Forecasting for Environmental Flows –
What does an accurate and timely runoff forecast buy you?

Chad Moore and Emily Thomas
California Cooperative Snow Conference
November 15, 2018
RESTORATION FLOW SCHEDULING
San Joaquin River Restoration Program
Flow Releases

San Joaquin River, Restoration Releases from Friant Dam,
as Reported by Exhibit B of the Stipulation of Settlement

San Joaquin River, Restoration Releases from Friant Dam,
as Reported by Exhibit B of the Stipulation of Settlement

1. NRDC v Rodgers, Stipulation of Settlement, CIV NO. S.88-1658 - LKK/GGH, Exhibit B. September 13, 2006
2. Hydrographs reflect assumptions about seepage losses and tributary inflows which are specified in the settlement

Total Volume
Flow Timing

[Graph showing flow timing with bars for different months, indicating agricultural demand and restoration flows.]

- Agriculture Demand
- Restoration Flows
Forecast Uncertainty

Millerton Unimpaired Runoff
7/23/2018

- NWS - 10%
- NWS - 50%
- NWS - 75%
- NWS - 90%

NWS 10% Smoothed
NWS 50% Smoothed
NWS 75% Smoothed
NWS 90% Smoothed

DWR - 10%
DWR - 50%
DWR - 75%
DWR - 90%

Observed Unimpaired Runoff (Natural River)
Runoff Forecast Verification

Forecast error for both models sometimes on the order of Millerton Lake active storage capacity ~395 TAF
What tools can narrow the forecast spread, especially between 90% and 50%?
Summary

- Majority of release volume for environmental flows is before most of the WY runoff reaches Millerton Lake
- Need to make decisions on biological objectives by April 1

Accurate April 1 forecasts are key to prevent over or under releases of Restoration Flows
## Temperature Objectives

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adult Migration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal: ≤59°F (15°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical: 62.6 – 68°F (17 – 20°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lethal: &gt;68°F (20°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adult Holding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Spring-Run Only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal: ≤55°F (13°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical: 62.6 – 68°F (17 – 20°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lethal: &gt;68°F (20°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spawning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Incubation and Emergence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>In-River Fry/Juvenile</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal: ≤60°F (15.6°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical: 64.4 – 70°F (18-21.1°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lethal: &gt;75°F (23.9°C), prolonged exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Floodplain Rearing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal: 55 – 68°F (13 – 20°C), unlimited food supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Outmigration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal: ≤60°F (15.6°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical: 64.4 – 70°F (18 – 21.1°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lethal: &gt;75°F (23.9°C), prolonged exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Millerton Reservoir

Capacity ~ 520,500 AF
Right Temperature, Right Time

• Critical Elements:
  – A spring pulse to move juveniles downstream
  – Enough cold water for adults to over summer, and maintain temperatures for egg incubation

• Filling of the cold water pool
  – Timing of inflow indicates final temperature of cold water pool
  – High inflow years with flood releases “flush” the cold water pool
Flood years

Temperature (Average Degrees per Day, Fahrenheit)

Month and Days, Annual

2010 (Normal-Wet)
2011 (Wet)
2012 (Dry)
2013 (Dry)
2017 (Wet)
2018 (Normal-Dry)

Juvenile Rearing: Lethal (≤ 75°F)*

Holding: Lethal (> 68°F)*

Holding: Optimal (≤ 55°F)*

Juvenile Rearing & Adult Holding: Critical (62.6°F - 68°F)*

2011, 2017 - Spillway Releases during Wet water year types (i.e. 2011, 2017).

* Adult Holding Temperature Objectives, Spring-Run Only (FMP, 2010).
Summary

• Understanding the timing of snowmelt allows prioritization of objectives

• Limited control of temperature in wet years, but better forecasts allow you to:
  – Take reservoir management actions early
  – Prevent unnecessary flood releases from river outlet
  – Manage overtopping
FLOOD FLOW RAMP-DOWN
Flood Flow Ramp-Down

- Flood flows are managed for the protection of life and property, environmental objectives may also be achieved.
- Natural hydrograph recession ~ 5% flow reduction per day.
- How reservoirs “ramp-down” is important ecologically.
Flood Flow Ramp-Down

Inundated Floodplain

Riparian vegetation provides shade, cover, and food for fish

Floodplains are where juvenile salmon grow best

Daniel Nylen, American Rivers
How do we manage flows for our limited floodplains?

1) Reduce Fish Stranding
   - Gradual ramp-down prevents juvenile salmon from getting stuck on a drying floodplain
   - Maximum stage reduction rate depends on floodplain topography

2) Recruit Riparian Vegetation
   - Gradual ramp-down provides suitable surface for germination and rooting of vegetation
   - $\sim 2.5 \text{ cm/day}$ reduction in river stage
Riparian Vegetation Recruitment

Idealized ramp-down

Graph showing the daily average Friant Dam release over time. The graph includes:
- Potential 2-day Friant Release Valve Adjustments for XS 546083 recession
- Potential 3-day Friant Release Valve Adjustments for XS 546083 recession
- Computed Friant Release for XS 546083 Target Surface

Dates and release values are indicated on the graph:
- 27-May: 4000 cfs
- 3-Jun: 3500 cfs
- 10-Jun: 3000 cfs
- 17-Jun: 2500 cfs
- 24-Jun: 2000 cfs
- 1-Jul: 1500 cfs
- 8-Jul: 1000 cfs
- 15-Jul: 500 cfs
Riparian Vegetation Recruitment

2011 Flood Flows Below Millerton

Reservoir Filled

Computed Friant Release for XS 557391 Target Surface
USGS flow data at Friant Gage (WY 2011)
Can these ramp-downs be implemented with little to no impact other water users?

Yes, if:

• Runoff forecast is accurate (volume and timing) as reservoir reaches capacity
• Ramp-down begins BEFORE reservoir has filled
2017 Reservoir Storage Re-analysis

- Millerton Storage
  - Actual
  - Reservoir Filled
  - Ramp Downs with ASO Data Integration

Legend:
- Actual Mill Storage
- Retrospect 0
- Retrospect 1
- Retrospect 2
2017 San Joaquin River Flows Re-analysis

Combined River Releases

Actual

Ramp Downs with ASO Data Integration
Flood Flow Ramp-Downs

Summary

• With a high level of forecast accuracy, gradual ramp-downs for riparian vegetation recruitment can be executed with little impact to residual water supply
• With a moderate level of forecast accuracy, ramp-downs to prevent juvenile salmon stranding can likewise be executed

Short-term runoff forecasts near time of reservoir filling are critical to floodplain management
GROUNDWATER MANAGEMENT
Sustainable Groundwater

- Precipitation variability encourages groundwater use during drought

- Sustainability achieved through groundwater recharge in wet years – aquifer as a reservoir – or “conjunctive use”

Dettinger et. al 2011
SGMA - Sustainable Groundwater Management Act (CA-2014)

- Approved Sustainability Plans for critical basins due in 2020
- Groundwater balance must be demonstrated by 2040
Groundwater Recharge

- Recharge basins are being constructed where soils are favorable in the San Joaquin Valley
- Recharge volume limited by conveyance capacity, recharge rate, and price per acre-foot
Summary:
It is critical to have early confirmation of how much water is unstoreable

- Lower price
- Utilize canal capacity when it is not being used for irrigation
<table>
<thead>
<tr>
<th>Environmental Flow Factor</th>
<th>Important Water Years</th>
<th>Important Timing</th>
<th>Ideal Runoff Forecast Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Restoration Flow Scheduling</td>
<td>Critical through Normal-Wet</td>
<td>Mar</td>
<td>+/- 50 TAF WY in Critical and Dry conditions, otherwise +/- 100 TAF WY (90% exceedance)</td>
</tr>
<tr>
<td>2) Water Temperature Management</td>
<td>Normal-Dry through Wet</td>
<td>Mar – May</td>
<td>Monthly runoff +/- 100 TAF</td>
</tr>
<tr>
<td>3) Flood Flow Ramp-Down</td>
<td>Normal-Wet, Wet</td>
<td>May – Jul</td>
<td>Monthly runoff +/- 50 TAF</td>
</tr>
<tr>
<td>4) Groundwater Management</td>
<td>Normal-Wet, Wet</td>
<td>Jan – Mar</td>
<td>Certainty that runoff will exceed reservoir storage</td>
</tr>
</tbody>
</table>
Conclusion

What does better runoff forecast accuracy and timing buy you?

1. More effective **conjunctive use** of water
2. **Less anxiety** among stakeholders
3. More **successful river restoration**
4. **Less impact to water users from environmental flows**
5. **Adaptation** to a changing climate