

Coupled System Operations and Water Temperature Simulation: *Challenges and Opportunities for Shasta Reservoir and the Central Valley*

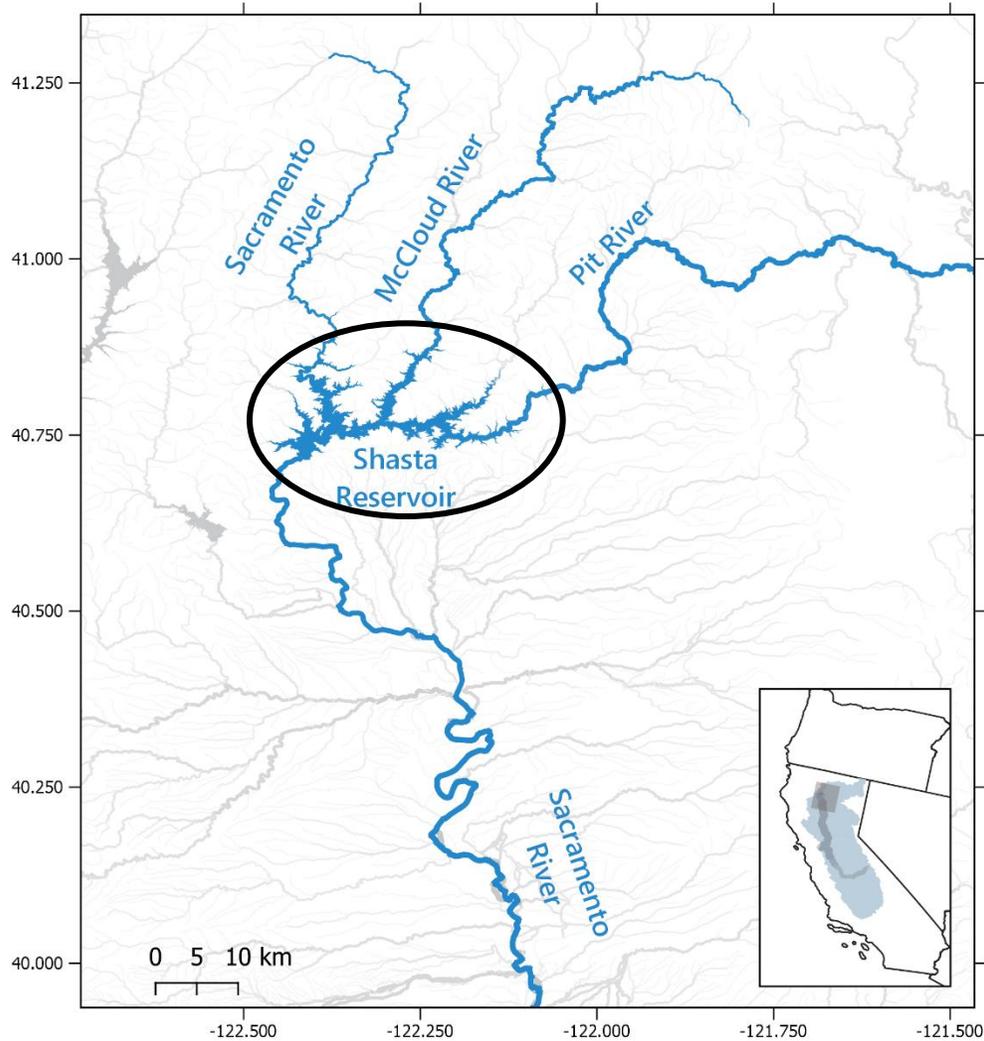
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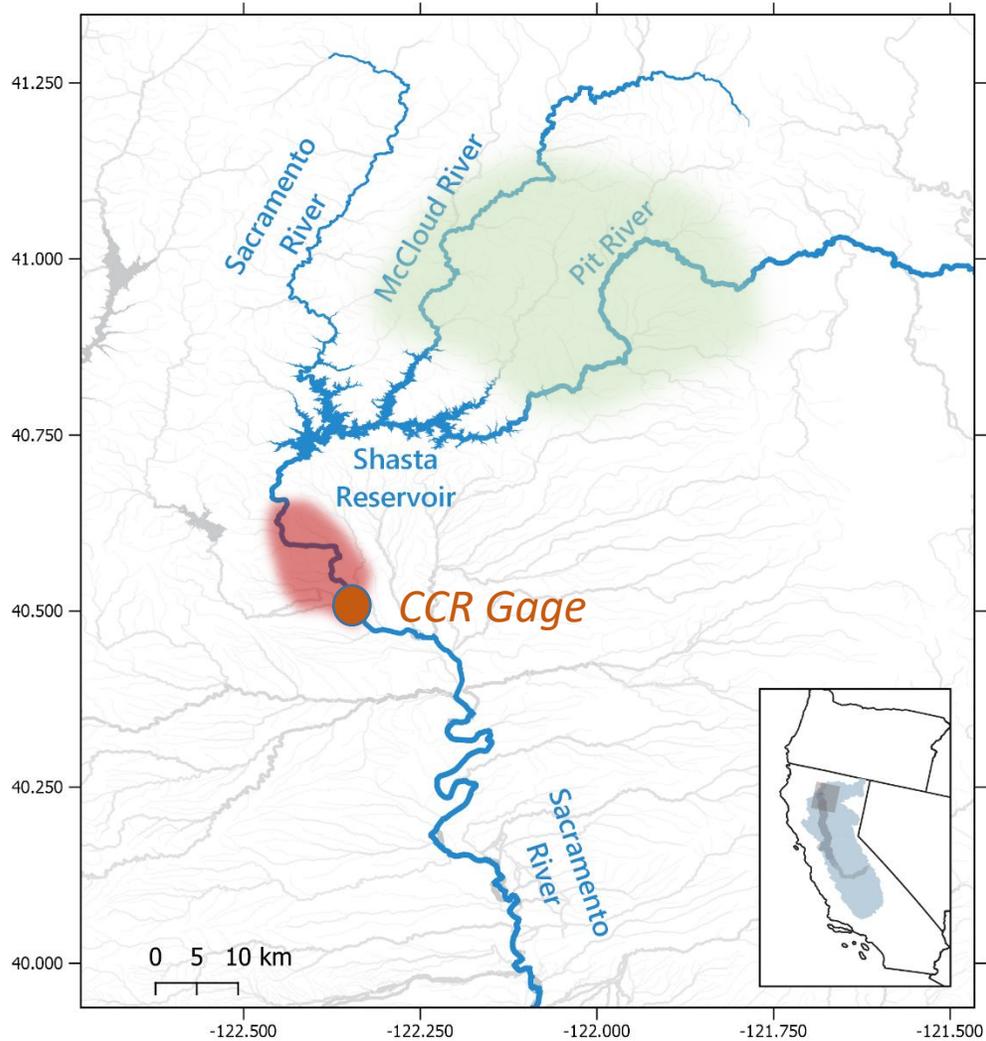
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Background: Shasta Reservoir and Sacramento River



- **Shasta Reservoir:**
 - California's biggest (~4.5 MAF or 5615 MCM)
 - At north end of California's Central Valley
 - Impounds waters from three main tributaries
- Shasta is managed for many (sometimes competing) purposes:
 - Supply and delivery
 - Environmental and regulatory compliance
 - Flood control
 - Temperature management and fisheries
 - Power generation

Background: Shasta Reservoir and Sacramento River



- Shasta and Keswick Dams block access to cold, spring-fed waters in these tributaries **historically used for salmon spawning**
- Spawning now occurs in the **reaches of the Sacramento River just below the dams**
- Temperatures managed to control points on the river, like the **Clear Creek confluence (CCR) gage**

Background: Endangered Salmon

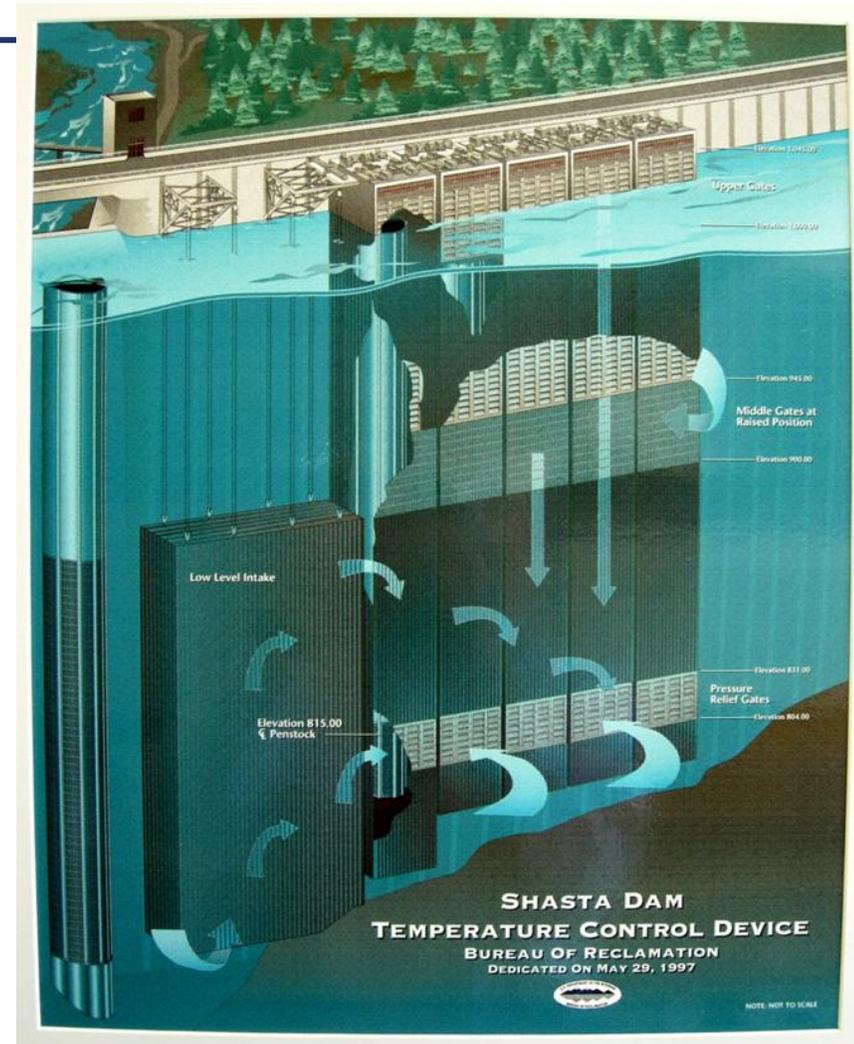


- Four main runs of Chinook salmon return to Central Valley rivers each year
- Winter Run Chinook (WRC) is critically endangered and spawns only in the Sacramento River
- Despite the name, WRC spawn in the summer
- Egg survival affected by thermal control from Shasta Reservoir
- Flow conditions in the river and Delta affect juvenile survival

Background: Temperature Management

Shasta Temperature Control Device (TCD)

- Installed in 1997
- Provides 4 levels for selective withdrawal and blending
- Operated to meet downstream temperature targets through the summer



Decisions and Considerations that Affect Temperature Outcomes

- **Water Supply and Delivery**

- Reservoir storage
- Inflow hydrology
- Flood pool limits/flood control
- Delta and regulatory release requirements
- Contractor allocations
- Release and delivery schedules

- **Temperature management**

- Cold water pool
- Meteorology
- Release schedules
- Temperature compliance location
- Temperature target, timing, duration
- Spawning location and timing
- TCD gate options



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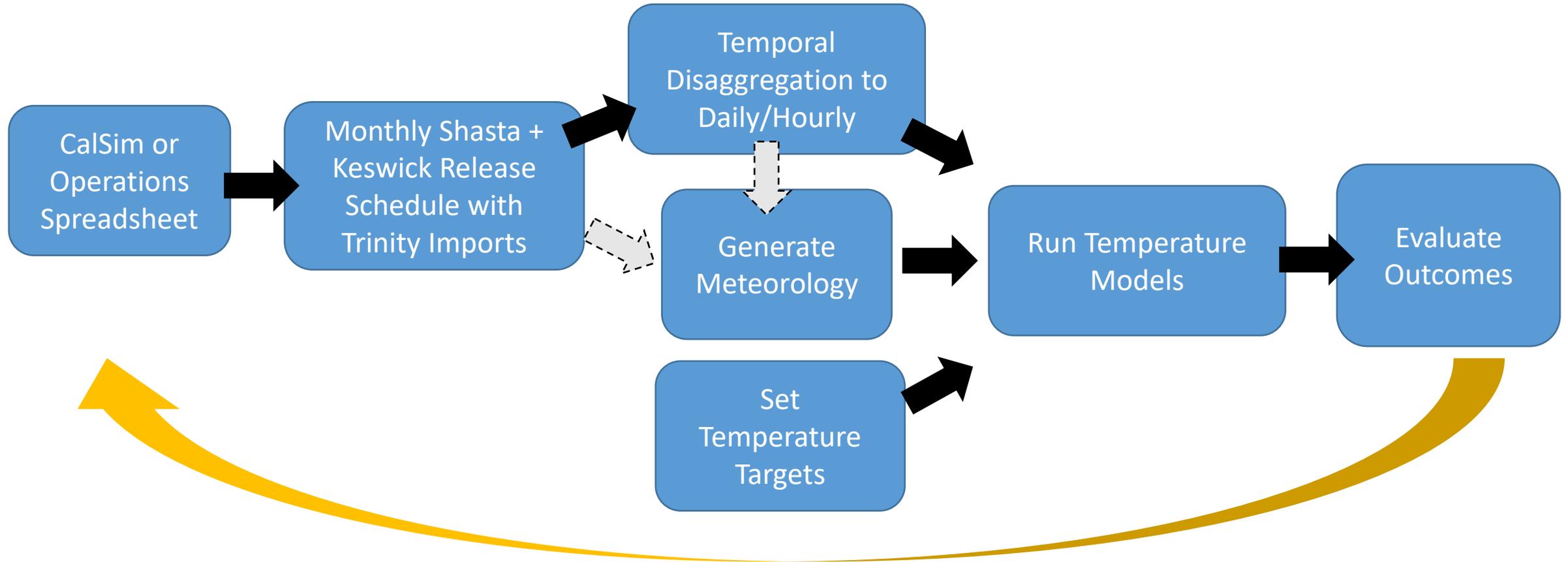
*Monthly (internal) operations plan,
CalSim models*

• **Temperature management**

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*Daily-Hourly Temperature Models
(HEC-5Q, HEC-ResSim, CE-QUAL-W2,
RAFT, UCSC Rapid Models)*

Conventional Modeling Process



*Looking for a different outcome? Need to understand sensitivity?
Explore options? Repeat the process*

Limits of Conventional Process

- Assumes temperature management is conditional on a set release schedule
- Introduces assumptions related to temporal disaggregation
- Potential for meteorological inconsistencies
- Connecting temperature management needs back to system-wide operations adjustments or impacts is cumbersome



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Operations-Temperature Management Connections

- Reservoir storage and Coldwater pool
 - Volume of cold water proportional to total storage (at least historically)
 - Spring operations that determine total storage can affect cold water availability

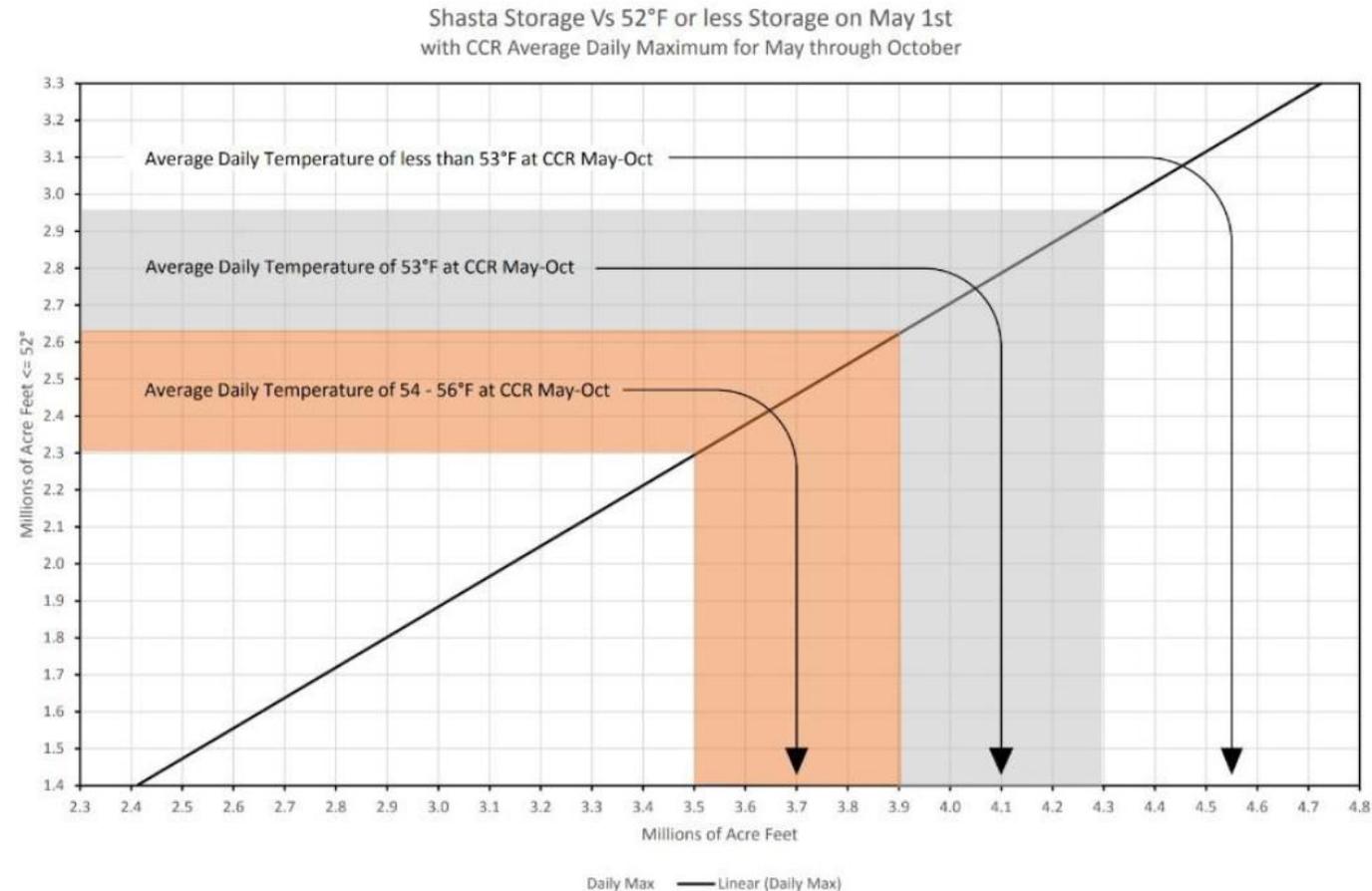
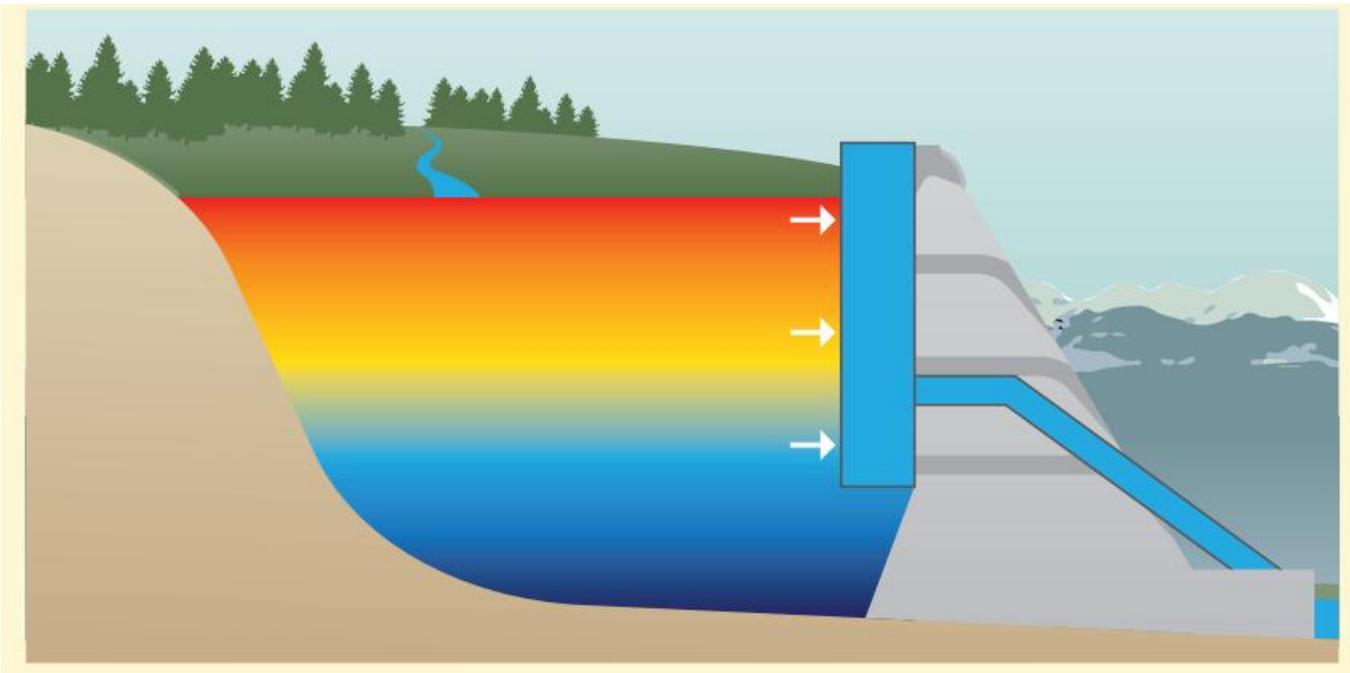


Figure 4-2. Relationship between Temperature Compliance, Total Storage in Shasta Reservoir, and Cold Water Pool in Shasta Reservoir

Operations-Temperature Management Connections

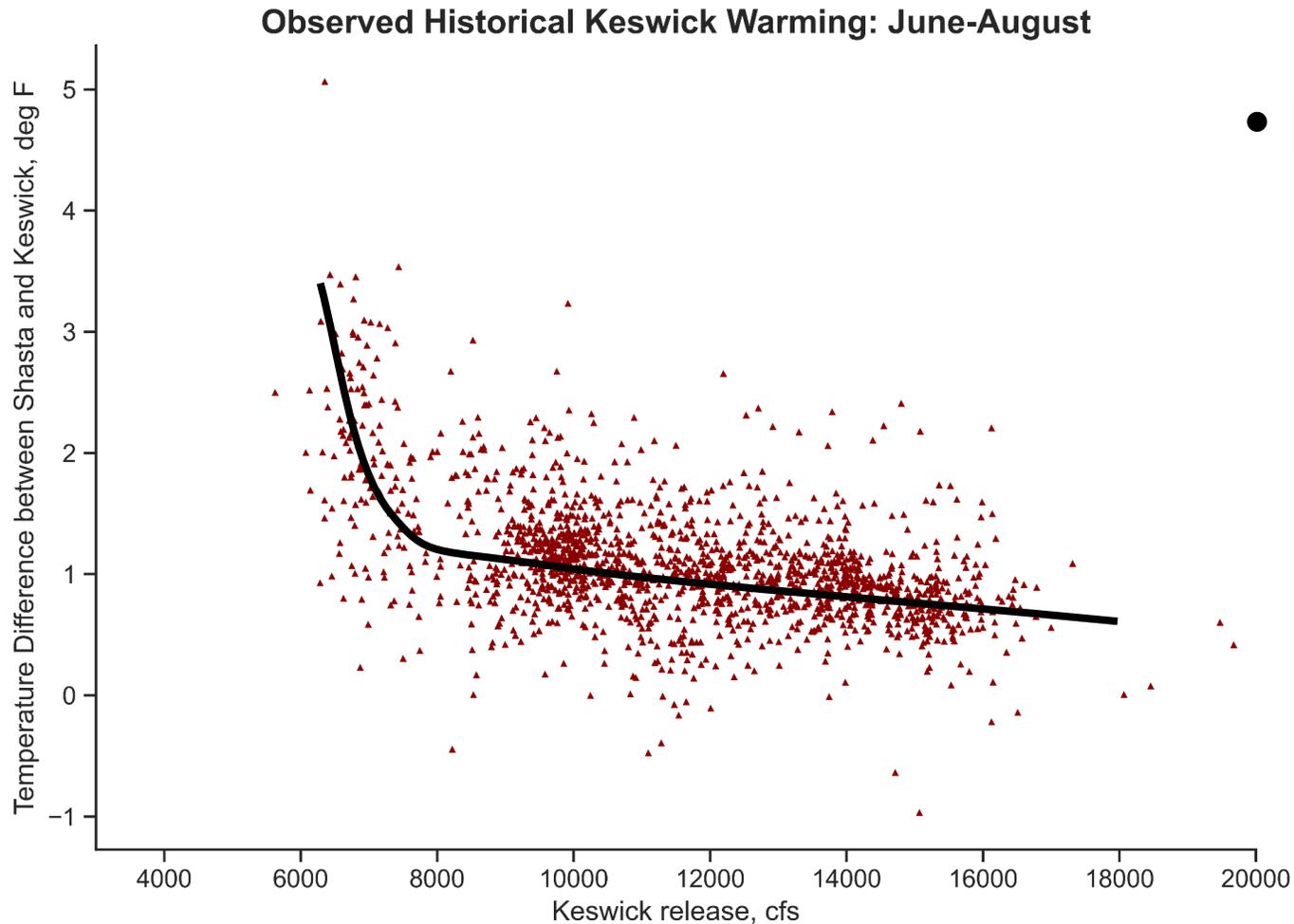


Source: "Water Temperature Management in Reservoir-River Systems through Selective Withdrawal"
<https://www.usbr.gov/mp/bdo/docs/cvp-wtm-selective-withdrawal-2017-09.pdf>

- Release rates and timing
 - Releasing more water may deplete cold water
 - Depends on reservoir thermal stratification, which TCD gates are available
 - Late-spring flood releases may require releasing colder water than intended
 - Intentional power bypass releases can skim warm water if TCD gates aren't available



Operations-Temperature Management Connections

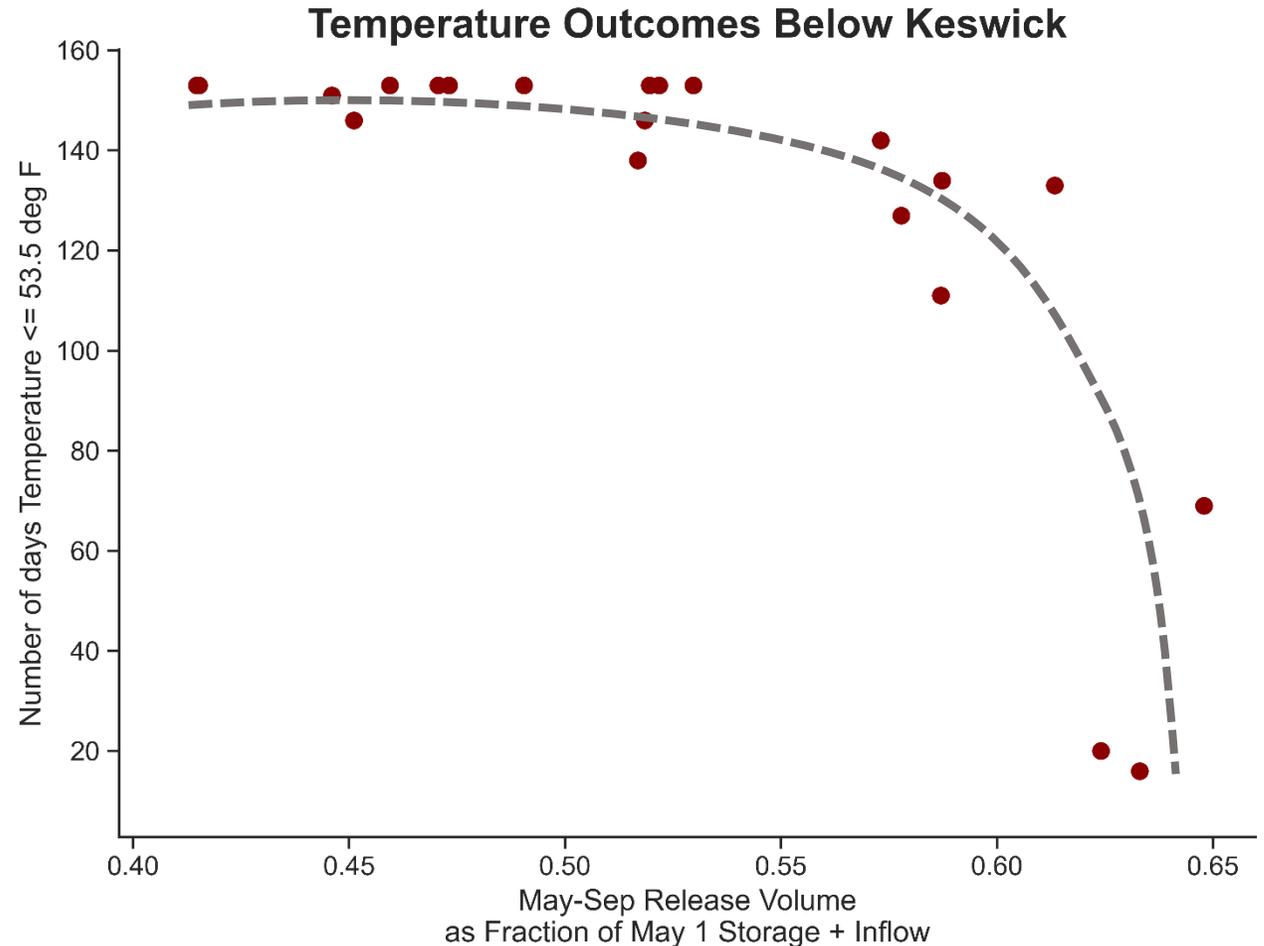


- Release rates and timing
 - Releasing higher flows maintains thermal inertia and reduces travel time after water leaves Shasta
 - Low mid-summer releases are subject to incrementally more downstream warming



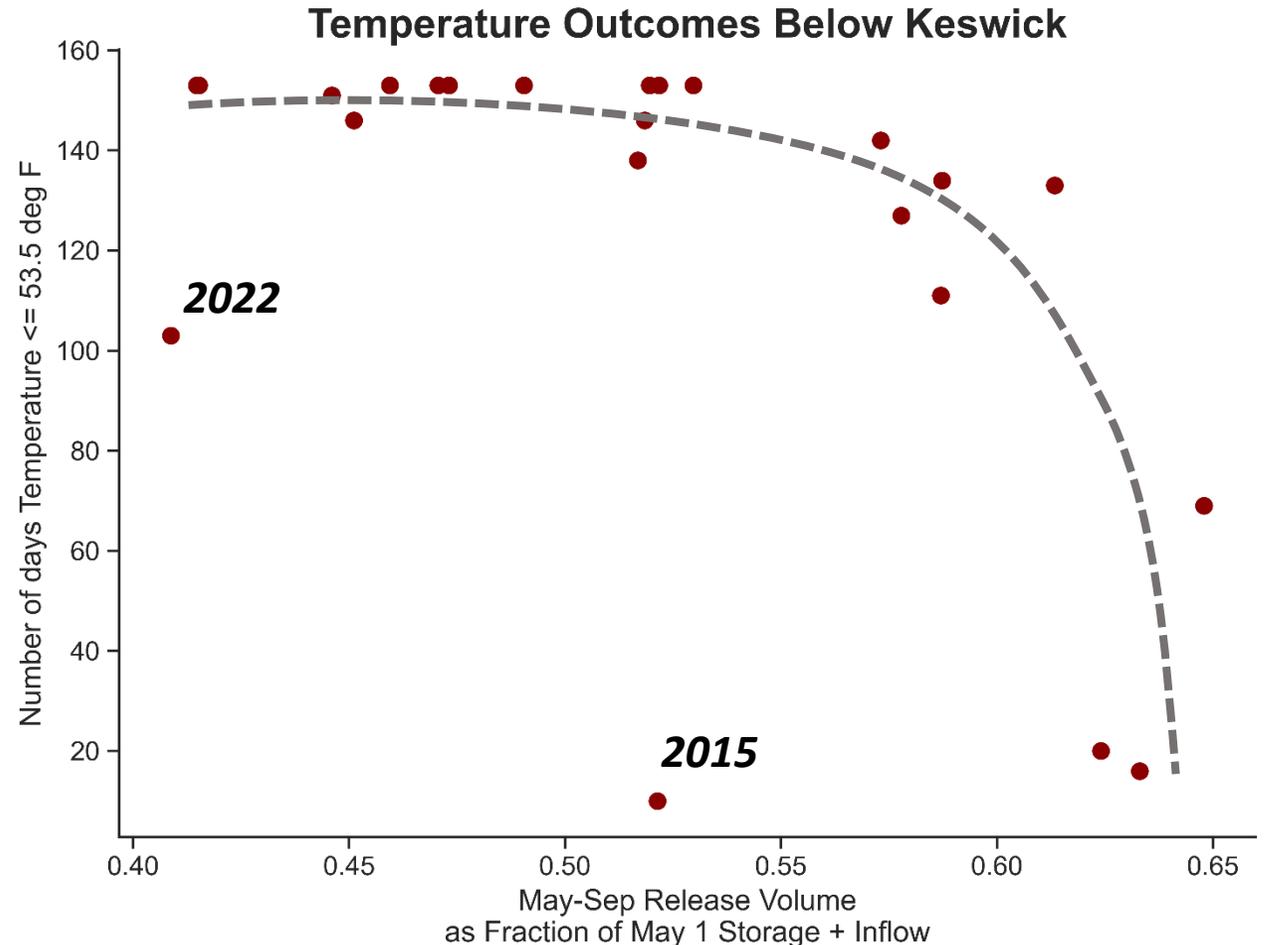
Operations-Temperature Management Connections

- Temperature management outcomes (number of days at or below a target of 53.5°F [12°C]) are generally a function of:
 - Summer release volumes
 - May 1st Shasta storage and summer inflows



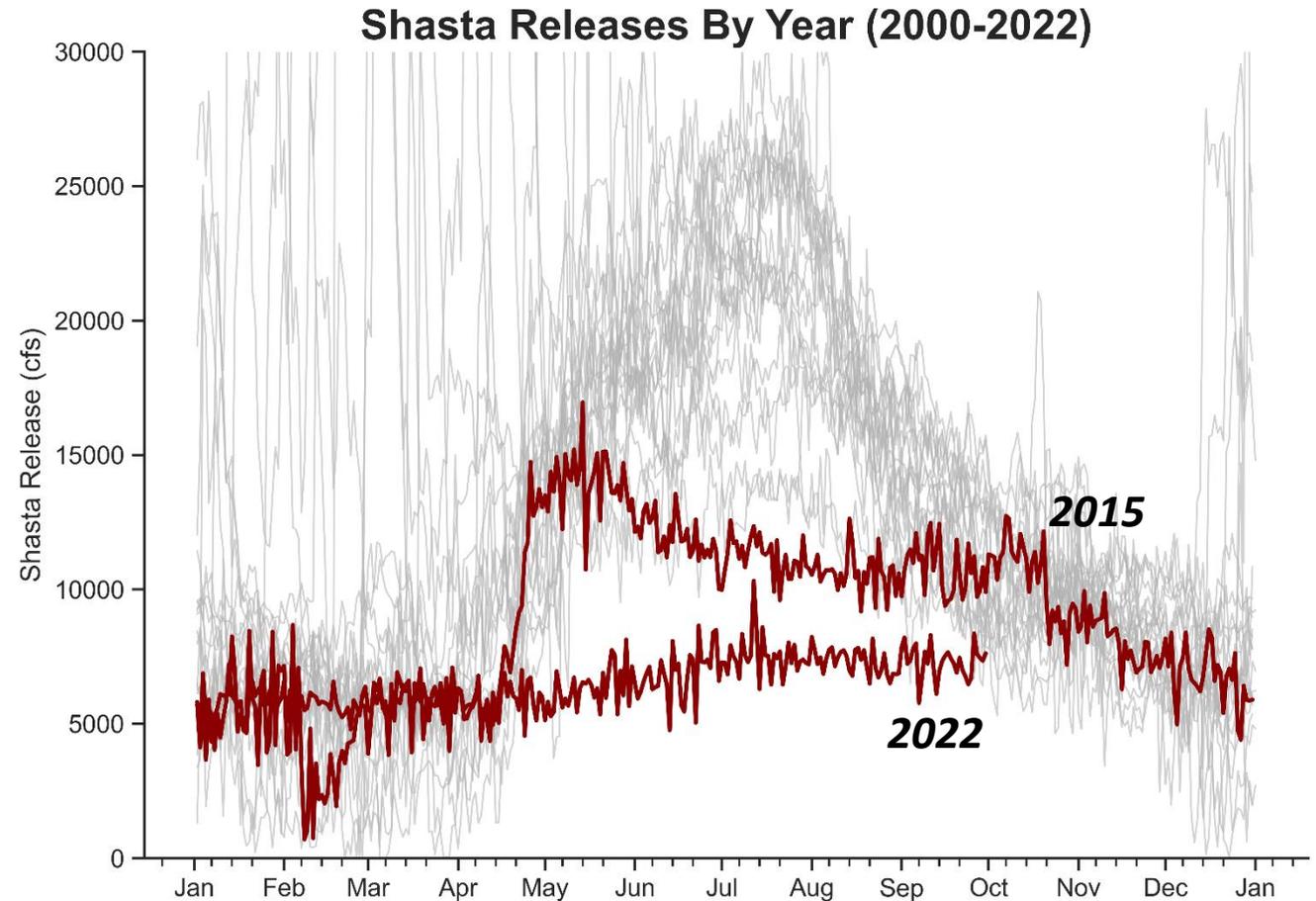
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- *However – the relationship only holds for years with “normal” release patterns*



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- Temperature management outcomes (number of days at or below a target of 53.5°F (12°C)) are generally a function of:
 - Summer release volumes
 - May 1st Shasta storage and summer inflows...
- *However – the relationship only holds for years with “normal” release patterns*
- *Timing and rate of release important for temperature outcomes in dry years*



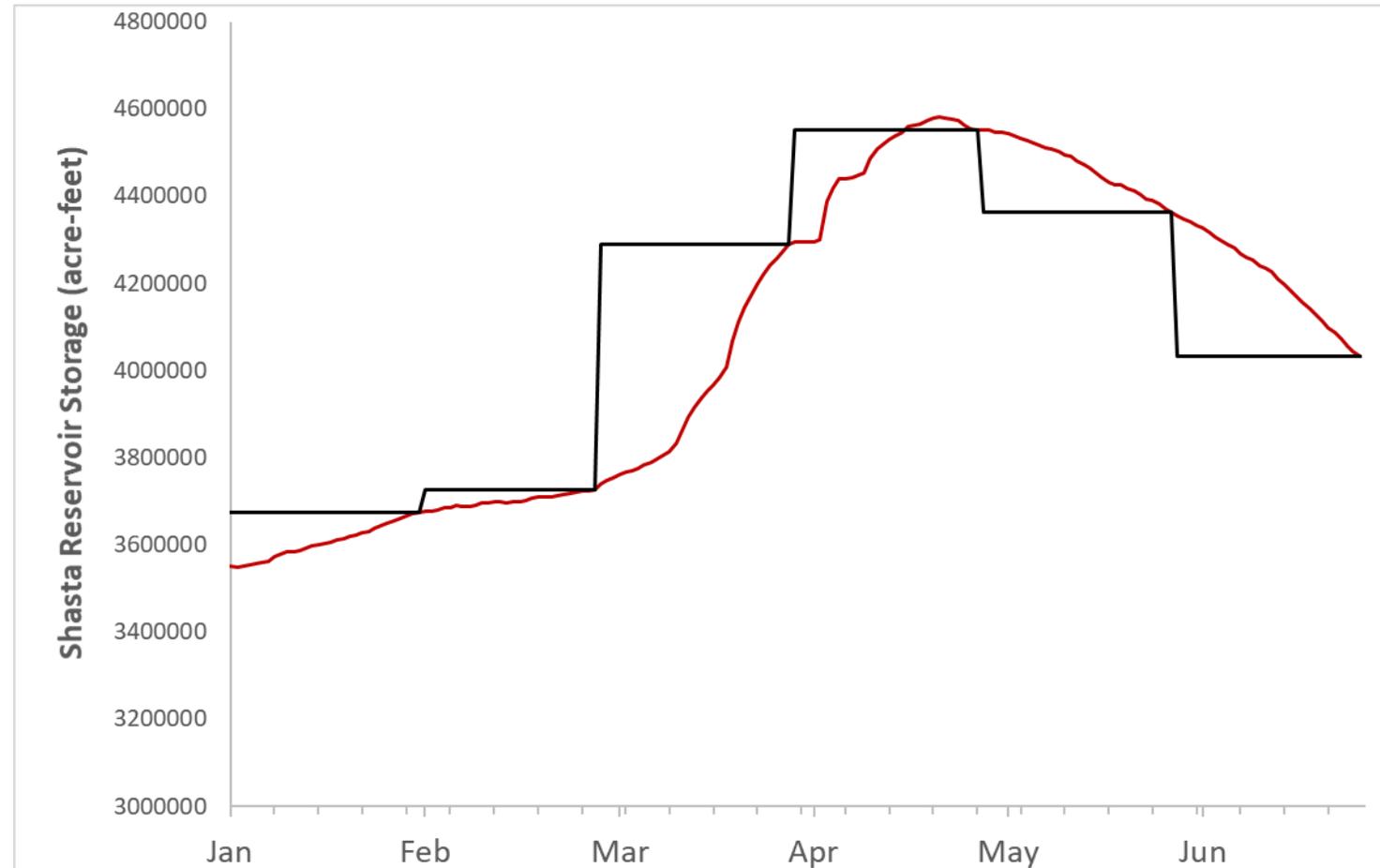
Operations-Temperature Management Connections

- Assumes temperature management is conditional on a set release schedule
- **Introduces assumptions related to temporal disaggregation**
- Introduces potential for meteorological inconsistencies
- Connecting temperature management needs back to system-wide operations adjustments or impacts is cumbersome



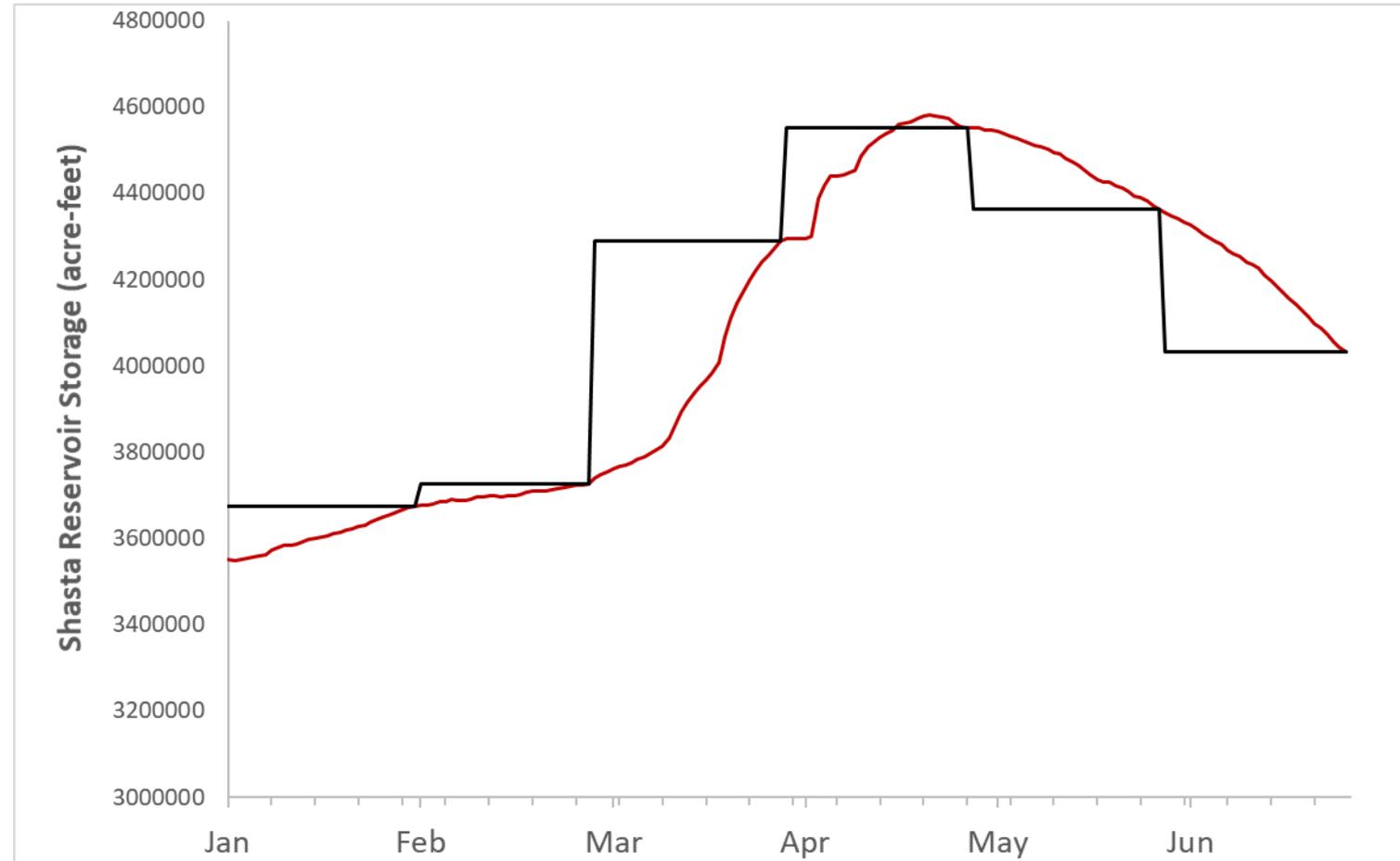
Monthly-to-Daily Disaggregation Challenges

- Translating monthly inflow and releases into daily values for temperature models requires assumptions about disaggregation
- These assumptions can create inconsistencies in the temperature modeling



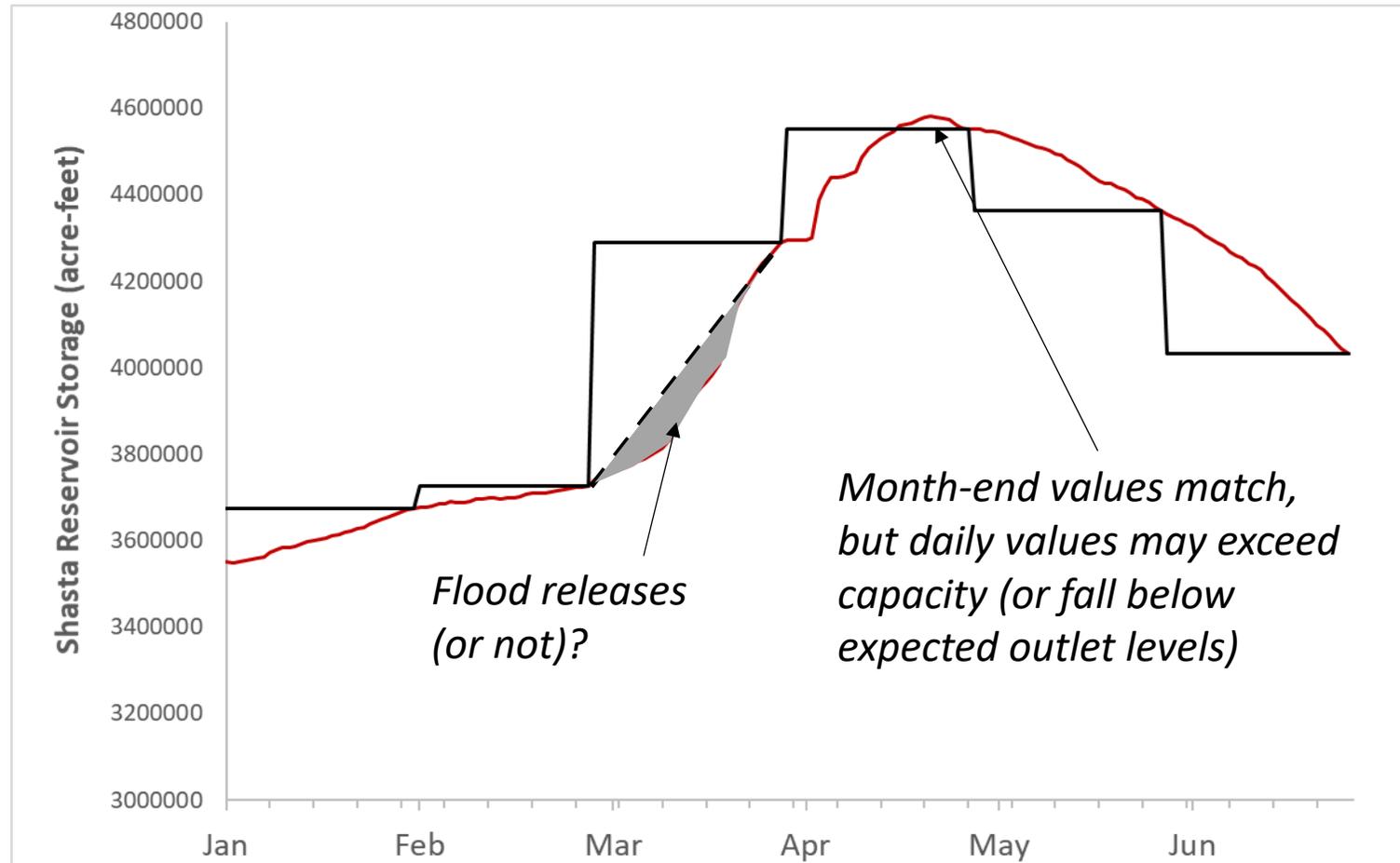
Monthly-to-Daily Disaggregation Challenges

- These assumptions can create inconsistencies in the temperature modeling
- Example at right (**red line**) arises from a commonly used method:
 - Match closest monthly inflow and release volumes in daily record to model value
 - Distribute monthly model value to daily by observed daily fraction



Monthly-to-Daily Disaggregation Challenges

- These assumptions can create inconsistencies in the temperature modeling
- Attempts to reconcile storage, inflow, and outflow require setting rules and constraints → operations model
- Otherwise default to constant daily values that equal monthly average

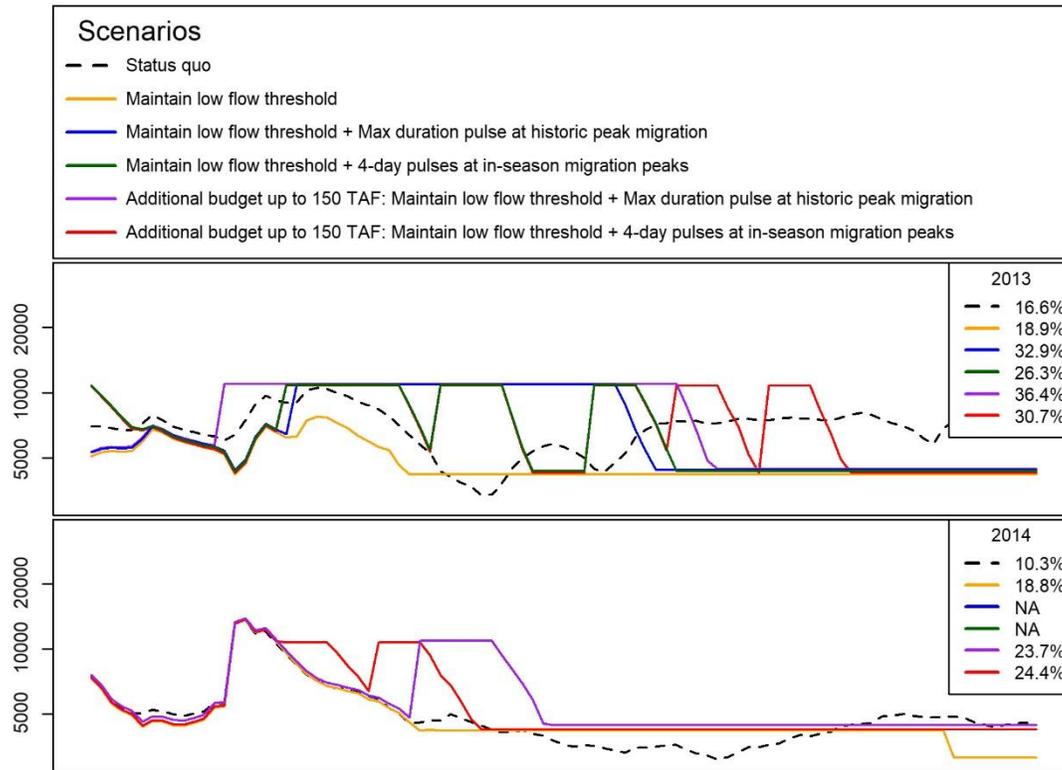


Operations-Temperature Management Connections

- Assumes temperature management is conditional on a set release schedule
- Introduces assumptions related to temporal disaggregation
- Introduces potential for meteorological inconsistencies
- **Connecting temperature management needs back to system-wide operations or impacts (understanding tradeoffs) is cumbersome**



Exploring tradeoffs in operations – Pulse flows for salmon



- Spring and early summer pulse flows improve outmigrating salmon survival
- Pulse releases reduce water available for Sacramento River diversions
- In dry years, pulse flows may have a cold water cost as well
- Interest in understanding tradeoffs for benefitting different salmon runs (and different life stages!) and costs to deliveries or other system demands
- *Current analytical approaches consider each component in a piecemeal fashion*

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Nonlinear survival of imperiled fish informs managed flows in a highly modified river

Cyril J. Michel ✉ Jeremy J. Notch, Flora Cordoleani, Arnold J. Ammann, Eric M. Danner

First published: 19 May 2021 | <https://doi.org/10.1002/ecs2.3498> | Citations: 9



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Water temperatures and operations in a changing climate

- Intuition about how water temperatures and reservoir operations interact is derived from what we've seen in recent past
- Understanding if and how this intuition may fail us in a warmer climate requires models and the ***data*** to support them
 - Tributary region meteorology, water temperature, flow, groundwater
- Questions to consider:
 - Shifts in inflow timing and temperatures – will warmer AR storms lead to a full but less cold reservoir? How will temperature strategies need to change?
 - Dry year timing and intensity – how often would deviations from “standard” release schedule be needed to meet a specific temperature goal?



Value in coupling daily operations and water temperature modeling

- Tight coupling or integration allows dynamic feedbacks
 - May not be as important in wetter years; much more important in dry years where modified release patterns are beneficial for temperature
- A more direct framework for exploring operational strategies and alternatives
- Allows more consistent evaluation of Shasta reservoir operational objectives
 - Water supply, flood control, temperature & fisheries management, power generation
- When operations model is system-wide, can also evaluate tradeoffs with other system objectives



If you want to...

- Explore temperature management strategies on the Sacramento River...
- ...while considering different reservoir release amounts or timing...
- ...and evaluating those impacts across the Central Valley system...
- ...in a single modeling framework that operates on consistent time steps...
- ...and integrates power generation and fisheries conditions
- What are your options? **CALFEWS + Temperature + Fish!**



Summary

- Shasta Reservoir is managed for many objectives
- Temperature management at Shasta is closely tied to operations, especially in recent dry years. Climate change may intensify this.
- Our current modeling does not always reflect the multi-objective reality – it is difficult to explore and understand what alternatives exist
- A path forward – coupling a system-wide daily operations model like CALFEWS with temperature models would be a useful complement to existing modeling analysis



Questions?

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