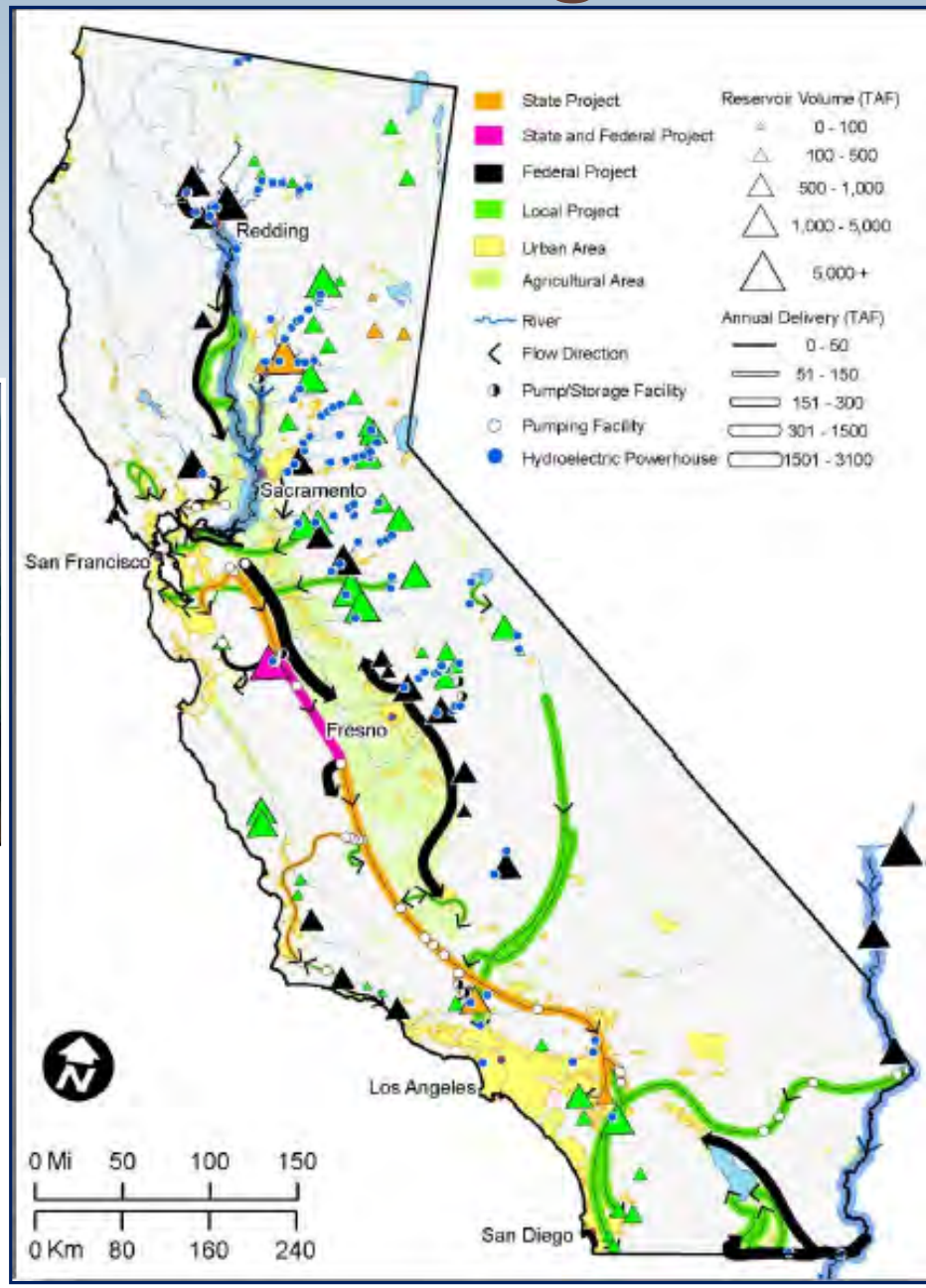
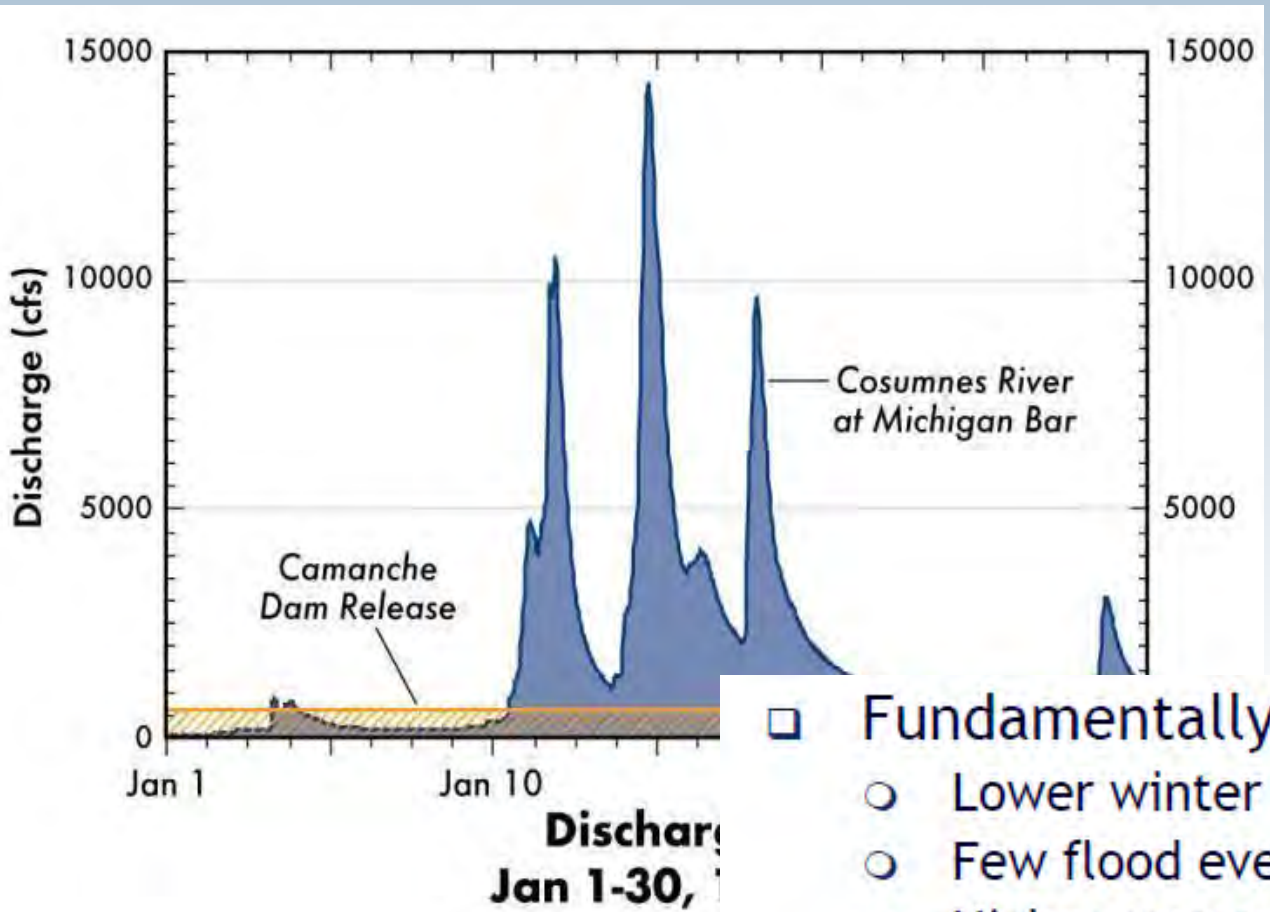
Establishing Environmental Flows for California Streams

Eric Stein
Southern California Coastal Water Research Project

California's Legacy of Water Management



Greatest Impact: Loss of Hydrologic Variability



- Fundamentally altered flow regime
  - Lower winter flows
  - Few flood events
  - Higher summer flows
  - Disconnect river from floodplain
  - Reduced sediment transport
  - Channel morphology more static
  - Biotic Repercussions

What Do We Know About the Status of Flows Statewide?

- First comprehensive study recently published
  - Statistical analysis of gauged locations
- 95% of gauged locations have at least some altered flows; 11% have pervasive alteration
  - Depletion of high flows
  - Augmentation of low flows
  - Reduction in seasonal variability
- **Results NOT related to any ecological endpoints**

Depletion of high flows

Augmentation of low flows

Zimmerman et al. 2017

Need an approach to define "flow impairment"

Statewide Needs for Environmental Flows

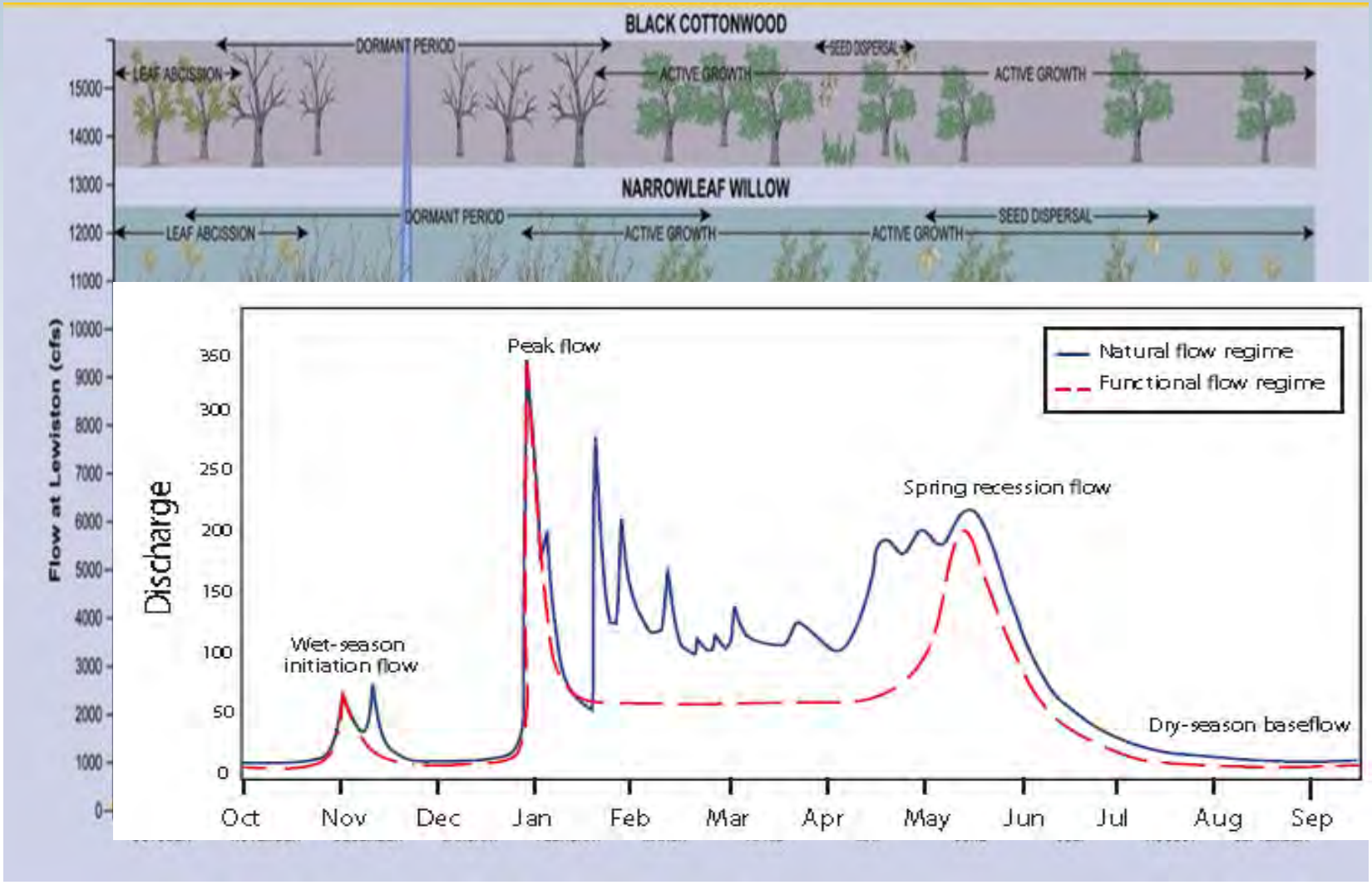
- Set instream flow standards to protect biological communities
  - Process for selecting appropriate ecological endpoints
- Assess vulnerability of streams to future changes in flow conditions
  - Prioritize areas for restoration/management
- Evaluate/inform management actions
  - e.g., reservoir operations, water withdrawals

What are Environmental Flows?

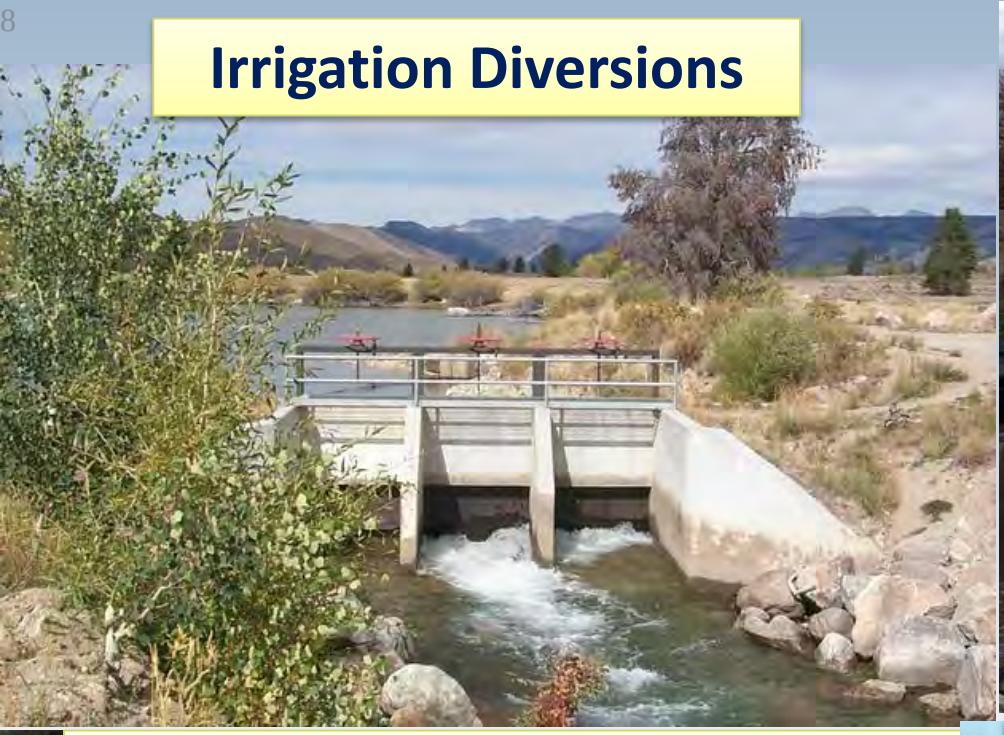
The magnitude, timing, duration, rate of change, and frequency of flows and associated water levels necessary to sustain the biological composition, ecological function, and habitat processes within a water body and its margins

Environmental flows are not necessarily “natural flows”. They allow for some degree of hydrologic alteration due to other uses. However, environmental flows are intended to mimic the patterns and ecological outcomes of the natural flow regime

Environmental Flows



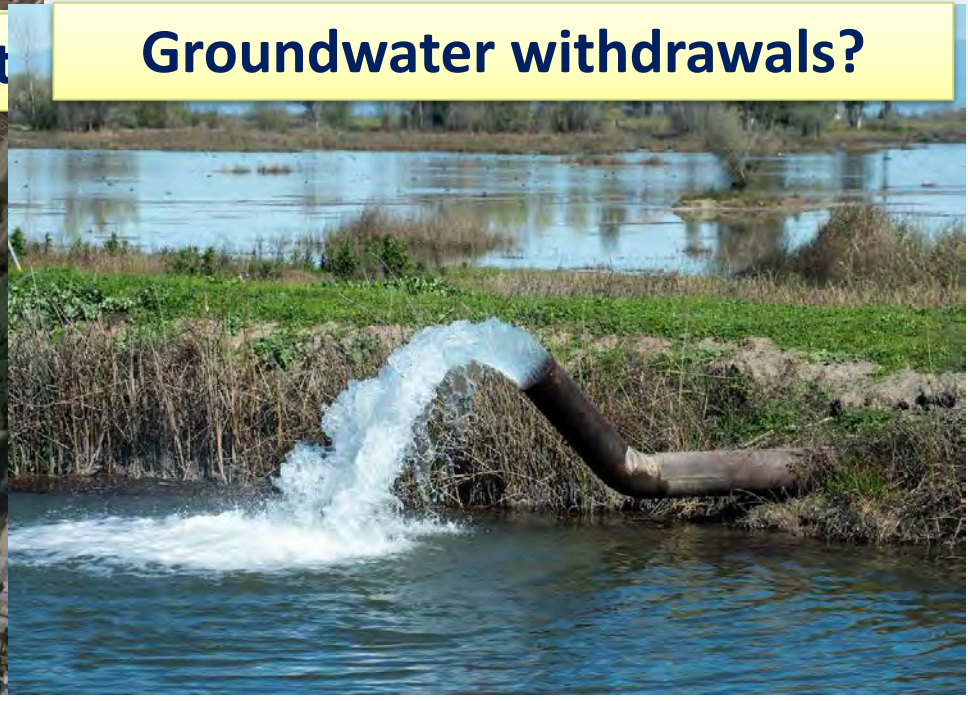
Irrigation Diversions



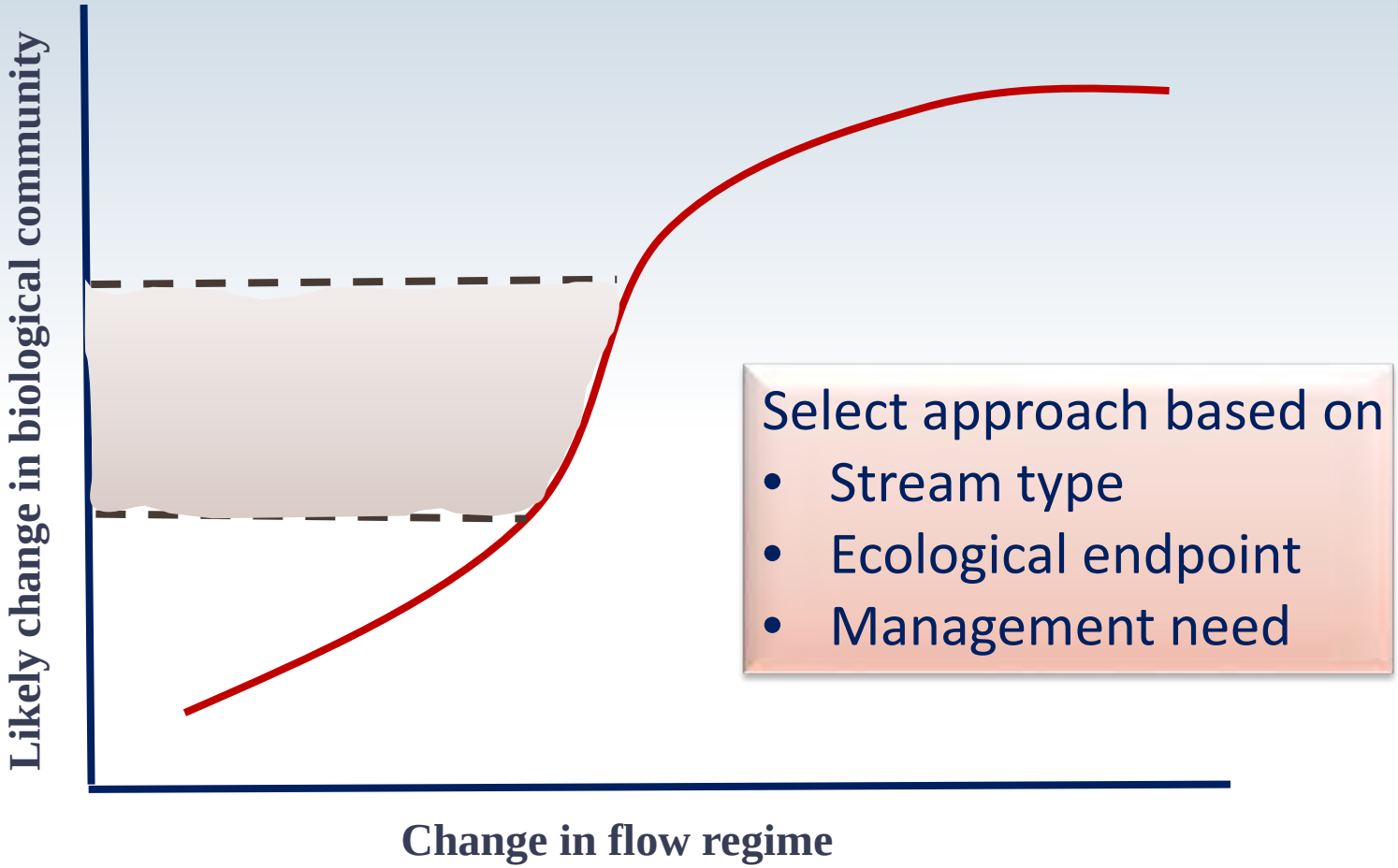
Stormwater Retention

Use or Reuse of Treated Effluent

Groundwater withdrawals?



Setting Flow Targets to Inform Management Decisions



Select approach based on

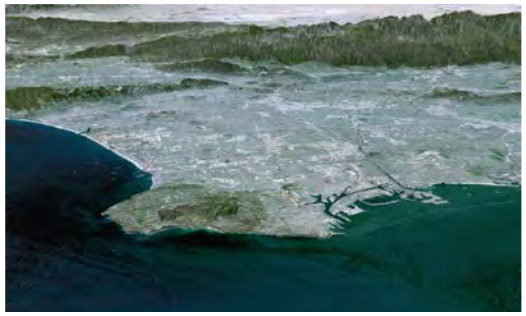
- Stream type
- Ecological endpoint
- Management need

Challenges

- California is a very complex/diverse state

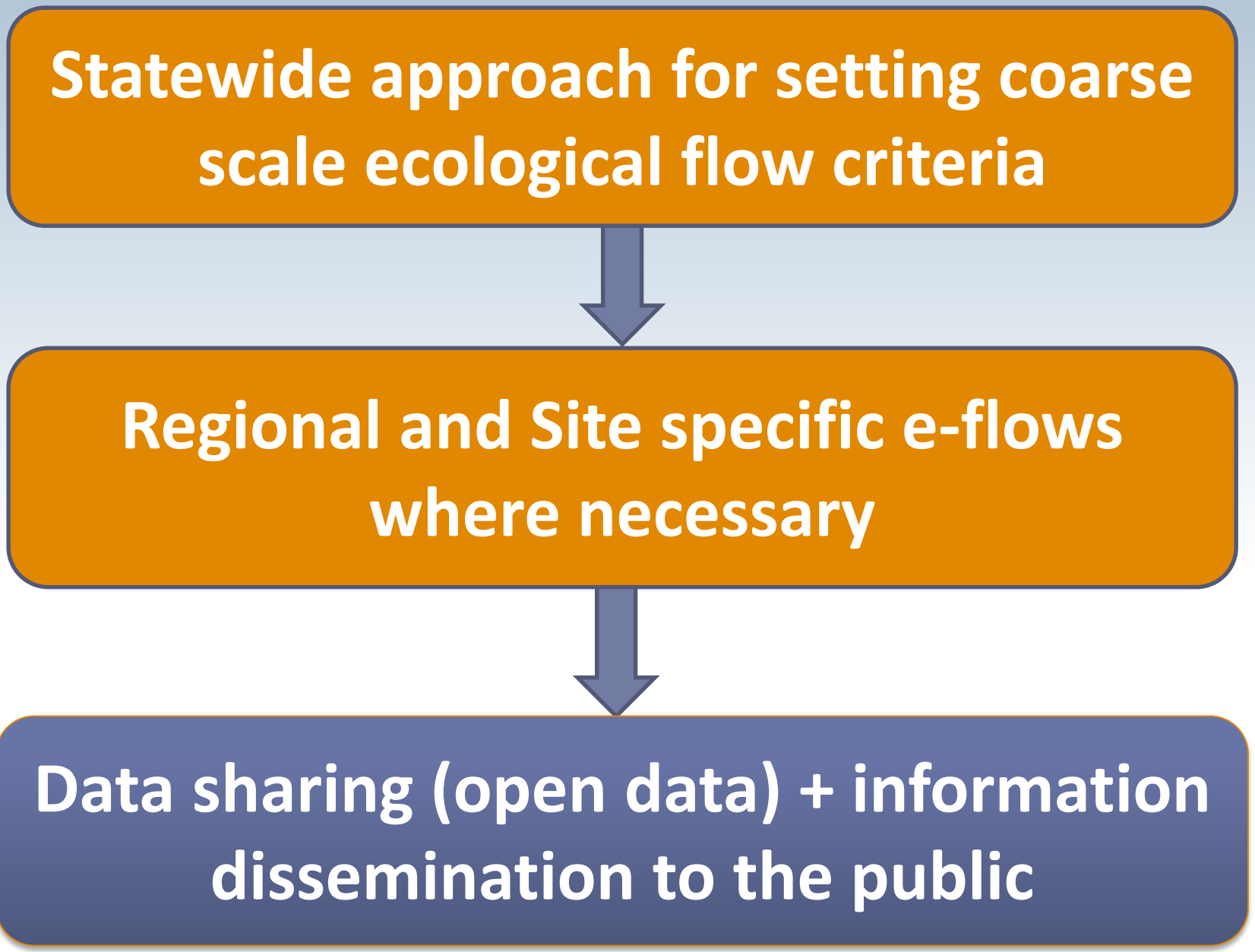


- Hard to balance environmental flow needs with a broad range of other demands


- No mechanism for coordination and information sharing among agencies and with the public

California E-flows Framework



Statewide approach for setting coarse scale flow targets

- Stream classification
- Dimensionless hydrographs
- Functional flow metrics and ecological endpoints
- E-flow targets: rapid, comprehensive, coarse

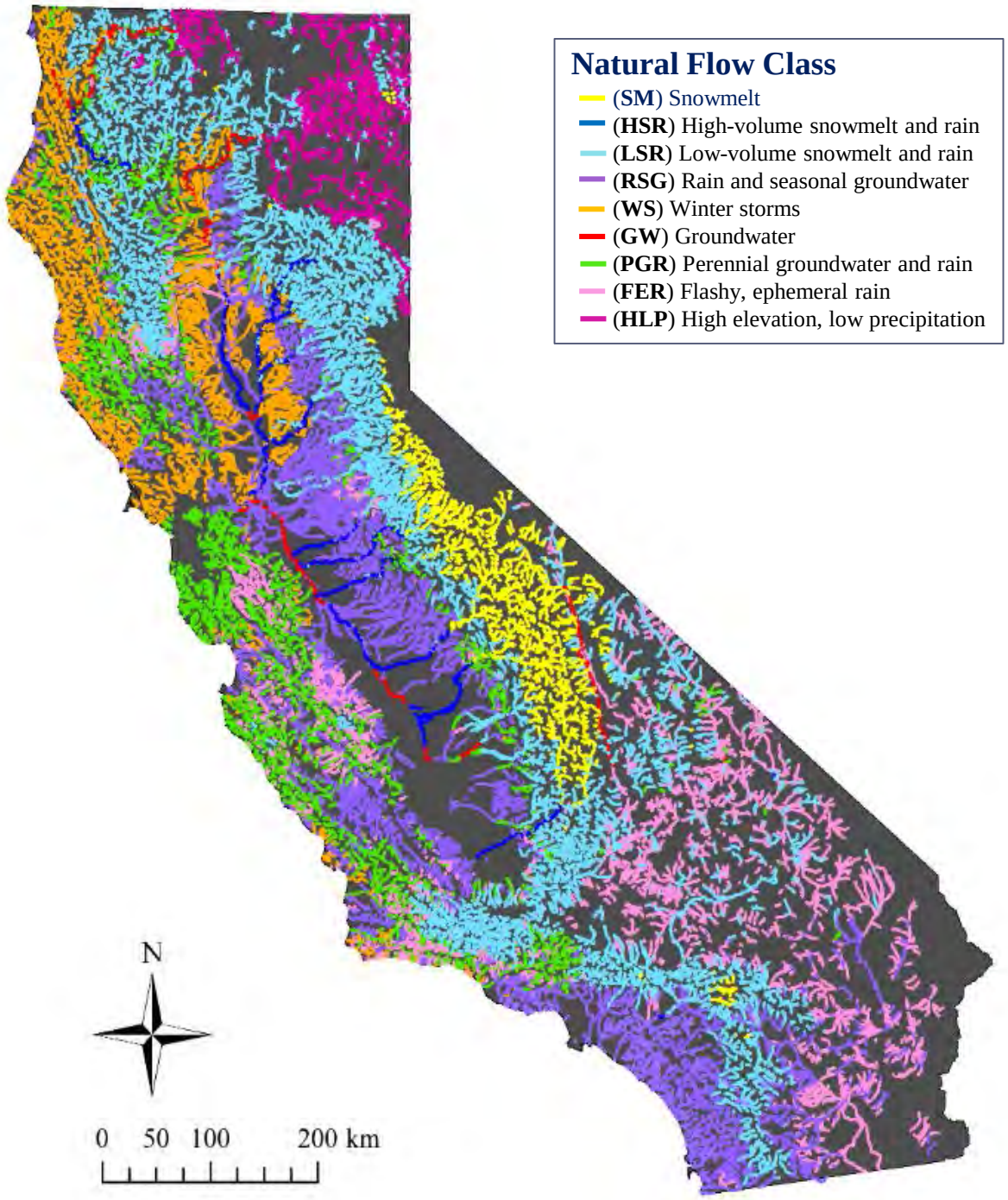
Stream Classification

Catchment Properties

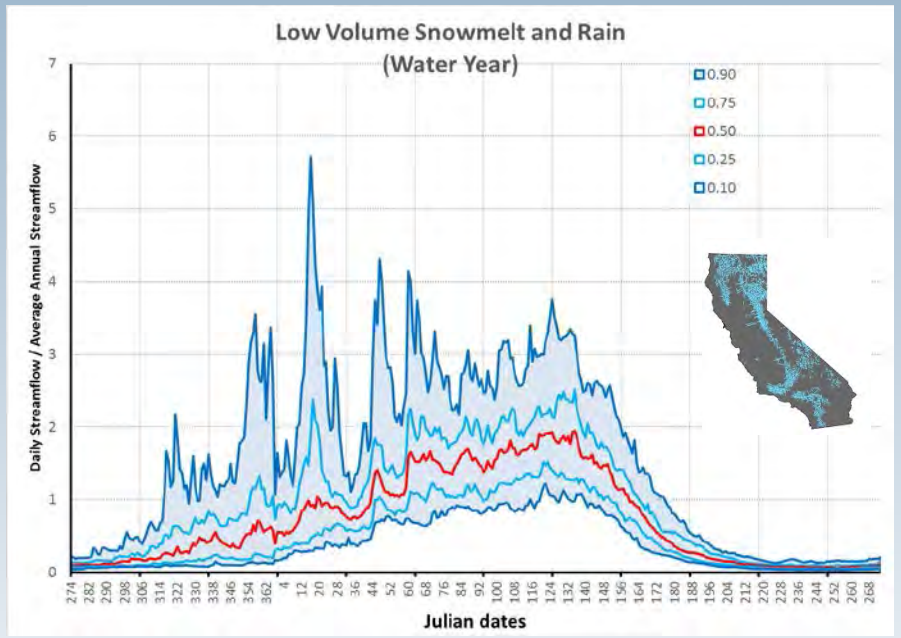
Rainfall Patterns

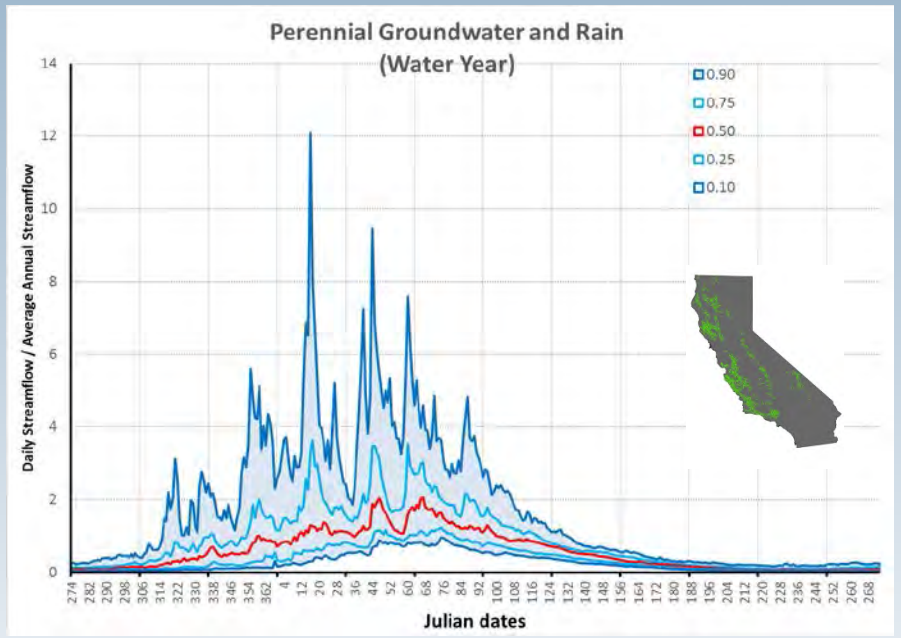
Geology

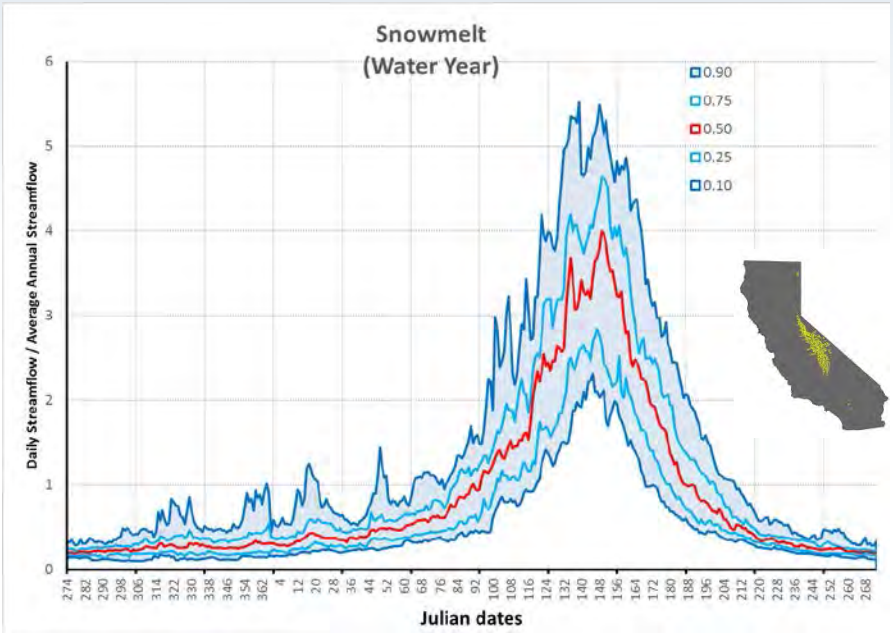
Soil Properties



Lane et al., *in review*


Low Volume Snowmelt and Rain
(Water Year)
0.90
0.75
0.50
0.25
0.10
Daily Streamflow / Average Annual Streamflow
Julian dates


Perennial Groundwater and Rain
(Water Year)
0.90
0.75
0.50
0.25
0.10
Daily Streamflow / Average Annual Streamflow
Julian dates


Snowmelt
(Water Year)
0.90
0.75
0.50
0.25
0.10
Daily Streamflow / Average Annual Streamflow
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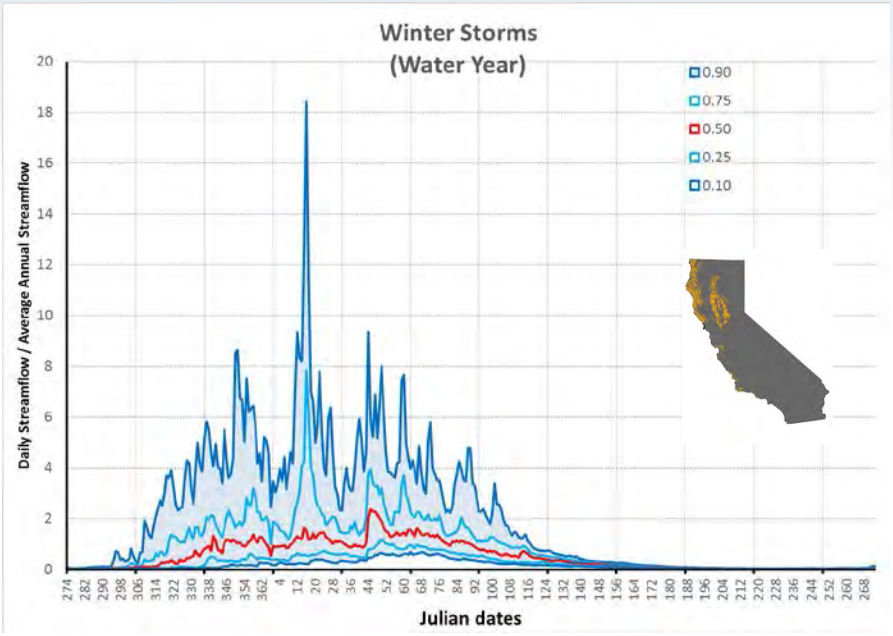
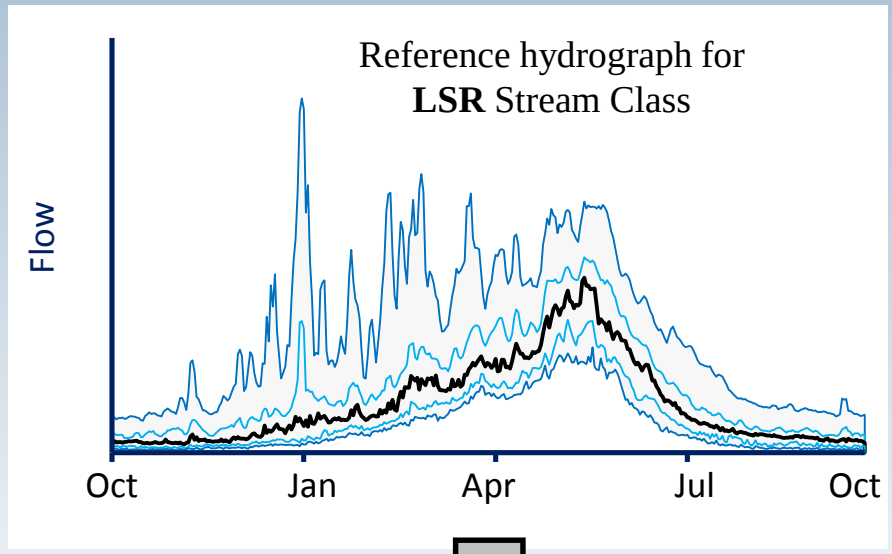

Winter Storms
(Water Year)
0.90
0.75
0.50
0.25
0.10
Daily Streamflow / Average Annual Streamflow
Julian dates

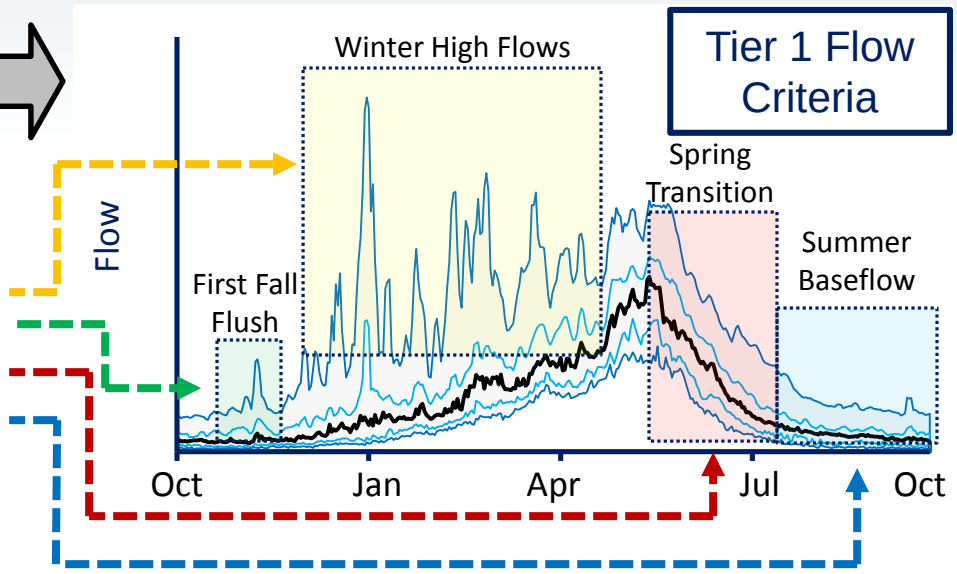
Stream Classification

Develop reference hydrographs and identify flow components



TIER 1

	Flow Metrics			
Flow Component	Magnitude	Timing	Duration	…
Winter High Flows	2,000 cfs	Jan 3	7 days	
First Fall Flush	200 cfs	Nov 22	3 days	
Spring Transition	-10 cfs/day	May 19	82 days	
Summer Baseflow	50	Aug 20	123 days	



Estimate and Predict Functional Flow Metrics

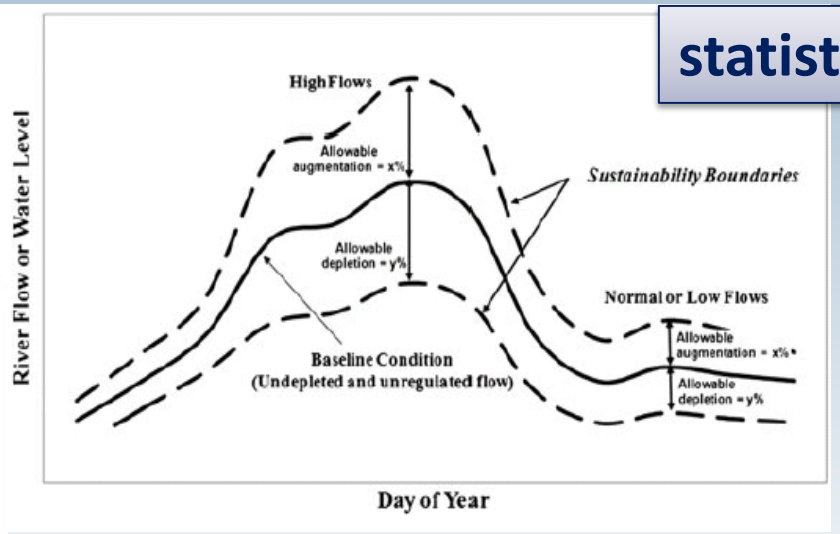
Develop quantitative flow criteria

Site specific e-flows where necessary

- Assess available methodologies
- Define ecological and management context
- Tailor approach to hydrologic alteration, stream class, management needs, biological outcomes
- E-flow targets: specific, objectives-based

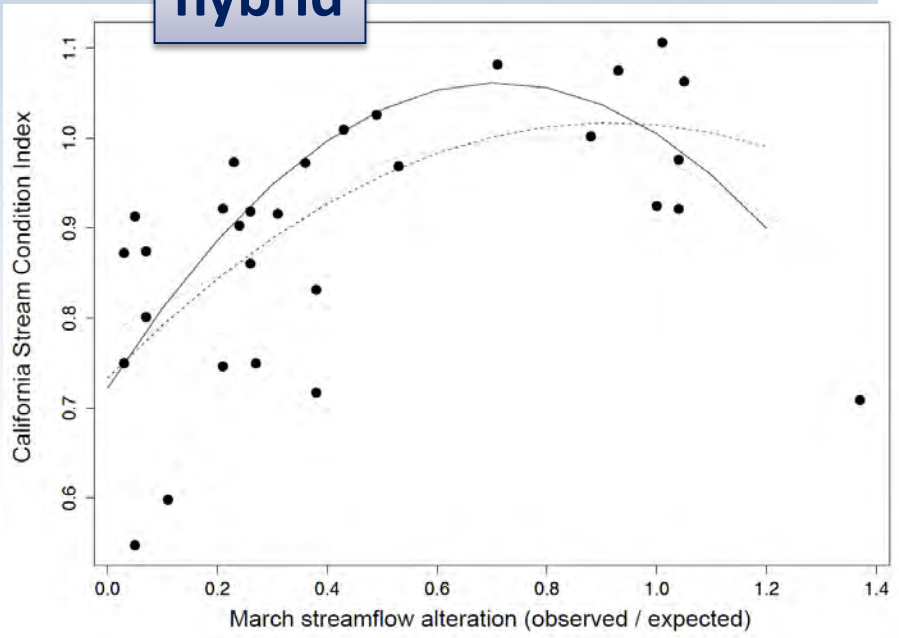
There are Many Technical Approaches

statistical



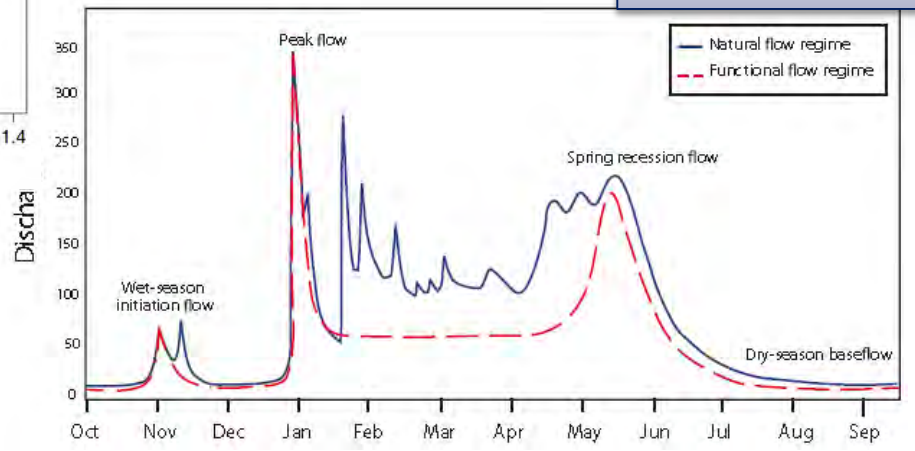
resumptive Standard – Richter et al. 2013

hybrid



ELOHA -Carlisle et al. 2015

mechanistic

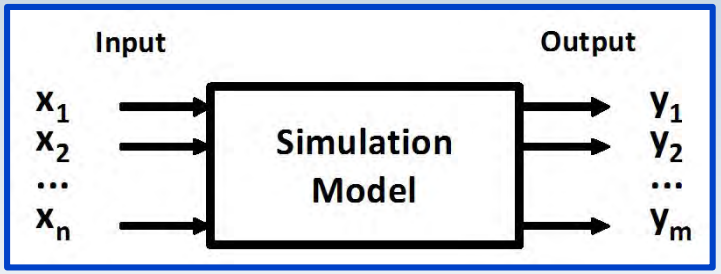


Functional Flows - Yarnell et al. 2015


CLEAN WATER ALGAE

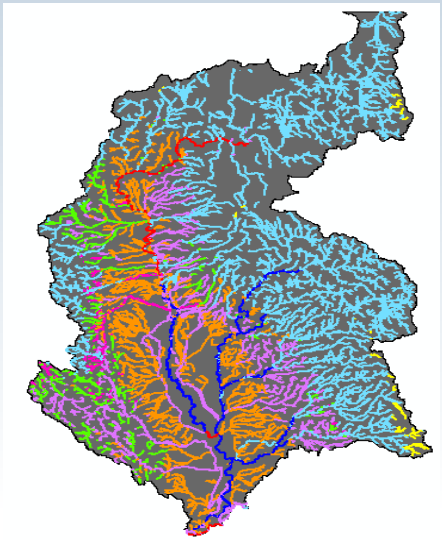
Incorporate Local Data

Hydrology



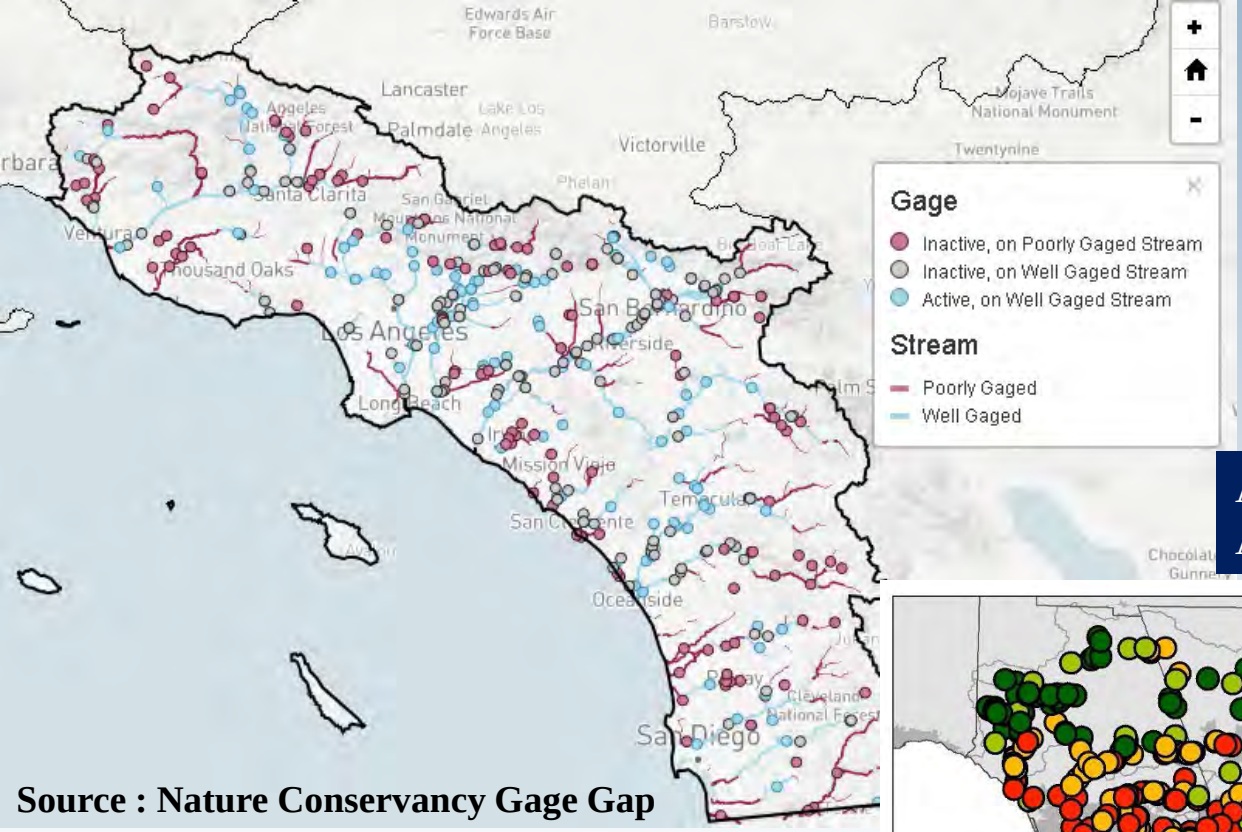
Geomorphology

Ecology



Reach scale environmental flow methods

Flow targets

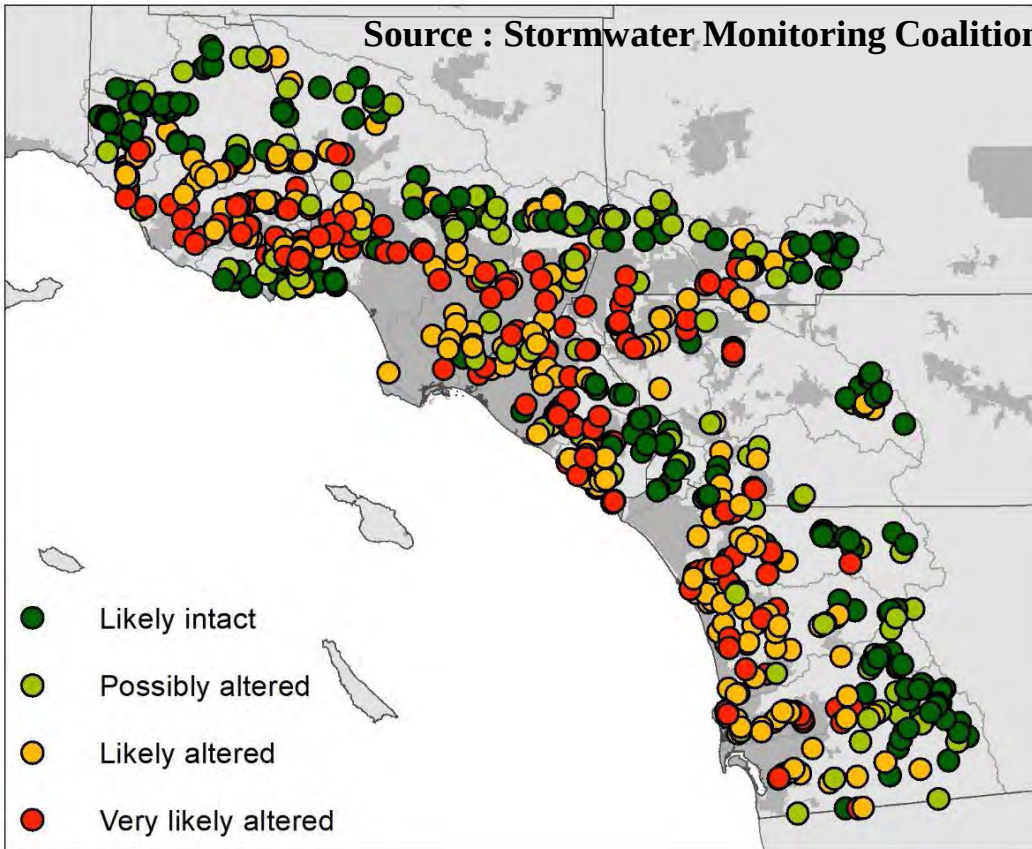


Source : Nature Conservancy Gage Gap

Approximately 900 sites sampled
Approximately 30% considered intact

Out of **10,732 km of streams** in the region:
- **8,782 km** are **poorly** gaged
- **1,950 km** are **well** gaged

Out of **433 gages** in the region:
- **283 gages** are **inactive**
- **150 gages** are **active**



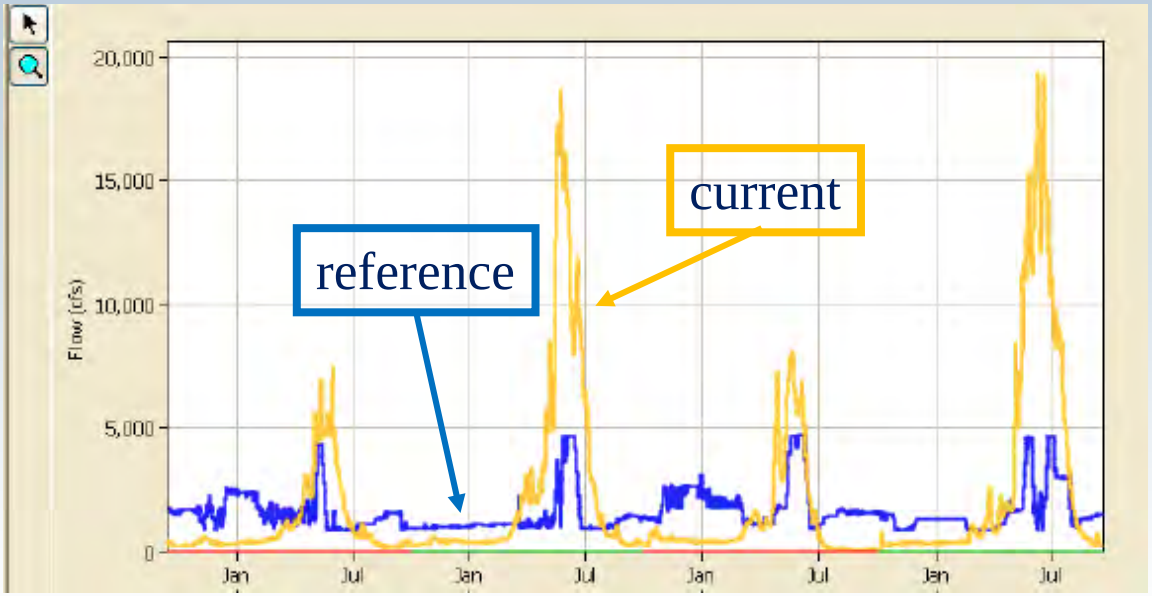
Source : Stormwater Monitoring Coalition

Ecological Limits of Hydrologic Alteration (ELOHA)

- Estimate degree of hydrologic alteration
  - Calculate a series of flow metrics
  - Current vs. "natural" conditions
- Compare hydrologic change to response of the biological community
  - Based on benthic invertebrate CSCI
  - Establish thresholds of biological response

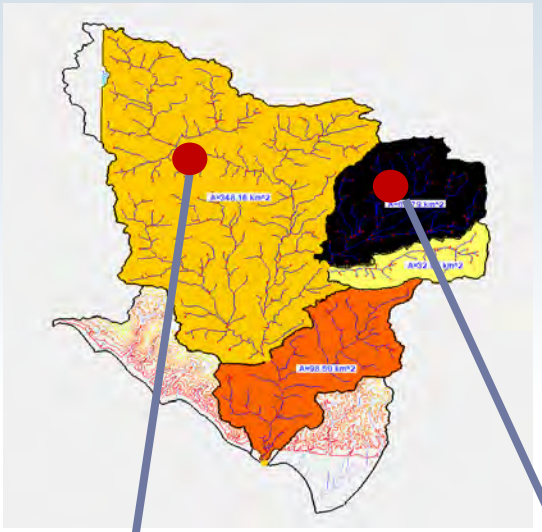
- Develop a regional index of hydrologic alteration based on priority metrics
- *Apply index to evaluate management options in terms of their likely effect on biological communities*

Estimating Hydrologic Change



Compare reference vs. current flow to produce measures of hydrologic change

Regional model ensemble

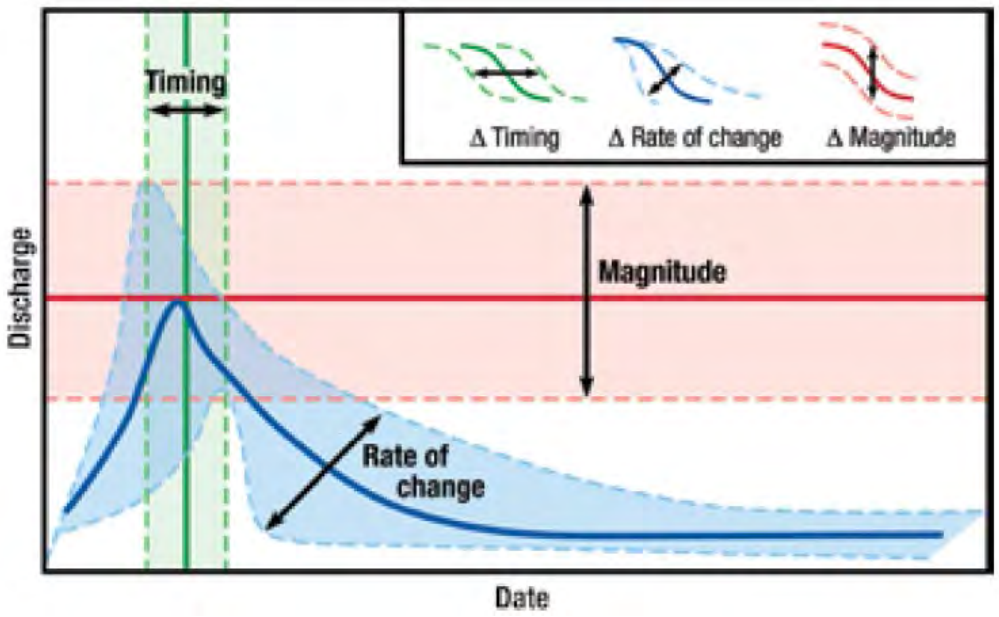


Consider a Broad Suite of Flow Metrics

- Magnitude
  - streamflow (mean, max)
  - median annual number of high flow events
- Variability
  - median percent daily change in streamflow
  - Interannual variability (min, max, median)
- Duration
  - Storm flow recession
  - Duration above baseflow
- Timing
  - month of minimum streamflow
  - Frequency of high flow events

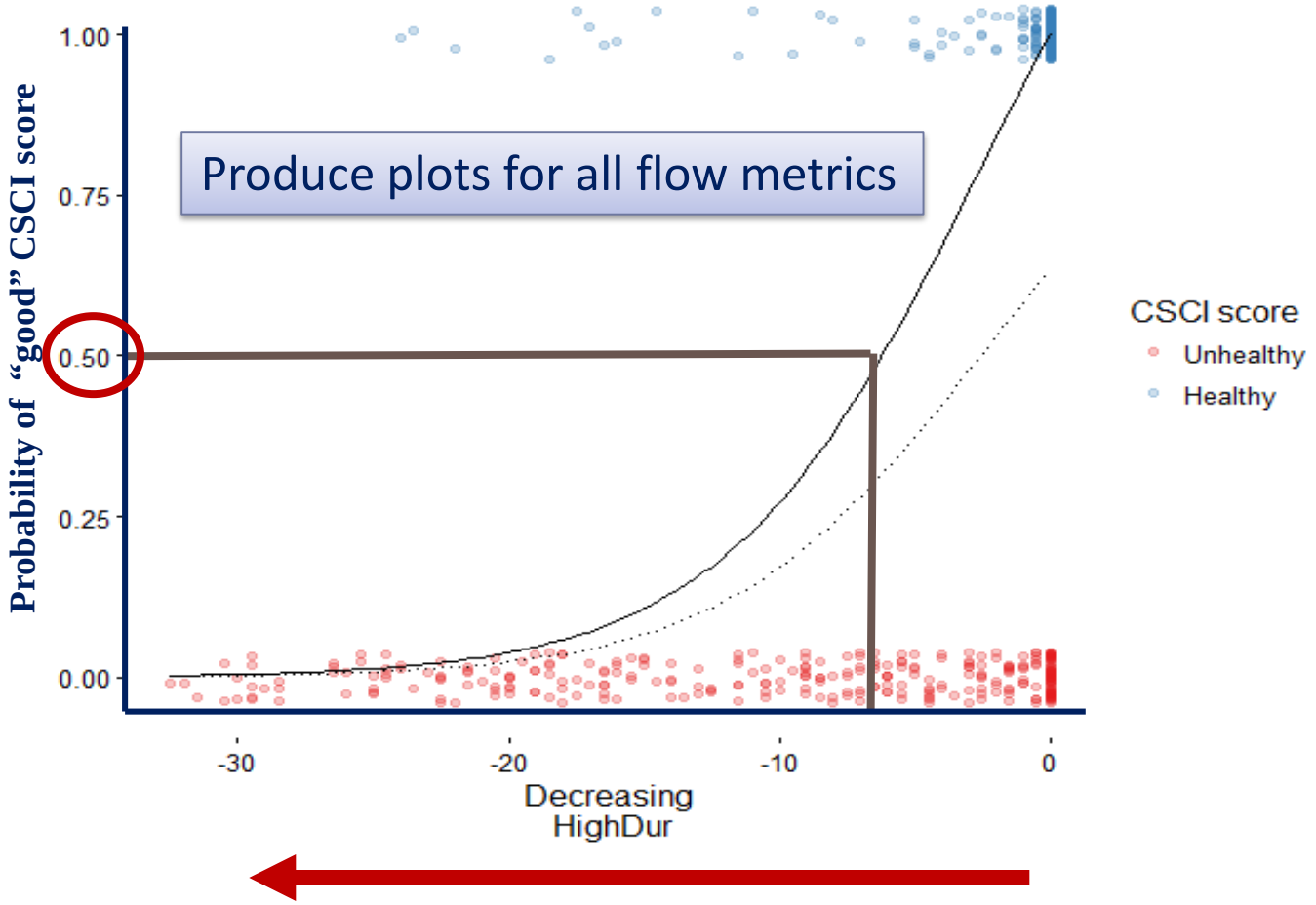
Evaluate for multiple climatic conditions

- Average years
- Wet years
- Dry years
- All years



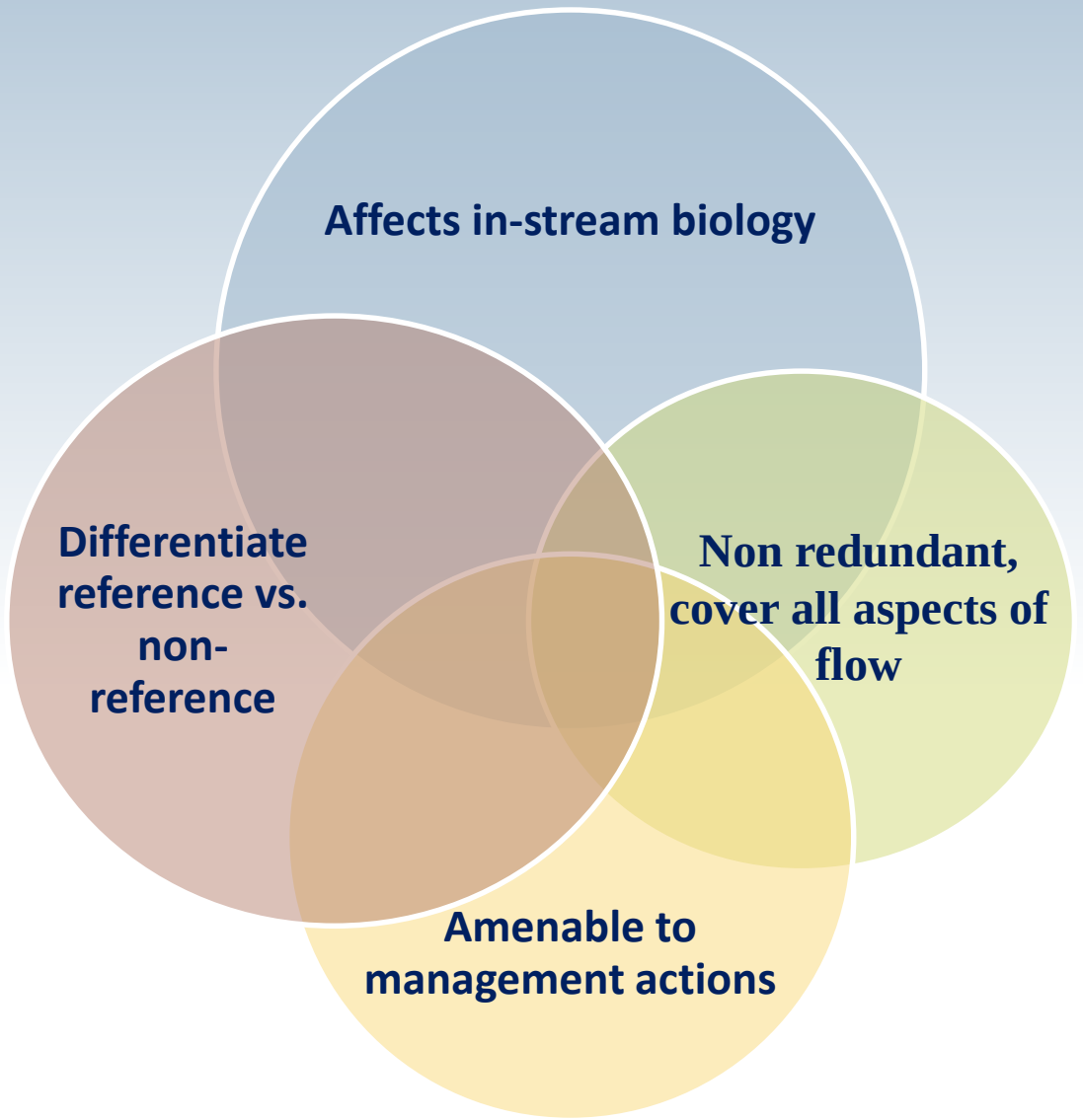
Establish Thresholds; example High Duration (days)

Logistic regression: Likelihood of healthy biology at each level of hydrologic alteration



Produce plots for all flow metrics

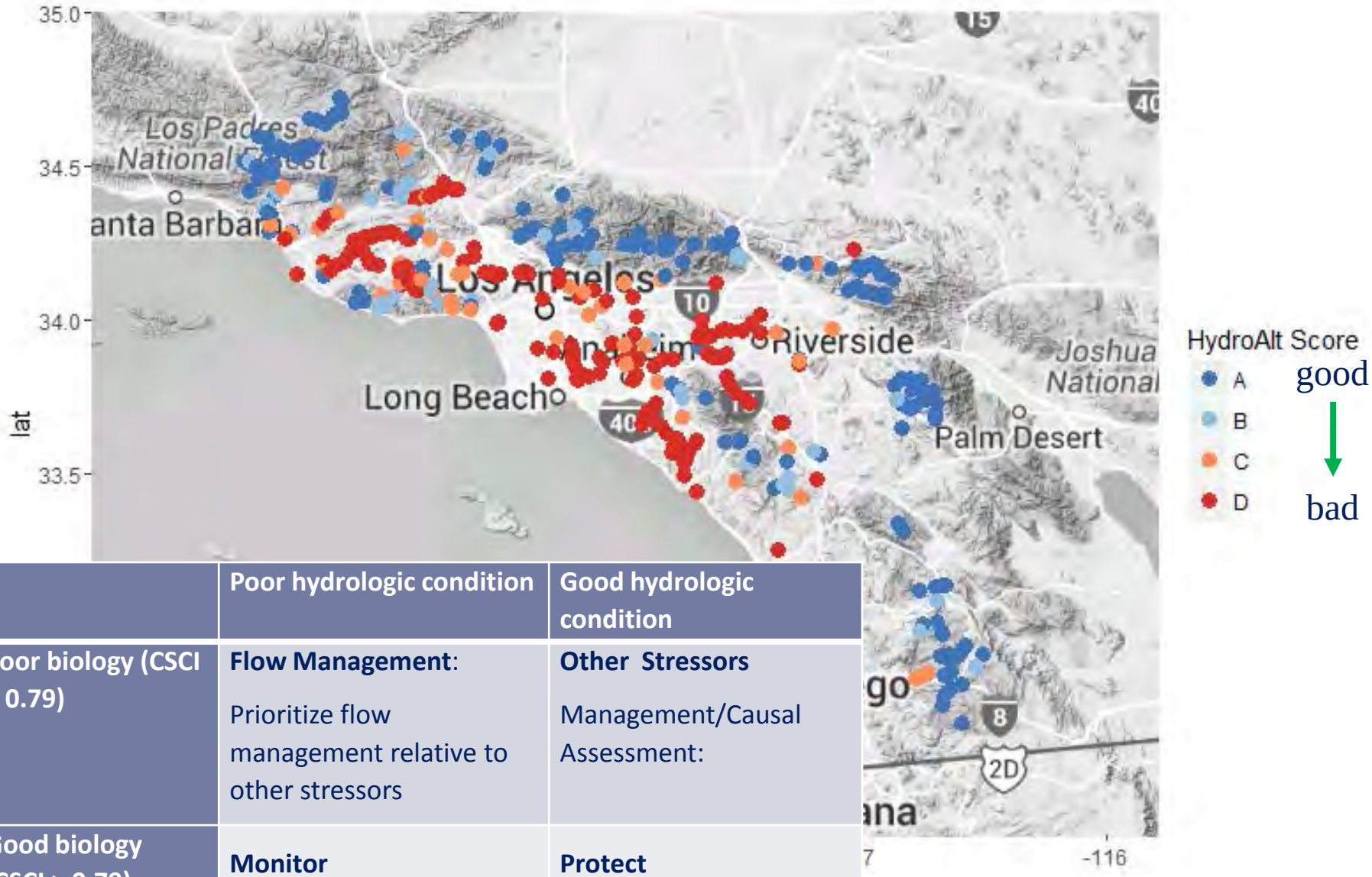
Select Priority Metrics



Priority Metrics (expressed as CHANGE in metric value)

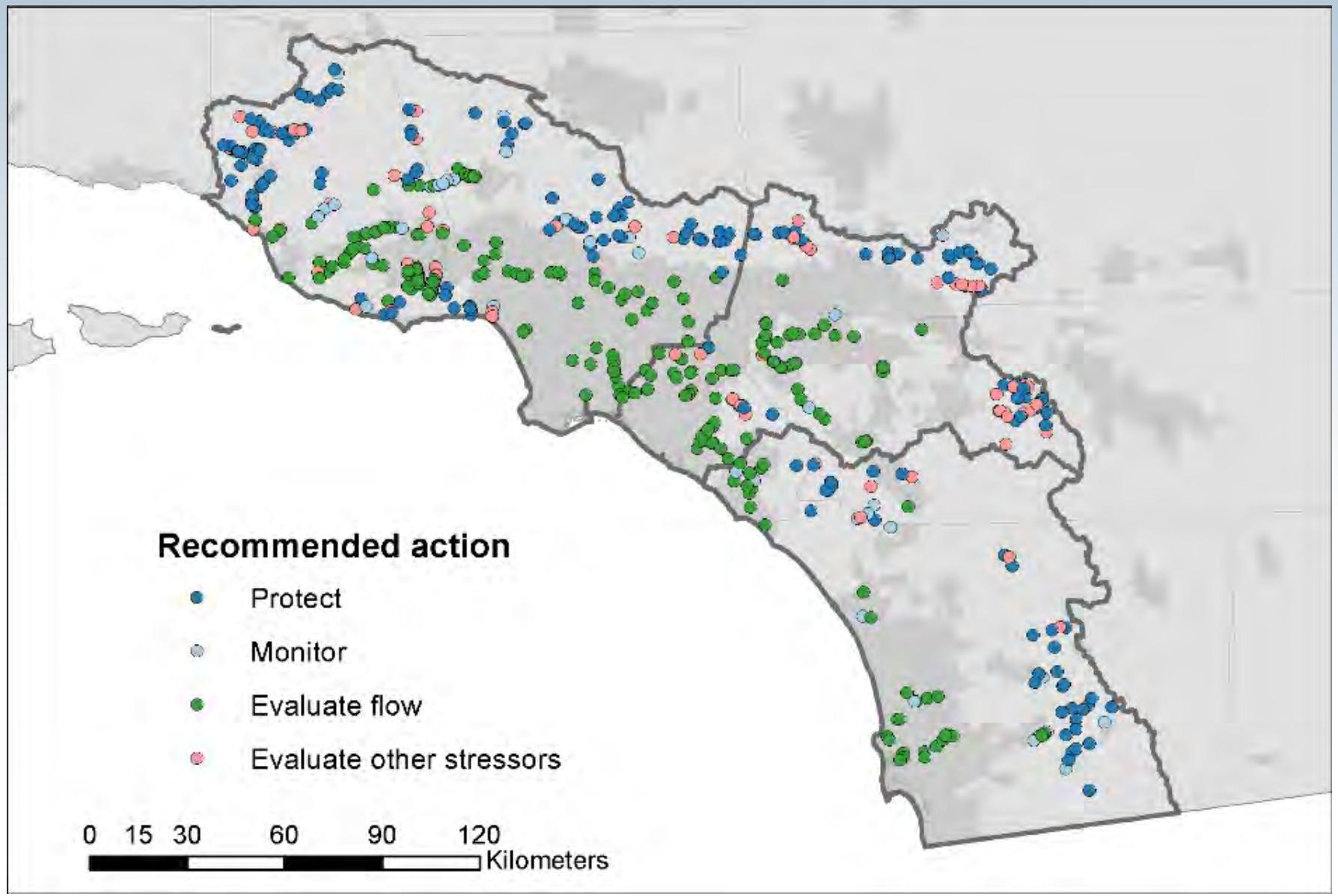
Hydrograph Component	Metric Definition	Critical precipitation condition	Decreasing Threshold	Increasing Threshold
Duration (days)	longest number of consecutive days that flow is between the low and high flow threshold	Average	-64	NT
	longest number of consecutive days that flow was greater than the high flow threshold	Wet	-3	24
Magnitude (cms)	Maximum mean monthly streamflow	Wet	NT	1.5
	streamflow exceeded 99% of the time	Wet	NT	32
Variability (unitless)	Richards-Baker index of stream flashiness	Dry	NT	0.25
Frequency (# of events)	number of events that flow was greater than high flow threshold	Dry	NT	3

Regional Hydrologic Condition



	Poor hydrologic condition	Good hydrologic condition
Poor biology (CSCI < 0.79)	**Flow Management**: Prioritize flow management relative to other stressors	**Other Stressors** Management/Causal Assessment:
Good biology (CSCI > 0.79)	**Monitor**	**Protect**

Regional Management Priorities



Environmental Flows Workgroup

CA.GOV

California Water Quality Monitoring Council

My Water Quality

A COLLABORATION BETWEEN THE CALIFORNIA ENVIRONMENTAL PROTECTION AND NATURAL RESOURCES AGENCIES

Search

Portals | About Us | Work Groups

These web portals, supported by a wide variety of public and private organizations, present California water quality and aquatic ecosystem monitoring data and assessment information that may be viewed across space and time.

1

Are Our Aquatic Ecosystems Healthy?

California has many types of aquatic habitats. Follow the links below to learn more …

CA Environmental Flows Workgroup

Wetlands Portal

Wetlands form along the shallow margins of deepwater ecosystems such as lakes, estuaries, and rivers. They also form in upland settings where groundwater or runoff makes the ground too wet for upland vegetation.

Estuaries Portal

Estuaries are unique habitats found where rivers and the ocean mix. They feature a diverse array of plants and animals adapted to life along the mixing zone.

Streams & Rivers Portal

California's streams and rivers flow through diverse habitats, from mountain canyons, valleys, deserts, estuaries and urban areas. Riparian woodlands develop along stream banks and floodplains, linking forest, chaparral, scrubland, grassland, and wetlands. California lakes, supporting deep water, wetlands, riparian woodlands, offer a quiet refuge for plants, animals and humans alike.

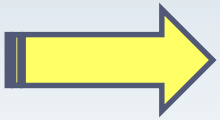
Ocean & Coastal Portal

California has 1,100 miles of shoreline and 220,000 square miles of state and federal oceanic habitat, featuring one of the world's most diverse marine ecosystems.

Ca. Env. Flows Workgroup Mission

The mission of the California Environmental Flows Workgroup is to advance the science of environmental flows assessment and its application for supporting management decisions aimed at balancing natural resource needs with consumptive water uses.

Technical Products



Implementation Products

- Analytical frameworks
- Classification systems
- Assessment tools
- Modeling approaches and models
- Databases
- Statistical analysis of patterns and relationships

- Guidance for environmental flow criteria
- Appropriate application of tools, databases and models
- Prioritize knowledge gaps for funding
- Interpretation tools
- Communication approaches
- Ways to reconcile different approaches

Ca. Env. Flows Workgroup Members

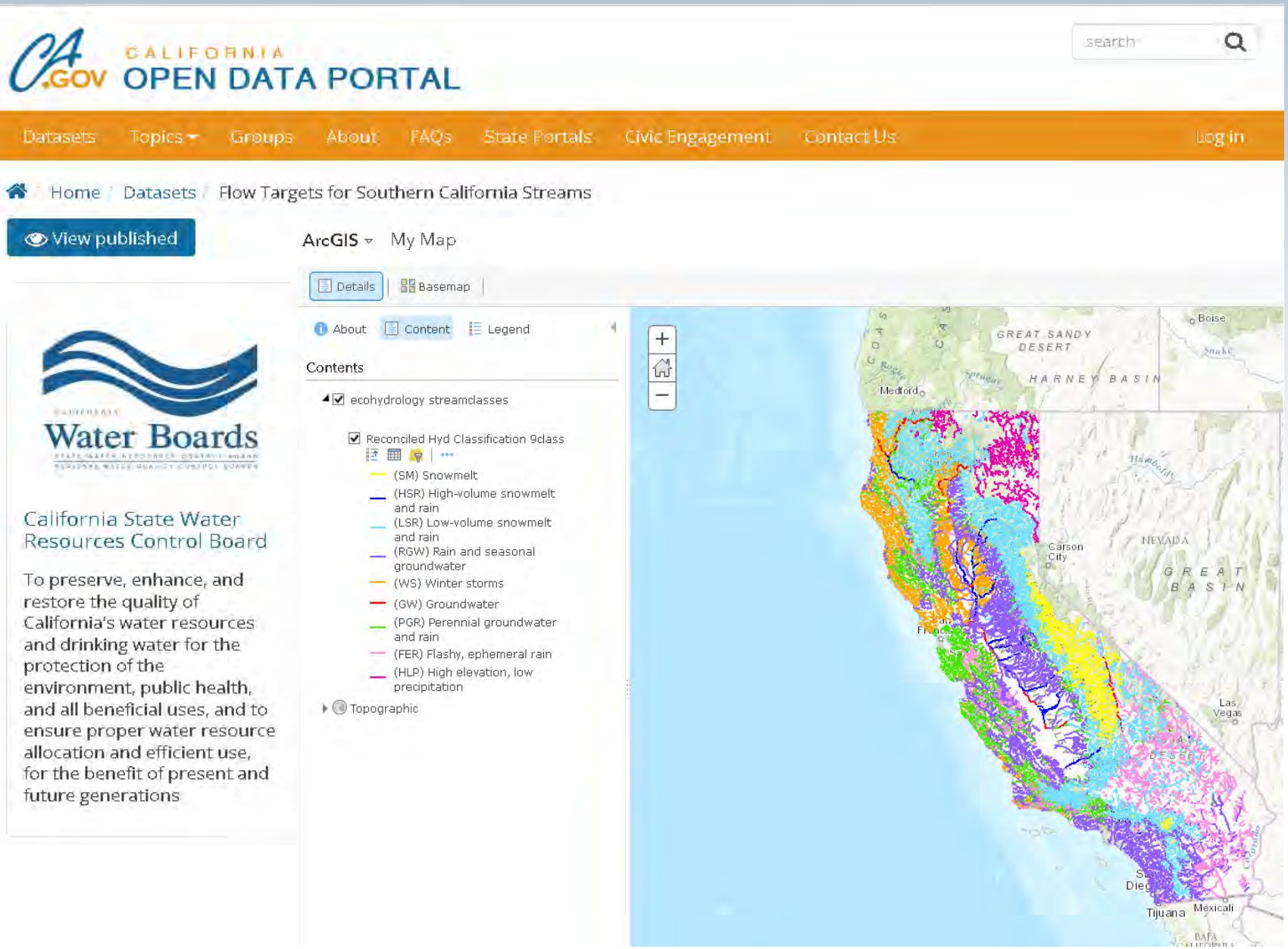
Technical Participants

- University of California, Davis
- University of California, Berkeley
- University of California Agriculture and Natural Resources
- Utah State University
- Southern California Coastal Water Research Project
- The Nature Conservancy
- California Trout
- US Geological Survey

Agency Members

- State Water Board - Water Quality
- State Water Board - Water Rights
- Department of Water Resources
- California Department of Fish and Wildlife
- US Fish and Wildlife Service
- US Forest Service
- US Geological Survey
- Regional Water Quality Control Boards
- Bureau of Reclamation
- NOAA Fisheries

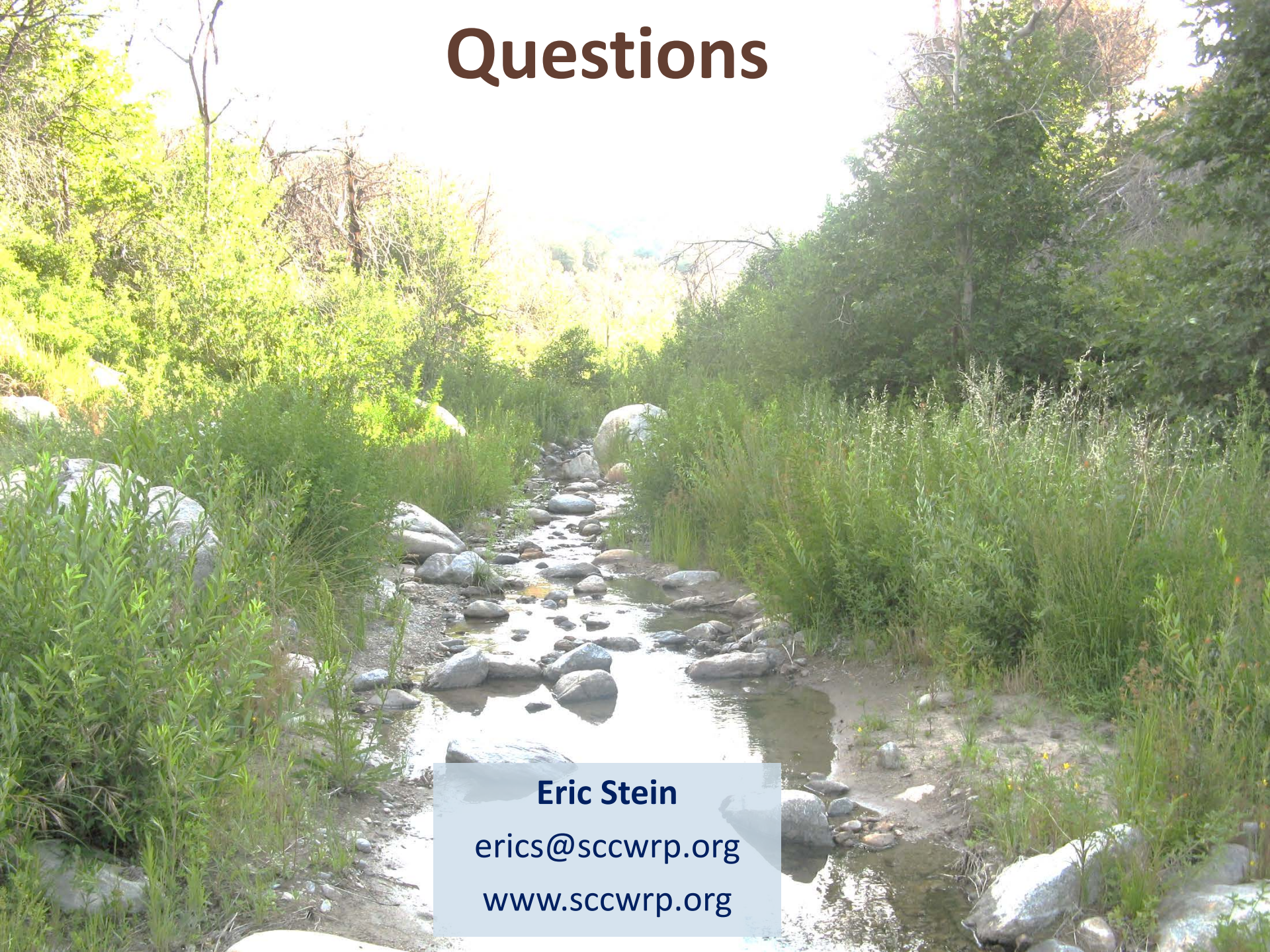
Improve Information Dissemination



Final Thoughts

- Lots of emerging science around environmental flows
  - Moving beyond dams and fish to a broader set of ecological endpoints and management needs
- Statewide framework provides tools and approaches for coordination and collaboration
- Opportunities for partnership in Tier 2 case studies and trial implementation of environmental flow products

Questions



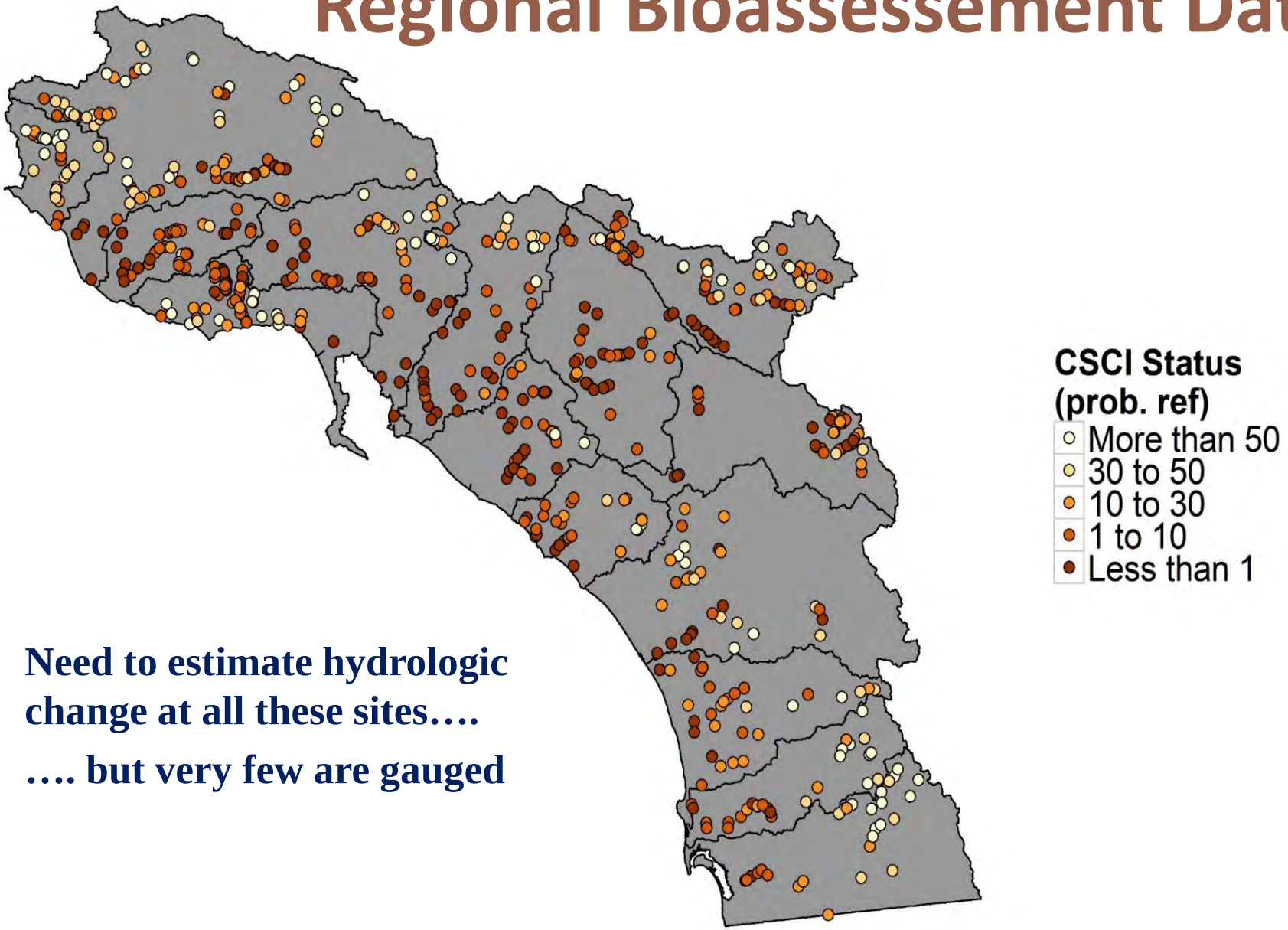
Eric Stein

erics@sccwrp.org

www.sccwrp.org

EXTRA SLIDES

Regional Bioassessement Data

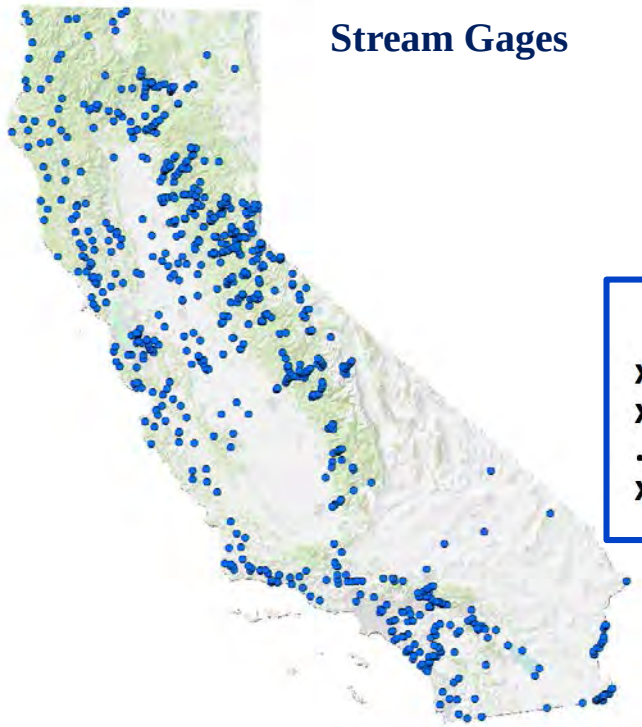


Need to estimate hydrologic change at all these sites….

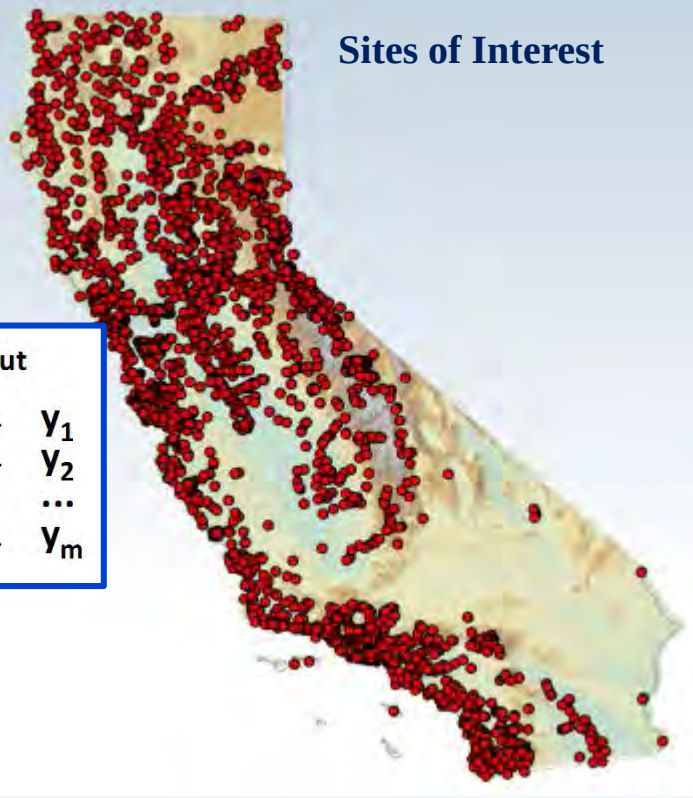
…. but very few are gauged

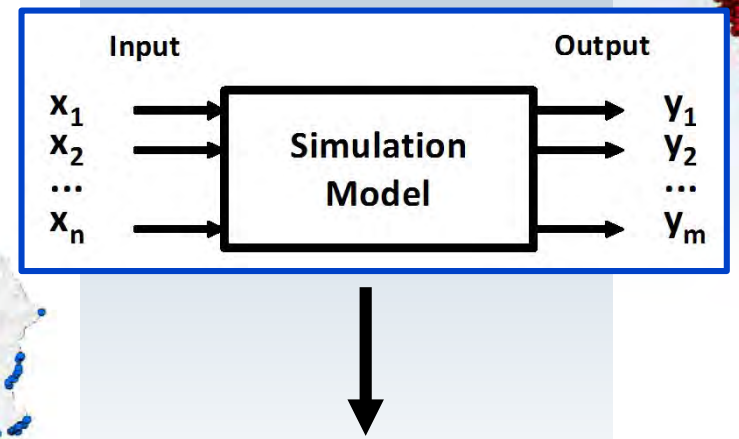
Local Targets

Stream Gages



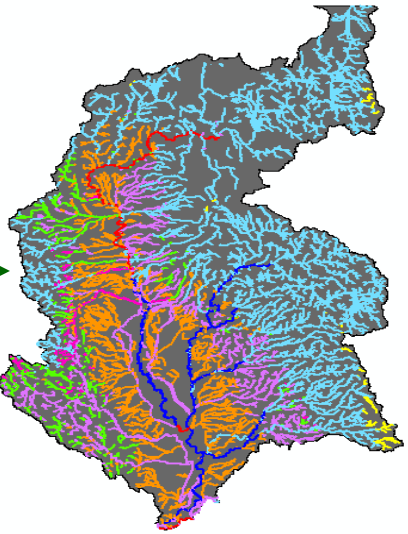
Sites of Interest





Geomorphology

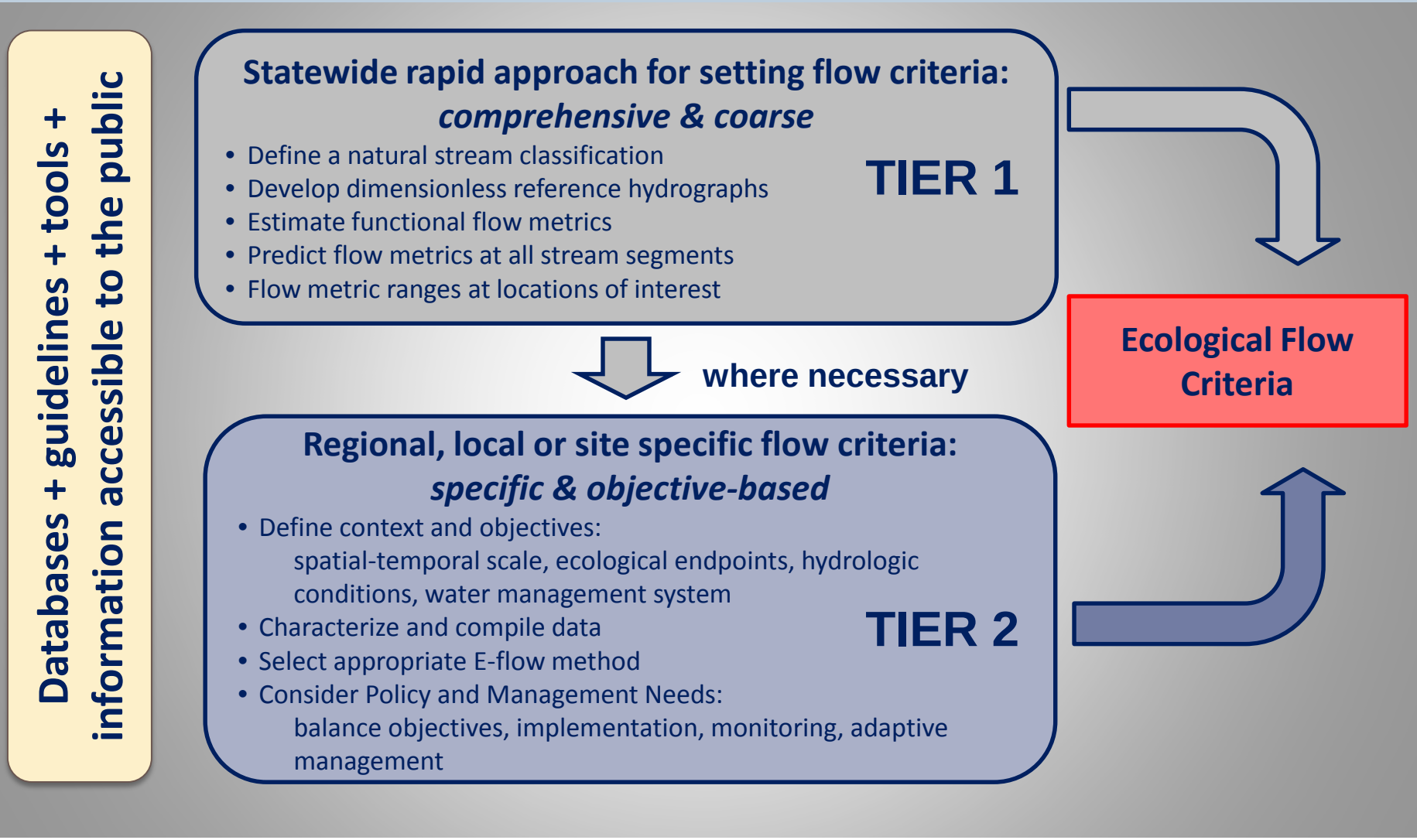
Ecology



Reach scale environmental flow methods

Flow targets

CEFF - Two Tiered Approach

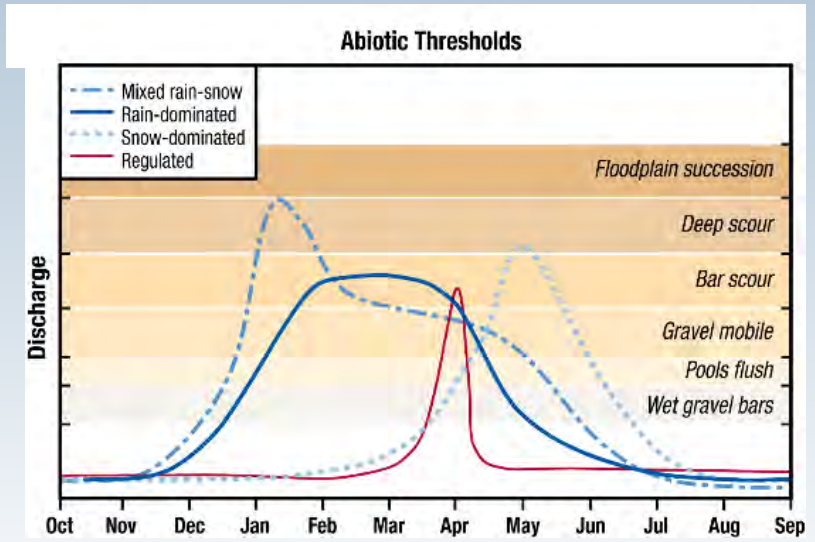


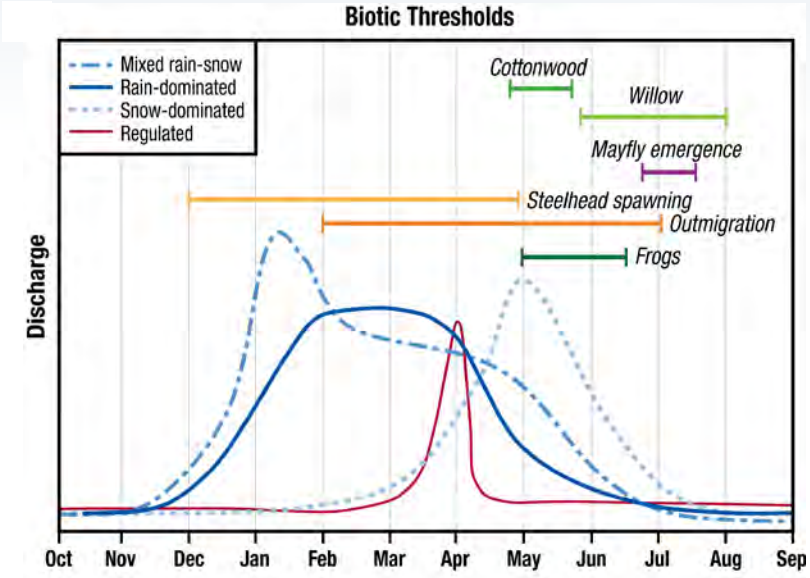
Functional Flows Approach

Focus on hydrograph flow components that:

- Support natural disturbances
- Promote physical dynamics
- Drive ecosystem functions
- Support high biodiversity

Consideration of geomorphic setting and channel-floodplain dynamics





(Yarnell et al. 2010)

Statewide

Regional

Local Case Study

ELOHA

Statewide Classification

Compile Bioassessment Data

Regional Survey

Estimate Hydrologic Alteration

Regional Hydro Models

Compare Bio and Hydro Alteration Data

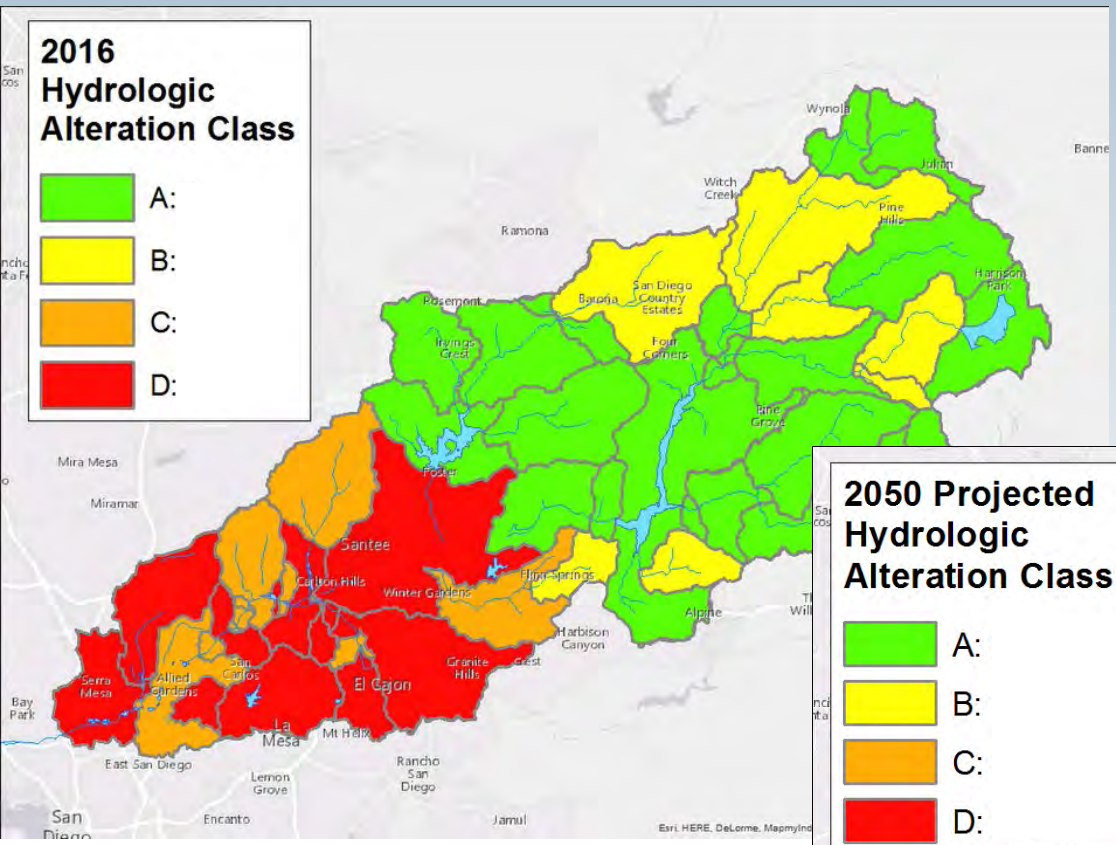
Logistic Regression

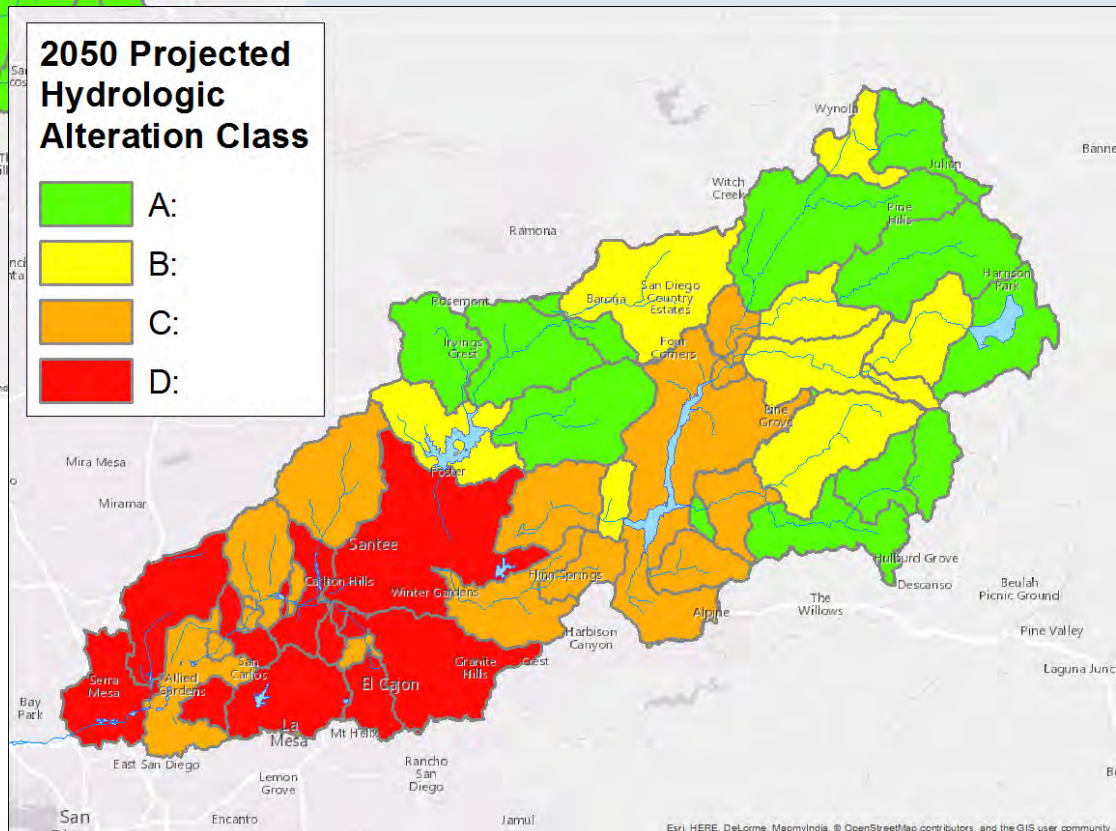
Select Priority Flow Metrics

Metric Screening

Evaluate Local Management Actions

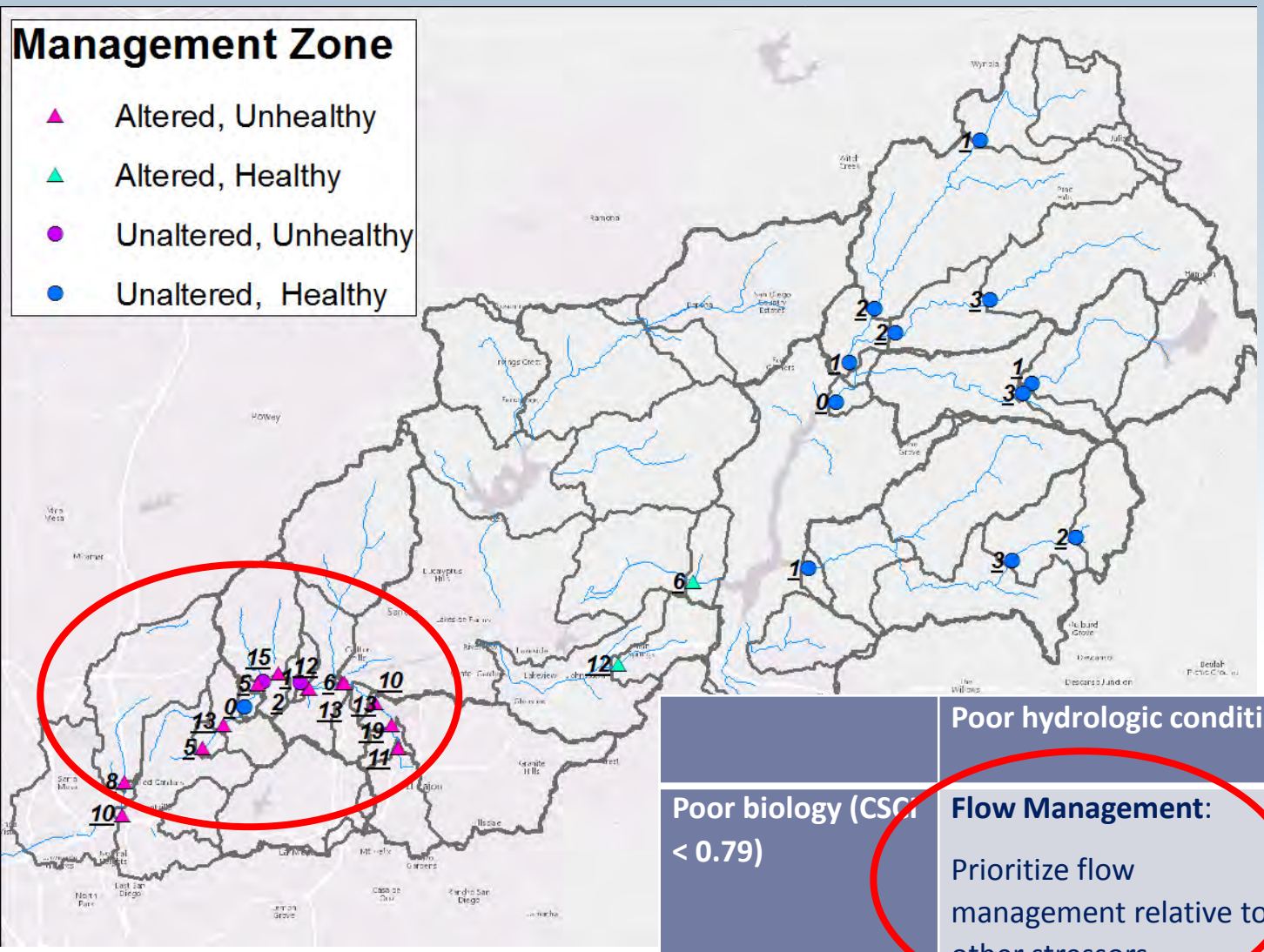
Map Hydrologic Alteration





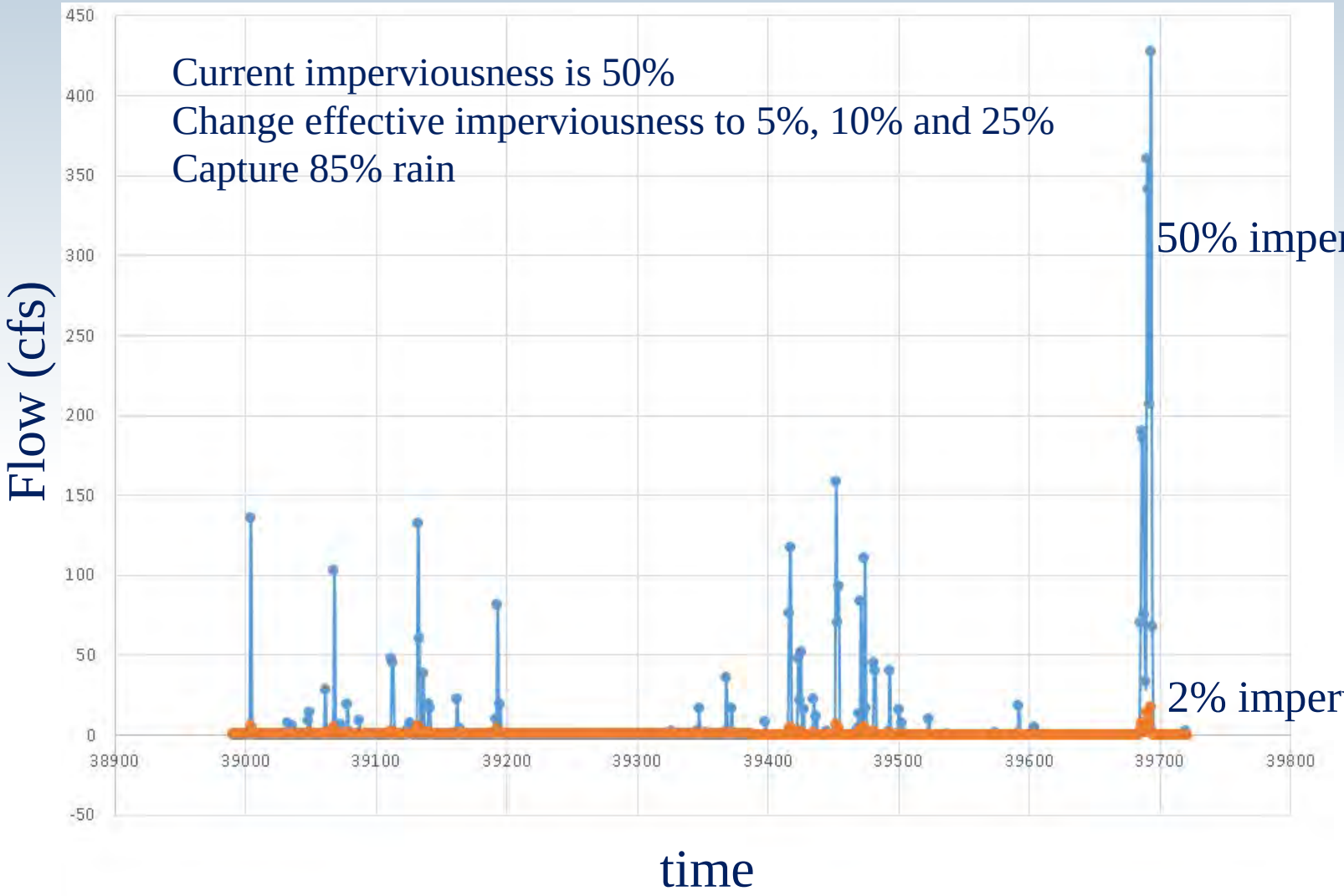
Inform land planning process

Flow Management Zones



	Poor hydrologic condition	Good hydrologic condition
Poor biology (CSCI < 0.79)	**Flow Management**: Prioritize flow management relative to other stressors	**Other Stressors** Management/Causal Assessment:
Good biology (CSCI > 0.79)	**Monitor**	**Protect**

Scenario Analysis: Alvarado Creek Stormwater Management



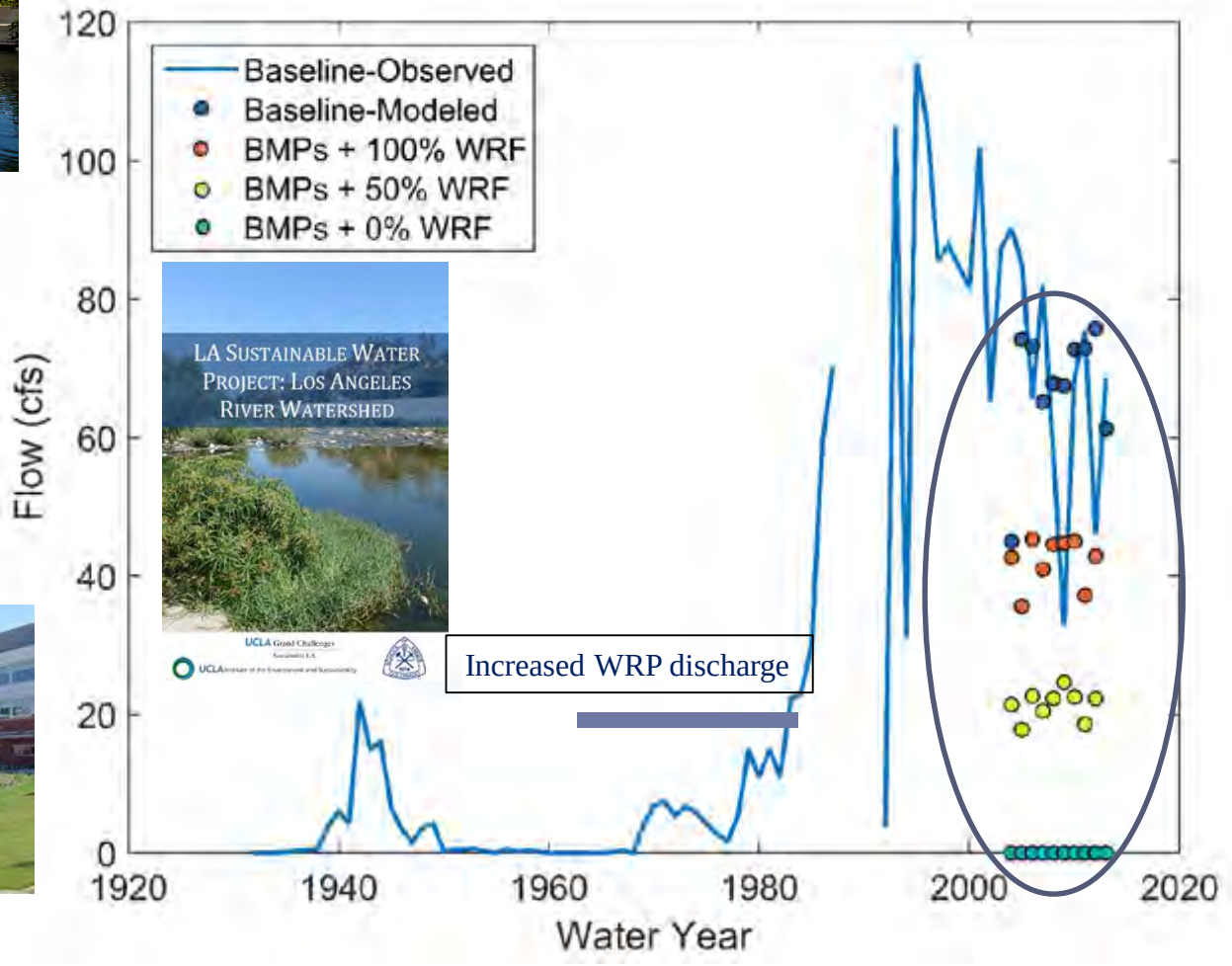
Alvarado Creek Results

Metric	Units	Imperviousness				Target
		2%	5%	10%	25%	Upper threshold
MaxMonthQ	cms	0.22	0.56	1.12	2.81	0.2
Q99	cms	6	31	69	71	70
RBI	unitless	0.15	0.25	0.33	0.41	1.4

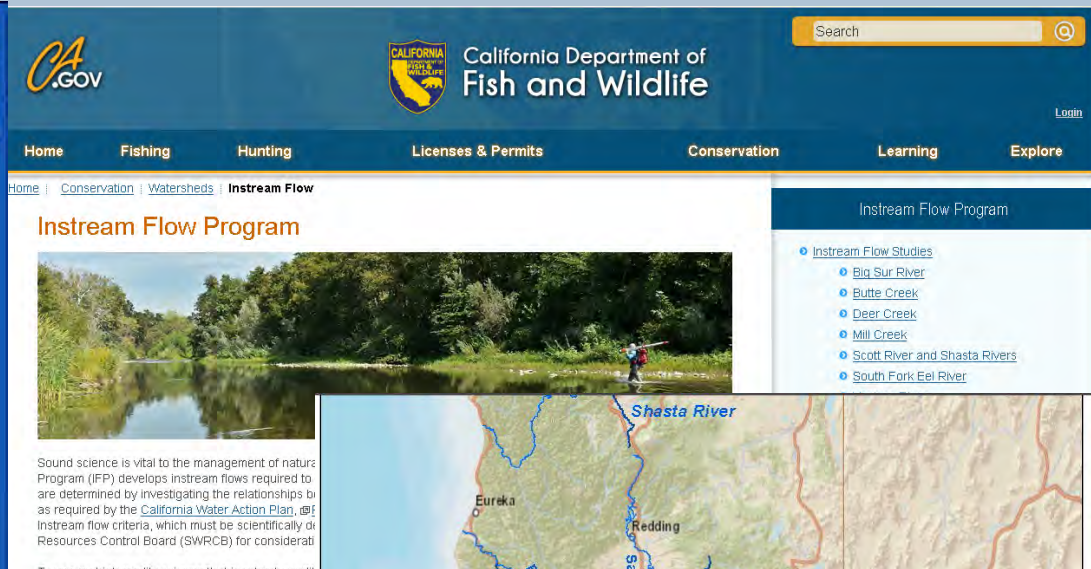
- 85% capture produces hydrologic conditions associated with healthy invertebrates
- Must reduce effective imperviousness to 2-5% to provide optimal hydrologic conditions
- Flashiness not an issue for this site

Changes in Wastewater and Stormwater Management

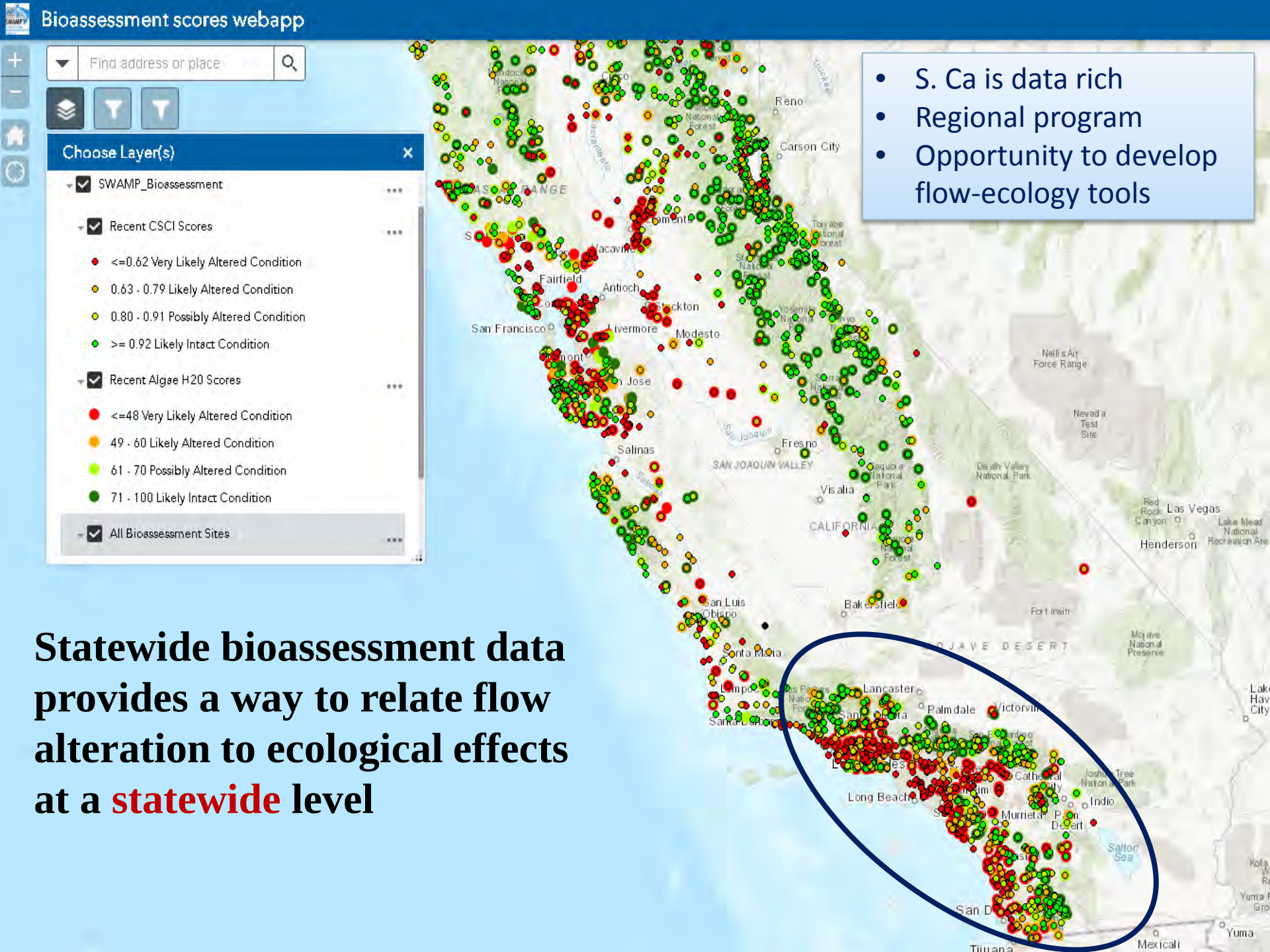
Annual minimum flows at Glendale Narrows



Need for Coordination



Important to Combine Technical and Policy Discussions in a Single Workgroup


Bioassessment scores webapp
Find address or place
Choose Layer(s)
SWAMP_Bioassessment
Recent CSCI Scores
<=0.62 Very Likely Altered Condition
0.63 - 0.79 Likely Altered Condition
0.80 - 0.91 Possibly Altered Condition
>= 0.92 Likely Intact Condition
Recent Algae H20 Scores
<=48 Very Likely Altered Condition
49 - 60 Likely Altered Condition
61 - 70 Possibly Altered Condition
71 - 100 Likely Intact Condition
All Bioassessment Sites
• S. Ca is data rich
• Regional program
• Opportunity to develop flow-ecology tools
Statewide bioassessment data provides a way to relate flow alteration to ecological effects at a statewide level
Reno
Carson City
Fairfield
Antioch
Stockton
San Francisco
Livermore
Modesto
San Jose
Salinas
Fresno
SAN JOAQUIN VALLEY
Visalia
CALIFORNIA
Bakersfield
Nellis Air Force Range
Nevada Test Site
Death Valley National Park
Las Vegas
Henderson
Fort Irwin
MOJAVE DESERT
Mojave National Preserve
San Luis Obispo
Santa Maria
Lancaster
Palmdale
Victorville
Long Beach
Murrieta
Indio
Joshua Tree National Park
Salton Sea
Yuma
Mexicali
Tijuana

Bioassessment

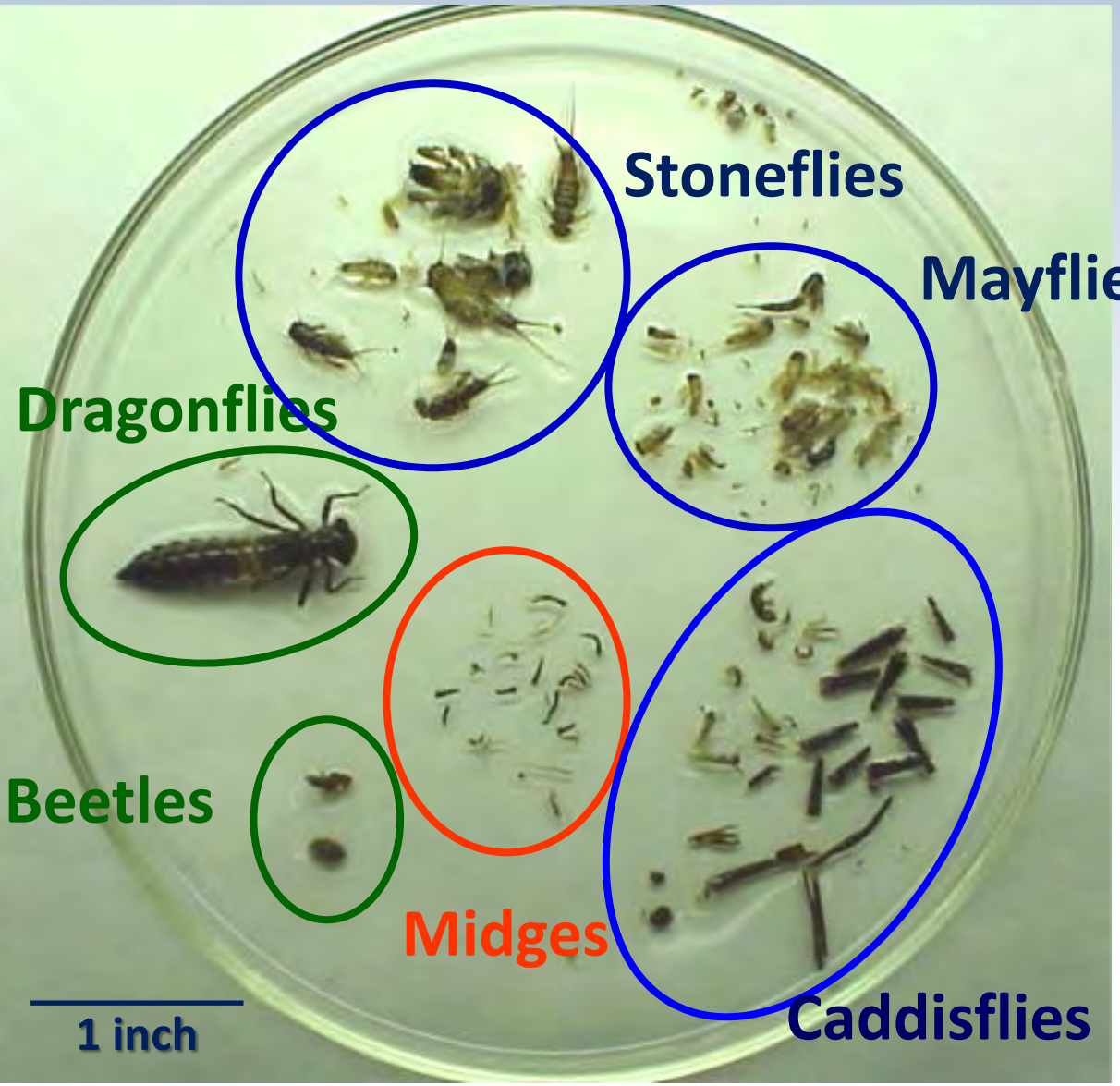
Most waterbodies (*streams, wetlands, lakes, oceans*) contain diverse groups of plants and animals that have predictable responses to different stressors

Resident organisms integrate stream conditions over time

Monitoring biology provides a direct measure of stream health

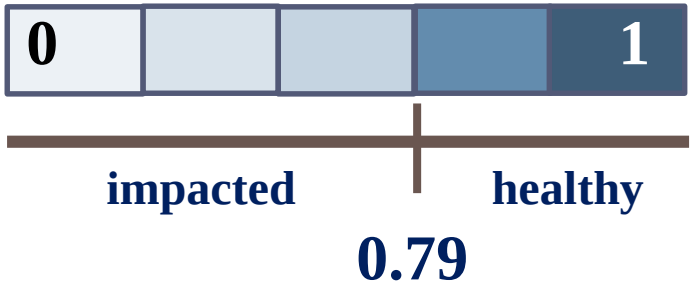
Incorporates responses to chemical AND non-chemical stresses

Management Based on Benthic Macroinvertebrate Indices



Score / Index

California Stream Condition Index (CSCI)



There are Lots of Regulatory Drivers

- Stormwater and non-point source programs
- Freshwater Bioobjectives (Bio-integrity)
- Wetland and Riparian Area Protection Policy
- Hydromodification & Flow Management
- Nutrient Numeric Endpoints
- Sustainable Groundwater Management Act