

US EPA ARCHIVE DOCUMENT



# Climate change predictions and management options from coupled watershed and salmon population dynamics models

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David Yates, Peter Moyle



EPA Grant Number: R833017

# Big picture points

- Long-term survival of salmon in our study area is questionable
- Water management adaptations may extend survival
- Analytical framework we developed here may be useful elsewhere



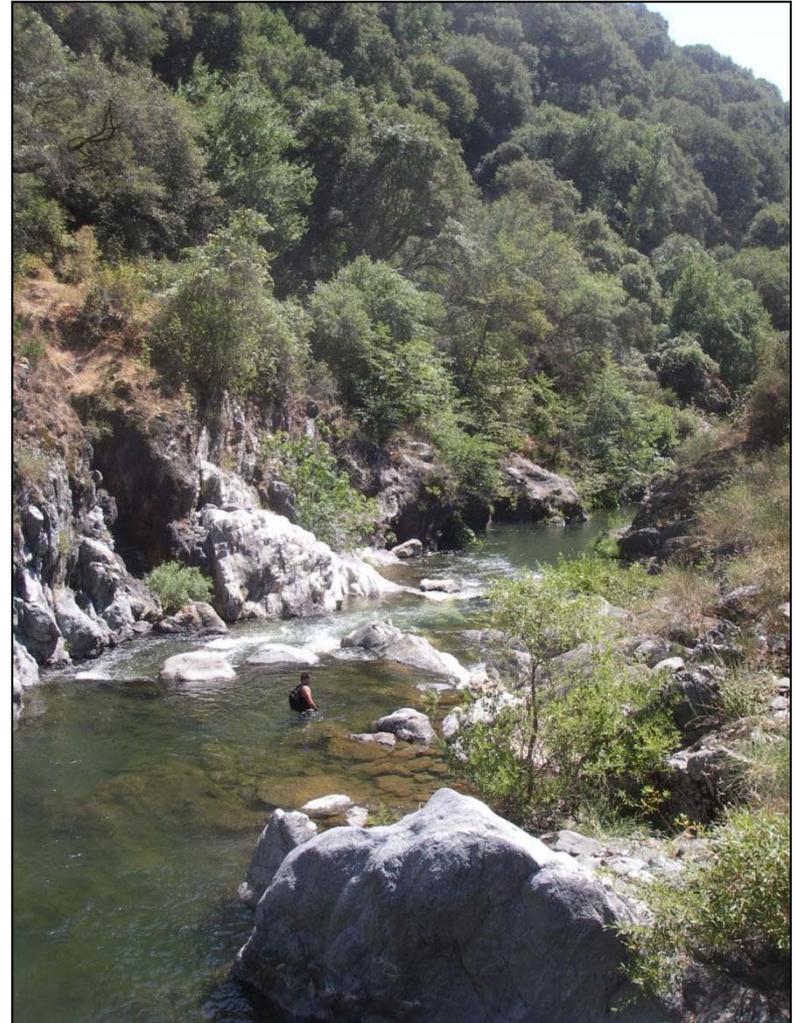
Photo by Allen Harthorn, Friends of Butte Creek

# Project Goals

- How might climate change impact water temperature and flow?
- How might these changes impact spring-run Chinook salmon?
- Can we counter-act climate impacts through water management?
- Thompson, L.C., Escobar, M.I., Mosser, C.M., Purkey, D.R., Yates, D., Moyle, P.B. 2011. **Water management adaptations to prevent loss of spring-run Chinook salmon in California under climate change.** J. Water Resour. Plann. Manage., 10.1061/(ASCE)WR.1943-5452.0000194 (Aug. 31, 2011).

# Outline

- Butte Creek watershed
- Modeling approach
  - WEAP model
    - Hydrology
    - Water temperature
  - SALMOD model
    - Population dynamics
- Climate scenarios
- Management options

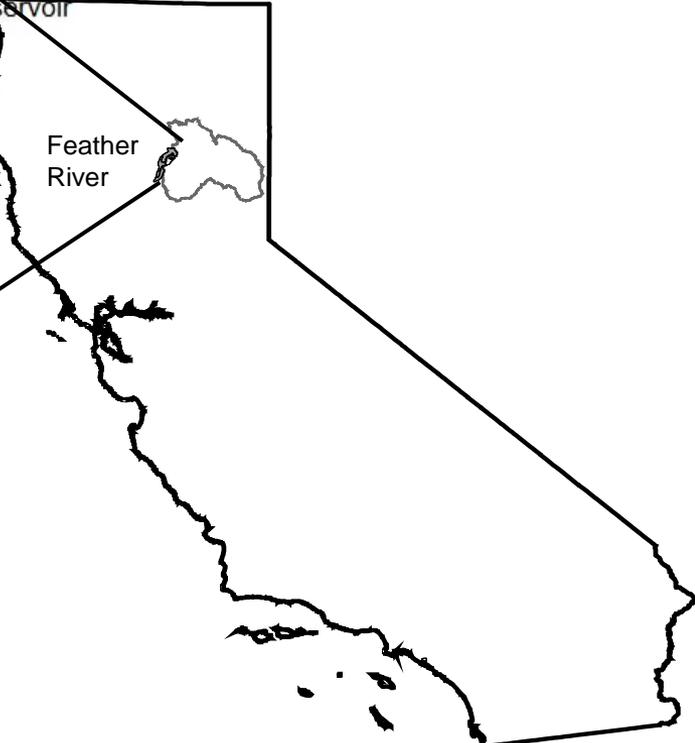
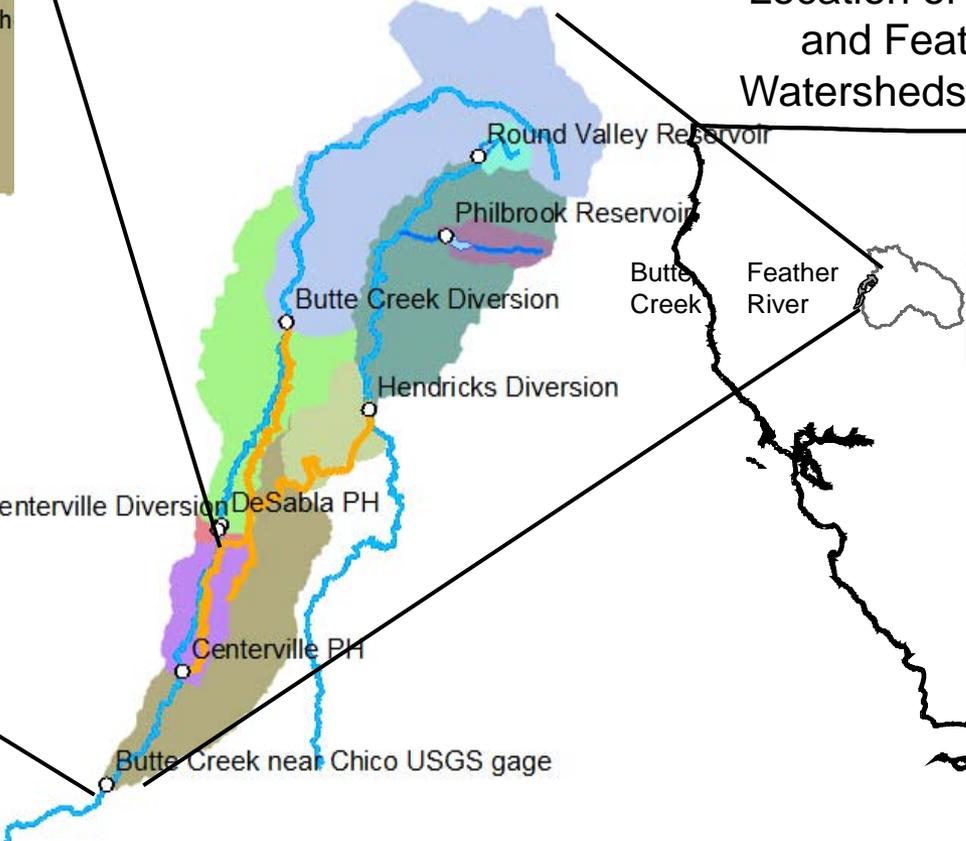
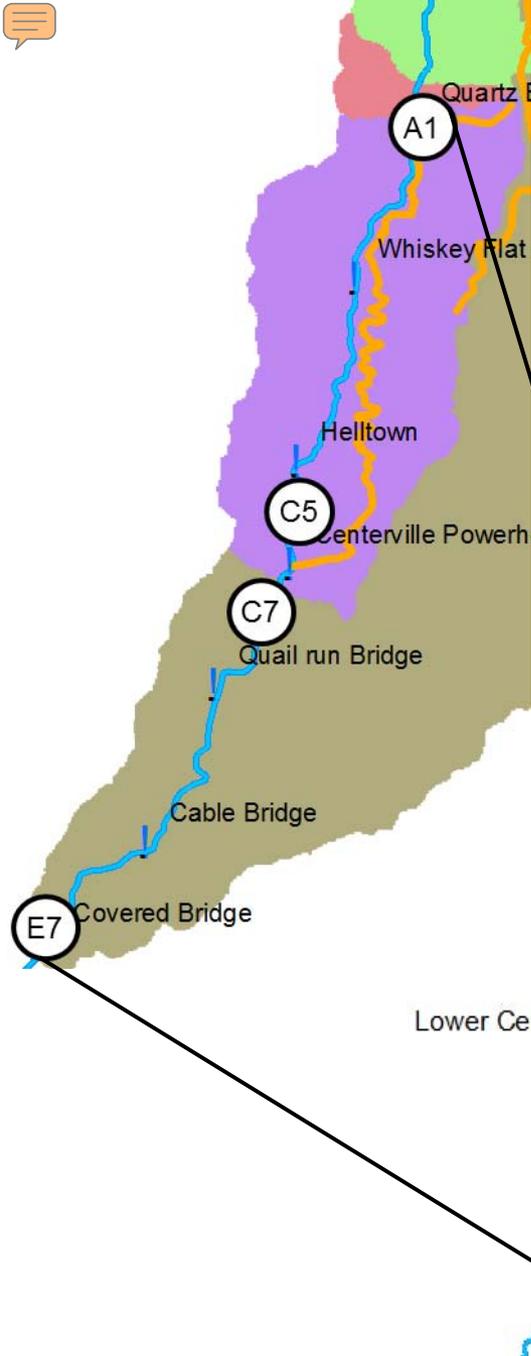


# Butte Creek Watershed

Reaches and Subreaches for Temperature Module

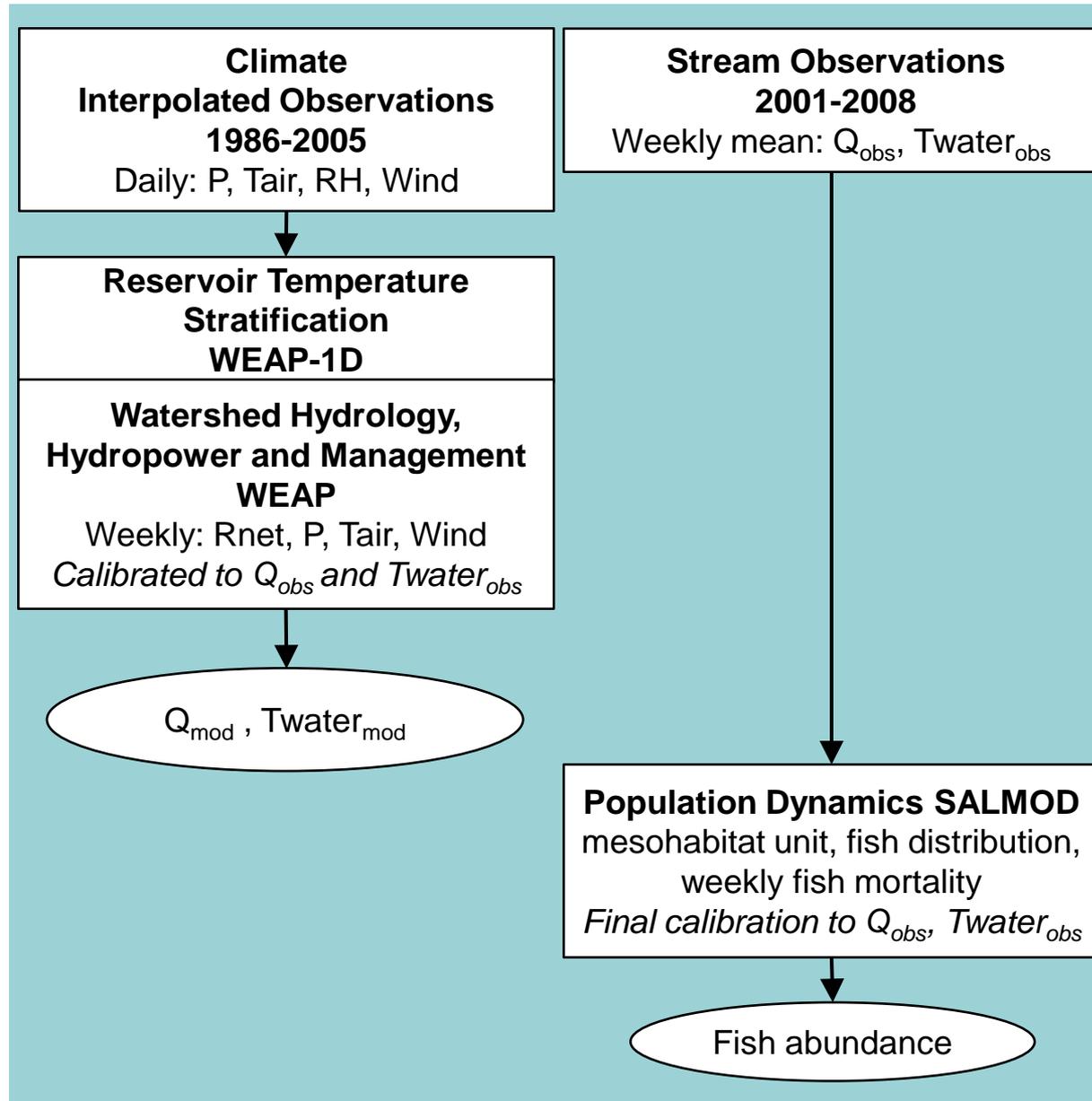
Subwatersheds for Rainfall Runoff Module

Location of Butte Creek and Feather River Watersheds in California



# Analytical Framework

## Calibration



### Definitions:

P = precipitation

Tair = air temperature

RH = relative humidity

Rnet = net radiation

$Q_{obs}$  = observed flow

$Twater_{obs}$  = observed water temperature

$Q_{mod}$  = modeled flow

$Twater_{mod}$  = modeled water flow

# Analytical Framework

## Calibration

## Projections

**Climate**  
**Interpolated Observations**  
**1986-2005**  
Daily: P, Tair, RH, Wind

**Stream Observations**  
**2001-2008**  
Weekly mean:  $Q_{obs}$ ,  $T_{water_{obs}}$

**Climate**  
**Downscaled Projections**  
**2009-2099**  
Daily: P, Tair, RH, Wind

**Reservoir Temperature**  
**Stratification**  
**WEAP-1D**

**Reservoir Temperature**  
**Stratification**  
**WEAP-1D**

**Watershed Hydrology,**  
**Hydropower and Management**  
**WEAP**  
Weekly: Rnet, P, Tair, Wind  
*Calibrated to  $Q_{obs}$  and  $T_{water_{obs}}$*

**Watershed Hydrology,**  
**Hydropower and Management**  
**WEAP**  
Weekly: Rnet, P, Tair, Wind

$Q_{mod}$ ,  $T_{water_{mod}}$

$Q_{mod}$ ,  $T_{water_{mod}}$

**Population Dynamics SALMOD**  
mesohabitat unit, fish distribution,  
weekly fish mortality  
*Final calibration to  $Q_{obs}$ ,  $T_{water_{obs}}$*

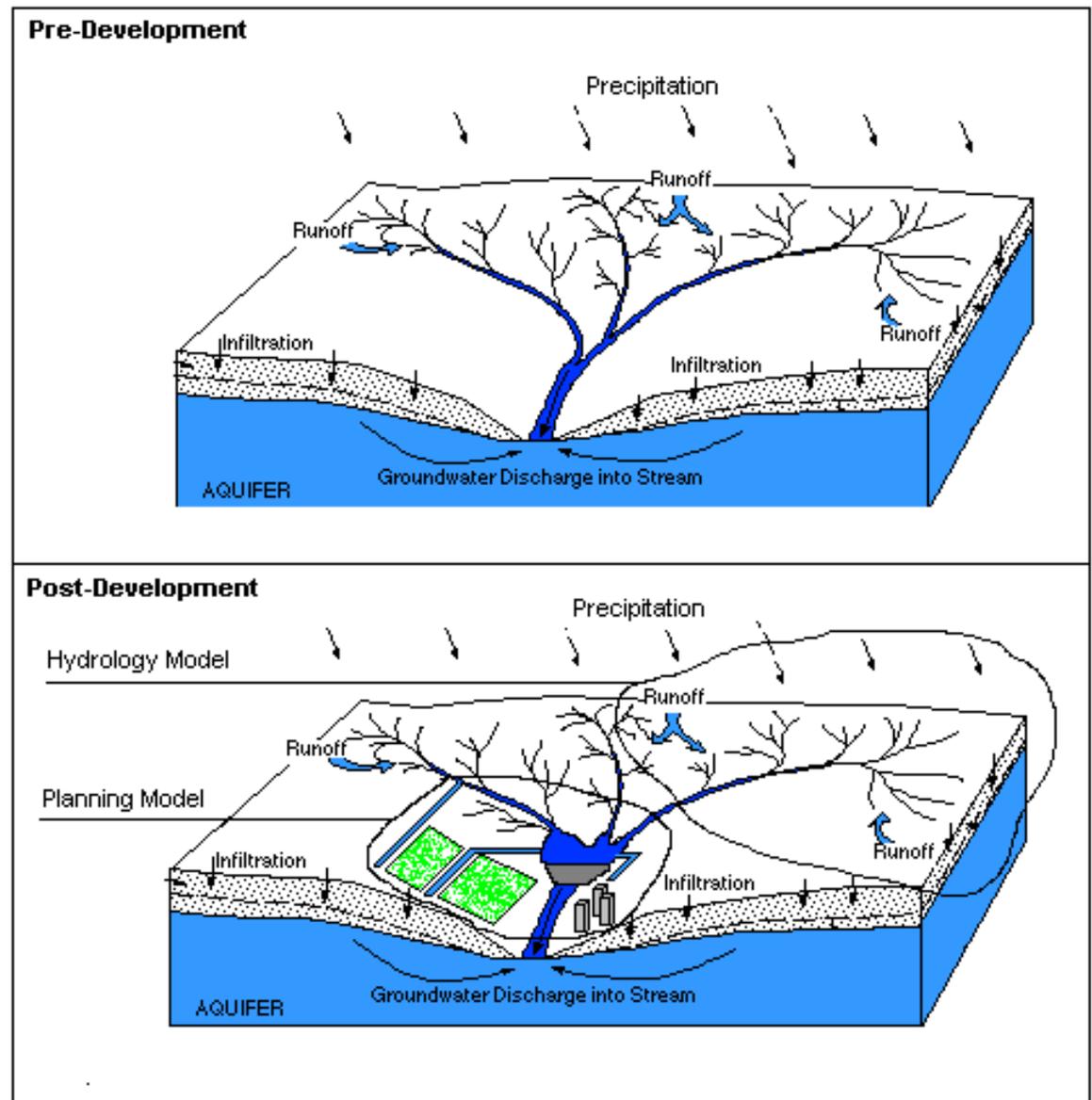
**Population Dynamics SALMOD**  
mesohabitat unit, fish distribution

Fish abundance

Fish abundance

# WEAP: Hydrologic and water management model

- Developed by Stockholm Environment Institute
- Integrates watershed hydrologic processes with the water resources management system
  - Climatic information direct input
  - Based on a holistic vision of integrated water resources management – supply and demand

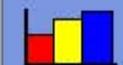




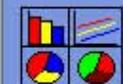
Schematic



Data



Results



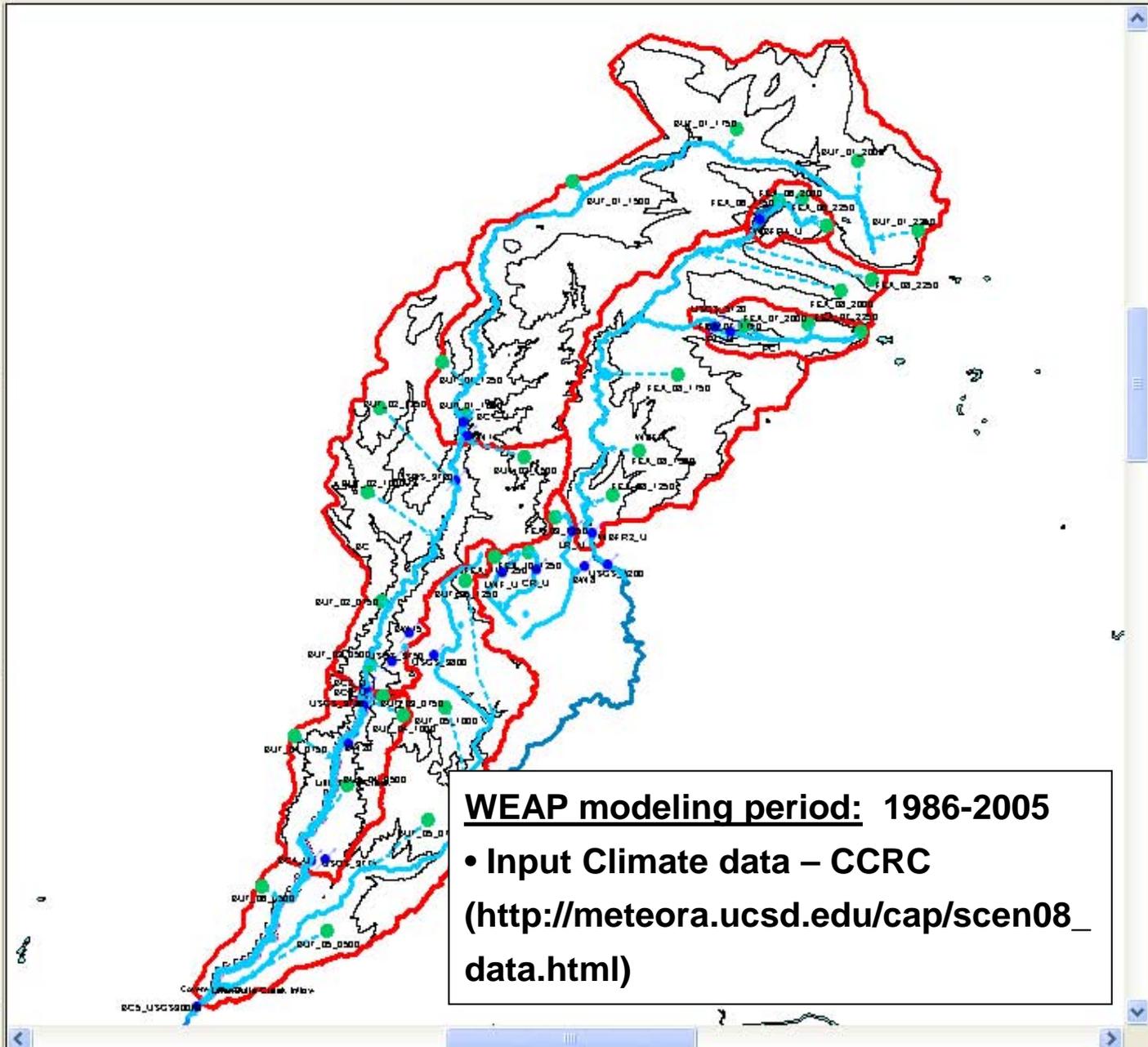
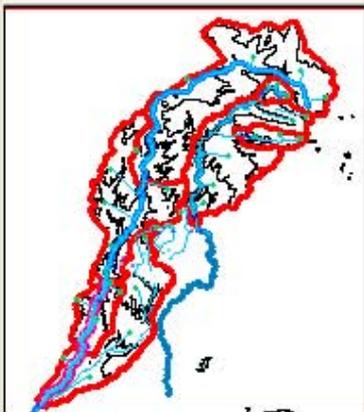
Scenario Explorer



Notes

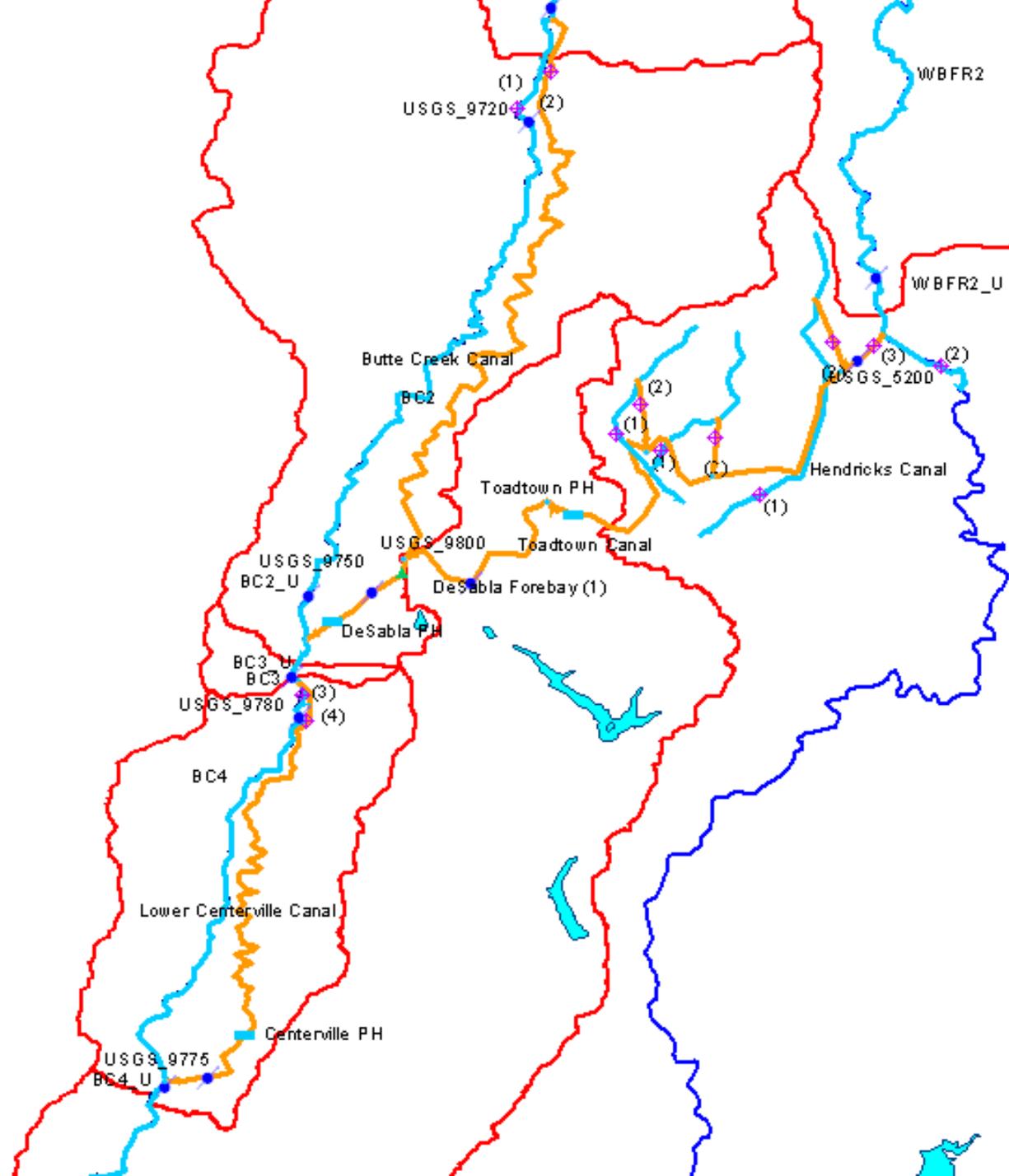
- River (7)
- Diversion (7)
- Reservoir (2)
- Groundwater
- Other Supply
- Demand Site
- Catchment (34)
- Runoff/Infiltration (34)
- Transmission Link
- Wastewater Treatment Plant
- Return Flow
- Run of River Hydro (3)
- Flow Requirement (15)
- Streamflow Gauge (22)

- Reaches\_clean\_project
- BUT\_CREEK\_Project
- BUT\_streams\_Project
- BUT\_watershed\_Project
- BUT\_watersheds&catchments\_P
- FEA\_WB\_Project
- hydrpolabutte\_Project



# Operations

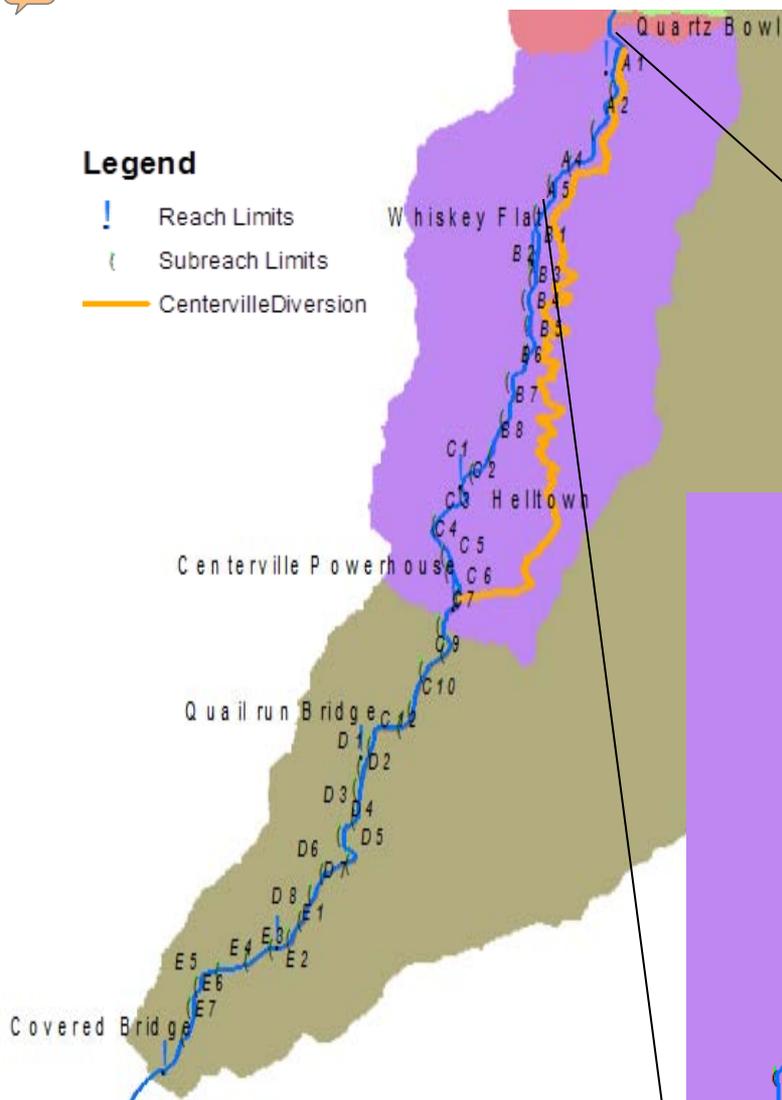
- Infrastructure
  - Diversions
  - Reservoirs
  - Powerhouses
- Operations
  - Flow Requirements
  - Operation Rules
  - Priorities



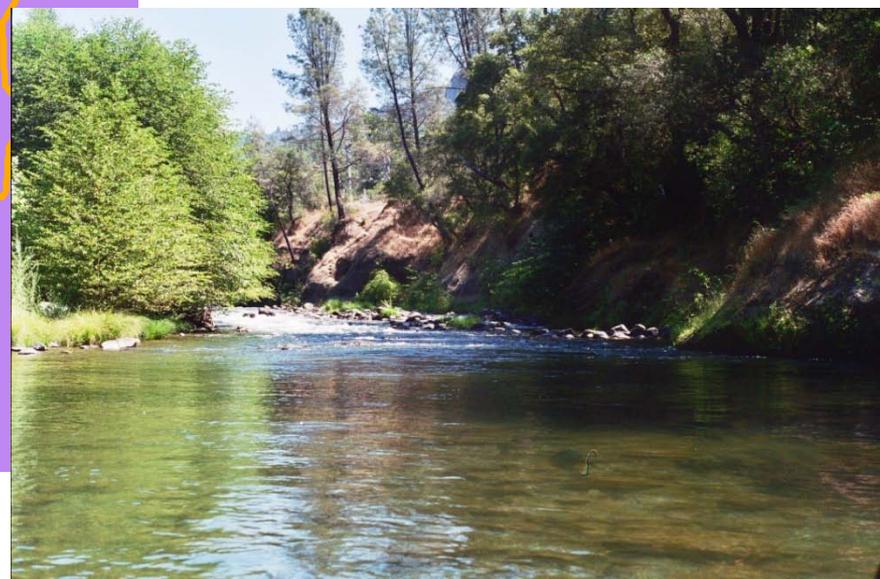


### Legend

-  Reach Limits
-  Subreach Limits
-  Centerville Diversion

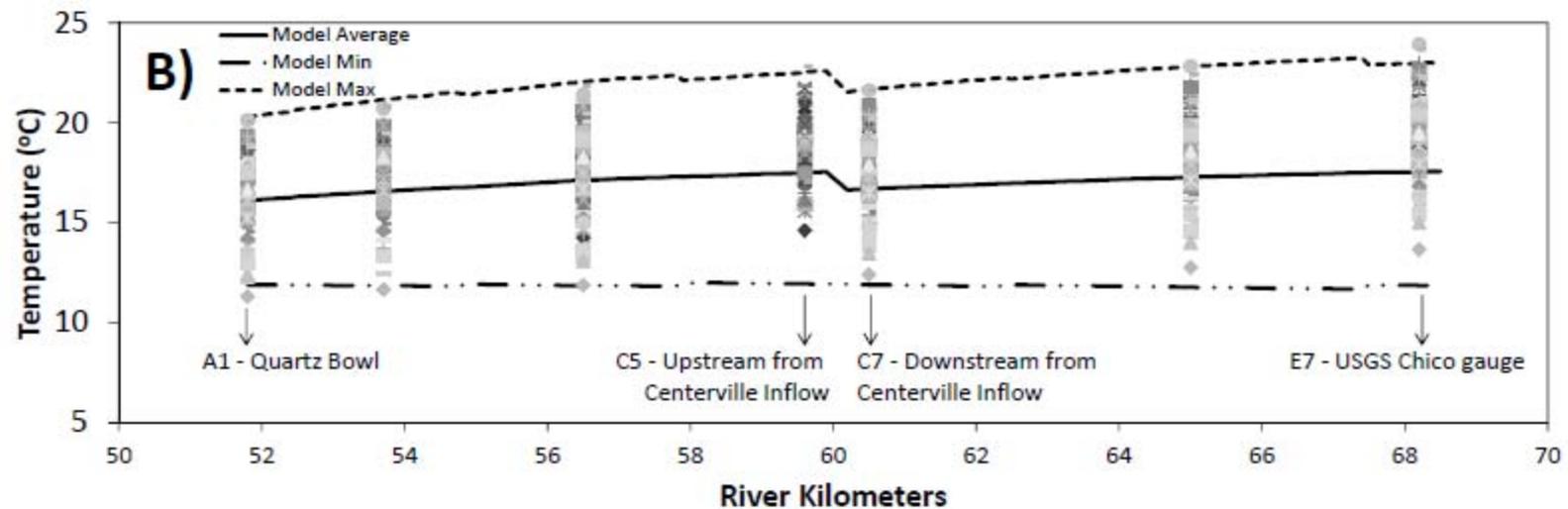
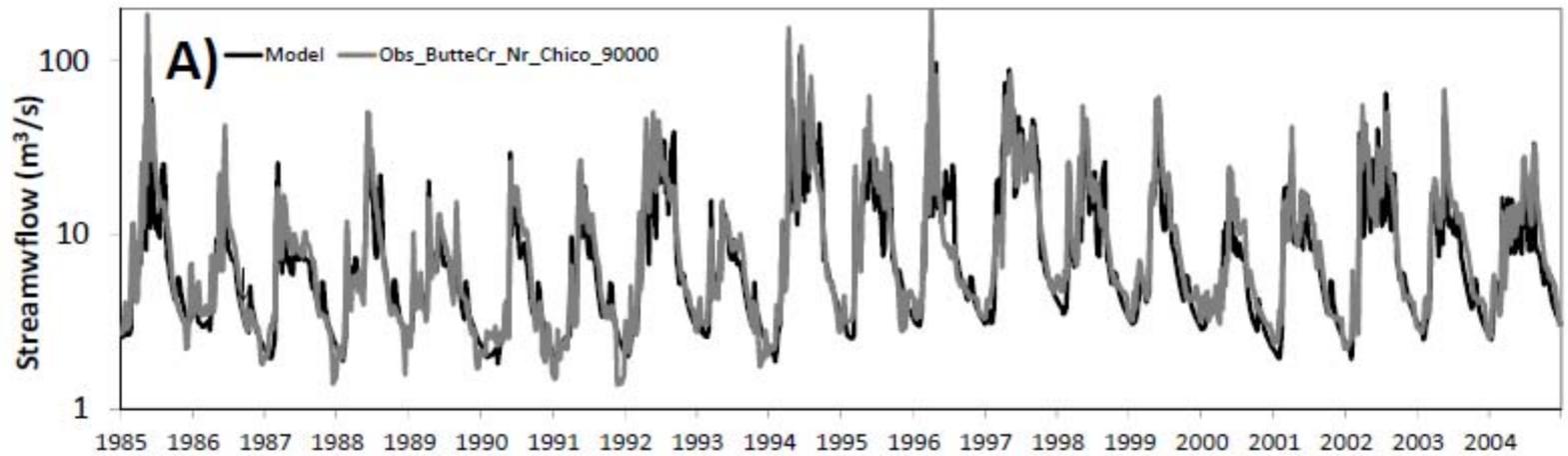


Pool  
Riffle  
Run



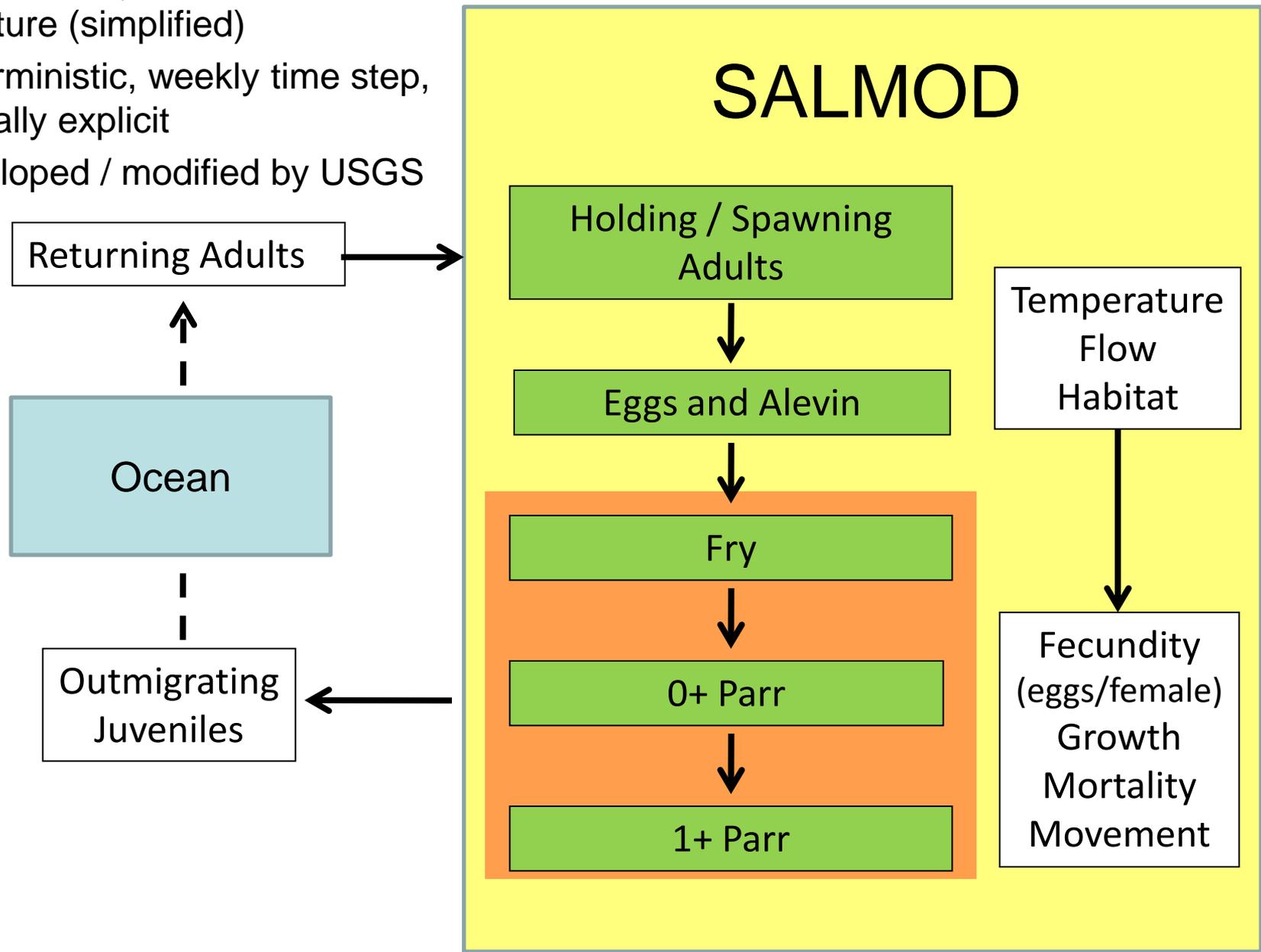
# Temperature Model Domain

# WEAP Streamflow and Temperature Calibrations

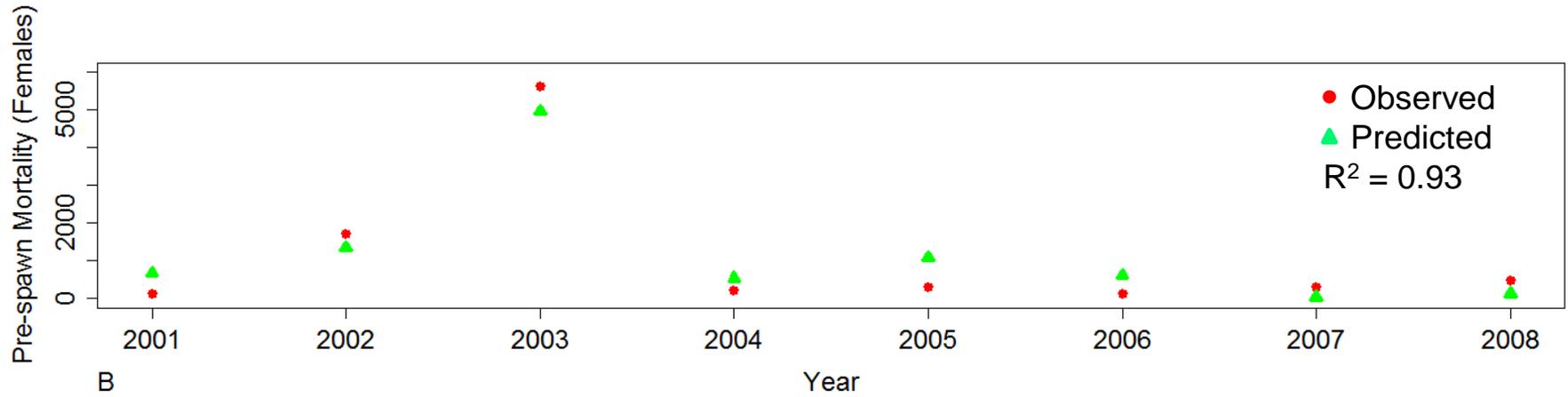
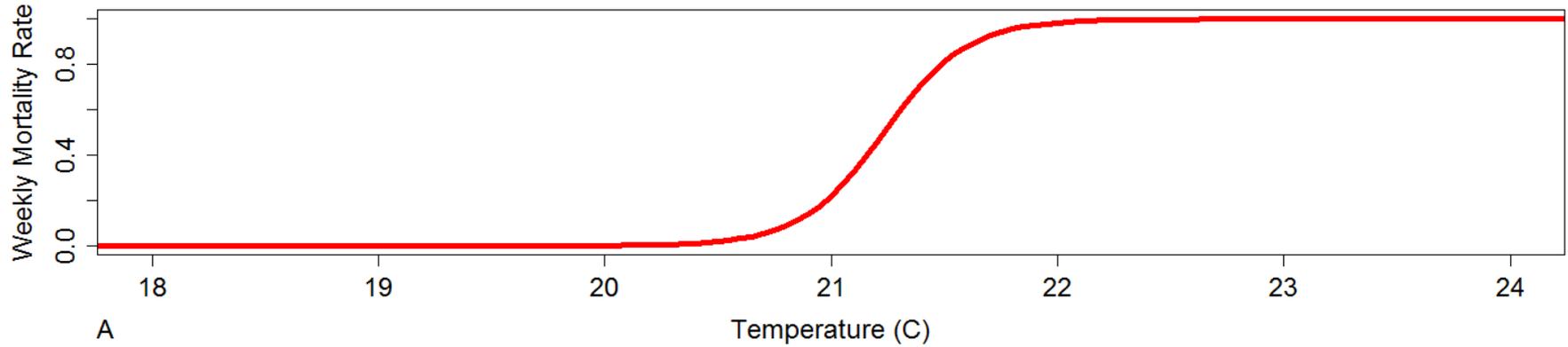




- Population dynamics model structure (simplified)
- Deterministic, weekly time step, spatially explicit
- Developed / modified by USGS

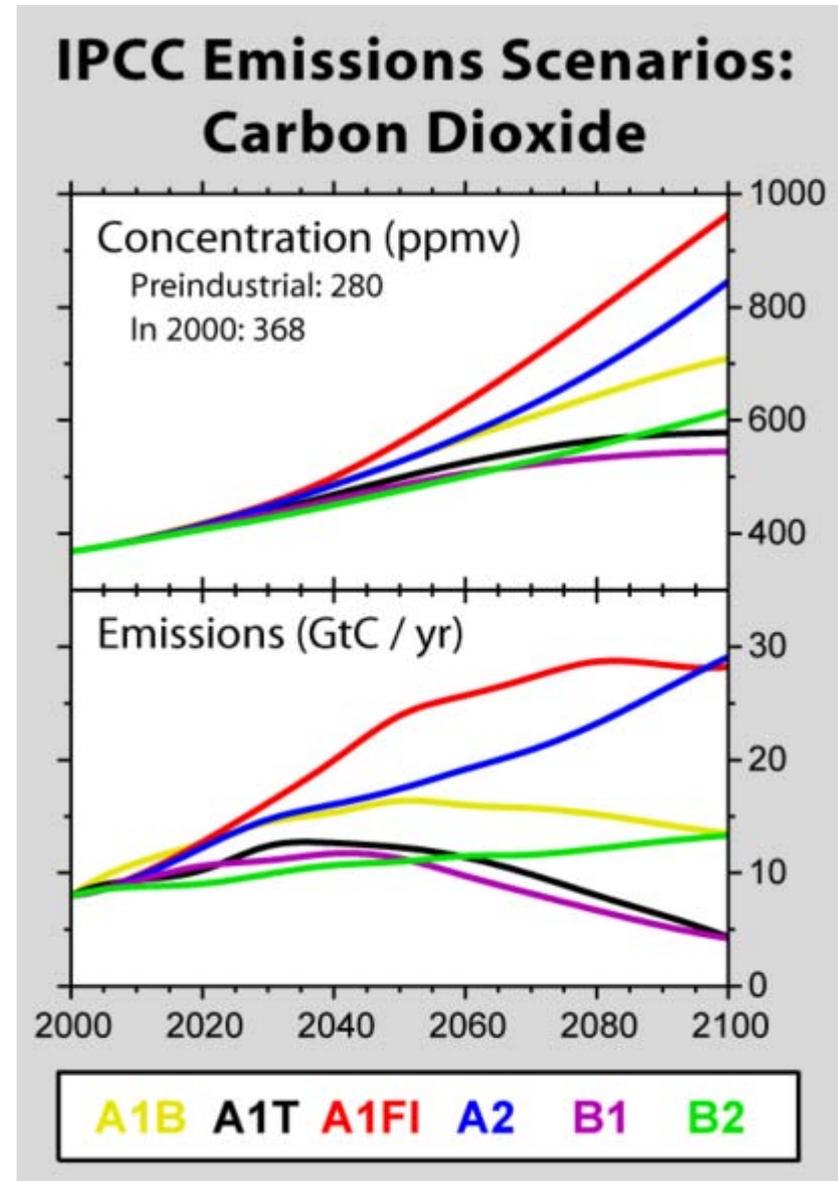


# SALMOD Calibration

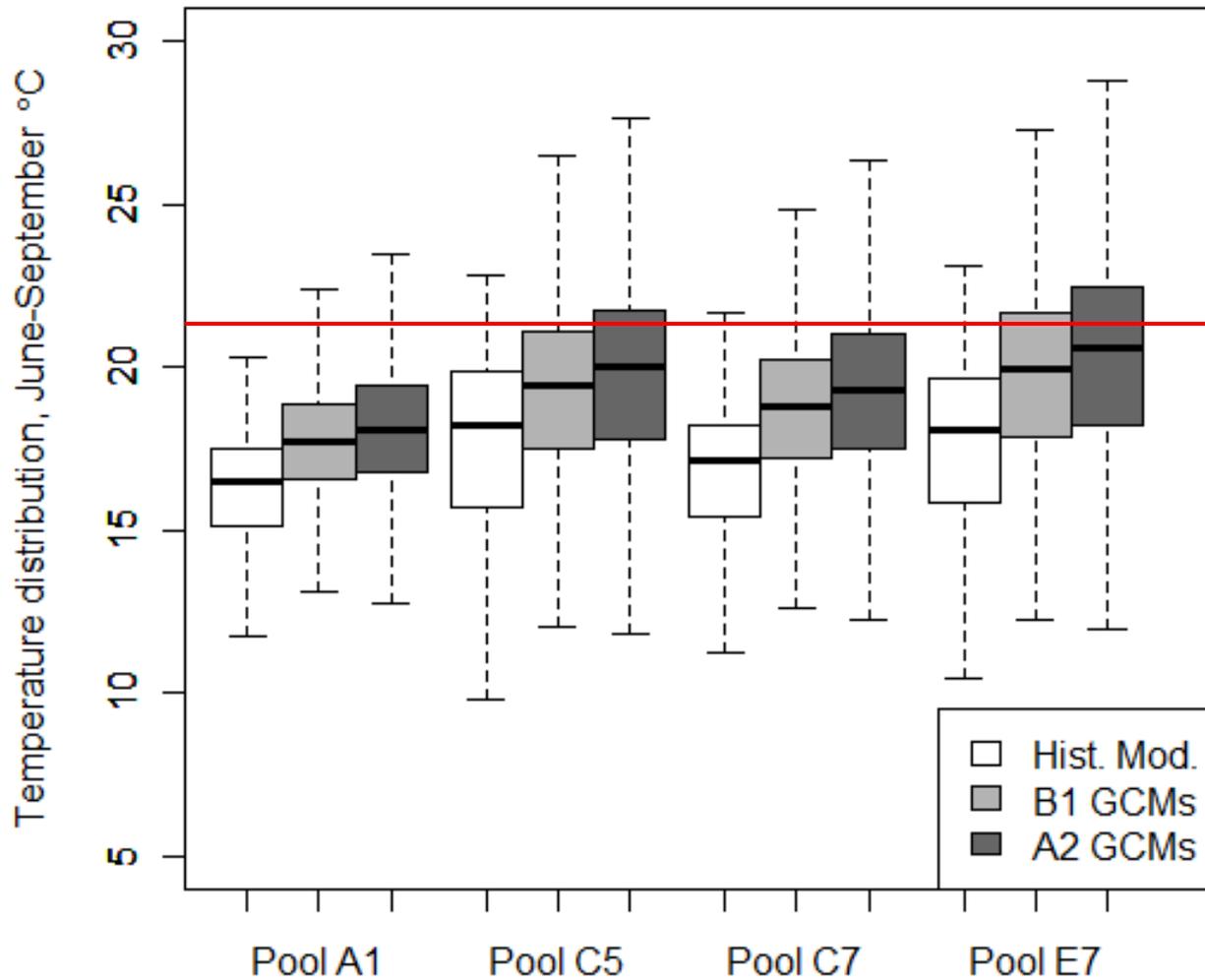


# Climate Predictions

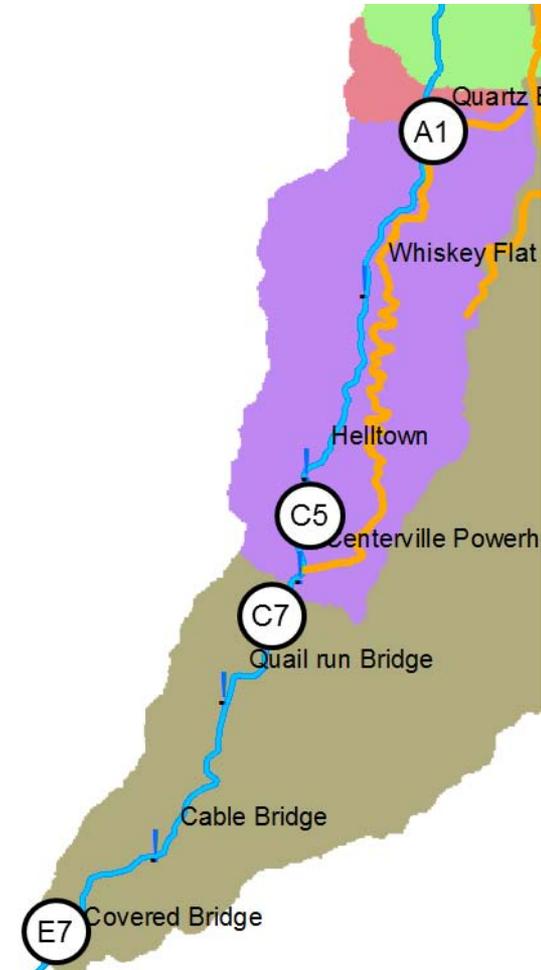
- California Climate Change Center
  - Bias corrected
  - Spatially downscaled
  - Maurer and Hidalgo, 2008
- 2 Emission Scenarios
  - SresA2 = business as usual
  - SresB1 = low emission
- 6 General Circulation Models (**GCMs**)
  - cnrmcm3 (CNRM CM3)
  - gfdlcm21 (GFDL CM2.1)
  - miroc32med (CCSR MIROC 3.2 med. Res.)
  - mpiecham5 (MPI-OM ECHAM5)
  - ncarccsm3 (NCAR CCSM3.0)
  - ncarpcm1 (NCAR PCM1)
- Ensemble of models and scenarios
- Envelope of climate predictions



# Temperature Change Along Creek



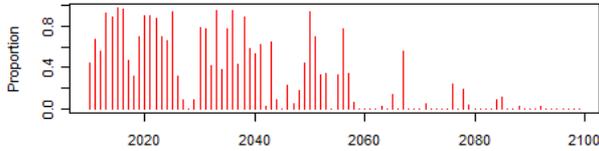
Hist. Mod. (1986-2005) and 6 GCMs A2/B1 (2009-2099)



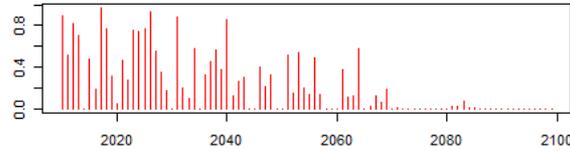
# Summer Survival of Adult Salmon



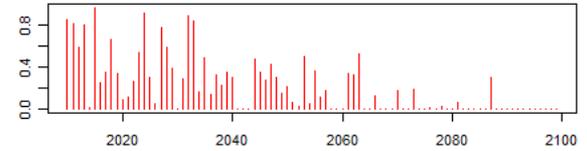
A2 CNRMCM3



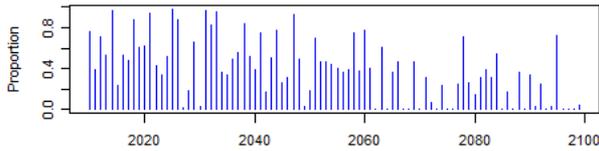
A2 MIROC32MED



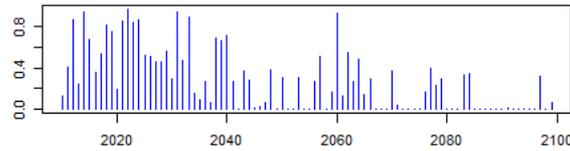
A2 NCARCCSM3



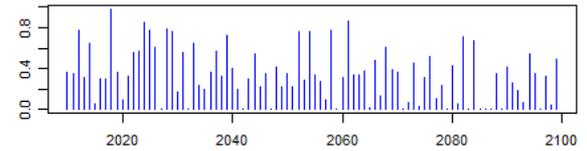
B1 CNRMCM3



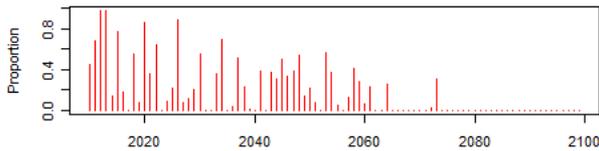
B1 MIROC32MED



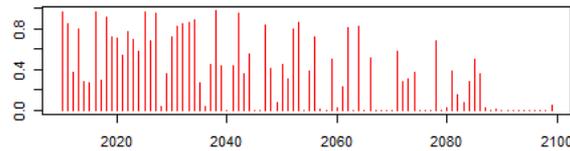
B1 NCARCCSM3



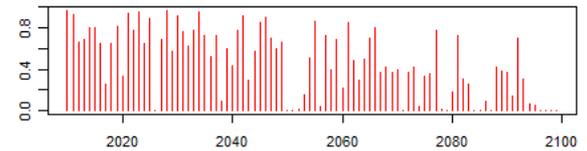
A2 GFDLCM21



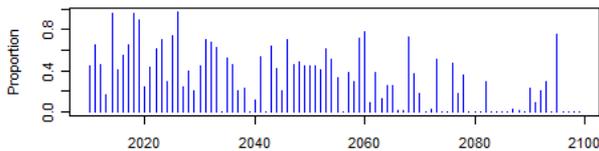
A2 MPIECHAM5



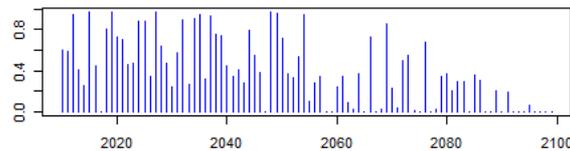
A2 NCARPCM1



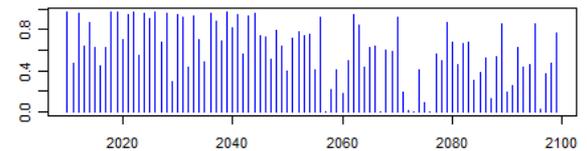
B1 GFDLCM21



B1 MPIECHAM5



B1 NCARPCM1



Year

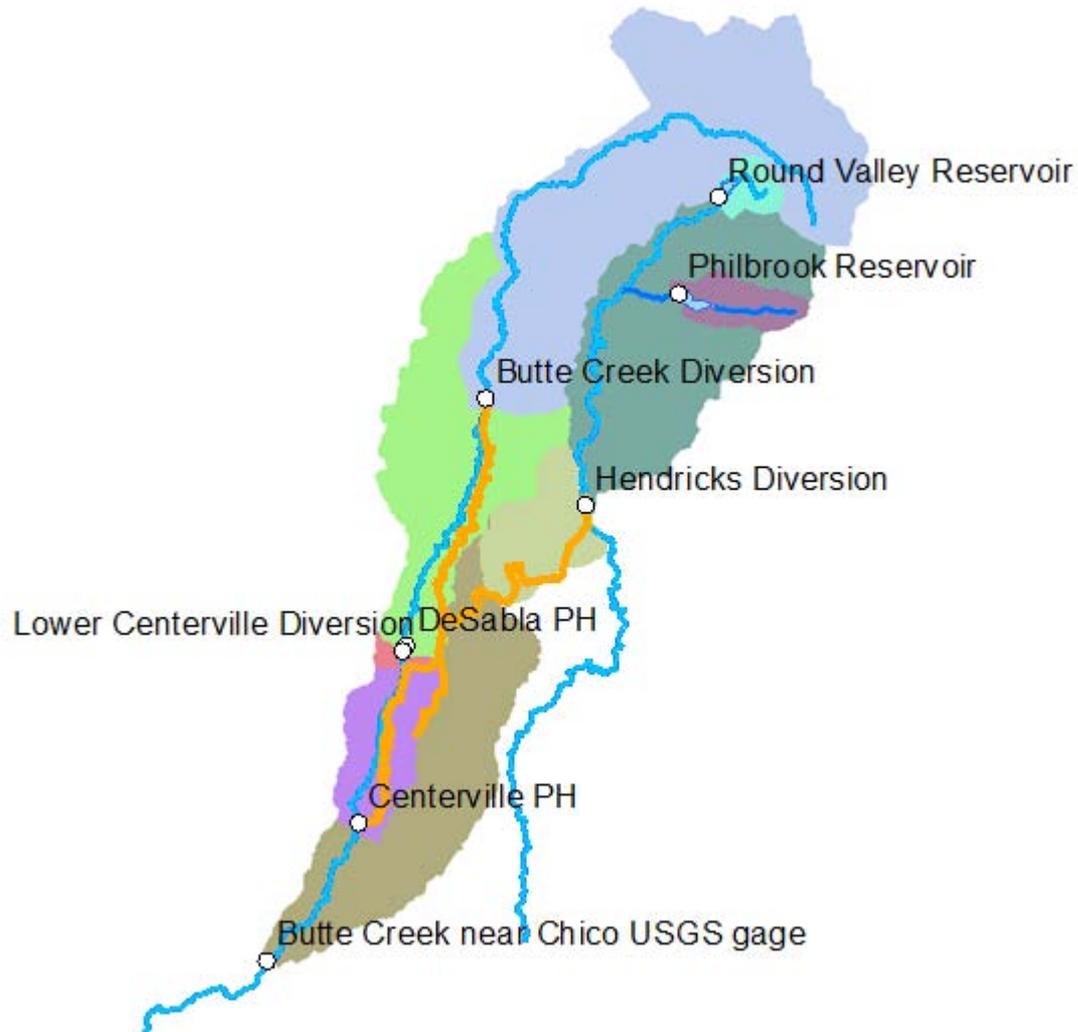
Year

Year

Added 15,000 adults each spring  
Calculated proportion that survived to spawn

Extinction criterion = 4 years with no survival

# Management Adaptations



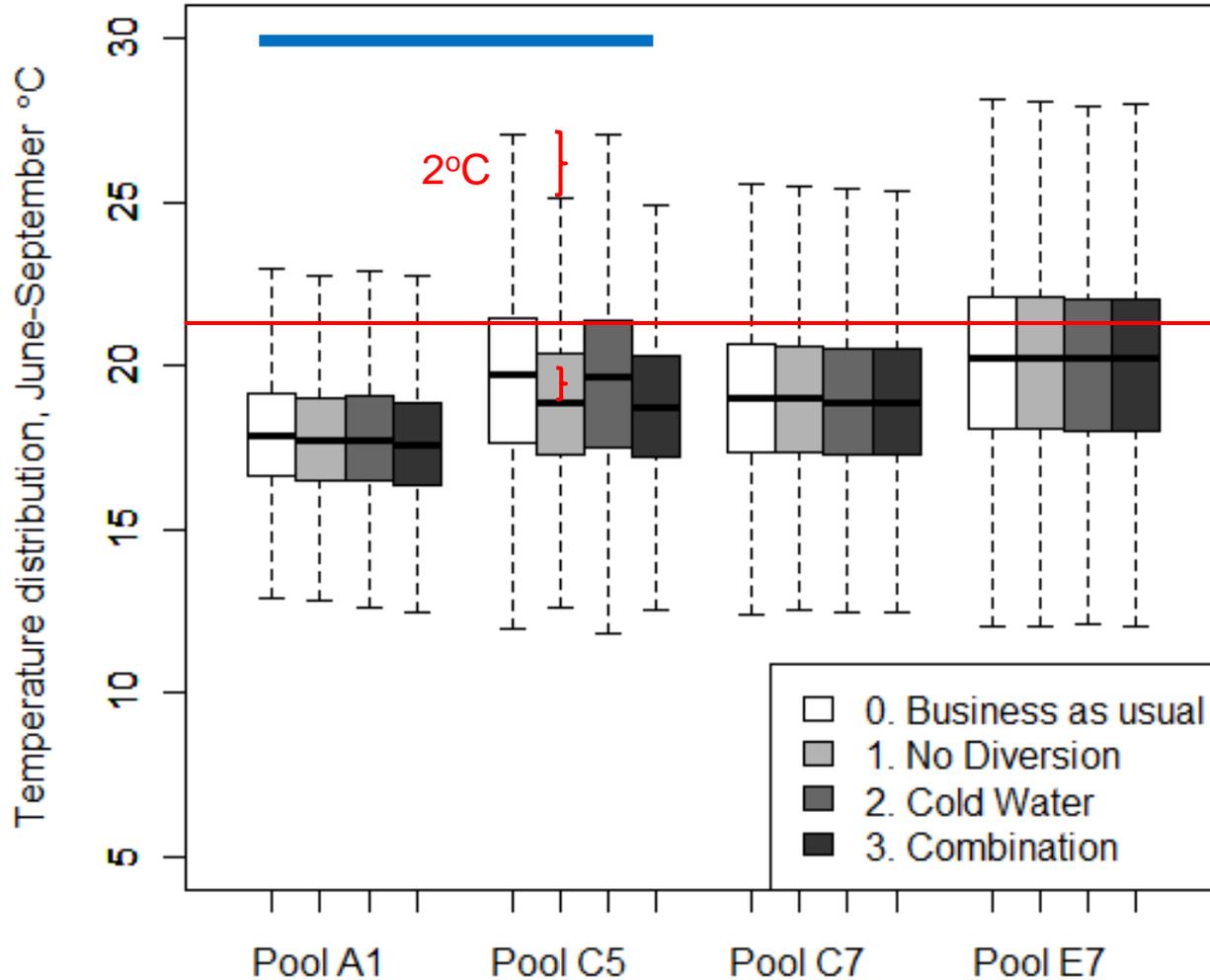
No diversion

Cold water savings

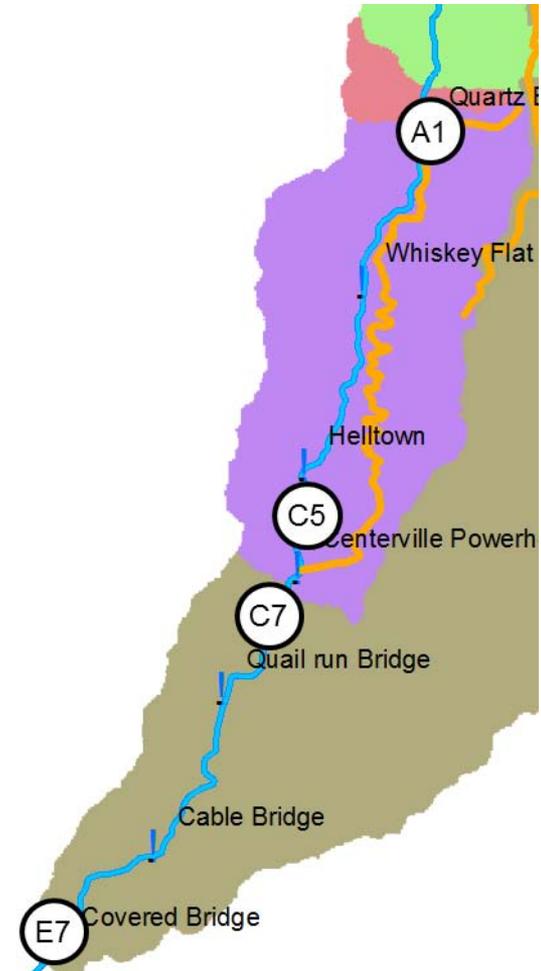
Combination of both

# Management Adaptations and Temperature

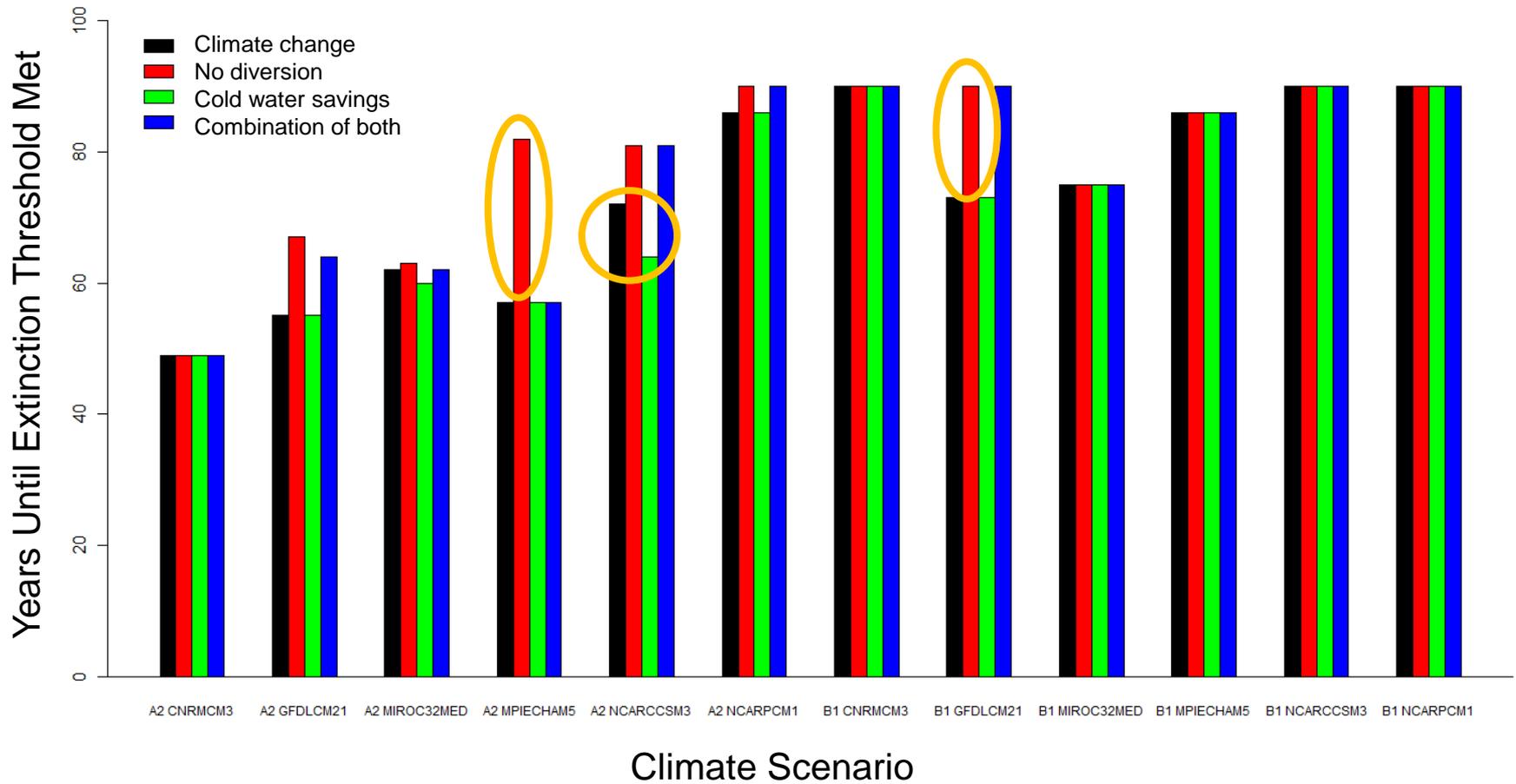
Leave water in upper half of salmon habitat



Management scenarios for 6 GCMs A2/B1 (2009-2099)



# Management Adaptations and Survival Time



# Outcomes

- Climate Scenarios
  - A2 - Salmon gone for all models
  - B1 - Salmon may last to end of century
- Management Adaptations
  - No diversion
    - Salmon survival time extended 0 – 17 years
    - Loss of hydropower production
  - Cold water savings
    - No improvement or worse
  - No diversion + cold water savings
    - Any benefits due to “no diversion”

# Implications

- More water management adaptations
  - Additional reservoir operations
  - Improve reservoir management – use short-term weather predictions to improve timing of water transfer
- Hydropower impacts due to water management changes
- Economic implications of water management for agricultural production
- Climate change impacts on fish in other watersheds

# Big picture points

- Long-term survival of spring-run Chinook salmon in Butte Creek is questionable
- Water management adaptations may extend survival
- Analytical framework (linked models) we developed here may be a useful tool elsewhere

# Acknowledgements

- US Environmental Protection Agency
- US Geological Survey
- California Department of Fish and Game
- Pacific Gas and Electric
- US Fish and Wildlife Service
- Friends of Butte Creek
- California Sportfishing Protection Alliance
- Journal of Water Resources Planning & Management
  - Editors and reviewers



**Photo by Lisa Thompson**

# Streamflow and Temperature Change

