Assessing hydrologic change in the nation's rivers

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Environmental flows

the quantity, timing, and quality of water required to sustain freshwater and estuarine ecosystems and the human livelihoods and well being that depend on these ecosystems

∆flow ~ ecological indicator

Limited flow data

Sparse gauging network, getting sparser

Flows altered by dams and land use

Limited pre-impact records

USGS Flow Gage, somewhere in Colorado

Limited flow data

Sparse gauging network, getting worse

Flow regulation and land use

models!

Limited pre-impact records

USGS Flow Gage, somewhere in Colorado

Hydrologic models used for…

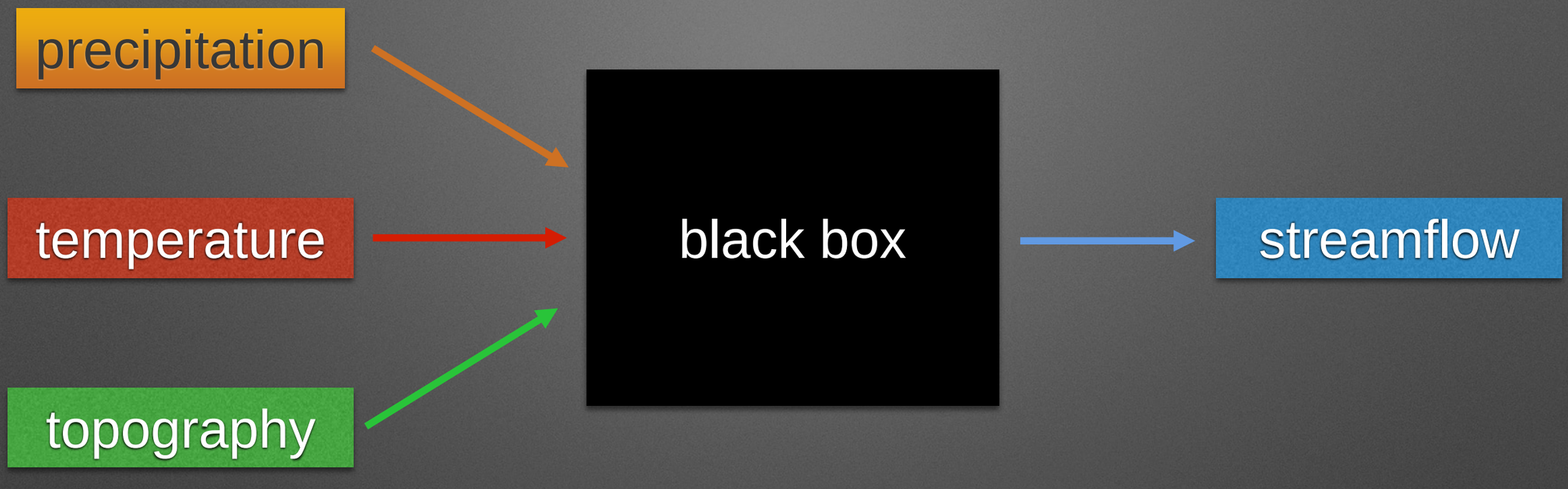
(1) Classifying stream types

(2) Predicting natural flows at ungauged sites

(3) Assessing flow alteration

(4) Establishing environmental flow standards

Statistical modeling of flows



Methods: linear regression, principal components analysis, neural networks, support vector machine regression, regression trees (CART), random forest, etc.

Assessing flow alteration

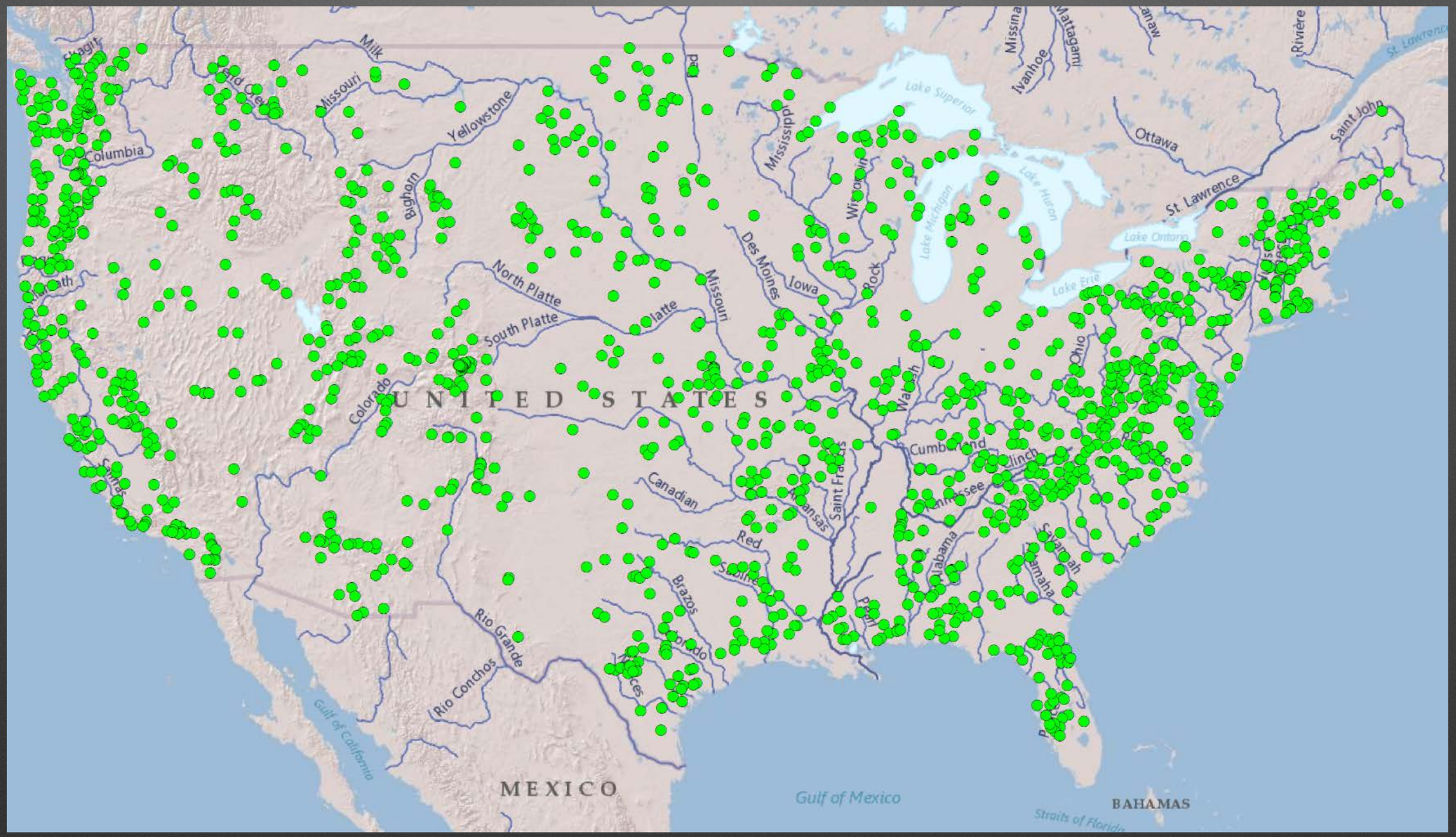
Step 1. Develop models to predict ”natural”, unimpaired flow metrics from basin features

Step 2. Apply models to predict unimpaired flows at gauged basins and compare with observed values

Step 1

Develop models to predict natural, or unimpaired, flow metrics

Methods



Reference-quality gauge stations with >20-year record

Methods

1200 reference quality sites

Compute 612 hydrologic metrics

98 “natural” geospatial predictors

- climate, soils, topography

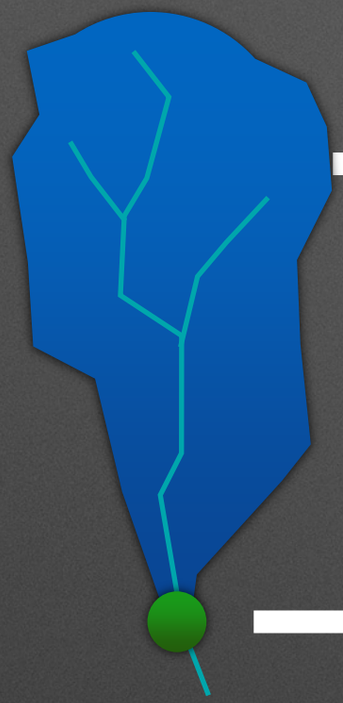
Random forest models

- 80% training / 20% validation

Assess model performance: bias, accuracy, etc.

Methods

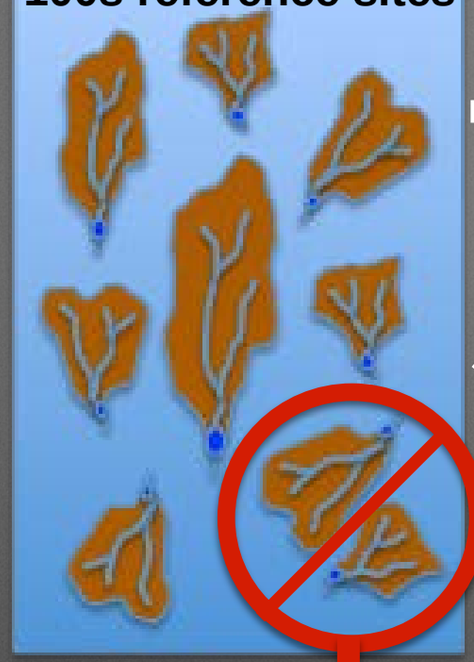
reference



climate
topography
soils
geology

flow$_{obs}$

100s reference sites



climate
topography
soils
geology

flow$_{obs}$

model

model

climate
topography
soils
geology

flow$_{obs}$

flow$_{pred}$

PERFORMANCE EVALUATION

Observed/Predicted

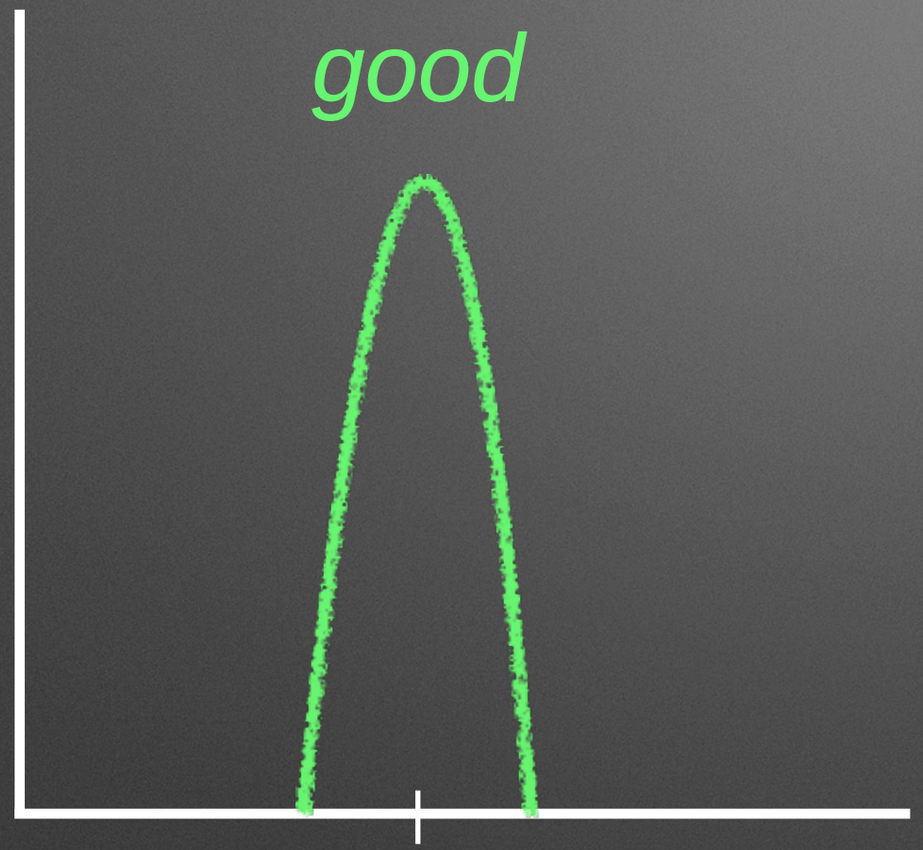
Nash-Sutcliffe

Percent Bias

Predictive performance

Metric 1

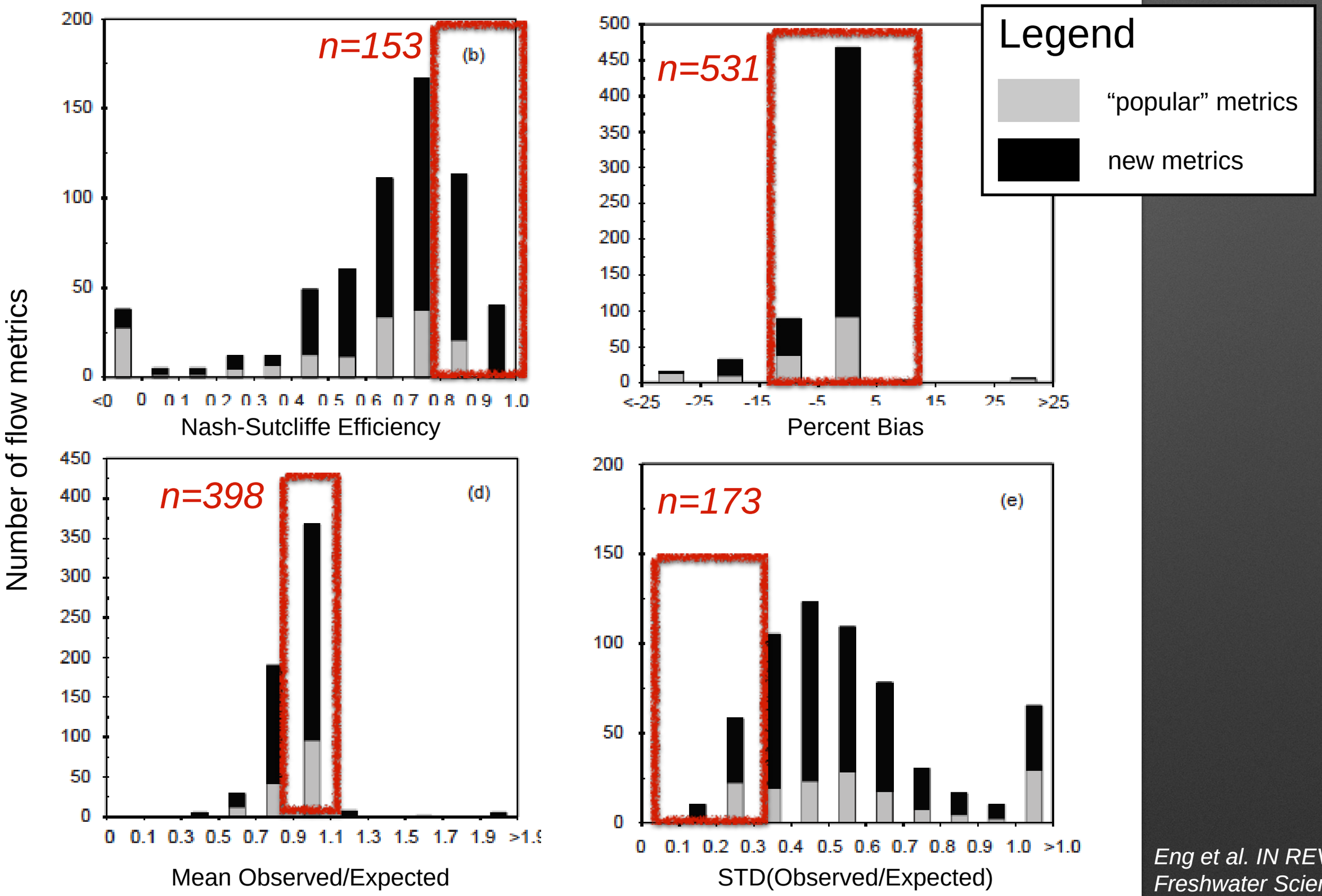
good



Metric 2

poor

$Mean_{O/E}$ =	1.0	1.2
$STD_{O/E}$ =	0.1	0.6



Eng et al. IN REVIEW Freshwater Science

“Step 1” Findings

Many popular flow metrics cannot be reliably predicted, particular those representing low-flows

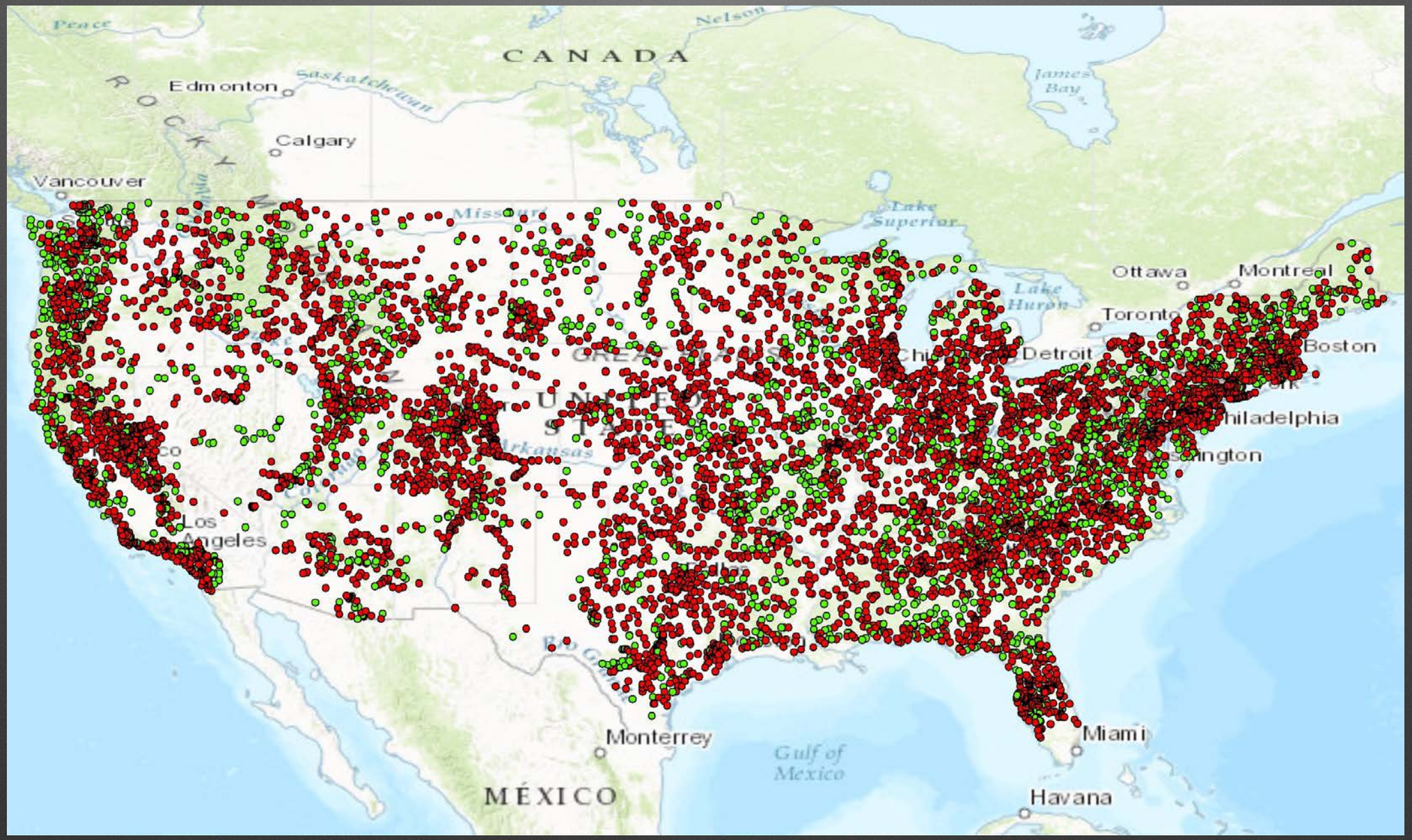
Most dimensions of the flow regime represented by at least one “predictable” metric

“Predictability” can be useful for guiding selection of metrics in river studies

Step 2

Quantify dimensions and magnitude of flow alteration

Methods

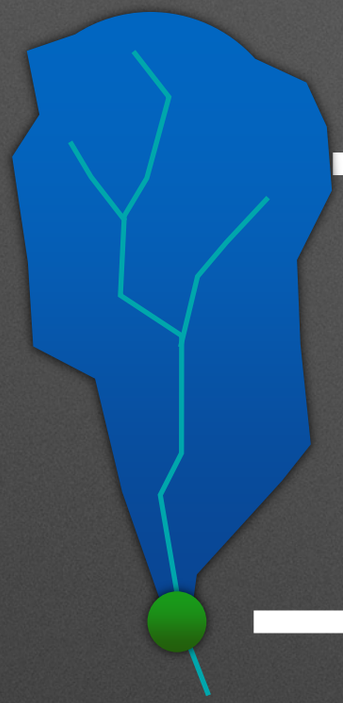


1,200 reference-quality gauge stations

3,800 altered gauge stations

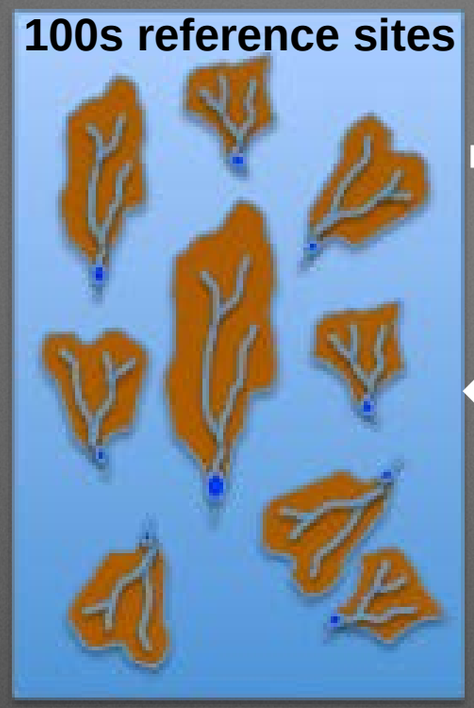
Methods

reference



climate
topography
soils
geology

$flow_{obs}$



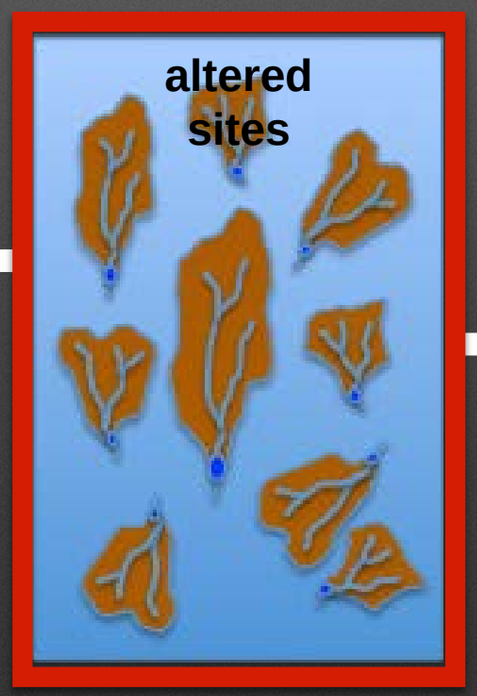
climate
topography
soils
geology

$flow_{obs}$

model

model

climate
topography
soils
geology

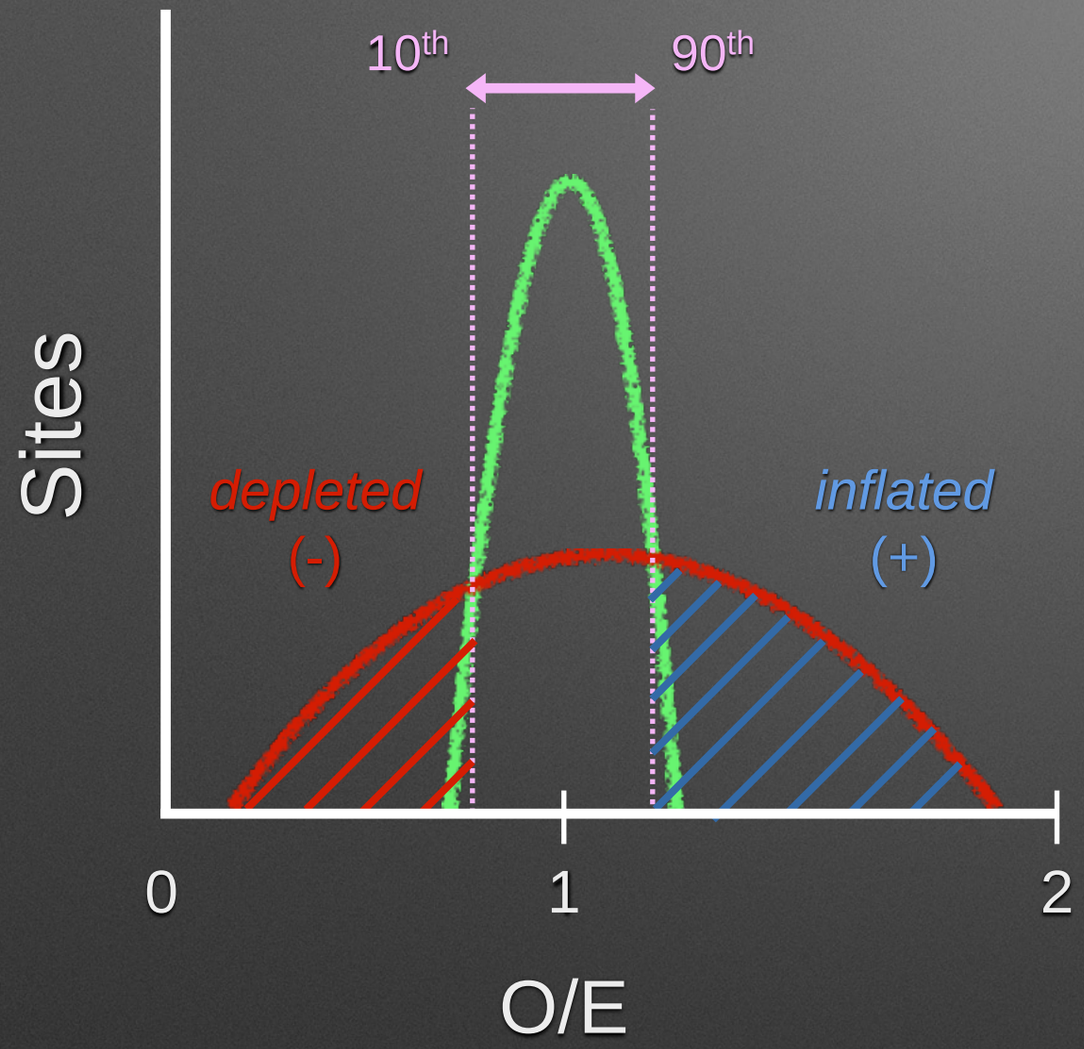


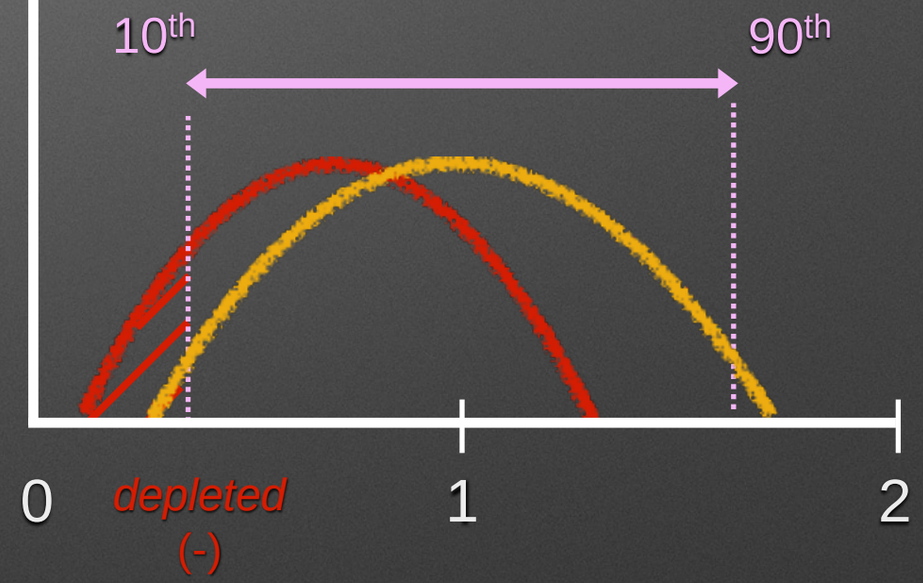
$flow_{obs}$

$flow_{pred}$

O/E

Change Detection





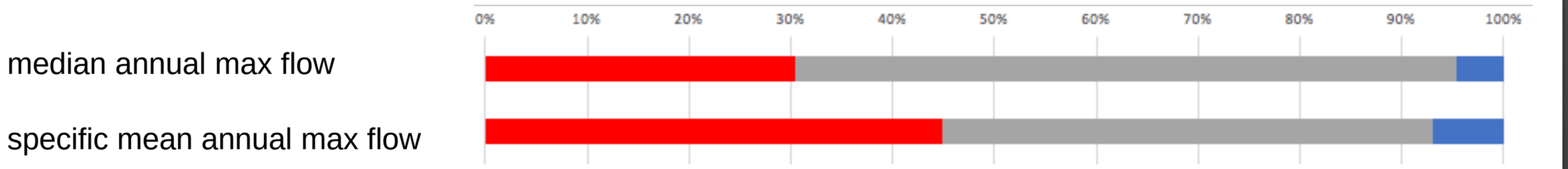
Representative flow dimensions

Dimension	Magnitude	Frequency	Duration	Variability	Timing	Rate of Change
High flow events	X	X	X	X	X	
Low flow events	X	X	X	X	X	
Monthly flows	X			X	X	
Daily flows	X			X		x

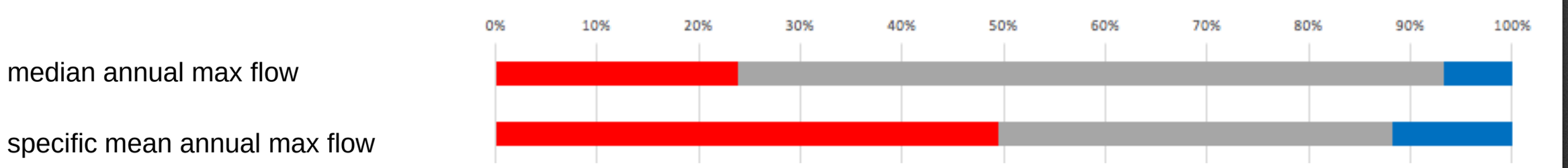
Alteration of high flows

depleted
inflated
indeterminate

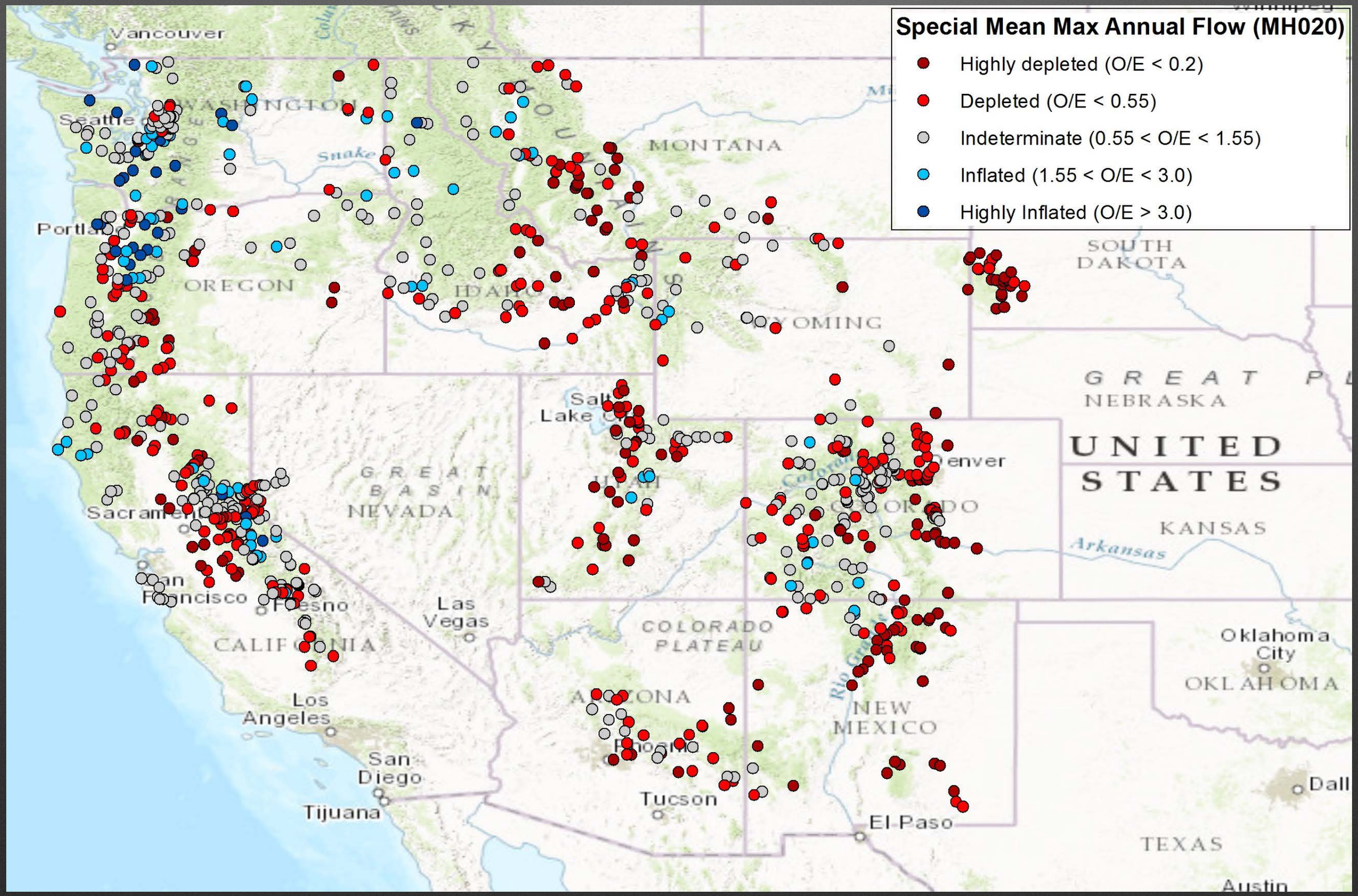
national (n = 3,842)



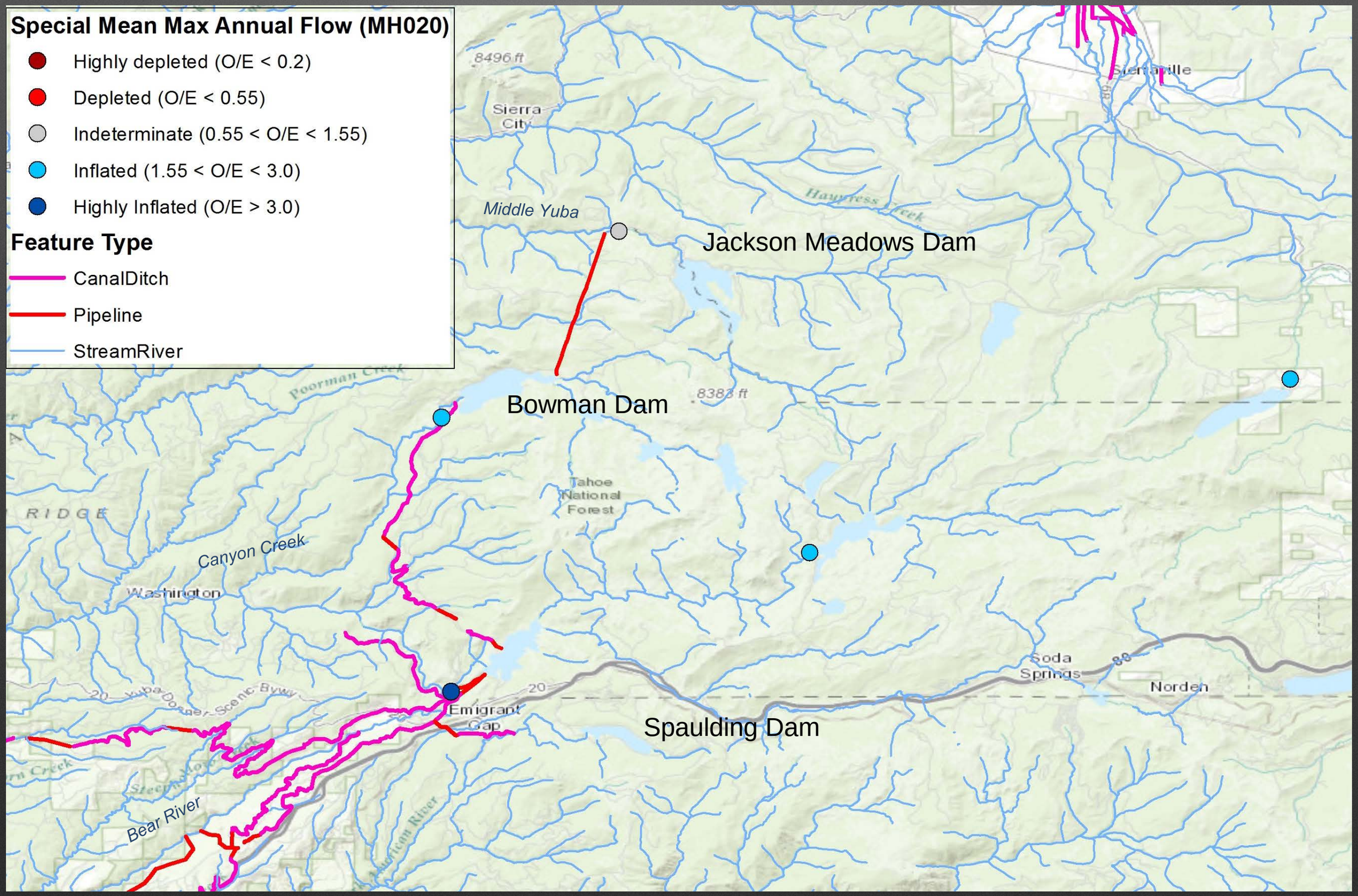
western mountains (n = 881)



High Flow Depletion in Western Mountain Region



Flow Inflation in Sierra Nevada?



“Step 2” Preliminary Findings

Most “altered” gauges are impaired for multiple metrics (>90% of sites have more than 50 flow metrics that are depleted or inflated beyond natural range)

High flows and flow variability tend to be depleted and measures of low-flows inflated

BUT, there are often exceptions

Evidence of regional flow alteration “signatures”

There is evidence of widespread alteration to multiple aspects of river flow regimes

Modeling and impact assessment can inform targeted management of ecologically relevant metrics