Ensemble Flow Forecasts for Risk Based Reservoir Operations of Lake Mendocino: An Adaptive Approach to Reservoir Management

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BACKGROUND

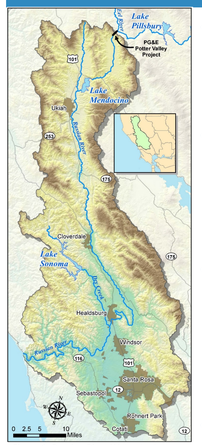


Figure 1: Russian River Watershed.

- Forecast informed reservoir operations (FIRO) is a water management strategy that seeks to improve water supplies (and other beneficial outcomes) while maintaining adequate flood protection to help water managers selectively retain or release water by leveraging skill in weather and water forecasts.
- Under conventional management practices, available storage for multi-purpose reservoirs is allocated according to storage guide curves, which define the maximum allowable water supply storage level for each day of the year. Because guide curves are developed to maintain a low risk of flooding downstream of reservoirs, they are typically conservative for flood protection, which can impact water supply storage and other uses.
- Lake Mendocino was selected as a demonstration project for the FIRO program that is being supported by an inter-agency group (Steering Committee) with members from the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), Center for Western Weather and Water Extremes (CW3E), Sonoma Water, and others. The results presented in this poster are a part of an ongoing process to implement FIRO strategies for Lake Mendocino.
- Lake Mendocino is located near the headwaters of the Russian River in Mendocino County, located approximately ~110 miles north of San Francisco, CA (Figure 1). Water released from Lake Mendocino flows into the Russian River, which provides water to a thriving agricultural region, numerous water municipalities in Mendocino and Sonoma Counties and maintains habitat for three species of endangered salmon.
- Lake Mendocino is a multi-purpose reservoir, which is owned and operated for flood control by the USACE and is operated by Sonoma Water for water supply. Lake Mendocino has a total capacity of 116,500 acre-feet and receives natural inflows from the ~105 mi² watershed area impounded by the Coyote Valley Dam as well as trans-basin imports from the Eel River through the Potter Valley Project, a hydroelectric facility upstream.
- Operations incorporate a reservoir Guide Curve (Figure 2, gray dashed line), which allocates a flood control pool at the top of the reservoir and a water supply pool below that. The allocation strikes a balance between managing flood water and providing adequate water supply. As shown in Figure 2, for the example years of 2012 and 2013, water supply is sensitive to the annual timing and quantity of rainfall.

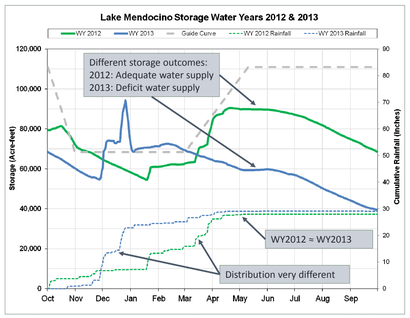


Figure 2: Lake Mendocino storage and cumulative precipitation for water years 2012 and 2013.

PRELIMINARY VIABILITY ASSESSMENT

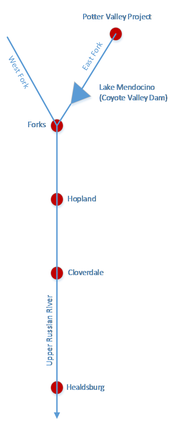


Figure 3: FIRO Model schematic.

Preliminary Viability Assessment (PVA) completed in 2017

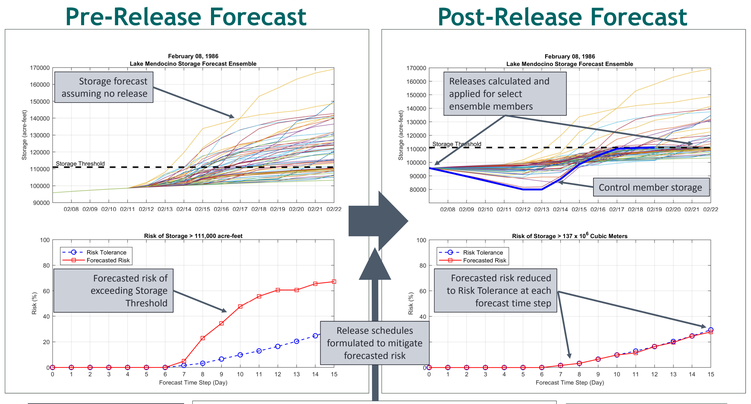
- Can FIRO improve water supply reliability of Lake Mendocino,
- While not increasing flood risk to downstream communities?

PVA FIRO Model

- Model developed to evaluate FIRO alternatives for the PVA
- Model extents: Potter Valley Project to City of Healdsburg
  - 60-mile reach of the Russian River
  - 6 Model Junctions (Figure 3) – correspond with long standing USGS discharge gages and forecast points of the California Nevada River Forecast Center (CNRFC)
- Water Balance Model
  - Daily time step
  - 1985 to 2010 (limited by GEFS V10 reforecast)
- Lake Mendocino Operational Constraints
  - Maximum release schedules
  - Release rate of change limits (ramping rates)
  - Flood Control: Flood control release should contribute to flows greater than 8,000 cfs at Hopland (nuisance flooding level)
  - Water Supply: Downstream demands and minimum flow requirements for environmental needs

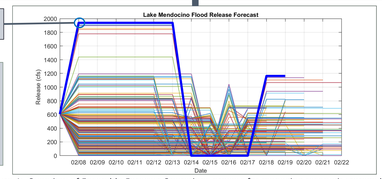
ENSEMBLE FORECAST OPERATIONS

- Ensemble Forecast Operations (EFO) - risk based approach for determining releases.
  - Utilizes flow forecast ensembles prepared by California-Nevada River Forecast Center (CNFRC) with the Hydrologic Ensemble Forecast System (HEFS) to forecast Lake Mendocino storage and downstream flows for each ensemble member.
  - Release schedules are formulated that mitigate forecasted risk of exceeding the maximum conservation level of Lake Mendocino of 111,000 acre-feet, as well as not contribute to flooding downstream (figure 4).
  - System conditions are forecasted for each hydrologic ensemble member out to 15-days.
- CNRFC developed hindcast of HEFS from 1985 to 2010.
  - Hindcast consistent with current operational forecasting skill (GEFS V10 driven).
  - Enabled simulation of EFO approach for a variety of hydrologic condition to support PVA.



Control member = the max day 1 release to mitigate forecasted risk

Calculation of Flood Release
- ❖ Considers max release constraints and
- ❖ Release rate of change constraints.



Downstream Constraints
- ❖ Releases do not contribute to downstream flows above nuisance flood stage (8,000 cfs).

Figure 4: Overview of Ensemble Forecast Operations process for managing reservoir storage levels.

FEBRUARY 1986 EXAMPLE

- Simulation results from February 1986 provide example to compare system conditions with EFO scenario to Existing Operations (figure 5). February 1986 is the largest flood event in the model simulation period (1985 – 2010). This example has been divided into 4 periods explained below.

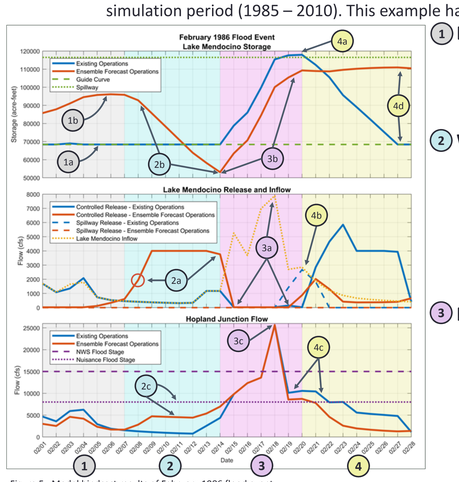


Figure 5: Model hindcast results of February 1986 flood event.

1 Dry Forecast Period:
- a) Existing Operations storage levels maintained to Guide Curve.
- b) EFO scenario stores water because forecasts indicate low risk.

2 Wet Forecast Period:
- a) Wet forecast (February 8 example provided in figure 4) results in 7 days of pre-event flood control releases.
- b) EFO scenario storage level reduced below Guide Curve in advance of storm event.
- c) Pre-event releases maintain downstream flows below flood levels.

3 Flood Event:
- a) Flood event results very high inflows. Releases minimized for both scenarios to not contribute to flooding downstream.
- b) High inflows and low releases result in rapid rise in storage for both scenarios.
- c) EFO scenarios shows no increase in flows above flood stage.

4 Post Flood Event:
- a) Existing Operations scenario storage levels exceed emergency spillway, which causes
- b) Emergency spillway release, and c) increased duration of nuisance flooding downstream.
- d) Existing Operations storage levels returned to Guide Curve, but EFO scenario retains stored water from flood event because forecast is dry.

FIRO MODEL SIMULATION RESULTS 1985 TO 2010

- Hindcast simulation from 1985 to 2010 completed to support analysis in the PVA.
- 3 Model Scenarios:
  1) Existing Operations – incorporates current Guide Curve
  2) Ensemble Forecast Operations (EFO)
  3) Perfect Forecast Operations – uses observed flows in place of hindcasted HEFS and simulates the maximum possible benefit from EFO alternative.

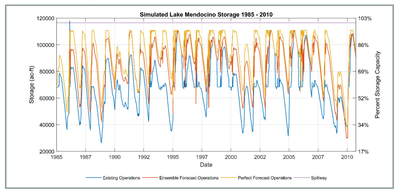


Figure 6: Lake Mendocino Storage levels from PVA Study.

Improved Water Supply Reliability
- ❖ Perfect Forecast Operations scenario demonstrates largest gain in water supply (figure 7).
- ❖ EFO scenario also shows significant improvement in end of water year storage for all but 6 of the wettest years.
  - ➢ 36% increase in median end of water year storage relative to Existing Operations scenario.

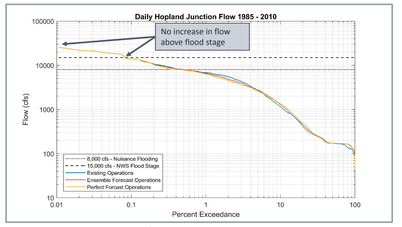


Figure 8: Daily Hopland junction flow percent exceedance.

Increased Water Capture
- ❖ Perfect Forecast Operations demonstrates largest increases in peak annual storage levels relative to Existing Operations scenario (figure 6).
- ❖ EFO scenario also demonstrates significant increases in storage levels.

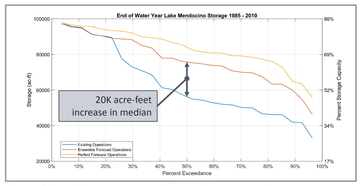


Figure 7: Lake Mendocino end of water year storage percent exceedance.

Downstream Flow Conditions
- ❖ Perfect Forecast Operations and EFO scenarios demonstrate no instances of increased flows above flood stage at Hopland, the most flood prone region downstream of Lake Mendocino (figure 8).
- ❖ Flows for all three scenarios demonstrate very similar distributions.

FINDINGS:

- EFO alternative would likely improve water supply reliability of Lake Mendocino.
- EFO alternative demonstrates no increase in flood risk for downstream communities for the historical period simulated (1985 – 2010).
- Results of the Perfect Forecast Operations scenario indicate that future improvements forecasting skill could improve the water supply and flood protection benefits of the EFO alternative.
- Modeling analysis completed for this study is subject to the following limitations:
  - Limited historical period of analysis: flood of record occurred outside of the simulation timeframe;
  - Coarse Resolution: operational decisions are typically made at a sub-daily time step;
  - EFO Model only simulates conditions in the Upper Russian River; flood release decisions of EFO alternative may increase flood risk to points further downstream.

NEXT STEPS

- **2019 Major Deviation:** The USACE recently approved a Major Deviation for Lake Mendocino to operate a portion of the Lake Mendocino flood pool (orange shaded region in figure 9) using a forecast informed approach for the 2018/2019 winter and spring seasons.
- **Future Major Deviation Requests:** Incrementally expand the use of forecast based operations with future major deviation requests.
- **Final Viability Assessment:** Multidisciplinary study that will build off of the research of the PVA. This study will include refinement of the EFO alternative to address limitations of PVA study.
- **Modification of the Water Control Manual:** Research from the Final Viability Assessment will provide the foundation to support permanent implementation of FIRO for Lake Mendocino.

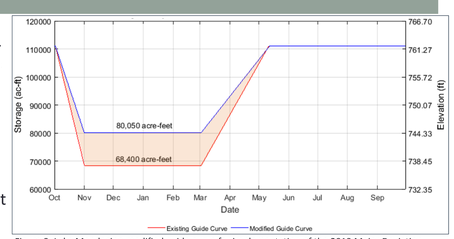


Figure 9: Lake Mendocino modified guide curve for implementation of the 2019 Major Deviation.

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