# PREDICTING NATURAL FLOWS FOR CA STREAMS


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# QUESTIONS:

***What are the expected natural flows?**

***How do natural flows vary on seasonal and annual basis?**

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# APPROACH

- **Predict monthly flow statistics**
- **Empirical models (vs. process-based)**

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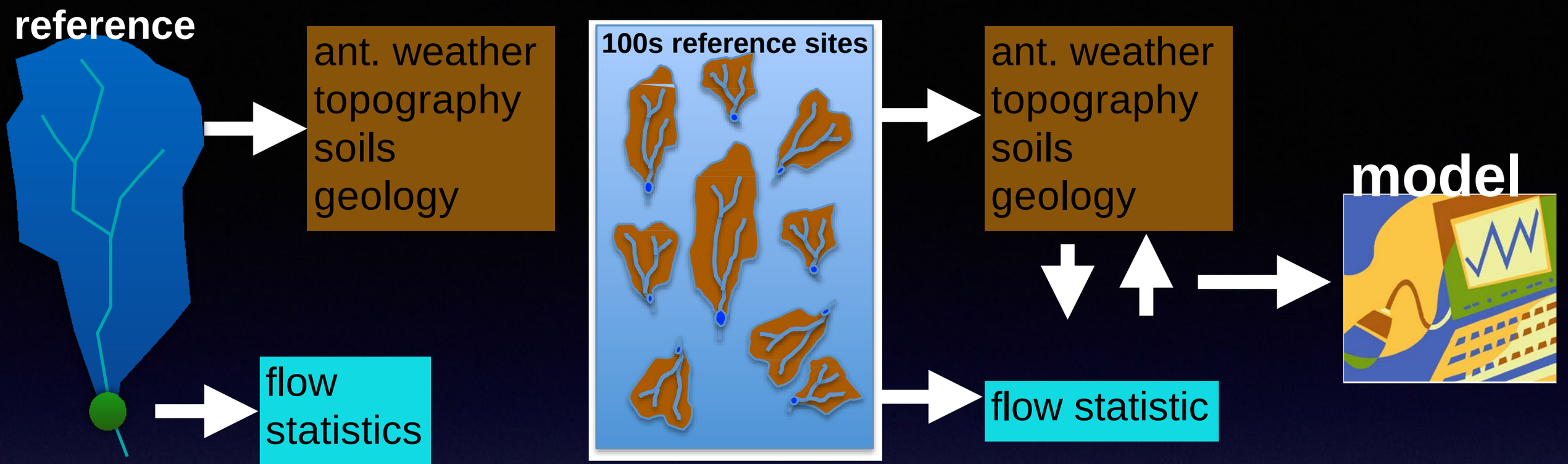
# EMPIRICAL MODELS

- "Reference" watersheds
  - minimal human influence on hydrology
  - streamflow measurements (USGS)

- Robust modeling technique for "big data"

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# 2 PROJECT PHASES

- **PHASE 1**
  - **use previously ID'd reference sites**
  - **model monthly mean flow**
  - **evaluate various modeling approaches**
- **PHASE 2**
  - **ID additional reference sites**
  - **model additional flow statistics**
  - **predict natural conditions for ALL CA stream segments (NHDPlus v2)**



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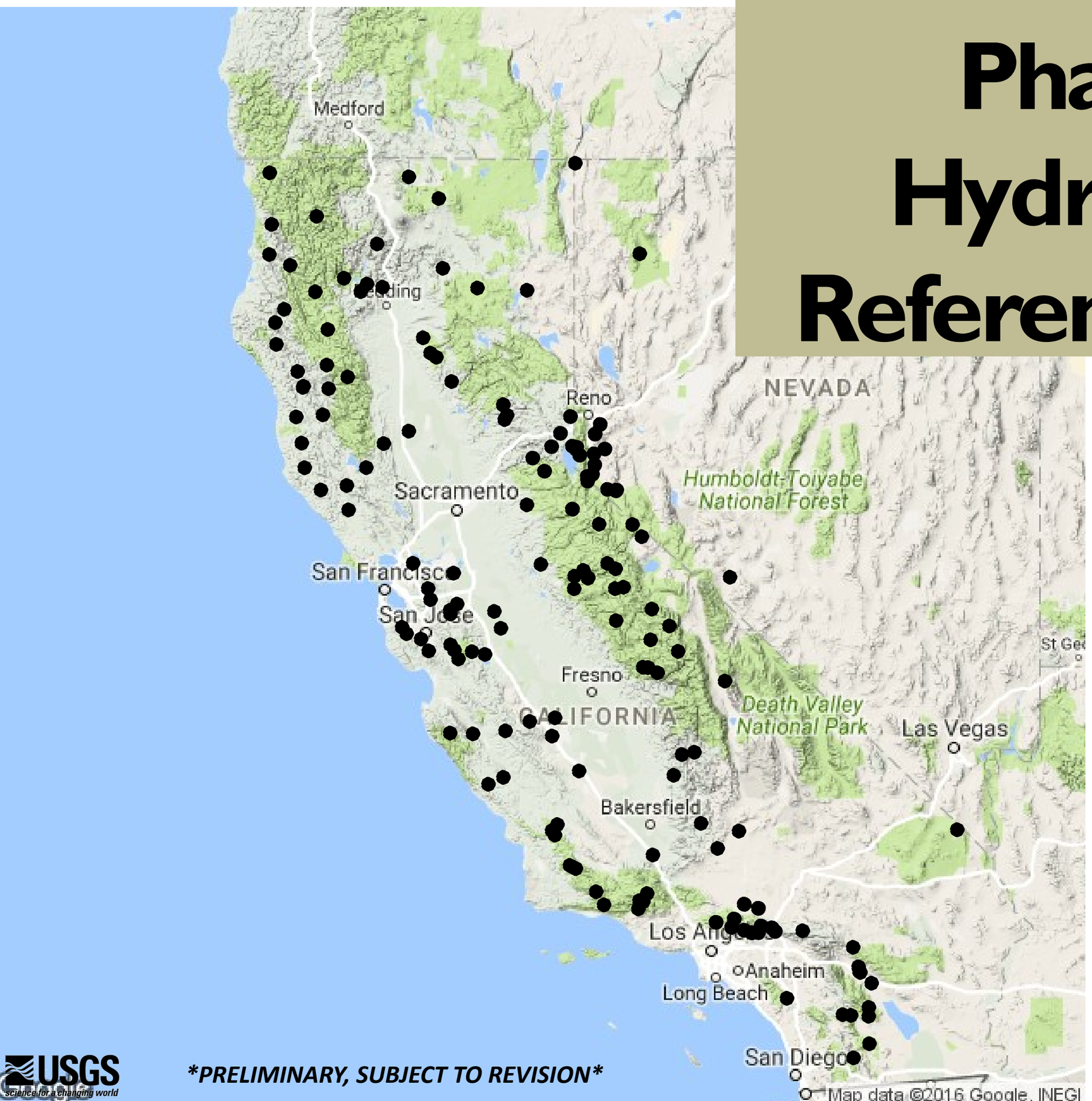
# Phase I Hydrologic Reference Sites

N=163

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# Regionalization

"North Coastal Mts"

"Interior Mts"

"Xeric"


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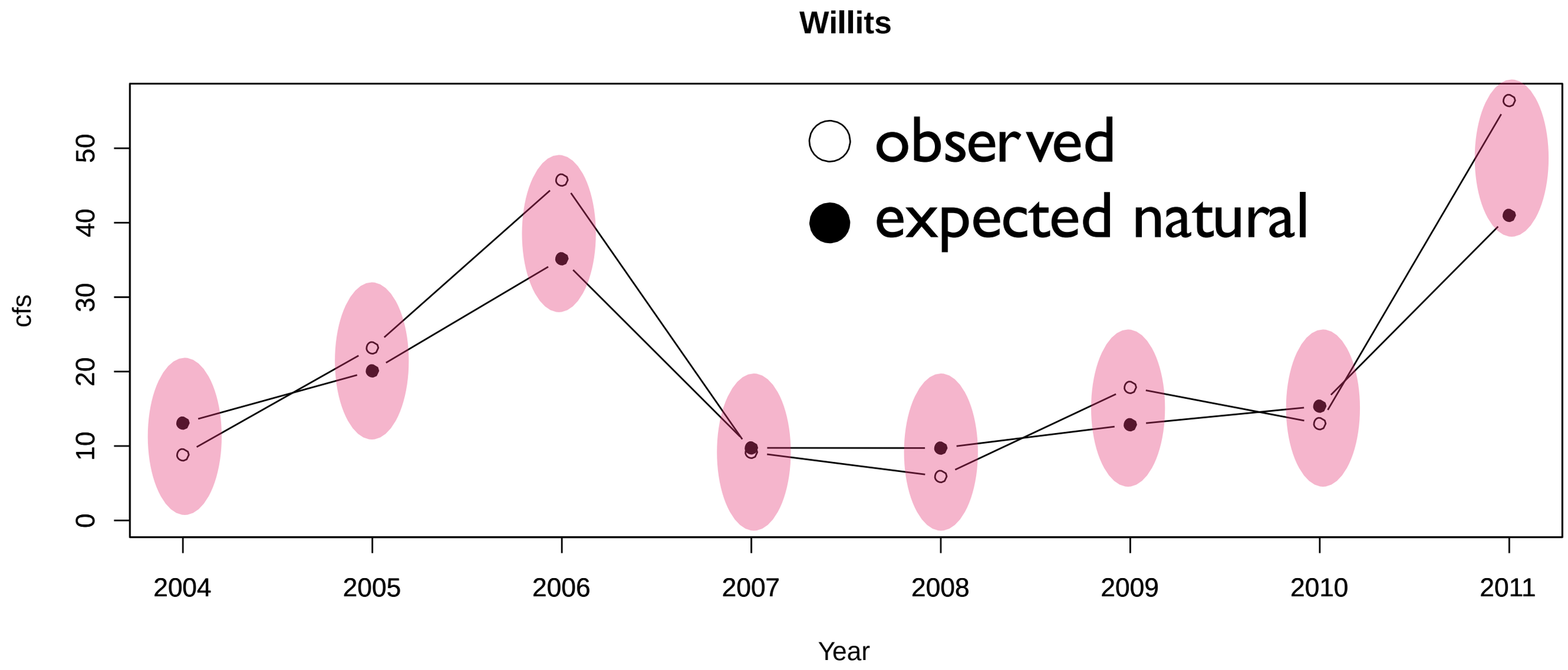
# Model Performance




mean O/E= 1.04

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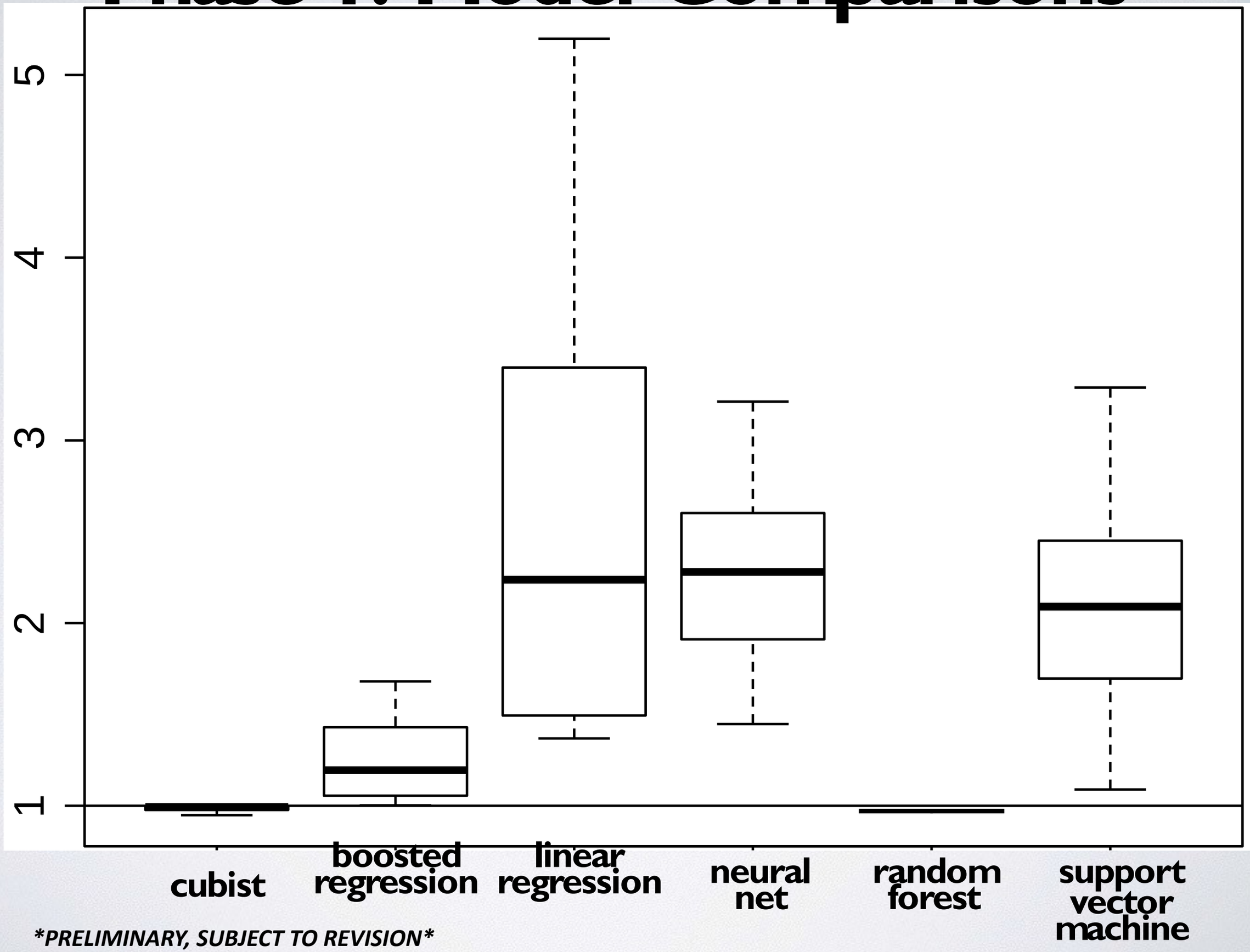
# Phase 1: Model Comparisons

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# Random Forest

- Assumption-free
- Nonlinear & interactions
- Resists overfitting

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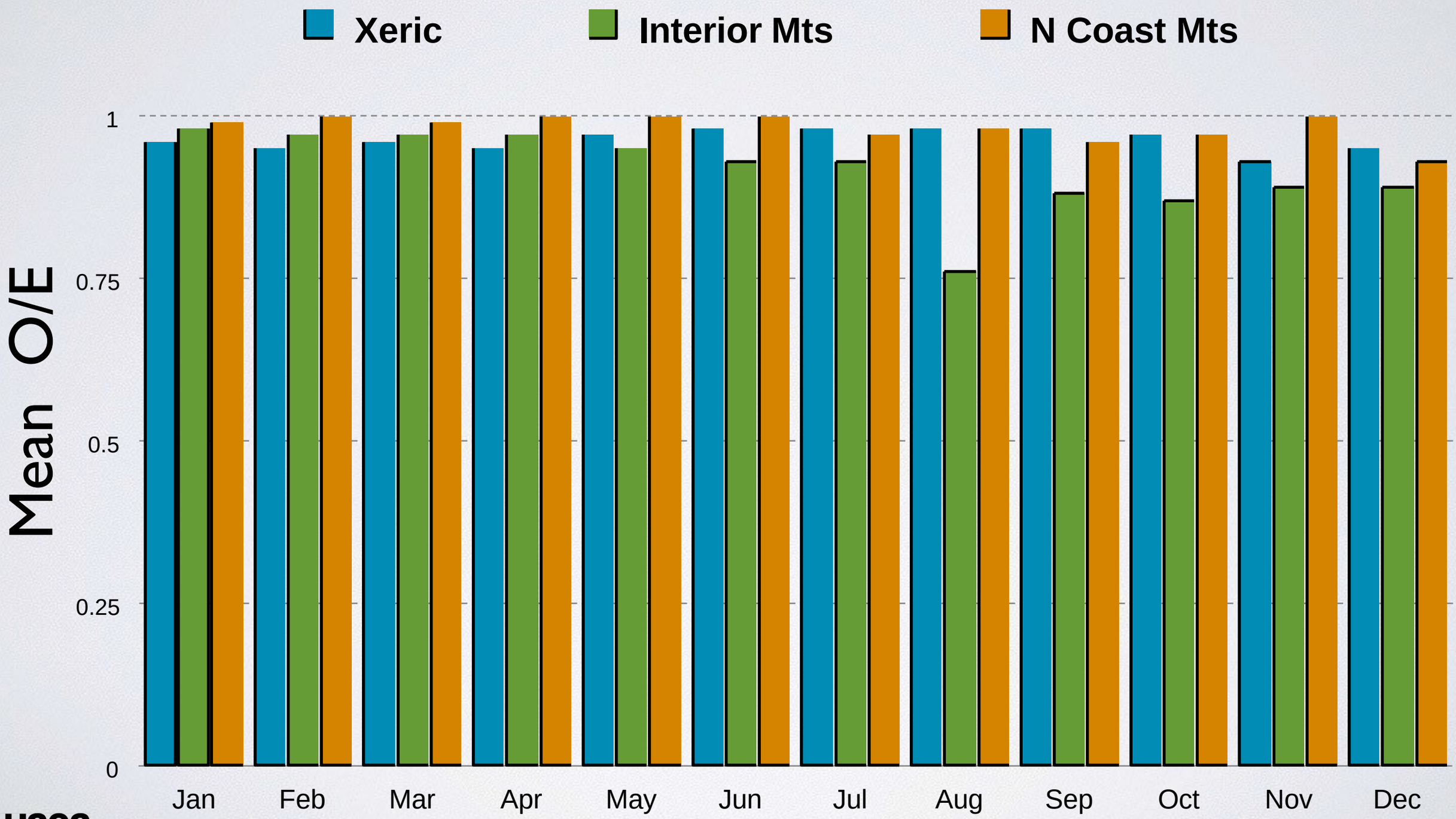
# Phase 1: Model Performance

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# PHASE 2

# OBTAIN MORE REFERENCEWATERSHEDS

- **HISTORICAL REFERENCE**
  - **Inactive gages with >5 yrs record (1950+)**

- **PARTIAL-RECORD REFERENCE**
  - **Current "non-reference" gages with records pre-dating human influence**

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# Reference Watershed Screening Process (Historical Reference)

1. All USGS stream gages in California (~1400)

2. 5+ yrs daily flow record since 1950

3. Examine monthly flow data

4. Verify lack of urban or agric. land cover (1970+) & dams (1950)



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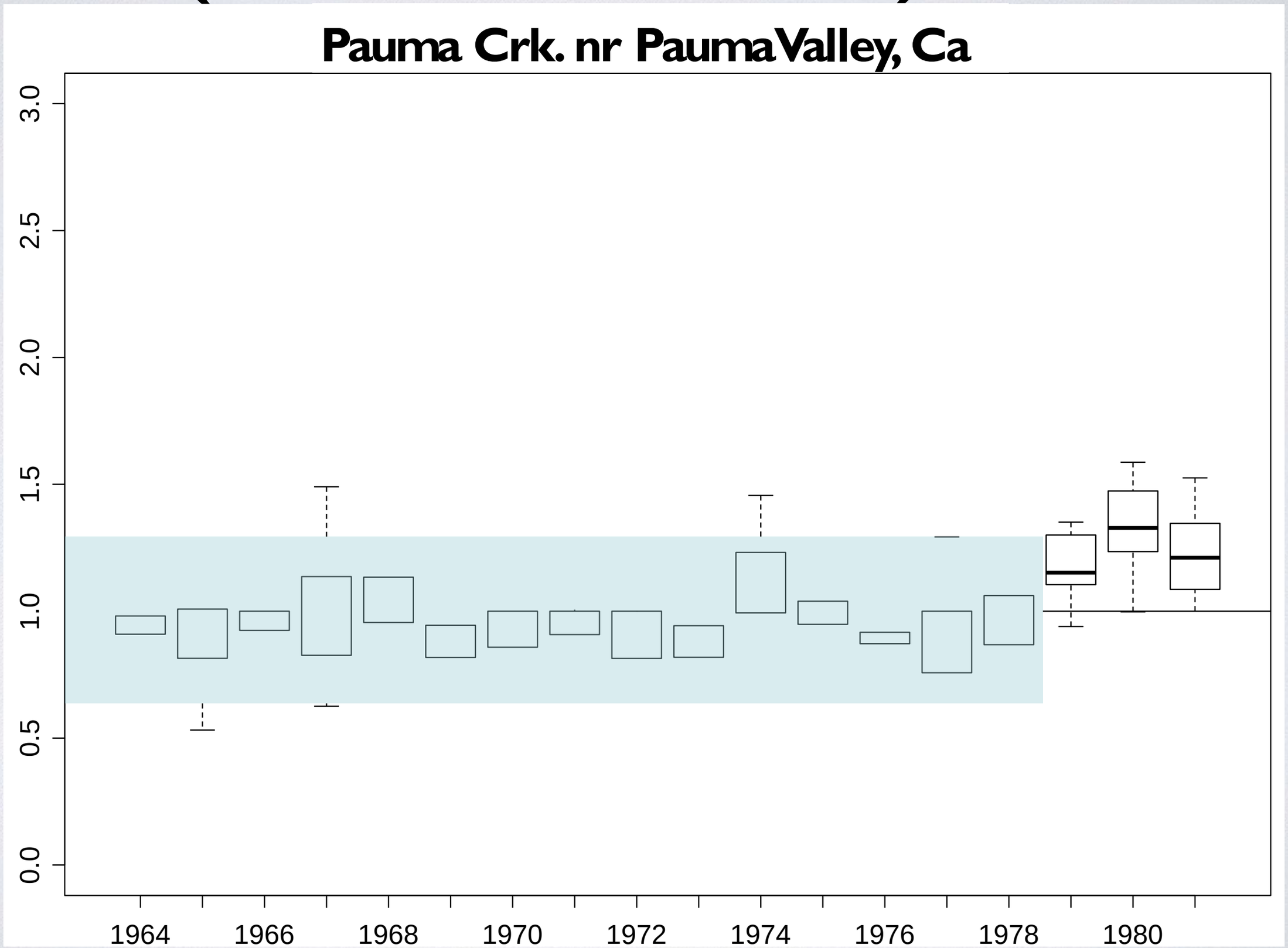
# Reference Watershed Screening Process (Historical Reference)



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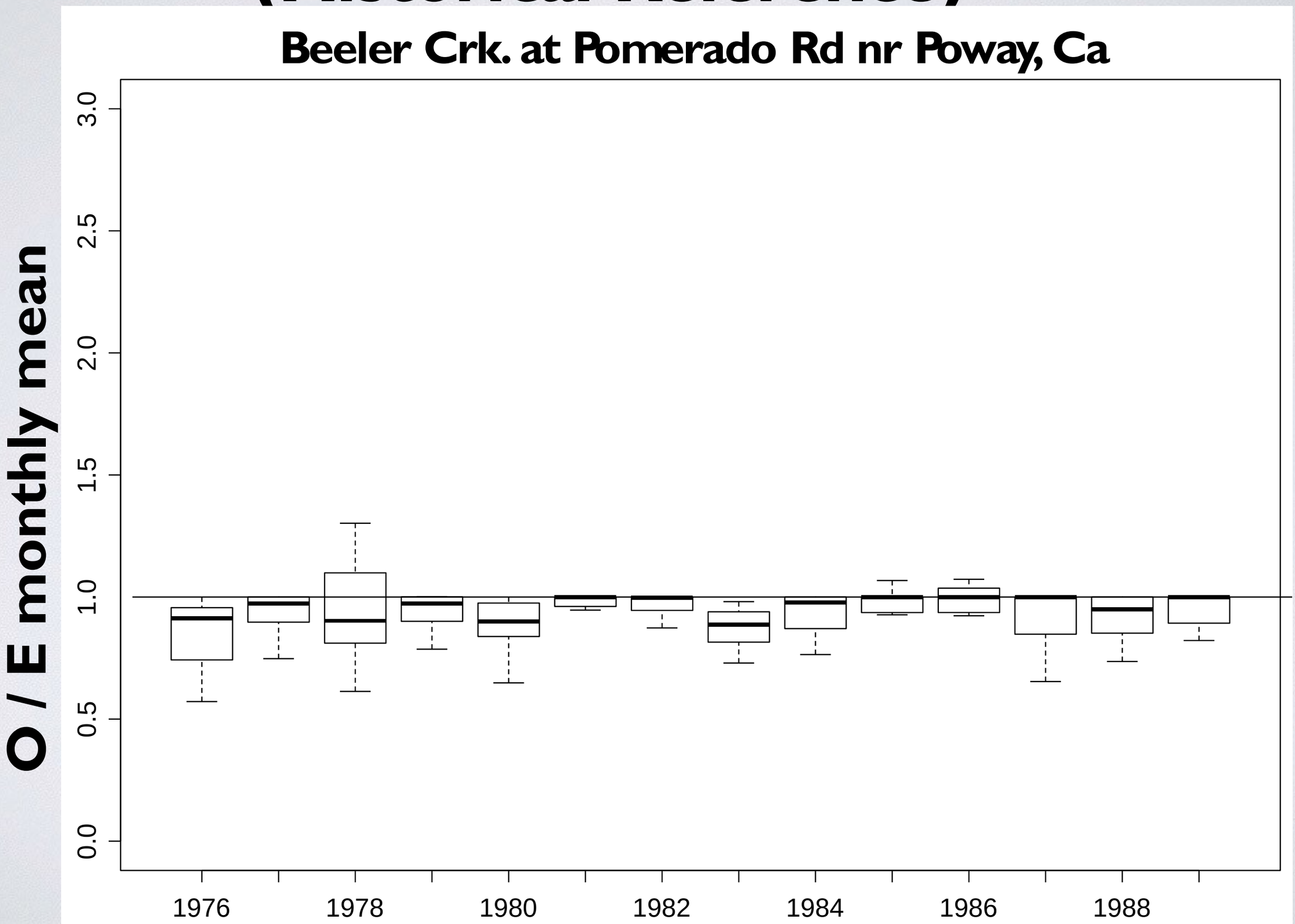


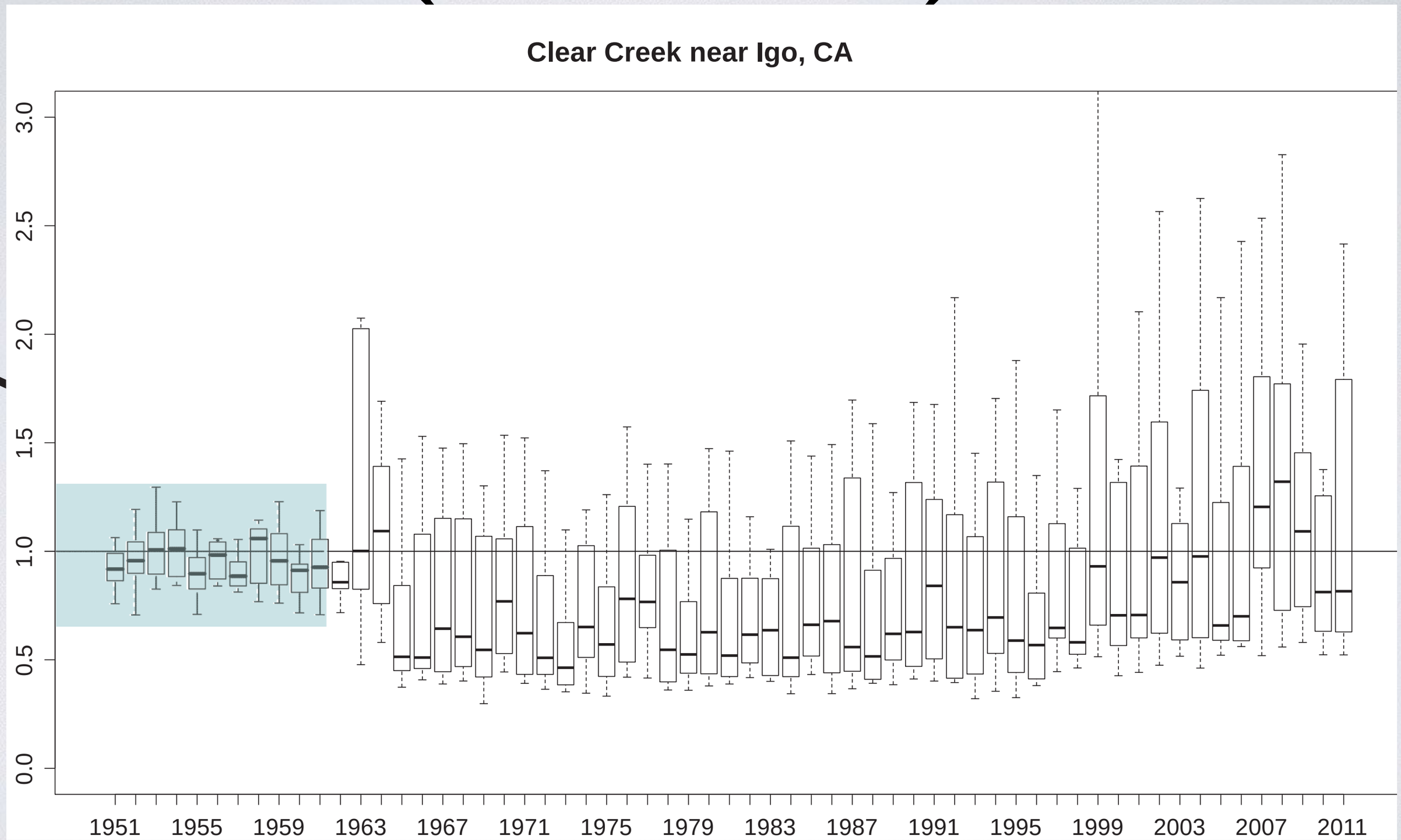
# Reference Watershed Screening Process (Partial Record)

1. Examine USGS Annual Data Reports, other info about begin date of hydrologic modification

2. Examine monthly flow data

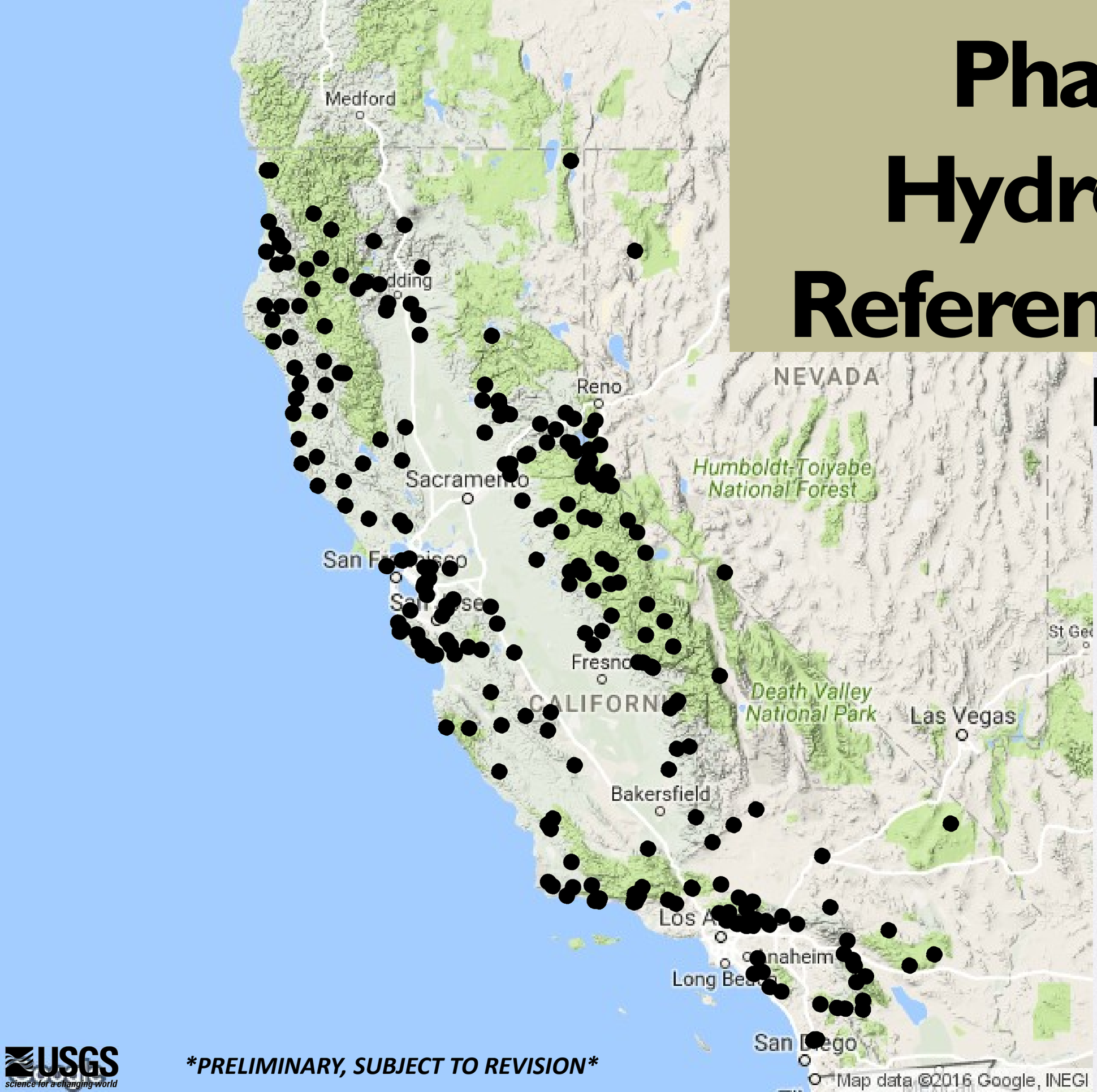
3. Verify lack of urban or agric. land cover (1970+) & dams (1950)

# Reference Watershed Screening Process (Partial Record)



# Phase 2 Hydrologic Reference Sites

N= ~~163~~ 254

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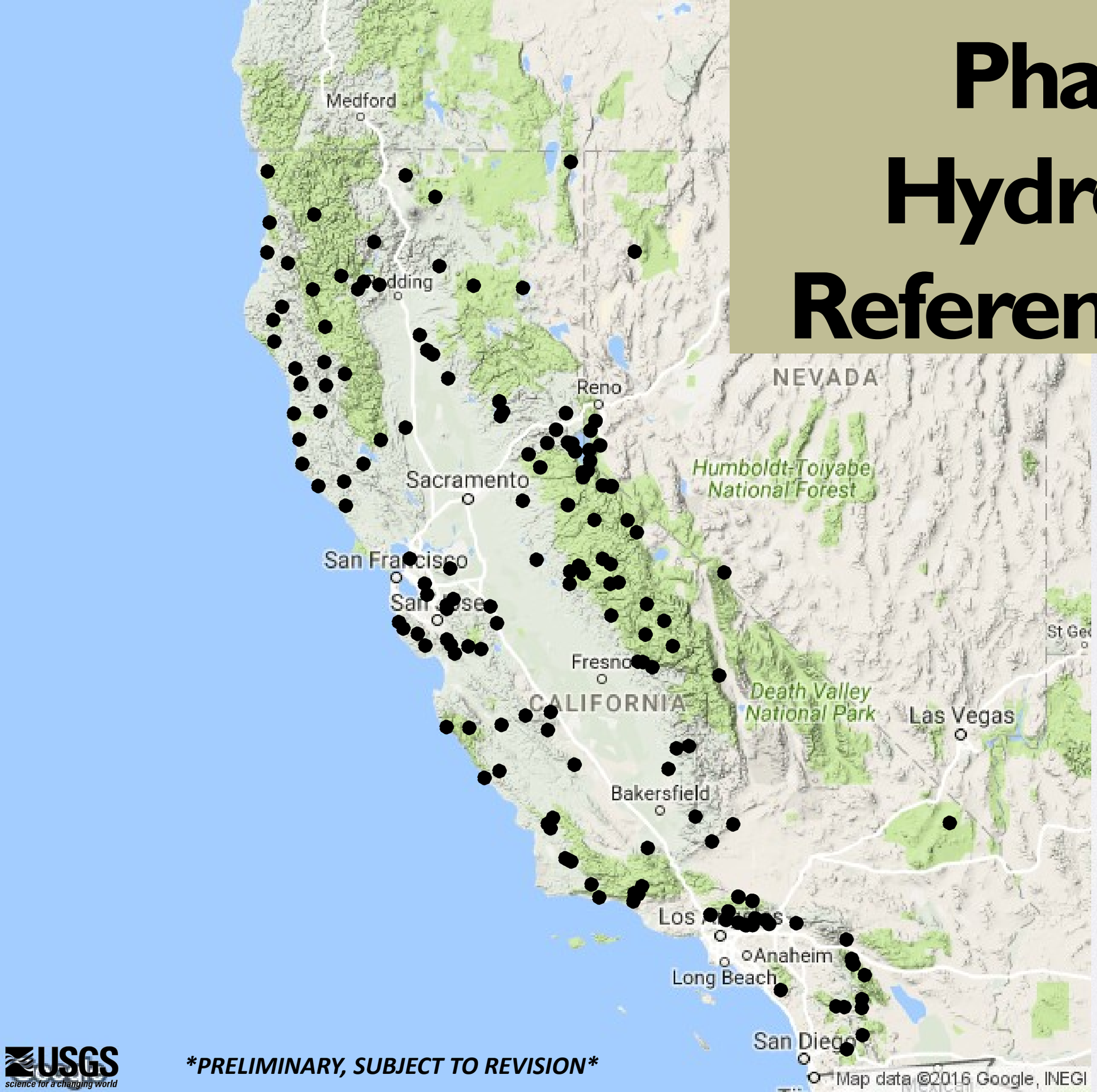
# Phase I Hydrologic Reference Sites

N=163

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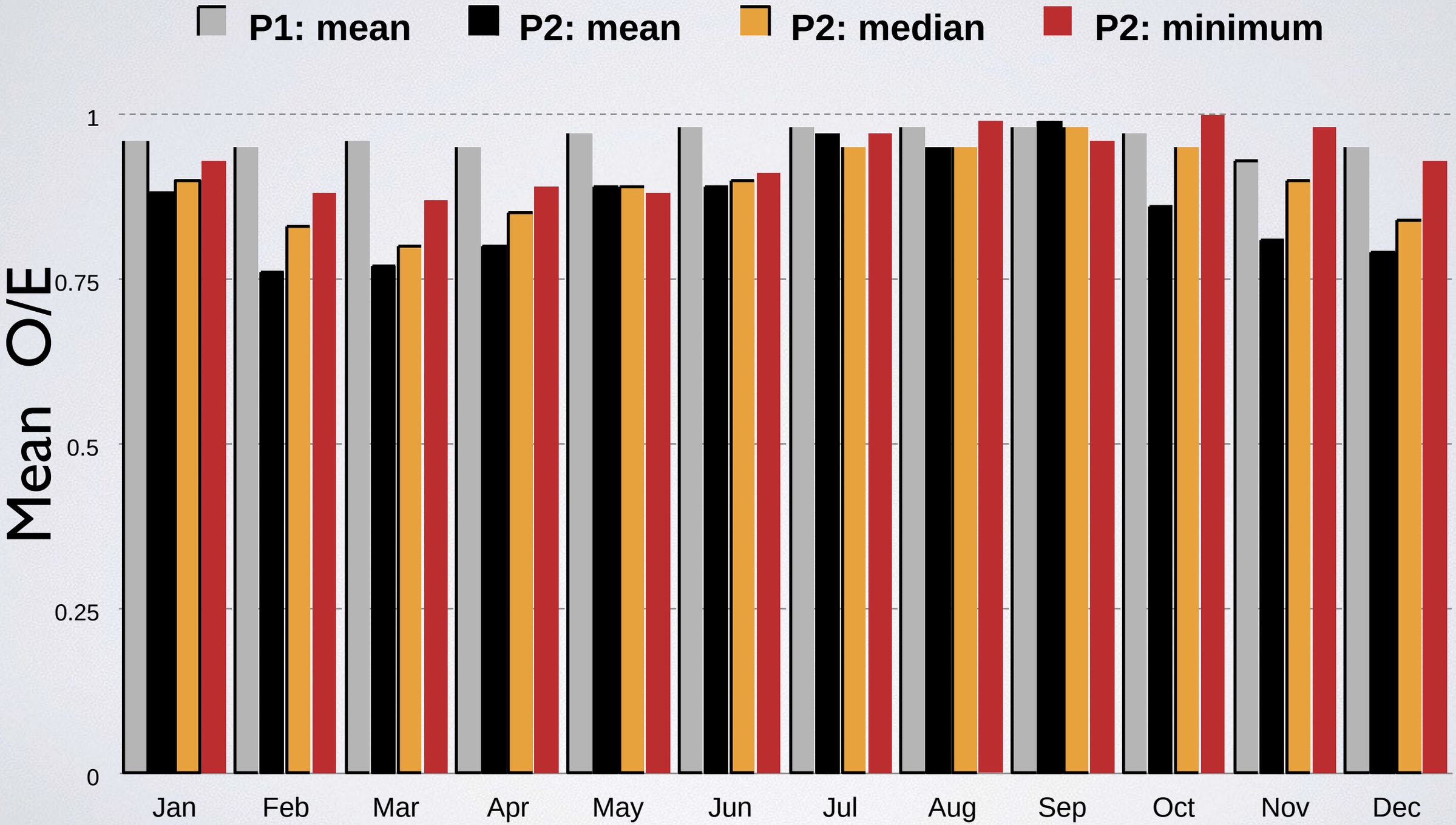
# Performance, Phase 2 (xeric region)



# Using model output to examine natural temporal variation of streamflows

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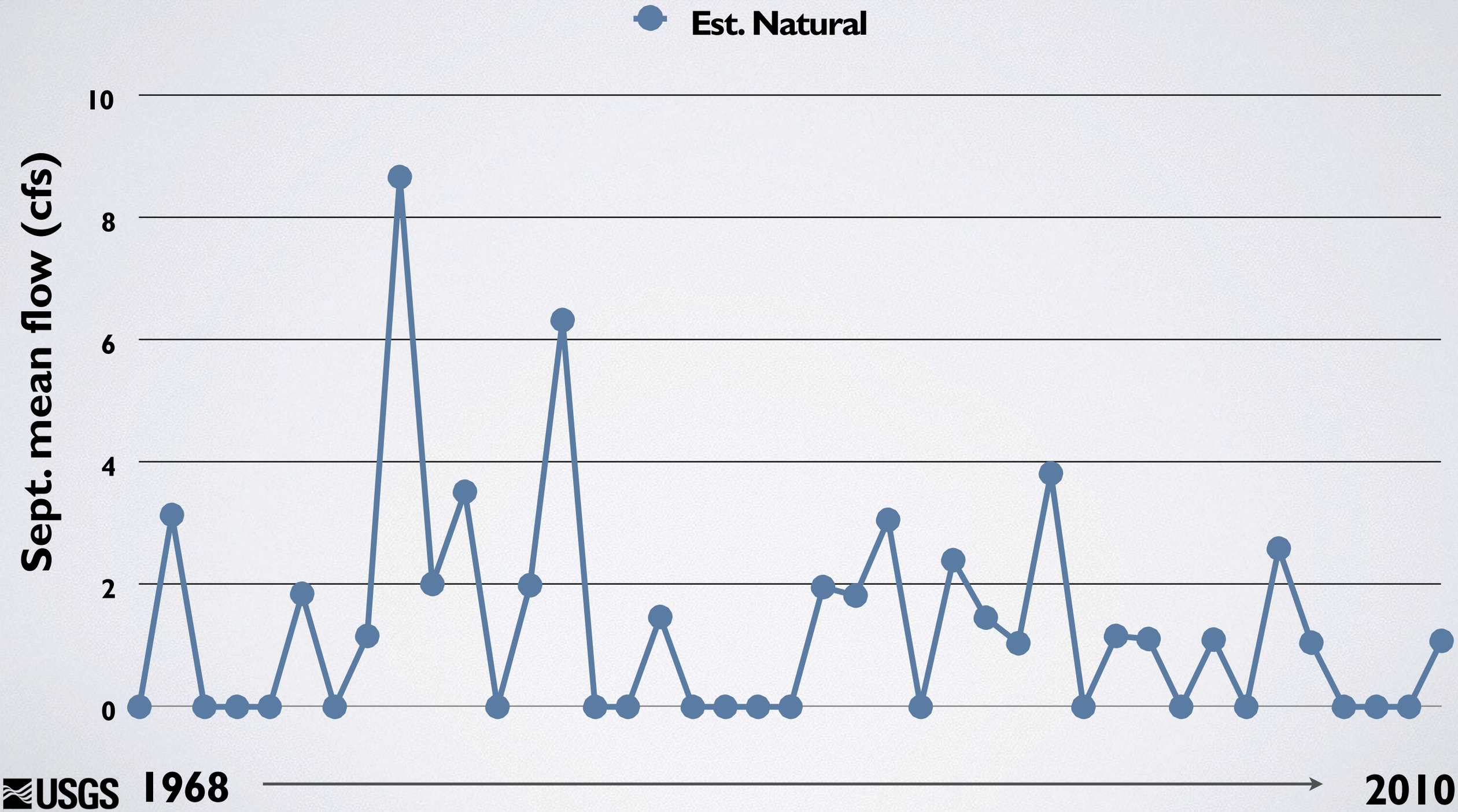
# Cucamonga Creek

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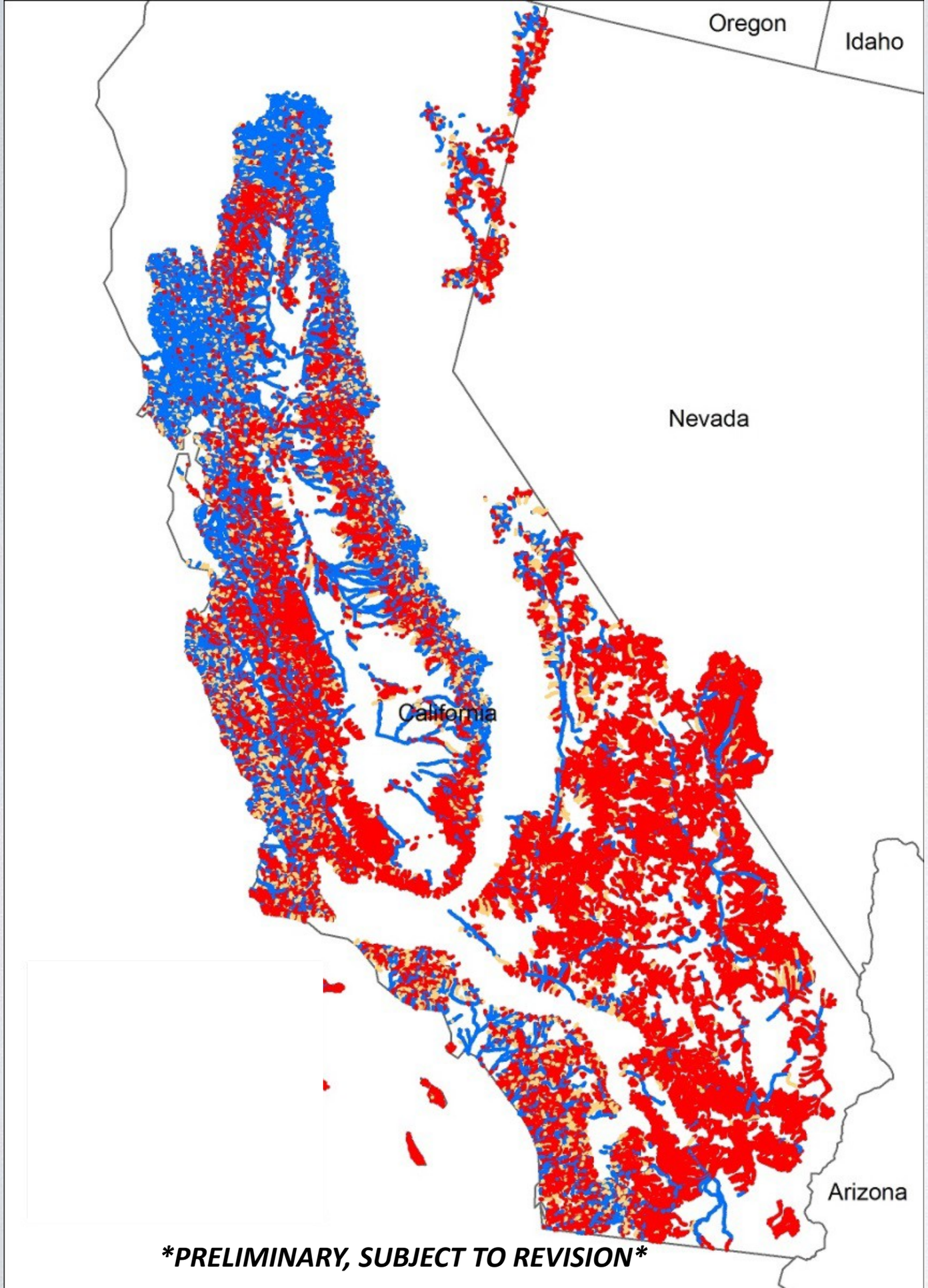


# Frequency April natural flows > 0

- 0 to 0.33
- 0.34 to 0.66
- 0.67 to 1

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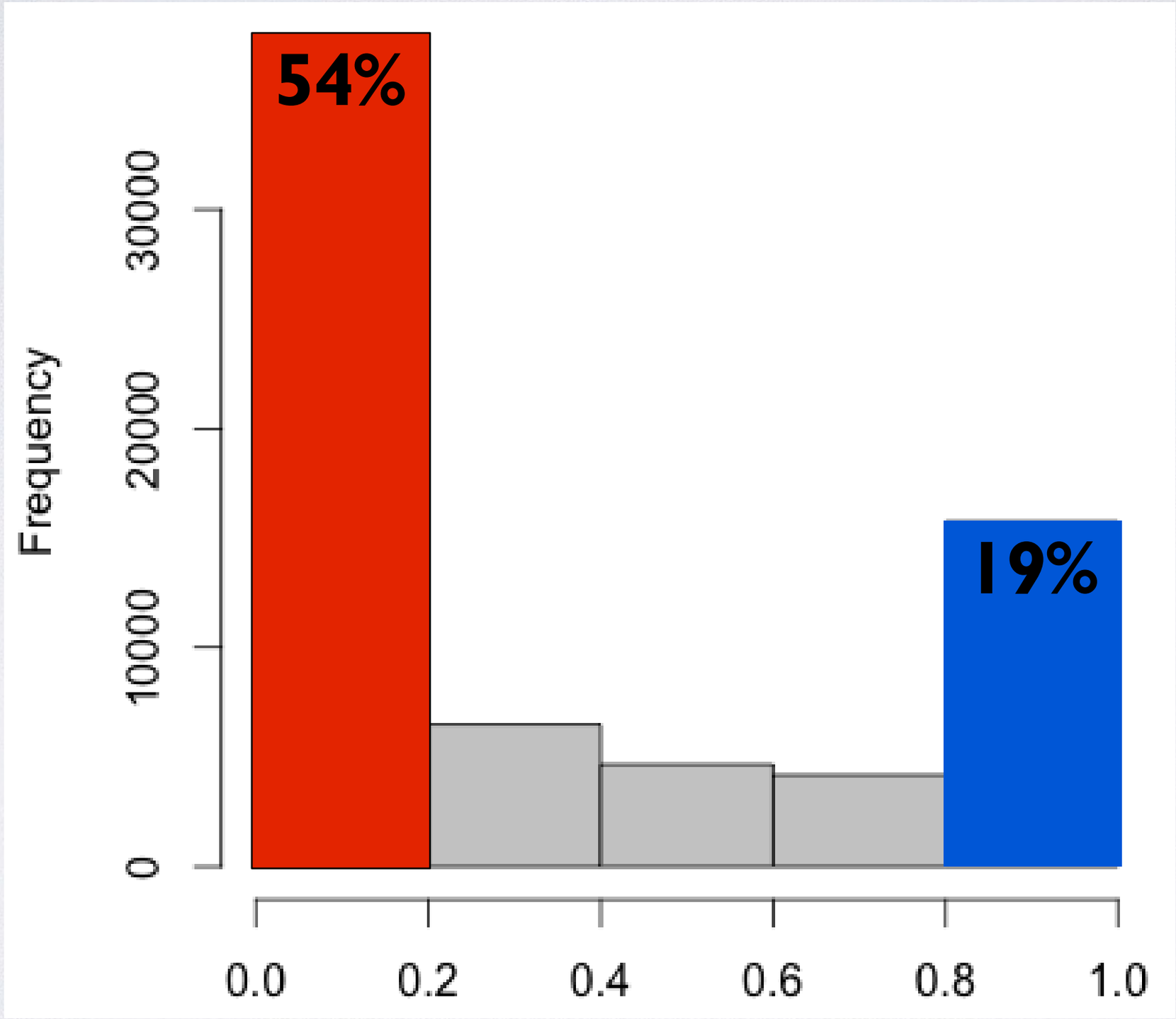
# Under natural conditions, 19% of stream segments have flow in April



# Using model output to assess streamflow alteration

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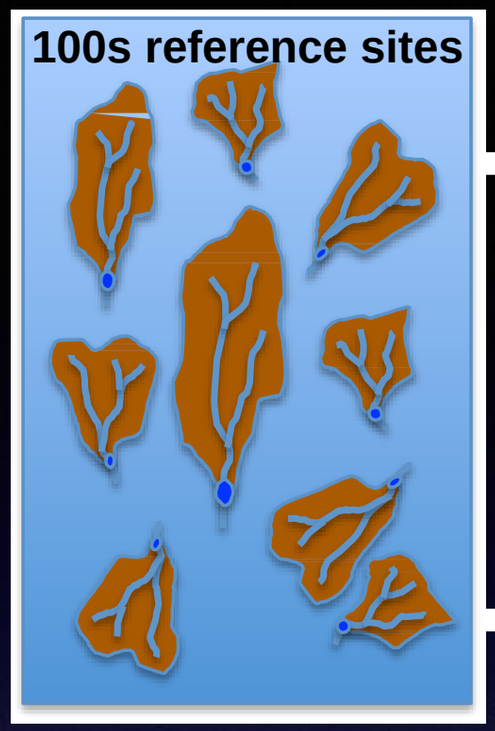
reference

climate
topography
soils
geology

September
mean flow




climate
topography
soils
geology

model

September
mean flow

model

Expected
Baseline
mean Sept. Q

Observed
mean Sept. Q

O / E

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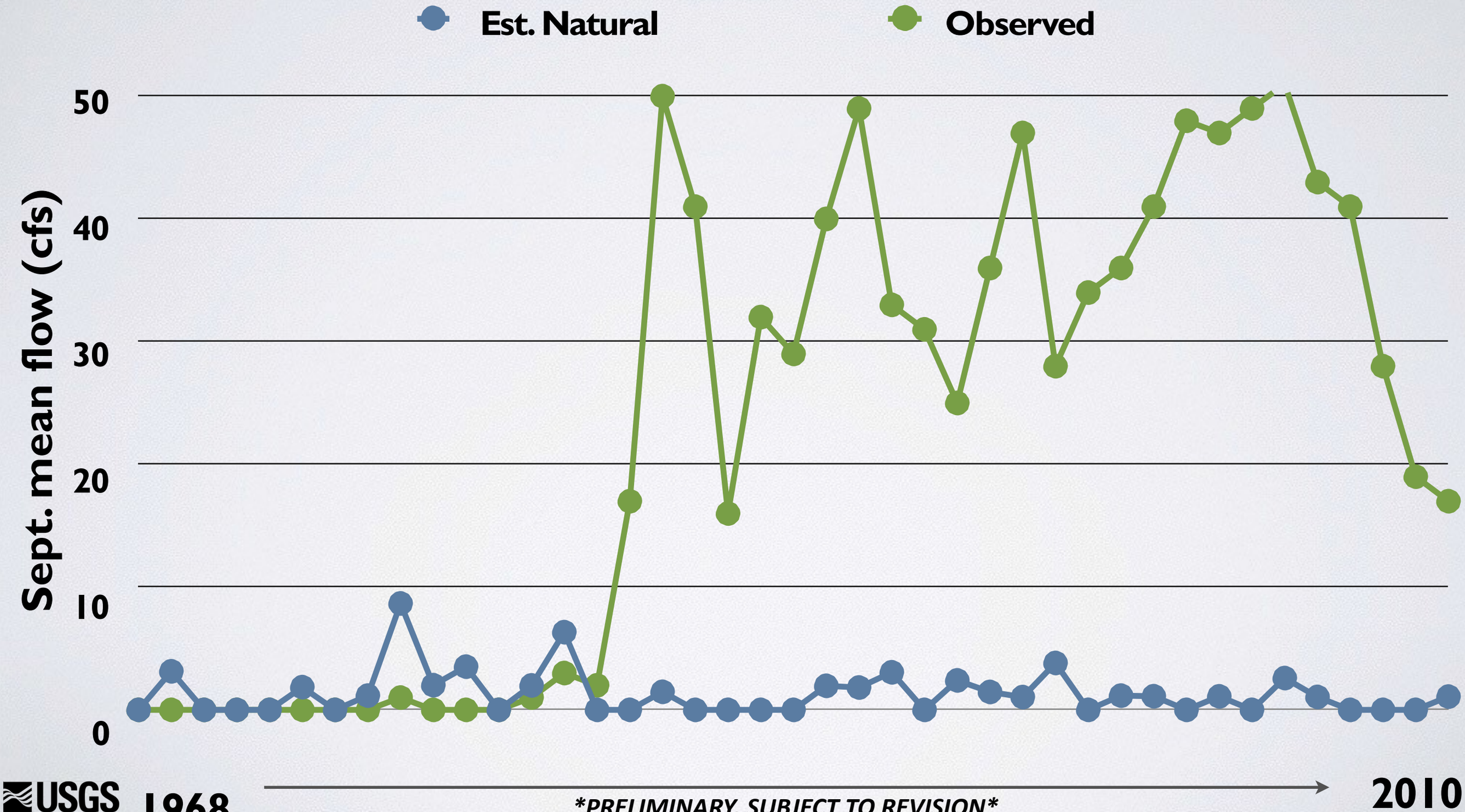
# Cucamonga Creek

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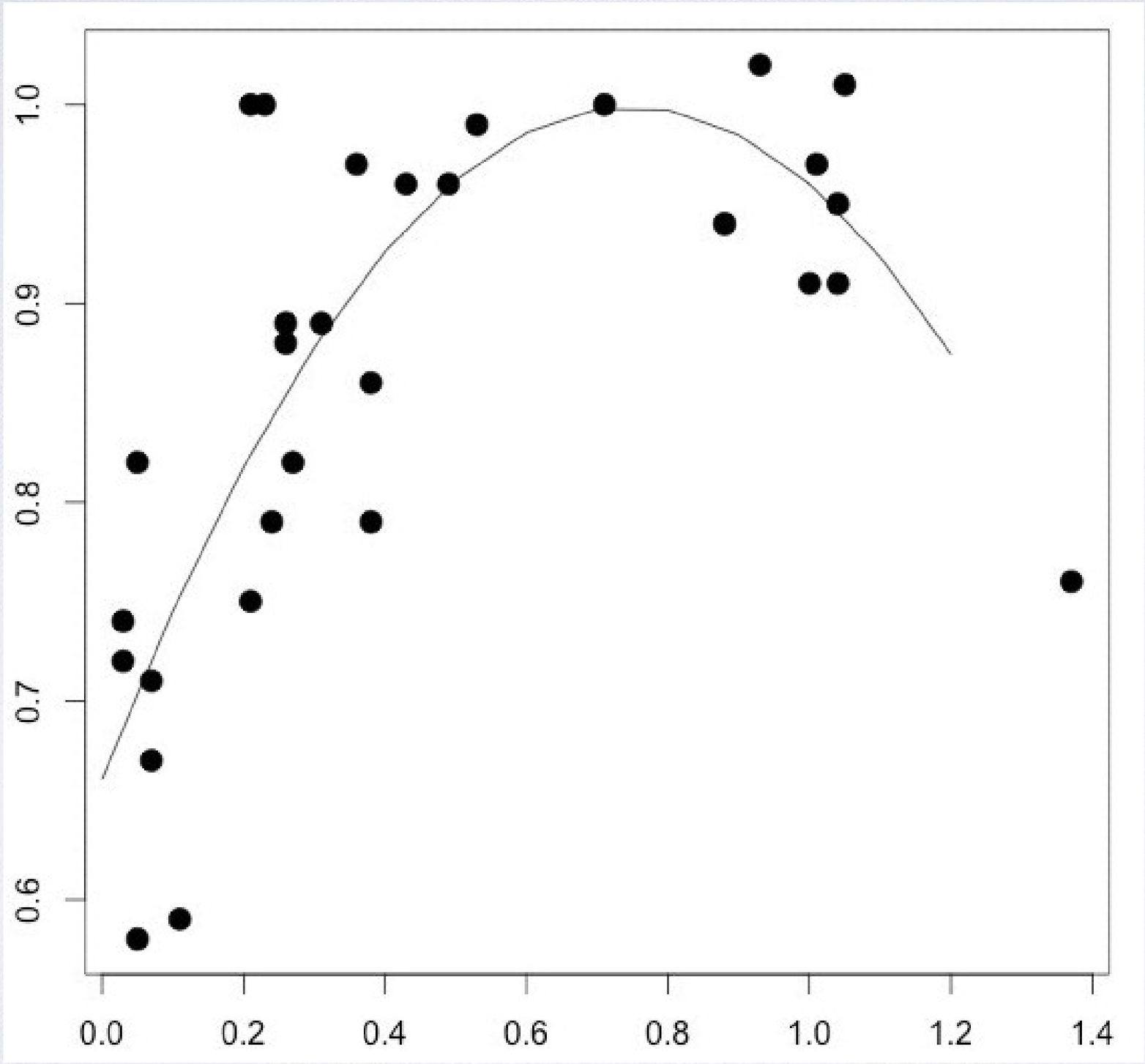
# Apply models to gaged sites with biological assessment data

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# Caveats and Limitations

- Limited dimensions of streamflow
    - monthly mean
    - monthly maximum
    - monthly minimum

- Model performance varies by month, region, & flow dimension

- Underlying limitation of spatial coverage of weather stations and stream gages



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# Time Line

**2017** - *final report Phase 2*

**2016** - *Sept: natural flow predictions for all CA stream segments*

**2015** - *begin Phase 2*

- *draft report on Phase 1*

**2012** - *begin Phase 1*

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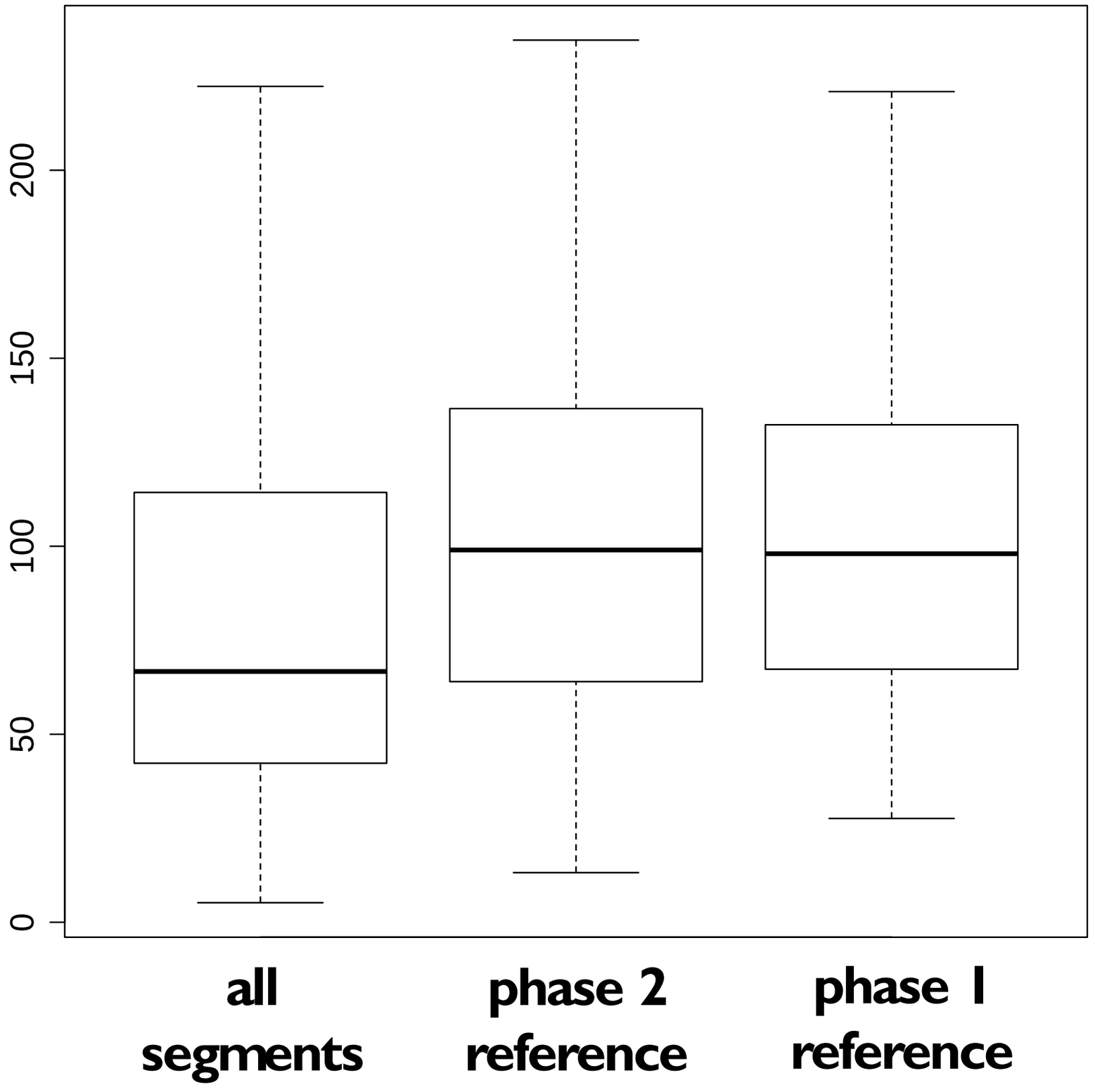
# Mean annual precipitation (mm)



# Example Output

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | COMID | AREA | Year | Month | P10_Q | P50_Q | P90_Q | Estimated.Q |
| 2 | 123456789 | 41.2 | 1958 | 1 | 1.61 | 5.19 | 13.62 | 6.55 |
| 3 | 123456789 | 41.2 | 1959 | 1 | 2.17 | 4.29 | 16.34 | 7.28 |
| 4 | 123456789 | 41.2 | 1960 | 1 | 1.46 | 3.76 | 16.57 | 6.94 |
| 5 | 123456789 | 41.2 | 1961 | 1 | 1.51 | 3.51 | 12.34 | 5.71 |
| 6 | 123456789 | 41.2 | 1962 | 1 | 1.46 | 4.24 | 13.26 | 6.09 |
| 7 | 123456789 | 41.2 | 1963 | 1 | 1.67 | 3.63 | 16.50 | 6.75 |
| 8 | 123456789 | 41.2 | 1964 | 1 | 1.14 | 2.94 | 13.44 | 5.50 |
| 9 | 123456789 | 41.2 | 1965 | 1 | 1.51 | 4.27 | 13.13 | 6.28 |
| 10 | 123456789 | 41.2 | 1966 | 1 | 2.29 | 8.40 | 18.94 | 10.25 |
| 11 | 123456789 | 41.2 | 1967 | 1 | 2.23 | 7.28 | 22.46 | 10.10 |
| 12 | 123456789 | 41.2 | 1968 | 1 | 1.79 | 4.89 | 13.35 | 6.49 |
| 13 | 123456789 | 41.2 | 1969 | 1 | 5.68 | 17.77 | 33.03 | 19.28 |
| 14 | 123456789 | 41.2 | 1970 | 1 | 2.17 | 5.46 | 16.90 | 8.09 |
| 15 | 123456789 | 41.2 | 1971 | 1 | 2.12 | 7.97 | 19.10 | 9.96 |
| 16 | 123456789 | 41.2 | 1972 | 1 | 1.48 | 4.43 | 13.60 | 6.68 |
| 17 | 123456789 | 41.2 | 1973 | 1 | 1.57 | 5.60 | 14.93 | 7.61 |
| 18 | 123456789 | 41.2 | 1974 | 1 | 3.61 | 8.58 | 25.37 | 11.71 |
| 19 | 123456789 | 41.2 | 1975 | 1 | 1.34 | 3.94 | 12.34 | 5.54 |
| 20 | 123456789 | 41.2 | 1976 | 1 | 1.23 | 2.99 | 16.05 | 5.92 |
| 21 | 123456789 | 41.2 | 1977 | 1 | 1.83 | 4.27 | 16.20 | 7.05 |
| 22 | 123456789 | 41.2 | 1978 | 1 | 3.45 | 8.92 | 29.17 | 13.92 |
| 23 | 123456789 | 41.2 | 1979 | 1 | 3.95 | 9.09 | 26.96 | 12.46 |
| 24 | 123456789 | 41.2 | 1980 | 1 | 2.74 | 7.16 | 23.55 | 9.95 |
| 25 | 123456789 | 41.2 | 1981 | 1 | 2.07 | 5.16 | 16.69 | 7.72 |
| 26 | 123456789 | 41.2 | 1982 | 1 | 2.07 | 5.99 | 15.49 | 7.55 |
| 27 | 123456789 | 41.2 | 1983 | 1 | 3.45 | 8.57 | 23.90 | 11.02 |
| 28 | 123456789 | 41.2 | 1984 | 1 | 2.20 | 5.08 | 12.34 | 6.47 |
| 29 | 123456789 | 41.2 | 1985 | 1 | 1.93 | 6.56 | 14.63 | 8.50 |
| 30 | 123456789 | 41.2 | 1986 | 1 | 1.53 | 3.90 | 14.85 | 6.40 |
| 31 | 123456789 | 88.5 | 1959 | 1 | 1.73 | 7.74 | 35.93 | 14.56 |

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