Overview of Tier 1 and Tier 2
Process and Products
California E-Flows Framework

Tier 1
Statewide approach for setting reference-based flow targets

Tier 2
Regional or Site-specific eflows where necessary

Data sharing and information dissemination to the public
Tier 1: Statewide ecological flow criteria based on reference hydrology

- Identify reference stream class from statewide classification
- Determine reference hydrology patterns
- Assess reference functional flow metrics for stream class
- Assess functional flow metrics for local stream reach
- Set functional flow metric ranges at locations of interest

Tier 2: Regional, local or site-specific ecological flow criteria Considers specific species/habitats and management needs

- Define hydrologic context and ecological objectives
- Characterize physical, biological and infrastructure data
- Select environmental flow method
- Incorporate policy and management needs
- Consider implementation needs and management plans

databases, guidelines, tools, and information accessible to the public
Outline of CEFF Guidance Document

• Background and overview
  ✓ Comparison of Tier 1 vs. Tier 2

• Tier 1 process
  ✓ General steps and process
  ✓ How to use Tier 1 products
  ✓ Focus on use of tools to calculate Tier 1 criteria

• Tier 2 guidance
  ✓ How to decide when Tier 2 is necessary
  ✓ Checklist of features that are consistent with CEFF approach
  ✓ General approach

• Case study examples
CEFF Background and Conceptual Approach

**Target audience = practitioners who will estimate ecological flow criteria**

- What are functional flows and why do we base CEFF on a functional flows approach
  - Consideration of all aspects of the annual hydrograph
  - Quantifiable links to ecological function

- Importance of Tiered approach
  - Tier 1 → based on reference hydrology, statewide, **prescriptive**
  - Tier 2 → Regional, local or site specific, **more detailed**, **more guidance**

- Supporting resources
  - Websites
  - Guidance document
  - Glossary
  - Case studies
California Environmental Flows Framework (CEFF)

Ecology
- Community of Species
- Functional Flows
- Water Quality

Hydrology
- Reference Hydrographs
- Stream Classification
- Flow Alterations
- Geomorphology

Set Ecological Flow Criteria
- Rapid statewide approach
- Regional or site-specific approach

Balance Beneficial Uses
- Water Availability
- Water Demands
- System Operations

Outreach
- Community Involvement

Implementation
- Policy
- Regulations
- Compliance

ceff.ucdavis.edu, ultimately to be hosted through CWQMC Portal
## Comparison of Tier 1 and Tier 2

<table>
<thead>
<tr>
<th></th>
<th>Tier 1</th>
<th>Tier 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial scale of application</strong></td>
<td>Statewide</td>
<td>Region or watershed or stream segment</td>
</tr>
<tr>
<td><strong>Type of criteria</strong></td>
<td>Ecological flow criteria</td>
<td>Environmental flow recommendations</td>
</tr>
<tr>
<td><strong>Basis for setting criteria</strong></td>
<td>Comparison of functional flow metrics to reference ranges</td>
<td>Establishment of functional flow criteria relative to specific habitat and/or species needs</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>Broad ranges</td>
<td>Narrower, more prescriptive</td>
</tr>
<tr>
<td><strong>General analytical approach</strong></td>
<td>Statistical analysis and modeling of reference conditions</td>
<td>Combination of statistical and mechanistic models</td>
</tr>
<tr>
<td><strong>Physical basis</strong></td>
<td>Functional flow metrics</td>
<td>Includes consideration of geomorphic forms and infrastructure with hydrology</td>
</tr>
<tr>
<td><strong>Biological basis</strong></td>
<td>Functional flow components</td>
<td>Includes consideration of local or regional aquatic communities or species of interest</td>
</tr>
</tbody>
</table>
Tier 1

A prescribed approach for statewide ecological flow criteria
Tier 1 Approach

Natural Streamflow Classification

Dimensionless Reference Hydrographs for Each Reference Gage

Flow

Oct Jan Apr Jul Oct

Modeled natural predictions for all stream reaches

Functional Flow Metrics

Tier 1 Ecological Flow Criteria

Flow Characteristics

M干itude Timing Duration Frequency Rate of Change

Wet Season Initiation Peak Magnitude Flows Spring Recession Flow Dry Season Low Flows

X X X X

X X X X

X X X X

X X X X

X X X X

Functional Flows Components and Metrics for reference conditions/gauges
Tier 1 Steps

• Regional reference hydrology and FF metric calculation code at:
  
  *eflows.ucdavis.edu*

• Modeled monthly natural flows and FF metrics at:
  
  *flowline.codeofnature.org*

• Stream reach specific Tier 1 targets can be produced using:
  a. Measured data (i.e. gauge data)
  b. Local modeled data
  c. Statewide model predictions
Classification and Reference Hydrology

Ultimately to be hosted through CWQMC Portal

Explore and visualize California's unimpaired streamflow patterns, including natural stream classes and functional flow metrics.

Metrics

Documentation

Stream Classification
- California is organized into nine stream classes with distinct natural flow regime patterns and watershed controls.

Dimensionless Reference Hydrographs
- Summary stream class hydrographs illustrate season and inter-annual daily flow patterns.

Functional Flow Metrics
- Flow metrics quantify key aspects of the natural flow regime linked to critical ecosystem functions.
Steps 1 and 2: Explore Regional and Local Reference Hydrology

**WHAT:** Identify which regional hydrologic class you are in and identify relevant reference gauges for your location of interest

**WHY:** Provides context for your location of interest and allows for direct comparison to appropriate reference condition (some functional flow metrics may not apply for certain stream classes)

**WHERE:** eflows.ucdavis.edu
Catchment Properties

Rainfall Patterns

Geology

Soil Properties

Natural Flow Class

- (SM) Snowmelt
- (HSR) High-volume snowmelt and rain
- (LSR) Low-volume snowmelt and rain
- (RSG) Rain and seasonal groundwater
- (WS) Winter storms
- (GW) Groundwater
- (PGR) Perennial groundwater and rain
- (FER) Flashy, ephemeral rain
- (HLP) High elevation, low precipitation

Lane et al., 2018
Purpose:
To characterize comparable seasonal and inter-annual flow patterns for each stream class.

Methods:
For each reference gage in a stream class, divide daily flow values by water year average annual flow. Calculate nondimensional flow percentiles for each date across all gauges and years.

dimensionless reference hydrographs

eflows.ucdavis.edu
Step 3: Evaluate Reference Functional Flow Metrics

WHAT: Characterize reference hydrology for your location of interest using a series of *hydrologically representative* and *ecologically relevant* metrics.

WHY: Functional flow metrics provide a way to quantify ranges of reference condition for each functional flow component. Hydrology at your location of interest can then be compared to relevant reference expectations.

WHERE: eflows.ucdavis.edu (reference gauges) and flowline.codeofnature.org (stream reach in development)
# Functional Flow Metrics

## Metrics not related to any specific organism.

## Metrics relate to general health based on reference conditions

<table>
<thead>
<tr>
<th>Flow Component</th>
<th>Flow Characteristic</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual</strong></td>
<td>Rate of change (%)</td>
<td>coeff. of variation of daily flow</td>
</tr>
<tr>
<td></td>
<td>Average (cfs)</td>
<td>average annual daily flow</td>
</tr>
<tr>
<td><strong>Wet Season Initiation</strong></td>
<td>Magnitude (cfs)</td>
<td>magnitude</td>
</tr>
<tr>
<td></td>
<td>Timing (date)</td>
<td>start date</td>
</tr>
<tr>
<td></td>
<td>Duration (days)</td>
<td># days (start-end)</td>
</tr>
<tr>
<td><strong>Peak Magnitude Flows</strong></td>
<td>Timing (date)</td>
<td>start of wet season</td>
</tr>
<tr>
<td></td>
<td>Magnitude (cfs)</td>
<td>wet season average baseflow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>peak magnitude: 2%, 5%, 10%, 20%, 50% exceedances</td>
</tr>
<tr>
<td></td>
<td>Timing (date)</td>
<td>start date: 2%, 5%, 10%, 20%, 50% exceedances</td>
</tr>
<tr>
<td></td>
<td>Duration (days)</td>
<td># days: 2%, 5%, 10%, 20%, 50% exceedances</td>
</tr>
<tr>
<td></td>
<td>Frequency (#)</td>
<td># of events in record: 2%, 5%, 10%, 20%, 50%</td>
</tr>
<tr>
<td><strong>Spring Recession</strong></td>
<td>Magnitude (cfs)</td>
<td>flow at start (spring peak)</td>
</tr>
<tr>
<td></td>
<td>Rate of change (%)</td>
<td>percent decrease per day</td>
</tr>
<tr>
<td></td>
<td>Timing (date)</td>
<td>start date</td>
</tr>
<tr>
<td></td>
<td>Duration (days)</td>
<td># days (start-end)</td>
</tr>
<tr>
<td><strong>Dry Season Low Flow</strong></td>
<td>Magnitude (cfs)</td>
<td>baseflow magnitude</td>
</tr>
<tr>
<td></td>
<td>Timing (date)</td>
<td>start date of summer</td>
</tr>
<tr>
<td></td>
<td>Duration (days)</td>
<td># days (start-wet) and (start to first wet season event)</td>
</tr>
<tr>
<td></td>
<td>Frequency (#)</td>
<td># of no flow days</td>
</tr>
</tbody>
</table>
Ways to Determine Functional Flow Expectations

• Scaling the dimensionless reference hydrograph for local conditions

• Based on local reference gauge(s)

• Locally calibrated and validated model → flow time series → metrics

• Statewide natural flows model → functional flow metrics
Stream Class: Low-volume Snowmelt and Rain
Functional Flow Component: Spring Recession
Functional Flow Metrics: Start timing, magnitude
Modeled Monthly Natural Flows

Streams

Select a stream segment on the map and click 'Add to Queue' to add stream to download queue.

Statistics

- Min
- Median
- Max
- Mean

Variables

- Estimated
- Observed
- p10
- p90

Years

- From: 1950
- To: 2015

Months

- January
- May
- September
- October
- November
- April
- August
- December

COMID: 8058609

North Yuba River

Estimated Natural Flow

- Dry Years
- All Years
- Wet Years

Statistics

- Min
- Median
- Mean
- Max

Variables

- Estimated
- Observed
- p10
- p90

Years

- From: 1950
- To: 2015

Months

- January
- May
- September
- October
- November
- April
- August
- December
Functional Flows Calculator (eflows.ucdavis.edu)

Select by water year type: Wet, moderate, dry
Water Year Typing

• Determined water year type for all stream segments with monthly modeled flow in TNC Natural Flow database
• Calculated mean annual flow for each stream segment based on modeled monthly flows
• Calculated tercile cutoffs to define wet, dry, and moderate for each segment for entire period of record (1950-2016)
• Categorized each mean annual flow into a water year type

<table>
<thead>
<tr>
<th>COMID</th>
<th>STATION_</th>
<th>Water_Year</th>
<th>Mean_Annual_Flow</th>
<th>WYT</th>
</tr>
</thead>
<tbody>
<tr>
<td>22684930</td>
<td>BIG ROCK</td>
<td>1951</td>
<td>2.5833333333</td>
<td>Dry</td>
</tr>
<tr>
<td>22684930</td>
<td>BIG ROCK</td>
<td>1952</td>
<td>24.5</td>
<td>Wet</td>
</tr>
<tr>
<td>22684930</td>
<td>BIG ROCK</td>
<td>1953</td>
<td>6.5833333333</td>
<td>Dry</td>
</tr>
<tr>
<td>22684930</td>
<td>BIG ROCK</td>
<td>1954</td>
<td>10.666666667</td>
<td>Moderate</td>
</tr>
<tr>
<td>22684930</td>
<td>BIG ROCK</td>
<td>1955</td>
<td>8.0833333333</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Steps 4 and 5: – Estimate Reach-scale Functional Flow Metrics Relative to Tier 1 Criteria

WHAT: Quantitatively characterize current hydrologic conditions at your location of interest using the functional flow metrics.
  • Measured data (i.e. gauge data)
  • Local modeled data

WHY: Determine whether your location of interest meets Tier 1 Ecological Flow Criteria

WHERE: calculated from code at eflows.ucdavis.edu or downloaded from flowline.codeofnature.org
Calculating Tier 1 Functional Flow Metric Ranges

<table>
<thead>
<tr>
<th>Flow Characteristics</th>
<th>Wet Season Initiation</th>
<th>Peak Magnitude Flows</th>
<th>Spring Recession Flow</th>
<th>Dry Season Low Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Timing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Duration</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of Change</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Flow Metrics**

<table>
<thead>
<tr>
<th>Flow Metrics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude at start (cfs)</td>
<td>2028 – 4880 cfs</td>
</tr>
<tr>
<td>Rate of change (%)</td>
<td>5 – 8%</td>
</tr>
<tr>
<td>Start Date (date)</td>
<td>May 11 – May 27</td>
</tr>
<tr>
<td>Duration (days)</td>
<td>36 to 50 days</td>
</tr>
</tbody>
</table>
Do I Meet Tier 1 Criteria?

South Fork American River

Flow Metrics Values

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Daily flow (1000 cfs)
Tier 1 Products

• Hydrologic classification
• Dimensionless reference hydrographs
• List of priority functional flow metrics
  ✓ Functional flows calculator
• Functional flow metric predictions for all stream reaches in the state
• Sample applications
Uses of Tier 1 Products

• Reference-based ecological flow criteria

• Assessing regional hydrologic condition
  ✓ Status and trends assessments

• Planning study to prepare for Tier 2
Reference Based Ecological Flow Criteria

South Fork American River

The graph shows the daily flow (1000 cfs) for the South Fork American River with percentile markers for 10th, 25th, 50th, 75th, and 90th percentiles.

Key dates and flow events are highlighted:
- Oct 1
- Nov 20
- Jan 9
- Feb 28
- Apr 19
- Jun 8
- Jul 28
- Sep 16

The graph indicates flow events and their corresponding percentiles, which are crucial for ecological flow criteria.
Assessing Regional Hydrologic Condition

Proportion of functional flow metric ranges met under current conditions

HYPOTHETICAL DATA BASED ON PRELIMINARY MODELLING

Similar maps could be produced for individual functional flow metrics by water year type
Planning for Tier 2 Analysis

Inform land and conservation planning processes
Implementation Questions for Agencies to Consider

• How good is good enough?
  ✓ What level of confidence do you want in Tier 1 criteria (e.g. how big of a “box” do we want to draw)?

• How do you want to spatially aggregate results?
  ✓ If one reach “fails” what does that mean? How many “failures” indicate that there is a problem?

• How often do you need to meet criteria?
  ✓ Focus on certain water year types?
  ✓ Do you need to “pass” during a minimum number of years or % of years?
Tier 2

Guidelines and information for developing finer scale environmental flow recommendations
## Comparison of Tier 1 and Tier 2

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<td>Functional flow components</td>
<td>Includes consideration of local or regional aquatic communities or species of interest</td>
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</tbody>
</table>
When is Tier 2 Necessary?

• Tier 1 criteria are too coarse

• Desire to focus on flow effects on specific ecological conditions (e.g. particular species, communities, or habitats)

• Need to consider specific physical settings or constraints

• Need to address specific management issues

• Desire to balance ecological flow needs with other (human use) demands
Tier 2 Approach

Hydrology

Input
\( x_1 \)
\( x_2 \)
\( \ldots \)
\( x_n \)

Output
\( y_1 \)
\( y_2 \)
\( \ldots \)
\( y_m \)

Simulation Model

Reach-scale Environmental Flow Methods

Ecological Flow Criteria

Policy & Management Needs

Environmental Flow Recommendations

Geomorphology

Ecology

Water quality

Temperature
What are the Features of a Tier 2 Approach

Not all environmental flow projects are consistent with the CEFF framework . . . and that is OK . . . But CEFF provides important elements that ensure comprehensive consideration of hydrology in an ecologically relevant way

CEFF Tier 2 approach:

• Addresses specific questions or management needs
• Includes consideration of relevant reference conditions
• Employs a functional flows approach
• Includes consideration of balancing multiple objectives
• Provides guidance on monitoring and adaptive management
General Tier 2 Process

• Start with Tier 1 Functional Flow Metrics
• Consider specific management targets, species, habitats
• Consider constraints of the system you are working in.
• Prioritize functional flow metrics based on issues/constraints and justify choice of priorities
• Establish flow-ecology relationships, provided they are consistent with functional flow metrics
• Assess functional flows using locally relevant models/tools
• Optimize flows to account for other demands and management actions
  ✓ balance objectives, implementation, monitoring, adaptive management
Tier 2 Tools and Products

• Key data sets
  ✓ Geomorphic classification
  ✓ Regional species assemblages
  ✓ Impaired flows classification

• Models and tools
  ✓ List of hydrologic models and decision support for model selection
  ✓ Hydrologic/hydraulic needs of key species
  ✓ Flow-ecology tools and relationships and decision support for tool selection

• Summary of programs and policies that involve environmental flow considerations

• Implementation considerations
  ✓ General design for monitoring effect of environmental flow management
  ✓ Recommended indicators and monitoring approaches
  ✓ Recommendations for adaptive management
  ✓ Data management considerations → possible future data repository/clearing house
Case Studies

Examples of how Tier 1 and Tier 2 is being implemented. Templates to guide future implementation
Regional Case Study Examples

• South Fork of the Eel River – balancing new water rights (cannabis growers) with instream habitat needs

• Southern California – flow requirements for water quality criteria based on benthic invertebrates

• Los Angeles River – balancing recycled water use with instream habitat needs

• Central and Northern California – dam relicensing for salmonid protection

• North Coast – water withdrawals for fish passage
Next Steps and Future Topics

• Additional discussion on application of Tier 1 products.

• Hydrologic modeling and model selection process

• Mapping and prioritization of habitats and species

• How to deal with highly modified landscapes

• Other?
Welcome to the California Environmental Flows Framework website

deff.ucdavis.edu
Functional Flow Components

- Wet Season Initiation
- Peak Magnitude Flows
- Spring Recession
- Dry Season Low Flows
Functional Flow Metrics

• Focus on quantifying hydrograph flow components that:
  ✓ Support natural disturbances
  ✓ Promote physical dynamics
  ✓ Drive ecosystem functions
  ✓ Support high biodiversity

• Consideration of geomorphic setting and channel-floodplain dynamics

• Quantification of functional flow components provides a way to link ecological theory with discrete quantifiable measures of flow

Yarnell et al., 2019
Refine flow criteria based on geomorphic setting and specific species needs.
Flow Sensitive Fish Assemblages

Table 1. Flow sensitive species in each of the five hydrogeographic assemblages in the North Coast region.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue chub</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>California Coast fall Chinook salmon</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>California roach</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central California coast winter steelhead</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central Coast coho salmon</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central Valley fall Chinook salmon</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Central Valley late fall Chinook salmon</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central Valley spring Chinook salmon</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central Valley winter Chinook salmon</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Delta smelt</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

Table 5. Flow sensitive species in each of the five hydrogeographic assemblages in the South Coast region.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyo chub</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central California coast winter steelhead</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Inland threespine stickleback</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Monterey hitch</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Monterey sucker</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pacific lamprey</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Riffle sculpia</td>
<td></td>
<td>+</td>
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<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sacramento pikeminnow</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
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<tr>
<td>Sacramento speckled dace</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Santa Ana speckled dace</td>
<td></td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Santa Ana sucker</td>
<td></td>
<td>+</td>
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</tr>
</tbody>
</table>
Tier 2: Incorporate local data, define objectives, refine recommendations

Hydrology

Input

$x_1$

$x_2$

$\ldots$

$x_n$

Output

$y_1$

$y_2$

$\ldots$

$y_m$

Simulation Model

Management objectives

Temperature

Ecology

Geomorphology

Environmental Flow Methods

Ecological Flow Criteria