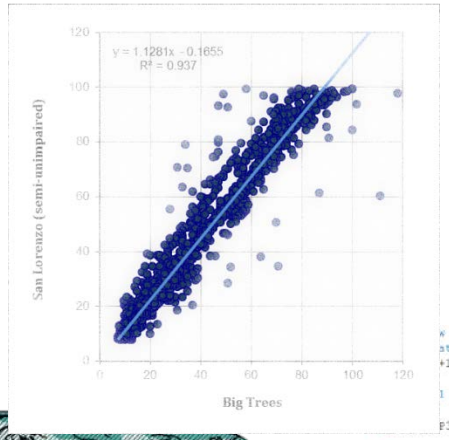
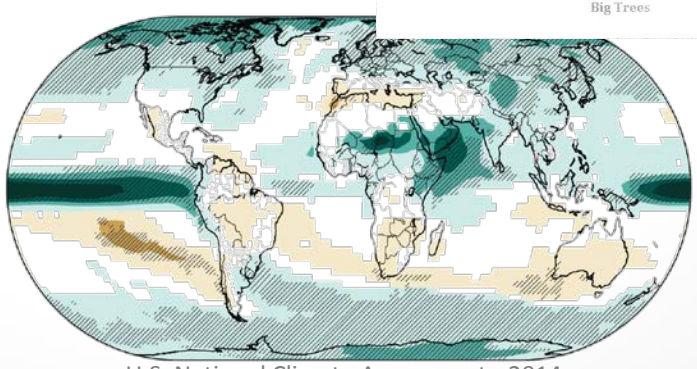
City of Santa Cruz HCP

Climate Change (CC) Hydrologic Modeling Support

Shawn M. Chartrand





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U.S. National Climate Assessment - 2014

Balance Hydrologics, Inc.

Presentation Overview

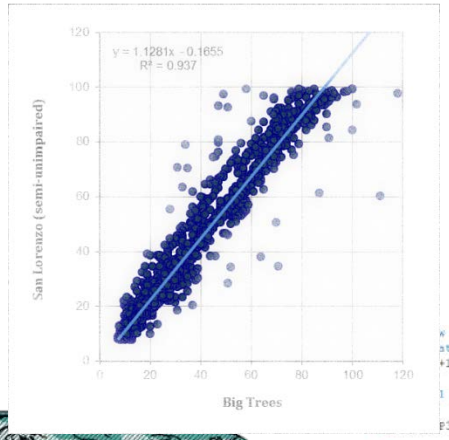
1. Technical role and objectives
2. Motivation for work
3. Climate change analysis:
   - Model steps and framework
   - Development of input data
4. Review a few results
5. Questions?

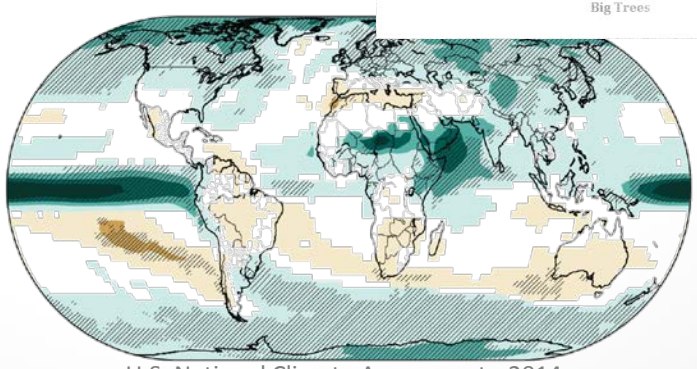
Caveats

1. No one can **predict** the future
2. Global Climate Models provide **plausible** climate trajectories
3. Modeled daily streamflows are **not estimates or predictions** of future conditions
4. Simulations permit **comparisons** between historical and **plausible** future conditions
5. Team **collaboration** and expert **guidance**
6. Work used for HCP **and** water supply planning

City of Santa Cruz HCP

Review Technical Role and Objectives





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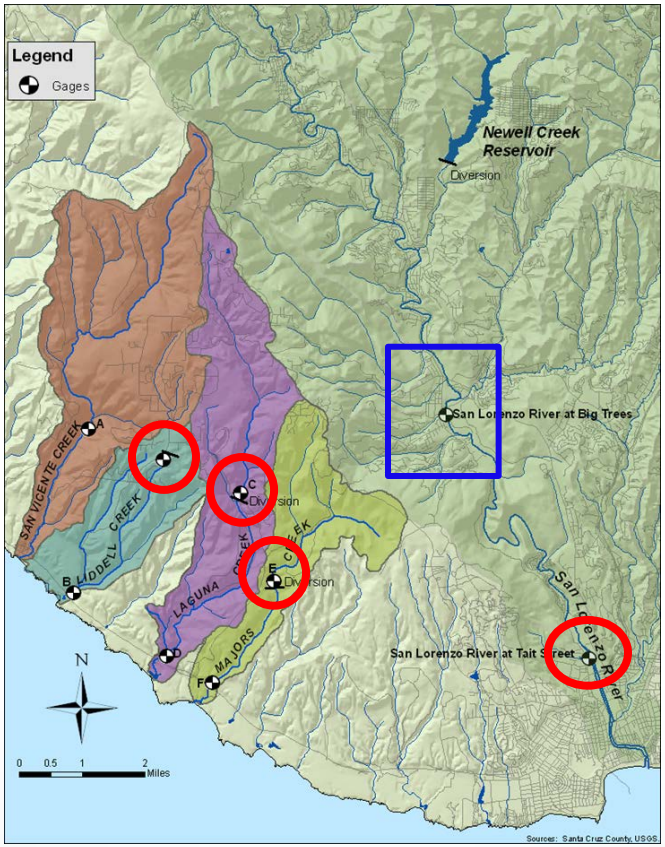
Technical Role

Support the project team in identifying (*modeling*) the availability of water for habitat and water supply under ***projected climate change conditions***

Liddell, Laguna, Majors & San Lorenzo



Location of Climate Change Projections

Locations of Production

Balance Hydrologics, Inc.

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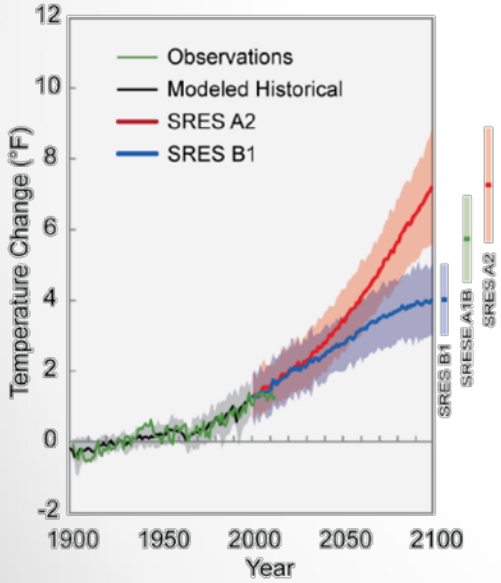
Support the project team in identifying (*modeling*) the availability of water for habitat and water supply under ***projected climate change conditions***

Liddell, Laguna, Majors & San Lorenzo

GFDL2.1 A2 PCM1 B1



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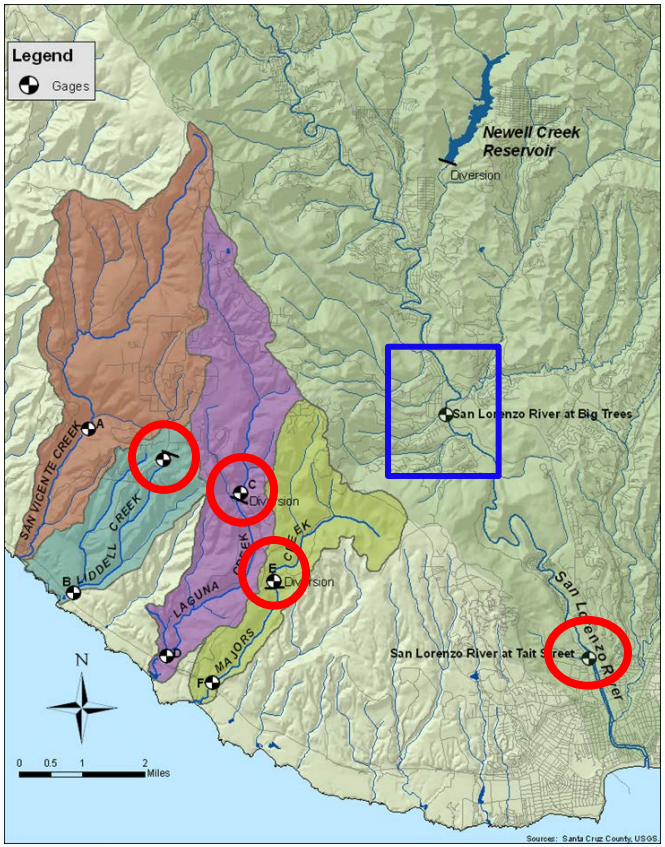

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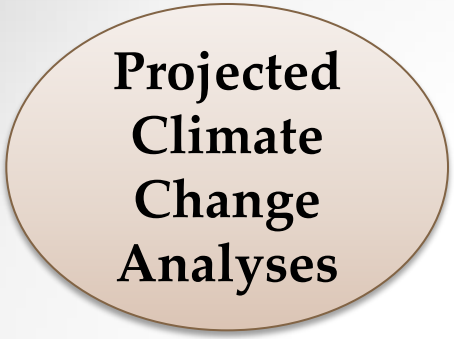
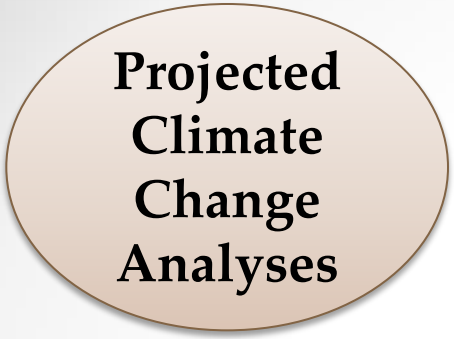


Specific Objectives

- Complete the analysis with data **adopted by the State** for water supply and climate change adaptation studies



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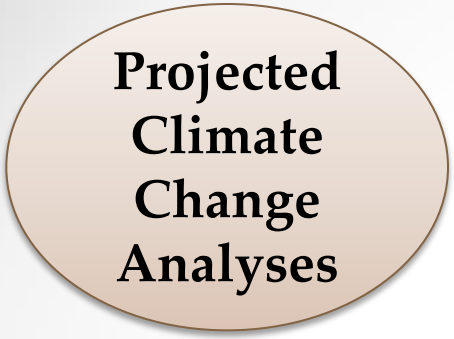
- Complete the analysis in a manner consistent with HCP review and simulation of the historical period (’36 – ’09).



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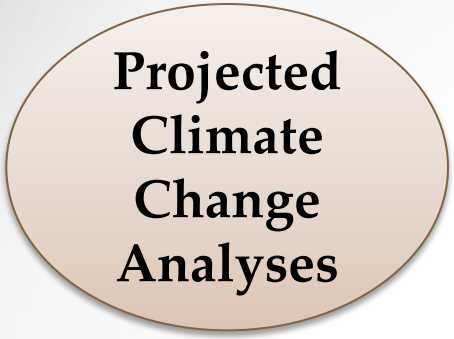
- Provide datasets for direct input into *Confluence®* to complete water supply analyses



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- Provide datasets for completion of HCP effects analysis

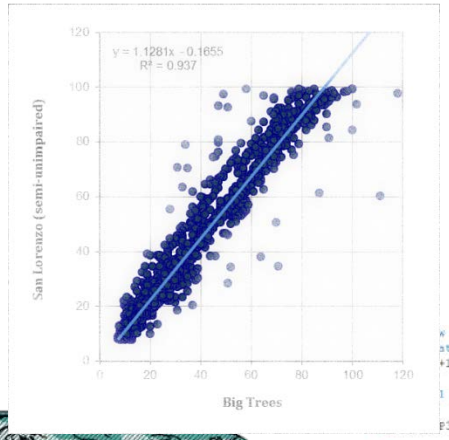
Projected Climate Change Analyses

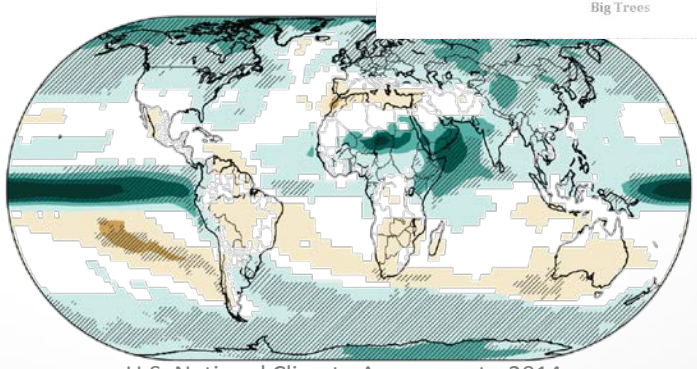
Specific Objectives

- Complete the analysis with data **adopted by the State** for water supply and climate change adaptation studies
- Complete the analysis in a manner consistent with HCP review and simulation of the historical period (’36 – ’09).
- Provide datasets for direct input into *Confluence®* to complete water supply analyses
- Provide datasets for completion of HCP effects analysis
- Help the City make more informed decisions concerning water supply and instream habitat

City of Santa Cruz HCP

Motivation for Work





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MOTIVATION

Habitat and Supply Needs Pose a Serious Challenge

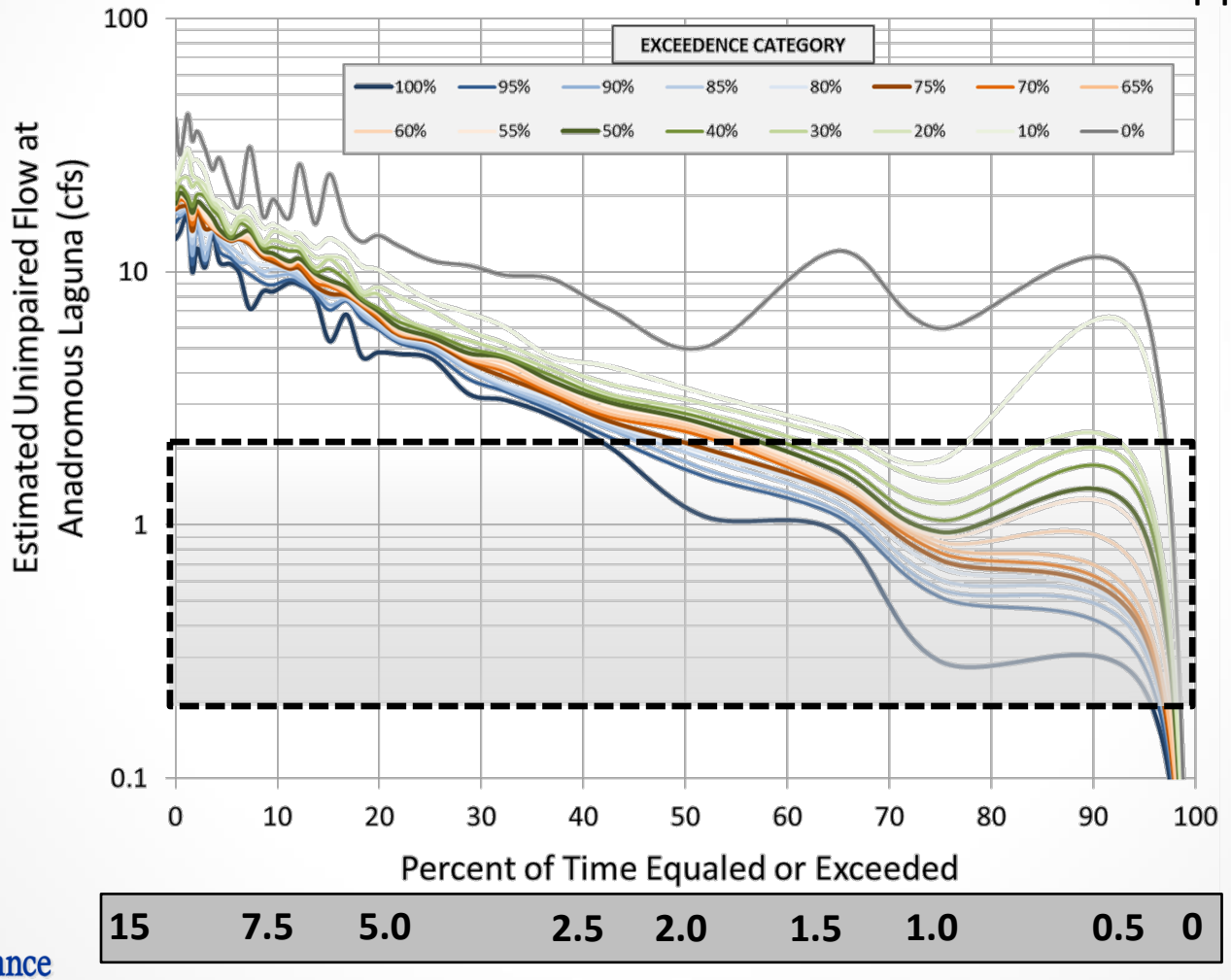
Difficult and sometimes not feasible to meet habitat and water supply needs.

MOTIVATION

RECENT

Habitat and Supply Needs Pose a Serious Challenge

Difficult and sometimes not feasible to meet habitat and water supply needs.



WY 2003 - 2011

Range in Rearing Flow Goal for Anad. Laguna

Upper Laguna Flow (cfs)

Balance Hydrologics, Inc.

MOTIVATION

Habitat and Supply Needs Pose a Challenge

Difficult and sometimes not feasible to meet habitat and water supply needs.

Executive Order S-13-08 (2008)

Natural Resource Agencies to identify how they can respond to Climate Change

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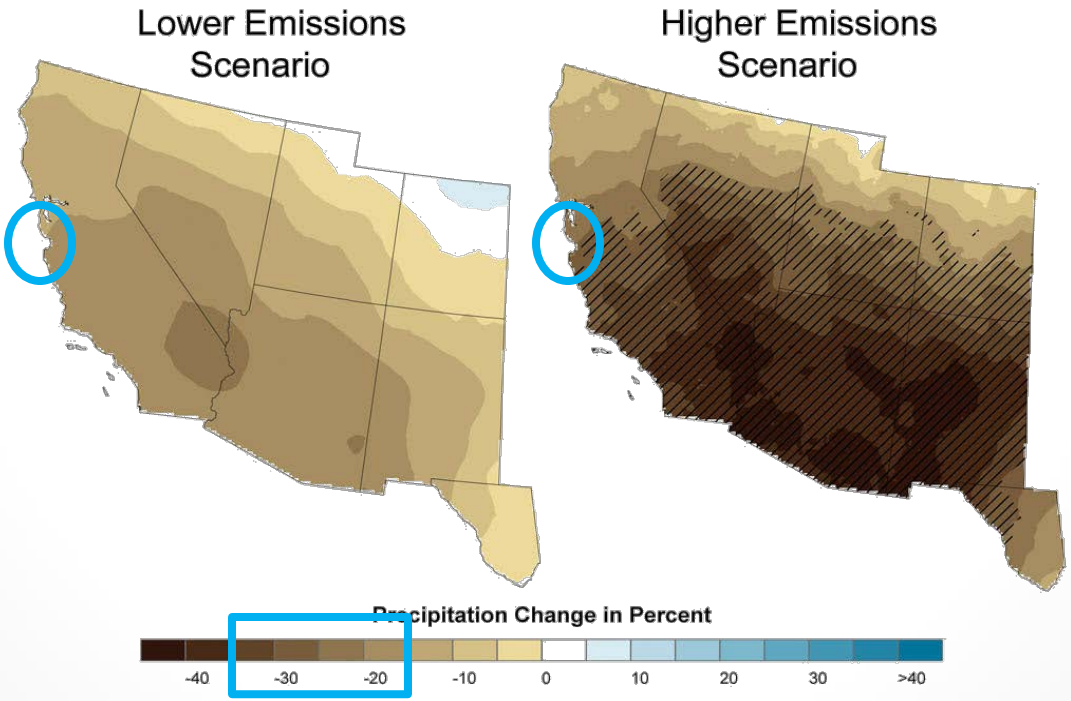

Source: USGCRP (2009). Global Climate Change Impacts in the United States.
Change computed for 2080-2099 vs. 1961-1979

MOTIVATION

Habitat and Supply Needs Pose a Challenge

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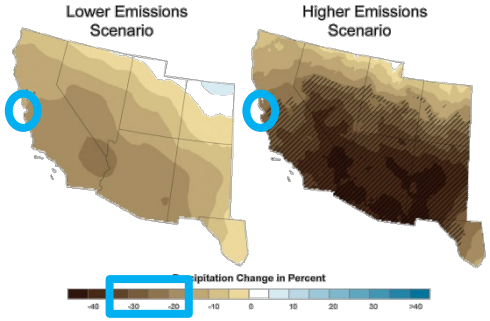

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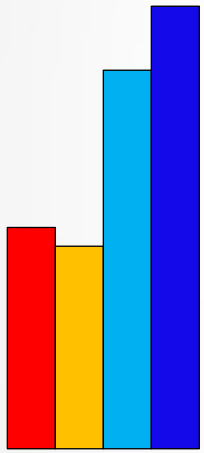
Evaluate potential impacts to habitat and water supply conditions under plausible future climate trajectories

MOTIVATION

Results from September 2010 Summary Memo

GFDL2.1



Big Trees WY1950 - 00

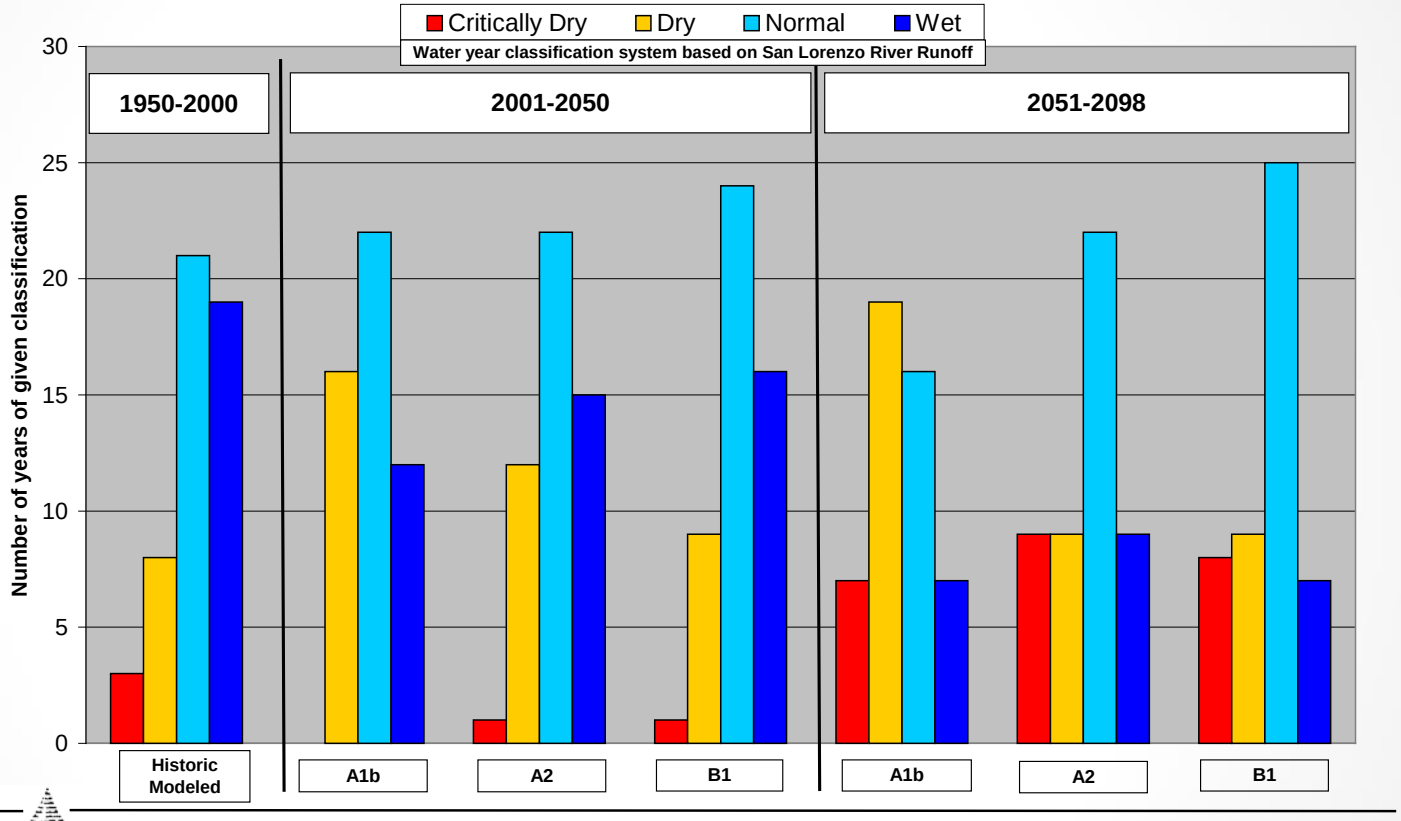


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Figure 1. Historic and projected count of water year types for periods 1950-2000, 2001-2050 and 2051-2098. These estimates use the modeled streamflow based on historic observations of precipitation and air temperature for the 1950-2000 period and the GFDL2.1 model data of precipitation and air temperature, downscaled, with the labled emission scenarios for the 2001-2050 and 2051-2098 periods.

MOTIVATION

Table 1.	Big Trees	NRA2	GFDL2.1 A1b	GFDL2.1 A2	GFDL2.1 B1
	1950-2000				
Critically Dry	9	3	3	3	3
Dry	8	5	8	8	8
Normal	16	23	21	21	21
Wet	18	20	19	19	19

Number of years of a given water year type for the historic period 1950-2000.

MOTIVATION

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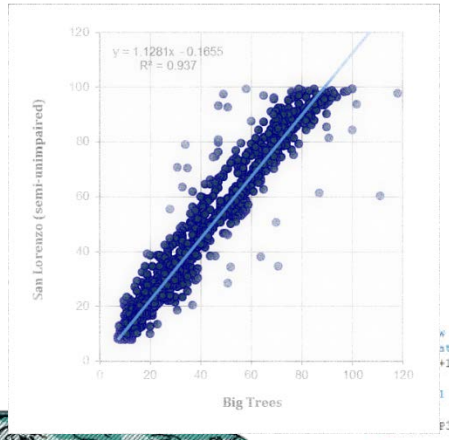
Number of years of a given water year type for the historic period 1950-2000.

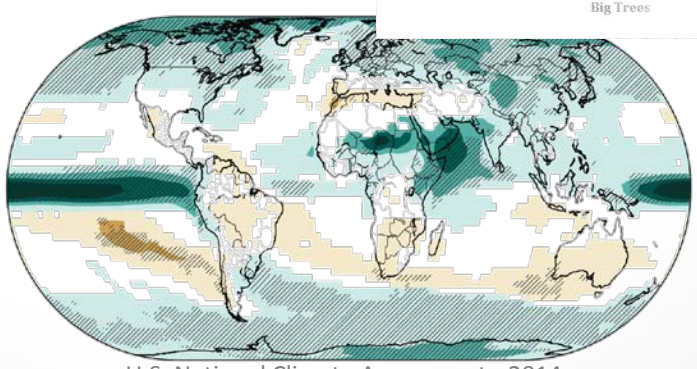
Primary Recommendation at the time:

further analysis of potential CC impacts warranted

City of Santa Cruz HCP

Review of climate change analysis:





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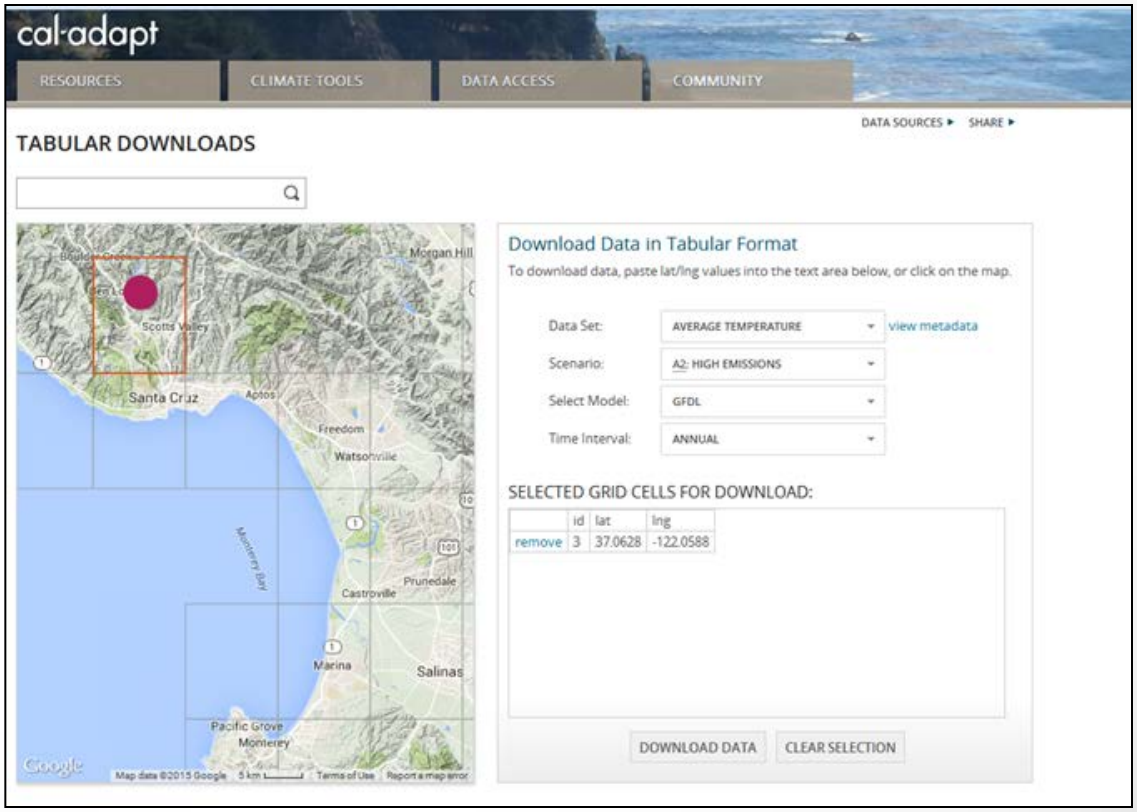
Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

GFDL2.1 A2 PCM1 B1

Precipitation: monthly total (mm/month)

Air Temperature: monthly mean and avg. maximum



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Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Specify Water Balance Model

$$Q = P - ET - R + B(CoS)$$

Q: streamflow discharge (ft/day)

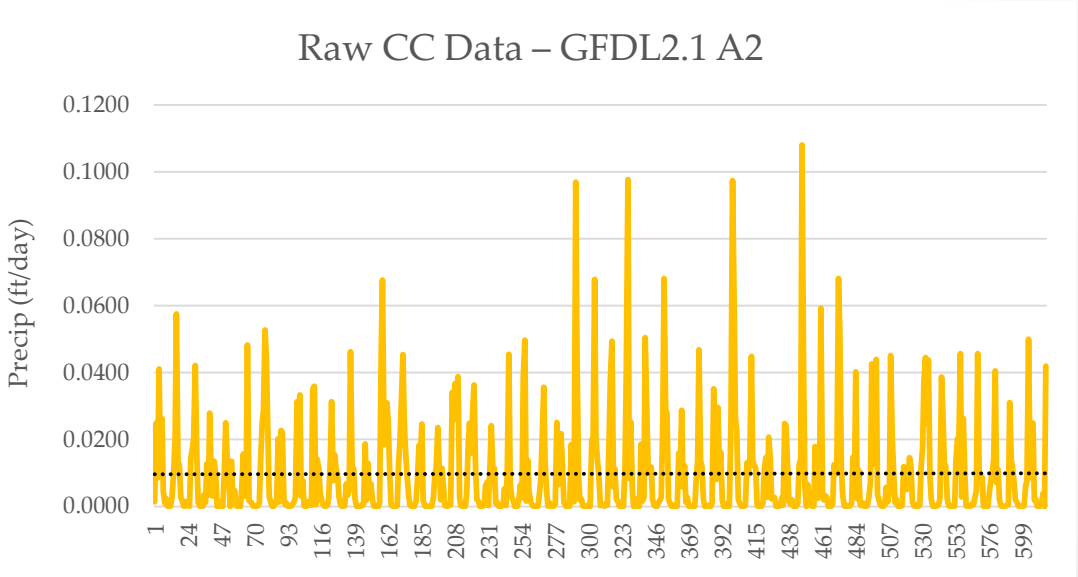
Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Specify Water Balance Model

$$Q = P - ET - R + B(CoS)$$

P: precipitation (ft/day)



Model Steps and Framework

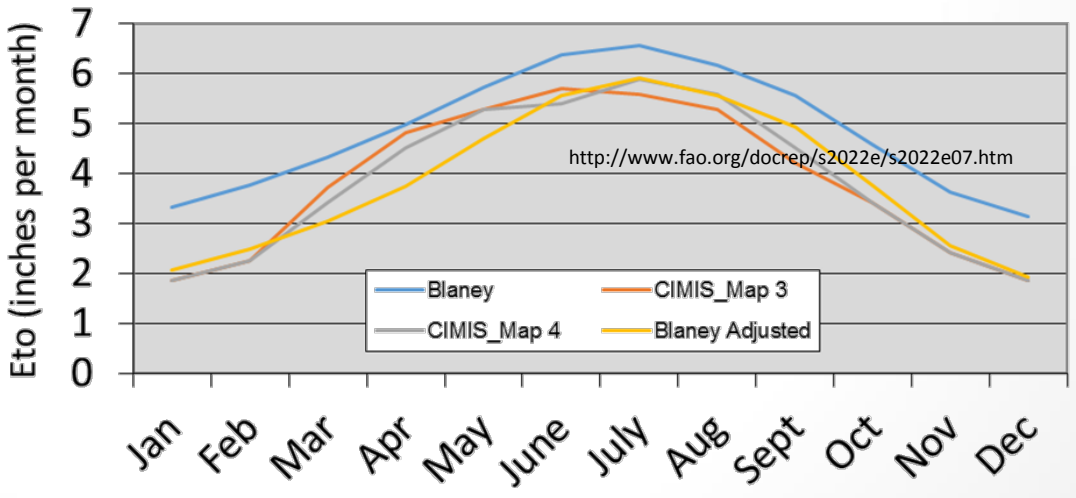
1950 - 2099
Acquire CC Data - CalAdapt

Specify Water Balance Model

$$Q = P - ET - R + B(CoS)$$

ET: evapotranspiration (ft/day)

$ET = \bar{P}_{sun\text{-}day}\,(0.75\,\bar{T} + 0.5)$



Model Steps and Framework

1950 - 2099
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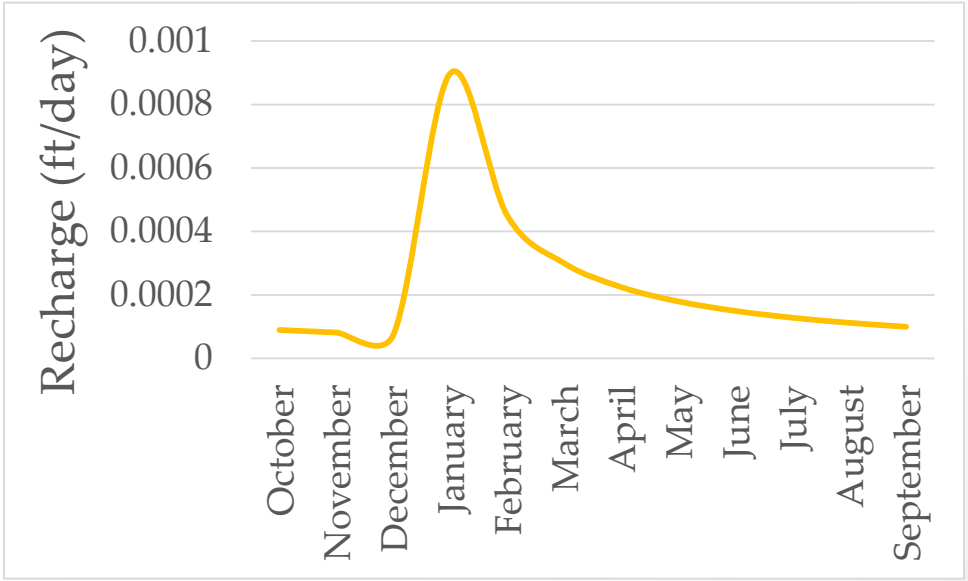
R: groundwater recharge (ft/day)

0.328 ft/year – 0.009 ft/day



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Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Specify Water Balance Model

$$Q = P - ET - R + B(CoS)$$

B: baseflow addition (ft/day)

- dependent upon *CoS* (relative groundwater carry-over storage)

$$B = \sum_{i=-1month}^{-6months} P_{daily} * K * CoS \left[\frac{ft}{d}, -, -\right]$$

K = 0.099

$$CoS = \frac{\left(\sum_{i=0}^{-9months} P_{daily}\right)}{\bar{P}_{daily}} \left[-\right]$$

CoS = precip. momentum

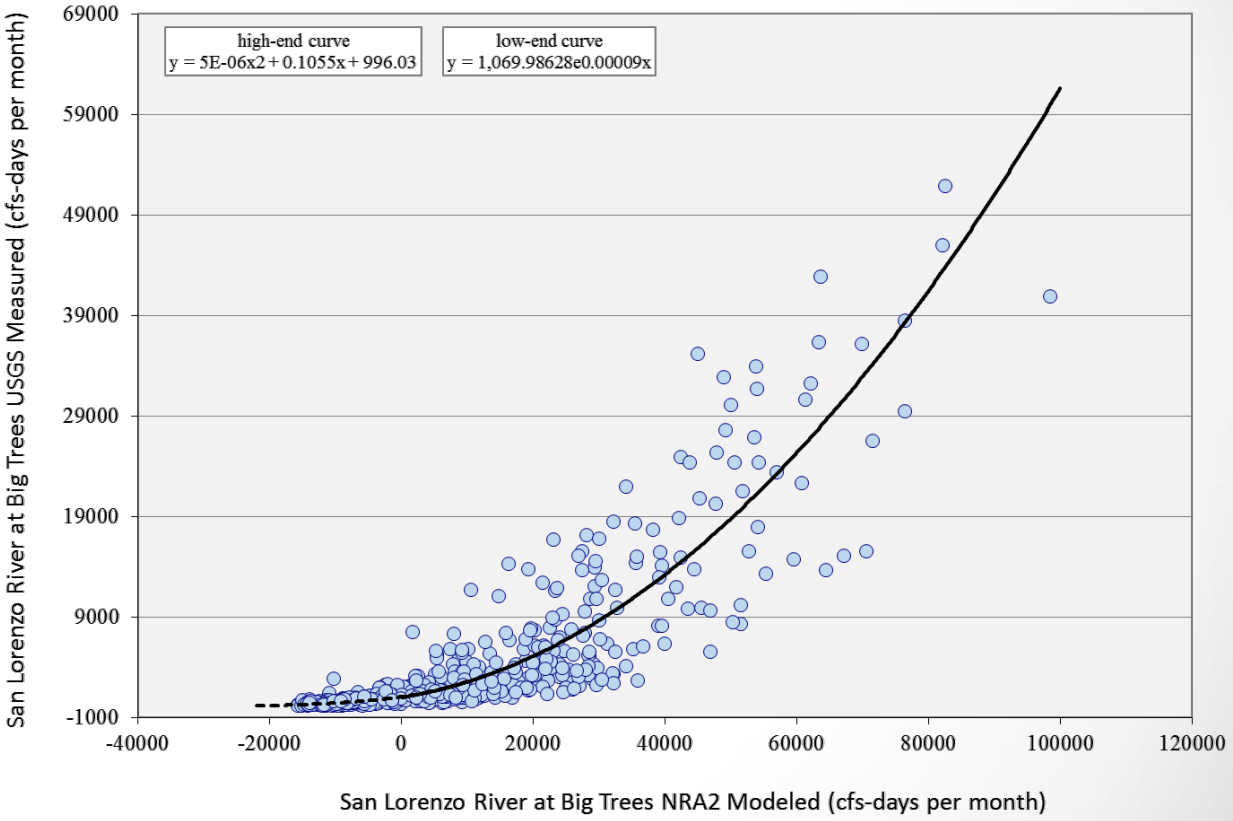
Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Specify Water Balance Model

1950 - 2000
Develop Calibration Model

BIG TREES



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Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Compute Calibrated Record

Specify Water Balance Model

1950 - 2000
Develop Calibration Model

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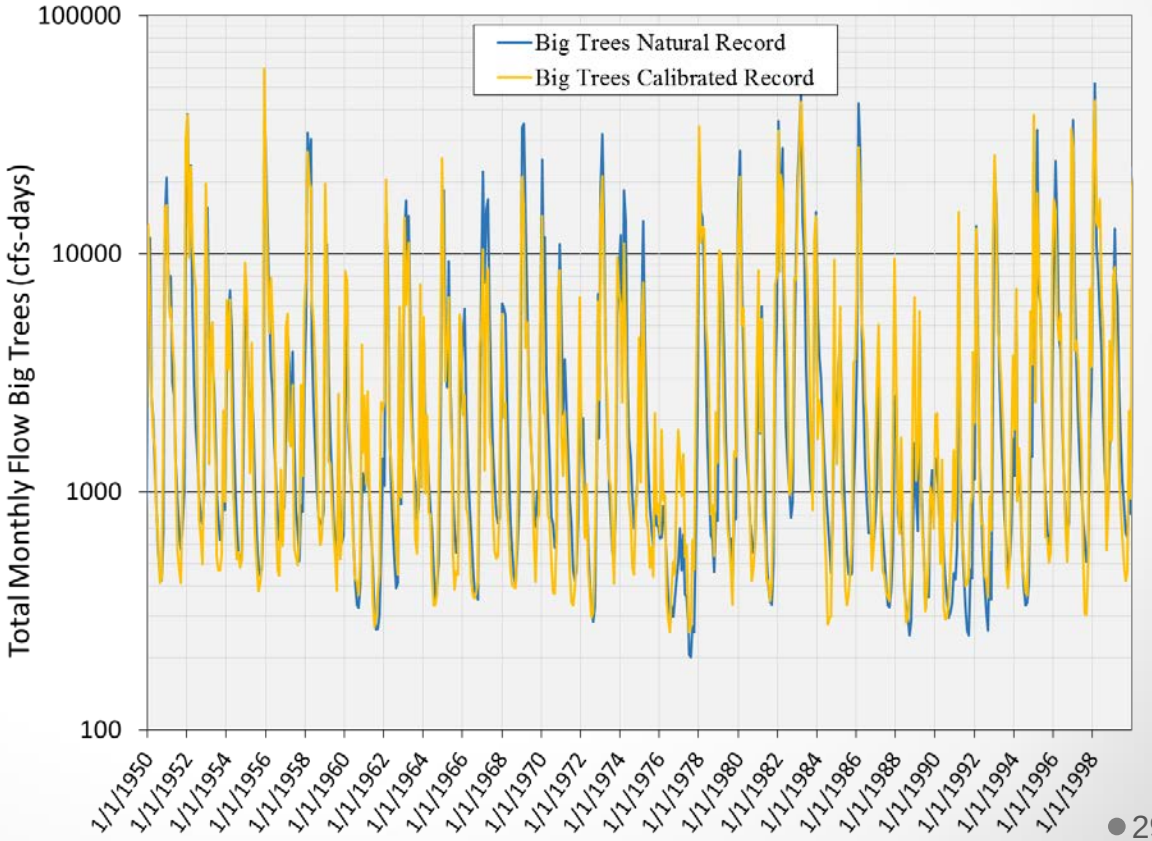

Model Steps and Framework

1950 - 2099
Acquire CC Data - CalAdapt

Compute Calibrated Record

Compute Daily Calibrated Record

BIG TREES

Specify Water Balance Model

1950 - 2000
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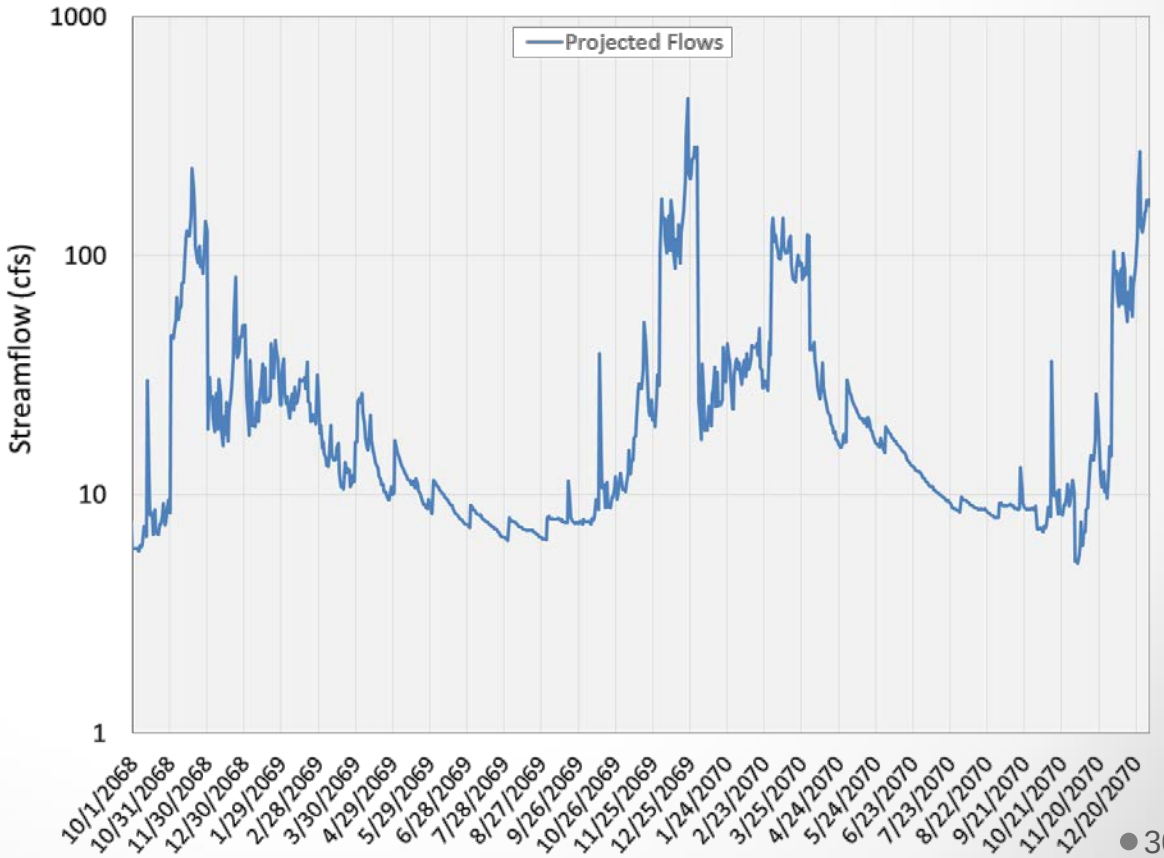


Balance Hydrologics, Inc.

Development of Input Data

1950 - 2099
Acquire CC Data - CalAdapt

Compute Calibrated Record

Compute Daily Calibrated Record

Specify Water Balance Model

1950 - 2000
Develop Calibration Model

BCSD projected data has a wet bias

Development of Input Data

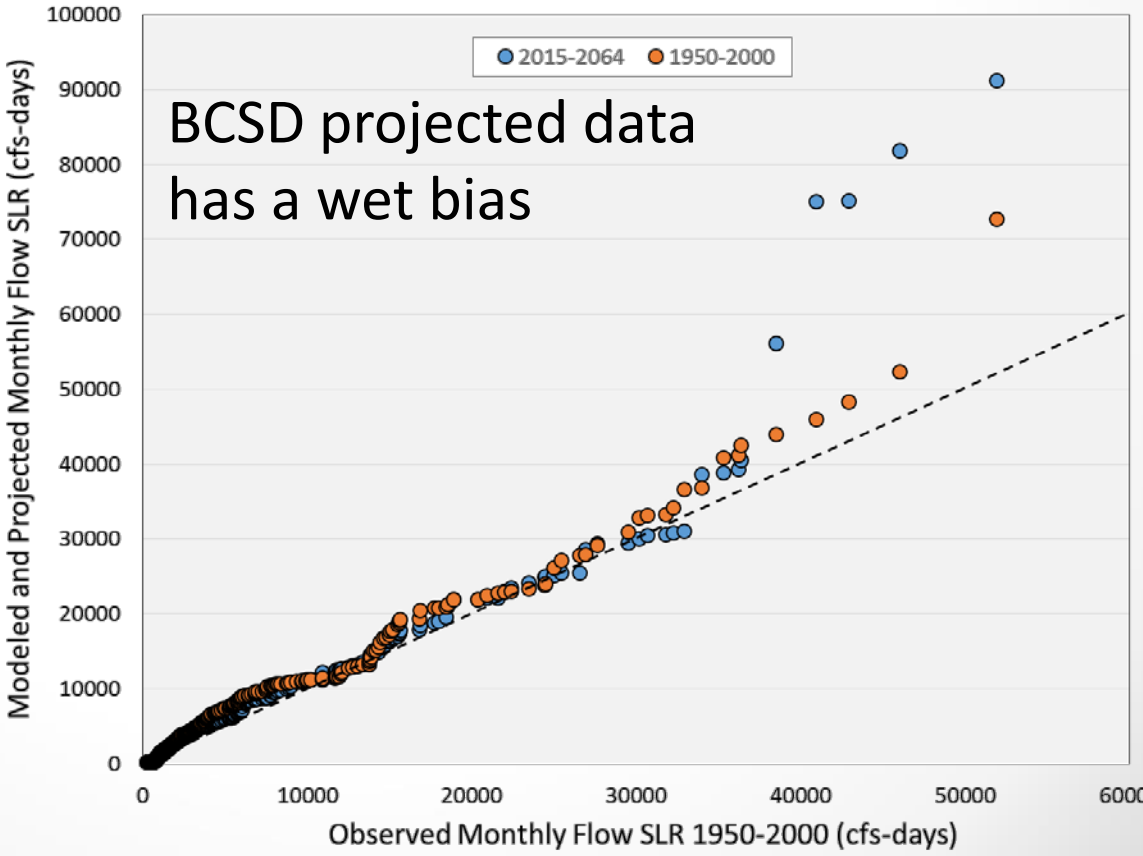
1950 - 2099
Acquire CC Data - CalAdapt

Compute Calibrated Record

Compute Daily Calibrated Record

Specify Water Balance Model

1950 - 2000
Develop Calibration Model



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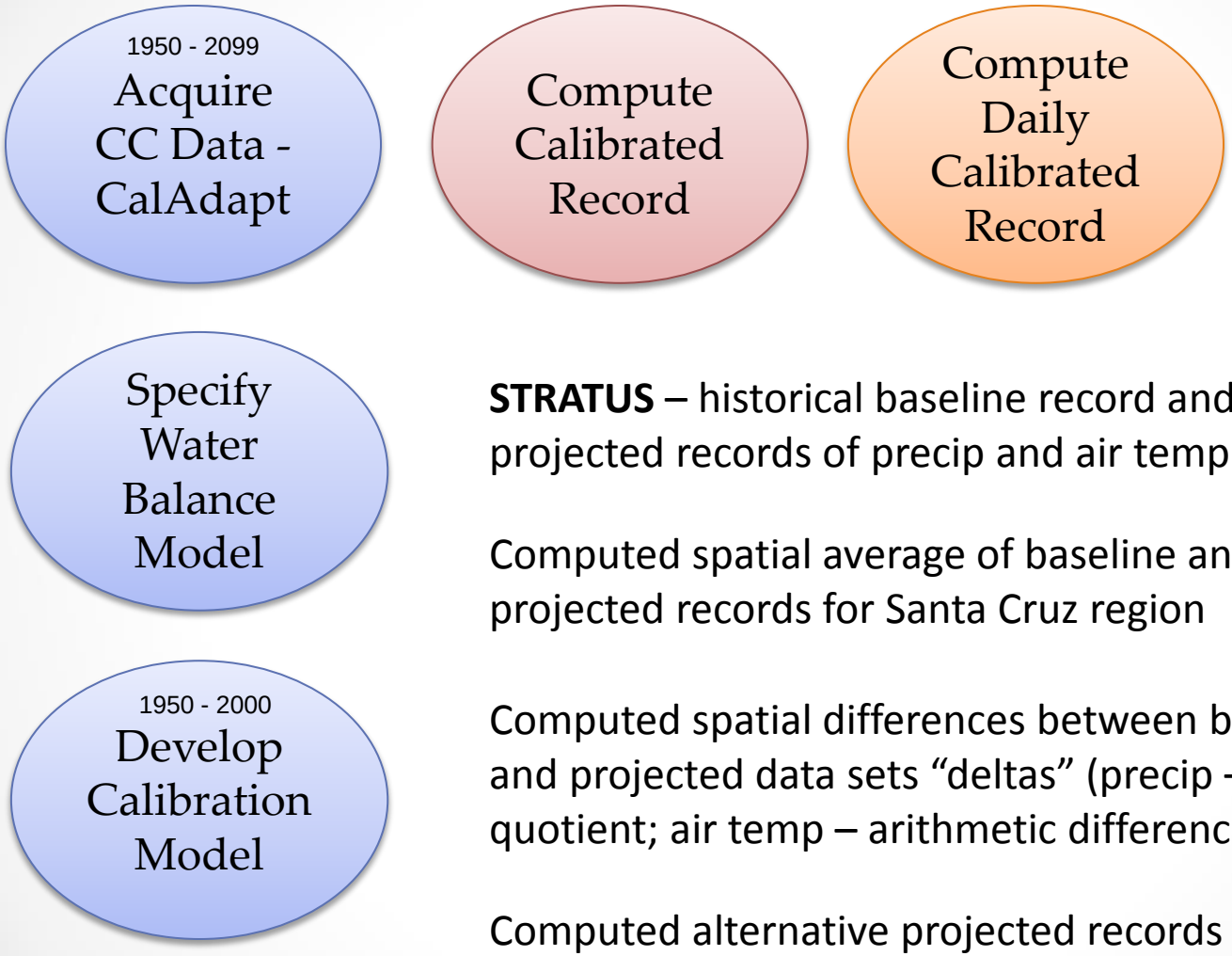
Development of Input Data



STRATUS – historical baseline record and projected records of precip and air temp

Computed spatial average of baseline and projected records for Santa Cruz region

Computed spatial differences between baseline and projected data sets “deltas” (precip – quotient; air temp – arithmetic difference)

Computed alternative projected records by applying “deltas” to baseline records

Development of Input Data

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Compute Daily Calibrated Record

Specify Water Balance Model

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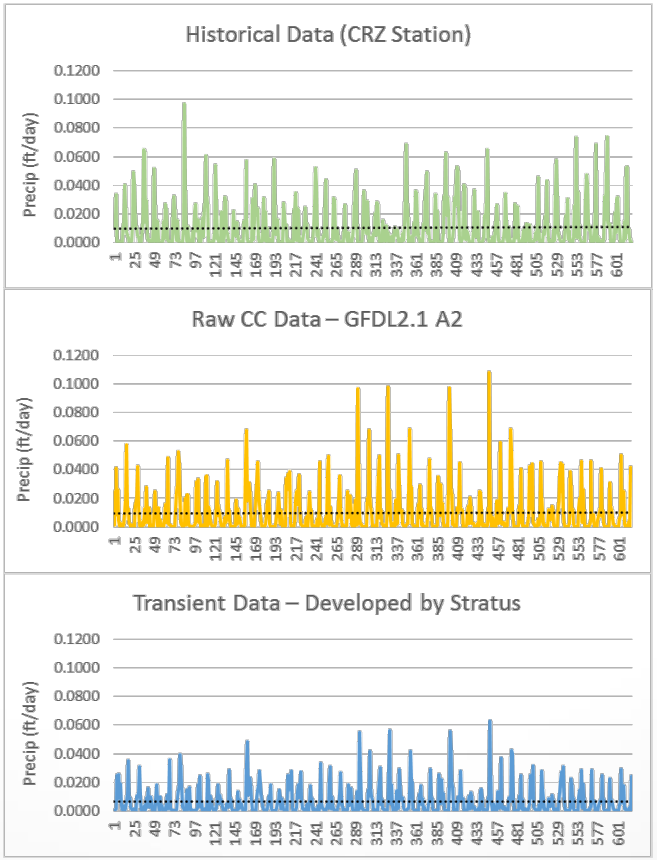
Develop Calibration Model



- Reduces rainfall magnitude
- Preserves projected variability
- Produces a drier and warmer* projection

Balance Hydrologics, Inc.

Development of Input Data

1950 - 2099
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Compute Calibrated Record

Compute Daily Calibrated Record

Specify Water Balance Model

1950 - 2000
Develop Calibration Model

Smoothed monthly flow transitions to better emulate SLR hydrology (> 1.25ΔQ) and improve comparability of HCP analysis with historical results

$$Q_{corrected} = Q_{uncorrected}^{previous\ day} - ((1 - e^{-a}) * (Q_{uncorrected}^{previous\ day} - Q_{uncorrected}^{3\ days\ ahead}))$$

a = 0.5 – 2.0

Filtered the flow record to smooth out artificial daily trends

Projected mass conservation

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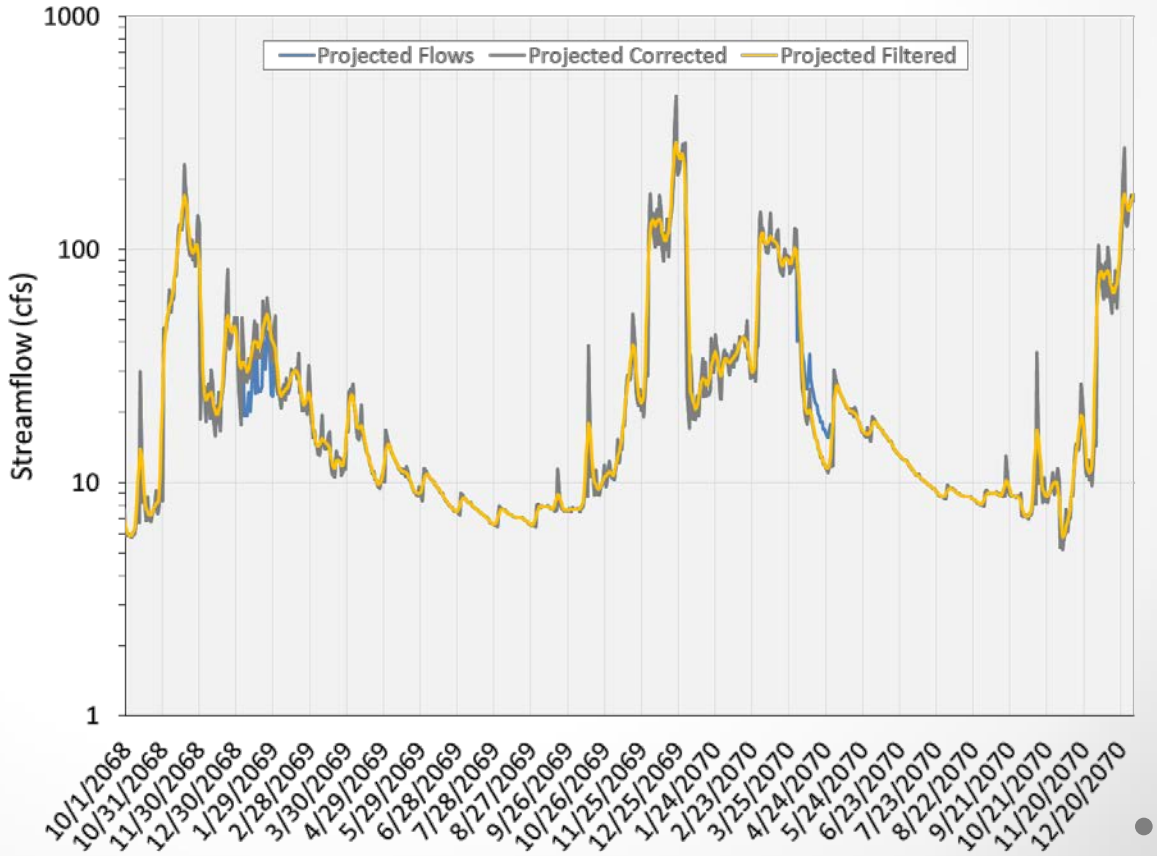

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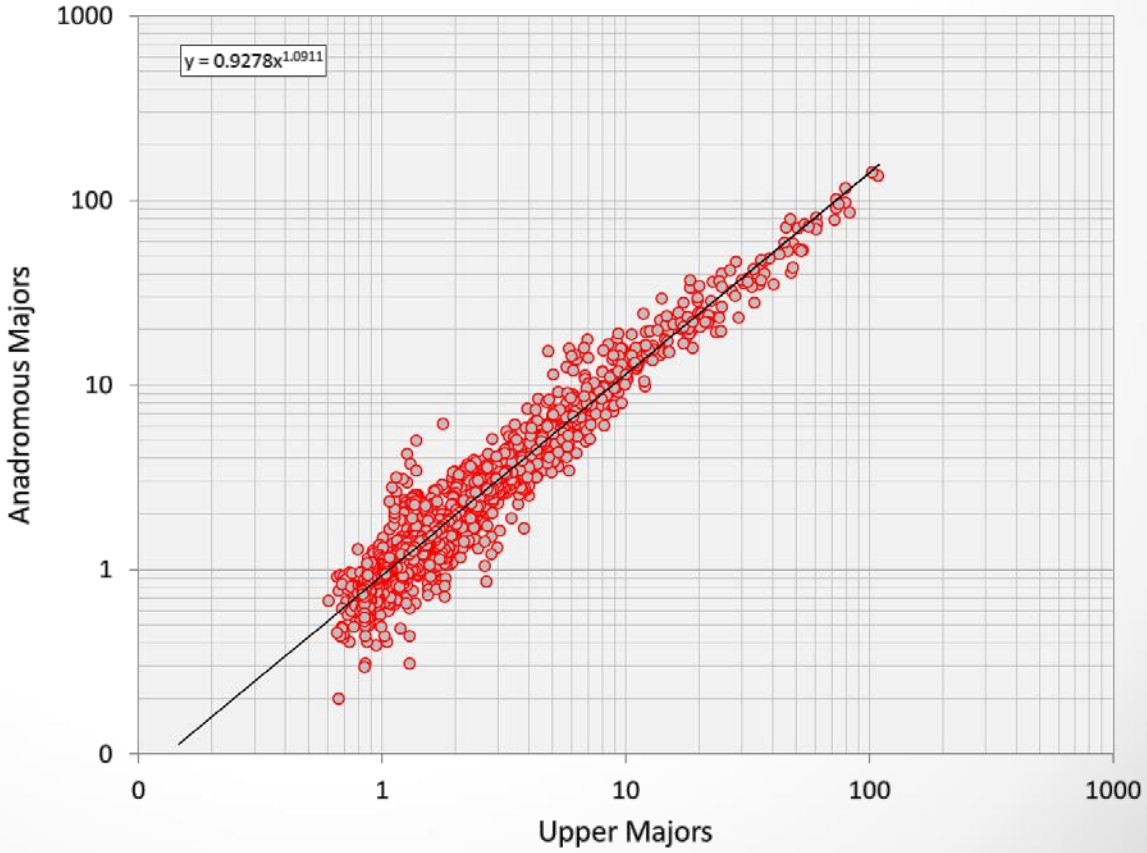
1950 - 2000
Develop Calibration Model



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Development of Input Data

1950 - 2099
Acquire CC Data - CalAdapt

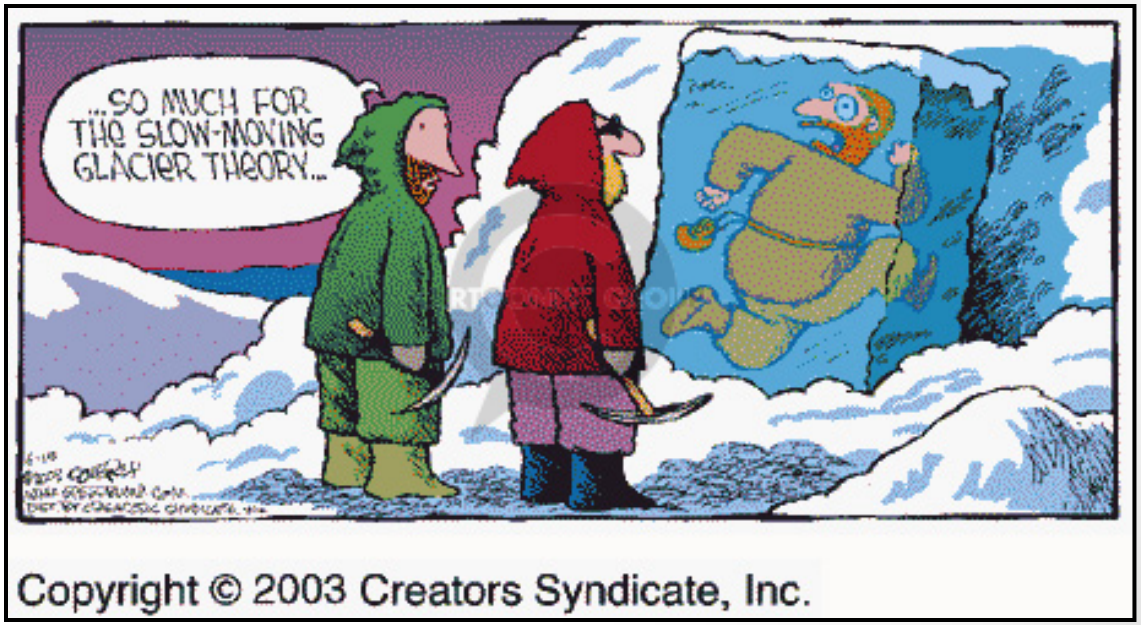
Compute Calibrated Record

Compute Daily Calibrated Record

Run HCP Hydrology Model

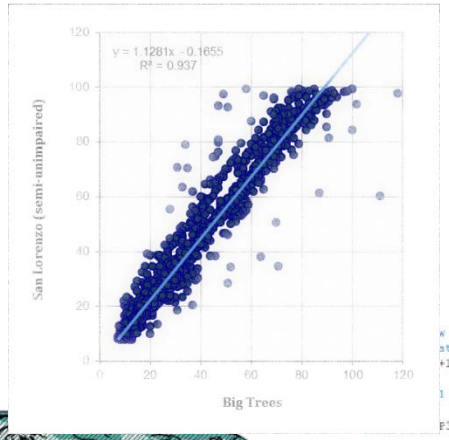
Specify Water Balance Model

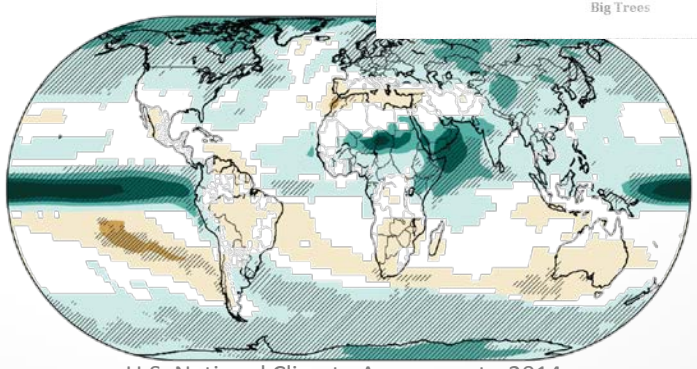
1950 - 2000
Develop Calibration Model



City of Santa Cruz HCP

Review general results:



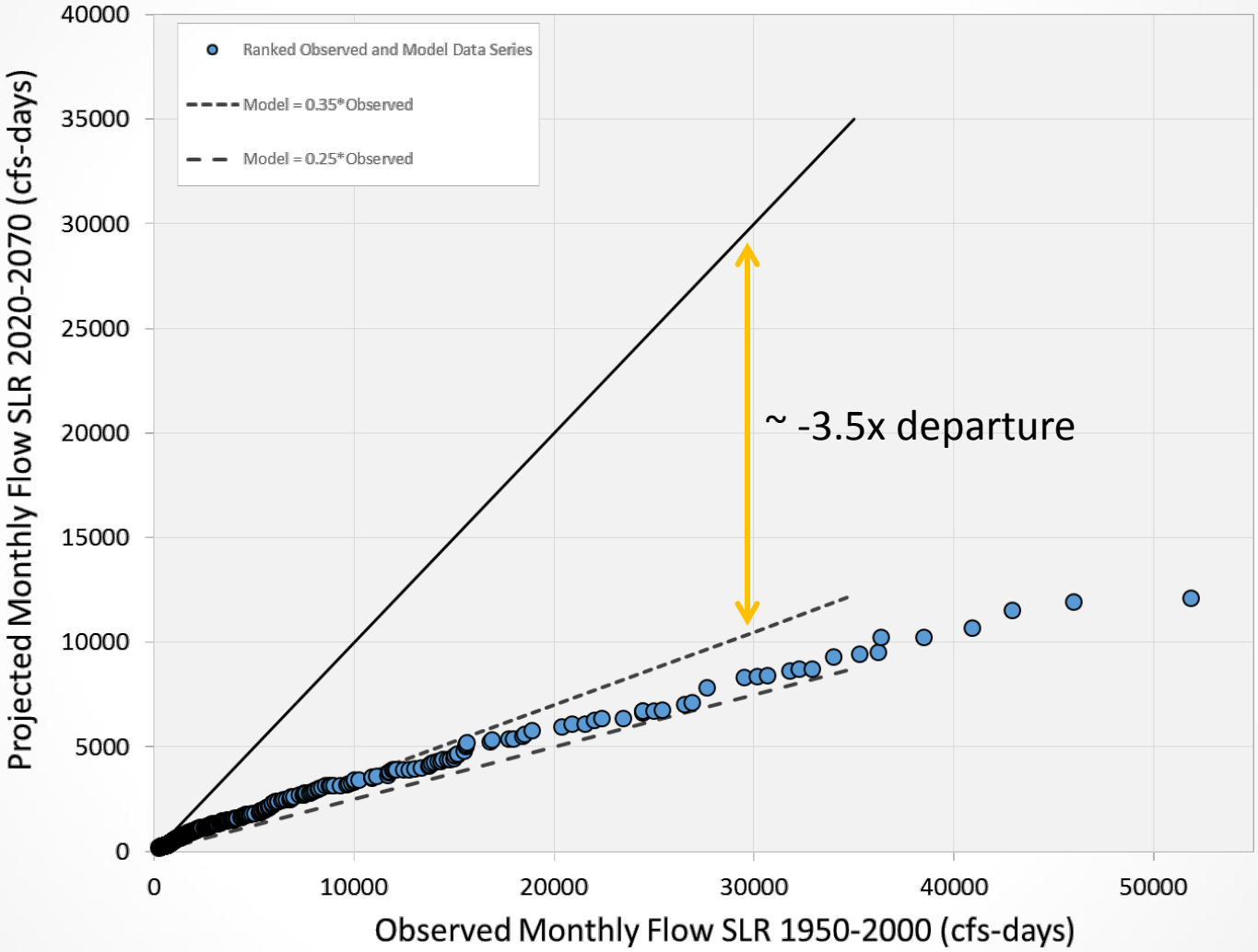


```
% the day after is less than the
ation trigger
+1,4) < MJAMig(1,1)

l i-1 WY type is dry or drier and cell i is

P3(i-1,8) <= 2 && MJAHCP3(1,8) >= 3

% This series of operations/queries will
% compute the vector length of flows that
% exceed some threshold from the last value
% above the threshold. This is used to
% accumulate counts against a counter that
% begins if the hydrologic condition
% changes as queried above.
less = 13:-1:1;
z = length(less);
flow = MJAHCP3(i-less,4);
[flowgreater] = find(flow > MJAMig(1,1));
numberofvalues = length(flowgreater);
last = max(flowgreater);

if numberofvalues >= 2

    MJAHCP3(i,6) = 201 + (z - last);
    MJAHCP2(i,7) = MJAMig(1,2);
    MJAHCP3(i,7) = MJAMig(1,2);
```

U.S. National Climate Assessment - 2014

General Results

GFDL2.1 A2

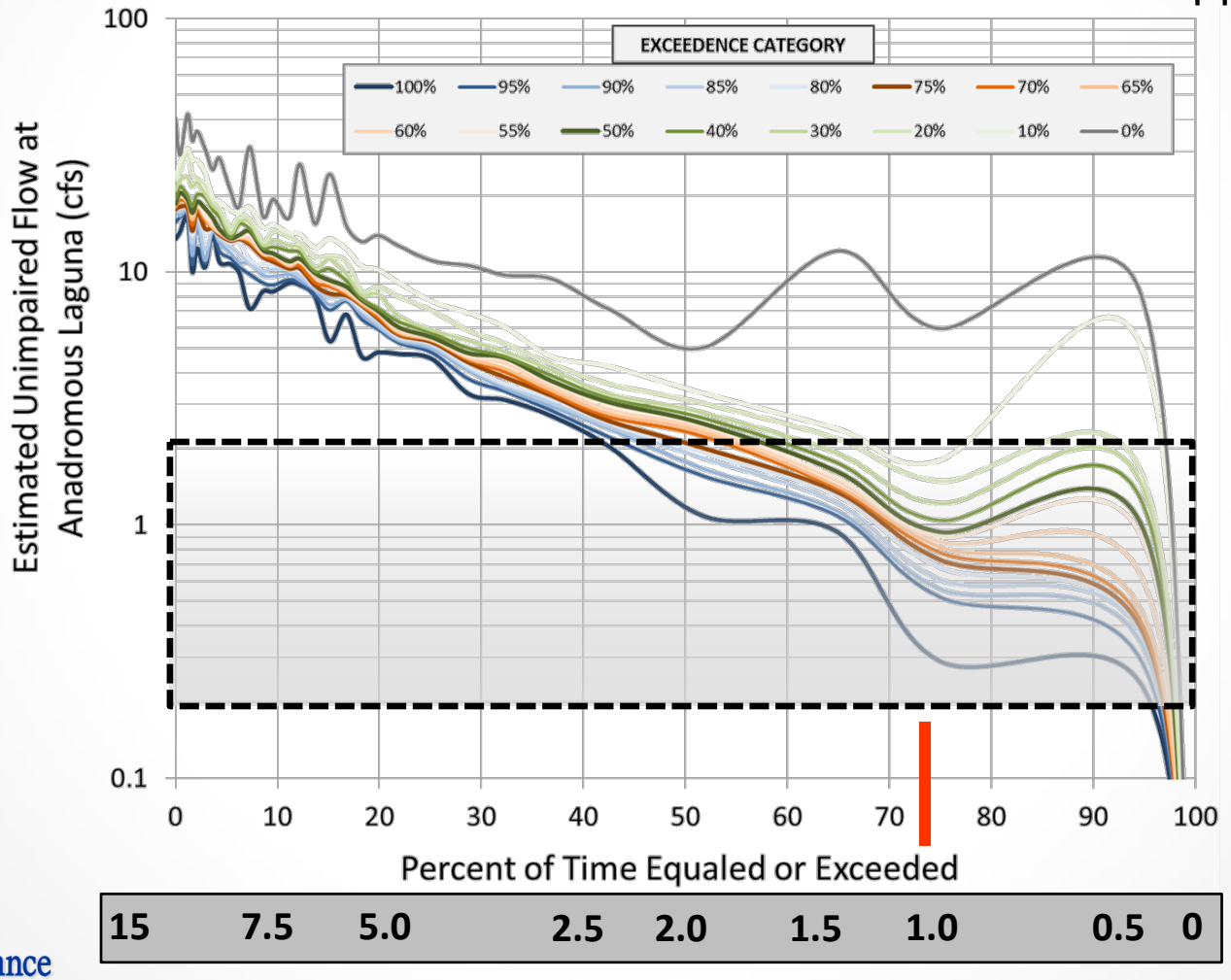


MOTIVATION

RECENT

Habitat and Supply Needs Pose a Serious Challenge

Difficult and sometimes not feasible to meet habitat and water supply needs.



WY 2003 - 2011

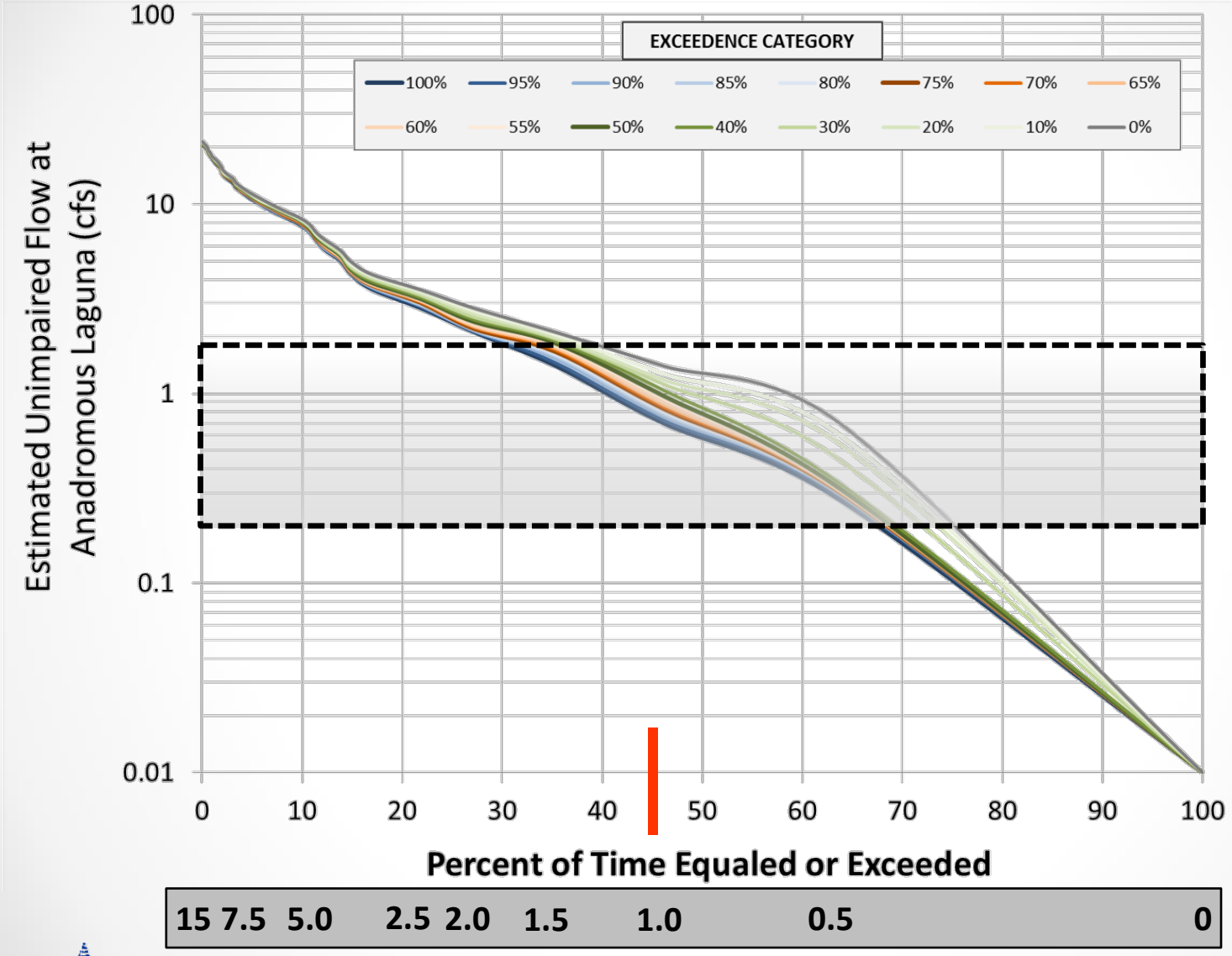
Range in Rearing Flow Goal for Anad. Laguna

Upper Laguna Flow (cfs)

Balance Hydrologics, Inc.

General Results

GFDL2.1 A2



WY 2020 - 2028

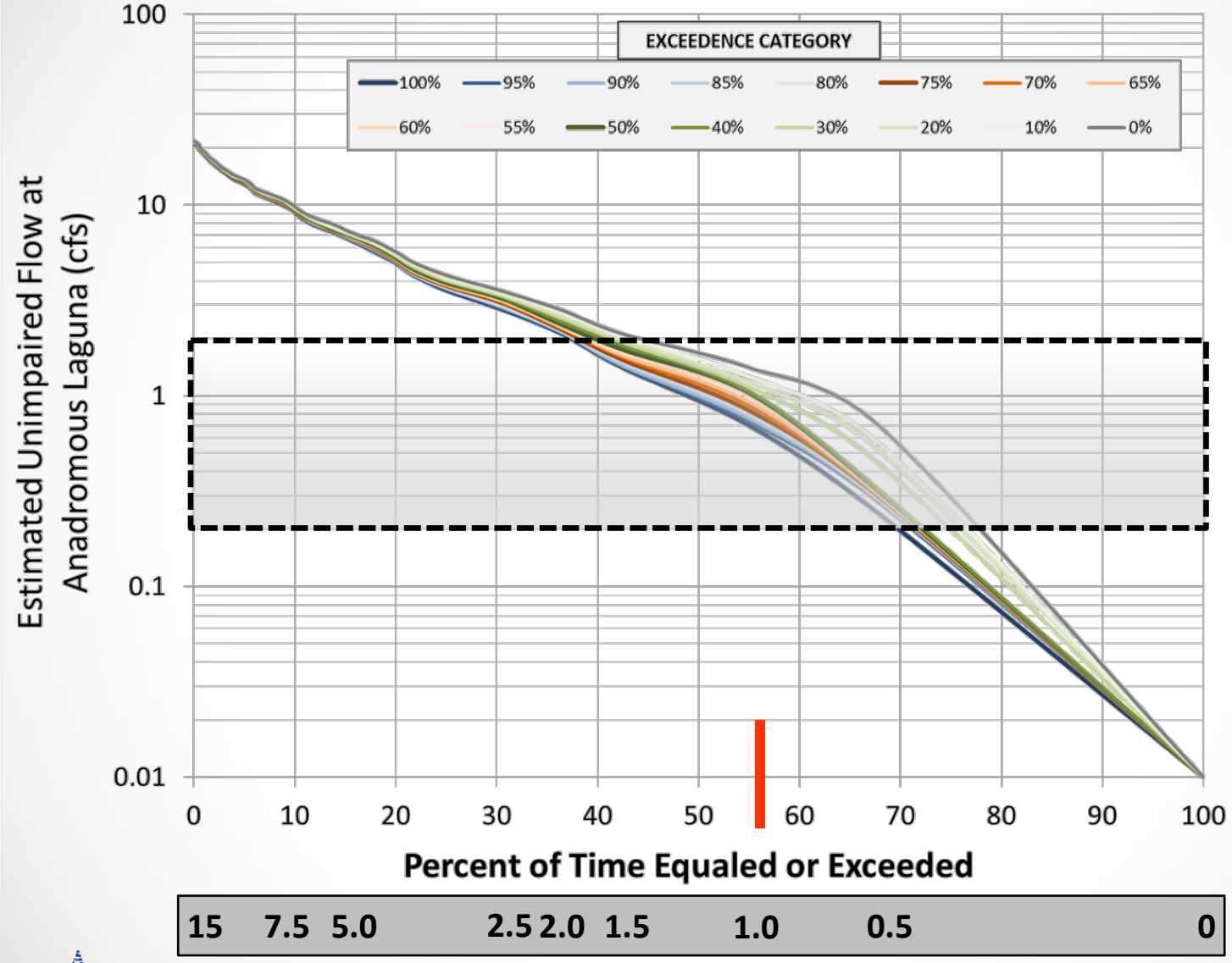
Range in Rearing Flow Goal for Anad. Laguna

Upper Laguna Flow (cfs)

Balance Hydrologics, Inc.

General Results

GFDL2.1 A2



WY 2045 - 2053

Range in Rearing Flow Goal for Anad. Laguna

Upper Laguna Flow (cfs)

Balance Hydrologics, Inc.

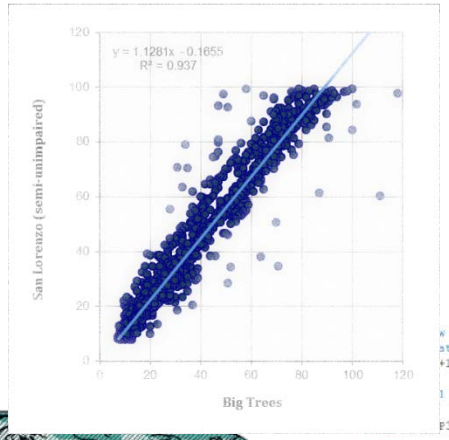
Next Steps

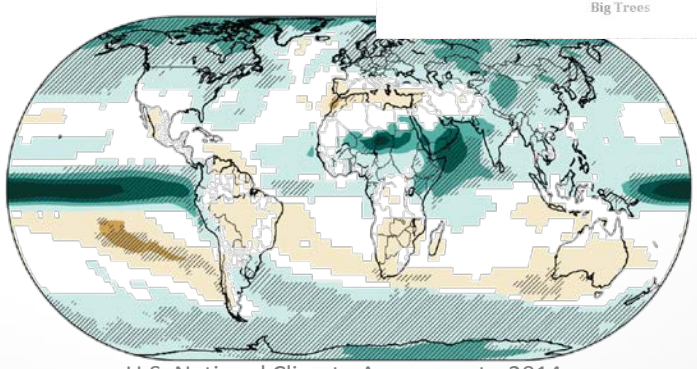
Building the input files to run analysis for B1 emissions scenario – complete by early May

Review Climate Change analysis with regulatory agencies and work to factor CC into HCP

Additional scenarios, rules testing, etc. ?

Questions and Discussion





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