Headwaters in a Changing Climate: Implications for Water Supply and Forest Health

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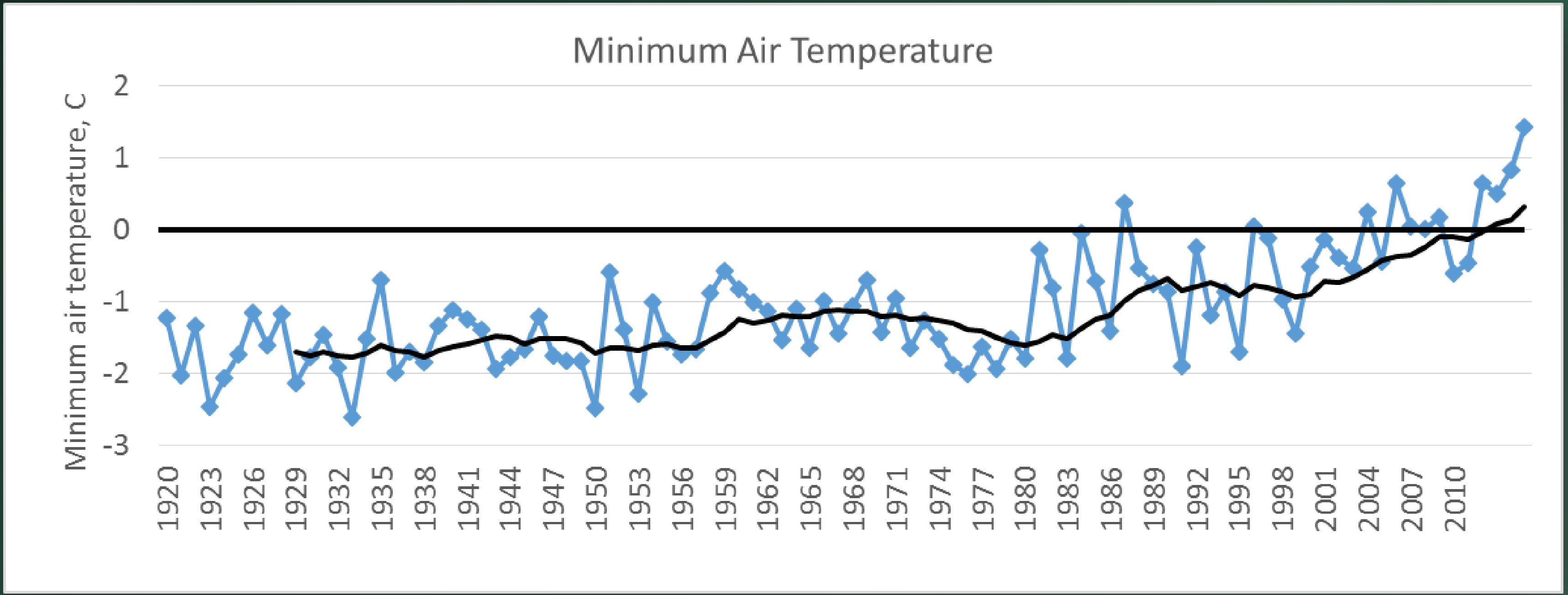
USGS California Water Science Center (CAWSC)

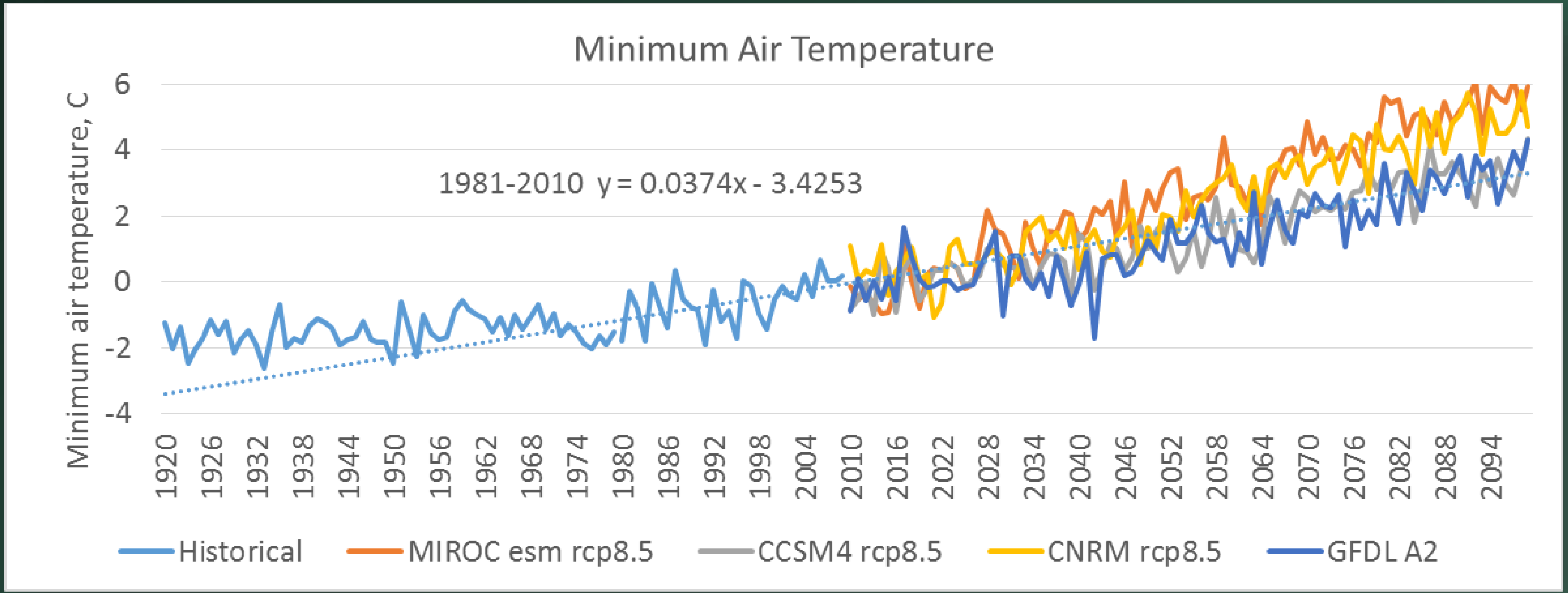
- One of 28 Centers in US
- Provides foundational data and scientific analyses to address the water issues facing the nation.
- Conducts hydrologic monitoring
- Partners with state, regional, local, tribal, and federal entities to address key CA water issues:
  - Water supply and availability
  - Water quality assessments and sediment dynamics
  - Climate change, variability, droughts, and floods
  - Aquatic ecology
  - Groundwater availability and use

Lake Tahoe Basin
Minimum Air Temperature



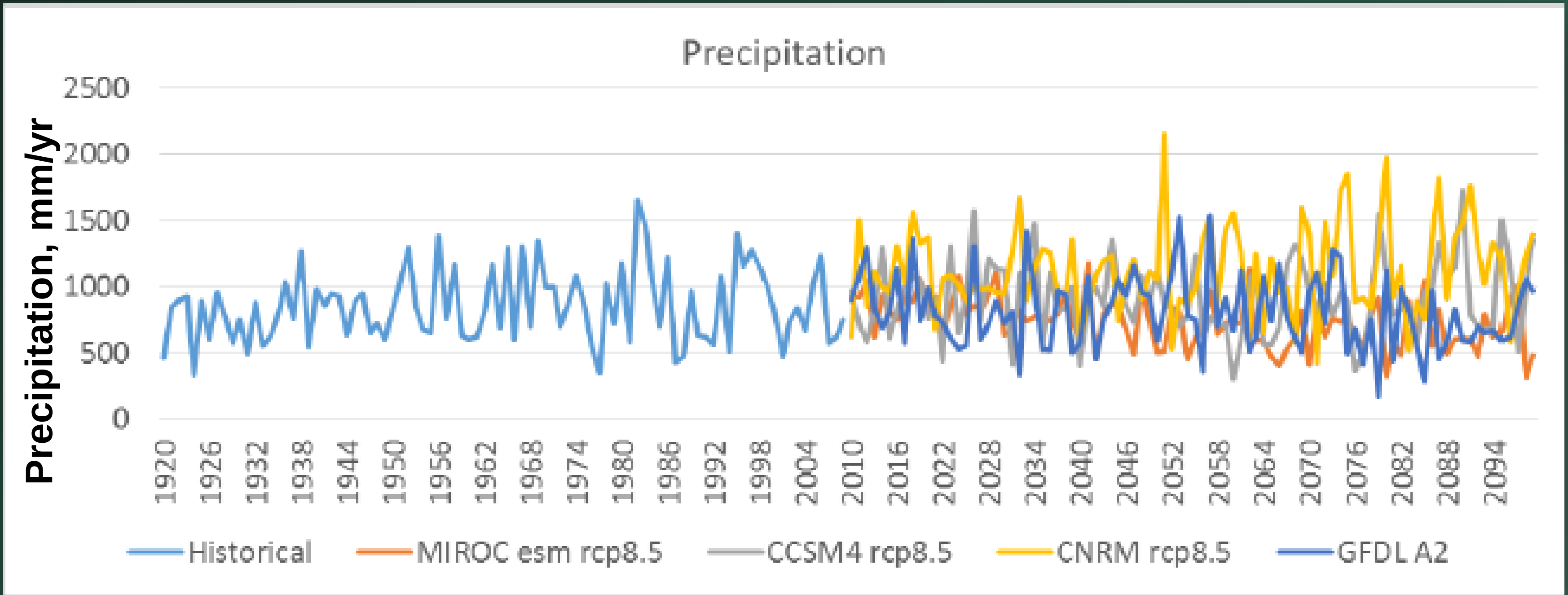
11 of the last 20 years have average minimum air temperatures above 0 C

Lake Tahoe Basin
Minimum Air Temperature



By mid century all years have average minimum air temperatures above 0 C

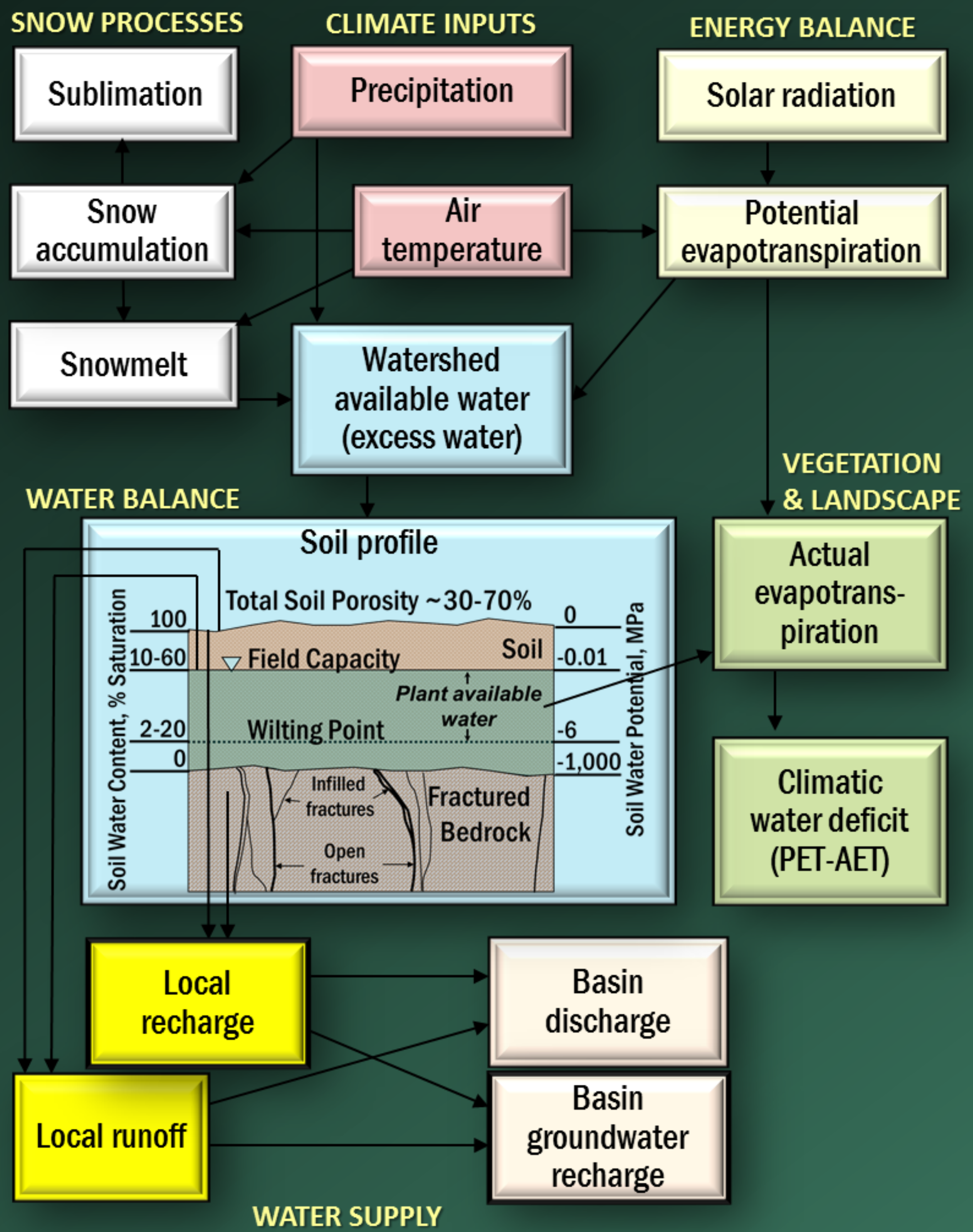
Lake Tahoe Basin Precipitation



Model consensus is poor, but nearly all models project more variability, higher extreme years, more droughts


Changes in Water
Availability

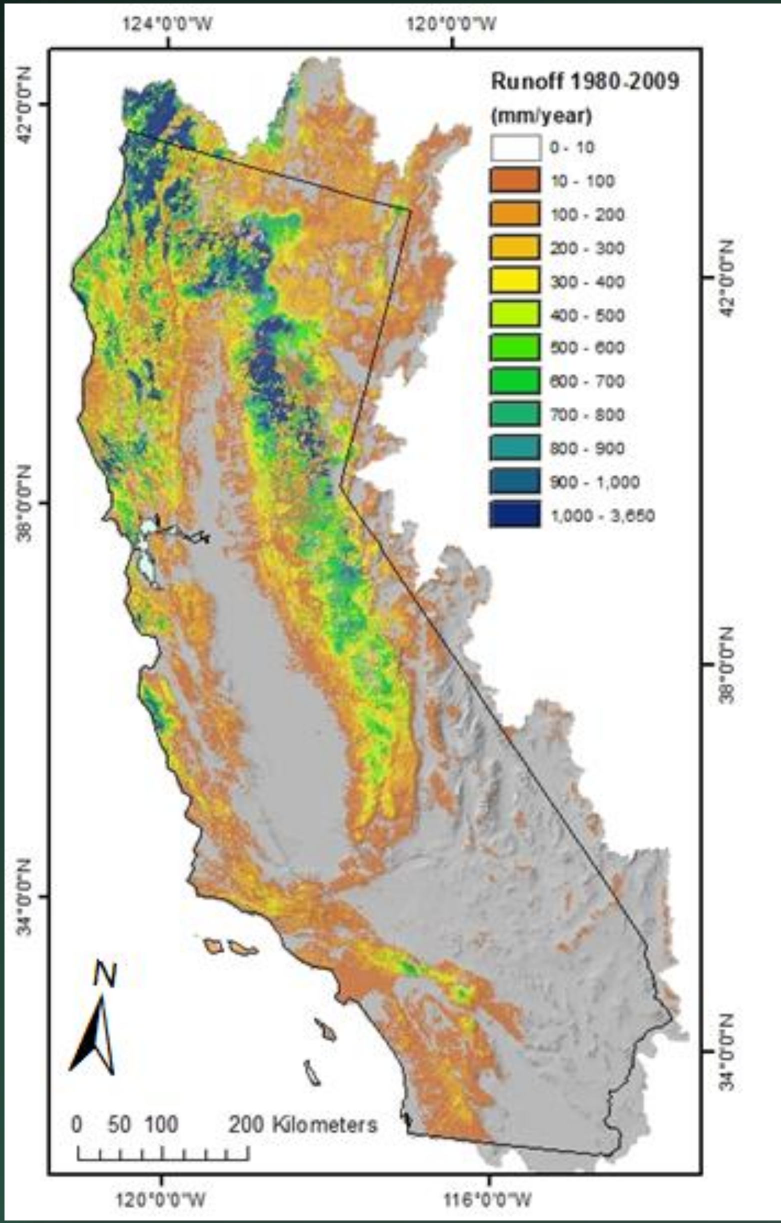
Basin Characterization Model



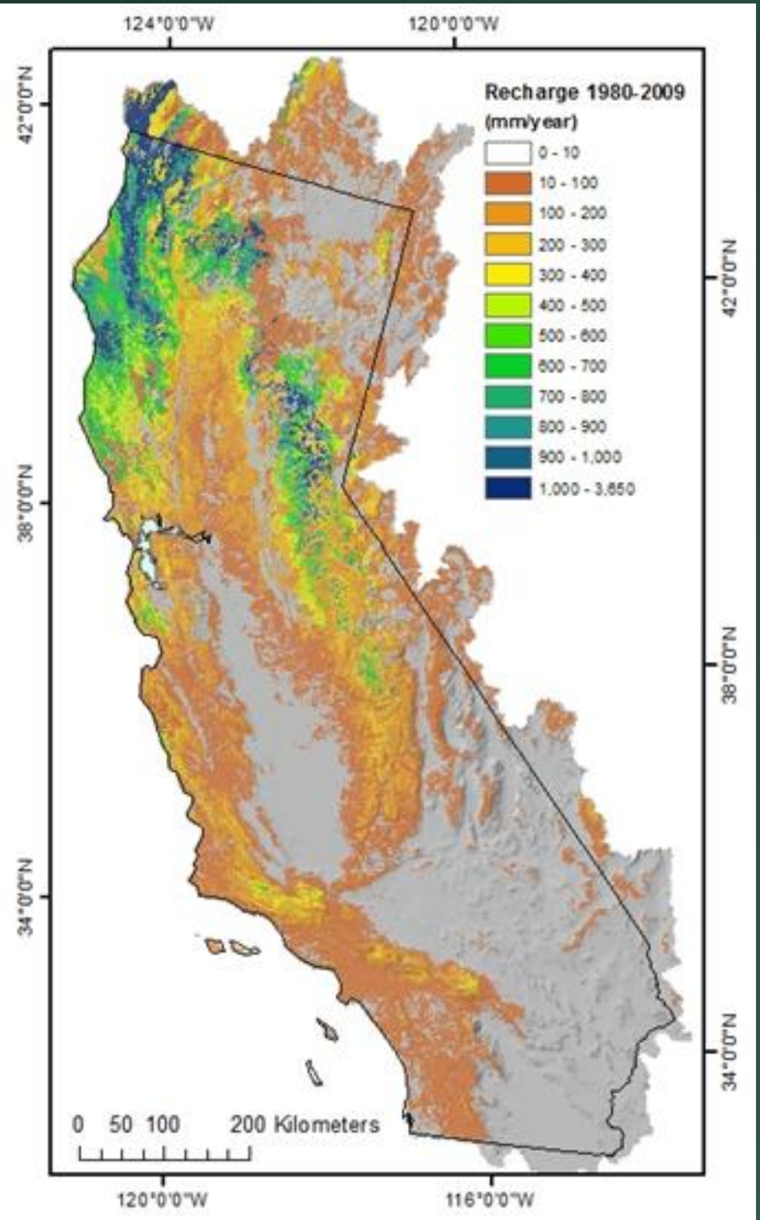
A grid-based water balance model

- Uses gridded climate data downscaled to fine spatial scales 270-m (historical and future)
- Incorporates detailed soil properties and estimates of bedrock permeability
- Calculates spatially distributed water supply as recharge and runoff
- Calculates climatic water deficit as an estimate of demand and stress

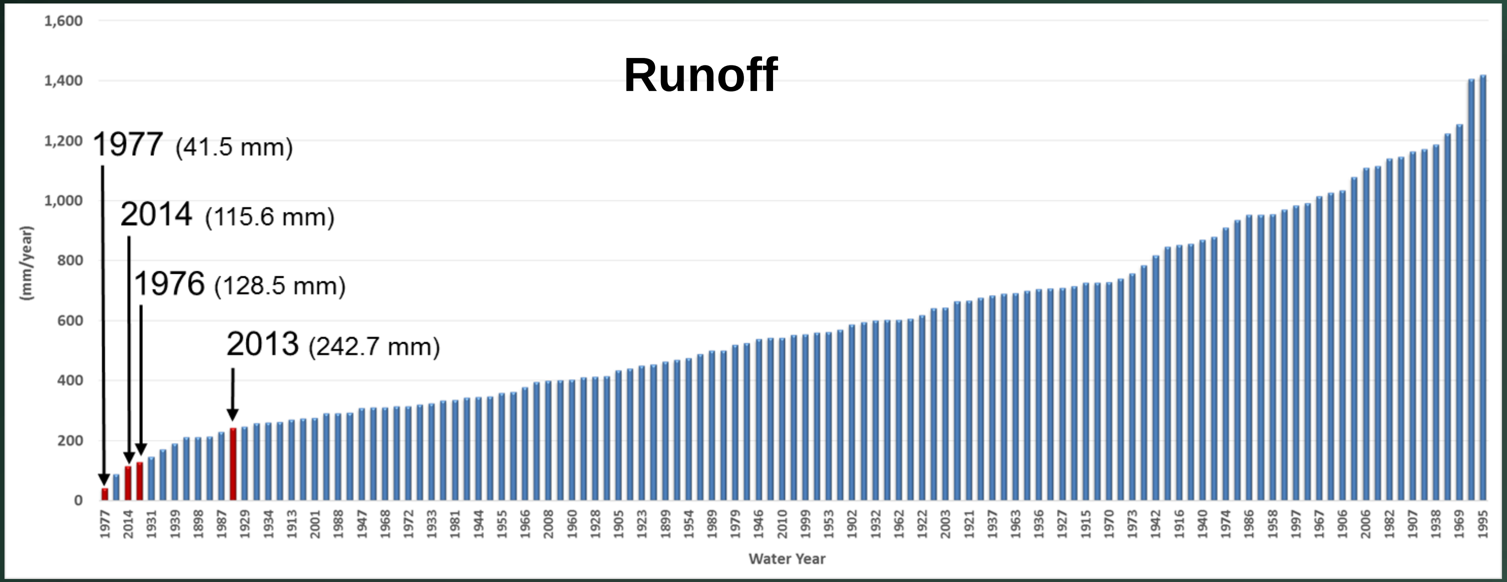
Runoff

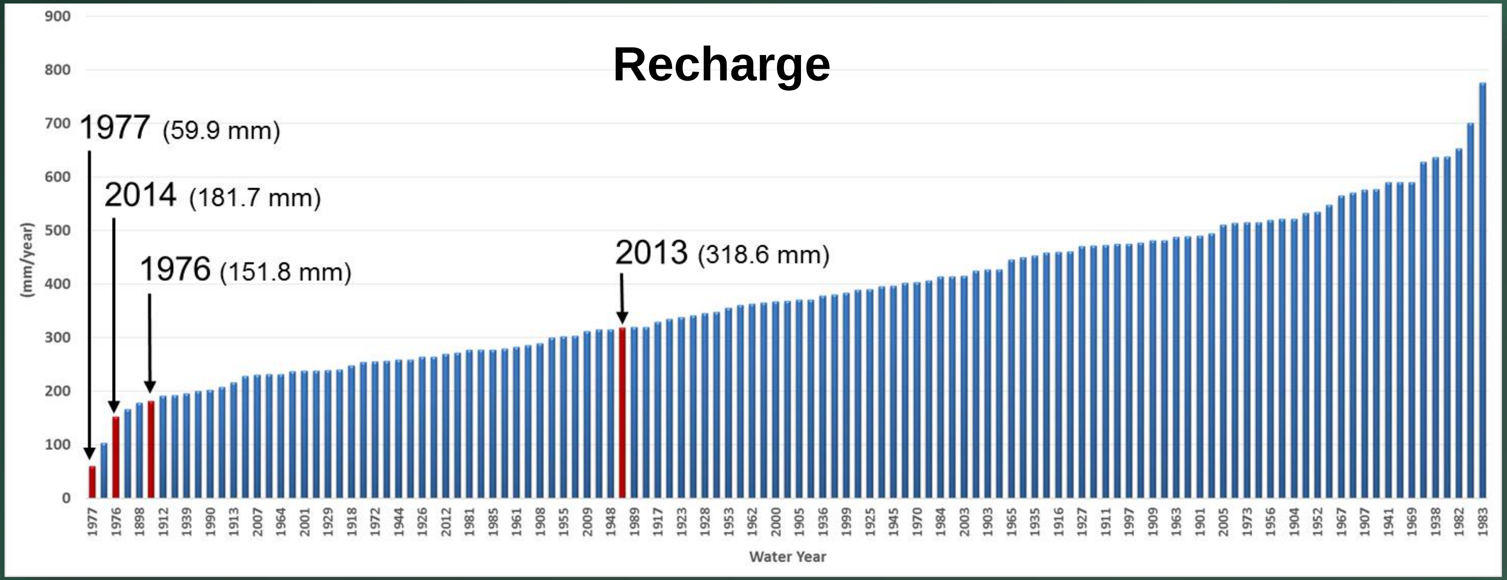


Recharge



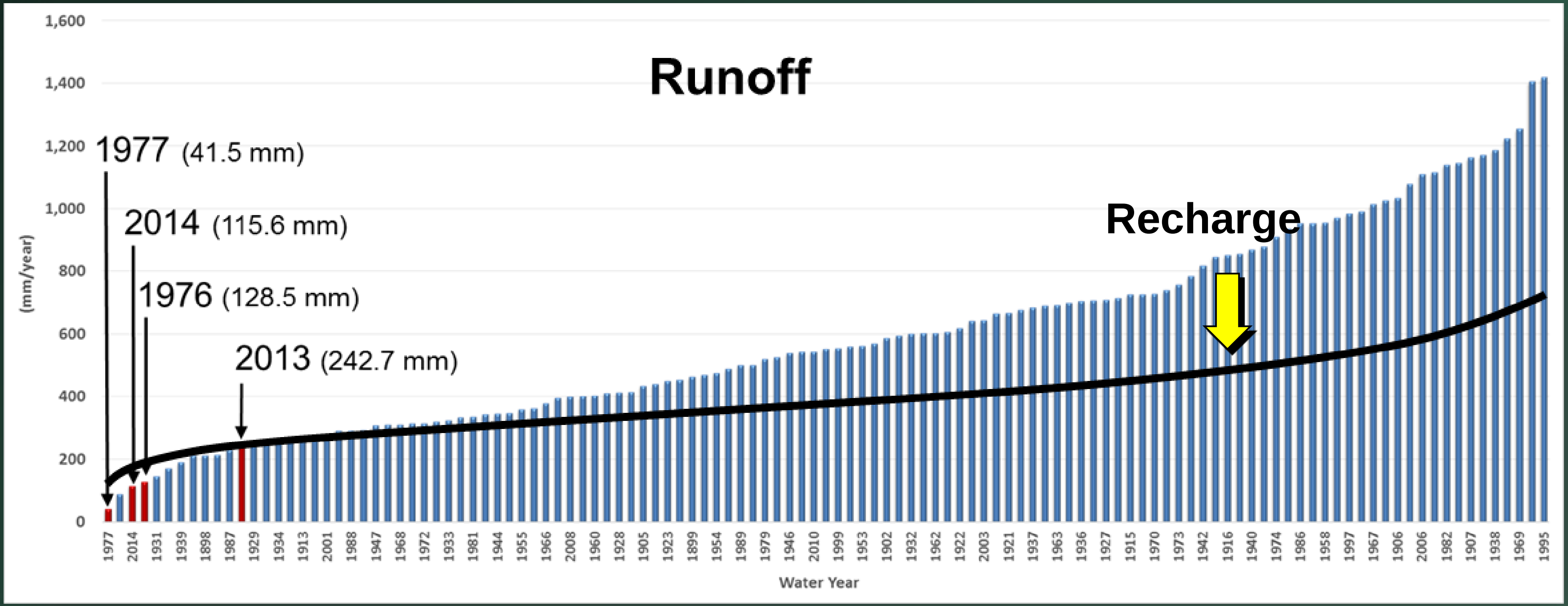
Sum of Sierra Nevada Regions





Sacramento River, San Joaquin River, Tulare Lake regions

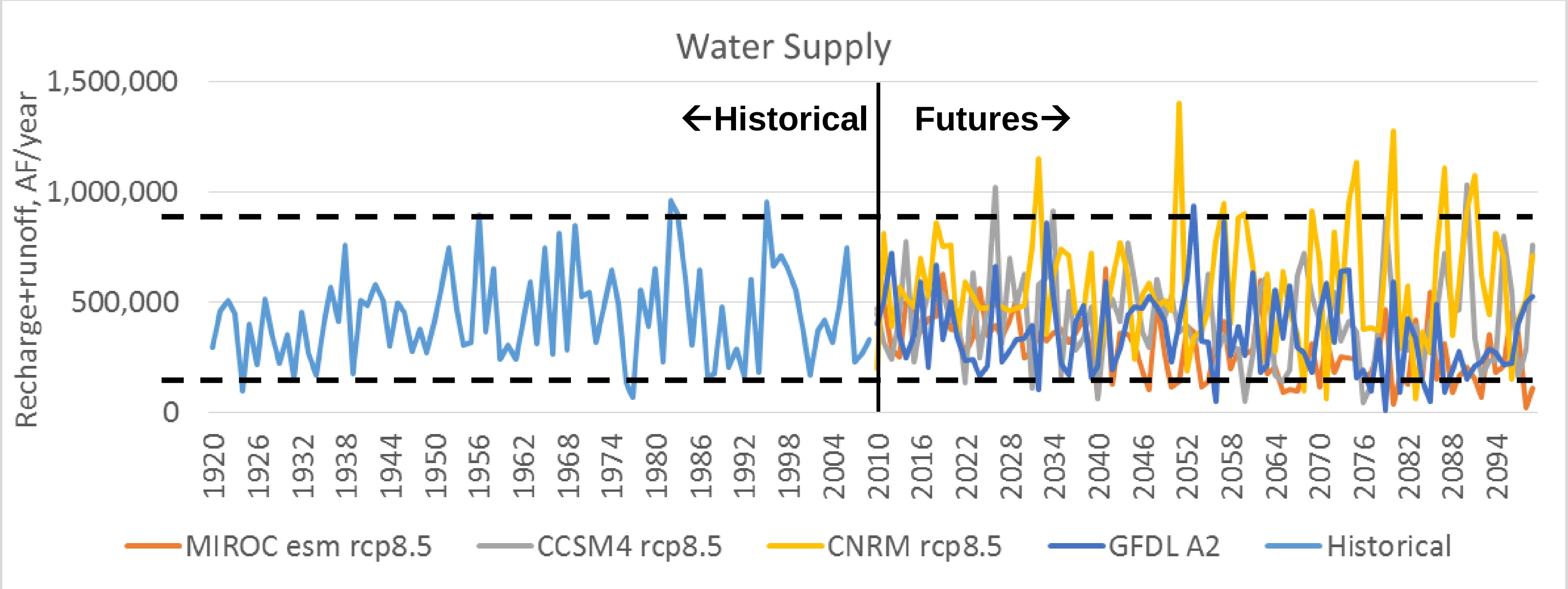
Sum of Sierra Nevada Regions



Runoff (bars) and Recharge (line) in California

Sacramento River, San Joaquin River, Tulare Lake regions

Extreme Water Supply in the Future
Recharge + Runoff



Years exceeding 850,000 AF

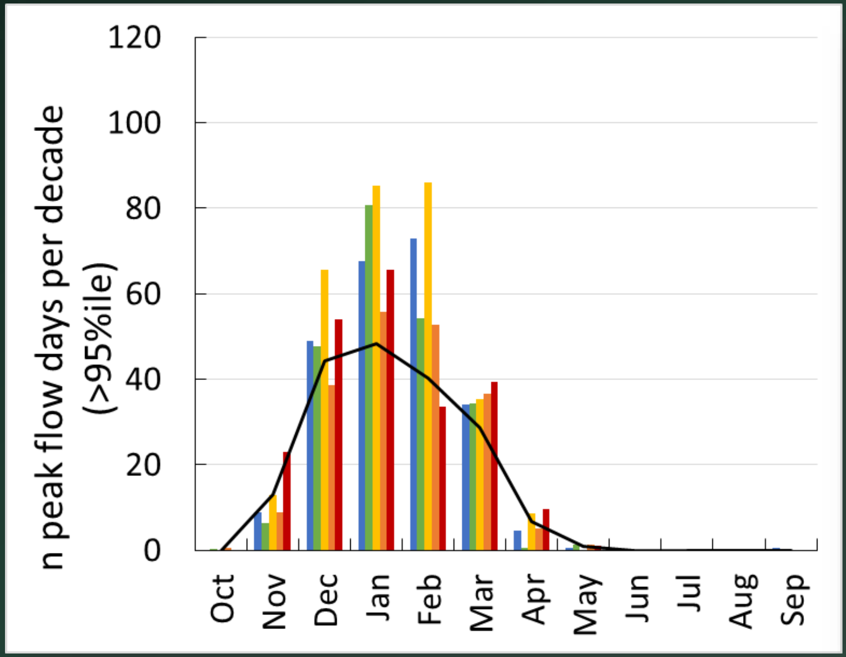
0	4	13	3	3

Years lower than 160,000 AF

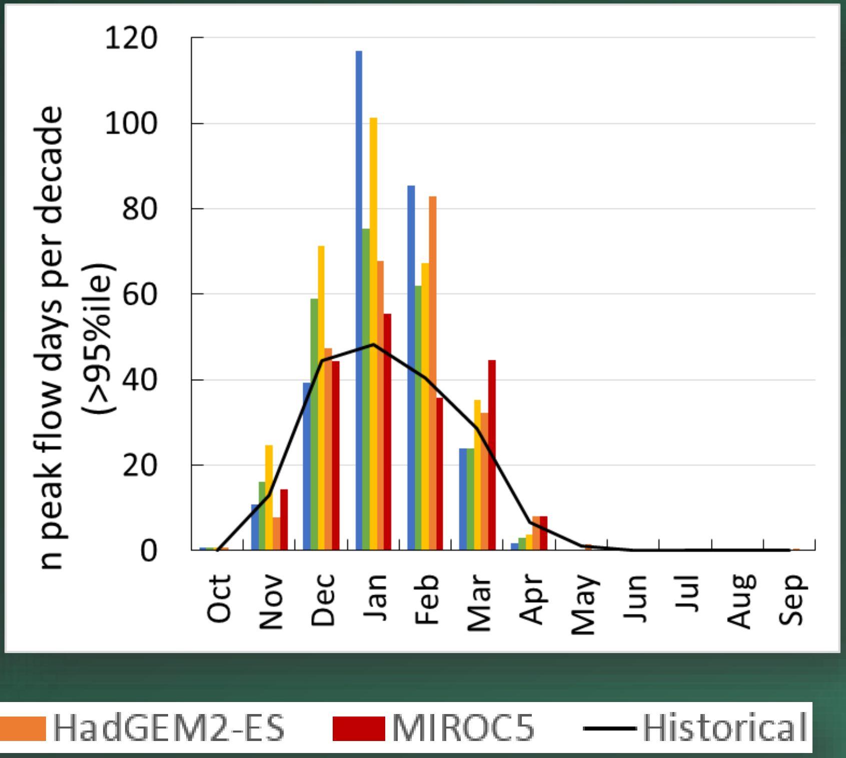
23	10	4	12	7

Number of peak days per decade (top 5%)

RCP 4.5
(mitigated emissions)



RCP 8.5
(business-as-usual)



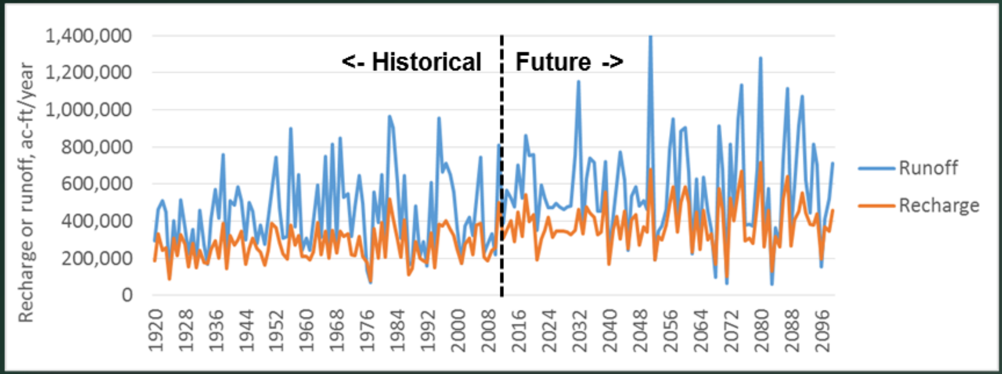
Take home message:
more sediment transport, erosion → water quality issues

Recharge and runoff

- Recharge infiltrates into the soil and beyond plant roots
- It stays in the watershed longer than runoff to produce late season baseflows
- Runoff moves downhill to reservoirs or leaves the watershed

Recharge and Runoff in Sierra Nevada

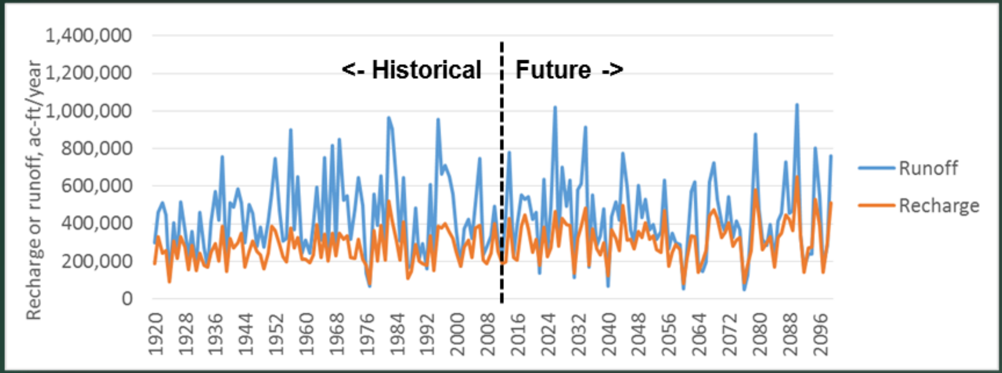
Warm & High Rainfall



Average Historical Recharge 249 mm/yr Runoff 410 mm/yr

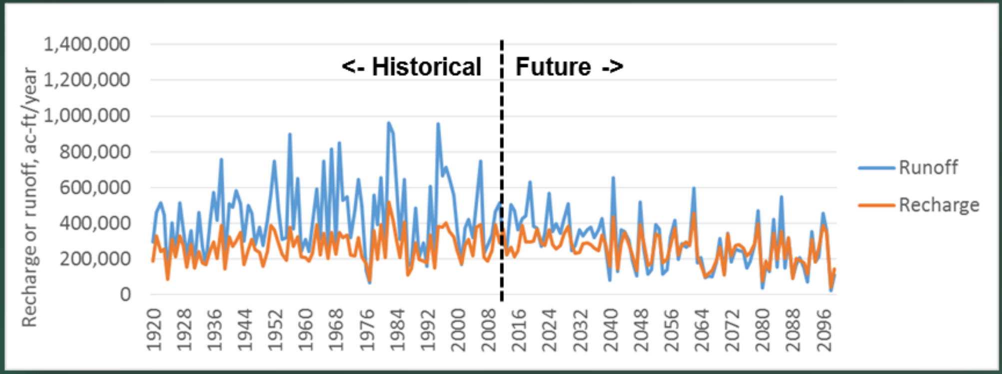
Average Future Recharge 362 mm/yr Runoff 538 mm/yr

Warm & Moderate Rainfall



Average Future Recharge 296 mm/yr Runoff 405 mm/yr

Hot & Low Rainfall (worst scenario)



Average Future Recharge 242 mm/yr Runoff 273 mm/yr

Over range of future conditions: **Recharge goes up or or *doesn't change in dry conditions***
Runoff ranges from a large increase to a large decrease

What about snow?

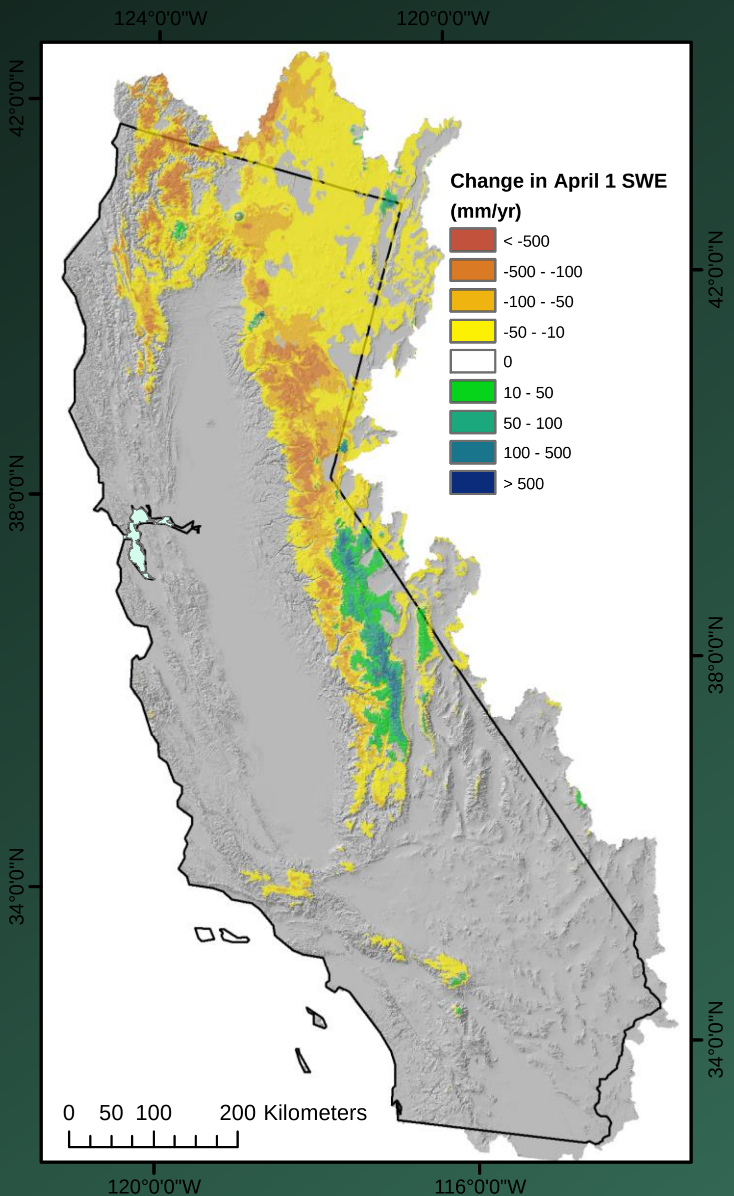
- It stores our water supply so we can use it when there's no precipitation
  - Creates baseflows lasting through the summer
- It reduces environmental demand as the seasonal temperatures rise and the ET season ramps up in spring and summer
- Provides snow dependent habitat

Snowpack

April 1 Percent of Average

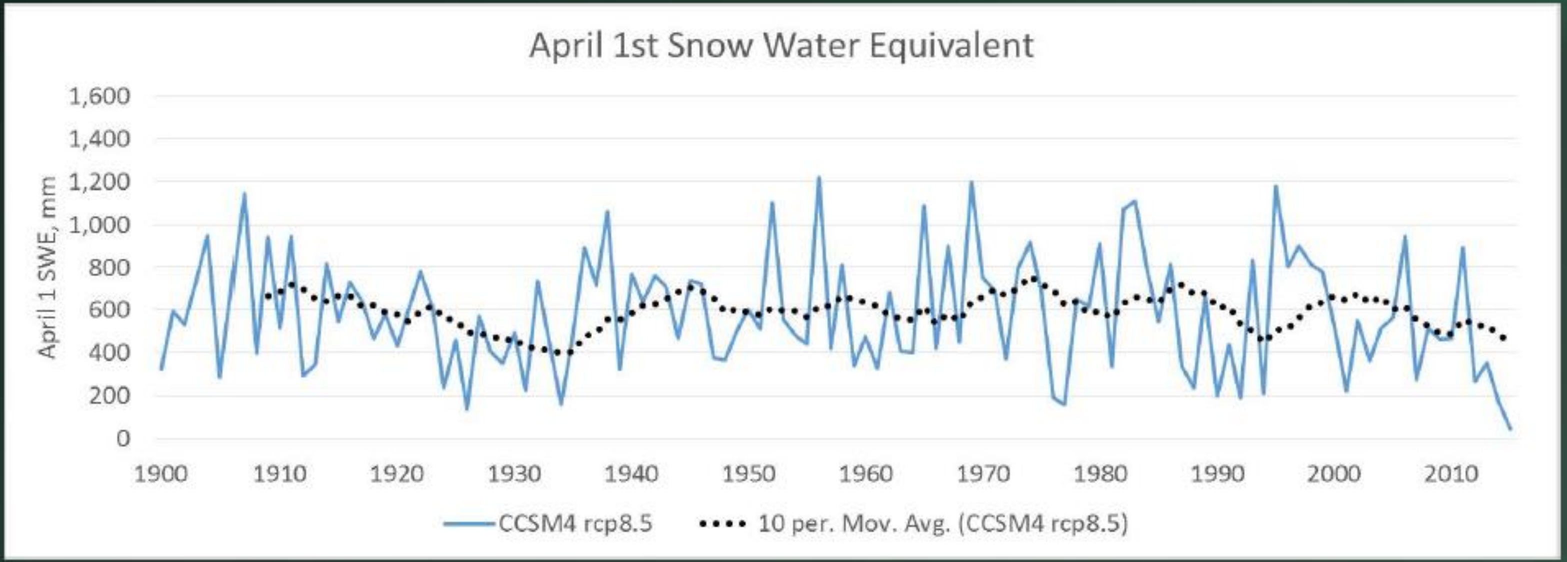
2018	52%
2017	160%
2016	85%
2015	5%
2014	25%
2013	40%
2012	50%
2011	171%
2010	104%
2009	83%
2008	102%
2007	39%

Changes in April 1st snowpack (SWE)

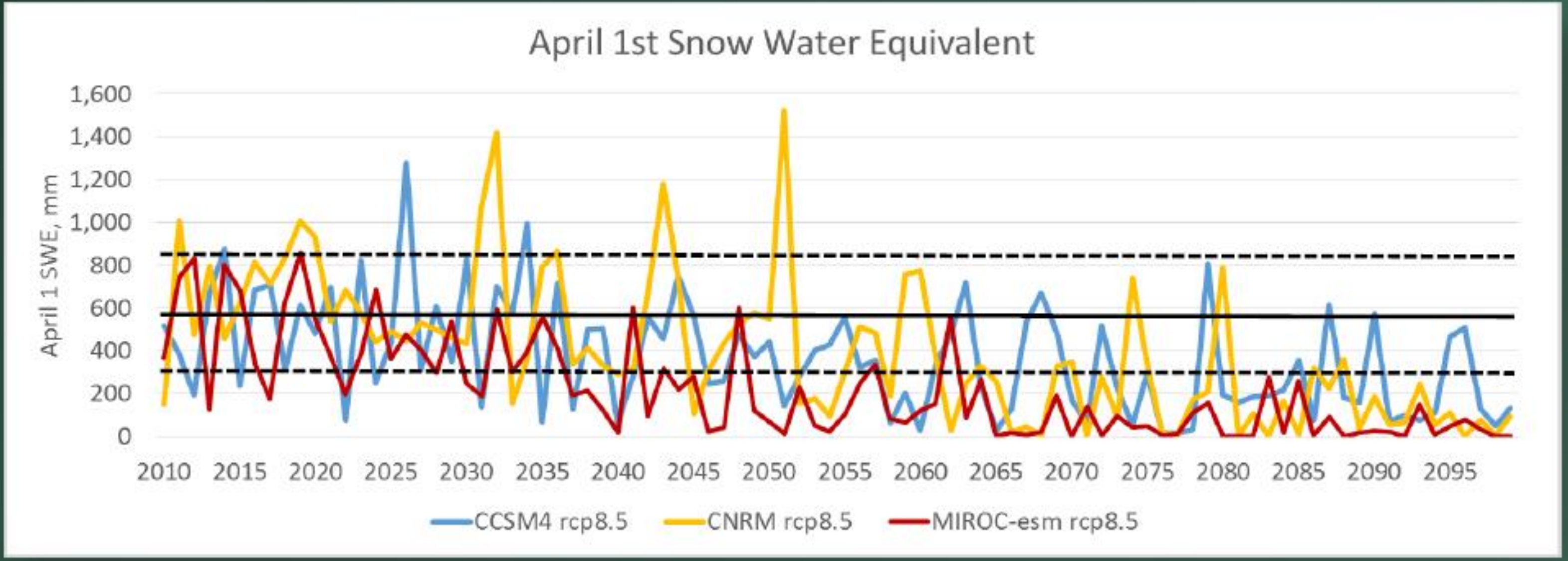


- Change from baseline (1951-1980) to current (1981-2010)
- Decreases due to warming at all but the highest elevations

What about the futures?



Range of projected futures



SD
Mean
SD

Implications for Sierra headwaters

- As snowpack/cover is reduced, what happens to our water supply….runoff, recharge?
- What are the implications of increased environmental demand?

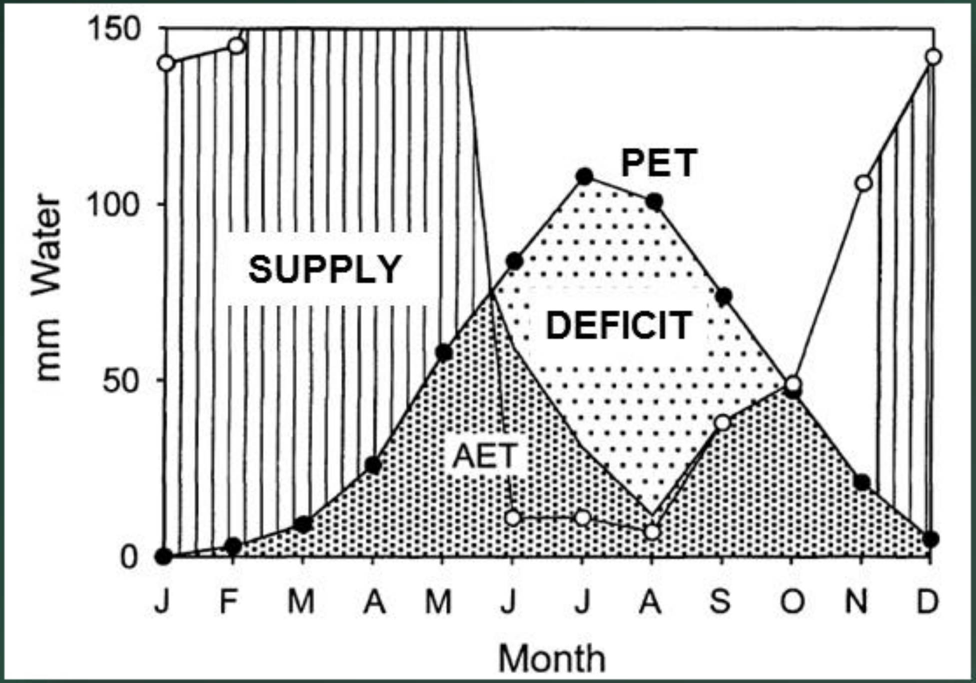
Hotter and longer dry seasons

➡ ***More Landscape Stress***

Climatic Water Deficit

Annual evaporative demand that exceeds available water

Potential – Actual Evapotranspiration

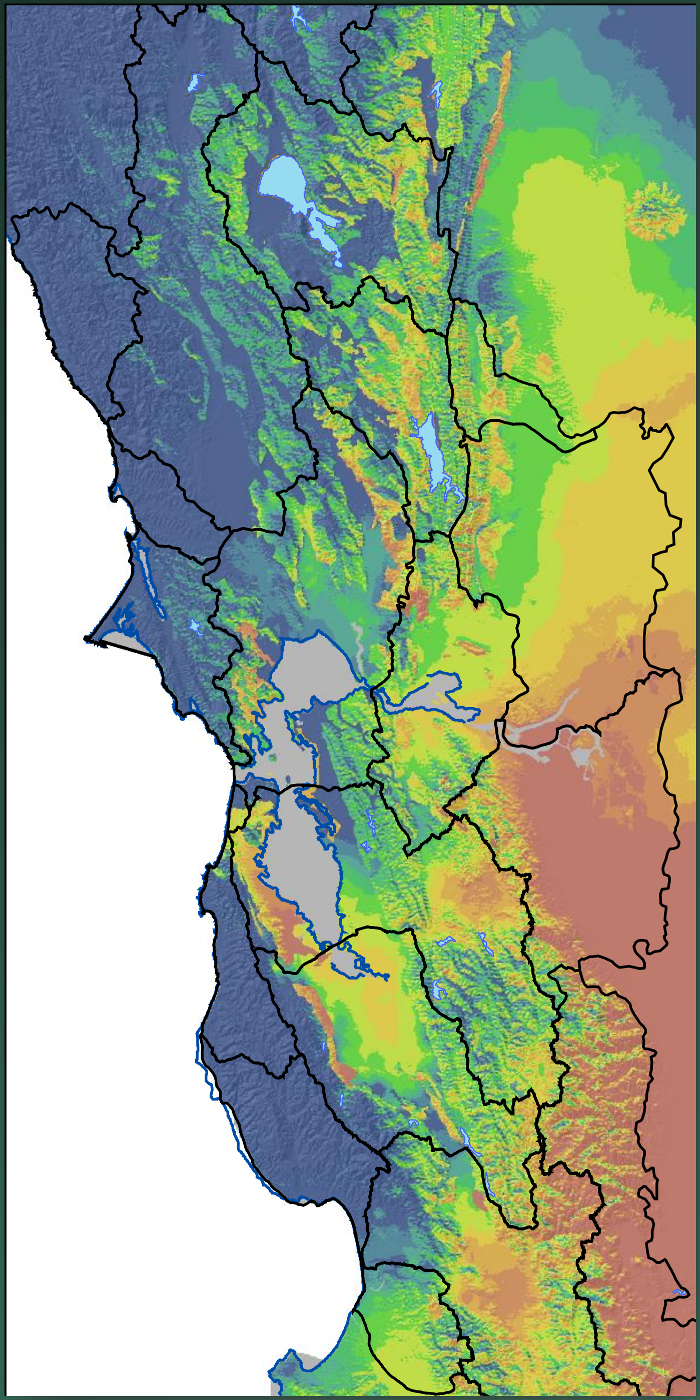


- Integrates climate, energy loading, drainage, and available soil moisture storage
- Addresses irrigation demand
- Defines level of stress on landscape

Climatic Water Deficit

Annual evaporative demand that exceeds available water

Potential – Actual Evapotranspiration

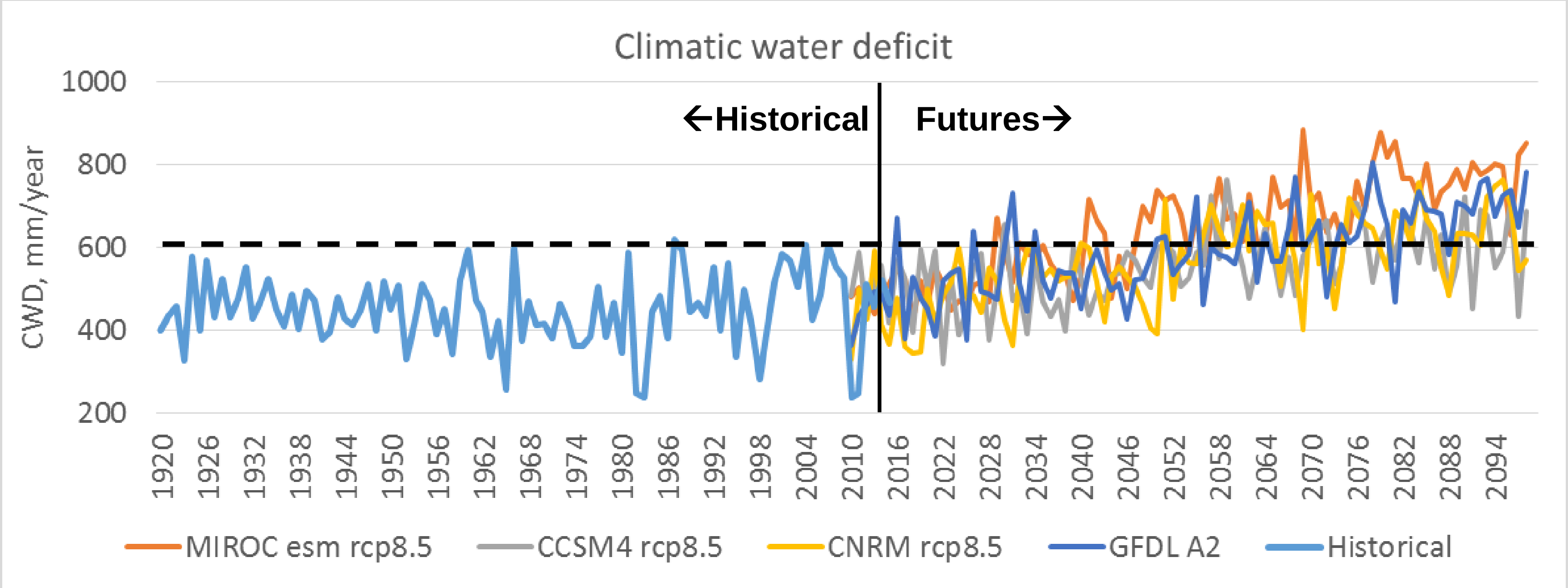


2001

mm/yr

- <775
- 775 - 800
- 800 - 825
- 825 - 850
- 850 - 875
- 875 - 900
- 900 - 925
- 925 - 950
- 950 - 975
- 975 - 1000

Extreme CWD in the Future

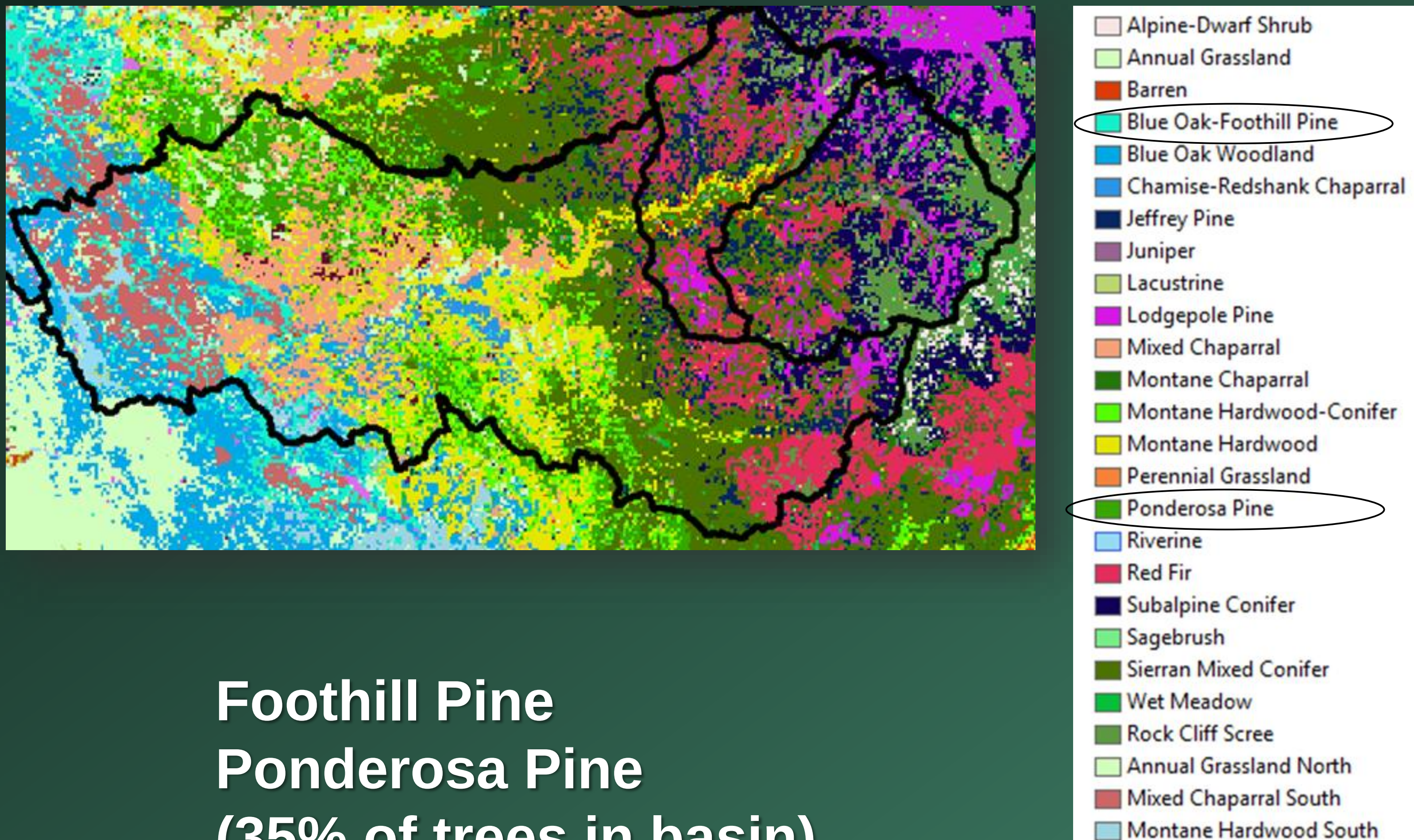


Years exceeded 600 mm

56	**24**	**31**	**39**	**3**

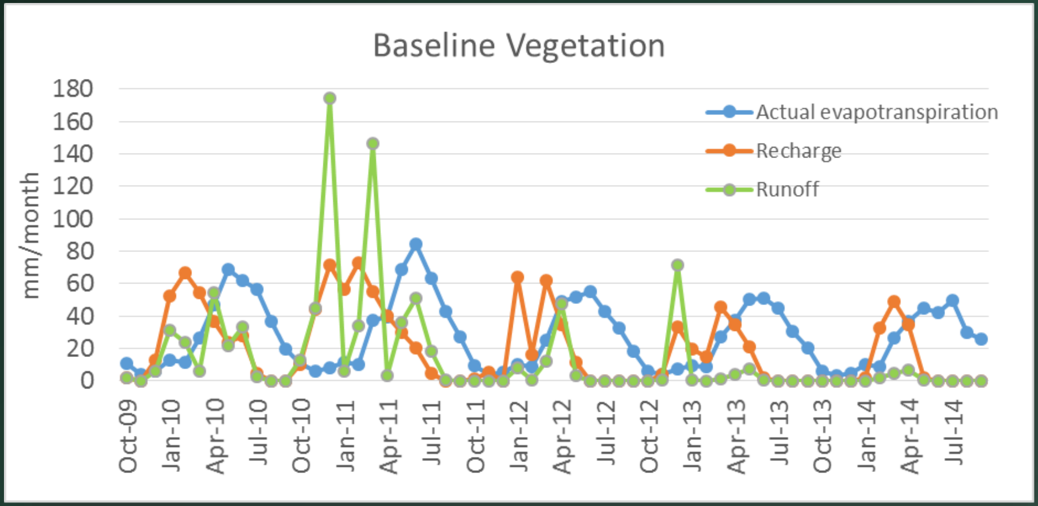
Question: what happens to the water in my basin if the trees die?

Merced River Basin Forest Die-off 2015

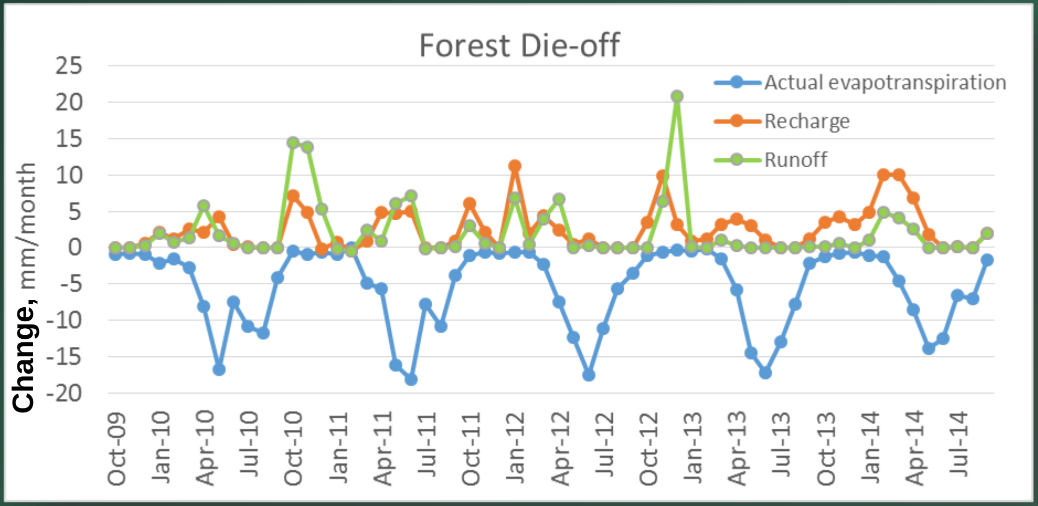


Foothill Pine
Ponderosa Pine
(35% of trees in basin)

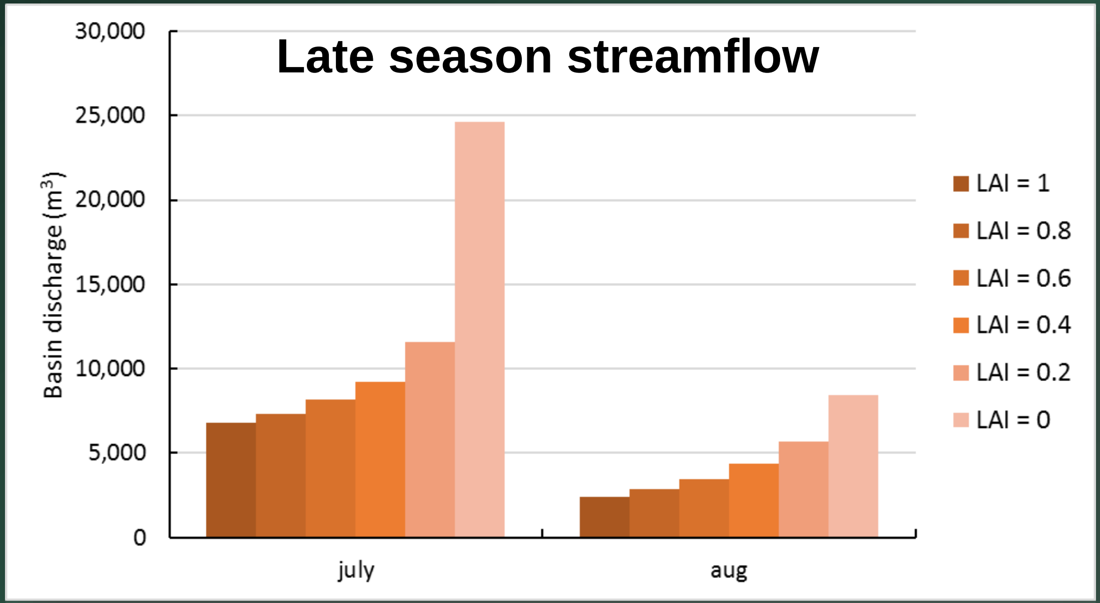
Hydrology with baseline vegetation

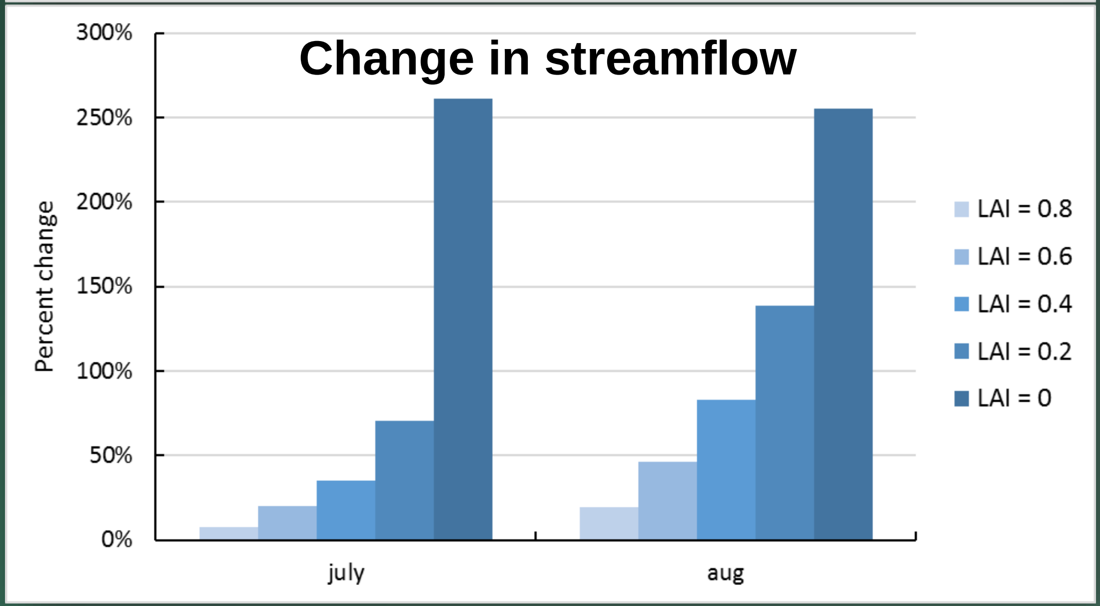


Change in hydrology with forest die-off



Sensitivity of summer flows to reduction in tree density





What to expect in a Sierra Nevada with less snow

- Refugia such as meadows and fens will likely provide early warning to declines in snowmelt and recharge
  - may continue to provide habitat for snow dependent and rare species
  - →Monitor widely to prioritize management
- Other sensitive areas such as riparian zones may also provide clues as to the watersheds most at risk
  - →Streamflow monitoring at multiple elevations in a watershed

Recharge and Runoff

- Earlier snowmelt → changes in timing of streamflow, longer dry season, lower late season baseflows
- More peak flows, carry more sediment and water quality constituents
- Recharge goes up under wet futures but doesn't change in very dry ones → more resilient to future climates than runoff
- Recharge sustains meadows and potential climate refugia

Implications to Forests

- Increasing temperatures change the timing of forest growth and the suitability of habitat for different species → structure of the forests and their species and ecosystems will change
- Increasing climatic water deficit stresses the forested landscape, increasing forest die-off and fire risk
- Forests can be managed to reduce stress, increase summer baseflows, and sequester carbon

THANK YOU!

QUESTIONS?