Using Real-Time Watershed Information in Reservoir Operations—A Case Study of Folsom Reservoir

Katherine Maher
Project Engineer
GEI Consultants
2868 Prospect Park Drive, Suite 400
Rancho Cordova, CA 95670

Tel: (916) 631-4594
Email: kmaher@geiconsultants.com
Web: geiconsultants.com

BIOGRAPHICAL SKETCH

Katherine Maher works as a Project Engineer for GEI Consultants. She completed her M.S. in Civil Engineering at U.C. Davis in 2011. While completing her Master's degree, Katherine worked as an intern at the U.S. Army Corps of Engineers' Hydrologic Engineering Center on studies related to Folsom Reservoir operations, including studies that provided the basis for her Master's thesis. Prior to entering the Master's program, Katherine worked for the Department of Water Resources in its Bay Delta Office, after receiving her B.S. in Civil Engineering from U.C. Davis.

ABSTRACT

This case study evaluates the potential benefits of variable index rule curves that incorporate current precipitation and snowpack into the operation of Folsom Reservoir in the American River watershed. Over 100 synthetic flood hydrographs generated from seven historical flood events are used to assess each rule curve's flood management performance. Water supply performance is also evaluated over 53 water years in the period of record. Trade-offs between flood control and water supply are analyzed using the probability of exceeding downstream channel capacity, and the probability of refill.

Two types of variable rule curves are presented. The first type of alternative rule curve used a precipitation-based index (Type P curves), and the second type used a precipitation index and a snowpack index (Type S curves). In total, 91 Type P curves and 55 Type S curves were evaluated to determine the effects of varying the index range, flood pool size range, and reservoir refill start and end dates.

In general, Type P curves were found to improve water supply benefits while maintaining or reducing flood risk. Type P curves with lower precipitation index ranges performed better for flood management while those with higher ranges performed better for water supply. Larger flood pool sizes functioned best in balancing water supply and flood management performance. Adjusting the precipitation index during the refill period using normalized snowpack data to produce Type S curves generated small but noticeable improvements in refill.

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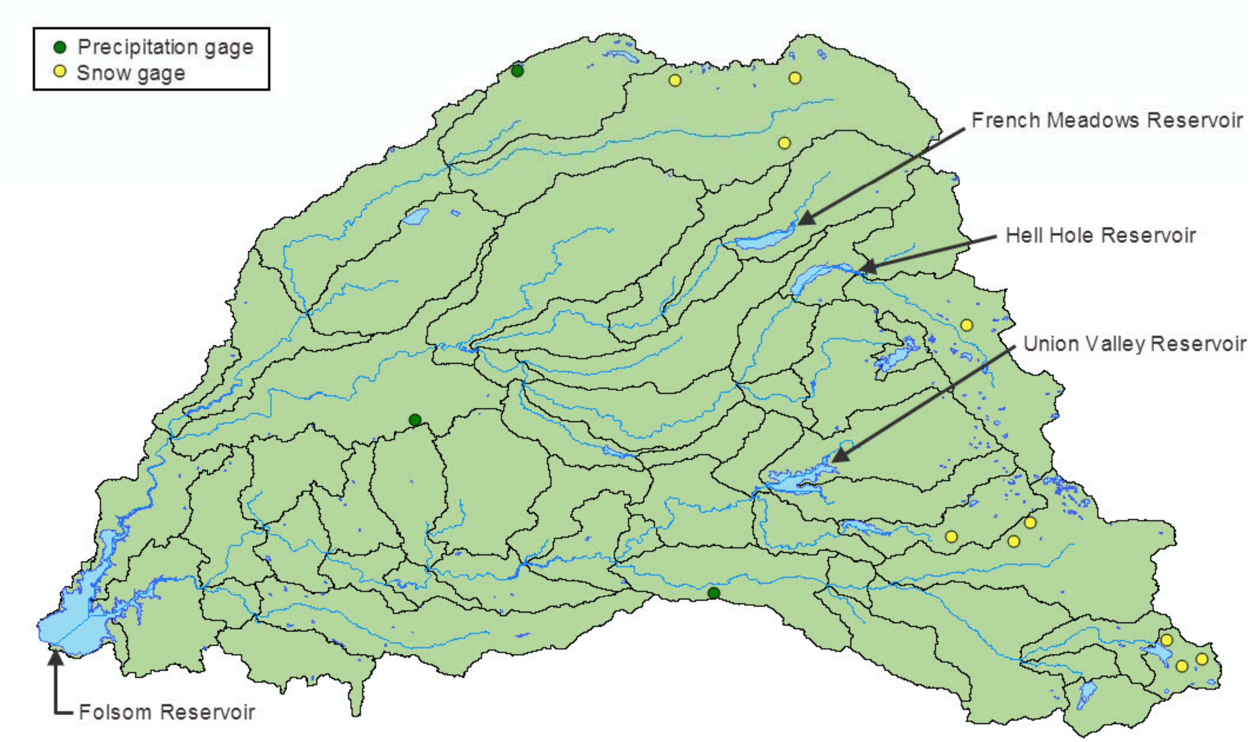
Overview

- Introduction
- Study purpose
- Background
- Data and methods
  - Wetness index development
  - Rule curve development
  - Flood hydrograph development
- Results
- Conclusions
- Potential further study

Background

- New auxiliary spillway at Folsom Dam increases release capacity, allowing more flexibility in managing flood pool.



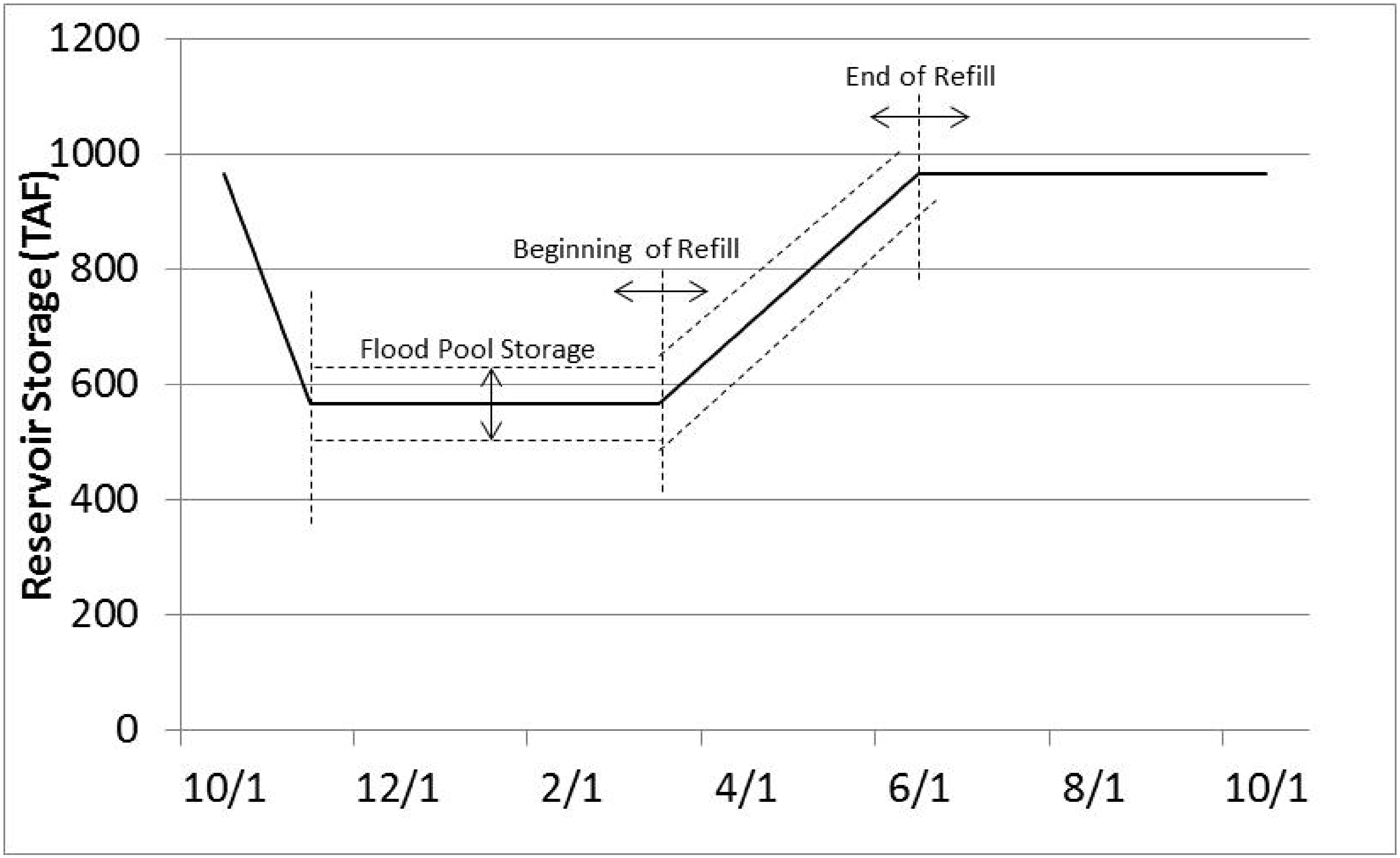
Background

- New auxiliary spillway at Folsom Dam increases release capacity, allowing more flexibility in managing flood pool.
- Current release capacity of ~30,000 cfs until spillway crest elevation is reached at 418 ft.
- New auxiliary spillway crest elevation is 50 ft lower (368 ft), allowing larger releases earlier in a flood. Design release capacity of ~140,000 cfs at 418 ft.

Study Purpose

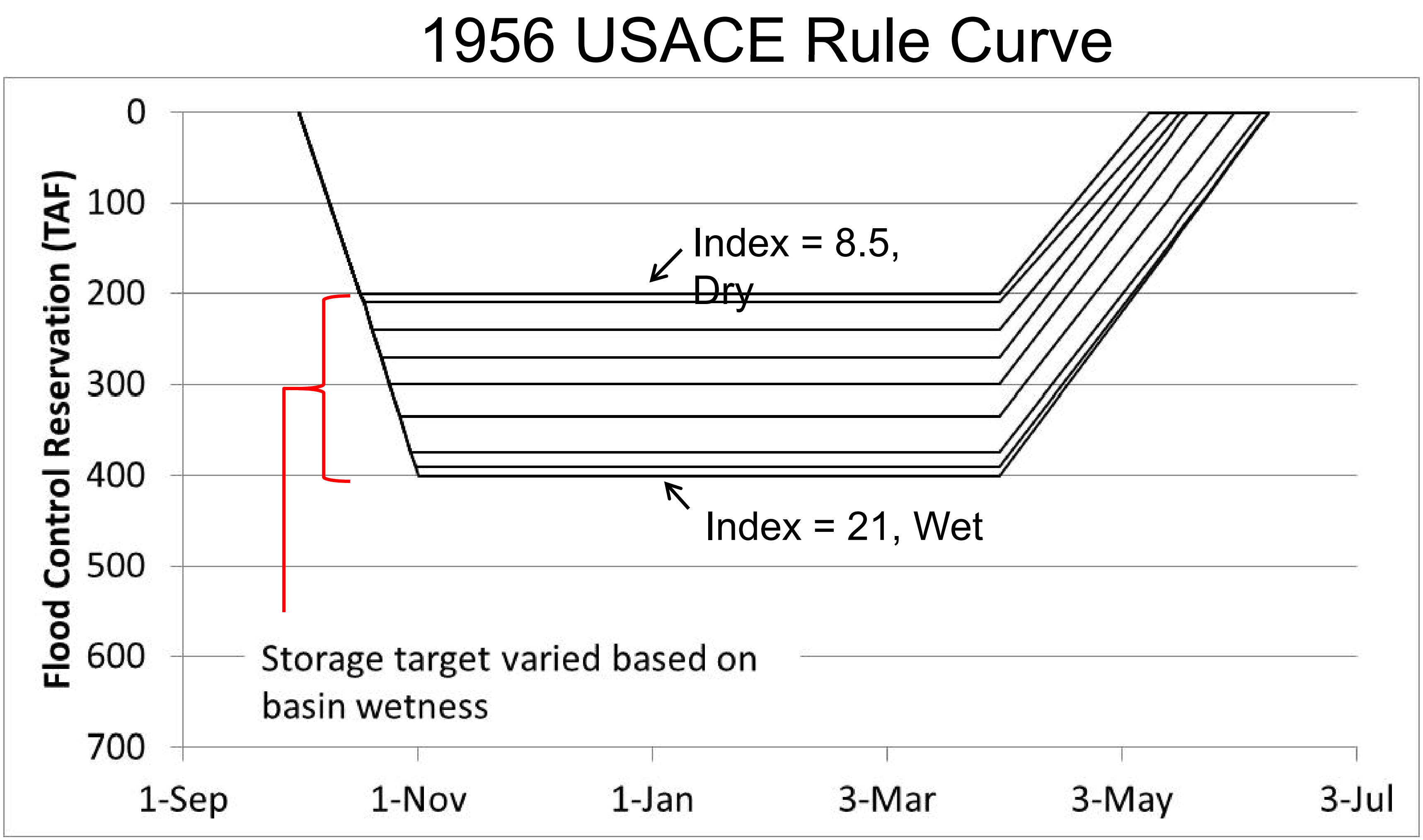
- Demonstrate an approach to sizing a reservoir flood pool in response to basin wetness indices.
- Explore whether using basin-wetness index based rule curves can improve flood protection without increasing risk to water supply.
- Focus is on current watershed conditions, not forecasted conditions.

Concepts



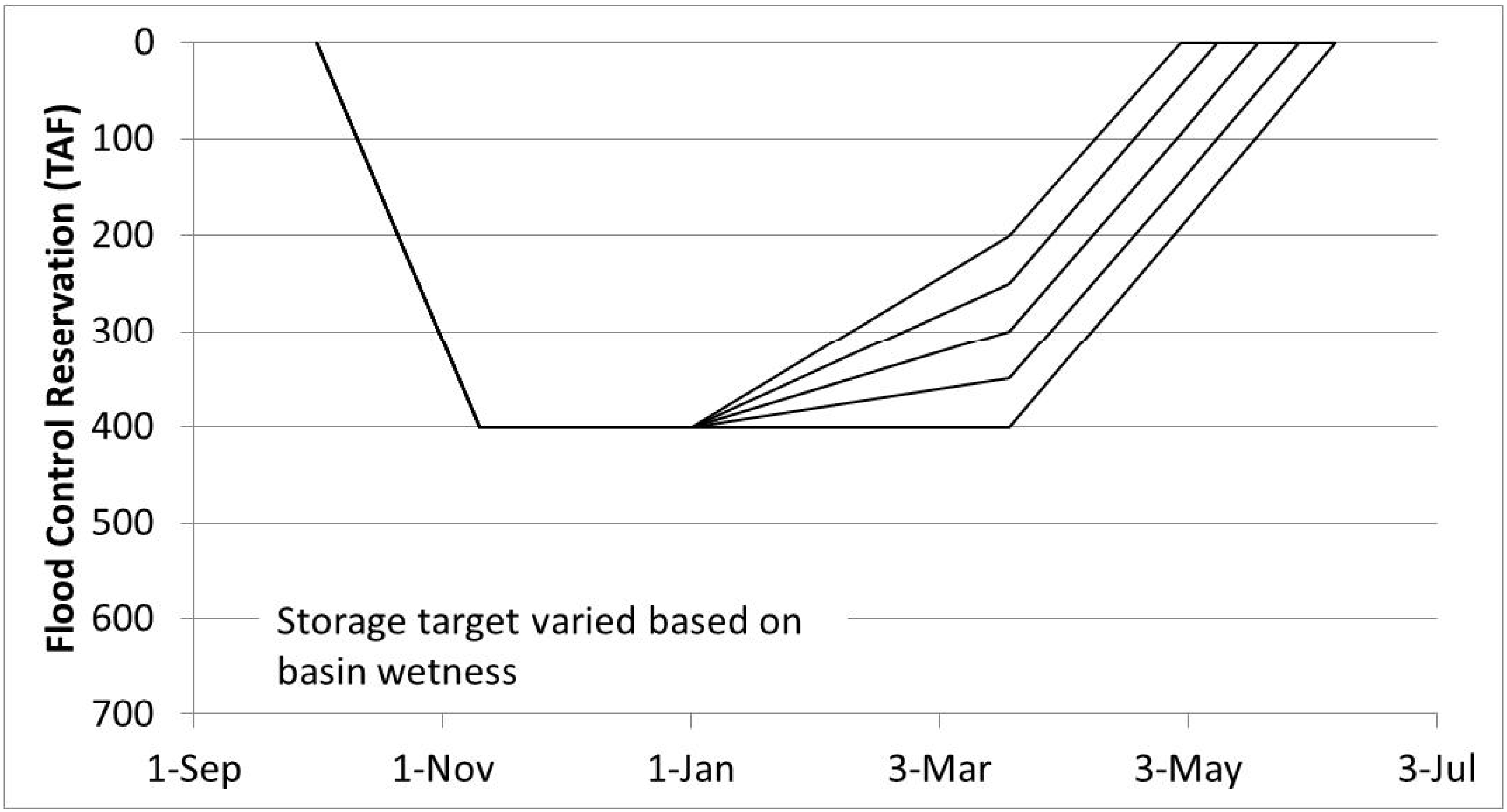
Reservoir Storage (TAF)
1200
1000
800
600
400
200
0
10/1
12/1
2/1
4/1
6/1
8/1
10/1
End of Refill
Beginning of Refill
Flood Pool Storage

Folsom Reservoir Rule Curve History



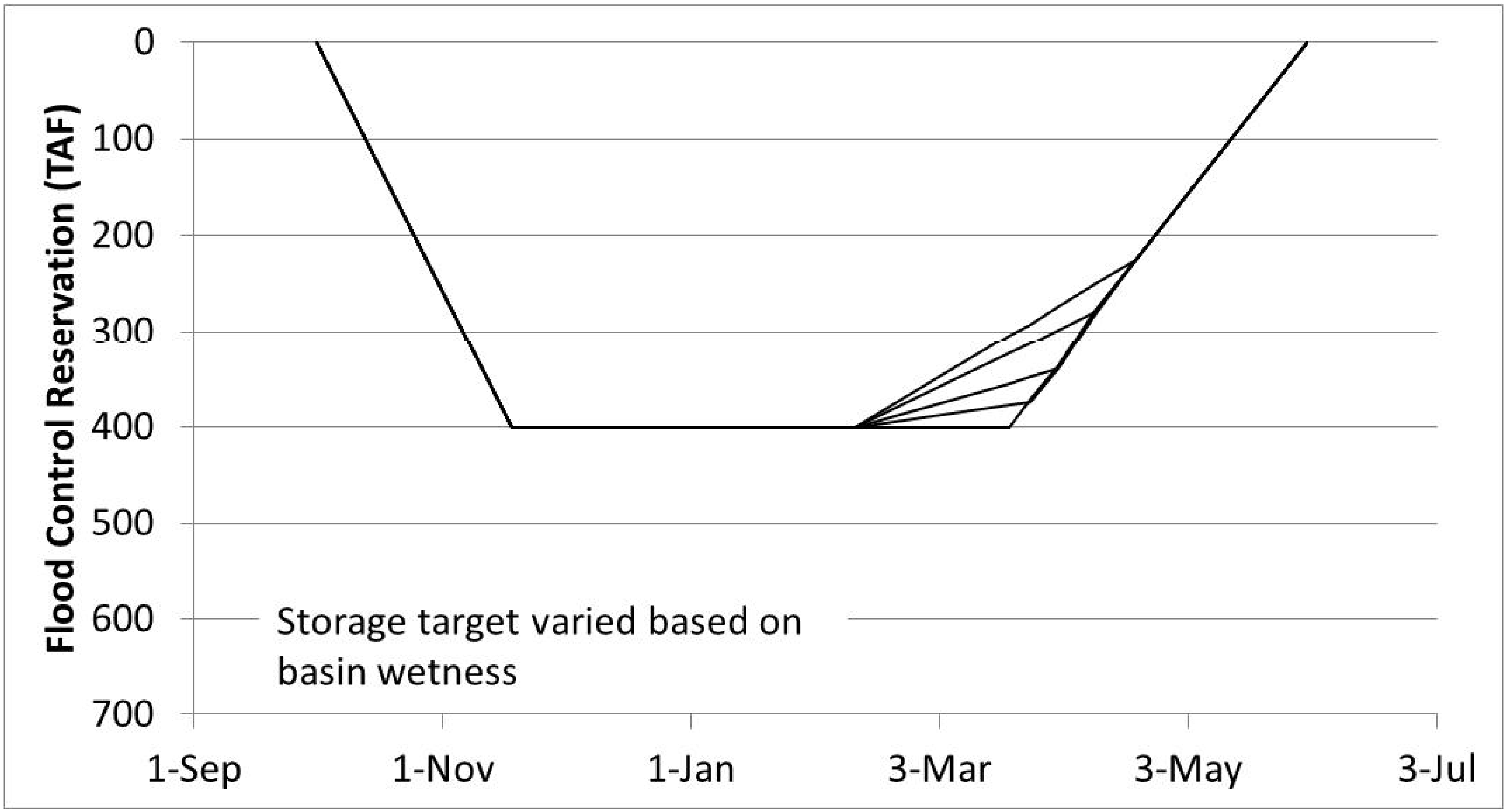
Folsom Reservoir Rule Curve History

1977 USACE Rule Curve

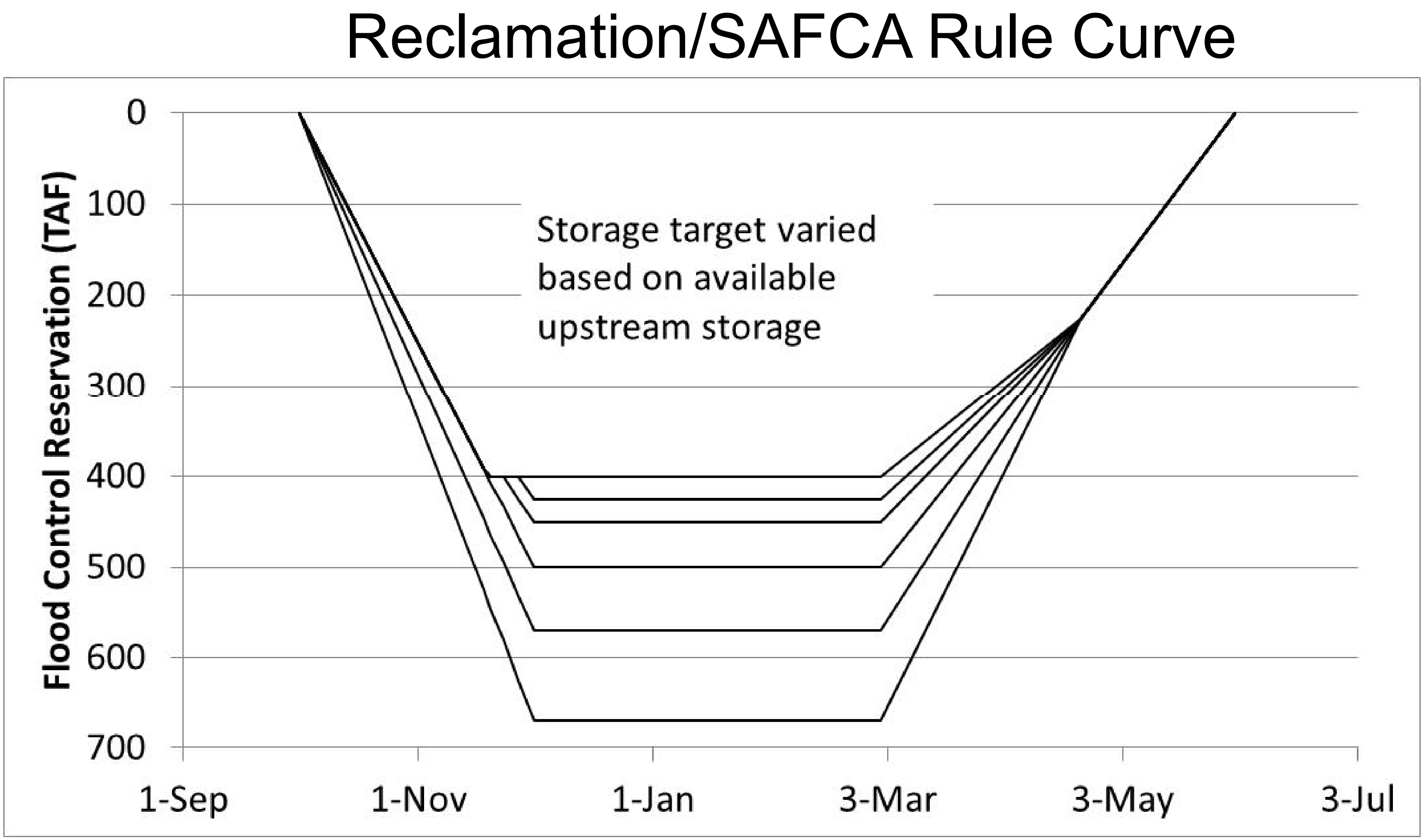


Folsom Reservoir Rule Curve History

1986 USACE Rule Curve



Folsom Reservoir Rule Curve History



Concepts

- Fixed or static rule curve does not account for current conditions in the watershed.
- Flood protection can potentially be improved by incorporating seasonal data into flood control operations.
- May also increase probability of refill without increasing flood risk.
- Potential negative impacts – less efficient operation if high basin wetness but no additional precipitation so the reservoir doesn’t refill.

Methods: Basin Wetness Index

Index(t) = 97%×Index(t-1) + (today's precipitation)

Precipitation Index

- Composite of 3 precipitation gages:
  Georgetown, Blue Canyon, Pacific House
- Period of record = WY1955-WY2008

Methods: Basin Wetness Index

$$\text{Index}(t) = 97\% \times \text{Index}(t-1) + (\text{today's precipitation})$$

<u>Precipitation-Snow Index</u>

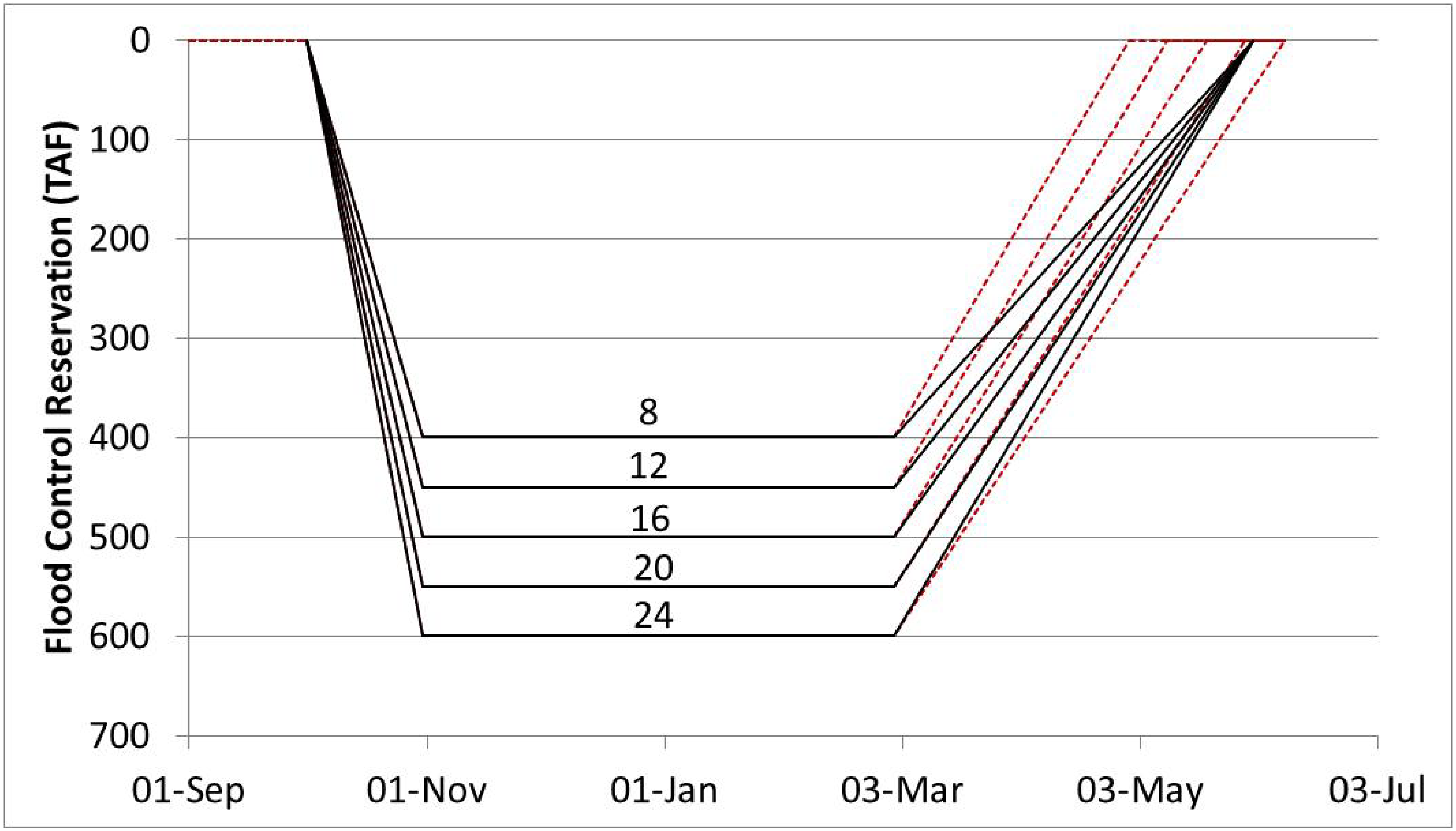
- Snow water content from 10 snow courses used to adjust precipitation index during refill period (March-June).
- If snowpack < normal, rule curve shifted higher (smaller flood pool)
- If snowpack ≥ normal, no adjustment

Methods: Reservoir Rule Curves

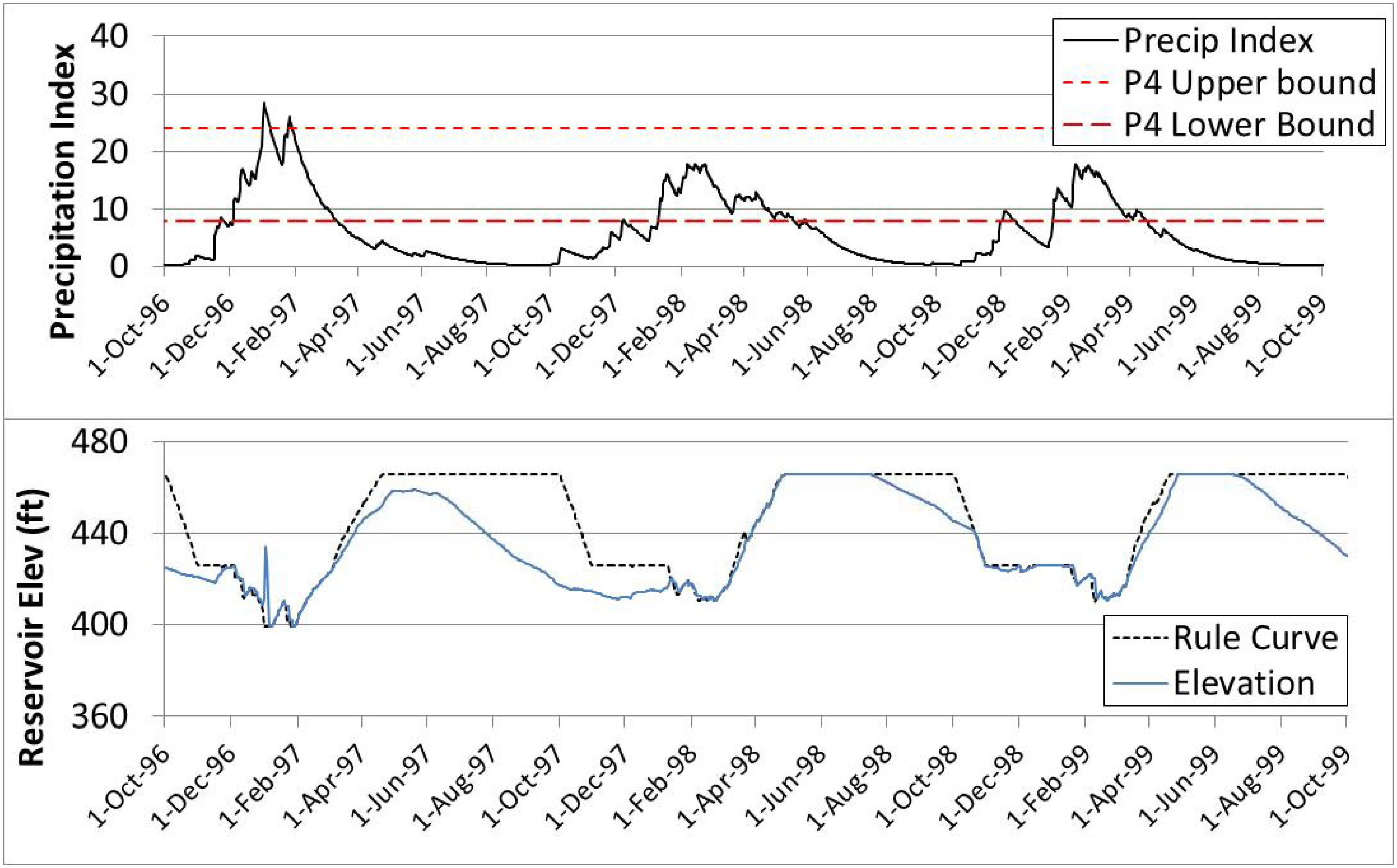
- Selecting the range of flood pool size
  - What is the largest and smallest flood pool?
- Selecting the wetness index value range
  - How frequently will the flood pool reach its maximum size?
- Varying the refill period
  - How soon can the reservoir be refilled without increasing flood risk?

➡ In total, 146 rule curves were developed.

Methods: Example Rule Curve



Methods: Example Rule Curve



Methods: Evaluating Rule Curves

- HEC-ResSim model
- Metrics:

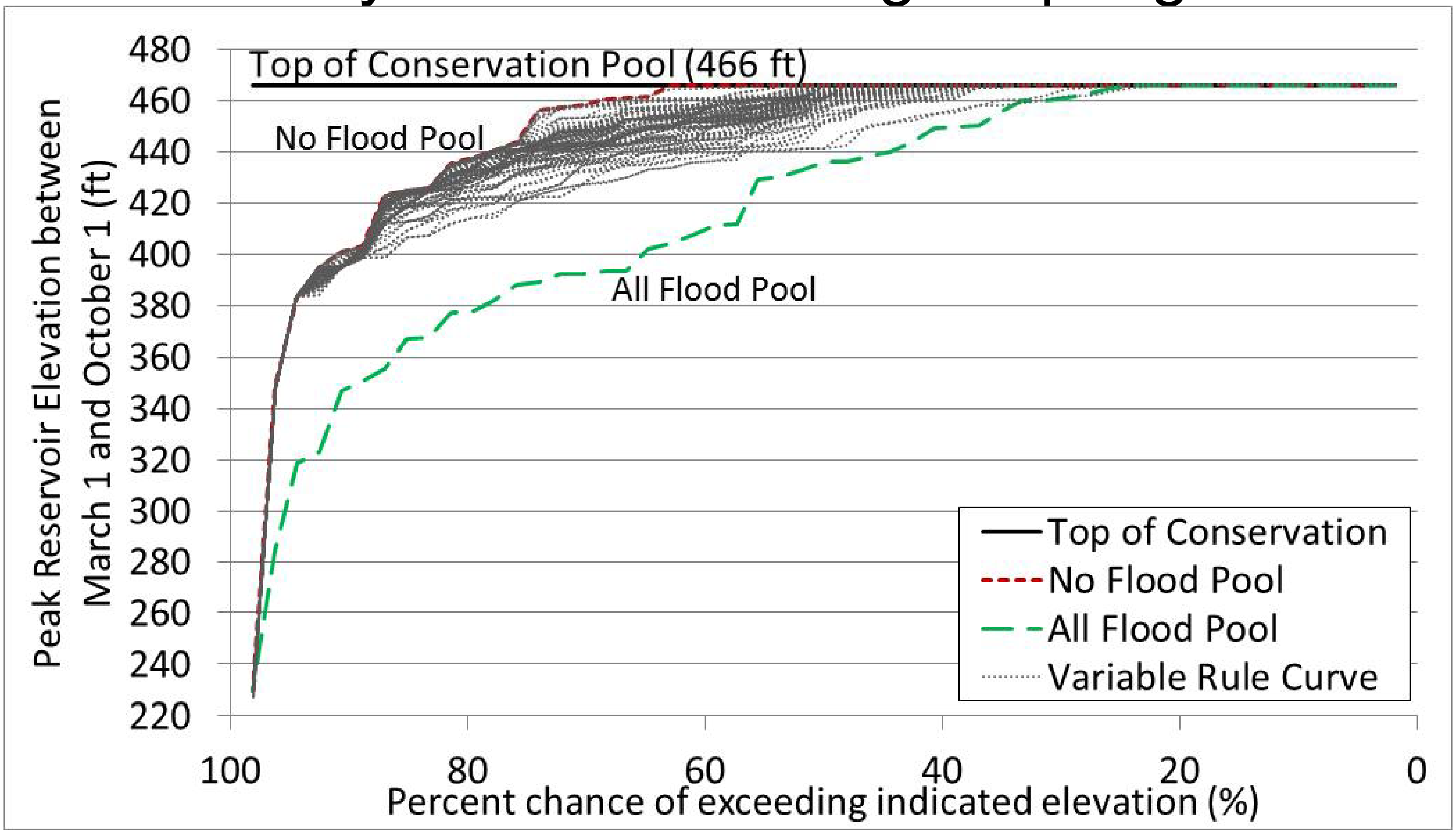
1. Rate of reservoir refilling in spring
   - Period of Record: WY1955-WY2008
2. Rate of outflow exceeding channel capacity
   - 100 synthetic flood events

Methods: Synthetic Flood Events

- Based on seven historical flood events
  - 1955, 1963, 1964, 1980, 1982, 1986, 1997
- 100 synthetic events created by scaling historic events
- Events have return periods of 50-5,000 yrs

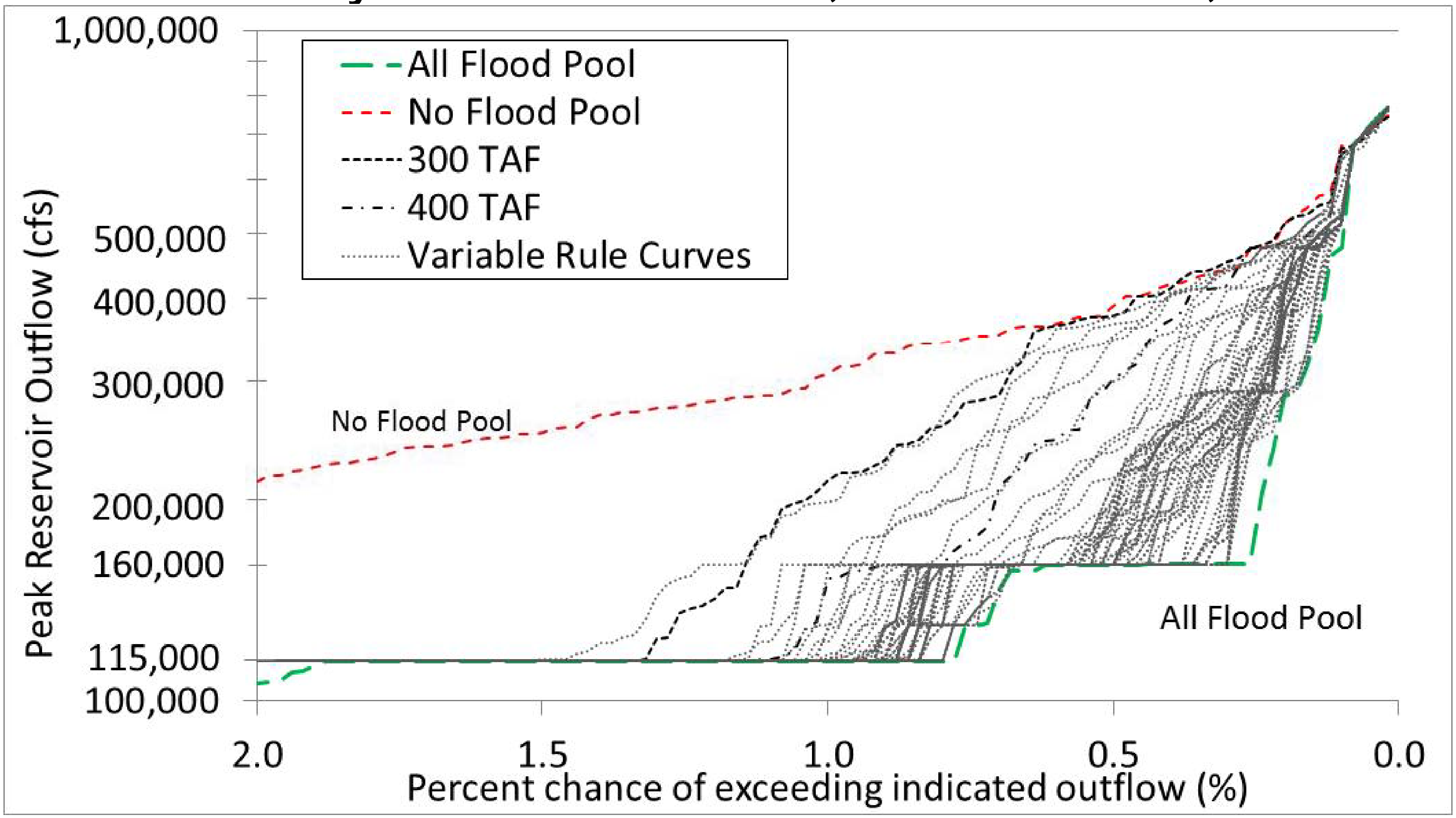
Results: Water Supply Performance

- Probability of reservoir filling in spring months



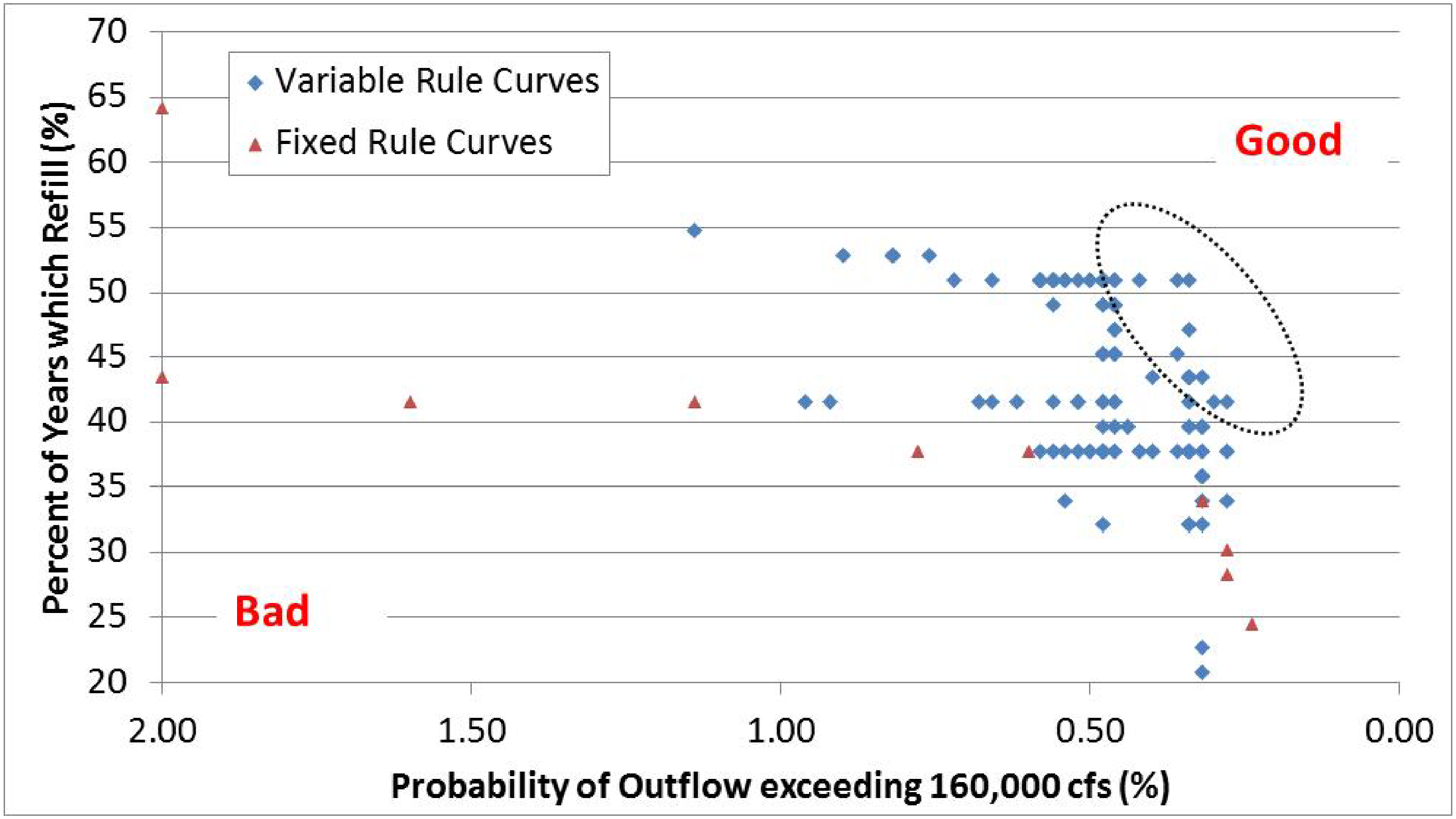
Results: Flood Control Performance

- Probability of outflow ≥ 115,000cfs & 160,000 cfs



Results

- Trade-offs between refill and flood control



Conclusions

- Incorporating basin wetness into rule curves improves refill opportunities while reducing the probability of exceeding channel capacity.
- Lower index ranges (e.g. 2-10) performed better than higher index ranges (e.g. 10-30) for flood control.
- Incorporating snowpack generated small but noticeable improvements in refill.
- Larger flood pool sizes (400-600 TAF vs. 200-400 TAF) performed best in balancing refill and flood control.
- Refill period with a single start date and variable end date performed best for refill (e.g. starting March 1 and ending April 30-June 9).

Potential Further Study

- Combining additional parameters such as available upstream storage
- Improvements to the snowpack index
  - Rain on snow events could become more common with climate change
- Incorporating forecasted precipitation into the wetness index

Questions?

Katherine Maher, P.E.
Project Engineer
GEI Consultants, Sacramento CA
kmaher@geiconsultants.com

Work performed at USACE Hydrologic Engineering Center in collaboration with Beth Faber