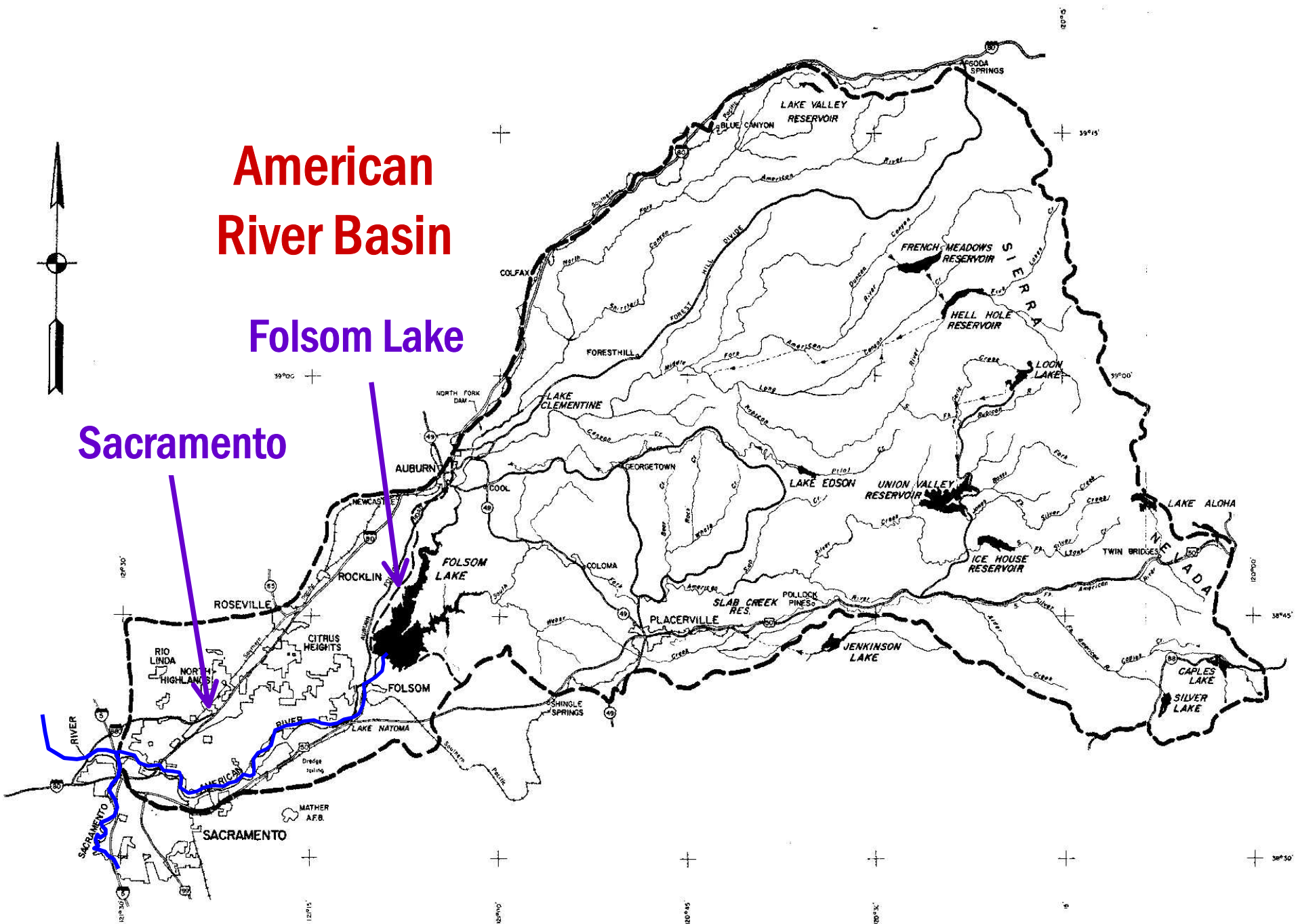
Forecast Uncertainty

- Streamflow forecast uncertainty is based on precip uncertainty
- Uncertainty is greater for time-periods that are further in the future
- Uncertainty is greater on larger flows (near the flood peak) than smaller
- Forecasts of extremely large events are more certain than smaller events, because the weather systems are slow moving and stable

American River Basin

Folsom Lake

Sacramento



Facts about Folsom Lake

- 1,000,000 Acre-Foot reservoir on the American River
- Approximately 500,000 AF of flood storage reservation
 - adjusted based on storage in upstream reservoirs
- Maximum Normal Flood Release is **115,000 cfs** *remember this number!*
 - currently requires spillway
- Current low outlet capacity \cong 32,000 cfs
 - with proposed modifications, will be $>$ 115,000 cfs
- Downstream channel is impacted above 20,000 cfs

Preliminary Study of Advance Release

- HEC studied Advance Release at Folsom Reservoir on the American River
- Focused on increasing flood protection while preventing negative impact of Advance Release operation. Want to avoid:
 - higher release than needed without Advance Release
 - failure to refill reservoir after event
 - loss of stored cold water for temperature control

Preliminary Study of Advance Release

- Negative impacts considered result from "false alarm" forecasts that overestimate the flood event
- In this study, focused on ensuring the reservoir's refill to avoid impact. The same actions make higher-than-necessary flow less likely.

"Base Case" OR, where are we now?

Current Operation of Folsom Dam

- Currently there is no "Advance Release" based on forecasts
- Operators act based on precipitation that's already "on the ground," giving 8–12 hour lead-time
- Forecast-based Advance Release can only **increase** flood protection

Forecast-based Advance Release

When would we use Advance Release?

- If used only for flood protection, intended for very rare events, larger than has been recorded on the American River ($> 100\text{yr}$ event)
- But, it's likely that some smaller storms are overestimated and so trigger Advance Release
 - So the likelihood of triggering Advance Release is greater than the intended use
(don't know this probability yet...)

Ways to be Wrong...

- **Small Forecasts, Big Event**

- doesn't trigger Advance Release, missed opportunity to prevent flood damage

- **Big Forecasts, Bigger Event**

- Advance Release triggered, but too low

- **Big Forecasts, Small Event ("false alarm")**

- Advance Release is too high

- unnecessarily high flow downstream
- might not refill reservoir drawdown

no worse than current operations

negative impacts

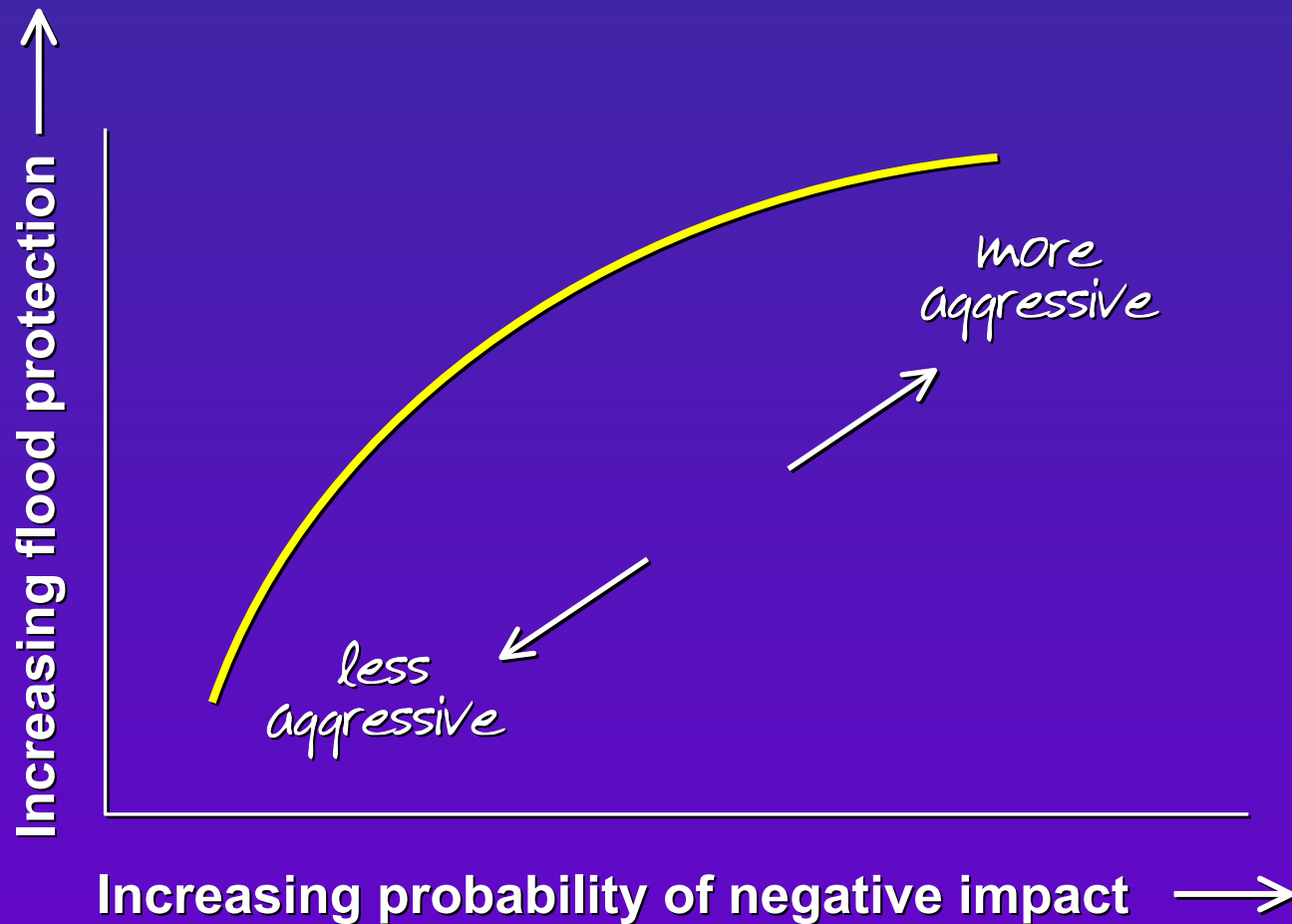
This means...

- Given the possibility and consequences of being "wrong", we would like a strategy that's effective when we're right, but not too damaging when we're not
- In other words, the Advance Release strategy must be **Robust**

Likelihood of Negative Impact

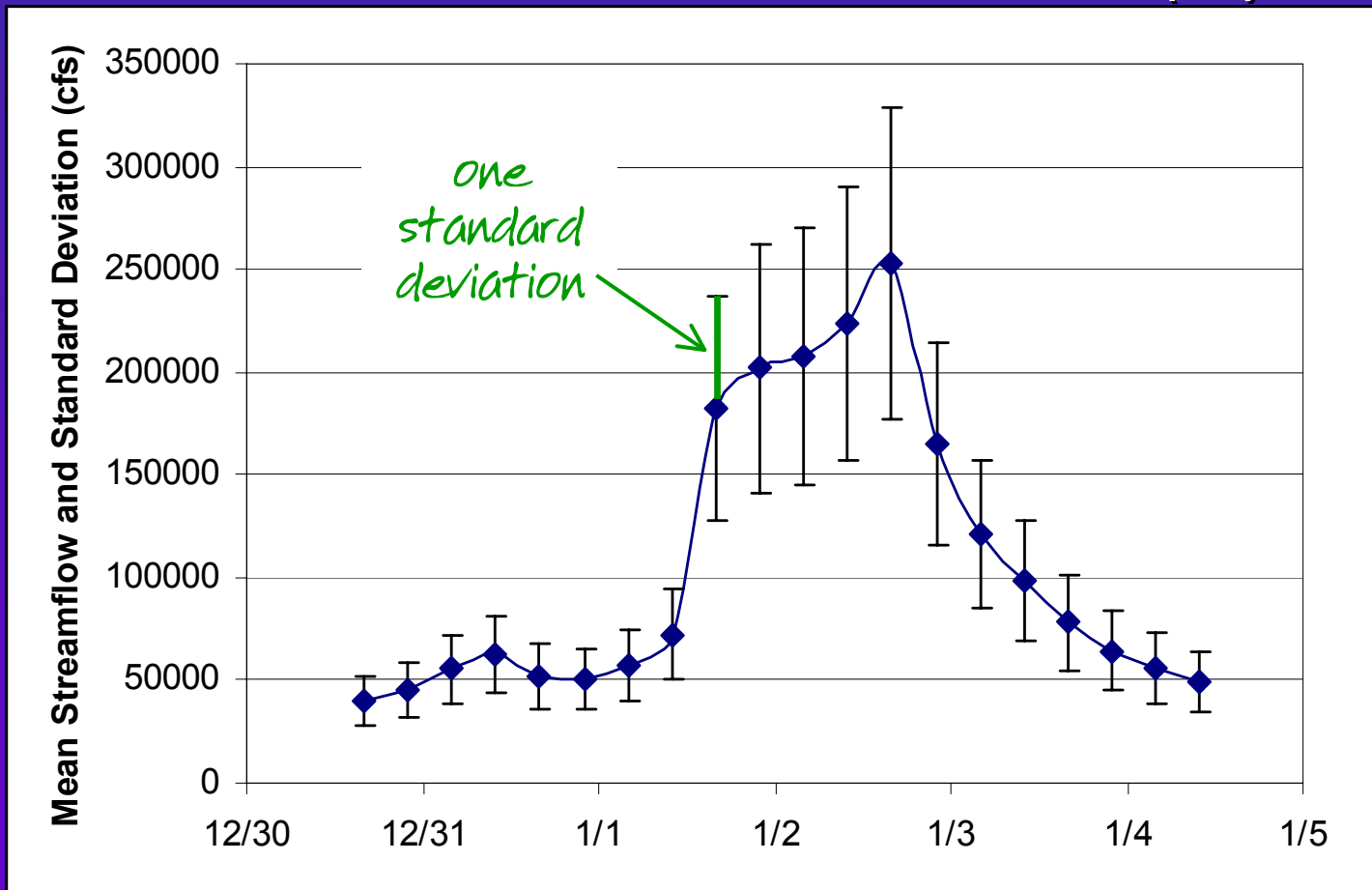
- There is a direct tradeoff between improved flood protection and likelihood of negative impact
- As Advance Release becomes more aggressive to provide more flood protection, the risk of negative impact increases.
- *The HEC study aimed for no impact (...1%) but evaluated sensitivity to various probabilities of impact*

Flood Protection vs Negative Impact Tradeoff Curve



NWS Forecast Product

American River Inflow to Folsom Reservoir (cfs)



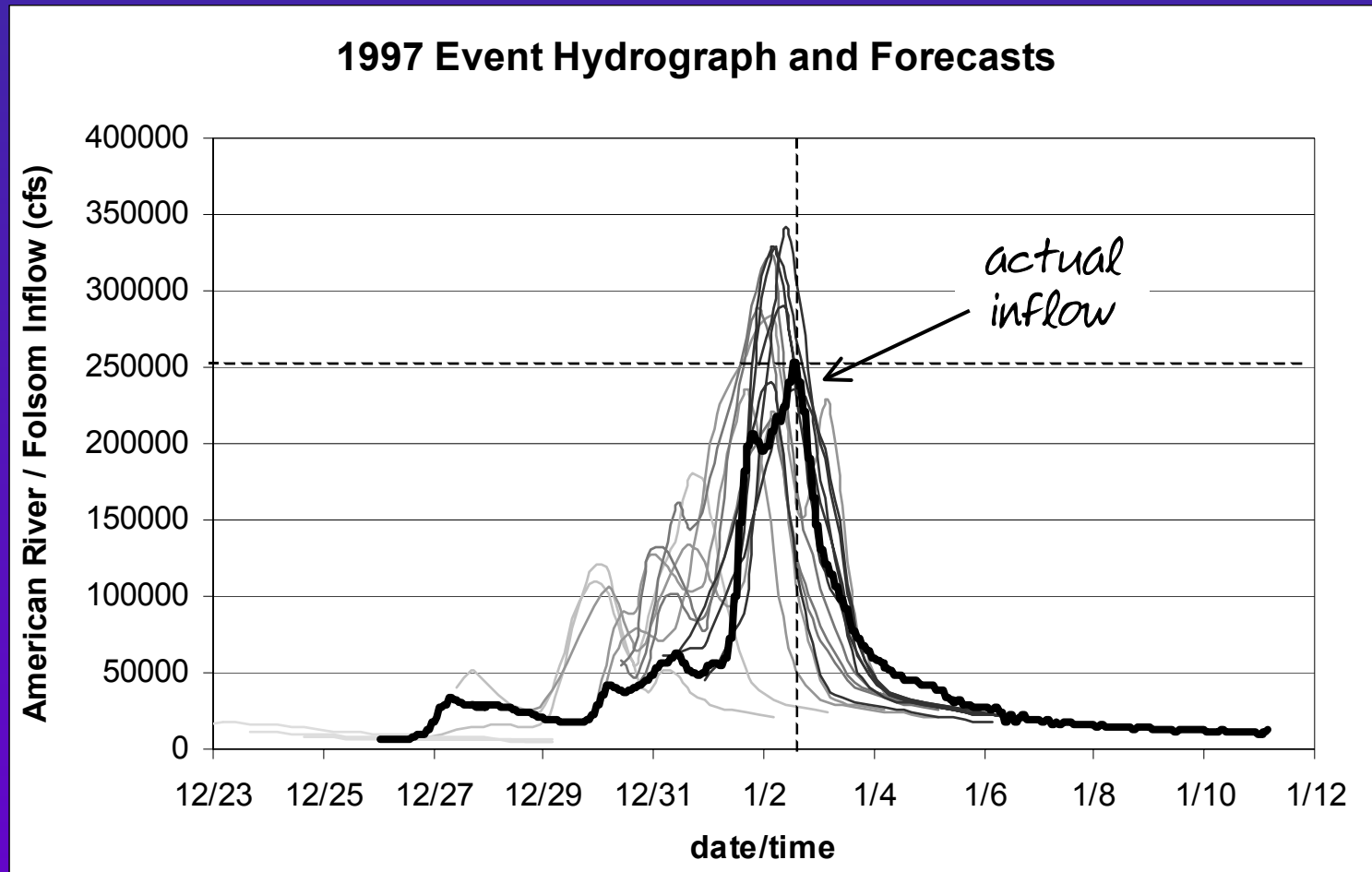
NWS Forecast Product

date/time	forecast 1	forecast 2	forecast 3	forecast 4	forecast 5	forecast 6	forecast 7	forecast 8
1/1 04:00								
1/1 10:00								
1/1 16:00								
1/1 22:00								
1/2 04:00								
1/2 10:00								
1/2 16:00								
1/2 22:00								
1/3 04:00								
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1/5 04:00								
1/5 10:00								
1/5 16:00								
1/5 22:00								

consecutive forecasts

reevaluate the situation with each forecast

1997 American River Forecasts



Advance Release Strategy

Components:

1) Lead-time for Action

– *how far in advance do we act?*

not encroached: initiate release as much as 3 days before forecasted event.

encroached: initiate 5 days before forecasted event.

2) Forecast Trigger to initiate Advance Release

– *what magnitude forecast tells us to act?*

3) Magnitude of Advance Release

– *how much do we release from the reservoir?*

4) Trigger to stop or decrease Advance Release

– *when do we discontinue release when forecasts no longer suggest it's necessary?*

2) Trigger to Initiate

What tells us to start the advance release?

triggers are based on the NWS 3- to 5-day forecast

- A)** peak flow greater than trigger value 300,000 cfs
- B)** event volume greater than trigger value 1,000,000 AF
- C)** forecast hydrograph causes release greater than 115,000 cfs
(incorporates peak, volume and reservoir state)
- D)** probability of release exceeding 115,000 cfs is greater than predefined value *(using USU ensemble and RRFM)*
(incorporates peak, volume, res. state, and uncertainty)

3) Level of Advance Release

After being triggered, the Advance Release level can have more or less dependence on the forecast

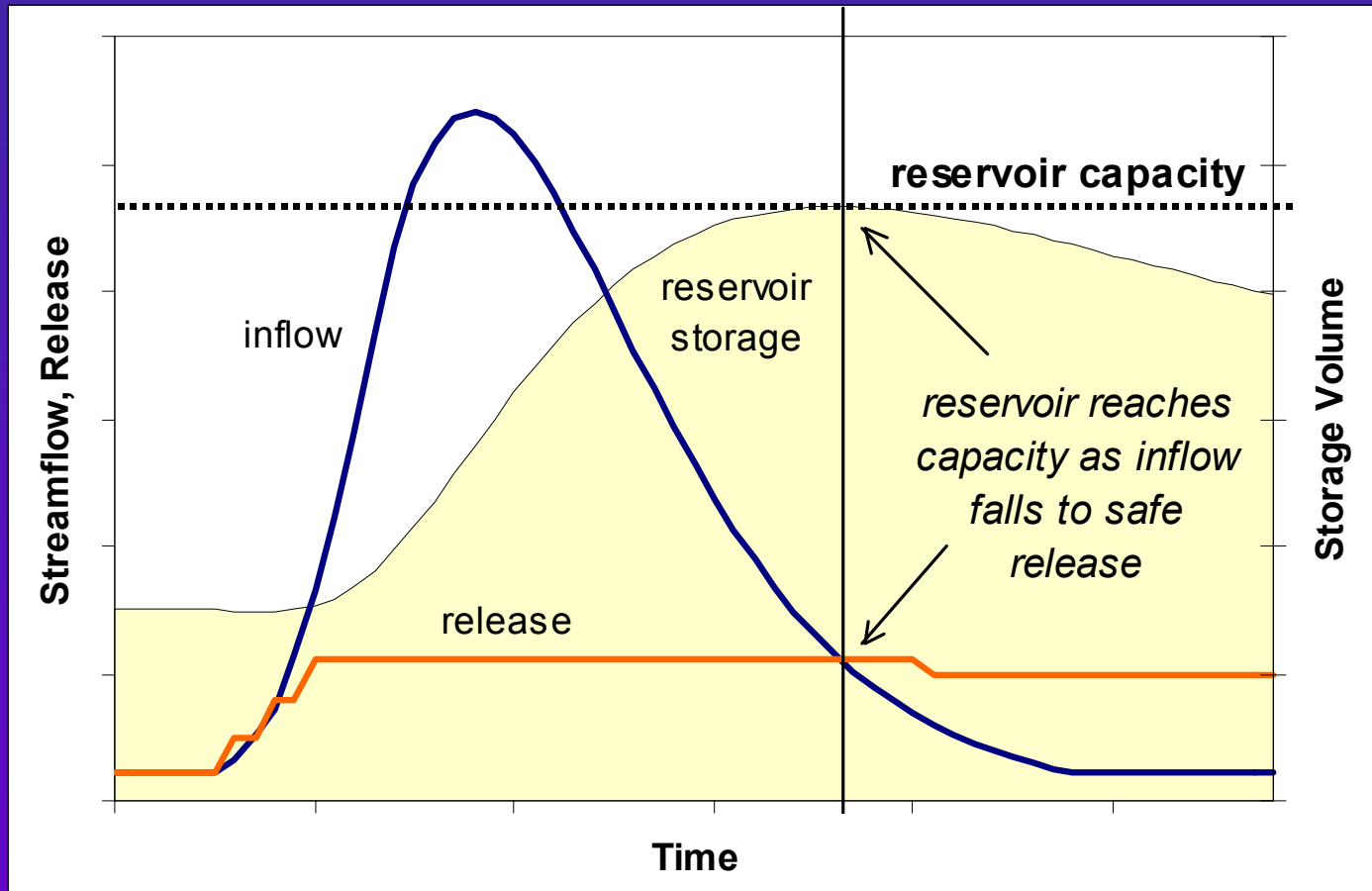
- **Less dependence on forecast:**

set release to 50,000 cfs greater than current inflow

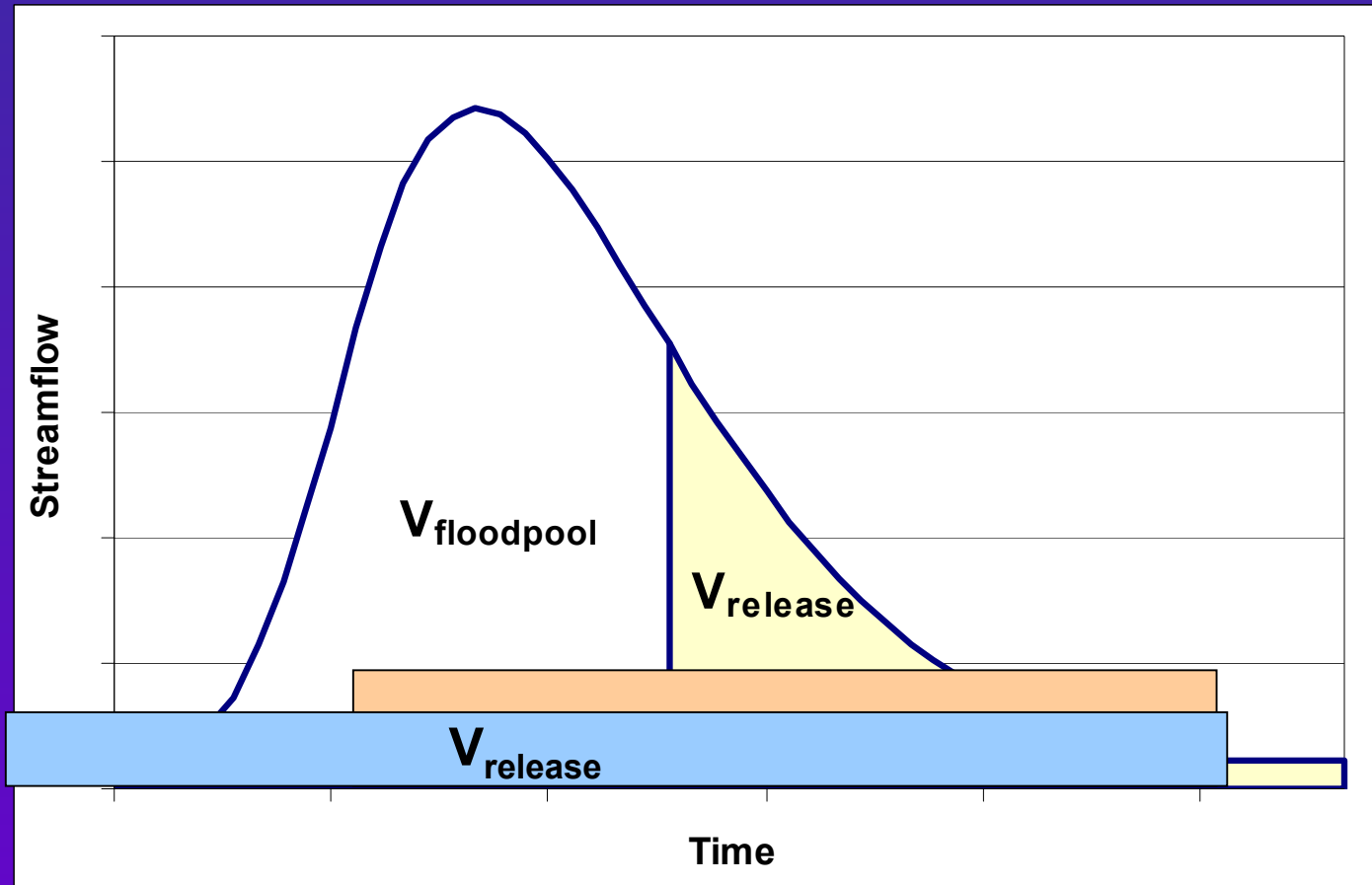
- **More dependence on forecast:**

set release based on the volume of forecasted inflow and the current reservoir level

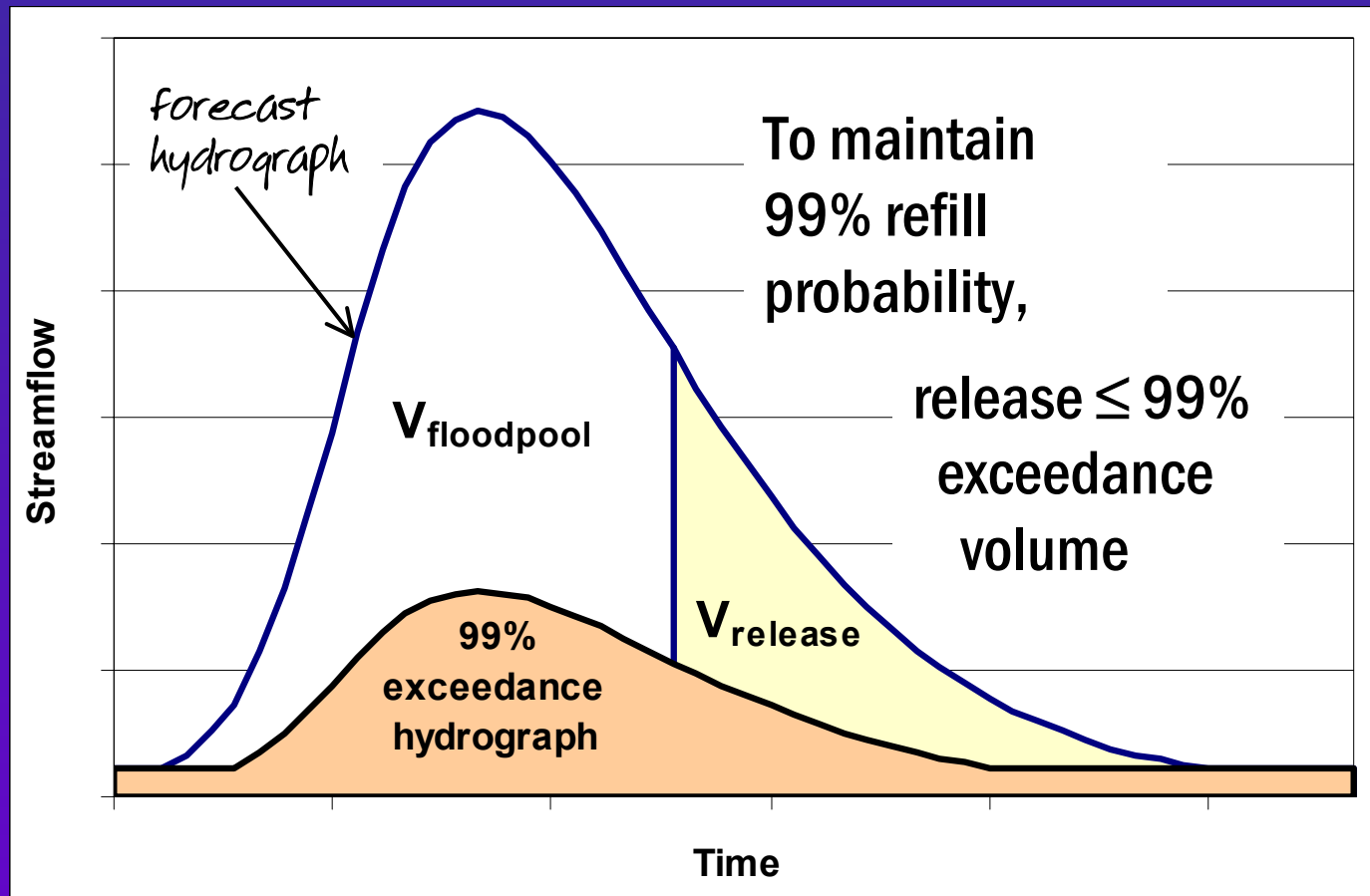
Completely Efficient Flood Operation



Necessary Release During Flood

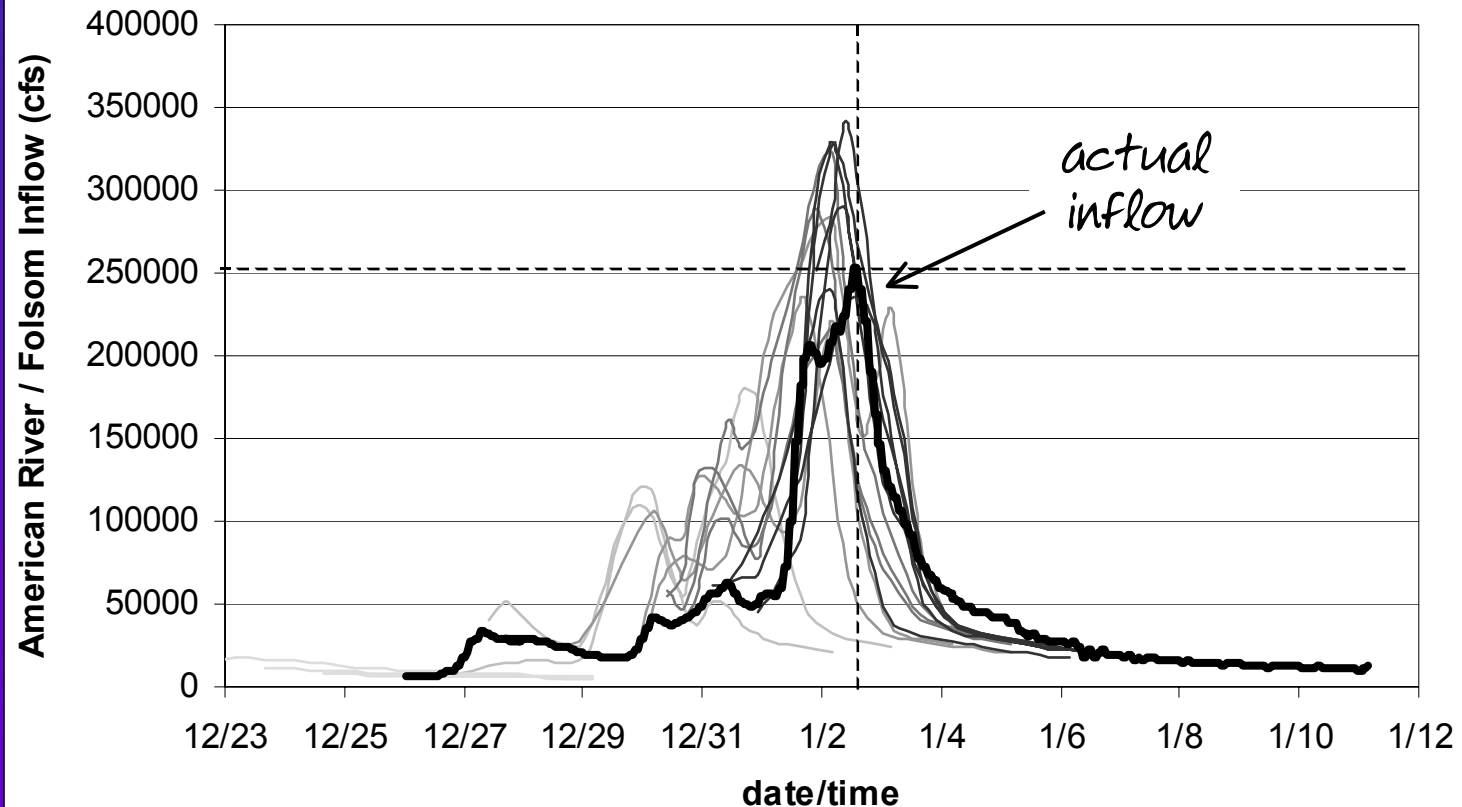


Limiting Probability of Impact

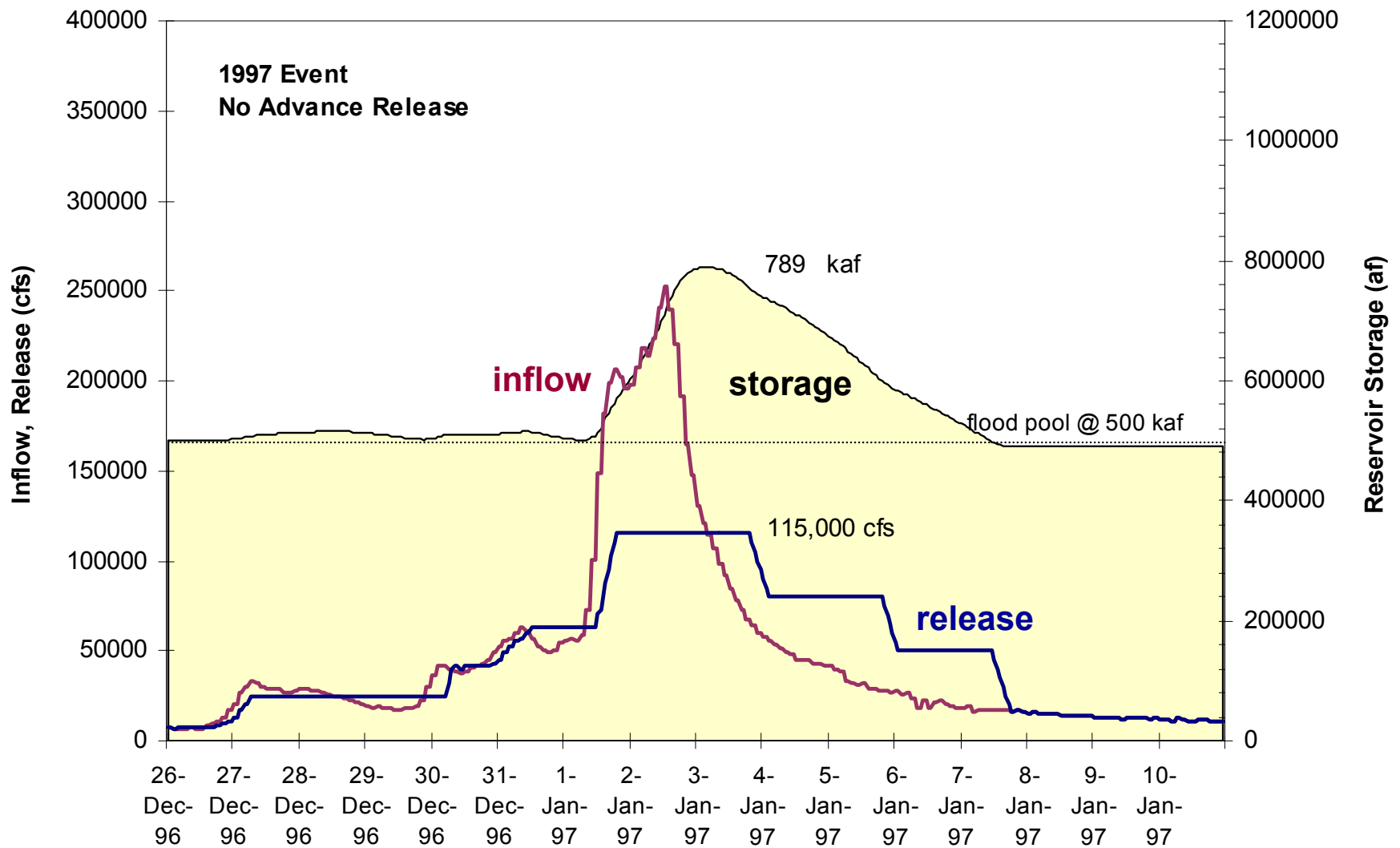


1997 American River Forecasts

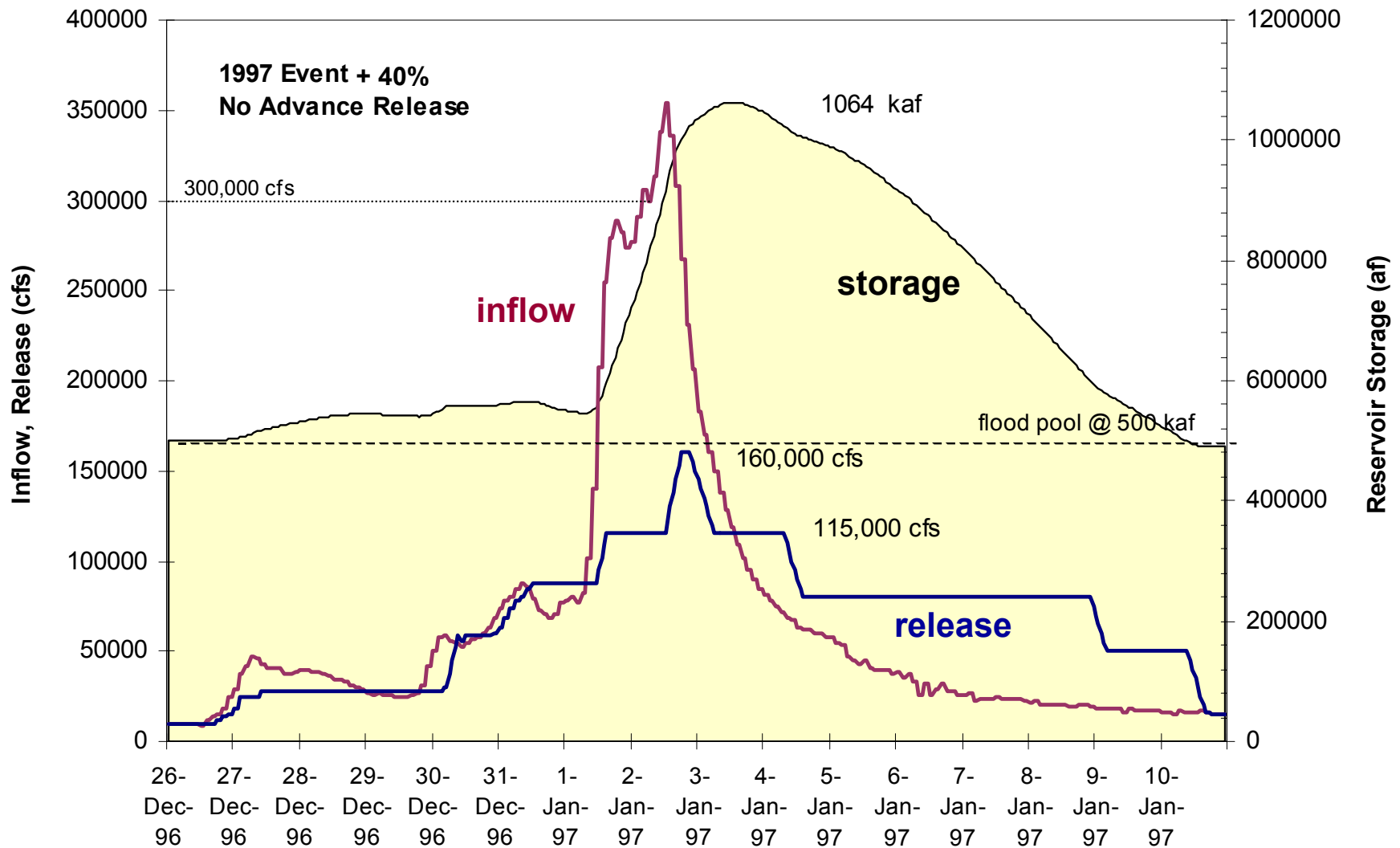
1997 Event Hydrograph and Forecasts



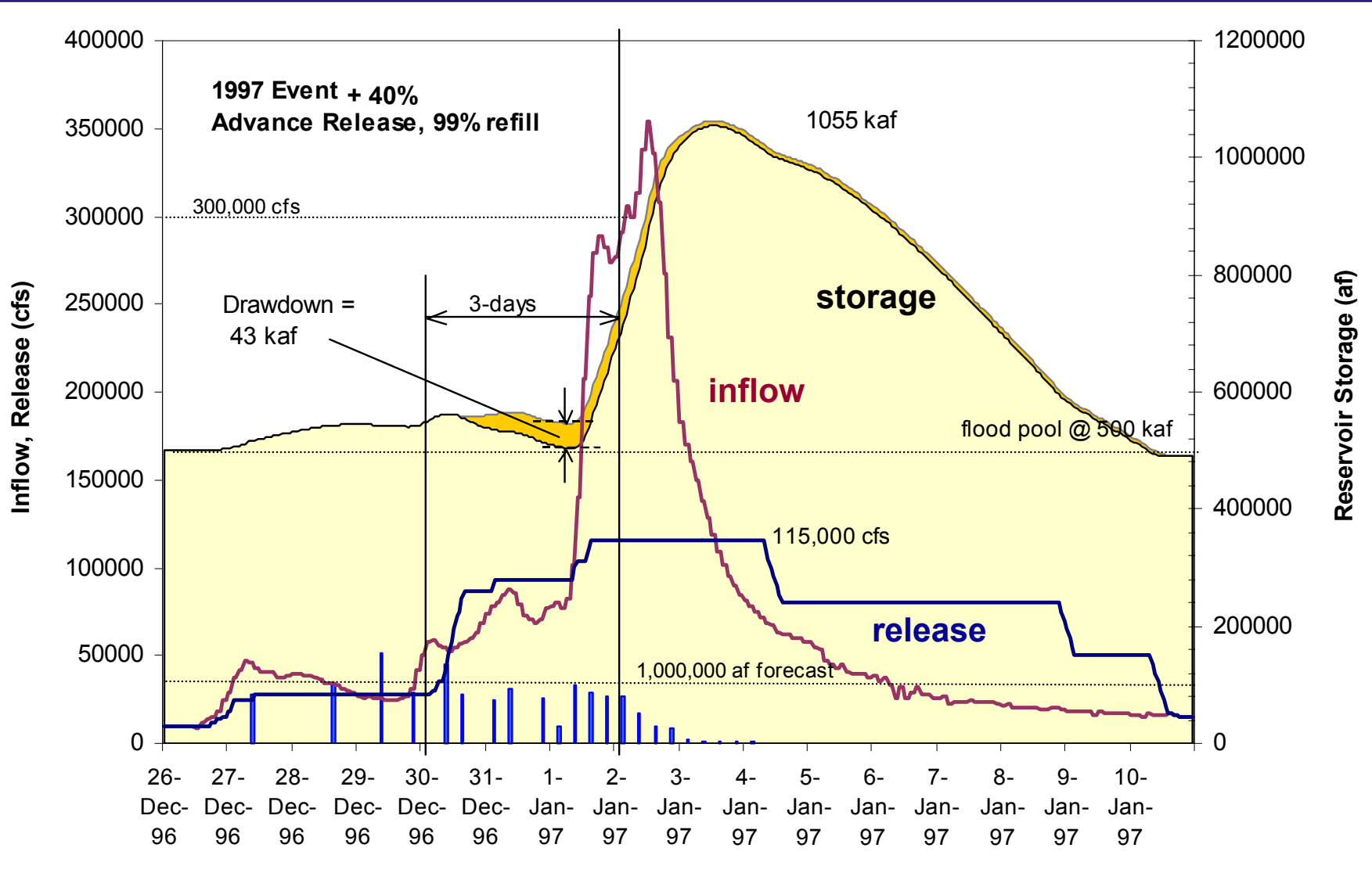
Simulated 1997 Event



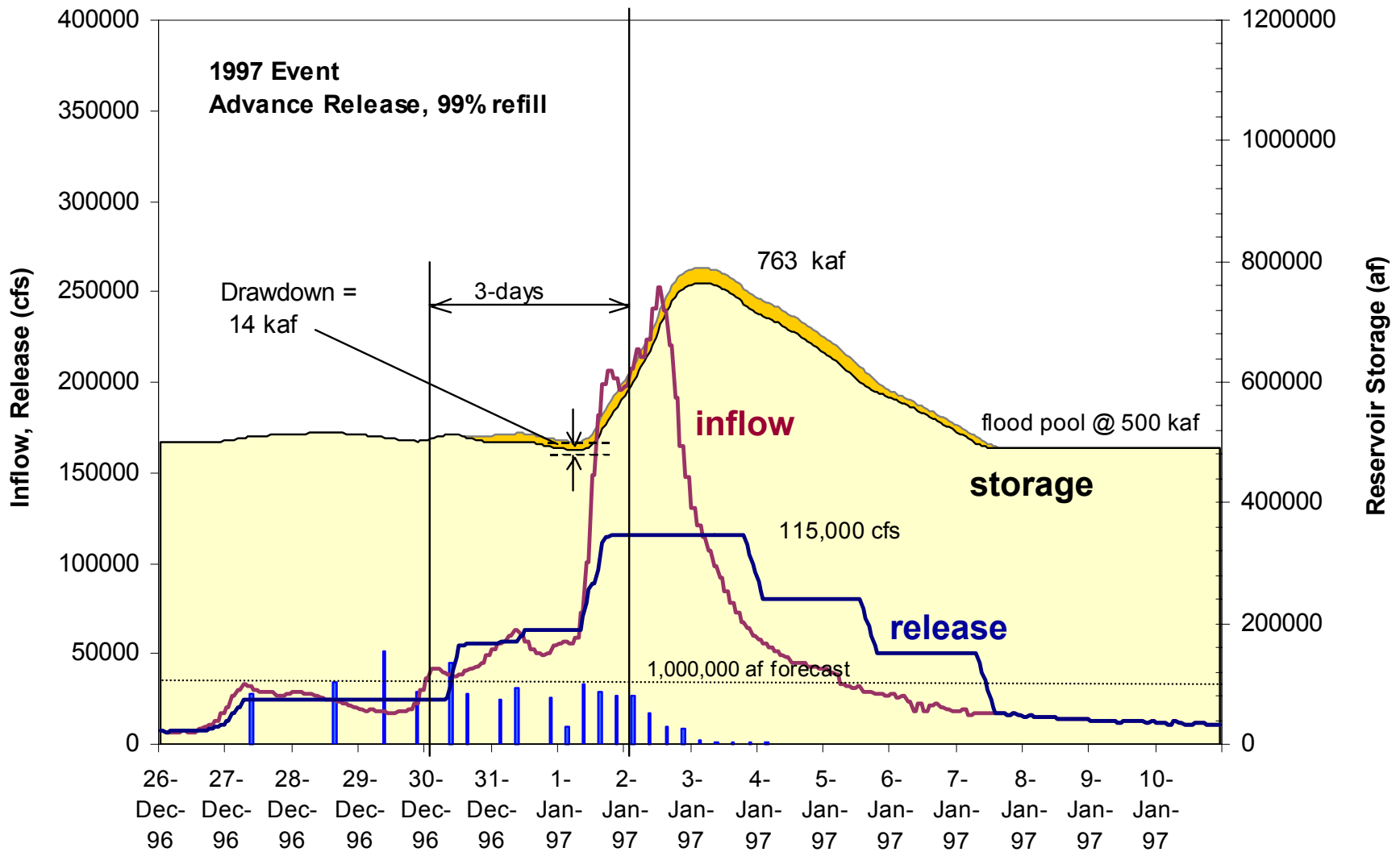
1997 Event + 40%



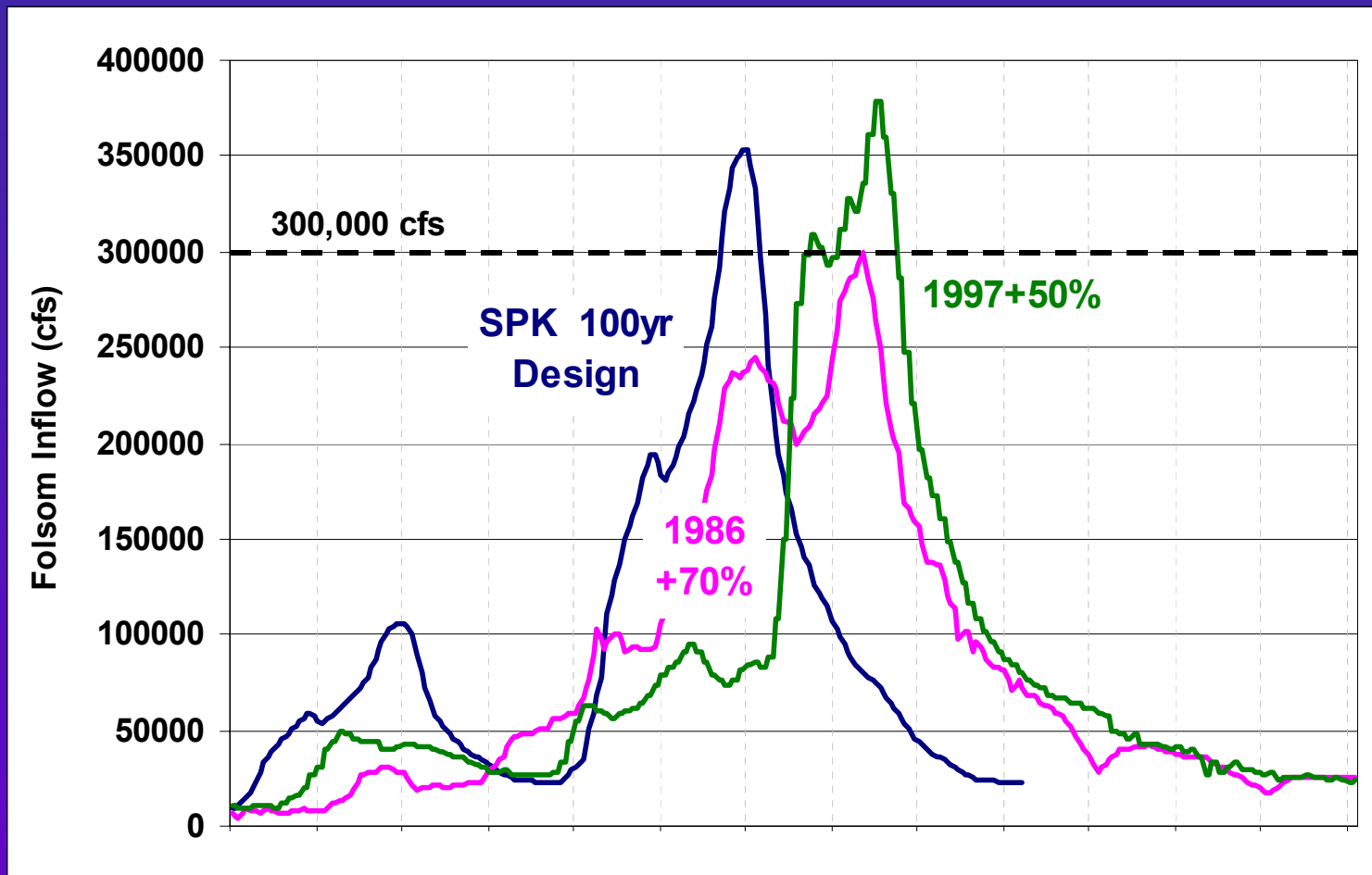
1997 Event +40%, Advance Release



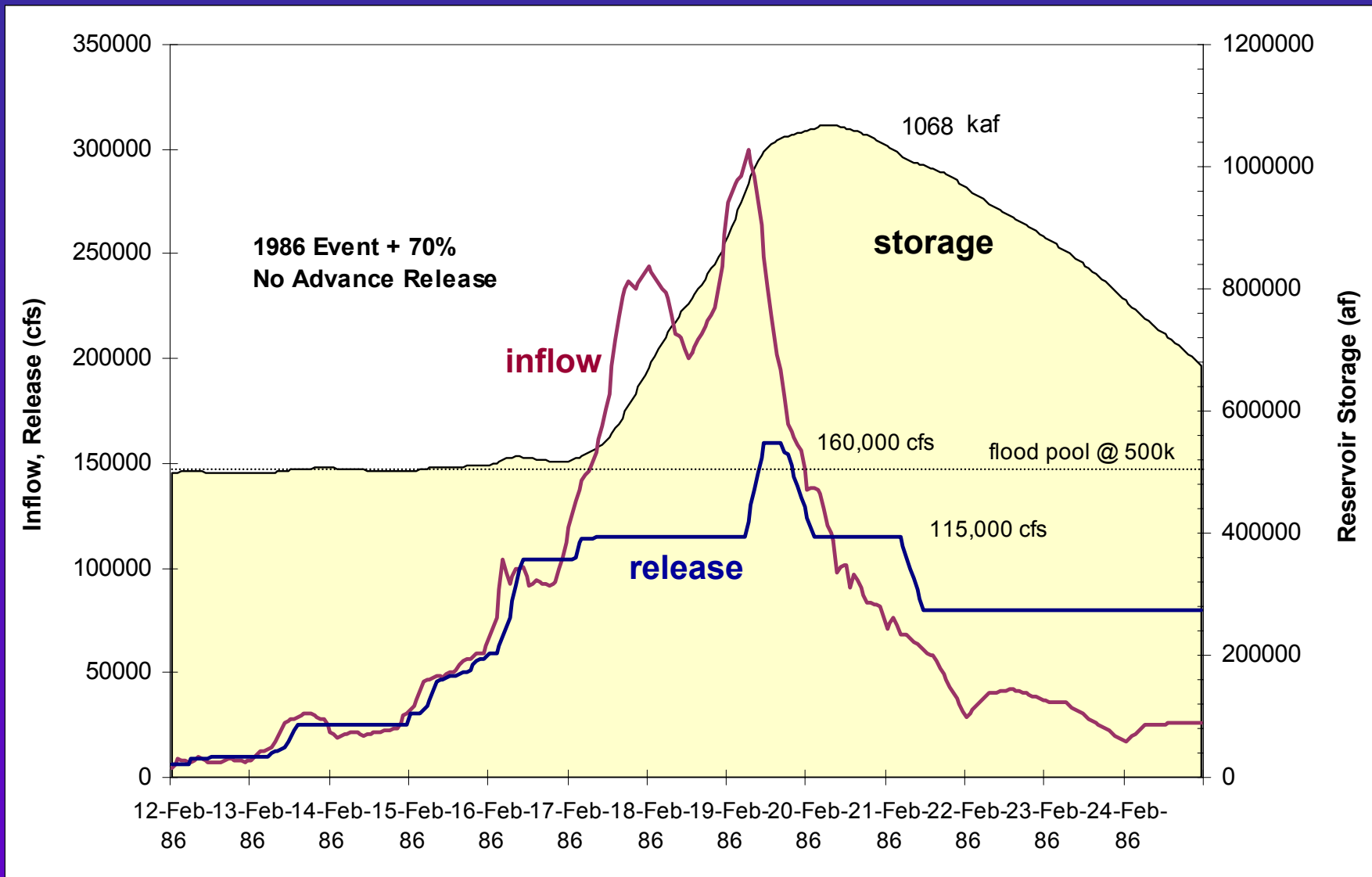
1997 Event, Advance Release



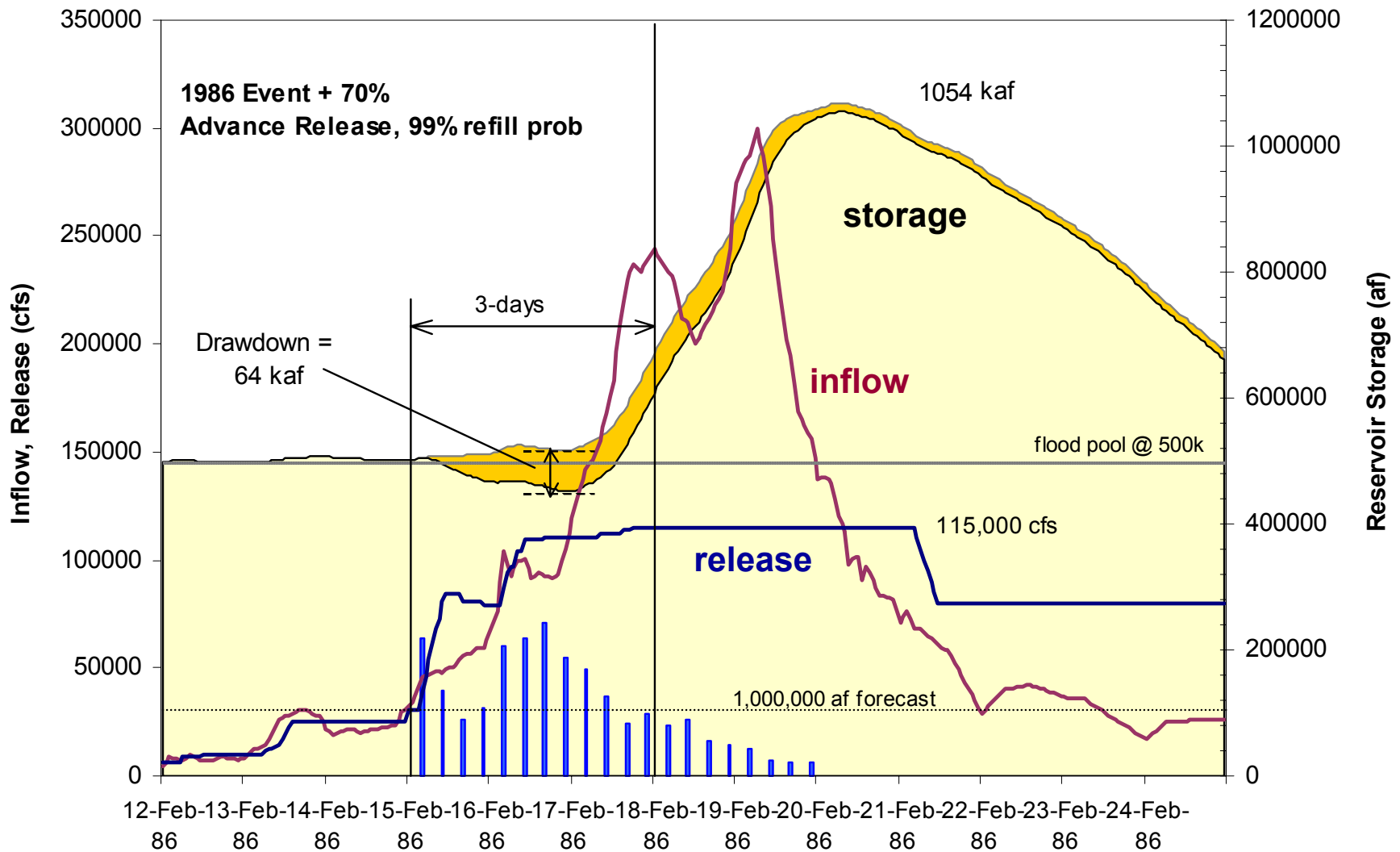
Flood Events Simulated



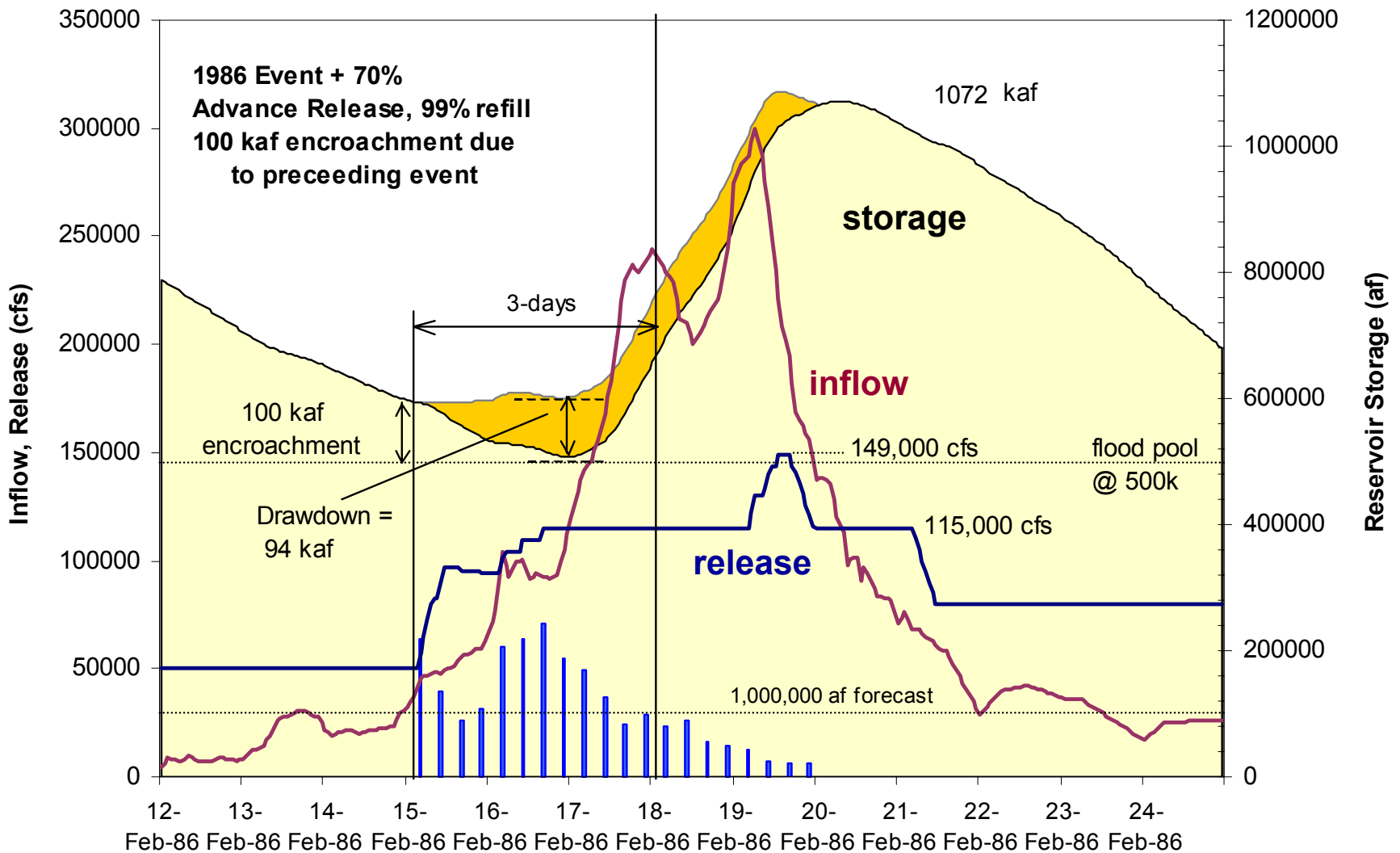
Without Advance Release



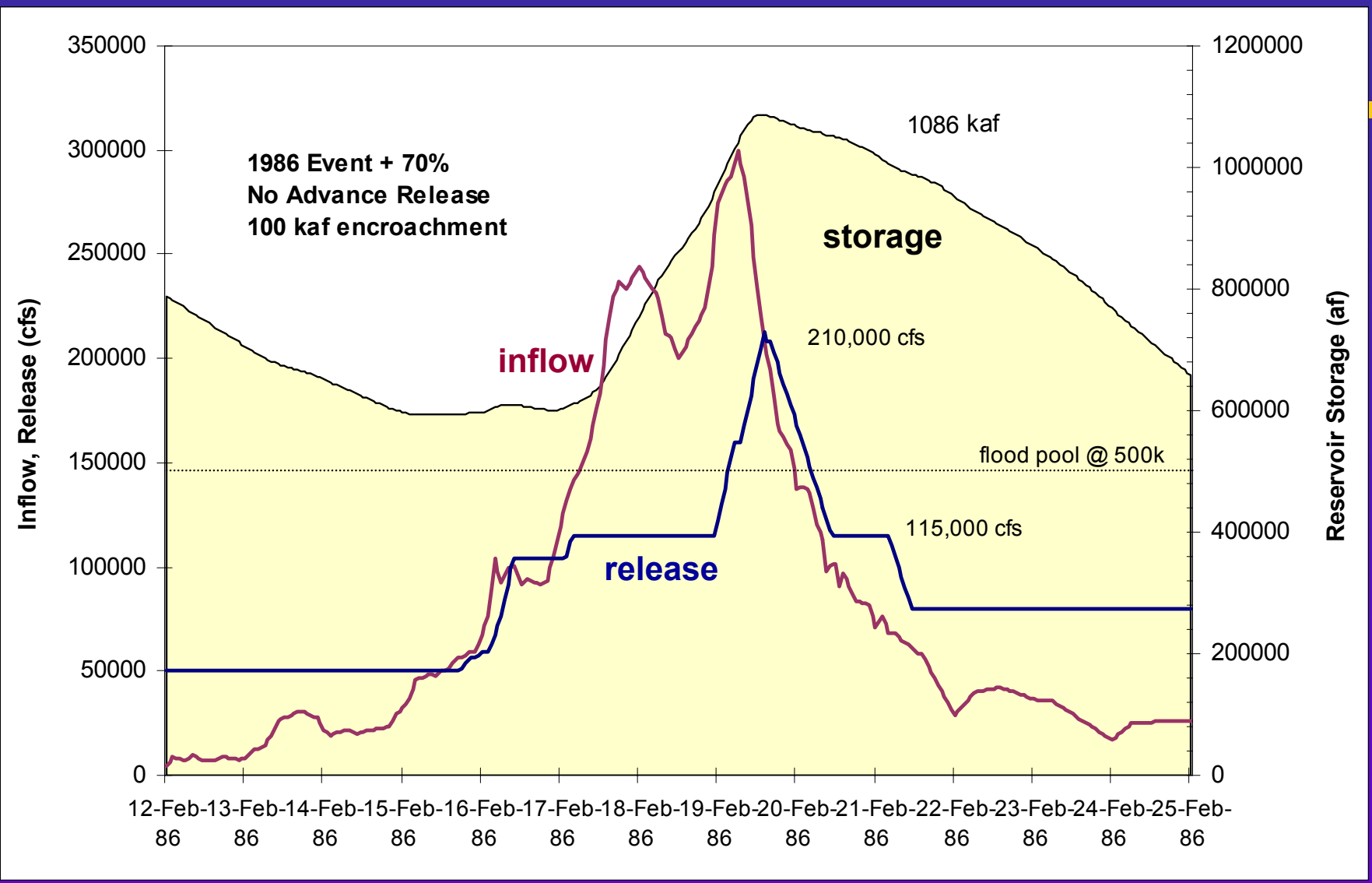
With Advance Release



With Advance Release, Encroachment



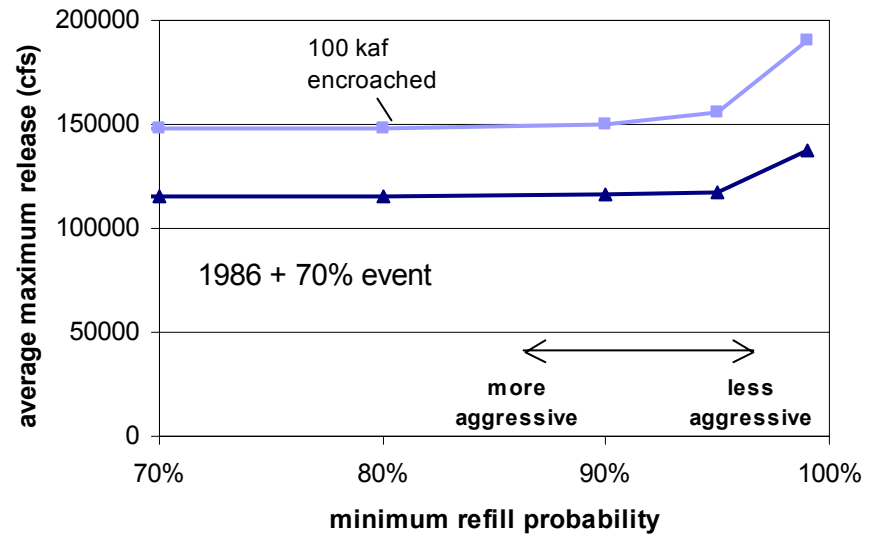
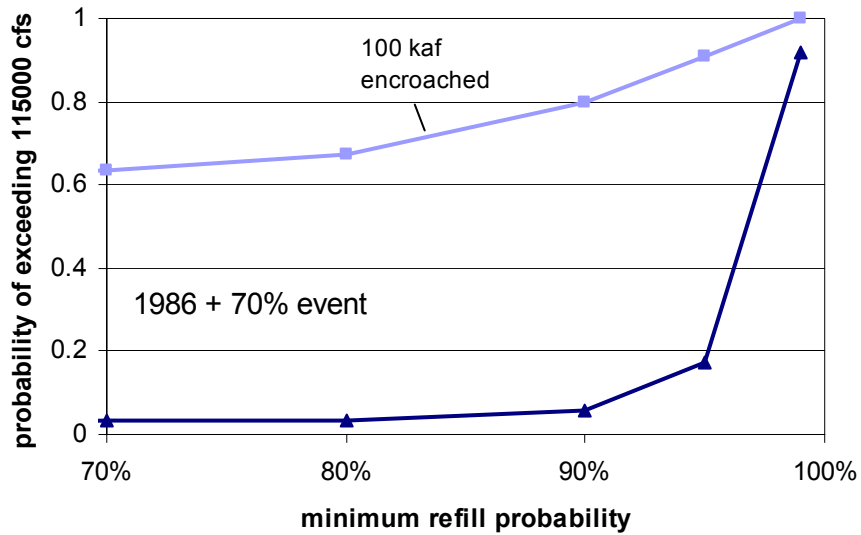
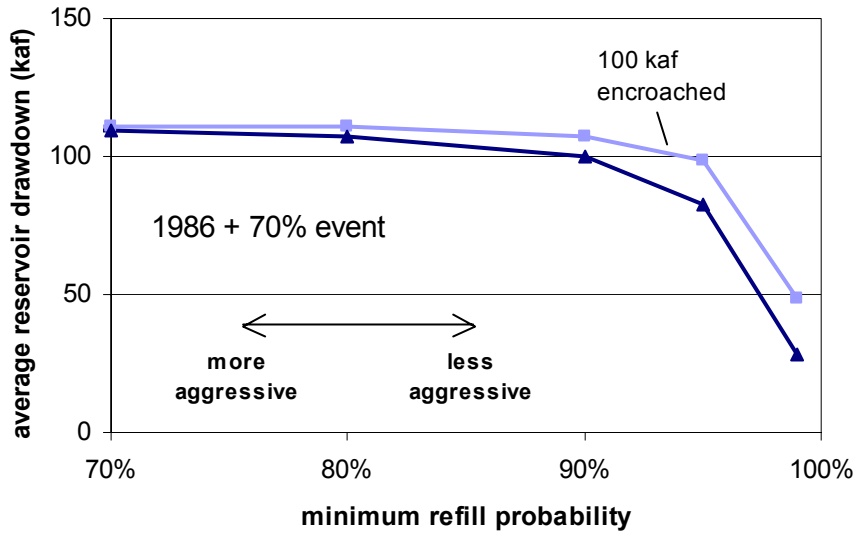
With Advance Release, Encroachment



Outcome Based on Forecasts

- In these simulations of the 1986+70% event, we assumed a particular forecast series
- What if the forecasts were different?
- Modeled the events with 120 different forecast sets...

Probability-based Results



Conclusions

- **Forecast-based Advance Release can be an effective way to**
 - make efficient use of forecast information
 - increase flood protection
- **Restricting the risk of impact is feasible**
- **This operation will require coordination between many agencies**