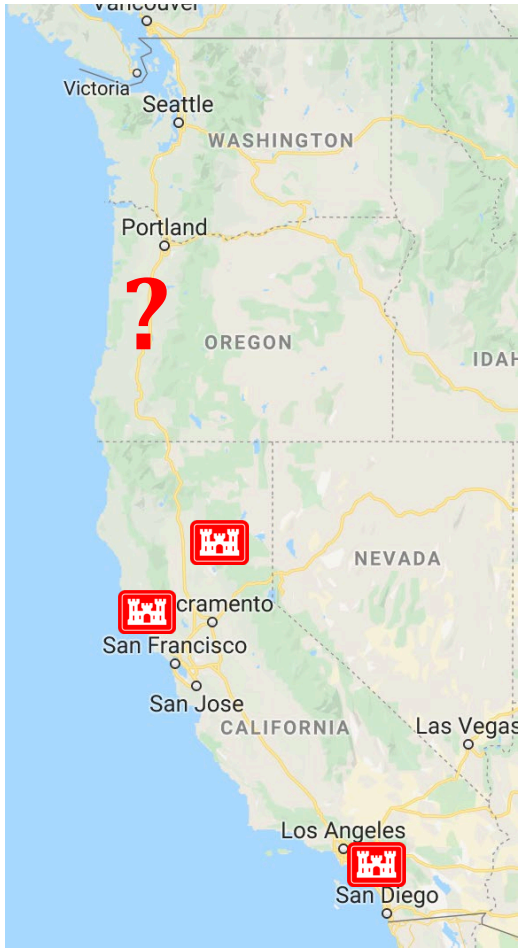
# Forecast Informed Reservoir Operations

## Research and Operational Strategies to Enhance Water Supply Reliability and Environmental Co-Benefits and to Enhance Flood-Risk Reduction

https://cw3e.ucsd.edu/firo/

# FIRO 2014 - 2020




| Reservoir | Capacity | Purposes | Ecosystem Impacts | Coordinated Ops? |
|---|---|---|---|---|
| Lake Mendocino (Russian R.) | 116,500 | 60% Supply<br>40% Flood | Salmonids | Yes, Lake Sonoma |
| Prado Dam (Santa Ana R.) | 174,000 | 10% Buffer<br>90% Flood | Songbirds | No |
| New Bullards Bar (Yuba R.) | 966,000 | 80% Supply<br>20% Flood | Fish, Bay Delta | Yes, Oroville through fed/state program |
| Lake Oroville (Feather R.) | 3,538,000 | 80% Supply<br>20% Flood | Fish, Bay Delta | Yes, New Bullards Bar through fed/state program |

# Importance of FIRO Effort to USACE

May 2016 update to Corps Engineer Regulation governing Water Management

- "Forecasted conditions may be used for planning future operations…"
- Policy change is in place, FIRO effort is defining how it will be implemented

# FIRO Success

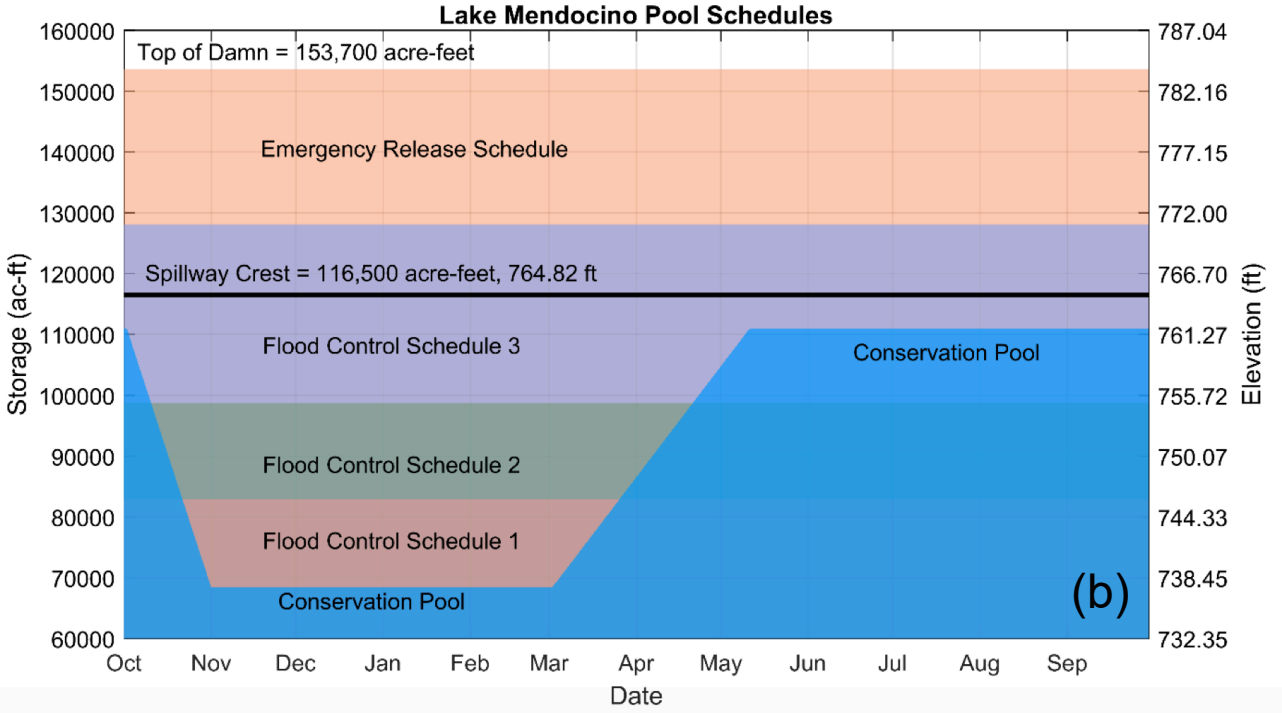
Recognizes, develops, and supports relationships

# Formula for FIRO Projects

1. Partner with local stakeholder(s)
   - Lake Mendocino – Sonoma Water
   - Prado Dam – Orange County Water District
   - Yuba-Feather System – Yuba Water Agency and CA State Water Project
2. Form a Steering Committee with a Support Team
3. Initiate Research Investigations
4. Develop Workplan for the Viability Assessment
5. Conduct the Viability Assessment
6. Provide Analysis to Support an Update to the Water Control Manual

Lets take a look at a project that has completed all steps

# Lake Mendocino and the Russian River


a) Russian River Watershed with location of water supply reservoirs and the flood prone town of Guerneville, CA.

b) Lake Mendocino "Guide Curve" showing management schedules by US Army Corps of Engineers.

# A History of Floods

February, 1915. Guerneville.

February, 1986. Guerneville.

December, 1955. Guerneville.

December, 1995. Guerneville.

Historically,

The river has reached flood stage at Hopland, CA in approx. 22% of years since 1959. (Post-CVD)

and at Guerneville, CA in approximately 50% of all years since 1940.

# And of Drought

Left: Lake Mendocino during CA drought in Dec. 2013

Annual precipitation and streamflow are highly variable in N. CA, with standard deviation approaching annual mean in the latter.

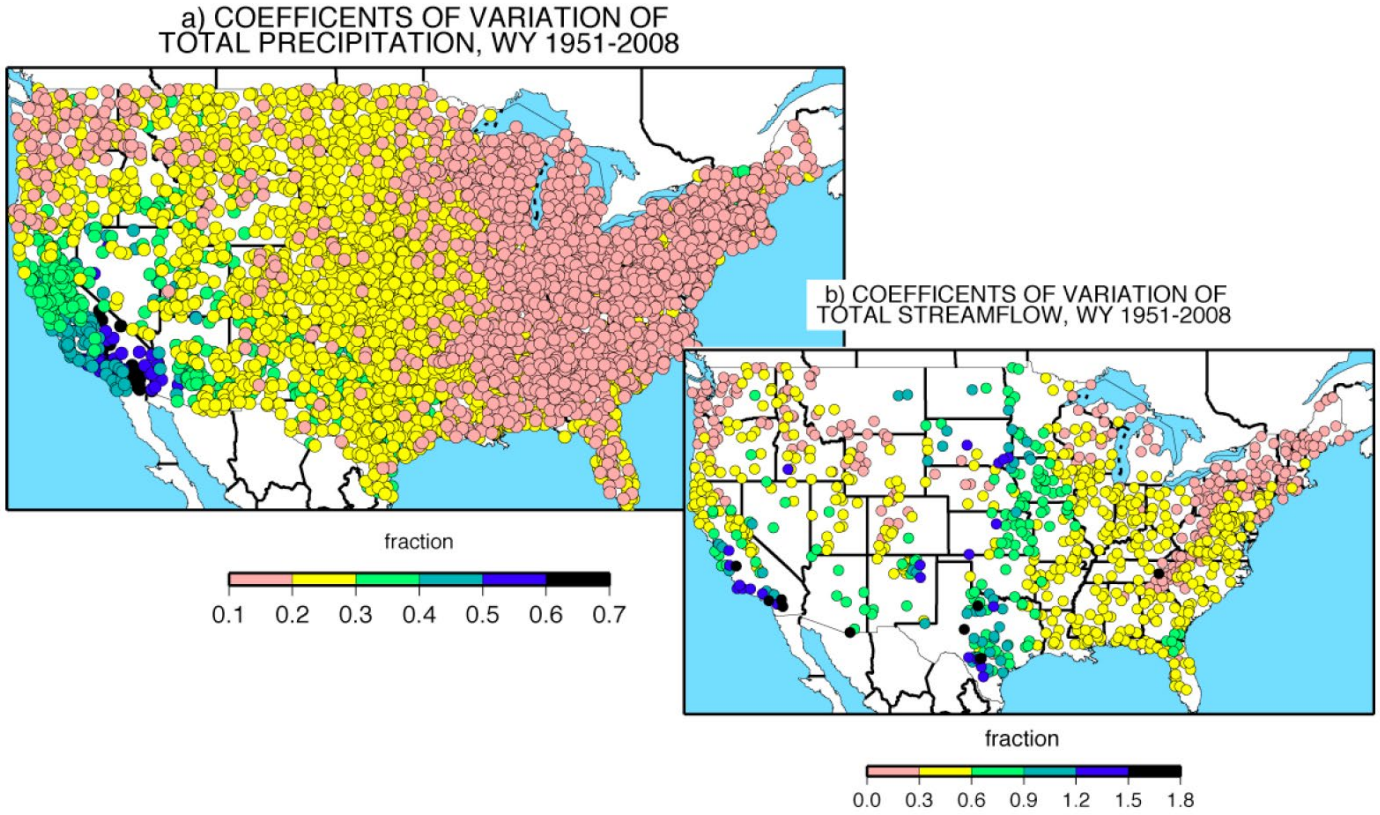




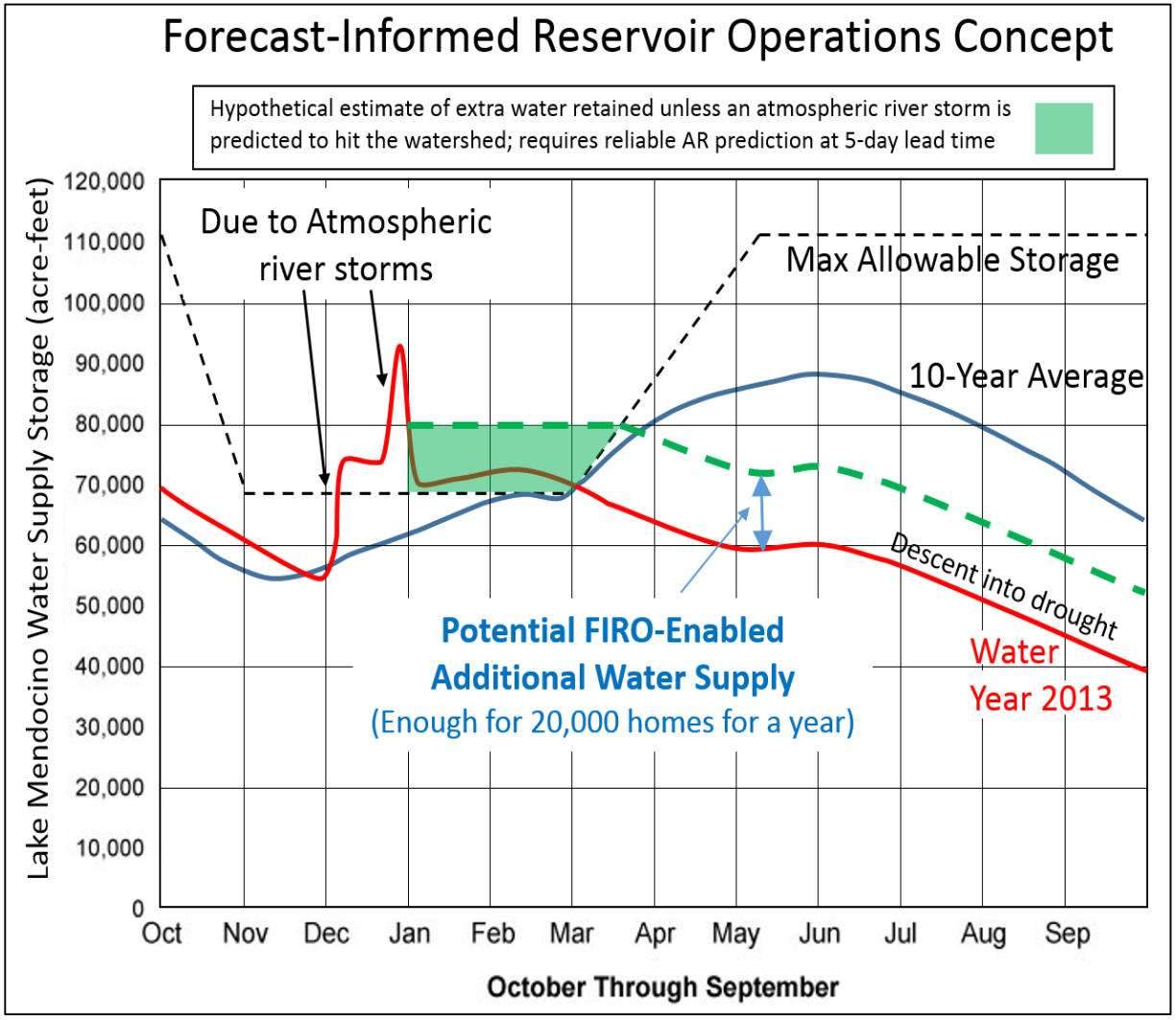

Photo: Santa Rosa Press Democrat;
Figures: Dettinger et al. (2011 – *Water*)

# Downstream Requirements: SWRCB, Grapes and Salmonids

- The SCWA permit dates to April, 1986 and is junior to the permit governing minimum flows from the PVP.
- Flows from Lake Mendocino must meet minimum flow requirements for Dry Creek and the Lower Russian River (two economically valuable AVAs)
- The Russian River below Lake Mendocino is also subject to a NMFS Biological Opinion covering Steelhead, Coho and Chinook Salmon.

**Coho Salmon**

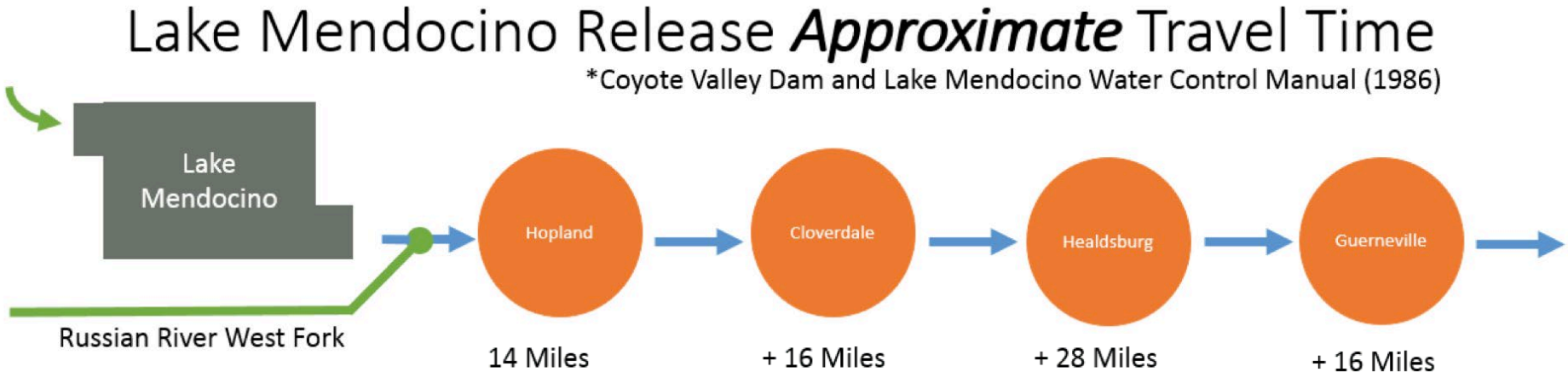
# Modified Operations to Increase Summertime Water Supply




FIRO is investigating a deviation from rule curve to green line, but also must:

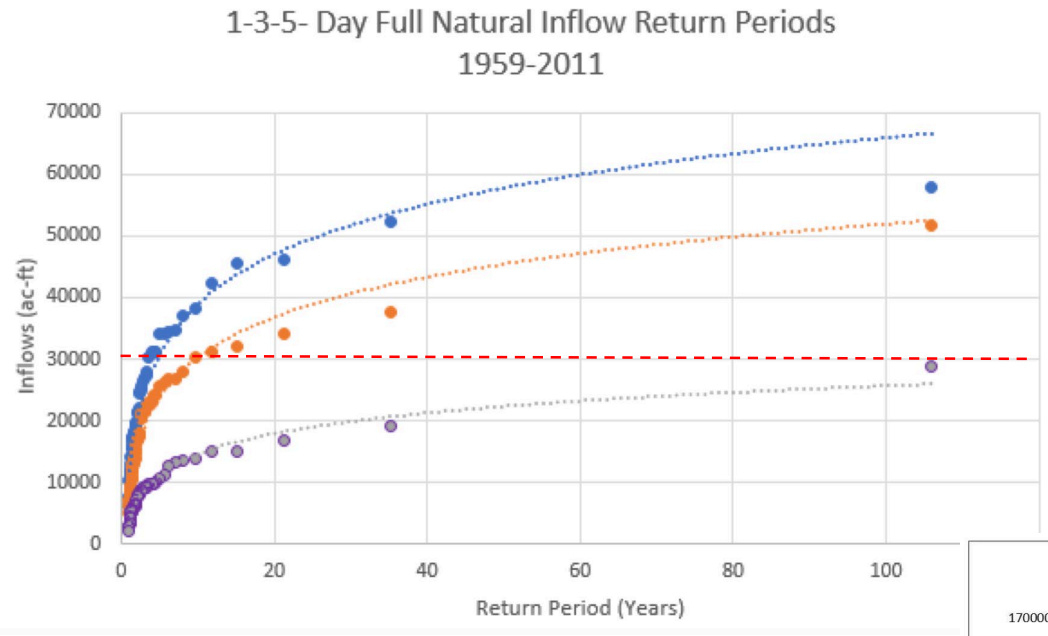
- Release water to meet original rule curve if large (30,000 AF) inflow is forecast.
- Cannot release if
  - Downstream gauges exceed flood-critical thresholds.
- Must not reduce releases too quickly.

# Improvements in Rainfall and Streamflow Forecasting



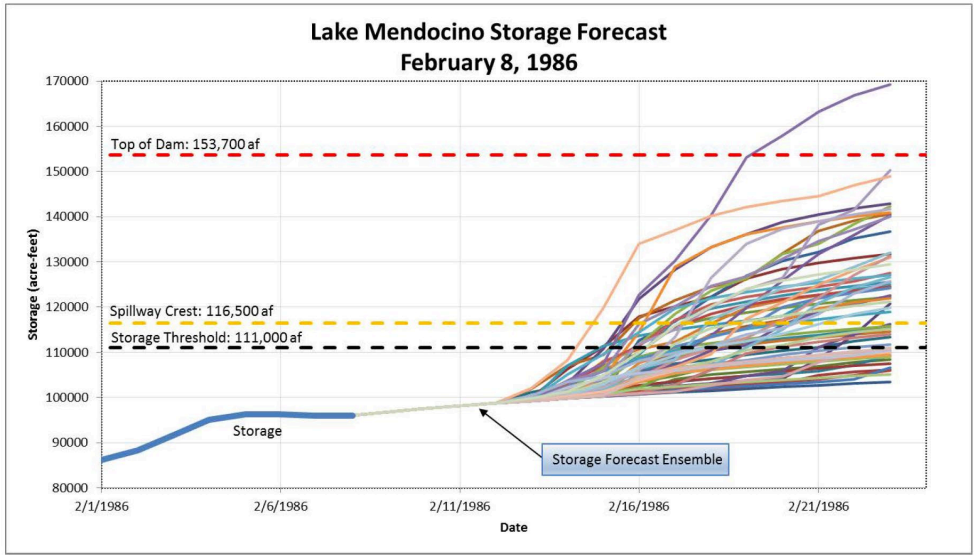

- To make new conservation level feasible, both inflows (for dam safety) and downstream flows (to avoid exacerbating flood with releases) must be accurately forecast.
- Total travel time for released water to pass Guerneville ranges from **26 to 85 hours**.
- With extra buffer to observe ramping rate (BiOp), this means decisions need to account for forecasted conditions in the next 5 days.

# When Should We Expect Problematic Inflows?



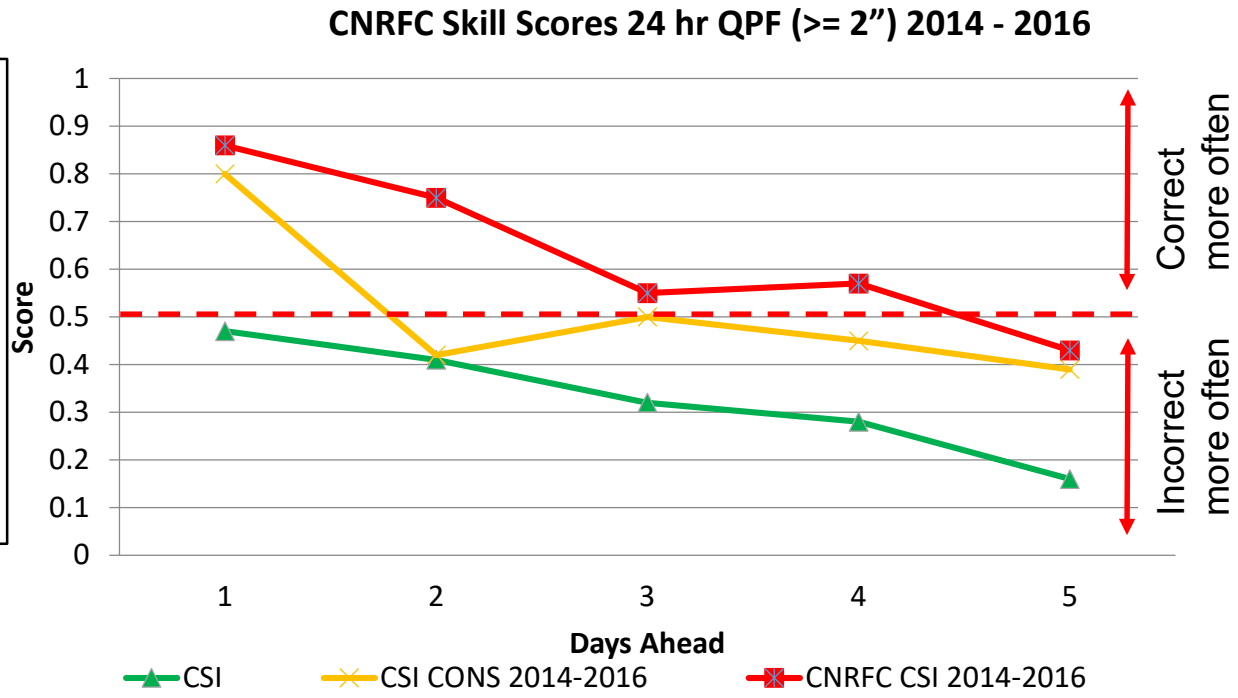

5 day inflows exceeding 30,000 AF have ~ 33% chance in any given year.

SCWA and SIO **experimental** forecast ensemble estimates the probability of problematic inflow 5+ days in advance



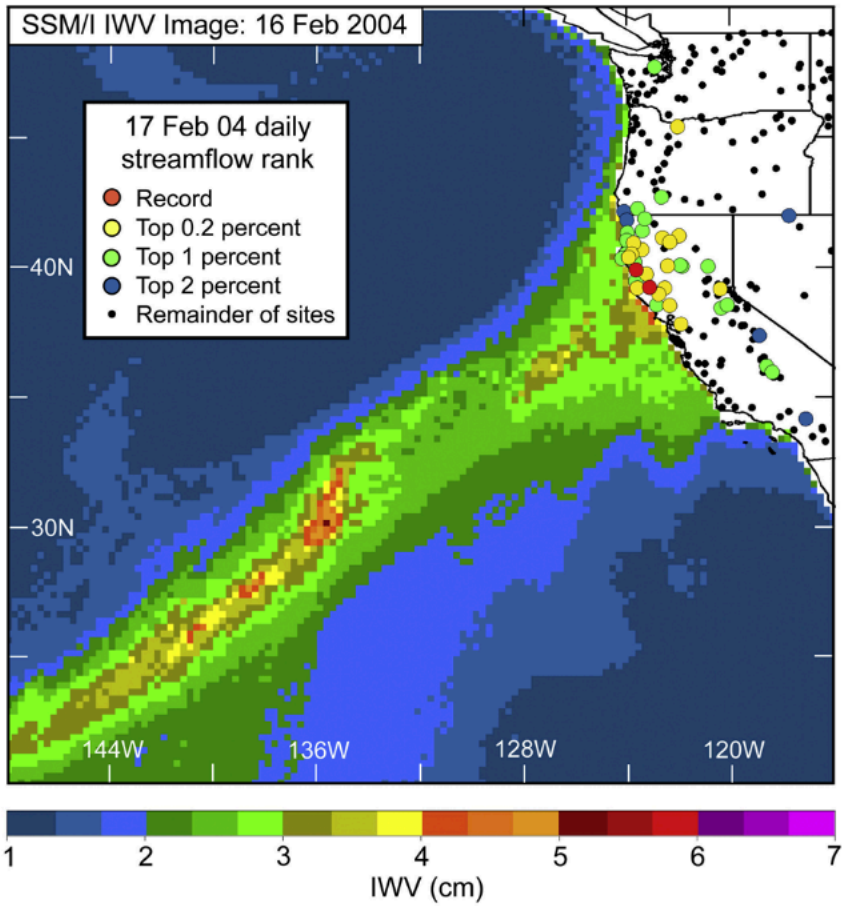
# How Accurate are Rainfall Forecasts Currently?

An analysis of daily flows > 2500 cfs at Ukiah (1986 – 2016)
Shows **94% of these are also *Atmospheric River* days**.
Mean 24 hour QPE = 2.7”



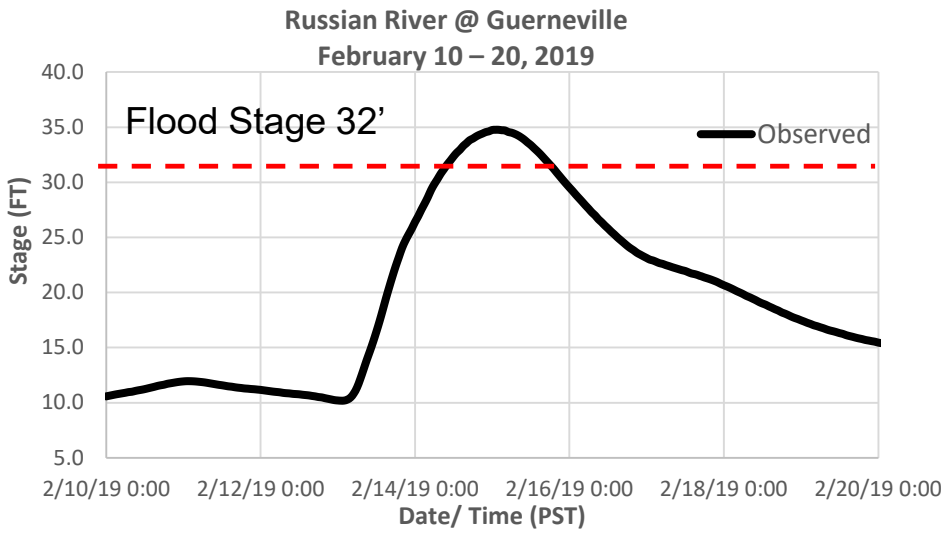

- Current models do not show required level of skill at predicting rainfall amounts linked to critical downstream flows.
- Human-aided forecasts are better, but need to improve days 3-5.

# Regional Hydroclimate



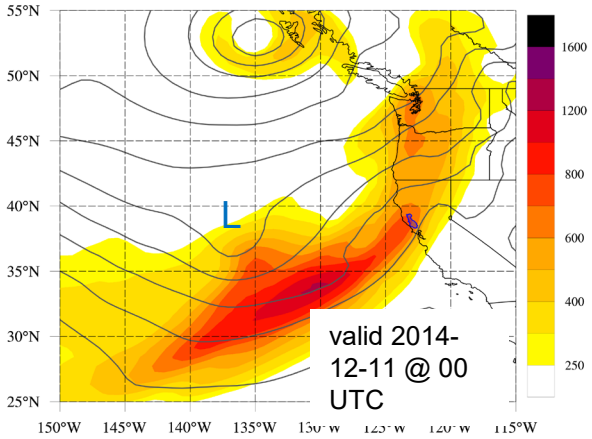

Ralph et al., 2004: "Flooding on California's Russian River: Role of Atmospheric Rivers" found that 6 of 7 largest floods at Guerneville were caused by AR.

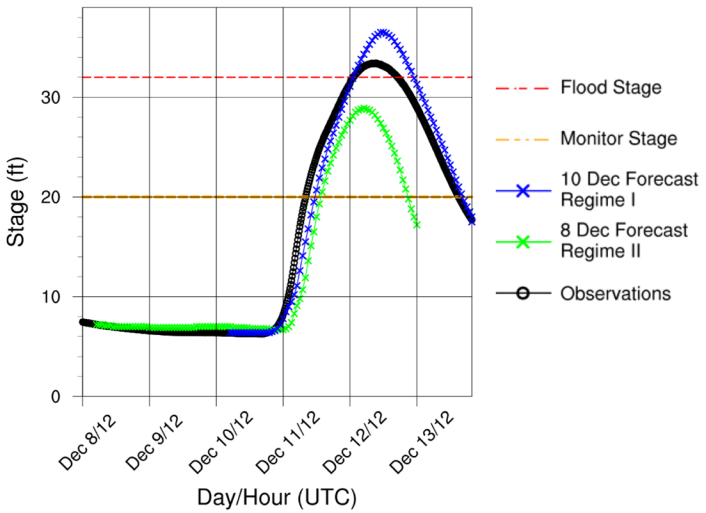
Since FIRO project started, researchers have observed additional AR-caused floods in 2014 (**x2**), 2017 (**x2**) and 2019 (**x2**).



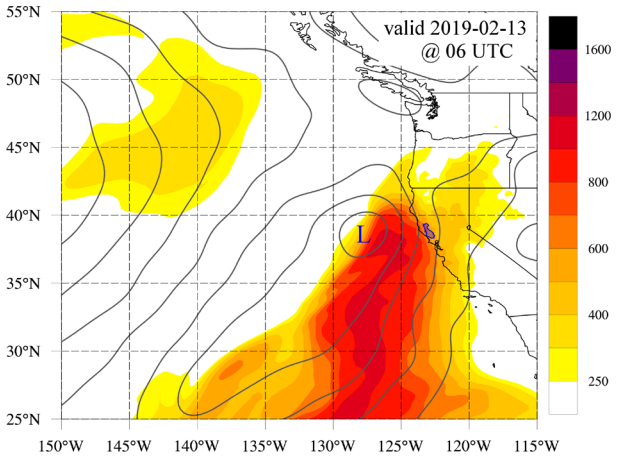
# What are some Worst Case Forecast Scenarios?

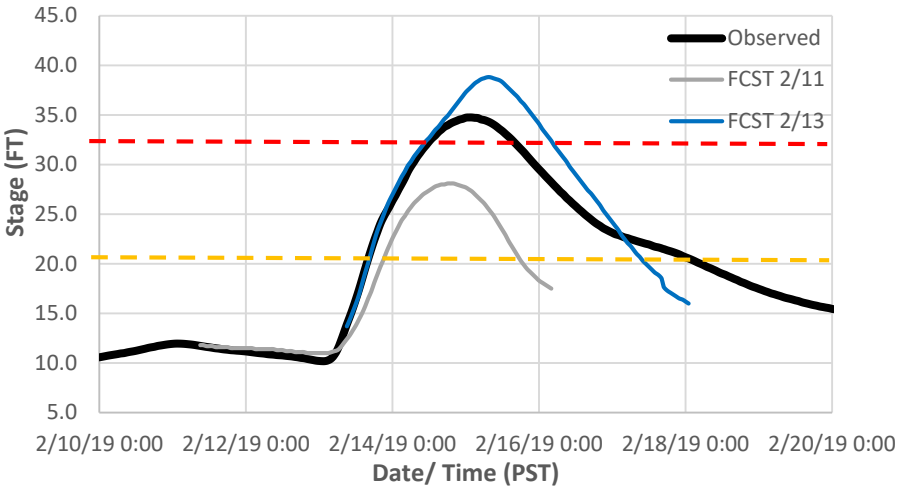
December 11-13, 2014




February 13-18, 2019



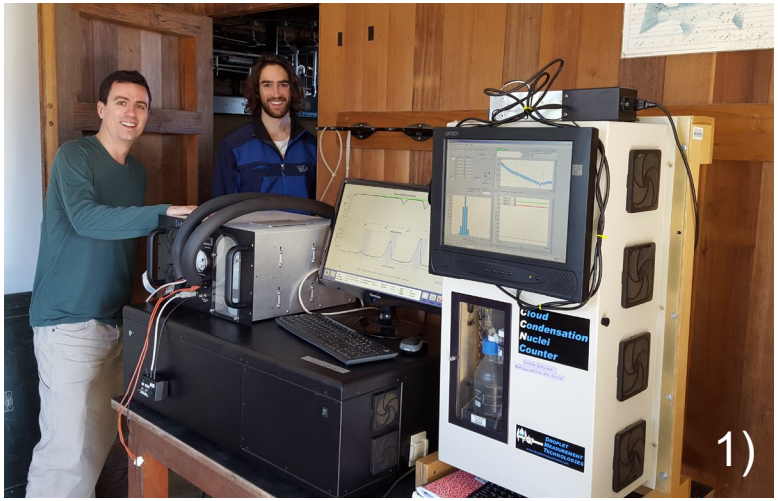




In each case, a frontal cyclone ("L") developed with little warning near the AR (colors). River forecasts adjusted from no flood to flood less than 24 hours before the river began to rise.

# Basic Research to Understand the Hydroclimate: Atmosphere

**Clockwise from top-right**:

1. Researchers installing instruments to measure atmospheric chemistry
2. Automatic precipitation sampling equipment next to field trailer
3. Graduate students prepare to launch weather balloon
4. A “micro-rain” radar



1)


4)


3)


2)

# Basic Research to Understand the Hydroclimate: Land Surface

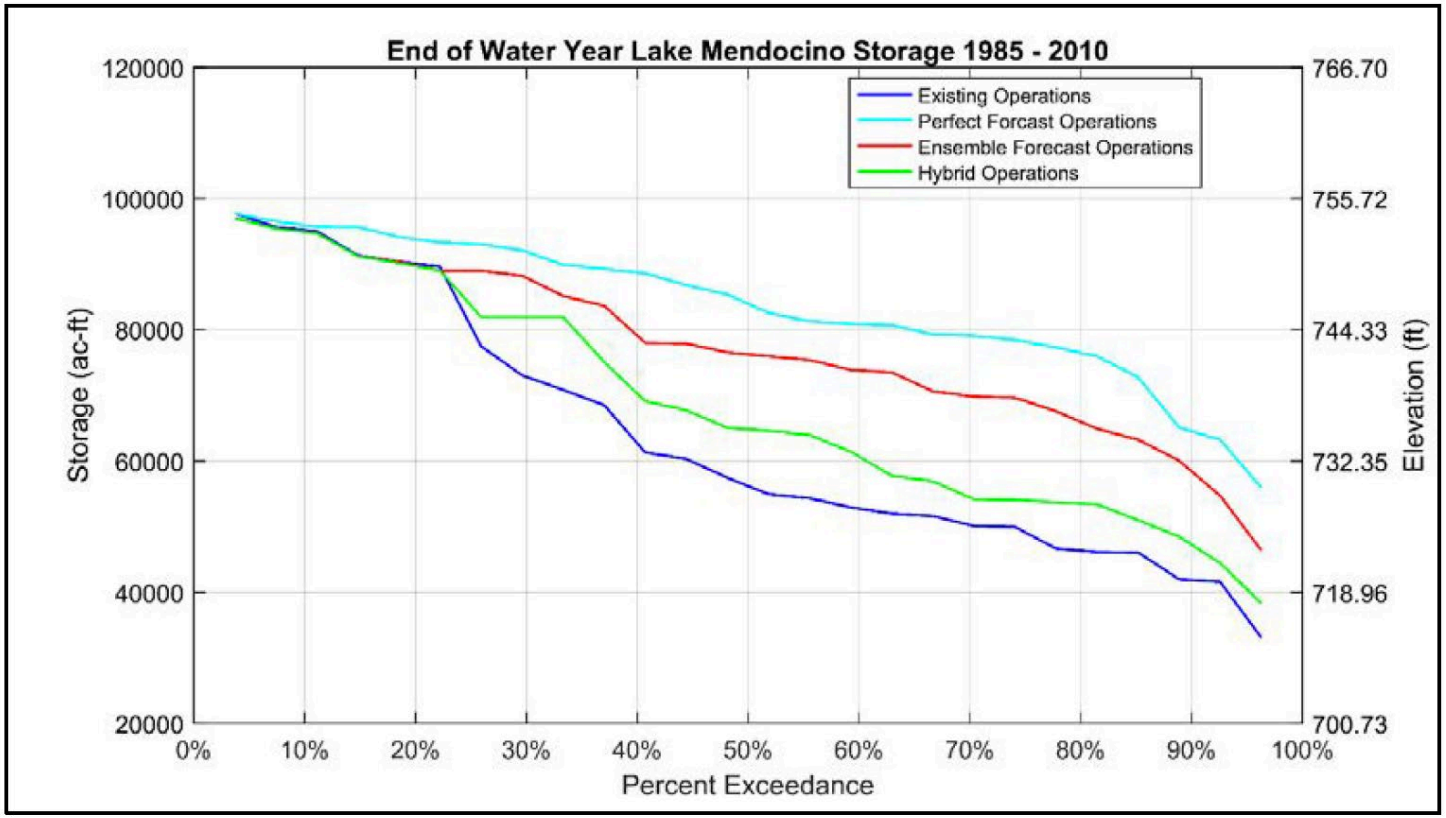




**Clockwise from top-left**:

1. Installing a stream gauge in a seasonal creek.
2. Setting up an automated weather and soil moisture monitoring site inside a recent burn.
3. Digging in preparation to install soil-moisture monitoring equipment.
4. Preparing an automated stream-water sampler.

# How Have Operations Changed?




**Red curve**: let the forecast ensemble prescribe releases regardless of current storage

**Green curve**: limit to WCM deviation if forecasts say risk is low.

**Adopted 2018**

The FIRO *Preliminary Viability Assessment* Report found that current technology (including forecasts) allowed for a partial implementation of FIRO at Lake Mendocino.

Simulated operations (above chart) under the Hybrid scenario estimates that median end of year storage would increase by 8,600 AF without impacting downstream flood risk.

# Imagining a FIRO Willamette

- How and when will additional water be useful?
- When do the greatest downstream and project risks occur?
- How do events differ: for flood/infrastructure/life, for habitat?
- What roles will the project play in future climates: supply/flood protection/quality?
- How are the regional ecosystems (and disturbances) related?
- How to engage partnerships (state, local water or irrigation districts, tribes)?

# Acknowledgements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