Exploring Water Resources Systems Vulnerabilities and Adaptations to Climate Change in California

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Romain Maendly | September 5th 2019
Outline

• Why this project – Background, goals, projects overview
• General study design for vulnerability assessment
• Adaptive planning strategy
• Next steps
Connecting Climate to Flood

- Must link climate process to daily time scale
- This linkage is also important for drought understanding
Background and Purpose

• Past studies have shown increasing flood risk in the Central Valley in the future due to climate change.

• 2017 CVFPP Update Climate Change Study has integrated climate change risks in flood planning in the Central Valley.

• This project aims to enhance and extend climate change vulnerability assessment efforts and improve stakeholder understanding.
Goals

• **Quantify deep uncertainties** in flood and drought prediction under climate change

• **Formulate a systematic framework** for assessing future risks and developing economically efficient, robust, and flexible plans to mitigate risk

• **Inform other project/planning efforts**
Top Down Approach

Select a couple of GCM Projections

Downscaling, Hydrologic Modeling

Operations and Planning Models

Conditional System Performance Projections
Top Down Approach

Select a couple of GCM Projections

Downscaling, Hydrologic Modeling

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Bottom Up Approach

Adaptive Planning

Climate Model Ensemble

Vulnerability Assessment

Operations and Planning Models
General Study Design

- Operations and Planning Models (HEC-WAT)
- Global Climate Model Projections
- System Response Surface/Stress Test
- System Base Performance/Probabilistic Vulnerability Assessment
- Adaptive Planning
- Weather Generator
- Systematic Climate Perturbations
Weather Generator

- Annual Module
- Seasonal Module
- Daily Module
- Hourly Module

Observed or historical time series of weather data

Many simulated time series of weather data
Systematic Climate Perturbations

Annual Maximum Precipitation

Thermodynamic

Today’s Result

Temperature Change
Clausius-Clapeyron

Dynamic

Inter-Annual
Precipitation

Pfahl et al (2017), Understanding the regional pattern of projected future changes in extreme precipitation
Systematic Climate Perturbations

Climate Perturbation Scenarios

- Temperature Change: 0, 2, 3, and 4°C
- Precipitation Change: -12%, -9%, -6%, -3%, 0%, 3%, 6%, 9% and 12%
- Clausius-Clapeyron: none, 1X and 2X

Fischer et al (2017), Observed heavy precipitation increase confirms theory and early models
Operations and Planning Models
HEC-WAT

Weather Generator

Simulation Data and Results (DSS)

HEC-WAT System Based Performance

HMS
RES SIM
RAS
FIA
HEC-HMS Model Overview

- 27 total subbasins
- Unimpaired flow simulation
  - Calibration points: Unimpaired inflow to each reservoir and Dry Creek @ Modesto
- Results compared to daily unimpaired flow estimates from Steiner FERC model
HEC-ResSim Model Overview

Three upstream reservoirs

San Joaquin Pipeline

Combined Canals

Don Pedro

Inflow from HMS
HEC-RAS Model Overview

- Based from CVFED Model
- Calibrated with the 2011 and 2017 events
- Model handles extreme events (~320,000cfs)
HEC-FIA Model Overview

• The inventory is a combination of point structure data from:
  ➢ CVFPP 2017 Update’s HEC-FDA
  ➢ And, the National Structure Inventory

• Warning System/Time Feedback based on local input

• Calibrated based on the 1997 and 2017 events
Preliminary Results

- Start from the top of the watershed down to the reservoir release
- A subset of the data computed
- Preliminary results, therefore need to take them with a grain of salt
Assessment Synthetic 1997 Event

85% rain

7% increase

14% increase

52% reduction
Hydrological Cycle Shift

![Graphs showing hydrological cycle shift with different temperature scenarios.

- Current
- +2C (cc 1x)
- +3C (cc 1x)
- +4C (cc 1x)
Don Pedro October Storage
Increase in Flood Events

![Graph showing the relationship between DNP 3-Day Inflow and DNP 3-Day Outflow for current conditions and +2C, +3C, +4C scenarios.]

- **Current**: Dotted line
- **+2C (cc 1x)**: Red dots
- **+3C (cc 1x)**: Orange dots
- **+4C (cc 1x)**: Green dots
- **Flood Stage**: Yellow line
- **Monitor Stage**: Green line

![Bar chart showing annual max event count for different change in average annual temperature.]

- **0** change: 7 events, [1 event per 150 yrs]
- **2** change: 21 events, [1 event per 50 yrs]
- **3** change: 44 events, [1 event per 24 yrs]
- **4** change: 60 events, [1 event per 17 yrs]

- **Monitor Stage**
  - **0** change: 142 events, [1 event per 7 yrs]
  - **2** change: 166 events, [1 event per 6 yrs]
  - **3** change: 266 events, [1 event per 3 yrs]
  - **4** change: 254 events, [1 event per 4 yrs]

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**Note**: This graph illustrates the increase in flood events due to changes in average annual temperature, showing a significant rise with higher temperature scenarios.
Vulnerability Assessment Metric

- **Flood Risk**
  - Expected Annual Damage / Life Loss
  - Population and Assets in 100yr Floodplain

- **Water Supply/Irrigation**
  - Don Pedro storage on Apr 1st, July 1st, and Oct 1st
  - Don Pedro deliveries to irrigation channel

- **Environmental**
  - San Joaquin River Basin Index
  - Evapotranspiration
  - Snow Water Equivalent (SWE)
Vulnerability Assessment Next Steps

Hypothetical Expected Annual Damage

Better than current conditions scenarios:
- ~15% likelihood
- Limited or No Adaptation

Likely Scenarios
- worse than current conditions
- ~65% likelihood
- Some level of new protection needed

Outlier Scenarios
- Extreme outcomes
- ~10% likelihood
- Massive additional protection needed
Integrated Adaptation Strategies

Based on the system’s vulnerabilities, formulate robust actions and flexible plan to deal with future risks and uncertainties.

Projects/actions that foster sustainability and integrated water resources management

- Flood-MAR
- Rule curve shift/modification
- FIRO
- Increase capacity of infrastructures
- Non structural improvement
Next Steps

• Finalize Vulnerability Assessments

• Evaluate Adaptive Strategies

• Documentation

• Continue to Engage and Communicate the Study Status with Locals and other Stakeholders
Thank You

Romain Maendly,
California Department of Water Resources
Romain.Maendly@water.ca.gov

But also Wyatt Arnold¹, David Arrate¹, John Kucharski², Jenny Olszewski², Lee Bergfeld³, Wesley Walker³, Scott Steinchneider⁴, Patrick Ray⁵ and Rahat Saiful Haque⁵

¹California Department of Water Resources
²USACE
³MBK
⁴Cornell University
⁵University of Cincinnati

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